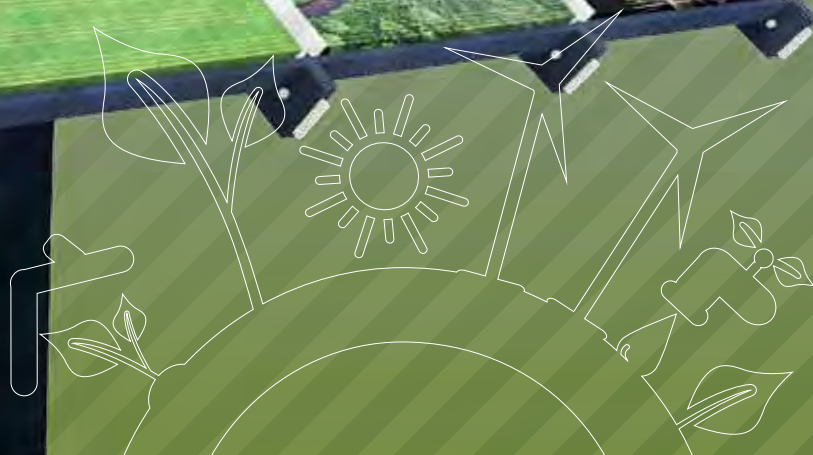




Towards a  
**GREEN economy**  
Pathways to Sustainable Development and Poverty Eradication



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Towards a

# GREEN economy

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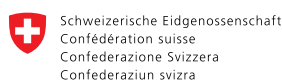
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# Foreword

**Nearly 20 years after the Earth Summit, nations are again on the Road to Rio, but in a world very different and very changed from that of 1992.**

Then we were just glimpsing some of the challenges emerging across the planet from climate change and the loss of species to desertification and land degradation.

Today many of those seemingly far off concerns are becoming a reality with sobering implications for not only achieving the UN's Millennium Development Goals, but challenging the very opportunity for seven billion people – rising to nine billion by 2050 – to be able to thrive, let alone survive.

Rio 1992 did not fail the world – far from it. It provided the vision and important pieces of the multilateral machinery to achieve a sustainable future.

But this will only be possible if the environmental and social pillars of sustainable development are given equal footing with the economic one: where the often invisible engines of sustainability, from forests to freshwaters, are also given equal if not greater weight in development and economic planning.

Towards a Green Economy is among UNEP's key contributions to the Rio+20 process and the overall goal of addressing poverty and delivering a sustainable 21st century.

The report makes a compelling economic and social case for investing two per cent of global GDP in greening ten central sectors of the economy in order to shift development and unleash public and private capital flows onto a low-carbon, resource-efficient path.

Such a transition can catalyse economic activity of at least a comparable size to business as usual, but with

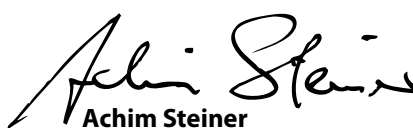
a reduced risk of the crises and shocks increasingly inherent in the existing model.

New ideas are by their very nature disruptive, but far less disruptive than a world running low on drinking water and productive land, set against the backdrop of climate change, extreme weather events and rising natural resource scarcities.

A green economy does not favour one political perspective over another. It is relevant to all economies, be they state or more market-led. Neither is it a replacement for sustainable development. Rather, it is a way of realising that development at the national, regional and global levels and in ways that resonate with and amplify the implementation of Agenda 21.

A transition to a green economy is already underway, a point underscored in the report and a growing wealth of companion studies by international organisations, countries, corporations and civil society. But the challenge is clearly to build on this momentum.

Rio+20 offers a real opportunity to scale-up and embed these "green shoots". In doing so, this report offers not only a roadmap to Rio but beyond 2012, where a far more intelligent management of the natural and human capital of this planet finally shapes the wealth creation and direction of this world.



**Achim Steiner**

UNEP Executive Director

United Nations Under-Secretary General





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# Introduction

Setting the stage for a green economy transition







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# 1 Introduction: Setting the stage for a green economy transition

## 1.1 From crisis to opportunity

The last two years have seen the idea of a “green economy” float out of its specialist moorings in environmental economics and into the mainstream of policy discourse. It is found increasingly in the words of heads of state and finance ministers, in the text of G20 communiques, and discussed in the context of sustainable development and poverty eradication.

This recent traction for a green economy concept has no doubt been aided by widespread disillusionment with the prevailing economic paradigm, a sense of fatigue emanating from the many concurrent crises and market failures experienced during the very first decade of the new millennium, including especially the financial and economic crisis of 2008. But at the same time, there is increasing evidence of a way forward, a new economic paradigm – one in which material wealth is not delivered perforce at the expense of growing environmental risks, ecological scarcities and social disparities.

Mounting evidence also suggests that transitioning to a green economy has sound economic and social justification. There is a strong case emerging for a redoubling of efforts by both governments as well as the private sector to engage in such an economic transformation. For governments, this would include leveling the playing field for greener products by phasing out antiquated subsidies, reforming policies and providing new incentives, strengthening market infrastructure and market-based mechanisms, redirecting public investment, and greening public procurement. For the private sector, this would involve understanding and sizing the true opportunity represented by green economy transitions across a number of key sectors, and responding to policy reforms and price signals through higher levels of financing and investment.

### An era of capital misallocation

Several concurrent crises have unfolded during the last decade: climate, biodiversity, fuel, food, water, and more recently, in the global financial system. Accelerating carbon emissions indicate a mounting threat of climate change, with potentially disastrous human consequences. The fuel price shock of 2007-2008 and the related skyrocketing food and commodity prices,

reflect both structural weaknesses and unresolved risks. Forecasts by the International Energy Agency (IEA) and others of rising fossil fuel demand and energy prices suggest an ongoing dependence as the world economy struggles to recover and grow (IEA 2010).

Currently, there is no international consensus on the problem of global food security or on possible solutions for how to nourish a population of 9 billion by 2050. See Box 1 for further information on the population challenge. Freshwater scarcity is already a global problem, and forecasts suggest a growing gap by 2030 between annual freshwater demand and renewable supply (McKinsey and Company 2009). The outlook for improved sanitation still looks bleak for over 1.1 billion people and 844 million people still lack access to clean drinking water (World Health Organization and UNICEF 2010). Collectively, these crises are severely impacting the possibility of sustaining prosperity worldwide and achieving the Millennium Development Goals (MDGs) for reducing extreme poverty. They are also compounding persistent social problems, such as job losses, socio-economic insecurity, disease and social instability.

The causes of these crises vary, but at a fundamental level they all share a common feature: the gross misallocation of capital. During the last two decades, much capital was poured into property, fossil fuels and structured financial assets with embedded derivatives. However, relatively little in comparison was invested in renewable energy, energy efficiency, public transportation, sustainable agriculture, ecosystem and biodiversity protection, and land and water conservation.

Most economic development and growth strategies encouraged rapid accumulation of physical, financial and human capital, but at the expense of excessive depletion and degradation of natural capital, which includes the endowment of natural resources and ecosystems. By depleting the world's stock of natural wealth – often irreversibly – this pattern of development and growth has had detrimental impacts on the well-being of current generations and presents tremendous risks and challenges for the future. The recent multiple crises are symptomatic of this pattern.



## Box 1: Managing the population challenge in the context of sustainable development

The link between population dynamics and sustainable development is strong and inseparable, as reflected in Principle 8 of the 1992 Rio Declaration on Environment and Development.

*"To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies."* Rio Declaration, Principle 8 (UN 1992).

This year the world population will reach 7 billion and by mid century grow to over 9 billion. Contrary to previous projections the most recent population projections expect continued population growth thereafter (UN DESA 2009 and 2011). Population growth raises the stakes in efforts to reduce poverty. It not only increases the challenge of feeding a growing population, which crucially depends on higher agricultural output (FAO 2009 and 2010; Tokgoz and Rosegrant 2011), but also requires creation of sufficient employment opportunities, which in turn depend on favorable economic development (ILO 2011; UNFPA 2011a; Basten et al. 2011; Herrmann and Khan 2008).

A transition to a green economy can assist in overcoming the contribution that population growth makes to the depletion of scarce natural resources. The world's least developed countries (LDCs) are more strongly affected by environmental degradation than most other developing countries (UNCTAD 2010a), so therefore have much to gain from the transition to a green economy.

In addition, changing spatial distributions of populations, driven both by rural to urban migration and by urban growth, are changing environmental impacts and vulnerabilities. When planned,

urbanisation can be a powerful driver of sustainable development. Given that in 2008 the share of the urban population has for the first time exceeded the share of people living in the rural areas at the global level (UNFPA 2007), a transition to a green economy becomes increasingly important. Significantly, in the least developed countries where the majority of people are still living in the rural areas, 2000 to 2010 was the first decade that growth of the urban population outpaced the growth of the rural populations. These types of changes at a societal level can also present opportunities for a green economy to develop.

For example cities can provide essential services, including health and education, at lower costs per capita due to economies of scale benefits. Efficiencies are also realised in the development of vital infrastructure including housing, water, sanitation and transport. Urbanisation can also reduce energy consumption, particularly in transport and housing, and create interactive spaces that further cultural outreach and exchange. Realisation of these positive benefits requires proactive planning for the future demographic changes.

Forward planning by governments and local authorities can address population dynamics in a proactive way. For example, one tool available to assist countries is to make better use of available population data and conduct a systematic population situation analysis (UNFPA 2011b), aiming to highlight how current and projected population trends affect the development of countries. Such analysis provides the necessary foundation to address population dynamics and their links to sustainable development and poverty reduction strategies.

Source: UNFPA

Existing policies and market incentives have contributed to this problem of capital misallocation because they allow businesses to run up significant, largely unaccounted for, and unchecked social and environmental externalities. To reverse such misallocation requires better public policies, including pricing and regulatory measures, to change the perverse incentives that drive this capital misallocation and ignore social and environmental externalities. At the same time, appropriate regulations, policies and public investments that foster changes in the pattern of private

investment are increasingly being adopted around the world, especially in developing countries (UNEP 2010).

### Why is this report needed now?

UNEP's report, *Towards a Green Economy*, aims to debunk several myths and misconceptions about greening the global economy, and provides timely and practical guidance to policy makers on what reforms they need to unlock the productive and employment potential of a green economy.

Perhaps the most prevalent myth is that there is an inescapable trade-off between environmental sustainability and economic progress. There is now substantial evidence that the greening of economies neither inhibits wealth creation nor employment opportunities. To the contrary, many green sectors provide significant opportunities for investment, growth and jobs. For this to occur, however, new enabling conditions are required to promote such investments in the transition to a green economy, which in turn calls for urgent action by policy makers.

A second myth is that a green economy is a luxury only wealthy countries can afford, or worse, a ruse to restrain development and perpetuate poverty in developing countries. Contrary to this perception, numerous examples of greening transitions can be found in the developing world, which should be replicated elsewhere. *Towards a Green Economy* brings some of these examples to light and highlights their scope for wider application.

UNEP's work on green economy raised the visibility of this concept in 2008, particularly through a call for a Global Green New Deal (GGND). The GGND recommended a package of public investments and complementary policy and pricing reforms aimed at kick-starting a transition to a green economy, while reinvigorating economies and jobs and addressing persistent poverty (Barbier 2010a). Designed as a timely and appropriate policy response to the economic crisis, the GGND proposal was an early output from the United Nations' Green Economy Initiative. This initiative, coordinated by UNEP, was one of the nine Joint Crisis Initiatives undertaken by the Secretary-General of the UN and his Chief Executives Board in response to the 2008 economic and financial crisis.

*Towards a Green Economy* – the main output of the Green Economy Initiative – demonstrates that the greening of economies need not be a drag on growth. On the contrary, the greening of economies has the potential to be a new engine of growth, a net generator of decent jobs and a vital strategy to eliminate persistent poverty. The report also seeks to motivate policy makers to create the enabling conditions for increased investments in a transition to a green economy in three ways.

First, the report makes an economic case for shifting both public and private investment to transform key sectors that are critical to greening the global economy. It illustrates through examples how added employment through green jobs offsets job losses in a transition to a green economy.

Second, it shows how a green economy can reduce persistent poverty across a range of important sectors

– agriculture, forestry, freshwater, fisheries and energy. Sustainable forestry and ecologically friendly farming methods help conserve soil fertility and water resources. This is especially critical for subsistence farming, upon which almost 1.3 billion people depend for their livelihoods (UNEP et al. 2008).

Third, it provides guidance on policies to achieve this shift by reducing or eliminating environmentally harmful or perverse subsidies, addressing market failures created by externalities or imperfect information, creating market-based incentives, implementing appropriate regulatory frameworks, initiating green public procurement and by stimulating investment.

## 1.2 What is a green economy?

UNEP defines a green economy as one that results in “improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities” (UNEP 2010). In its simplest expression, a green economy is low-carbon, resource efficient, and socially inclusive. In a green economy, growth in income and employment are driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services.

These investments need to be catalysed and supported by targeted public expenditure, policy reforms and regulation changes. The development path should maintain, enhance and, where necessary, rebuild natural capital as a critical economic asset and as a source of public benefits. This is especially important for poor people whose livelihoods and security depend on nature.

The key aim for a transition to a green economy is to enable economic growth and investment while increasing environmental quality and social inclusiveness. Critical to attaining such an objective is to create the conditions for public and private investments to incorporate broader environmental and social criteria. In addition, the main indicators of economic performance, such as growth in Gross Domestic Product (GDP) need to be adjusted to account for pollution, resource depletion, declining ecosystem services, and the distributional consequences of natural capital loss to the poor.

A major challenge is reconciling the competing economic development aspirations of rich and poor countries in a world economy that is facing increasing climate change, energy insecurity and ecological scarcity. A green economy can meet this challenge by offering a development path that reduces carbon dependency,

promotes resource and energy efficiency and lessens environmental degradation. As economic growth and investments become less dependent on liquidating environmental assets and sacrificing environmental quality, both rich and poor countries can attain more sustainable economic development.

The concept of a green economy does not replace sustainable development; but there is a growing recognition that achieving sustainability rests almost entirely on getting the economy right. Decades of creating new wealth through a “brown economy” model based on fossil fuels have not substantially addressed social marginalisation, environmental degradation and resource depletion. In addition, the world is still far from delivering on the Millennium Development Goals by 2015. The next section looks at the important linkages between the concept of a green economy and sustainable development.

### **A green economy and sustainable development**

In 2009, the UN General Assembly decided to hold a summit in Rio de Janeiro in 2012 (Rio+20) to celebrate the 20th anniversary of the first Rio Earth Summit in 1992. Two of the agenda items for Rio+20 are, “Green Economy in the Context of Sustainable Development and Poverty Eradication”, and “International Framework for Sustainable Development”. With the green economy now firmly established on the international policy agenda, it is useful to review and clarify the linkages between a green economy and sustainable development.

Most interpretations of sustainability take as their starting point the consensus reached by the World Commission on Environment and Development (WCED) in 1987, which defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987).

Economists are generally comfortable with this broad interpretation of sustainability, as it is easily translatable into economic terms: an increase in well-being today should not result in reducing well-being tomorrow. That is, future generations should be entitled to at least the same level of economic opportunities – and thus at least the same level of economic welfare – as is available to current generations.

As a result, economic development today must ensure that future generations are left no worse off than current generations. Or, as some economists have succinctly expressed it, per capita welfare should not be declining over time (Pezzey 1989). According to this view, it is the total stock of capital employed by the economic system, including natural capital, which determines the full range of economic opportunities, and thus well-being,

available to both current and future generations (Pearce et al. 1989).

Society must decide how best to use its total capital stock today to increase current economic activities and welfare. Society must also decide how much it needs to save or accumulate for tomorrow, and ultimately, for the well-being of future generations.

However, it is not simply the aggregate stock of capital in the economy that may matter but also its composition, in particular whether current generations are using up one form of capital to meet today’s needs. For example, much of the interest in sustainable development is driven by concern that economic development may be leading to rapid accumulation of physical and human capital at the expense of excessive depletion and degradation of natural capital. The major concern is that by irreversibly depleting the world’s stock of natural wealth, today’s development path will have detrimental implications for the well-being of future generations.

One of the first economic studies to make the connection between this capital approach to sustainable development and a green economy was the 1989 book *Blueprint for a Green Economy* (Pearce et al. 1989). The authors argued that because today’s economies are biased towards depleting natural capital to secure growth, sustainable development is unachievable. A green economy that values environmental assets, employs pricing policies and regulatory changes to translate these values into market incentives, and adjusts the economy’s measure of GDP for environmental losses is essential to ensuring the well-being of current and future generations.

As pointed out by the *Blueprint for a Green Economy* authors, a major issue in the capital approach to sustainable development is whether substitution among different forms of capital – human capital, physical capital and natural capital – is possible. A strong conservationist perspective might maintain that the natural component of the total capital stock must be kept intact, as measured in physical terms. However, this may be questioned in practice, especially in the context of developing countries, if natural capital is relatively abundant while physical and human capital needs to be developed to meet other human demands. This type of substitution reflects the unfortunate reality that the creation of physical capital – for example roads, buildings and machinery – often requires the conversion of natural capital. While substitution between natural capital and other forms of capital is often inevitable, there is often room for efficiency gains. There is also a growing recognition of environmental thresholds that would constrain substitution beyond minimum levels needed for human welfare.

Biodiversity	Ecosystem goods and services (examples)	Economic values (examples)
Ecosystems (variety & extent/area)	<ul style="list-style-type: none"> <li>• Recreation</li> <li>• Water regulation</li> <li>• Carbon storage</li> </ul>	Avoiding greenhouse gas emissions by conserving forests: US\$ 3.7 trillion (NPV)
Species (diversity & abundance)	<ul style="list-style-type: none"> <li>• Food, fiber, fuel</li> <li>• Design inspiration</li> <li>• Pollination</li> </ul>	Contribution of insect pollinators to agricultural output: ~US\$ 190 billion/year
Genes (variability & population)	<ul style="list-style-type: none"> <li>• Medicinal discoveries</li> <li>• Disease resistance</li> <li>• Adaptive capacity</li> </ul>	25-50% of the US\$ 640 billion pharmaceutical market is derived from genetic resources

**Table 1: Natural capital – Underlying components and illustrative services and values**  
Source: Eliasch (2008); Gallai et al. (2009); TEEB (2009)

Yet, there has always been concern that some forms of natural capital are essential to human welfare, particularly key ecological goods and services, unique environments and natural habitats, and irreplaceable ecosystem attributes. Uncertainty over the true value of these important assets to human welfare, in particular the value that future generations may place on them if they become increasingly scarce, further limits our ability to determine whether we can adequately compensate future generations for today's irreversible losses in such essential natural capital. This concern is reflected in other definitions of sustainable development. For example, in 1991, the World Wide Fund for Nature, the International Union for Conservation of Nature (IUCN), and UNEP interpreted the concept of sustainable development as "improving the quality of human life within the carrying capacity of supporting ecosystems" (WWF, IUCN and UNEP 1991).

As this definition suggests, the type of natural capital that is especially at risk is ecosystems. As explained by Partha Dasgupta (2008): "Ecosystems are capital assets. Like reproducible capital assets ... ecosystems depreciate if they are misused or are overused. But they differ from reproducible capital assets in three ways: (1) depreciation of natural capital is frequently irreversible (or at best the systems take a long time to recover); (2) except in a very limited sense, it isn't possible to replace a depleted or degraded ecosystem by a new one; and (3) ecosystems can collapse abruptly, without much prior warning."

Rising ecological scarcity is an indication that we are irrevocably depleting ecosystems too rapidly, and the consequence is that current and future economic welfare is affected. An important indicator of the growing ecological scarcity worldwide was provided by the *Millennium Ecosystem Assessment* (MEA) in 2005, which found that over 60 per cent of the world's major ecosystem goods and services covered in the assessment were degraded or used unsustainably.

Some important benefits to humankind fall in this category, including fresh water; capture fisheries; water

purification and waste treatment; wild foods; genetic resources; biochemicals; wood fuel; pollination; spiritual, religious and aesthetic values; the regulation of regional and local climate; erosion; pests; and natural hazards. The economic values associated with these ecosystem services, while generally not marketed, are substantial (see Table 1).

One major difficulty is that the increasing costs associated with rising ecological scarcity are not routinely reflected in markets. Almost all the degraded ecosystem goods or services identified by the *Millennium Ecosystem Assessment* are not marketed. Some goods, such as capture fisheries, fresh water, wild foods, and wood fuel, are often commercially marketed, but due to the poor management of the biological resources and ecosystems that are the source of these goods, and imperfect information, the market prices do not reflect unsustainable use and overexploitation.

Nor have adequate policies and institutions been developed to handle the costs associated with worsening ecological scarcity globally. All too often, policy distortions and failures compound these problems by encouraging wasteful use of natural resources and environmental degradation. The unique challenge posed by rising ecological scarcity and inefficient resource and energy use today is to overcome a vast array of market, policy, and institutional failures that prevents recognition of the economic significance of this environmental degradation.

Reversing this process of unsustainable development requires three important steps. First, as argued by the *Blueprint for a Green Economy* authors, improvements in environmental valuation and policy analysis are required to ensure that markets and policies incorporate the full costs and benefits of environmental impacts (Pearce et al. 1989; Pearce and Barbier 2000). Environmental valuation and accounting for natural capital depreciation must be fully integrated into economic development policy and strategy. As suggested above, the most undervalued components of natural capital are ecosystems and

the myriad goods and services they provide. Valuing ecosystem goods and services is not easy, yet it is fundamental to ensuring the sustainability of global economic development efforts.

A major international research effort supported by UNEP, the Economics of Ecosystems and Biodiversity (TEEB), is illustrating how ecological and economic research can be used to value ecosystem goods and services, as well as how such valuation is essential for policy making and investments in the environment (Sukhdev 2008; TEEB 2010).

Second, the role of policy in controlling excessive environmental degradation requires implementing effective and appropriate information, incentives, institutions, investments and infrastructure. Better information on the state of the environment, ecosystems and biodiversity is essential for both private and public decision making that determines the allocation of natural capital for economic development. The use of market-based instruments, the creation of markets, and where appropriate, regulatory measures, have a role to play in internalising this information in everyday allocation decisions in the economy. Such instruments are also important in correcting the market and policy failures that distort the economic incentives for improved environmental and ecosystems management.

However, overcoming institutional failures and encouraging more effective property rights, good governance and support for local communities, is also critical. Reducing government inefficiency, corruption and poor accountability are also important in reversing excessive environmental degradation in many countries. But there is also a positive role for government in providing an appropriate and effective infrastructure through public investment, protecting critical ecosystems and biodiversity conservation, creating new incentive mechanisms such as payment for ecosystem services, fostering the technologies and knowledge necessary for improving ecosystem restoration, and facilitating the transition to a low-carbon economy.

Third, continuing environmental degradation, land conversion and global climate change affect the functioning, diversity, and resilience of ecological systems and the goods and services they supply. The potential long-term impacts of these effects on the health and stability of ecosystems are difficult to quantify and value. Increasing collaboration between environmental scientists, ecologists and economists will be required to assess and monitor these impacts (MEA 2005; Polasky and Segerson 2009). Such interdisciplinary ecological and economic analysis is also necessary to identify and assess the welfare consequences for current and future generations from increasing ecological scarcity. Further

progress in reversing unsustainable development calls for more widespread interdisciplinary collaboration to analyse complex problems of environmental degradation, biodiversity loss and ecosystem decline.

Interdisciplinary research also needs to determine the thresholds that should govern the transformation of specific types of natural capital into other forms of capital. For example, how much forestland is allowed for conversion into farmland, industrial use or urban development in a given area? How much underground water is allowed for extraction each year? How much and what fish species can be caught in a given season? Which chemicals should be banned from production and trading? And more important, what are the criteria for setting these thresholds? Once these standards are established, incentive measures at national or international levels can be devised to ensure compliance.

The other key to balancing different forms of capital recognises that substitutability is a characteristic of current technologies. Investing in changing and substituting these technologies can lead to new complementarities. Most renewable energy sources, such as wind turbines or solar panels, considerably reduce the amount of natural capital that is sacrificed in their construction and the lifetime of their operation, compared to fossil fuel burning technologies. Both of these types of solutions – setting thresholds and altering technologies – are important for achieving a green economy.

In sum, moving towards a green economy must become a strategic economic policy agenda for achieving sustainable development. A green economy recognises that the goal of sustainable development is improving the quality of human life within the constraints of the environment, which include combating global climate change, energy insecurity, and ecological scarcity. However, a green economy cannot be focused exclusively on eliminating environmental problems and scarcity. It must also address the concerns of sustainable development with intergenerational equity and eradicating poverty.

### **A green economy and eradicating poverty**

Most developing countries, and certainly the majority of their populations, depend directly on natural resources. The livelihoods of many of the world's rural poor are also intricately linked with exploiting fragile environments and ecosystems (Barbier 2005). Well over 600 million of the rural poor currently live on lands prone to degradation and water stress, and in upland areas, forest systems, and drylands that are vulnerable to climatic and ecological disruptions (Comprehensive Assessment of Water Management in Agriculture 2007; World Bank 2003). The tendency of rural populations to be clustered



on marginal lands and in fragile environments is likely to be a continuing problem for the foreseeable future, given current global rural population and poverty trends. Despite rapid global urbanisation, the rural population of developing regions continues to grow, albeit at a slower rate in recent decades (Population Division of the United Nations Secretariat 2008). Furthermore, around three-quarters of the developing world's poor still live in rural areas, which means about twice as many poor people live in rural rather than in urban areas (Chen and Ravallion 2007).

The world's poor are especially vulnerable to the climate-driven risks posed by rising sea levels, coastal erosion and more frequent storms. Around 14 per cent of the population and 21 per cent of urban dwellers in developing countries live in low elevation coastal zones that are exposed to these risks (McGranahan et al. 2007). The livelihoods of billions – from poor farmers to urban slum dwellers – are threatened by a wide range of climate-induced risks that affect food security, water availability, natural disasters, ecosystem stability and human health (UNDP 2008; OECD 2008). For example, many of the 150 million urban inhabitants, who are likely to be at risk from extreme coastal flooding events and sea level rise, are likely to be the poor living in cities in developing countries (Nicholls et al. 2007).

As in the case of climate change, the link between ecological scarcity and poverty is well-established for some of the most critical environmental and energy problems. For example, for the world's poor, global water scarcity manifests itself as a water poverty problem. One-in-five people in the developing world lacks access to sufficient clean water, and about half the developing world's population, 2.6 billion people, do not have access to basic sanitation. More than 660 million of the people without sanitation live on less than US\$ 2 a day, and more than 385 million on less than US\$ 1 a day (UNDP 2006). Billions of people in developing countries have no access to modern energy services, and those consumers who do have access often pay high prices for erratic and unreliable services. Among the energy poor are 2.4 billion people who rely on traditional biomass fuels for cooking and heating, including 89 per cent of the population of Sub-Saharan Africa; and, the 1.6 billion people who do not have access to electricity (IEA 2002).

Thus, finding ways to protect global ecosystems, reduce the risks of global climate change, improve energy security, and simultaneously improve the livelihoods of the poor are important challenges in the transition to a green economy, especially for developing countries.

As this report demonstrates, a transition to a green economy can contribute to eradicating poverty. A

number of sectors with green economic potential are particularly important for the poor, such as agriculture, forestry, fishery and water management, which have public goods qualities. Investing in greening these sectors, including through scaling up microfinance, is likely to benefit the poor in terms of not only jobs, but also secure livelihoods that are predominantly based on ecosystem services. Enabling the poor to access microinsurance coverage against natural disasters and catastrophes is equally important for protecting livelihood assets from external shocks due to changing and unpredictable weather patterns.

However, it must be emphasised that moving towards a green economy will not automatically address all poverty issues. A pro-poor orientation must be superimposed on any green economy initiative. Investments in renewable energy, for example, will have to pay special attention to the issue of access to clean and affordable energy. Payments for ecosystem services, such as carbon sequestration in forests, will need to focus more on poor forest communities as the primary beneficiaries. The promotion of organic agriculture can open up opportunities, particularly for poor small-scale farmers who typically make up the majority of the agricultural labour force in most low-income countries, but will need to be complemented by policies to ensure that extension and other support services are in place.

In sum, the top priority of the UN MDGs is eradicating extreme poverty and hunger, including halving the proportion of people living on less than US\$ 1 a day by 2015. A green economy must not only be consistent with that objective, but must also ensure that policies and investments geared towards reducing environmental risks and scarcities are compatible with ameliorating global poverty and social inequity.

### 1.3 Pathways to a green economy

If the desirability of moving to a green economy is clear to most people, the means of doing so is still a work in progress for many. This section looks at the theory of greening, the practice and the enabling conditions required for making such a transition. However, before embarking on this analysis, the section frames the dimensions of the challenge.

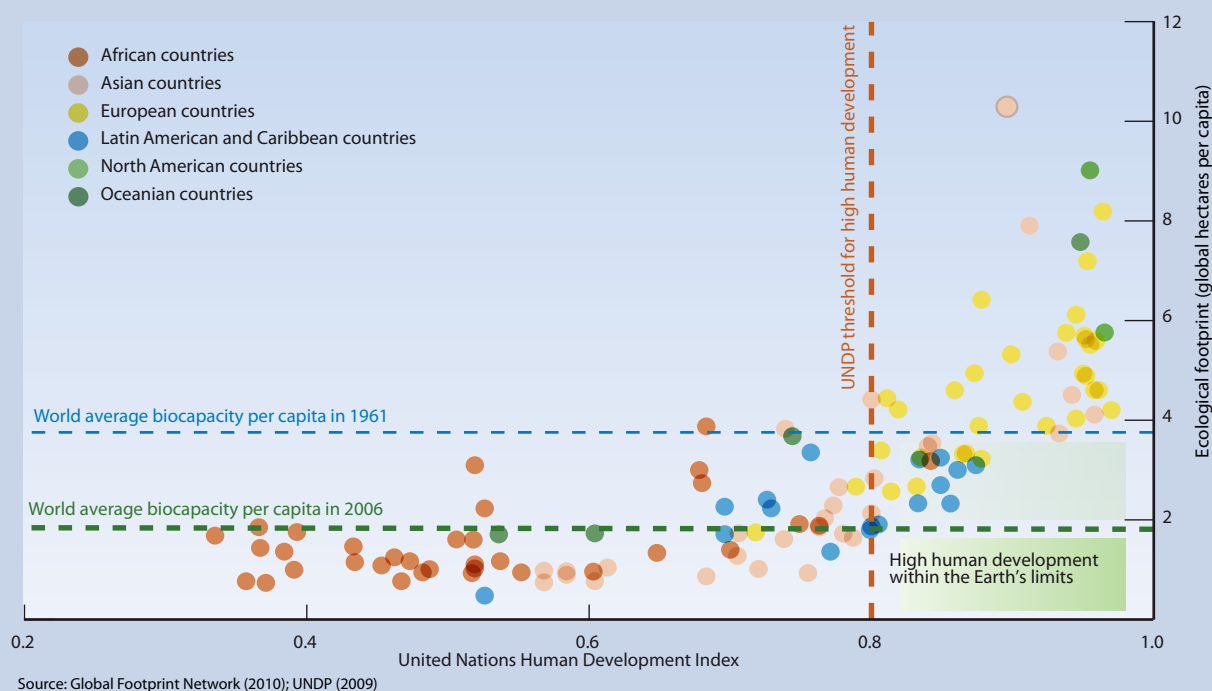
#### How far is the world from a green economy?

Over the last quarter of a century, the world economy has quadrupled, benefiting hundreds of millions of people (IMF 2006). However, 60 per cent of the world's major ecosystem goods and services that underpin livelihoods have been degraded or used unsustainably (Millennium Ecosystem Assessment 2005). This is because the

## Box 2: Towards a green economy – A twin challenge

Many countries now enjoy a high level of human development – but at the cost of a large ecological footprint. Others have a very low footprint, but face urgent needs to improve access to basic services such as

health, education, and potable water. The challenge for countries is to move towards the origin of the graph, where a high level of human development can be achieved within planetary boundaries.



economic growth of recent decades has been accomplished mainly through drawing down natural resources, without allowing stocks to regenerate, and through allowing widespread ecosystem degradation and loss.

For instance, today only 20 per cent of commercial fish stocks, primarily low priced species, are underexploited; 52 per cent are fully exploited with no further room for expansion; about 20 per cent are overexploited; and 8 per cent are depleted (FAO 2009). Water is becoming scarce and water stress is projected to increase with water supply satisfying only 60 per cent of world demand in 20 years (McKinsey and Company 2009). Agriculture saw increasing yields primarily due to the use of chemical fertilisers (Sparks 2009), yet has resulted in declining soil quality, land degradation, (Müller and Davis 2009) and deforestation – which resulted in 13 million hectares of forest lost annually over 1990-2005 (FAO 2010). Ecological scarcities are seriously affecting the entire gamut of economic sectors that are the bedrock of human food supply (fisheries, agriculture, freshwater, and forestry) and a critical source of livelihoods for the poor. At the same time, ecological

scarcity and social inequity are clear indicators of an economy that is not sustainable.

For the first time in history, more than half of the world population lives in urban areas. Cities now account for 75 per cent of energy consumption (UN Habitat 2009) and of carbon emissions (Clinton Foundation 2010).<sup>1</sup> Rising and related problems of congestion, pollution and poorly provisioned services affect the productivity and health of all, but fall particularly hard on the urban poor. With approximately 50 per cent of the global population now living in emerging economies (World Bank 2010) that are rapidly urbanising and developing, the need for green city planning, infrastructure and transportation is paramount.

The transition to a green economy will vary considerably among nations, as it depends on the specifics of each country's natural and human capital and on its relative level of development. As demonstrated graphically, there are many opportunities for all countries in such a transition (see Box 2). Some countries have attained high levels of

1. For a critique of these figures, see Satterthwaite, D. (2008), "Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions", *Environment and Urbanization*, 20 (2): 539-549..

human development, but often at the expense of their natural resource base, the quality of their environment, and high greenhouse gas (GHG) emissions. The challenge for these countries is to reduce their per capita ecological footprint without impairing their quality of life.

Other countries still maintain relatively low per capita ecological footprints, but need to deliver improved levels of services and material well-being to their citizens. Their challenge is to do this without drastically increasing their ecological footprint. As the diagram illustrates, one of these two challenges affects almost every nation, and globally, the economy is still very far from being green.

### Enabling conditions for a green economy

To make the transition to a green economy, specific enabling conditions will be required. These enabling conditions consist of national regulations, policies, subsidies and incentives, as well as international market and legal infrastructure, trade and technical assistance. Currently, enabling conditions are heavily weighted towards, and encourage, the prevailing brown economy, which depends excessively on fossil fuels, resource depletion and environmental degradation.

For example, price and production subsidies for fossil fuels collectively exceeded US\$ 650 billion in 2008 (IEA et al. 2010). This high level of subsidisation can adversely affect the adoption of clean energy while contributing to more greenhouse gas emissions. In contrast, enabling conditions for a green economy can pave the way for the success of public and private investment in greening the world's economies (IEA 2009). At a national level, examples of such enabling conditions are: changes to fiscal policy, reform and reduction of environmentally harmful subsidies; employing new market-based instruments; targeting public investments to green key sectors; greening public procurement; and improving environmental rules and regulations, as well as their enforcement. At an international level, there are also opportunities to add to market infrastructure, improve trade and aid flows and foster greater international cooperation (United Nations General Assembly 2010).

At the national level, any strategy to green economies should consider the impact of environmental policies within the broader context of policies to address innovation and economic performance (Porter and Van der Linde 1995).<sup>2</sup> In this view, government policy plays a critical role within economies to encourage innovation and growth. Such intervention is important as a means for fostering innovation and for choosing the direction of change (Stoneman ed. 1995; Foray ed. 2009).

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2. This point has been debated since at least the time of the initial statement of the Porter Hypothesis. Porter argued then that environmental regulation might have a positive impact on growth through the dynamic effects it engendered within an economy.

For some time, economists such as Kenneth Arrow have shown that competitive firms and competitive markets do not necessarily produce the optimal amount of innovation and growth within an economy (Arrow 1962; Kamien and Schwartz 1982).<sup>3</sup> Public intervention within an economy is therefore critically important for these purposes. This is because industries in competitive markets have few incentives to invest in technological change or even in product innovation, as any returns would be immediately competed away. This is one of the best-known examples of market failure in the context of competitive markets, and provides the rationale for various forms of interventions (Blair and Cotter 2005).

Examples of spurring growth and innovation can be seen from histories of many recently emerged economies. In the 1950s and 1960s, the Japanese and South Korean governments chose the direction of technological change through importing the technology of other countries (Adelman 1999). This changed in the 1970s when these economies shifted to aggressive policies for encouraging energy-efficient innovation. Shortly afterwards, Japan was one of the leading economies in the world in terms of research and development (R&D) investment in these industries (Mowery 1995).<sup>4</sup> This pattern of directed spending and environmental policies is being repeated today across much of Asia. The cases of South Korea and China in particular are illustrative, where a large proportion of their stimulus packages was directed at a "green recovery" and has now been instituted into longer-term plans for retooling their economies around green growth (Barbier 2010b).

Thus, moving towards a green development path is almost certainly a means for attaining welfare improvements across a society, but it is also often a means for attaining future growth improvement. This is because a shift away from basic production modes of development based on extraction and consumption and towards more complex modes of development can be a good long-term strategy for growth. There are several reasons why this shift might be good for long-term competitiveness as well as for social welfare.

First, employing strong environmental policies can drive inefficiencies out of the economy by removing those firms and industries that only exist because of implicit subsidies in under-priced resources. The free use of air, water and ecosystems is not a value-less good for any actor in an economy and amounts to subsidising negative net worth activities. Introducing effective regulation and market-based mechanisms to contain

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3. It has been known since at least the time of the seminal work of Kenneth Arrow (1962) and the structural work of Kamien and Schwartz (1982) that competitive firms and competitive markets need not produce the optimal amount of innovation and growth within an economy.

4. By 1987, Japan was the world leader in R&D per unit GDP (at 2.8 per cent) and the world leader in the proportion of that spent on energy-related R&D (at 23 per cent).



pollution and limit the accumulation of environmental liabilities drives the economy in a more efficient direction.

Second, resource pricing is important not just for the pricing of natural capital and services, but also for pricing of all the other inputs within an economy. An economy allocates its efforts and expenditures according to relative prices, and under-priced resources result in unbalanced economies. Policy makers should be targeting the future they wish their economies to achieve, and this will usually require higher relative prices on resources. An economy that wishes to develop around knowledge, R&D, human capital and innovation should not be providing free natural resources.

Third, employing resource pricing drives investments into R&D and innovation. It does so because avoiding costly resources can be accomplished by researching and finding new production methods. This will include investment in all of the factors (human capital and knowledge) and all of the activities (R&D and innovation) listed above. Moving towards more efficient resource pricing is about turning the economy's emphasis towards different foundations of development.

Fourth, these investments may then generate innovation rents. Policies that reflect scarcities that are prevalent in the local economy can also reflect scarcities prevalent more widely. For this reason, a solution to a problem of resource scarcity identified locally (via R&D investments) may have applicability and hence more global marketability. The first solution to a widely experienced problem can be patented, licensed and marketed widely.

Fifth, aggressive environmental regulation may anticipate future widely-experienced scarcities and provide a template for other jurisdictions to follow. Such policy leadership can be the first step in the process of innovation, investment, regulation and resource pricing described above (Network of Heads of European Environment Protection Agencies 2005).

In sum, the benefits from a strong policy framework to address market failures and ecological scarcities will flow down the environment pathway that comes from altering the direction of an economy. Policies and market-based mechanisms that enhance perceived resource prices creates incentives to shift the economy onto a completely different foundation – one based more on investments in innovation and its inputs of human capital, knowledge, and research and development.

### How to measure progress towards a green economy

It is difficult, if not impossible, to manage what is not measured. Notwithstanding the complexity of an overall transition to a green economy, appropriate indicators at

both a macroeconomic level and a sectoral level will be essential to informing and guiding the transition.

To complicate matters, conventional economic indicators, such as GDP, provide a distorted lens for economic performance, particularly because such measures fail to reflect the extent to which production and consumption activities may be drawing down natural capital. By either depleting natural resources or degrading the ability of ecosystems to deliver economic benefits, in terms of provisioning, regulating or cultural services, economic activity is often based on the depreciation of natural capital.

Ideally, changes in stocks of natural capital would be evaluated in monetary terms and incorporated into national accounts. This is being pursued in the ongoing development of the System of Environmental and Economic Accounting (SEEA) by the UN Statistical Division, and the World Bank's adjusted net national savings methods (World Bank 2006). The wider use of such measures would provide a better indication of the real level and viability of growth in income and employment. Green Accounting or Inclusive Wealth Accounting are available frameworks that are expected to be adopted by a few nations<sup>5</sup> initially and pave the way for measuring the transition to a green economy at the macroeconomic level.

### How might a green economy perform over time?

In this report, the macroeconomic Threshold 21 (T21) model is used to explore the impacts of investments in greening the economy against investments in business as usual. The T21 model measures results in terms of traditional GDP as well as its affects on employment, resource intensity, emissions, and ecological impacts.<sup>6</sup>

The T21 model was developed to analyse strategies for medium to long-term development and poverty reduction, most often at the national level, complementing other tools for analysing short-term impacts of policies and programmes. The model is particularly suited to analysing the impacts of investment plans, covering both public and private commitments. The global version of T21 used for purposes of this report models the world economy as a whole to capture the key relationships between production and key natural resource stocks at an aggregate level.

The T21 model reflects the dependence of economic production on the traditional inputs of labour and physical capital, as well as stocks of natural capital in the form of

5. World Bank, together with UNEP and other partners, have recently (at Nagoya, CBD COP-10, October 2009) announced a global project on Ecosystem Valuation and Wealth Accounting which will enable a group of developing and developed nations to test this framework and evolve a set of pilot national accounts that are better able to reflect and measure sustainability concerns.

6. See the Modelling chapter for details on the T21 model.

resources, such as energy, forest land, soil, fish and water. Growth is thus driven by the accumulation of capital – whether physical, human or natural – through investment, also taking into account depreciation or depletion of capital stocks. The model is calibrated to reproduce the past 40-year period of 1970-2010; simulations are conducted over the next 40-year period, 2010-2050. Business-as-usual projections are verified against standard projections from other organisations, such as the United Nations Population Division, World Bank, OECD, the International Energy Agency, and the Food and Agriculture Organization.

The inclusion of natural resources as a factor of production distinguishes T21 from all other global macroeconomic models (Pollitt et al. 2010). Examples of the direct dependence of output (GDP) on natural resources are the availability of fish and forest stocks for the fisheries and forestry sectors, as well as the availability of fossil fuels to power the capital needed to catch fish and harvest timber, among others. Other natural resources and resource efficiency factors affecting GDP include water stress, waste recycle and reuse and energy prices.<sup>7</sup>

Based on existing studies, the annual financing demand to green the global economy was estimated to be in the range US\$ 1.05 to US\$ 2.59 trillion. To place this demand in perspective, it is about one-tenth of total global investment per year, as measured by global Gross Capital Formation. Taking an annual level of US\$ 1.3 trillion (2 per cent of global GDP) as a reference scenario, varying amounts of investment in the 10 sectors covered in this report were modelled to determine impact on growth, employment, resource use and ecological footprint. The results of the model, presented in more detail in the modelling chapter, suggest that over time investing in a green economy enhances long-term economic performance. Significantly, it does so while enhancing stocks of renewable resources, reducing environmental risks, and rebuilding capacity to generate future prosperity. These results are presented in a disaggregated form for each sector to illustrate the effects of this investment on income, employment and growth, and more comprehensively, in the modelling chapter.

### 1.4 Approach and structure – Towards a green economy

This report focuses on 10 key sectors considered to be driving the defining trends of the transition to a green economy. These trends include increasing human well-

being and social equity, and reducing environmental risks and ecological scarcities. Across many of these sectors, greening the economy can generate consistent and positive outcomes for increased wealth, growth in economic output, decent employment and reduced poverty.

In Part I, the report focuses on those sectors derived from natural capital – agriculture, fishing, forests and water. These sectors have a material impact on the economy as they form the basis for primary production, and because the livelihoods of the rural poor depend directly upon them. The analysis looks at the principal challenges and opportunities for bringing more sustainable and equitable management to these sectors, and reviews investment opportunities to restore and maintain the ecosystem services that underpin these sectors. In so doing, the chapters highlight several sector-specific investment opportunities and policy reforms that are of global importance as they appear replicable and scalable in the goal to transition to a green economy.

In Part II, the report focuses on those sectors that may be characterised as “built capital”, traditionally considered the brown sectors of the economy. In these sectors – such as transportation, energy and manufacturing – the report finds large opportunities for energy and resources savings. These savings, it is argued, can be scaled up and become drivers of economic growth and employment, as well as having important equity effects in some cases. Resource efficiency is a theme that has many dimensions as it cuts across energy efficiency in manufacture and habitation, materials efficiency in manufacture, and better waste management.

Finally, after providing an in-depth overview of the modelling conducted for this report and before examining options for financing the green economy, Part III focuses on enabling conditions for ensuring a successful transition to a green economy. These include appropriate domestic fiscal measures and policy reforms, international collaboration through trade, finance, market infrastructure, and capacity building support. Much has been said about the potential for a green economy to be used as a pretext for imposing aid conditionalities and trade protectionism. This report argues that to be green, an economy must not only be efficient, but also fair. Fairness implies recognising global and country level equity dimensions, particularly in assuring a just transition to an economy that is low-carbon, resource efficient, and socially inclusive. These enabling conditions for a fair and just transition are described and addressed at length in the final chapters of this report before conclusions, along with the steps necessary to mobilise finance at scale for a global transition to a green economy.

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7. The T21 analysis purposely ignores issues such as trade and sources of investment financing (public vs private, or domestic vs foreign). As a result, the analysis of the potential impacts of a green investment scenario at a global level are not intended to represent the possibilities for any specific country or region. Instead, the simulations are meant to stimulate further consideration and more detailed analysis by governments and other stakeholders of a transition to a green economy.

# References

- Adelman, I. (1999). "The role of government in economic development." University of California, Berkeley.
- Arrow, K. (1962). "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*. National Bureau of Economic Research, Inc. 609-626.
- Barbier, E.B. (2005). *Natural Resources and Economic Development*. Cambridge University Press, Cambridge.
- Barbier, E.B. (2010). "Poverty, development and environment." *Environment and Development Economics* 15:635-660.
- Barbier, E.B. (2010a). *A Global Green New Deal: Rethinking the Economic Recovery*. Cambridge University Press and UNEP, Cambridge, UK.
- Barbier, E.B. (2010b). "A Global Green Recovery, the G20 and International STI Cooperation in Clean Energy." *STI Policy Review* 1(3):1-15.
- Basten, S., M. Herrmann and E. Lochinger (2011). *Population dynamics, poverty and employment challenges in the LDCs*, report prepared by IIASA and UNFPA, Laxenburg.
- Blair, R. and Cotter, T.F. (2005). *Intellectual property: Economic and legal dimensions of rights and remedies*. Cambridge University Press, Cambridge; New York.
- Chen, S. and Ravallion, M. (2007). "Absolute poverty measures for the developing world, 1981-2004." *Proceedings of the National Academy of Sciences* 104(43):16757-16762.
- Clinton Foundation. (2010). *Clinton Foundation Annual Report 2009*.
- Comprehensive Assessment of Water Management in Agriculture. (2007). "Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture". Earthscan, London and International Water Management Institute, Colombo, Sri Lanka.
- Dasgupta, P. (2008). "Nature in Economics." *Environmental and Resource Economics* 39:1-7.
- Eliasch, J. (2008). "Climate Change: Financing Global Forests." *The Eliasch Review*, UK. Available at: <http://www.official-documents.gov.uk/document/other/9780108507632/9780108507632.pdf>
- FAO. (2009). *Global agriculture towards 2050, How to Feed the World 2050*, High-Level Expert Forum, 12-13 October 2009, Rome. FAO, Rome.
- FAO. (2009a). *State of World Fisheries and Aquaculture 2008*. FAO, Rome.
- FAO. (2010). *FAO at work 2009-2010: growing food for nine billion*. FAO, Rome.
- FAO. (2010a). *Global Forest Resources Assessment 2010: Main Report*. FAO, Rome.
- Foray, D. (ed.). (2009). *Innovation Policy for Development: A Review*, Elgar.
- Gallai, N., Salles, J.-M., Settele, J. and Vaissière, B.E. (2009). "Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline." *Ecological Economics* 68(3): 810-21.
- Global Footprint Network. (2010). *The Ecological Wealth of Nations: Earth's Biocapacity as a New Framework for International Cooperation*.
- Guzmand, J.M. et al. (2009). "The Use of Population Census Data for Environmental and Climate Change Analysis", in J.M. Guzman et al. (eds). *Population Dynamics and Climate Change*, UNFPA and IIED, New York and London.
- Herrmann, M. and Khan, H. (2008). *Rapid Urbanization, Employment Crises and Poverty in African LDCs*, paper prepared for UNU-WIDER Project Workshop "Beyond the Tipping Point: African Development in an Urban World" (June 2008, Cape Town), Geneva.
- IEA. (2002). *World Energy Outlook 2002*. Chapter 10, Energy and Development. Organisation for Economic Co-operation and Development/IEA, Paris.
- IEA. (2009). *World Energy Outlook 2010*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2010). *Energy Technology Perspectives Scenarios & Strategies to 2050*. OECD/IEA, Paris.
- IEA, OPEC, OECD, and World Bank. (2010). "Analysis of the Scope of Energy Subsidies and Suggestions for the G20 Initiative." Joint report prepared for submission to the G20 Summit Meeting, Toronto (Canada), 26-27 June 2010, 4. Available at: <http://www.unep.org/greeneconomy>.
- IMF. (2006). "World Economic Outlook Database." IMF: Washington D.C. (September 2006). Available at: <http://www.imf.org/external/pubs/ft/weo/2006/02/data/download.aspx>.
- Kamien, M.I. and Schwartz, N.L. (1982). *Market Structure and Innovation*. Cambridge University Press, Cambridge.
- McGranahan, G., Balk, D. and Anderson, B. (2007). "The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones." *Environment and Urbanization* 19(1): 17-37.
- McKinsey and Company. (2009). "Charting our Water Future: Economic Frameworks to Inform Decision Making." 2030 Water Resources Group, Munich.
- Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, D.C.
- Mowery, D.C. (1995). "The Practice of Technology Policy", in Stoneman, P., (ed.). *Handbook of the Economics of Innovation and Technological Change*. Blackwell, Oxford.
- Müller, A. and Davis, J.S. (2009). *Reducing Global Warming: The Potential of Organic Agriculture*. Rodale Institute and FiBL. Kutztown, PA, and Frick, Switzerland.
- Network of Heads of European Environment Protection Agencies. (2005). "The contribution of good environmental regulation to competitiveness." Network of Heads of European Environment Protection Agencies, November 2005.
- Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Chateau, J. and Muir-Wood, R. (2007). "Ranking of the World's Cities Most Exposed to Coastal Flooding Today and in the Future: Executive Summary." OECD Environment Working Paper No. 1. OECD, Paris.
- OECD. (2008). *Costs of Inaction on Key Environmental Challenges*. OECD, Paris.
- Pearce, D.W. and Barbier, E.B. (2000). *Blueprint for a Sustainable Economy*. Earthscan, London.
- Pearce, D.W., Markandya A. and Barbier, E.B. (1989). *Blueprint for a Green Economy*. Earthscan, London.
- Pezzey, J.C.V. (1989). "Economic Analysis of Sustainable Growth and Sustainable Development." Environment Department Working Paper No. 15. The World Bank, Washington, D.C.
- Polasky, S. and Segerson, K. (2009). "Integrating Ecology and Economics in the Study of Ecosystem Services: Some Lessons Learned." *Annual Review of Resource Economics* 1:409-434.
- Pollitt, H. et al. (2010). *A Scoping Study on the Macroeconomic View of Sustainability*. Final report for the European Commission, DG Environment, Cambridge Econometrics and Sustainable Europe Research Institute (July 2010). Available at: [http://ec.europa.eu/environment/enveco/studies\\_modelling/pdf/sustainability\\_macroecomic.pdf](http://ec.europa.eu/environment/enveco/studies_modelling/pdf/sustainability_macroecomic.pdf).
- Population Division of the United Nations Secretariat. (2008). *World Urbanization Prospects: The 2007 Revision: Executive Summary*. United Nations, New York.
- Porter, M.E. and Van der Linde, C. (1995). "Toward a new conception of the environment-competitiveness relationship." *The Journal of Economic Perspectives* 9:97-118.
- Sparks, Donald L. (2009). *Advances in agronomy* 101. Elsevier Inc., London.
- Stoneman, P., (ed.). (1995). *Handbook of the Economics of Innovation and Technological Change*. Blackwell, Oxford.
- Sukhdev, P. (2008). *The Economics of Ecosystems & Biodiversity: An Interim Report*. European Communities, Brussels.

The Economics of Ecosystems and Biodiversity (TEEB). (2009). *TEEB for National and International Policy Makers. Summary: Responding to the Value of Nature*. TEEB – The Economics of Ecosystems and Biodiversity. Available at: <http://www.teebweb.org/LinkClick.aspx?fileticket=I4Y2nqqliCg%3d&tabid=1019&language=en-US>.

The Economics of Ecosystems and Biodiversity (TEEB). (2010). *The Economics of Ecosystems and Biodiversity: Mainstreaming the economics of nature: A synthesis of the conclusions and recommendations of TEEB*. TEEB, Bonn, Germany.

Tokgoz, S. and Rosegrant, M. (2011). *Population pressures, land use, and food security in the Least Developed Countries: Results from the IMPACT model, report prepared by IFPRI for UNFPA*, Washington, D.C.

UNCTAD. (2009). *Trade and Development Report 2009: Responding to the global crisis. Climate change mitigation and development*, Geneva and New York.

UNCTAD. (2010a). *The Least Developed Countries Report 2010: Towards a New International Development Architecture for LDCs*, Geneva and New York.

UNCTAD. (2010b). *Trade and Environment Review 2009/ 2010: Promoting Poles of Clean, Sustainable Growth in Developing Countries to Enhance Resilience to the Inter-related Economic, Food and Climate Crises*, Geneva.

UN. (1992). Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, Annex I: Rio Declaration on Environment and Development, A/ CONF.151/26 (Vol. I), 12 August 1992, New York.

UN DESA. (2009). *World Population Prospects: The 2008 Revision*, New York.

UN DESA. (2011). *World Population Prospects: The 2010 Revision*, New York.

UN Habitat. (2009). *Cities and Climate Change Initiative Launch and Conference Report*. UN Habitat (March 2009).

UNDP. (2006). *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis*. United Nations Development Programme, New York.

UNDP. (2008). *Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World*. United Nations Development Programme, New York.

UNDP. (2009). *Human Development Report 2009 – Overcoming Barriers: Human Mobility and Development*.

UNEP, ILO, IOE, and ITUC (2008). *Green Jobs: Towards Decent Work in a Sustainable, Low-carbon World*. UNEP, Geneva.

UNEP. 2010. *Green Economy Developing Countries Success Stories*. UNEP, Geneva.

UNFPA. (2007). *State of World Population 2007: Unleashing the Potential of Urban Growth*, New York.

UNFPA. (2011a). *Population dynamics in the Least Developed Countries: Challenges and opportunities for development and poverty reduction*, New York.

UNFPA. (2011b). *Population situation analysis: A conceptual and methodological guide*, New York.

United Nations General Assembly. (2010). "Resolution Implementation of Agenda 21, the Programme for the Further Implementation of Agenda 21 and the outcomes of the World Summit on Sustainable Development." 64/53(a). Available at: <http://css.escwa.org.lb/GARes/64-236.pdf>

United Nations General Assembly. (2011). "Synthesis report on best practices and lessons learned on the objectives and themes of the conference." United Nations General Assembly, January 2011. 3756. Available at: <http://www.uncsd2012.org/files/intersessional/Synthesis-Report-Final.pdf>.

World Bank. (2003). *World Development Report 2003*. World Bank, Washington D.C..

World Bank. (2006). *Where is the Wealth of Nations? Measuring Capital for the 21st Century*. World Bank, Washington D.C.

World Bank. (2010). *World Development Indicators*. World Bank, Washington D.C.

World Commission on Environment and Development (1987). *Our Common Future*. Oxford University Press, New York.

World Health Organization and UNICEF. (2010). *Progress on Sanitation and Drinking Water: 2010 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. WHO, Geneva.

WWF, IUCN, and UNEP. (1991). *Caring for the Earth*. Gland, Switzerland.







# Part I

Investing in natural capital









# Agriculture

Investing in natural capital



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## List of acronyms

ADB	Asian Development Bank	IMF	International Monetary Fund
AKST	Agricultural knowledge, science and technology	IP	Intellectual Property
BAU	Business-as-usual	IPCC	Intergovernmental Panel on Climate Change
BCI	Better Cotton Initiative	IPM	Integrated Pest Management
BSI	Better Sugar Initiative	ITC	International Trade Centre
CAADP	Comprehensive Africa Agriculture Development Programme	LICs	Low Income Countries
CGIAR	Consultative Group on International Agricultural Research	LMICs	Lower Middle Income Countries
CSIRO	The Commonwealth Scientific and Industrial Research Organisation	MDG	Millennium Development Goal
DEFRA	Department for Environment, Food and Rural Affairs (UK)	MSCI	Morgan Stanley Capital International
EU	European Union	NCAR	National Centre for Atmospheric Research
FAO	Food and Agriculture Organisation of the United Nations	NGO	Non-governmental organisation
FAOSTAT	Food and Agriculture Organisation Statistical Databases	ODA	Oversees Development Assistance
FiBL	German Research Institute of Organic Agriculture	OECD	Organisation for Economic Co-operation and Development
G8	Group of Eight	PAHM	Plant and animal health management
GAP	Good Agricultural Practices	PES	Payment for Ecosystem Services
GDP	Gross Domestic Product	PICS	Purdue Improved Cowpea Storage
GHG	Greenhouse gas	R&D	Research and development
GMO	Genetically modified organism	ROI	Return on investment
GRID	Global Resource Information Database	RSPO	Roundtable on Sustainable Palm Oil
HICs	High Income Countries	RTRS	Round Table on Responsible Soy
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development	SAM	Sustainable Asset Management AG
ICARDA	International Centre for Agricultural Research in the Dry Areas	SOM	Soil organic matter
IDH	Dutch Sustainable Trade Initiative	SRI	System Rice Intensive
IEA	International Energy Agency	SWFs	Sovereign wealth funds
IFAD	International Fund for Agricultural Development	UMICs	Upper Middle Income Countries
IFOAM	International Federation of Organic Agriculture Movements	UNCTAD	United Nations Conference on Trade and Development
IFPRI	International Food Policy Research Institute	UN DESA	United Nations Department of Economic and Social Affairs
ILO	International Labour Organisation	UNDP	United Nations Development Programme
		UNEP	United Nations Environment Programme
		UNESCO ECA	United Nations Economic and Social Council, Economic Commission for Africa
		WDR	World Development Report
		WIPO	World Intellectual Property Organisation
		WTO	World Trade Organisation
		WWAP	World Water Assessment Programme



# Key messages

**1. Feeding an expanding and more demanding world population in the first half of this century, while attending to the needs of nearly one billion people who are presently undernourished and addressing climate change, will need managed transitions away from “business-as-usual” (BAU)**

in both conventional<sup>1</sup> and traditional<sup>2</sup> farming. In different ways and in varying degrees, current farming systems deplete natural capital and produce significant quantities of global greenhouse gases (GHG) and other pollutants, which disproportionately affect the poor. The continued demand for land-use changes is often responsible for deforestation and loss of biodiversity. The economic cost of agricultural externalities amounts to billions of US dollars per year and is still increasing. A package of investments and policy reforms aimed at greening agriculture<sup>3</sup> will offer opportunities to diversify economies, reduce poverty through increased yields and creation of new and more productive green jobs – especially in rural areas, ensure food security on a sustainable basis, and significantly reduce the environmental and economic costs associated with today’s industrial farming practices.

**2. Green agriculture is capable of nourishing a growing and more demanding world population at higher nutritional levels up to 2050.**

It is estimated that an increase, from today’s 2,800 Kcal availability per person per day to around 3,200 Kcal by 2050, is possible with the use of green agricultural practices and technologies. It is possible to gain significant nutritional improvements from increased quantity and diversity of food (especially non-cereal) products. During the transition to a greener agriculture, food production in high-input industrial farming may experience a modest decline, while triggering significant positive responses in more traditional systems run by small farmers in the developing world, and producing the majority of staple crops needed to feed the world population. Public, private and civil initiatives for food production and social equity will be needed for an efficient transition at farm level and to assure sufficient quality nutrition for all during this period.

**3. Green agriculture will reduce poverty.** Environmental degradation and poverty can be simultaneously addressed by applying green agricultural practices. There are approximately 2.6 billion people who depend on agriculture for livelihood, a vast majority of them living on small farms and in rural areas on less than US\$1 per day. Increasing farm yields and return on labour, while improving ecosystem services (on which the poor depend most directly for food and livelihoods) will be key to achieving these goals. For example, estimates suggest that for every 10 per cent increase in farm yields, there has been a 7 per cent reduction in poverty in Africa, and more than 5 per cent in Asia. Evidence shows that the application of green farming practices has increased yields, especially on small farms, between 54 and 179 per cent.

**4. Reducing waste and inefficiency is an important part of the green agriculture paradigm.**

Crop losses due to pests and hazards, combined with food waste in storage, distribution, marketing and at the household level, account for nearly 50 per cent of the human edible calories that are produced. Currently, total production is around 4,600 Kcal/person/day, but what is available for human consumption is around 2,000 Kcal/person/day. The Food and Agriculture Organisation (FAO) suggests that a 50 per cent reduction of losses and wastage in the production and consumption chain is a

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1. Refer to section 1.2 for more details about what this report categorises as conventional or industrial agriculture.

2. Refer to section 1.3 for detailed information about what this report considers traditional, smallholder and subsistence farming.

3. Refer to section 1.4 for detailed information about a green agriculture paradigm.

4. For details, refer to the Modelling Chapter of this report.

necessary and achievable goal. Addressing some of these inefficiencies – especially crop and storage losses – offers opportunities that require small investments in simple farm and storage technology on small farms, where it makes the most material difference to smallholder farmers. The FAO reports that although reducing post-harvest losses could be achieved relatively quickly, less than 5 per cent of worldwide agricultural research and extension funding currently targets this problem.

**5. Greening agriculture requires investment, research and capacity building.** This is needed in the following key areas: soil fertility management, more efficient and sustainable water use, crop and livestock diversification, biological plant and animal health management, an appropriate level of mechanisation, improving storage facilities especially for small farms and building upstream and downstream supply chains for businesses and trade. Capacity building efforts include expanding green agricultural extension services and facilitating improved market access for smallholder farmers and cooperatives. The aggregate global cost of investments and policy interventions required for the transition towards green agriculture is estimated to be US\$ 198 billion per year from 2011 to 2050.<sup>4</sup> The value added in agricultural production increases by 9 per cent, compared with the projected BAU scenario. Studies suggest that “Return on investments (ROI) in agricultural knowledge, science and technology across commodities, countries and regions on average are high (40-50 per cent) and have not declined over time. They are higher than the rate at which most governments can borrow money”. In terms of social gains, the Asian Development Bank Institute concluded that investment needed to move a household out of poverty, in parts of Asia, through engaging farmers in organic agriculture, could be as little as US\$ 32 to US\$ 38 per capita.

**6. Green agriculture has the potential to be a net creator of jobs that provides higher return on labour inputs than conventional agriculture.** Additionally, facilities for ensuring food safety and higher quality of food processing in rural areas are projected to create new better quality jobs in the food production chain. Modelled scenarios suggest that investments aimed at greening agriculture could create 47 million additional jobs in the next 40 years, compared with the BAU scenario.

**7. A transition to green agriculture has significant environmental benefits.** Green agriculture has the potential to: rebuild natural capital by restoring and maintaining soil fertility; reduce soil erosion and inorganic agro-chemical pollution; increase water-use efficiency; decrease deforestation, biodiversity loss and other land use impacts; and significantly reduce agricultural GHG emissions. Importantly, greening agriculture could transform agriculture from being a major emitter of GHG to one that is net neutral, and possibly even be a GHG sink, while reducing deforestation and freshwater use by 55 per cent and 35 per cent, respectively.

**8. Green agriculture will also require national and international policy reforms and innovations.** Such policy changes should focus particularly on reforming environmentally harmful subsidies that artificially lower the costs of some agricultural inputs and lead to their inefficient and excessive use. In addition, they should promote policy measures that reward farmers for using environmentally-friendly agricultural inputs and farming practices and creating positive externalities such as improved ecosystem services. Changes in trade policies that increase access of green agricultural exports, originating in developing countries to markets in high income countries, are also required, along with reforms of trade-distorting production and export subsidies. These will facilitate greater participation by smallholder farmers, cooperatives and local food processing enterprises in food production value chains.

# 1 Introduction

This chapter makes a case for investing in greening the agriculture<sup>5</sup> sector, emphasising the potential global benefits of making this transition. It provides evidence to inspire policymakers to support increased green investment and guidance on how to enable this transformation, which aims to enhance food security, reduce poverty, improve nutrition and health, create rural jobs, and reduce pressure on the environment, including reducing GHG emissions.

The chapter begins with a brief overview of agriculture at the global level, followed by a discussion on conceptual issues including two predominant farming-practice paradigms, i.e. conventional (industrialised) agriculture systems and traditional (subsistence) smallholder agriculture. The section ends with a brief description of key characteristics of the green agriculture paradigm. Section 2 presents the major challenges and opportunities related to the greening the agriculture sector and Section 3 discusses a wide range of sustainable agriculture practices, mostly using examples and evidence from the organic sector, which is relatively rich in data. The section starts with an overview of the cost of degradation resulting from current agricultural practices and benefits of greening the sector. It is followed by an outline of some of the priorities for investment. The section ends with a discussion on the results of an economic modelling exercise, which presents future scenarios for green agriculture and business-as-usual (BAU). Section 4 shows how global and national policy as well as capacity building and awareness raising can facilitate necessary investments and encourage changes in agricultural practices. Section 5 concludes the discussion.

## 1.1 General background

Agriculture is a major occupational sector in many developing countries and is an important source of income for the poor. World Bank statistics (2010) show agricultural value-added as a percentage of GDP to be 3 per cent for the world as a whole, and 25 per cent for low income countries (LICs), 14 per cent for lower middle income countries (LMICs), 6 per cent for upper middle income countries (UMICs) and 1 per cent for high income countries (HICs).<sup>6</sup> Approximately 2.6 billion people rely on agricultural production systems – farming, pastoralism, forestry or fisheries – for their livelihoods (FAOSTAT 2004).

To date, global agricultural productivity has more than kept up with population growth (FAO 2009; IAASTD

2009). However, agricultural productivity per worker and per land unit varies a great deal across countries. Agricultural productivity per worker in 2003-05 was 95 times higher in HICs than in LICs, and this difference increased compared with 1990-1992, when it was 72 times higher. Industrial agriculture mostly practiced in developed countries, continues to generate high levels of production – more than 50 per cent of the world value added in agriculture and food processing – but it also accounts for proportionally more adverse environmental impacts than lower-yield traditional farming (World Bank 2010). Agriculture in developing countries is becoming more productive. Over the above period, aggregate agricultural productivity per worker in developed countries increased by 21 per cent, albeit from a very low base.

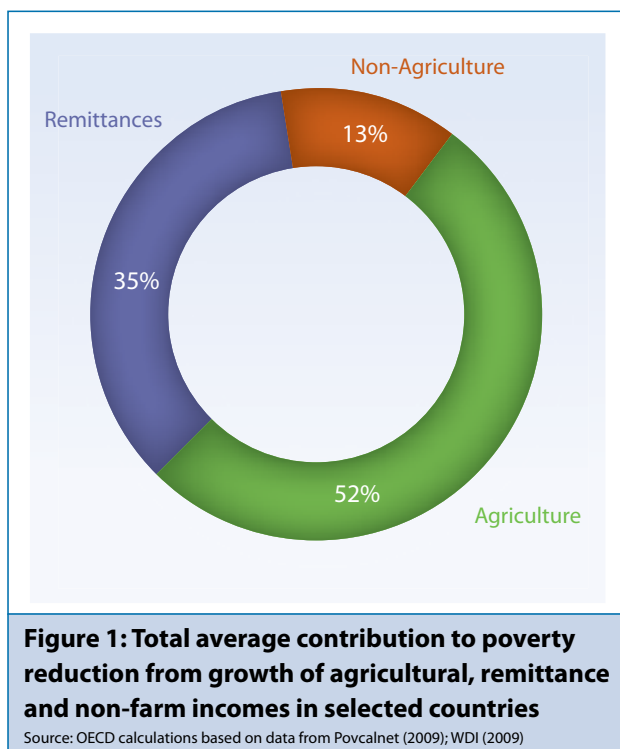
Despite the increasing productivity of agriculture, nearly 1 billion people remain malnourished. Between 2000 and 2007, over a quarter (27.8 per cent) of children under the age of five in LICs were malnourished (World Bank 2010). Moreover, over half of food-insecure families are rural households, often in countries such as India that have food surpluses. A transition in the agricultural paradigm must also assist in meeting this challenge.

Agriculture also has tremendous potential to alleviate poverty. A large proportion of the rural population and labour force in developing countries is employed in agriculture. On average, the contribution of agriculture to raising the incomes of the poorest is estimated to be at least 2.5 times higher than that of non-agriculture sectors in developing countries. Underscoring the relationship between increasing yields and return on labour with poverty, Irz et al. (2001) estimate that for every 10 per cent increase in farm yields, there was a 7 per cent reduction in poverty in Africa and more than a 5 per cent poverty-reduction effect for Asia. Growth in manufacturing and services do not show a comparable impact on poverty reduction. The World Bank (2010) reported that an increase in overall GDP derived from agricultural labour productivity was, on average, 2.9 times more effective in raising the incomes of the poorest quintile in developing countries than an equivalent increase in GDP derived

5. In this report agriculture includes only crop and animal husbandry unless clearly indicated otherwise. Forestry and fisheries are covered in separate chapters.

6. World Bank Classification: Low-income economies (US\$ 1,005 or less), Lower-middle-income economies (US\$ 1,006 to US\$ 3,975), Upper-middle-income economies (US\$ 3,976 to US\$ 12,275), High-income economies (US\$ 12,276 or more); Available at: <http://data.worldbank.org/about/country-classifications/country-and-lending-groups>.





from non-agricultural labour productivity. Using cross-country regressions per region, Hasan and Quibriam (2004) found greater effects from agricultural growth on poverty (defined as less than US\$ 2 per day per person) reduction in sub-Saharan Africa and South Asia. (This trend was not seen in East Asia and Latin America where there were greater poverty-reducing effects of growth originating in non-agriculture sectors).

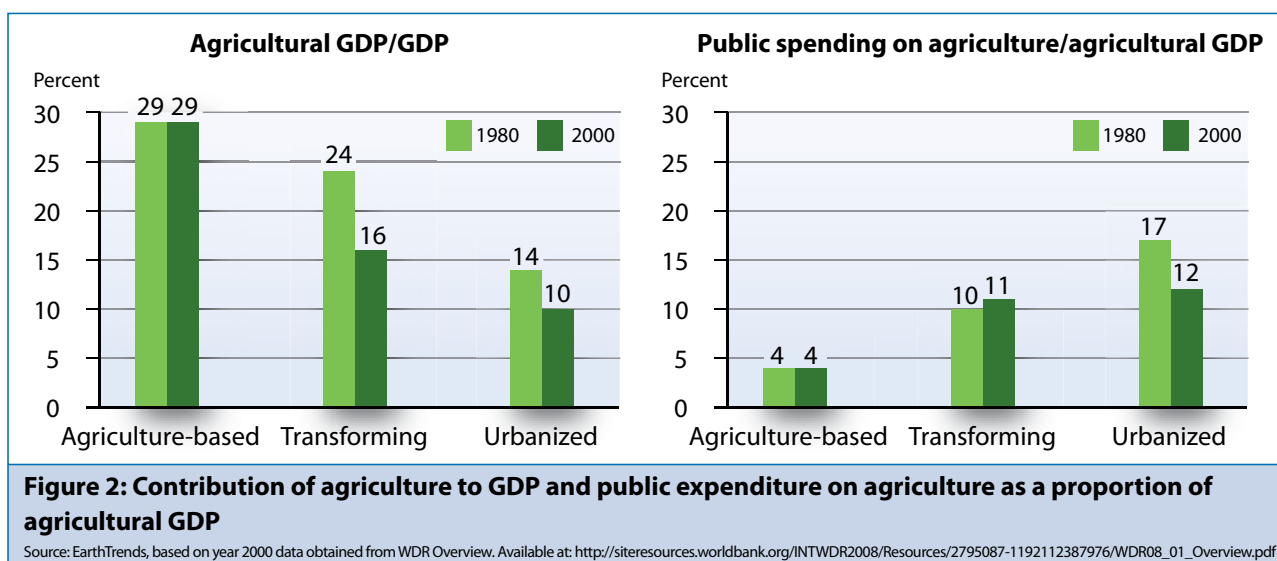
Despite the potential contribution of agriculture to poverty alleviation, mainly owing to the urban bias of many national government policies (Lipton 1977), rural sectors in most developing countries have not received the levels of public investment required to support

the development of a thriving agriculture sector. Government expenditure on agriculture in developing countries dropped from 11 per cent in the 1980s to 5.5 per cent in 2005, with the same downward trend observed in official development assistance going to the agriculture sector, which fell from 13 per cent in the early 1980s to 2.9 per cent in 2005 (UN-DESA Policy Brief 8, October, 2008). In Africa, governments publicly committed in the Maputo Declaration of 2000 to spending 10 per cent of their GDP on agriculture, including rural infrastructure spending (UNESCO ECA 2007). However, only eight countries had reached the agreed level by 2009 (CAADP 2009).

Between 1980 and 2000, an inverse association was noted between the contribution of agriculture to GDP and public spending on agriculture as a percentage of agricultural GDP as shown in Figure 2, which distinguishes between agriculture-based, transforming and urbanised countries.<sup>7</sup>

The result of this long-term neglect of the agriculture sector in developing countries is that rural poverty rates consistently exceed those in urban areas, with more than 75 per cent of the world's most impoverished people living in rural areas, and many seeking ways to migrate to cities (IFAD 2003). We note that in this scenario, poverty can result in environment-related economic consequences if crop production is based upon unsustainable land use, which in turn results in the depletion of soil nutrients and cultivation of unsuitable, marginal land that can lead to soil erosion, degradation of ecosystems and the reduction of natural habitats<sup>8</sup> for biodiversity.

In the following paragraphs, we discuss particular attributes of conventional and small-scale agricultural practices that have exacerbated these trends.



7. Agriculture based = developing, Transforming = new industrialised, Urbanised = developed countries.

8. This poverty-environment nexus is a well researched area. For a framework and review, see Opschoor (2007).

## 1.2 Conventional/industrial agriculture

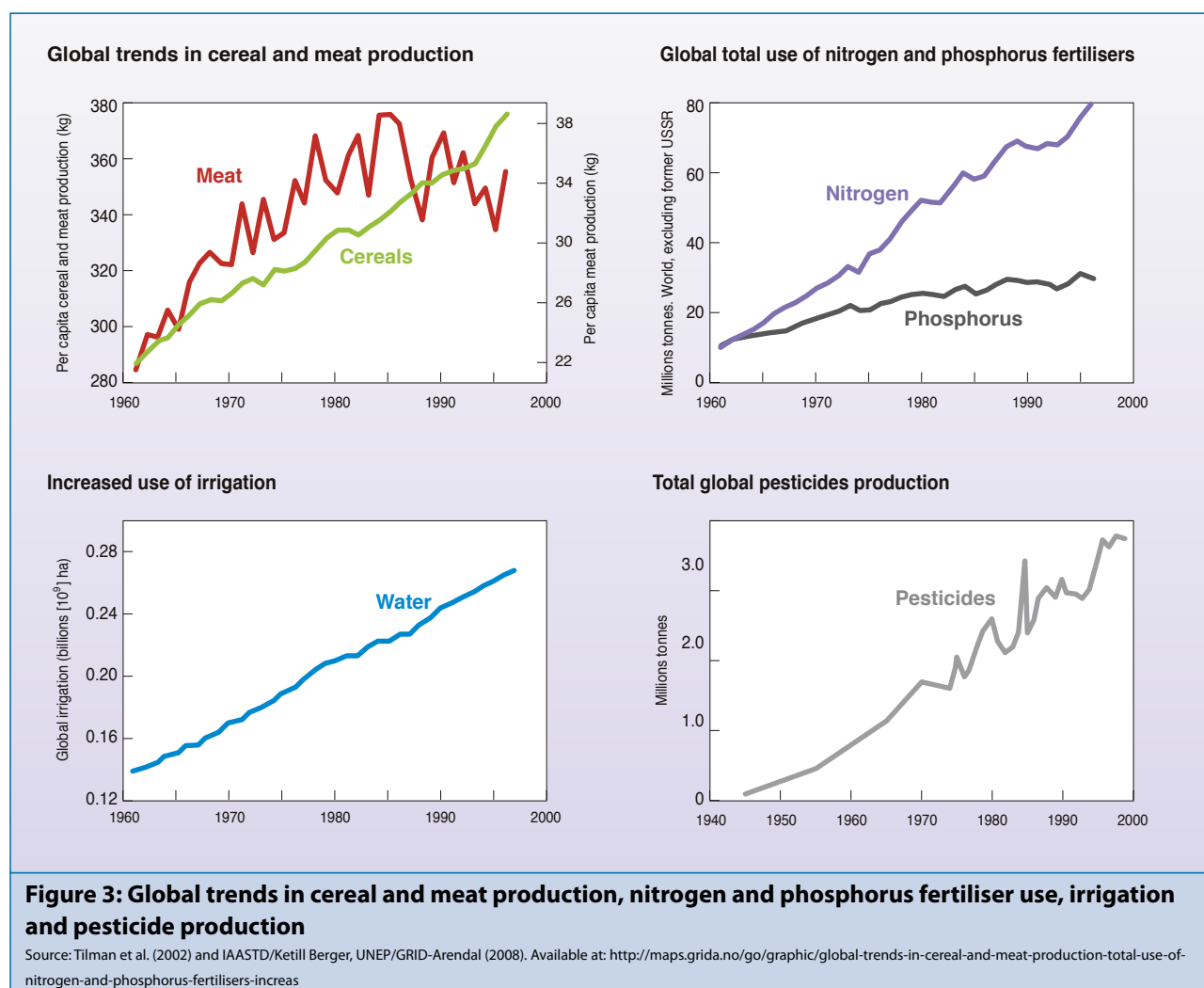
Conventional (industrial) agriculture is characterised by farming practices that rely on use of external farming inputs. Most of the large scale industrial farming is considered energy-intensive (using 10 calories of energy for every calorie of food produced), whose high productivity (kg/ha) relies on the extensive use of chemical fertilisers, herbicides, pesticides, fuel, water, and continuous new investment (e.g. in advanced seed varieties and machinery).

The impressive productivity gains of the Green Revolution of the last few decades took place mainly in conventional agriculture. These productivity gains were triggered by investment in agricultural research and expansion in public-sector extension services.<sup>9</sup> The productivity increases of the Green Revolution relied primarily on the development of higher-yield varieties of major cereal crops (i.e. wheat, rice and corn/maize), a significant increase in the use of irrigation, inorganic

fertilisers, pesticide/herbicide use and fossil fuel-based farm machinery.

Despite substantial gains in total crop production, the consequences of the revolution have not been entirely positive. Production gains have been highly correlated with increased use of non-renewable resource inputs, and have often entailed significant environmental costs due to their overuse (Figure 3). Industrial agriculture consumes on average 10 exosomatic energy calories (derived from fossil fuel energy resources) for every food endosomatic energy calorie (derived from human metabolism of food) that is produced and delivered to the consumer (Giampietro and Pimentel 1994). This energy-intensity, in many cases, is encouraged by subsidising inorganic fertiliser, fuel and electric power used on farms. In addition, biodiversity losses have resulted from production subsidies targeted at a limited number of crops. Industrial agriculture has also resulted in shrinking the agricultural labour force even as farm outputs have dramatically increased, a trend intensified to some extent by subsidies for farm mechanisation. (Lyson 2005; Dimitri et al. 2005; Knudsen et al. 2005; ILO 2008).

9. For an overview refer to Ruttan (1977), and for a critique refer to Shiva (1989).



### 1.3 Traditional/small farm/ subsistence agriculture

Traditional (subsistence) smallholder agriculture typically relies on indigenous and traditional knowledge that is based on farming practices used for several generations, has limited or no use of off-farm inputs, and results in low-productivity, low value added per worker and primarily reliant on extracting soil nutrients with insufficient replenishment by either organic or inorganic fertilisers. Generally, it is susceptible to yield losses due to erratic rainfall, pest and weed infestations and other production-related risks. It can trap already poor farmers in a downward spiral of growing poverty and social marginalisation.

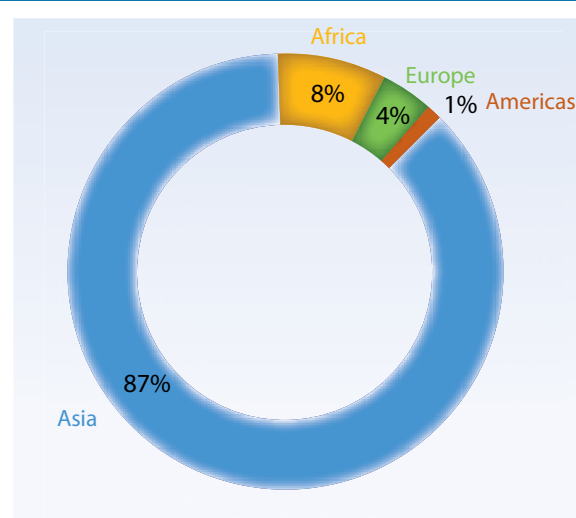
Traditional agriculture has limited scope for capital intensive farm mechanisation and intensive use of external agrochemical inputs. Many smallholders' plots, overarchingly located in developing countries, are too small to realise the economies of scale required for most of the available commercial farm machinery. In addition, the high cost of purchased inputs, such as chemical fertilisers, pesticides and seeds, generally require that at least some portion of the crops produced must be sold to recover costs. Failure to modernise land tenure systems, which can facilitate distribution, consolidation, and the use of land as security for bank loans are important barriers to the commercialisation of small-scale agriculture in many developing countries. Commercialisation is further limited by inadequate road transportation linking food-producing areas to large urban centres. For these reasons, value added per worker in developing countries is far below that of industrialised economies. Whereas the average value added per agricultural worker in OECD countries in 2003 was US\$ 23,081 (which grew at 4.4 per cent per year between 1992 and 2003, in Africa, the figures were only US\$ 327 and 1.4 per cent, respectively (IAASTD 2009b).

Worldwide, there are 525 million small farms, 404 million of which operate on less than two hectares of land (Nagayets 2005). These small farmers in the developing world produce the majority of staple crops needed to feed the planet's population (Altieri 2008). Their highest share is in Africa where about 90 per cent of all agricultural production is estimated to be derived from small farms, (Spencer 2002). In many instances their contribution is growing at the national level. While the issue is contested, there is substantial evidence that smaller farms have higher yields than large farms (Banerjee 2000; Rosset 1999; Faruquee and Carey 1997; Tomich et al. 1995; Barrett 1993; Ellis 1993; Cornia 1985 and Feder 1985). In Kenya, the share of national agricultural production contributed by smallholders increased from 4 per cent in 1965 to 49 per cent in 1985 (Lele and Agarwal 1989). In India, smallholders contributed over 40 per cent of food grain production in 1990-91, compared with only a third of

### Box 1: Agriculture at a crossroads

The key message of the Assessment of Agricultural Knowledge, Science and Technology for Development, published in 2009 is: "The way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with a growing population and climate change while avoiding social breakdown and environmental collapse." The Assessment calls for a fundamental shift in agricultural knowledge, science and technology (AKST) to successfully meet development and sustainability objectives. Such a shift should emphasise the importance of the multi-functionality of agriculture, accounting for the complexity of agricultural systems within diverse social and ecological contexts and recognising farming communities, farm households, and farmers as producers and managers of ecosystems. Innovative institutional and organisational arrangements to promote an integrated approach to the development and deployment of AKST are required as well. Incentives along the value chain should internalise as many negative externalities as possible, to account for the full cost of agricultural production to society. Policy and institutional changes should focus on those least served in the current AKST approaches, including resource-poor farmers, women and ethnic minorities. It emphasises that small-scale farms across diverse ecosystems need realistic opportunities to increase productivity and access markets.

Source: IAASTD (2009)



**Figure 4: Regional distribution of small farms**

Source: Nagayets (2005), based on FAO 2001c and 2004c and national statistical agencies.  
Note: Small-scale farms are defined as those of less than 2 hectares. The total number of small-scale farms is 404 million.

the total in 1980. As of the late 1990s, they also owned the majority of livestock and dominated the dairy sector (Narayanan and Gulati 2002).

Despite their higher output per hectare and the significant contribution they make to food production, however, small farmers are often very poor. In a survey of smallholder households, 55 per cent in Kenya and 75 per cent in Ethiopia, respectively, fell below the poverty line (Jayne et al. 2003). Low prices, unfair business practices and lack of transportation, storage and processing infrastructure contribute to this situation. Half of all undernourished people, three-quarters of malnourished African children and the majority of people living in absolute poverty are found on small farms (Millennium Project Task Force on Hunger 2004; IFAD 2001). In the majority of countries, poor rural people are both sellers of food commodities and buyers of foodstuffs, at different times of the year. Typically, they sell immediately after harvest, usually at very low prices, to meet their immediate cash requirements, and buy food in the months prior to the following harvest, usually at higher prices, to meet their food needs (IFAD 2010b).

It is expected that expanding smallholder production through green agricultural practices and greater commercialisation and integrating them into supply chains will create more better rewarding jobs in rural areas. As farmers get wealthier, they are likely to withdraw from occasional labour (Wiggins 2009). Wealthier farmers are also likely to spend more on locally-produced goods and services leading to multiplier effects. Rural linkage models in Africa have estimated multiplier effects ranging from 1.31 to 4.62 for Burkina Faso, Niger, Senegal and Zambia (Delgado et al. 1994).

## 1.4 The greening of agriculture

The greening of agriculture refers to the increasing use of farming practices and technologies that simultaneously:

- maintain and increase farm productivity and profitability while ensuring the provision of food and ecosystem services on a sustainable basis;
- reduce negative externalities and gradually lead to positive ones; and
- rebuild ecological resources (i.e. soil, water, air and biodiversity natural capital assets) by reducing pollution and using resources more efficiently.

A diverse, locally adaptable set of agricultural techniques, practices and market branding certifications such as Good Agricultural Practices (GAP), Organic/Biodynamic Agriculture, Fair Trade, Ecological Agriculture, Conservation Agriculture and related techniques and food supply protocols exemplify the varying shades of green agriculture.

Farming practices and technologies that are instrumental in greening agriculture include:

- restoring and enhancing soil fertility through the increased use of naturally and sustainably produced nutrient inputs; diversified crop rotations; and livestock and crop integration;
- reducing soil erosion and improving the efficiency of water use by applying minimum tillage and cover crop cultivation techniques;
- reducing chemical pesticide and herbicide use by implementing integrated and other environmental friendly biological pest and weed management practices; and
- reducing food spoilage and loss by expanding the use of post-harvest storage and processing facilities.

The greening of agriculture does not imply ruling out technologies or practices on ideological grounds. If a technology works to improve productivity for farmers, and does not cause undue harm to society and the environment, then it is very much part of the efforts for greening of agriculture. Although natural methods of pest and weed management and organic sources of fertiliser and seed are at one end of a green agriculture spectrum, the highly efficient and precise use of inorganic fertilisers, pest controls and technological solutions may also be included in the broad spectrum of sustainable farming practices. The Foresight Report (2011) presents resembling ideas given the need for the global food system to deliver much more than just food, and food security in the future. So greening of high input dependent agriculture, which has a high ecological footprint, could start by making the use of inputs most precise and efficient, gradually moving toward farming practices that have low or no ecological footprint.

To be able to measure success in moving towards the objectives of greening agriculture, two categories of indicators are proposed in Table 1.

Action indicators	Outcome indicators
Number of enacted and implemented policy measures and officially approved plans that promote sustainable agriculture (including trade and export policy measures, payment for ecosystem services through agriculture, etc.)	Percentage and amount of land under different forms of green agriculture (organic, GAP-good agriculture practices, conservation, etc.)
Level of governmental support to encourage farmers to invest in conversion to green agriculture and get the farm and the product certified	Decline in use of agro-chemicals as a result of conversion to green agriculture; and the number and percentage of farmers converting to green agriculture
Percentage of agricultural budget that is earmarked for environmental objectives	Increasing proportion of Payments for Environmental Services as a percentage of total farm income
Proportion of available producer support utilised for environmental objectives as a percentage of total agricultural producer support	Number of agriculture extension officers trained in green agriculture practices
Approved measures that reduce or eliminate barriers to trade in technologies and services needed for a transition to a green agriculture.	Number of enterprises set up in rural areas, especially those that produce local natural agricultural inputs, to offer off-farm employment opportunities.

**Table 1: Potential indicators for measuring progress towards green agriculture**

## 2 Challenges and opportunities

Today, agriculture stands at a crossroads. There are calls for changing the way food is produced and distributed if the poor and hungry are to be served better and if the world is to cope with a growing population and climate change. This section presents some major challenges and opportunities in transitioning to a green agriculture.

### 2.1 Challenges

Agriculture is facing a multitude of challenges on both the demand and supply side. On the demand side, these include food security, population growth, changing pattern of demand driven by increased income, and the growing pressure from biofuels. On the supply side, limited availability of land, water, mineral inputs and rural labour as well as the increasing vulnerability of agriculture to climate change and pre-harvest and post-harvest losses are the main challenges.

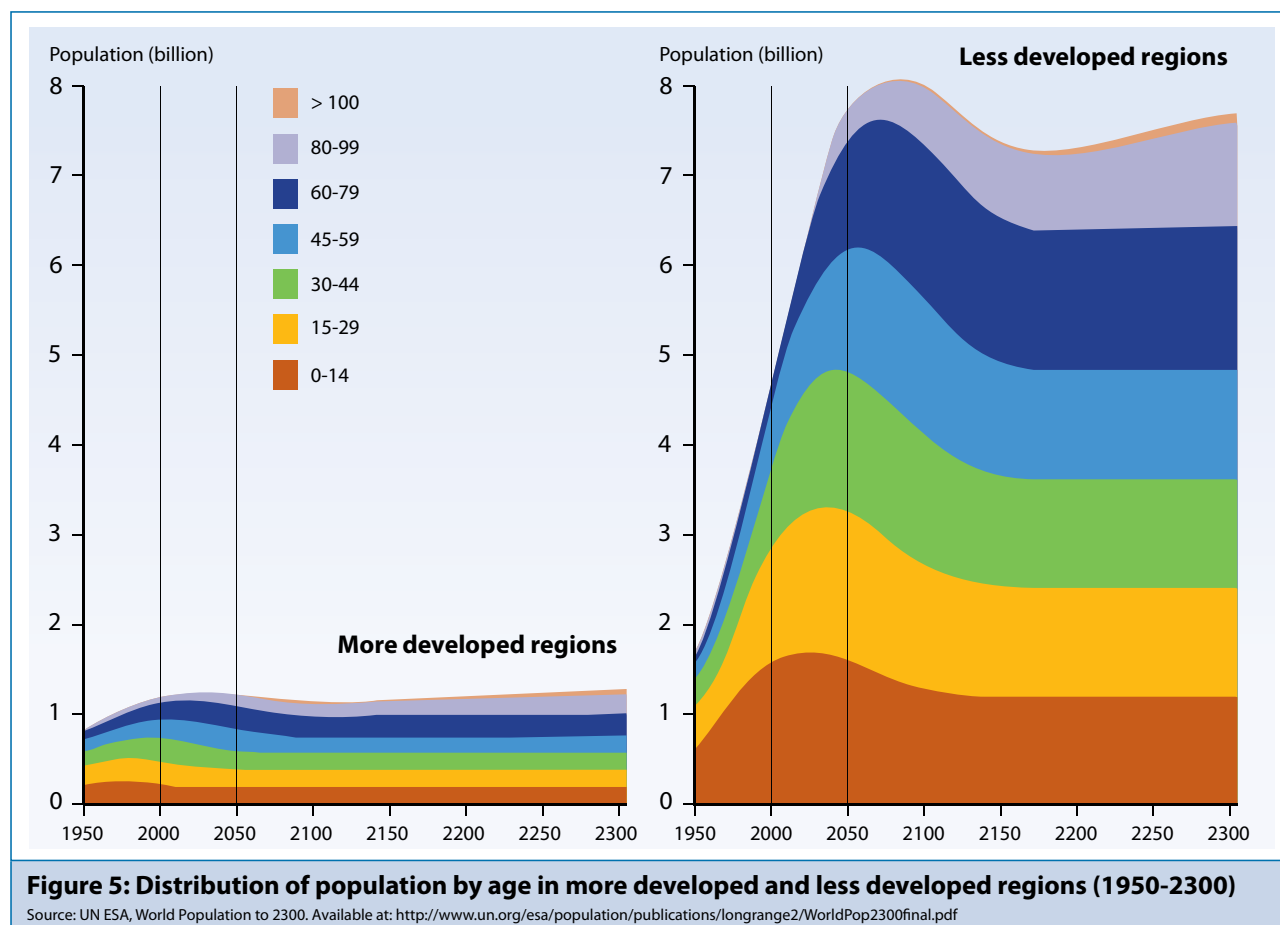
#### Increasing demand for food

The most significant factors contributing to the increasing demand for food are the continued growth of the global population, especially in developing

countries (Figure 5), and a rise in income levels in emerging economies. Demand for meat and processed food is rising with growing affluence. The current global population of more than 6 billion, of which 925 million are undernourished (FAO 2010), is forecast to reach 8.5-9 billion by 2050, and per capita incomes are expected to rise by as much as a factor of 20 in India and 14 in China, respectively (Goldman Sachs 2007). Figure 6 shows that rural populations are increasingly migrating to urban and peri-urban areas in developing countries. This has consequences for food demand and field-to-table supply chains because the diets of urban dwellers show an increased proportion of processed foods. The prospect of the human population expanding by almost a third by 2050, combined with an expected rise in per capita demand for meat, dairy and vegetable products, requires geographically-focused efforts and a change in agricultural production patterns.

#### Competing demand from biofuels

Growing interest in producing first-generation liquid biofuels to augment and replace petroleum-based transportation fuels is adding to the demand for starch, sugar and oilseed food commodities. For example,





the production of ethanol and bio-diesel fuels are predominantly based on food commodity feed stocks such as corn, sugarcane, soy, canola, sunflower and palm oil. Despite growing ethical, environmental, and economic concerns surrounding the use of food staples for producing these biofuels, there is continued public- and private-sector interest in their development. No matter where these crops are grown, they will inevitably compete with food crops for land, water and nutrients. Figure 7 shows food prices tracking fuel prices. At present, this alignment of food and energy prices may primarily result from the cost of fossil fuels used as an input in food production. But it is expected that the pattern will become more marked because of the competition for food crops that are used to produce biofuels.

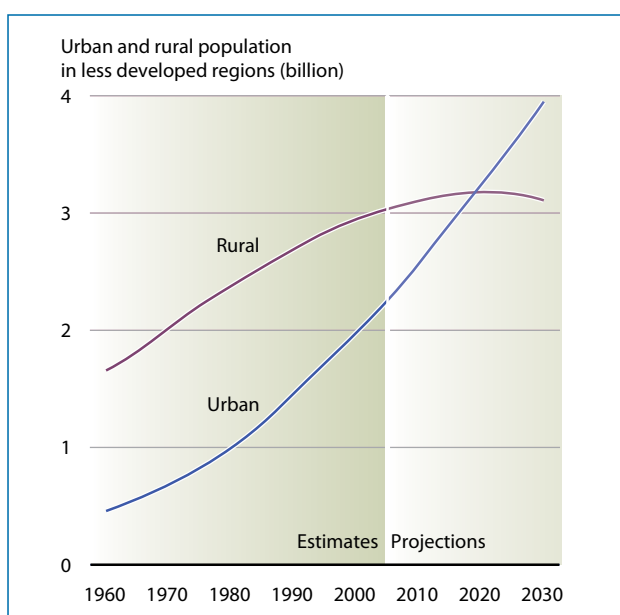
As a result, significant efforts are being made to develop technologies for second-generation biofuels, which can be produced from non-food biomass feedstock such as ligno-cellulosic wood and crop-residue wastes, perennially-grown switch grass and algae. Such technologies can potentially enable the production of biofuels to be scaled up with fewer adverse impacts on global food security. However, much more analysis is needed regarding the degree to which converting large quantities of cellulosic feedstock to biofuels would displace the recycling of organic nutrients from crop residues to arable land, pastures and forests (Balgopal et al. 2010).

#### Limited arable land and scarce water

Approximately 1.56 billion hectares or 12 per cent of the earth's total land surface area is arable land being used to produce crops for human and livestock consumption.

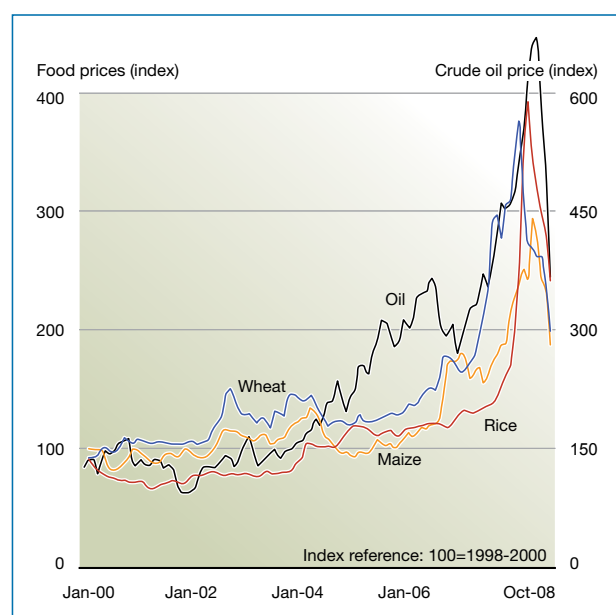
In addition, some 3.4 billion hectares of pasture and woodland are now used for livestock production (Bruinsma 2009). The agricultural productivity of the available arable land is extremely varied. Crop yields in developed countries are generally far greater than the yields realised in most developing countries. These productivity differences result from different levels of natural soil fertility; fertiliser, pesticide and herbicide use; quality of cultivated plant species and seeds; availability and access to water; farmers' education and access to information, credit and risk insurance and the degree of agricultural mechanisation.

Only limited additional land can be readily brought into agricultural production through conversion or rehabilitation. Moreover, the often highly fertile arable land surrounding cities is rapidly being converted into residential and commercial development as urbanisation gathers pace (Pauchard et al. 2006). Expanding cultivated areas is no longer the obvious way to increase production (exceptions are parts of sub-Saharan Africa and Latin America where some savanna areas could be brought into production). Furthermore, over-grazing by livestock and extended drought conditions are accelerating the desertification of fragile arid and semi-arid regions. Agriculture has contributed to land degradation in all regions, but is most severe in input-intensive production systems (notably in East Asia, Latin America, North America and Europe). Agricultural activities account for around 35 per cent of severely degraded land worldwide (Marcoux 1998). Given the high risk of further deforestation, developing countries will need to meet food-supply gaps by simultaneously increasing productivity and



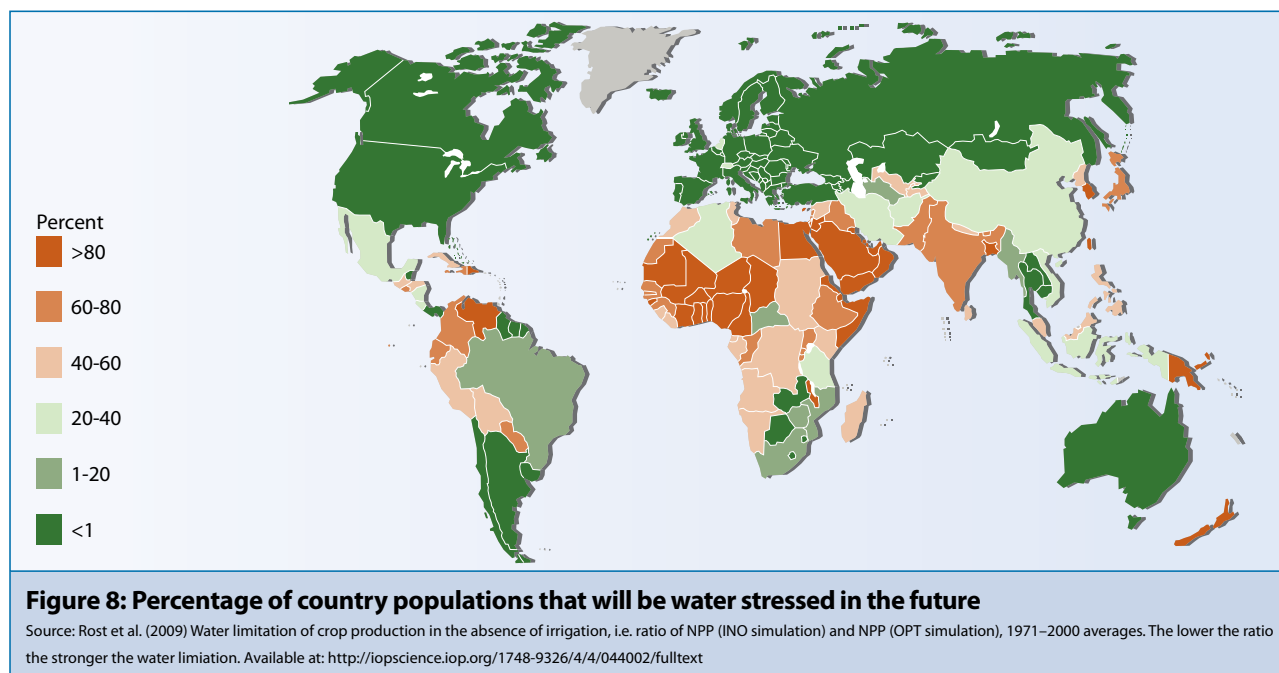
**Figure 6: Urban and rural population trends in developing regions**

Source: Nordpil, Ahlenius (2009); United Nations Population Division (2007); World Urbanization Prospects: The 2007 Revision Population Database, Available at: <http://esa.un.org/unup/index.asp?panel=1>



**Figure 7: Trends in food commodity prices, compared with trends in crude oil prices**

Source: Nordpil, Ahlenius (2009); Food and Agricultural Organisation of the United Nations (2008). International commodity prices, Available at: <http://www.fao.org/es/esc/prices>, IMF 2008. IMF Primary Commodity Prices, monthly data for 8 price indices and 49 actual price series, 1980 – current, Available at: <http://www.imf.org/external/np/res/commmod/index.asp>



greening their agricultural practices, rather than seeking widespread expansion of arable land.

The agriculture sector is the largest consumer of fresh water, accounting for 70 per cent of global use, including rainfall run-off. A majority of crop lands are exclusively rain-fed, and only 24 per cent of arable land is cultivated with the help of irrigation from flowing surface waters or groundwater aquifers (Portmann et al. 2009). This distinction is important because irrigated fields are much more productive and produce nearly a third of all agricultural output (Falkenmark and Rockstrom 2004).

The increasing disruption of historical rainfall patterns experienced in many areas of the world is a cause for great concern since rain-fed farming is the dominant form of agriculture. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concluded that many observed changes in extremes, such as more frequent, heavy precipitation events and longer, more intense droughts, are consistent with warming of the climate system (IPCC 2007a). While affecting rain-fed agriculture, precipitation changes also adversely affect the recharge rates of aquifers and watersheds. The continued worsening of water-stress conditions suggests that efforts to increase the use of irrigation will gradually increase agricultural production costs. Clearly, practices that increase water-use efficiencies are required to alleviate this trend.

Figure 8 shows projections for global water stress in the future. The figure also underscores the need for increased coordination in water use nationally and across borders. In this context, the Mekong River Commission, which coordinates the watershed development plans of member states, is one of several promising supra-national river basin initiatives.

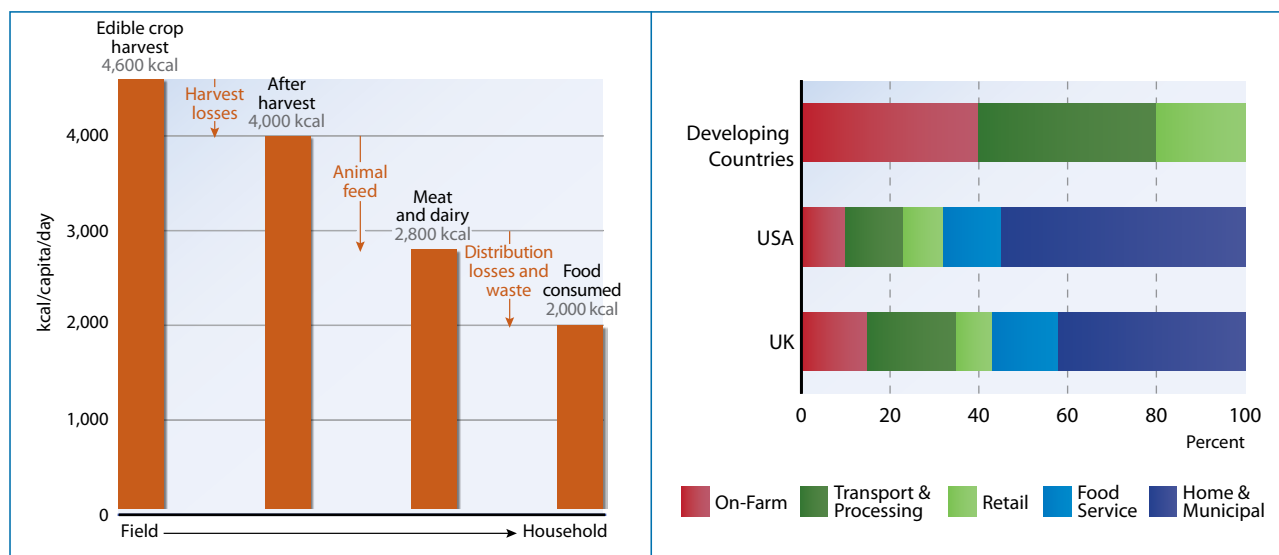
### Limited availability of mineral inputs

Industrial farming practices are dependent on inorganic fertilisers. In turn, the production and prices of these depend on the availability of fossil fuels, minerals and petro-chemicals. In this context, the demand for two major minerals – potassium and phosphorous – used

### Box 2: Opportunities for improved sanitation systems and organic nutrient recycling

There is a critical need to recover and recycle nutrients from organic waste streams and use them as productive inputs of organic fertiliser. Enormous quantities of valuable organic nutrients could be recovered from intensive livestock farming; food processing sites; municipal green wastes; and human sewage wastes in both rural and urban communities. It is particularly important to maximise the recovery of phosphorous nutrients from organic wastes; as a mineral, phosphate is essential to agricultural productivity and it has been estimated that economically recoverable global reserves may be depleted in 100 years (Cordell et al. 2010). Technologies are under development that would eliminate pathogens and other toxic elements from these waste streams and recover commercial quantities of phosphorus (Frear et al. 2010). It is expected that the rising costs of inorganic fertilisers will help accelerate research and commercialisation of such organic nutrient-recovery technologies.





**Figure 9a-b: The makeup of total food waste<sup>10</sup>**

Source: Lundqvist et al.: SIWI (2008). Saving Water: From Field to Fork; Curbing Losses and Wastage in the Food Chain. Available at: <http://maps.grida.no/go/graphic/losses-in-the-food-chain-from-field-to-household-consumption>; (Godfray (2010); Food Security: The Challenge of Feeding 9 Billion People. Available at: <http://www.sciencemag.org/content/327/5967/812.figures-only>

in fertiliser production, has been increasing. But known supplies of readily accessible, high-grade stocks, especially phosphate rock, are falling. Estimates of the longevity of these stocks vary dramatically.<sup>11</sup> Nevertheless, only one-fifth of the phosphorus mined for food production actually contributes to the food we consume, while the remainder is either polluting the world's water or accumulating in soils or urban landfills (Cordell et al. 2010<sup>12</sup>). Although it is expected that the increasing prices of phosphates and other minerals will lead to increases in supplies, including recovery of phosphate from wastewater treatment facilities, these prices are likely to continue to put upward pressure on the cost of fertilisers and food prices, which affects the poor's access to food disproportionately.

### Post-harvest spoilage

Today, the volume of food produced globally is more than sufficient to feed a healthy population. But significant amounts of food produced around the world are lost or wasted after harvesting. As Figure 9b shows, in developed countries this primarily occurs in the retail, home and municipal food-handling stages. For example in the USA, around 40 per cent of all food produced is wasted, resulting in losses of all embedded inputs such as energy (equivalent to wasting 350 million barrels of oil per year), water (equivalent to about 40 trillion litres of water every year) and huge volumes of fertilisers and pesticides (Hall et al. 2009). Losses in developed countries are often caused by factors such as retailers'

rejection of produce due to poor appearance or super-sized packages leading to post-retail spoilage. The latter can account for up to 30 per cent of the food bought by retail distributors. Post-retail food losses tend to be lower in developing countries. There, they mainly result from a lack of storage facilities, on-farm pest infestations, poor food-handling and inadequate transport infrastructure. For example, rice losses in developing countries may be as high as 16 per cent of the total harvest (Mejía 2003<sup>13</sup>). Thus, there is ample scope for increasing food supplies and food security in developing countries through simple targeted investments in post-harvest supply chains.

### Rural labour

The accelerating migration of rural populations to urban and peri-urban areas in developing regions of the world (Figure 6) has resulted in significant demographic changes in rural populations. Working-age men are likely to relocate to cities in search of employment, reducing the pool of men available for agricultural work. This rural out-migration of men has also resulted in a dominant role for women as smallholders in these regions; more than 70 per cent of smallholders in sub-Saharan Africa are women (World Bank, FAO and IFAD 2009). These demographic changes, while offering economic opportunities, have placed additional responsibilities on women, who invariably also have to care for their children and the elderly.

### Increased vulnerability of agriculture due to climate change

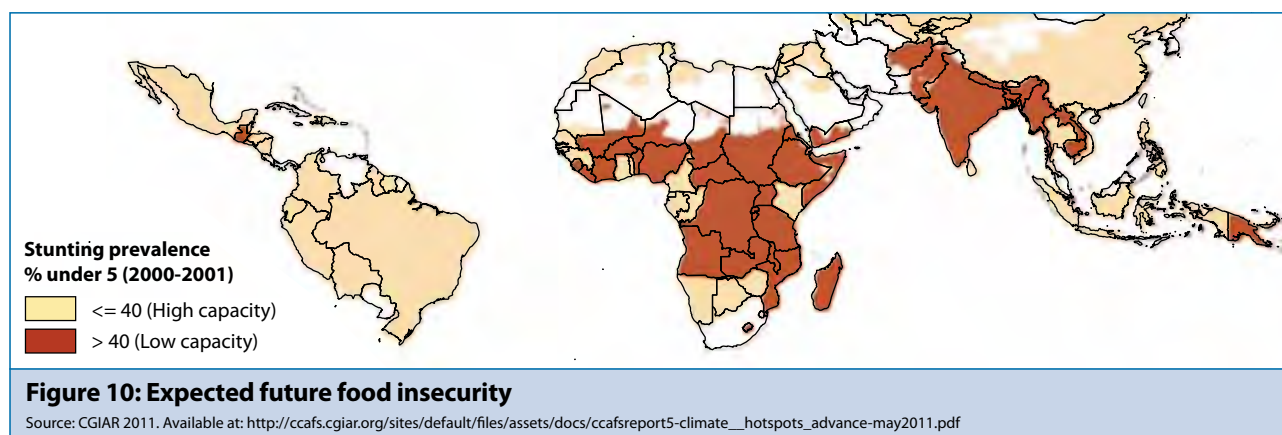
Modelling by the IPCC suggests that crop productivity could increase slightly at mid- to high-latitudes for mean temperature increases of up to 1-3°C (depending on the crop) (Easterling et al. 2007). However, at lower latitudes, especially in the seasonally dry and tropical regions, crop

10. Retail, food service, and home and municipal are aggregated for developing countries.

11. Steén (1998) indicates that phosphate stocks will be depleted by 50-100 per cent by the end of 21st century, whereas Isherwood (2003) suggests that supplies could last between 600-1,000 years.

12. Available at: <http://liu.diva-portal.org/smash/record.jsf?pid=diva2:291760>.

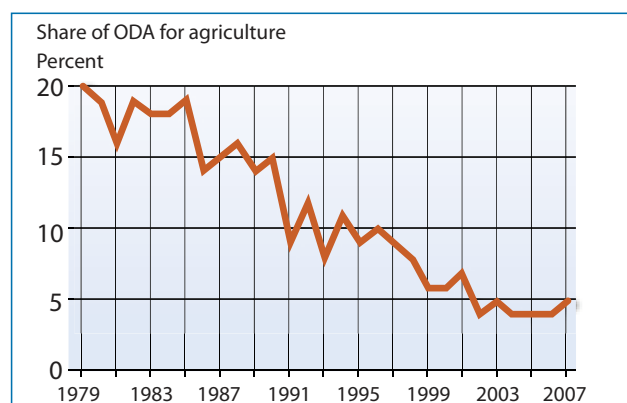
13. Available at: <http://www.fao.org/DOCREP/006/Y4751E/y4751e0o.htm>.



productivity could decrease as a result of even small local temperature increases (1-2°C).

Further warming could have increasingly negative impacts in all regions. Climate change scenarios suggest that by 2080 the number of undernourished people will increase, mostly in developing countries (see Figure 10), by up to 170 million above the current level. Intergovernmental Panel on Climate Change modelling indicates that an increased frequency of crop losses due to extreme climate events may overcome any positive effects of moderate temperature increases in temperate regions (Easterling et al. 2007).

In South Asia and sub-Saharan Africa, where some of the poorest people live and farm, the scenarios of climate change's impacts on agriculture present a dire picture. Recent studies confirm that Africa is the most vulnerable continent to climate change because of multiple abiotic and biotic stresses and the continent's low adaptive capacities (IPCC 2007b). Yields in Central and South Asia could decrease up to 30 per cent by the mid-21st century (IPCC 2007a). In drier areas of Latin America, climate change is expected to lead to salinity and desertification of some agricultural land, reducing the productivity of some important crops and animal husbandry (IPCC 2007a).



**Figure 11: Share of overseas development assistance for agriculture (1979-2007)**

Source: Based on OECD (2010). The agricultural sector includes forestry and fishing, although they are separately identifiable in the data from 1996 onwards. Private funding is not covered. Available at: <http://www.oecd.org/dataoecd/54/38/44116307.pdf>

## 2.2 Opportunities

Many opportunities exist for promoting green agriculture. They include increased awareness by governments, donor interest in supporting agriculture development in low income countries, growing interest of private investors in sustainable agriculture and increasing consumer demand for sustainably produced food.

### Government awareness

Governments, particularly in developed countries, have become increasingly aware of the need to promote more environmentally sustainable agriculture. Since the mid-1980s, OECD countries have introduced a large number of policy measures addressing environmental issues in agriculture. Some of these are specific to the agriculture sector, including the practice of linking general support to environmental conditions; others are included in broader national environmental programmes. The result is that the environmental performance of agriculture has begun to improve in OECD countries.

The proportion of global arable land dedicated to organic crops has increased from a negligible amount in 1990 to around to 2 per cent in 2010, and as much as 6 per cent in some countries. The extent of soil erosion and the intensity of air pollution have fallen; the amount of land assigned to agriculture has decreased even as production has increased, and there have been improvements in the efficiency of input use (fertilisers, pesticides, energy, and water) since 1990. However, subsidies for farm-fuel have continued to be a disincentive to greater energy efficiency (OECD 2008).

### Donor support for agriculture development

Agriculture-related Overseas Development Assistance (ODA), which has fallen steadily over the past 30 years, began to pick up in 2006 as the current food crisis escalated. In 2009, at the G8 summit in Italy, wealthy nations pledged US\$ 20 billion for developing-country agriculture. However, there is a pressing need to ensure that these investments, as Ban Ki-moon put it, "breathe new life into agriculture, one which permits sustainable

### Box 3: Innovations in the agricultural supply chain increase shareholder and societal value

For investors, water risk exposure is increasingly becoming material for mitigating investment risk in companies. For example, Robeco Asset Management invests in mainstream companies and encourages them, through active dialogue, to implement policies and innovative practices that mitigate risks resulting from water scarcity to their operations and reputations. In doing so, it also encourages companies to find solutions that can enhance their performance, increase shareholder value and therefore contribute in the long-term to building and sustaining a green economy.

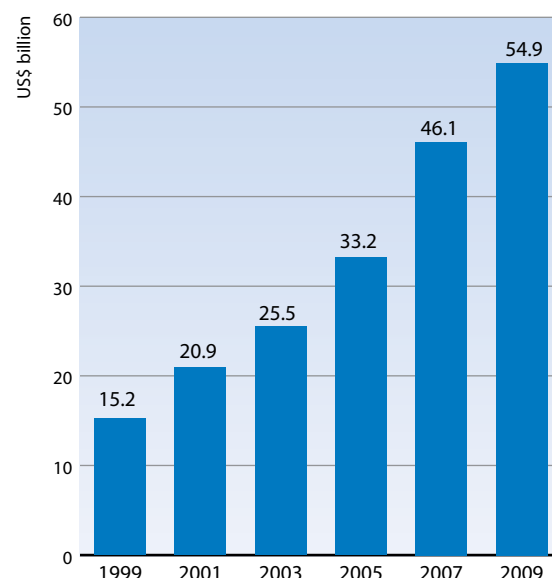
Cotton, one of the most water-intensive crops, is the focus of a dialogue with companies in the textile industry to develop water-efficiency targets and adopt sustainable supply-chain practices. Through Better Cotton Initiative (BCI), a platform has been created for exchange of experiences on the use of efficient irrigation technologies, farmer education programmes and reduction in the use of pesticides and acceptance of transparent sourcing efforts.

Source: Based on the information from Robeco Asset Management received through Lara Jacob, Senior Engagement Specialist (2010)

yield improvements with minimal environmental damage and contributes to sustainable development goals".<sup>14</sup> Recently, the Food and Agriculture Organisation (FAO), World Bank, the United Nations Conference of Trade and Development (UNCTAD) and the International Fund for Agricultural Development (IFAD) have jointly proposed Principles for Responsible Agricultural Investments.<sup>15</sup>

#### Private funding interest

Preferential access to credit and investment capital is one of the most important incentives to catalyse a transition to greener agriculture. The number, volume and rate of return of sovereign wealth funds (SWFs), pension funds, private equities and hedge funds with investment in agriculture, are increasing (McNellis 2009). Major financial institutions are expanding their green portfolios to offer investment credit to companies that manufacture and market products that enable more efficient use of agricultural inputs and introduce innovative private enterprises (see Box 3). The public sector, especially in developing countries, should support finance mechanisms (e.g. loan-guarantee funds)



**Figure 12: Global trade in organic food and drinks (1999-2009)**

Source: Prepared by Asad Naqvi, Pratyancha Pardeshi based on the data from Sahota, A. (2009)

that can leverage larger multiples of private capital loans to smallholders who need working capital to undertake sustainable agriculture practices.

#### Increasing consumer demand for sustainable food

Over the last few years, consumer demand for sustainably produced food has increased rapidly. Purchasing patterns of fairtrade products have remained strong despite the global economic downturn. In 2008, global sales of fairtrade products exceeded US\$ 3.5 billion. Data collected by the International Trade Centre (ITC) and the Forschungsinstitut für biologischen Landbau (FiBL) shows that the major markets for organic food and beverages expanded on average by 10 to 20 per cent per year between 2000 and 2007 and reached US\$ 54.9 billion in 2009. This figure does not include markets for organic fibre, cosmetics and other luxury products. This demand has driven a similar increase in organically managed farmland. Approximately 32.2 million hectares worldwide are now farmed organically. In addition, as of 2007, organic wild products were harvested on approximately 30 million hectares.

14. Ban Ki-moon. (2010). Media coverage of his statement: available at <http://www.un.org/apps/news/story.asp?NewsID=26670>, retrieved on 26 January 2011.

15. These Principles are available at: [http://siteresources.worldbank.org/INTARD/214574-1111138388661/22453321/Principles\\_Extended.pdf](http://siteresources.worldbank.org/INTARD/214574-1111138388661/22453321/Principles_Extended.pdf)

# 3 The case for greening agriculture

Both conventional and traditional agriculture generate substantial pressure on the environment, albeit in different ways. With very different starting positions, the pathways to green agriculture will vary substantially and will have to be sensitive to local environmental, social and economic conditions. Industrial agriculture needs to lessen its reliance on fossil fuels, water and other inputs. Both large and small farms can benefit from more on-farm recycling of nutrients by reintegrating livestock, which provide manure, and the cultivation of green manures to improve and maintain soil fertility (IAASTD 2009).

## 3.1 The cost of environmental degradation resulting from agriculture

Several studies have estimated the cost of externalities caused by current agricultural practices, which include those from use of inputs such as pesticides and fertilisers leading, for example, to the pollution of waterways and emissions from farm machinery and food-related transport.

Agricultural operations, excluding land use changes, produce approximately 13 per cent of anthropogenic global GHG emissions. This includes GHGs emitted by the use of inorganic fertilisers agro-chemical pesticides and herbicides; (GHG emissions resulting from production of these inputs are included in industrial emissions); and fossil fuel-energy inputs. Agriculture also produces about 58 per cent of global nitrous oxide emissions and about 47 per cent of global methane emissions. Both of these gases have a far greater global warming potential per tonne than CO<sub>2</sub> (298 times and 25 times respectively). Moreover, methane emissions from global livestock are projected to increase by 60 per cent by 2030 under current practices and consumption patterns (Steinfeld et al. 2006). The expansion of agricultural land at the expense of forests has been estimated to represent an additional 18 percent of total global anthropogenic GHG emissions (IAASTD 2009 and Stern 2007).

A study by Jules Pretty et al. (2001) estimated the annual costs of agricultural externalities to be US\$ 2 billion in Germany and US\$ 34.7 billion in the USA. This amounts to between US\$ 81 and US\$ 343 per hectare per year of grassland or arable land. In the UK, agriculture's total environmental externality costs, including transporting food from the farm to market and then to consumers, have been calculated to be £ 5.1 billion per year for 1999/2000, a cost greater than annual net farm income (Pretty et al. 2005). In China, the externalities of

pesticides used only in rice systems have been estimated to amount to US\$ 1.4 billion per year in health costs to people, and adverse effects on both on- and off-farm biodiversity (Norse et al. 2001). The national pollution census in China revealed that agriculture was a larger source of water pollution than industry, discharging 13.2 MT of pollutants (China's National Pollution Census 2007; New York Times 2010). In Ecuador, annual mortality in the remote highlands due to pesticides is among the highest reported anywhere in the world at 21 people per 100,000 people. The economic benefits of Integrated Pest Management (IPM) based systems that eliminate these effects are increasingly beneficial (Sherwood et al. 2005). Land degradation is costing ten Asian countries an economic loss of about US\$ 10 billion, equivalent to 7 per cent of their combined agricultural GDP (FAO 1994).

At the same time, as a result of the poor management of fertiliser usage during the last half-century, the phosphorus content in freshwater systems has increased by at least 75 per cent, and the flow of phosphorus to the oceans has risen to approximately 10 million tonnes annually (Bennett et al. 2001; Millennium Ecosystem Assessment 2005; Rockstrom et al. 2009). The combined effects of phosphate and nitrogen water pollution, much of it linked to the use of inorganic fertilisers is the main cause of eutrophication, the human-induced augmentation of natural fertilisation processes which spurs algae growth that absorbs the dissolved oxygen required to sustain fish stocks (Smith and Schindler 2009). The estimated costs of the eutrophication in the USA alone run as high as US\$ 2.2 billion annually (Dodds et al. 2009).

Not all agricultural externalities are quantified and thus the calculations above probably underestimate the total cost to society. Conventional agriculture, for example, causes millions of cases of pesticide poisoning per year, resulting in over 40,000 deaths (FAO-ILO 2009). It is important to note that most such cases remain unreported.

Farmers who use chemical/synthetic farm inputs are significantly more indebted, especially in developing countries (Eyhorn et al. 2005; Shah et al. 2005; Jalees 2008). For example, in Central India, cotton farmers bought inputs with loans at annual interest rates between 10-15 per cent (from cooperative societies) to over 30 per cent (from private money lenders). By contrast, those engaged in organic agriculture were far less likely to take loans owing to lower production costs and greater use of on-farm inputs (Eyhorn et al. 2005).

Although there is a difference of opinion on the issue, Jalees (2008) has argued that the main cause for the extremely high rate of suicide among Indian farmers is the debt-servicing obligations for working capital (e.g. fertilisers, pesticides and GM seeds) costs.

The following section presents some on- and off-farm investment strategies that will help minimise, eliminate and gradually reverse the environmental and economic costs resulting from currently predominant forms of agriculture.

### 3.2 Investment priorities for greening agriculture

#### Investments in R&D and Agribusinesses

One of the major reasons for the wide spread adoption of the Green Revolution that greatly increased agricultural productivity was the level of first public, then private-sector investment in R&D and the subsequent dissemination and commercial implementation of the results. These gains were also achieved with the introduction of irrigation and greater application of inorganic agrochemical inputs. A new wave of investment is needed to develop, deploy and diffuse resource-efficient technologies and agricultural inputs, farming practices, and seed and livestock varieties that would counter the environmental externalities that are often associated with the green revolution.

The International Assessment of Agricultural Knowledge, Science and Technology for Development noted that ROI in AKST across commodities, countries and regions on average are high (40-50 per cent) and have not declined over time. They are higher than the rate at which most governments can borrow money (Beintema and Elliott 2010). The commercial rate of return, however, should not be the only determinant of the decision to invest in R&D for greening agriculture. The social rate of return would be considerably higher if rural communities could adequately monetise the ecosystem, livelihood and socio-cultural benefits that would accrue with their adoption of greener agriculture practices and land stewardship (Perrings 1999).

Research to improve the performance of biological nitrogen fixation processes, breeding plant, livestock and aquatic species for improved yields and adaptive resilience and developing perennial cereal crops would enable significant reductions in the energy, water and fertiliser inputs needed to cultivate commodity grains. Such research may require several decades to produce commercially viable crop varieties with these beneficial attributes. However, the impacts would be significant in terms of providing options for future generations' dependency on expensive fossil fuel-based fertilisers and adapting to expected climate change.

#### Plant and animal health management (PAHM)

Field trials of improved PAHM practices have resulted in increased profitability of farms. Various intercropping strategies utilise selected plant species' biochemical emissions to either attract or repel different insects, nematodes and other pests. One of the most effective such techniques is known as "push-pull", which involves intercropping, for example, certain species of legumes and grasses with maize. Aromas produced by legumes planted on the perimeter of a field repel (push) maize pests, while scents produced by the grasses attract (pull) insects to lay their eggs on them rather than the maize.

The implementation of push-pull in eastern Africa has significantly increased maize yields and the combined cultivation of N-fixing forage crops has enriched the soil and has also provided farmers with feed for livestock. With increased livestock operations, the farmers are able to produce meat, milk and other dairy products and they use the manure as organic fertiliser that returns nutrients to the fields. In small-holder farming operations, the ability to support livestock for meat, milk and draft animal power is an important added benefit of this strategy (Khan et al. 2008). An economic analysis of a push-pull field trial in East Africa with 21,300 farmers revealed a benefit-cost ratio of 2.5 to 1. (Khan et al. 2008). The income returns for labour were US\$ 3.7 per person/day with push-pull as opposed to US\$ 1 person/day with their previous maize mono-cropping practice. The gross revenue ranges between US\$ 424 and US\$ 880 per hectare under push-pull and US\$ 81.9 to US\$ 132 per hectare in maize mono crop. Similar systems are being field-trialed for other cropping systems and it is likely that comparable rates of return will be realised.

Another example of PAHM practices is seen in Cameroon. In this case study (Dieu et al. 2006), cocoa farmers were trained in pruning, shade adjustment and phytosanitary harvesting methods that effectively maintained yields comparable to conventional practices that used multiple applications of fungicides. The farmers who practiced these techniques used 39 per cent fewer fungicides. Although labour costs increased by 14 per cent, total production costs decreased by 11 per cent relative to conventional practices. By introducing green farming, methods that relied on more knowledgeable labour inputs, a much larger share of the total costs of cocoa production was paid to workers within the local community. Imports of fungicide chemicals were also reduced, saving valuable foreign exchange. Additional benefits included reduced health costs and less environmental pollution (Velarde 2006).

Investments in PAHM should focus on research, training and investments in natural pest- management processes that defend, defeat and manage the many organisms that threaten agricultural production. While there are a



### Box 4: Cost of training smallholder farmers in green agriculture practices

In a recent report on organic agriculture, the ADB concluded that the cost of transition for farmers to move from conventional agricultural practices to organic practices, including the cost of certification, was approximately US\$ 77-170 per farmer for an average farm size of 1 hectare (ADB 2010). Training costs were estimated at US\$ 6-14/farmer. These are fairly modest compared to the overall investment required for extricating farmers from poverty (an approximate investment of US\$ 554-880, according to the World Bank (2008a). Yet there remain additional costs. These are the costs of enabling policies that allow research and development, market linkages and creating incentive systems on the demand and supply side. These costs cannot be understated and obviously require multilateral and bilateral support in the international arena.

suppress biotic stresses and combat pests, during the past few decades there has been a substantial increase of private and, to a much lesser degree, publicly-funded efforts to develop genetically modified (GM) crops to overcome pest and weed problems. After initial success, there is growing evidence of an evolving resistance to GMO crops by many pests and weeds. The IAASTD report (2009) recommended that research on the ecological, economic and social questions concerning the widespread application of GM crops should be increased, particularly in the public R&D sector, whose scientific advances could be more broadly and equitably available for use in developing countries.

Table 2 presents selected evidence on the costs and benefits of plant and animal health management strategies (PAHM). Plant and animal health management practices reduce farmers' input costs and their exposure to hazardous chemicals while effectively supporting productive crop yields. Plant and animal health management practices also reduce or replace the use of chemical insecticides that often kill non-targeted insects. Many insect species killed as collateral damage from such insecticides have beneficial environmental and agricultural roles as pollinators and as predators of other pests, and are part of the natural food chain.

wide range of low-cost natural bio-control practices that improve the ability of plants and livestock to resist and

Evidence presented in Table 2 show that all PAHM interventions are highly profitable. Intercropping is a particularly useful strategy with high benefit to cost

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Intercropping	Maize intercropped with Desmodium uncinatum, East Africa (Khan et al. 2008).	Most costs are associated with additional labour costs.	Maize grain yield increases ranged from double to five times in plots using push-pull strategies compared to monocropped plots. Levels of pests reduced significantly and were completely eliminated in some. (Reductions ranged from 75% to 99%).	Benefit to cost ratio is 2.5 to 1 using the push-pull strategy. Gross revenues with push-pull were US\$ 424-880/ha compared to 82-132/ha using a mono-maize cultivation strategy.
Pest Management	The wasp predator to fight the cassava bug in Africa (Norgaard 1988). Cocoa in Cameroon (Dieu et al. 2006).	The cost of introducing the wasp across cassava growing countries in Africa (1978-2003) is estimated at US\$ 14.8 million. This includes research and distribution costs. For cocoa, IPM meant that labour costs increased by 14%. But total production costs decreased by 11% due to reduced use of fungicides.	Introducing the wasp predator introduction helped avoid 60% of the losses caused by the cassava mealy bug. In cocoa plantation, IPM reduced cost of fungicides by 39%.	Benefit cost ratio of 149 to 1 for the wasp predator strategy, across all cassava growing countries in Africa, 1978-2003. Reduced costs of fungicides in the context of obtaining similar yields can lead to increase in profitability for the farmers.
Bio-pesticides	Fungal spores in fighting grasshopper in Benin, maize and cassava, cowpea and groundnuts crops (De Groote et al. 2001).	Estimated cost for effective intervention was US\$ 4/ha.	Cumulative mortality of grasshoppers after 20 days of spraying was over 90%.	Bio-pesticides have small costs and major benefits of avoided damage. Yield losses due to grasshoppers can reach 90% in cowpea and 33% in maize.

**Table 2: Selected evidence on benefits and costs of plant and animal health management**



ratios of 2.5 to 1. Compared with mono-cropping strategies push pull strategies and intercropping both imply an increased use of labour, but demonstrated returns are more than 200 per cent.

Similarly, pest management strategies that include introducing new predator species in Africa to combat losses caused by the mealy bug have proven to be extremely effective. Most significant costs are associated with research development and extension but the resulting increase in effective produce and diminished post-harvest losses contribute to more than an order of magnitude increase in returns. Unlike push-pull, these types of strategies are usually managed at a country or inter-country level and thus benefit from scale, while providing benefits to all farmers, regardless of their size and their possibility to invest in pest control.

### **Scaling up adoption of green agriculture by partnering with leading agribusinesses**

A small number of corporations control a large share of the global agribusiness. The four biggest seed companies control more than half of the commercial seed market (Howard 2009), the biggest ten corporations (four of them are among the top 10 seed companies) together control 82 per cent of the world pesticides business. The share of the top-ten corporations in the global market for food processing is 28 per cent, and the top 15 supermarket companies represent more than 30 per cent of global food sales (Emmanuel and Violette 2010). Investment decisions of these approximately 40 companies have the power to determine, to a large extent, how the global agriculture sector could endorse and encourage green and sustainable farming practices.

By greening the core business operations and supply chains, these corporations can play a major role in supporting a transition to greener agriculture. In addition, they can provide investments to develop and implement viable strategies for ensuring global food security based on optimal use of inorganic inputs and building capacity to recycle on-farm nutrients. Investing in building consumer awareness about benefits of sustainable agrifood products is another area that offers benefits for the environment and these businesses. One of the promising developments in the area of agribusiness and NGO partnerships to promote green agriculture is the Sustainable Food Laboratory.<sup>16</sup>

### **Strengthening the supply chains for green products and farm inputs**

Demand for sustainably produced products is increasing but it is concentrated in developed countries. Investments in developing new markets in

developing countries and expanding existing markets in developed countries could (i) create new and high return employment opportunities for on- and off-farm sectors (e.g. certification auditors); (ii) shorten the field-to-market supply chains, and thus offer better prices to farmers in these countries; and (iii) help maintain the price premiums, which can range from 10 per cent to more than 100 per cent over a variety of conventionally-produced foods (Clark and Alexander 2010). A major challenge in this regard is consumer demand for less expensive food and high demand elasticities associated with premium prices for organic food and other products. As incomes rise and consumers learn more about lifestyle diseases, and in the absence of good food safety regulations or lack of their implementation, the negative health effects of some cheaper, conventionally produced foods, we expect to see in upper and middle income consumers an increasing willingness to pay for more environmentally sustainable and ethically produced (e.g. fairtrade, etc.) foods at prices that would cover their higher costs.

The limited availability of substantial quantities of natural fertiliser and pesticides in many countries is a major constraint to the growth of sustainable farming practices. Large-scale composting of organic matter and recovery of livestock manures for commercial organic fertiliser products will be required in most farming regions. Investments in the production, supply and marketing of non-synthetic, natural inputs for farming will not only offer competitive returns but will also help in setting up new small-scale businesses in rural areas. The bulk and volume of organic fertilisers that are required for equivalent applications of inorganic fertilisers make them not very cost-effective for long distance transport, thus necessitating relatively localised or regional compost-production capacities.

### **Farm mechanisation and post-harvest storage**

Appropriate mechanisation of small and medium farms can significantly increase agricultural productivity and help green the farming practices. The degree to which there is access to farm mechanisation equipment (both draft animal and modern fuel-powered technology) will substantially determine achievable levels of productivity per unit of labour and of land. Use of (i) more energy-efficient cultivating machines that incorporate plant residues into the soil to increase fertility, (ii) zero-tillage and minimal-tillage direct seeders for optimum planting uniformity and minimal topsoil disturbance, (iii) precision application systems for more efficient use of agrochemicals, (iv) drip and sparkling irrigation, and (v) harvest and post-harvest operations that include village-level processing of farm products and by-products are central to the green mechanisation of farms (Rodulfo and Geronimo 2004).

Since most farm mechanisation technologies require modern fuels or electric power to operate and fossil fuel

16. <http://www.sustainablefoodlab.org>.

## Box 5: Simple storage: low investment, high returns

An FAO programme that supported the production and use of household and community- scaled metal silos for grain storage estimated that farmers who invested in silos were able to earn nearly three times the price for maize sold four months following harvest as opposed to the price paid at harvest (US\$ 38/100 kg of maize compared with US\$ 13/100 kg). The production costs for these metal silos ranged between US\$ 20 for a 120 kg small-capacity unit to US\$ 70-US\$ 100 for an 1800 kg large-capacity silo in a variety of countries. Most farmers realised a full return on their investment within the first year of use (Household Metal Silos, FAO 2008). The FAO reports that although reducing post-harvest losses could be relatively quickly achieved, less than 5 per cent of worldwide agricultural research and extension funding currently targets this problem.

Similar improvements in reducing post-harvest losses are possible with cost-effective hermetically sealed packaging materials and handling processes that protect grains and pulses from insect and mold contamination. A notable example of such technologies is the Purdue Improved Cowpea Storage (PICS) system, which is composed of two polyethylene bags and a third outer bag of woven polypropylene. The PICS materials are made by several West African manufacturers and have proven to offer safe and inexpensive storage of cowpea and other grains for 4-6 months and longer (Baributsa et al. 2010).

price increases are seen as inevitable, it is important that non-conventional energy sources such as biodiesel fuels and biogas power generation and process heat be developed and used in mechanised farming systems in developing countries. While there are examples of rural bioenergy production technologies operating throughout the world, in most cases these technologies remain uncompetitive mainly due to subsidies and policy support for fossil fuels and related farm machinery.

Coupled with farm mechanisation, which may negatively affect on-farm employment opportunities, investment in off-farm employment opportunities is needed. Food packaging and processing in rural areas would enable new non-farm jobs and could improve market access for agricultural produce. However, the feasibility of added

value processing would be substantially determined by the quality of rural road infrastructure that connect to urban centres, ports and airports and the availability of skilled labour capable of operating food-handling facilities. In those cases where rural food processing is implemented, the residues from food processing should be composted or processed into organic fertilisers in order to avoid waste and to return needed organic nutrients to the nearby farm land.

With regard to post-harvest storage, simple technologies with small investments can make a big difference. Small holder farmers with limited access to dry and sanitary storage and cold chain facilities often suffer post harvest food losses that can range from 20 per cent to more than 30 per cent of their crop yields. Furthermore, without crop storage systems, farmers are usually compelled to sell their entire crop immediately at the time of harvest when market prices are much lower than levels possible several months after harvest (Kader and Rolle 2004). Investments in post-harvest storage can bring multiple economic and development benefits (Box 5).

### Improving soil and water management and diversifying crops and livestock

One of the most significant consequences of conventional agriculture is the rapid depletion of soil organic matter (SOM). Repeated cultivation degrades soils and lowers crop yields hence increases production costs. Strategies for better soil management have been experimented in Colombia, England, Mexico, Morocco and the USA. Results show yield increases ranging from 30 per cent to 140 per cent. Some of these strategies include, growing and integrating back in soil nitrogen fixing fodder and green manure crops such as pea, ferns and clover or rice straw, no-tillage and planting new seeds in crop residues, using waste biomass or biochar (still needs research to fully understand its true potential), and organic and mineral fertilisers. Table 3 presents evidence from field trials and plots in Colombia, England, Morocco, Mexico and the USA that show yield increases ranging from 30 per cent to 140 per cent resulting from better soil management strategies. Nonetheless, each strategy does require some additional investments. Strategies such as nitrogen-fixing fodder or green manure mainly involve additional labour costs: additional labour is required to distribute fodder over land and for sowing and growing green manure plants. In addition, in some countries, the cost of fodder can be substantial since it can be used alternatively for feeding animals. Nevertheless, crop yield increases as high as 40 per cent are capable of making the investments profitable for farmers.

The use of a no-tillage system strategy mainly requires additional capital outlays, which can be significant. In countries with developed markets for agricultural equipment no-tillage systems can be cheaper than

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Use of nitrogen-fixing fodder and cultivating green manure	Cultivation of maize in Spain and rice in India, Indonesia and Philippines. (Tejada et al. 2008); (Ali 1999).	Costs varied depending on methods and country. Rice straw use (for green manure) costs ranged from US\$ 18/ha in Indonesia and Philippines, to US\$ 40/ha in India. Azolla (type of fern) for nitrogen fixing and green manure meant additional costs ranging from US\$ 34/ha in India, to US\$ 48/ha in the Philippines.	Maize crop yields increased approximately 40% in the first year, 5% in second year and 20% in year three. No significant increases in yields were observed in rice crops compared to the use of inorganic fertilisers but result in long term soil improvements. Maize crop yields increased after the first year, by 28%, 30% and 140% in the last 3 years of the study. No impact was seen on soybean crop yields.	Revenues increased even though there was no difference in the costs of using green manure over inorganic fertiliser for rice crops.
No-tillage practices	Maize in Mexico, wheat in Morocco and cereal grain crop in England. (Erenstein et al. 2008); Mrabet et al. 2001; Baker 2007). Sorghum and maize in Botswana, (Panin 1995) Maize, sorghum and cowpea in Nigeria, (Eziakor 1990). Soybean in Australia (Grabski et al. 2009).	The capital costs for a small scale No-tillage planting system are estimated to be US\$ 25,000 to 50,000 (ICARDA). No tillage system was cheaper by US\$ 156/ha when rented from a contractor in England, compared to renting tilling systems. In Botswana, cost per household of tractor was US\$ 218.	Maize yields increased by 29 per cent; wheat yields by 44 per cent. No impact on total cultivated areas, crop yields and total crop output in traditional tillage systems vs. animal power or manual usage (Botswana and Nigeria). An average yield increase in soybean yields of 27% over 14 years in no-tillage vs. till systems.	No-tillage systems are economically profitable, even after incorporating the costs of no-till systems. (Baker 2007).
Biochar use	Cultivation of maize intercropped with soybean (Colombia) and wheat (USA). (Major et al. 2010; Galinato et al. 2010).	Biochar production costs range between US\$ 87-350/tonne depending on source of inputs and mode of production.	Maize crop yields increased after the first year, by 28%, 30% and 140% in the last 3 years of the study. No impact was seen on soybean crop yields.	In the US, wheat production increased sufficiently to generate a profit of US\$ 414/acre, but only while using low-price biochar. Higher-cost biochar reduces profits.

**Table 3: Selected evidence on benefits and costs of soil management strategies**

using tilling machinery, in developing countries the investment in farm equipment may represent a significant barrier. Farmer cooperatives and extension services can help defray these costs.

Biochar usage represents a costly investment, mainly because of the high cost of production for biochar (US\$ 87-350 per tonne depending on the source of inputs and mode of production). Although it can bring significant increases in crop yields, biochar profitability is still highly dependent on the cost of production.

Similarly, the use of water for irrigation is rapidly exceeding the natural hydrological rate of recharge in many river basins (Johansson et al. 2002; WWAP 2003; Wani et al. 2009). Practices such as flooding fields, poor drainage and excessive pumping imply that there are many opportunities for using ground and rainwater in more efficient and sustainable ways (Steinfeld et al. 2006). Some sustainable water-use strategies include drip irrigation systems, pressurised water pipe and sprinkler systems and use of manual treadle pumps. According to some studies (Burneya et al. 2009; Sivanappan 1994; Belder et al. 2007), drip irrigation has resulted in yield gains of up to 100 per cent, and water savings of 40 to 80 per cent.

Using leaf and straw mulch reduces surface evaporation and helps to retain moisture near plant roots, thus increasing water-use efficiency (Sharma et al. 1998). Landscape contouring and vegetative barriers are an effective means of minimising rainfall runoff and retaining moisture in fields. Using drought-resistant varieties of crops can also help conserve water. For example, System Rice Intensive (SRI) practices substantially reduce the amount of water and other external inputs through decreased planting densities, which require less seed and fewer workers. The approach generally achieves between 40 per cent and 200 per cent greater crop yields compared with conventional flooded rice cultivation (Zhao 2009). Table 4 demonstrates that most water-saving technologies can bring about increased profits despite additional infrastructure and operating costs. Most water-saving techniques require additional equipment and increased working capital to cover the costs of increased labour use. Additional labour is required for strategies such as the use of mulching fields, raising plant beds and aligning furrows, and in other land contouring strategies. Such labour costs are nevertheless easily recovered through increased crop yields, and the reduced risk of losses during drought or dry years.

Table 4 shows that investment costs in drip irrigation systems and in manual treadle pumps are recovered more quickly; returns to investments have on average been more than 10-fold. These technologies have demonstrated their effectiveness in reducing income vulnerability and uncertainty for small-holder farmers across the continent. Drip irrigation systems also allow the more efficient use of water and are particularly useful for multiple cropping; in Nepal women farmers have been able to earn additional incomes by growing high value crops on otherwise barren land. Strategies such as the use of drought-resistant varieties of crops mainly involve investment in research and distribution of new seeds. In this context, estimated returns on investment are an order of magnitude higher, especially as witnessed in water-starved regions of Africa.

The success of these strategies also implies that agronomic research and development on improving water management practices in rain-fed agriculture and on tilling practices has been successful although much more is required. A strategy that remains relatively

untapped is community-led watershed management. Watershed management has conventionally meant large hydraulic engineering efforts that are applied to local streams or river basins to establish a network of water reservoirs, catchment areas and other water impoundment and storage infrastructures. However, community-led watershed management strategies that protect and improve soil, water and plant resources in a catchment area are rapidly gaining traction and are rapidly becoming a lucrative opportunity for farmers who can benefit from Payment for Ecosystem Schemes (PES). These community led watershed management strategies offer important opportunities for increased efficiencies in irrigation (Krishna and Uphoff 2002).

As far as crop and livestock diversification is concerned, genetic resources for plant and animal breeding are the basis for food production. Genetically diverse crops can combine the best traits of local varieties of crops derived from indigenous species and other higher yielding varieties. Similarly, selecting and mating local animal breeds with high-performance breeds increases

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Cover mulch	Grain in India (Sharma et al. 1998); Groundnut in India (Ghosh et al. 2006).	In groundnut cultivation the cost of wheat straw mulch was US\$ 58/ha. Cultivation required 5 tonnes of mulch per hectare. Black plastic covers cost much more (US\$ 1.8 /kg, vs. straw at US\$ 0.01/kg).	Average yields for grain and straw were the highest in fields that received cover mulch of 6 tonnes/ha: Yields increased by 130-149% over 3 years. Using wheat straw mulch cover increased pod yield of groundnut by 17–24%. Using both— wheat straw mulch and black plastic covers led to yield increases of 30 to 86% across test fields.	For groundnut crops, analysis of profitability showed that both systems (wheat straw and wheat straw with plastic cover) have positive income returns of US\$ 92/ha and US\$ 42/ha respectively. For grain crops, long-term profitability is possible with the use of mulch depending on the costs of mulch.
Furrow contouring	Corn in China (Li X. et al. 2001).	Technique used plastic covers and constructed furrows. Costs of plastic and labour are not provided.	Corn yields increased by 60-95% during drought years, 70-90% in wet years and 20-30% in very wet years.	Revenues and profits are likely to be positive and increase, except during very wet year.
Manual treadle pump	Major staples including cassava, maize, rice and yam in Ghana (Adeoti et al. 2007 and 2009) and a variety of crops, Zambia (Kay and Brabben 2000).	Depending on region the cost of a manual treadle pump in Ghana was US\$ 89. Users had to pay additionally for labour. Total production costs increased by US\$ 162/farm on average. In Zambia the cost of suction pumps ranged from US\$ 60–77 and cost of pressure pumps was US\$ 100–120.	In Ghana, treadle pump users were able to grow multiple crops. In Zambia Treadle Pump users were able to grow three crops a year.	Incomes for Treadle Pump users increased by more than 28 per cent in Ghana. On average users earned almost US\$ 343/farmer over non-users in Ghana. In Zambia, incomes rose more than six- fold. Farmers earned US\$ 125 with bucket irrigation on 0.25 ha of land to US\$ 850-1,700.
Drip irrigation	Vegetables in Nepal (Upadhyay 2004) Maize and vegetables in Zimbabwe (Maisiri et al. 2005).	On average farmers had to pay US\$ 12/farmer in Nepal for drip irrigation system (perforated tubing and a suspended water container).	Barren land became more productive in Nepal. In Zimbabwe no significant differences in yield were observed. Water use reduced by 35%.	In Nepal, women farmers earned an additional US\$ 70 annually by selling surplus vegetables.
Using low-water varieties of crops	Maize varieties in 13 countries of eastern, southern and West Africa (La Rovere et al. 2010).	US\$ 76 million was invested in cultivating low-water varieties of crops over 10 years in these countries.	Average yield increases estimated to be between 3–20%.	Maize yield increases translate into US\$ 0.53 billion. The ratio of returns to investment is estimated to be between 7 and 11 times.

**Table 4: Selected evidence on benefits and costs of water management strategies**



diversity and can bring significant biological, social and economic benefits. Replenishing soil nutrients with biological nitrogen fixation and crop-residue recycling, reducing thermal stress and water evaporation rates, and attracting beneficial insects for pollination and pest predation, and deterring pests are all important benefits of crop diversification. Combining the horticultural production of higher-value vegetables and fruits with the cultivation of cereals and cash commodity crops can raise farm income, along with grass-fed livestock, which also enables people to acquire protein and calories derived from otherwise inedible biomass resources. Recycling of livestock manures as organic nutrients for soil is an essential element of greening agriculture. In addition, there are numerous opportunities for combining a wide variety of trees and shrubs with the cultivation of crops, horticulture and specialty crops (e.g. coffee, tea, vanilla, etc.) to maximise the output of a farm.

Diversification strategies are not useful to ensure diminished vulnerability but also to increase profitability and yields of existing farming systems. Table 5 presents selected evidence for costs and benefits of agricultural diversification strategies in Asia and Africa. Diversifying across crops has demonstrated increased yields in India and Bangladesh and shows potential for recovering research and extension costs. In both Africa and Asia, diversifying into animal husbandry has meant increased profits. The main on-farm costs for all these strategies is usually the cost of increased labour, but also the cost of training and learning new practices. In addition, diversification into animal husbandries may involve important capital costs in farm equipment. In countries where employment opportunities are few, diversification represents a potent poverty alleviation strategy for both the farmer and the labourer. After the analysis of costs of current agriculture and some strategies for a managed transition away from BAU, the following section lays out the benefit expected from greening the agriculture sector.

### 3.3 The benefits of greening agriculture

The greening of the agriculture sector is expected to generate a range of benefits including increased profits and income for farmers, gains at the macroeconomic level, enabling the sector to adapt to climate change and benefits for ecosystem services.

#### Profitability and productivity of green agriculture

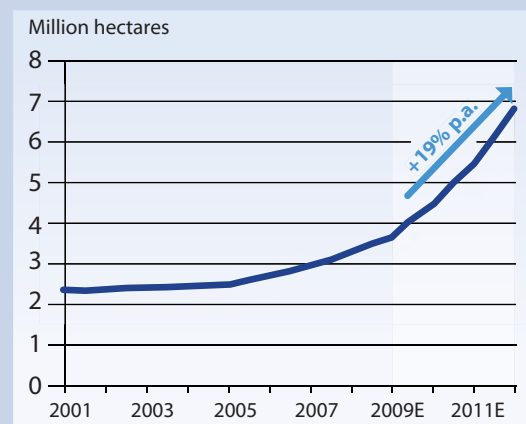
No business is sustainable unless it is also profitable. Many studies have documented the profitability and productivity of sustainable farms, both in developed and developing countries. An FAO study (Nemes 2009) that analysed 50 farms, mostly in the USA, reported: "The overwhelming majority of cases show that organic farms are more economically profitable".

There are various examples of higher productivity and profitability in developing countries. Another study by Pretty et al. (2006) showed an average yield-increase of nearly 80 per cent as a result of farmers in 57 poor countries adopting 286 recent best practice initiatives,

### Box 6: Investment in sustainable agriculture – case study

Current trends of population growth, climate change and resource scarcity make sustainable agriculture a compelling investment opportunity. Sustainable Asset Management AG (SAM) taps into this potential through its sustainable theme funds, investing in companies that offer cost-effective, eco-friendly technologies that enable more efficient use of water or more sustainable food production.

SAM has pursued water investments because the need for adequate water supplies is one of today's major challenges. Advanced micro or drip irrigation systems can halve farmers' water requirements and limit the need for chemicals while boosting yields by up to 150 per cent. Countries affected by water shortages are adopting these technologies at rapid rates (see chart).



The SAM Sustainable Water Fund currently encompasses an investment universe of about 170 companies worldwide and assets under management of € 1.14 bn. The fund has consistently outperformed its benchmark, the MSCI World, with annual return on average outperforming the benchmark by 4.14 per cent (in Euros) since launch in 2001 at a risk comparable to that of the MSCI. Strong growth in micro irrigation fosters sustainable agriculture and creates interesting investment opportunities.

Source: Based on text provided by Daniel Wild, PhD, Senior Equity Analyst, SAM (2010)

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Crop diversification	Rice with pigeon pea, groundnut and blackgram in India (Kar et al. 2004). Variety of crops in Bangladesh (Rahman 2009).	US\$ 41.8 million allocated to promoting crop diversification for a 5-year plan in Bangladesh. Empirical study shows reduced variable cost for diversified farmers of US\$ 40/ farm (Jan. 1997 exchange rate).	In India, intercropping of rice with pigeon pea, groundnut and blackgram approximately tripled the yield of crops (rice and alternative crops) vs. rice alone.	In Bangladesh, similar net profits were earned by diversified and non diversified farmers; but positive environmental benefits accrued to the diversified farms.
Diversification into animal husbandry and horticulture	Variety of crops and animals in Africa (Seo 2010). Survey of crops and countries in Africa and South East Asia (Weinberger 2007).	In Kenya the production of snowpeas and French beans, require 600 and 500 labour days per ha, respectively. In Mexico, the horticultural sector required more than 20% of the total labour days within the agricultural sector.	The impacts of climate change on farms diversified into animal husbandries range from 9% loss to 27% gain depending on climate scenarios.	Profits of farmers diversified into horticulture were consistently higher compared to non-diversified farmers (29% in Bangladesh to 497% in Kenya). Estimates show that integrated or diversified farms have the potential to become more profitable compared to non-integrated farms 50 years from now, in the context of climate change.

**Table 5: Selected evidence on benefits and costs of agricultural diversification**

including integrated pest and nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting and livestock integration. The study covered 12.6 million farms, encompassing over 37 million hectares (3 per cent of the cultivated area in developing countries). All crops showed water use efficiency gains, with the highest improvement occurring in rain-fed crops. Carbon sequestration potential averaged 0.35tC/ha/year. Of projects with pesticide data, 77 resulted in a decline in pesticide use by 71 per cent, while yields grew by 42 per cent. In another example, bio-dynamic farms recorded a 100 per cent increase in productivity per hectare due to the use of soil-fertility techniques such as compost application and the introduction of leguminous plants into the crop sequence (Dobbs and Smolik 1996; Drinkwater et al. 1998; Edwards 2007).

For small farms in Africa, where the use of synthetic inputs is low, converting to sustainable farming methods has increased yields and raised incomes. In a project involving 1,000 farmers in South Nyanza, Kenya, who were cultivating, on average, two hectares each, crop yields rose by 2-4 tonnes per hectare after an initial conversion period. In yet another case, the incomes of some 30,000 smallholders in Thika, Kenya rose by 50 per cent within three years after they switched to organic production (Hines and Pretty 2008).

A significant part of a farm's production costs is linked to its energy inputs and organic agriculture tends to be more energy-efficient. Growing organic rice can, for example, be four times more energy-efficient than the conventional method (Mendoza 2002). The study also shows that organic farmers required 36 per cent of the energy inputs per hectare compared with

conventional rice farmers. Niggli et al. (2009) found that organic agriculture reduces production systems' energy requirements by 25 to 50 per cent compared with conventional chemical-based agriculture. Energy consumption in organic farming systems is reduced by 10 to 70 per cent in European countries and by 28 to 32 per cent in the USA compared with high-input systems, with the exception of certain crops including potatoes and apples, where energy-use is equal or even higher (Pimentel et al. 1983; Hill 2009).

Market price premiums often exist for certified sustainably produced products, however this incentive may not be adequate in the long run unless there is a commensurate increase in global consumer demand for sustainable agricultural products (e.g. in countries other than primarily the EU and USA). Premium price incentives are likely to relatively decrease in response to supply and demand elasticities (Oberholtzer et al. 2005). However, if prices of conventionally grown food (crops and animals) included the costs of their externalities, sustainable products may become relatively less expensive than conventional products. Furthermore, if the positive ecosystem service benefits of sustainable practices were valued and monetised as incremental payments to green farmers, greener agriculture products would become more competitive with conventional products.

#### **Macroeconomic benefits from greening agriculture**

Significant secondary macro-economic and poverty reduction benefits are expected from greening agriculture. Investments aimed at increasing the productivity of the agriculture sector have proved to be more than twice as effective in reducing rural poverty



### Box 7: Innovative sustainable and social capital investment initiatives

Institutional investments for greening agriculture are emerging. For example, Rabobank Group is supporting sustainable agriculture through the launch of the Rabo Sustainable Agriculture Guarantee Fund and supporting initiatives such as the Dutch Sustainable Trade Initiative (IDH), the Schokland Fund and Round Table of Sustainable Palm Oil (RSPO), the Round Table on Responsible Soy (RTRS), and the Better Sugar Initiative (BSI). In addition, it has launched programmes to improve the financial strength and resilience of small farmers in developing countries via the Rabobank Foundation and Rabo Development. It has also introduced new financial services such as the Sustainable Agricultural Fund to try out innovative financing models such as the Xingu River Basin Project in Brazil, under which 83 hectares have been replanted in the last two years. Rabobank has invested nearly US\$ 50 million to purchase carbon emission reduction credits that are created by the Amazon reforestation by farmers.

Another example of social capital investment institutions is the Acumen Fund, which has channelled investment worth millions of US dollars to private entrepreneurs in developing countries, enabling businesses and other initiatives to flourish, from those that provide drip-irrigation products to those operating village-scale biogas power-generation services. Acumen provides both patient capital investments and business management capacity-building support to the private businesses in their portfolio.

than investment in any other sector (ADB 2010). The greatest success stories in terms of reducing hunger and poverty are from China, Ghana, India, Vietnam and several Latin American nations, all of which have relatively higher net investment rates in agriculture per agricultural worker than most developing countries (FAO n.d.). The World Bank has estimated that the cost of achieving the first Millennium Development Goal (MDG 1) amounts to between US\$ 554 and US\$ 880 per head (based on growth in income in general), while a study published by the Asian Development Bank Institute has concluded that the cost of moving a household out of poverty through engaging farmers in organic agriculture could be only US\$ 32 to US\$ 38 per head (Markandya et al. 2010).

### Box 8: Organic versus conventional cotton production

An Indo-Swiss research team compared agronomic data of 60 organic and 60 conventional farms over two years and concluded that cotton-based organic farming is more profitable. Organic farming's variable production costs were 13-20 per cent lower and inputs were 40 per cent lower. But yields and profits margins were 4-6 per cent and 30-43 per cent higher respectively during the two years. Although crops grown in rotation with cotton were sold without a price premium, organic farms achieved 10-20 per cent higher incomes compared with conventional agriculture (Eyhorn et al. 2005). Similarly, an impact assessment study for organic cotton farmers in Kutch and Surendranagar in eastern India, concluded that farmers who participated in the project enjoyed a net profit gain of 14 to 20 per cent resulting from higher revenues and lower costs. The updated version of the study surveying 125 organic cotton farmers concluded that 95 per cent of respondents found their agricultural income had risen since adopting organic agriculture, on average by 17 per cent. Most farmers attributed this largely to the reduced cost of production and an increase in output price (MacDonald 2004). Raj et al. (2005) also found in Andhra Pradesh that organic cotton was much more profitable.

Source: Nemes (2009)

In addition, green agriculture directs a greater share of total farming input expenditures towards the purchase of locally-sourced inputs (e.g. labour and organic fertilisers) and a local multiplier effect is expected to kick in. Overall, green farming practices tend to require more labour inputs than conventional farming (e.g. from comparable levels to as much as 30 per cent more) (FAO 2007 and European Commission 2010), creating jobs in rural areas and a higher return on labour inputs. This is especially important for developing countries, where large numbers of poor people continuously leave rural areas in search of jobs in cities and growing proportions of young people are imposing enormous pressures for job creation (Figure 6). In addition, most developing countries run substantial trade deficits (World Bank 2010) with the lack of foreign exchange representing a key resource constraint. Greening agriculture can relax the foreign-exchange constraint by reducing the need for imported inputs and by increasing exports of sustainable agrifood products. Reducing deficits would

Scenario	South Asia	East Asia and the Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	Sub-Saharan Africa	Developing countries
NCAR with developing-country investments							
Agricultural research	172	151	84	426	169	314	1,316
Irrigation expansion	344	15	6	31	-26	537	907
Irrigation efficiency	999	686	99	129	59	187	2,158
Rural roads (area expansion)	8	73	0	573	37	1,980	2,671
Rural roads (yield increase)	9	9	10	3	1	35	66
Total	1,531	934	198	1,162	241	3,053	7,118
CSIRO with developing-country investments							
Agricultural research	185	172	110	392	190	326	1,373
Irrigation expansion	344	1	1	30	-22	529	882
Irrigation efficiency	1,006	648	101	128	58	186	2,128
Rural roads (area expansion)	16	147	0	763	44	1,911	2,881
Rural roads (yield increase)	13	9	11	3	1	36	74
Total	1,565	977	222	1,315	271	2,987	7,338

**Table 6: Incremental annual agricultural investment figures by region needed to counteract climate-change impacts on child malnutrition<sup>17</sup>**

Note: These results are based on crop model yield changes that do not include the CO<sub>2</sub> fertilisation effect.

Source: Nelson et al. (2009)

enable these countries to purchase technology and other critical inputs for their economies.

### Climate adaptation and mitigation benefits, and ecosystem services

Making agriculture more resilient to drought, heavy rainfall events, and temperature changes is closely linked to building greater farm biodiversity and improved soil organic matter. Practices that enhance biodiversity allow farms to mimic natural ecological processes, enabling them to better respond to change and reduce risk. The use of intra and inter-species diversity serves as an insurance against future environmental changes by increasing the system's adaptive capabilities (Ensor 2009). Improved soil organic matter from the use of green manures, mulching, and recycling of crop residues and animal manure increases the water holding capacity of soils and their ability to absorb water during torrential rains.

The International Food Policy Research Institute (IFPRI) estimates that an additional US\$ 7.1-7.3 billion per year are needed in agricultural investments to offset the negative impact of climate change on nutrition for children by 2050 (Table 6). The International Food Policy Research Institute recommended investments were needed primarily for basic infrastructure such as rural roads in Africa and expanded irrigation, and

for agricultural research (Nelson et al. 2009). However, assessments of green investment options that would include agro-ecological soil fertility enhancement; water-use efficiency improvements for rain-fed farming; breeding for drought and flood tolerance; integrated pest management; and post harvest handling infrastructures, still remain to be done.

The IPCC estimates that the global technical mitigation potential from agriculture by 2030 is approximately 5,500-6,000 Mt CO<sub>2</sub>-eq/yr (Smith et al. 2007). Soil carbon sequestration would be the mechanism responsible for most of this mitigation, contributing 89 per cent of the technical potential. Therefore, agriculture has the potential to significantly reduce its GHG emissions, and possibly to function as a net carbon sink within the next 50 years. The most important opportunity for GHG mitigation is the application of carbon-rich organic matter (humus) into the soil. This would significantly reduce the need for fossil fuel-based and energy-intensive mineral fertilisers and be a cost-effective means of sequestering atmospheric carbon. Further GHG mitigation gains could be achieved by improving yields on currently farmed lands and reducing deforestation pressures and by adopting no/low tillage practices that reduce fuel usage (Bellarby et al. 2008; ITC and FiBL 2007; Ziesemer 2007).

The environmental services provided by greening farms are substantial. The Rodale Institute, for example, has

17. Note: 1) NCAR: The National Center for Atmospheric Research (US); 2) CSIRO: The Commonwealth Scientific and Industrial Research Organisation (Australia).

estimated that conversion to organic agriculture could sequester additional 3 tonnes of carbon per hectare per year (LaSalle et al. 2008). The carbon sequestration efficiency of organic systems in temperate climates is almost double (575-700 kg carbon per ha per year) that of conventional treatment of soils, mainly owing to the use of grass clovers for feed and of cover crops in organic rotations. German organic farms annually sequester 402 kg carbon/ha, while conventional farms experience losses of 637 kg (Küstermann et al. 2008; Niggli et al. 2009). From such studies, it is possible to approximate that if only all the small farms on the planet employed sustainable practices, they might sequester a total of 2.5 billion tonnes of carbon annually. Such verifiable carbon sequestration levels could be equivalent to US\$ 49 billion in carbon credits per year, assuming a carbon price of US\$ 20/tonne. The FAO has documented that a widespread conversion to organic farming could mitigate 40 per cent (2.4 Gt CO<sub>2</sub>-eq/yr) of the world's agriculture greenhouse gas emissions in a minimum implementation scenario; and up to 65 per cent (4 Gt CO<sub>2</sub>-eq/yr) of agriculture GHG emissions in a maximum carbon sequestration scenario (Scialabba and Muller-Lindenlauf 2010).

Furthermore, emissions of nitrous oxides and methane could be reduced if farmers use nitrogen and other fertilisers more efficiently, including through precision applications and introducing improved crop varieties that more effectively access and use available nitrogen in the soil. Greening agriculture also has the potential to eventually become self-sufficient in producing nitrogen through the recycling of manures from livestock and crop residues via composting; and by increased intercropping rotations with leguminous, nitrogen-fixing crops (Ensor 2009; ITC and FiBL 2007).

Additional ecosystem benefits resulting from greening of agriculture include better soil quality<sup>18</sup> with more organic matter, increased water supply, better nutrient recycling, wildlife and storm protection and flood control (Pretty et al. 2001; OECD 1997). Systems that use natural predators for pest control also promote on-farm and off-farm biodiversity and pollination services.

### 3.4 Modelling: Future scenarios for green agriculture

In this section we assess a scenario in which an additional 0.16 per cent of the global GDP is invested in green agriculture per year (equalling US\$ 198 billion) between 2011 and 2050. This is as part of a green investment scenario in which an additional 2 per cent of global GDP is allocated to a range of key sectors. More details are available in the Modelling chapter of this report. In the part of the modelling exercise, which focused on

agriculture sector, these additional green investments are undertaken equally in the following four activities:

- **Agricultural management practices:** one-fourth of the investment is assumed to be invested in environmentally sound practices;
- **Pre-harvest losses:** another one-fourth of the additional budget is invested in preventing pre-harvest losses, training activities and pest control activities;
- **Food processing:** one-fourth of the investment is assumed to be spent on preventing post-harvest losses, better storage and improved processing in rural areas.
- **Research and Development:** the remaining one-fourth amount is assumed to be spent on research and development especially in the areas of photosynthesis efficiencies, soil microbial productivity, climate adaptation biological processes, and improvements of energy and water-use efficiency.

The green scenario<sup>19</sup> is compared with a BAU2 scenario, where the same amount of additional investment is made in conventional and traditional agriculture over the 40-year period.

The results are stark. Overall, the green investments lead to improved soil quality, increased agricultural yield and reduced land and water requirements. They also increase GDP growth and employment, improve nutrition and reduce energy consumption and CO<sub>2</sub> emissions (Table 7).

■ **Agricultural production and value added:** In the green scenario, total agricultural production (including agricultural products, livestock, fishery and forestry) increases significantly compared to other scenarios.<sup>20</sup> This change is driven by increased crop production, which is able to satisfy a growing population that is projected to reach 9 billion by 2050. Similarly value added in agricultural production increases by 9 per cent compared with the BAU2 scenario. It is important to note that despite an increase in agricultural production and value added, there is no increase in area harvested. This suggests positive synergies between ecological agriculture investments and forest management. Similarly, improved water-efficiency reduces water demand by almost one-third by 2050, compared with the BAU2 scenario. On the other hand, energy consumption

18. Such soils are better quality, contain greater organic matter and microbial activity, more earthworms, have a better structure, lower bulk density, easier penetrability and a thicker topsoil (Reganold et al. 1992).

19. Here we have presented results of scenarios that are referred to as G2 and BAU2 in the Modelling chapter.

20. Detailed information about these results can be found in the Modelling chapter.

		Year	2011	2030		2050	
		Scenario	Baseline	Green	BAU2	Green	BAU2
Agricultural sector variables	Unit						
Agricultural production	Bn US\$/Yr		1,921	2,421	2,268	2,852	2,559
Crop	Bn US\$/Yr		629	836	795	996	913
Livestock	Bn US\$/Yr		439	590	588	726	715
Fishery	Bn US\$/Yr		106	76	83	91	61
Employment	M people		1,075	1393	1,371	1,703	1,656
b) Soil quality	Dmnl		0.92	0.97	0.80	1.03	0.73
c) Agriculture water use	KM3/Yr		3,389	3,526	4276	3,207	4,878
Harvested land	Bn Ha		1.20	1.25	1.27	1.26	1.31
Deforestation	M Ha/Yr		16	7	15	7	15
Calories per capita per day (available for supply)	Kcal/P/D		2,787	3,093	3,050	3,382	3,273
Calories per capita per day (available for household consumption)	Kcal/P/D		2,081	2,305	2,315	2,524	2,476

**Table 7: Results from the simulation model** (a more detailed table can be found in the Modelling chapter)

increases by 19 per cent in 2050 compared with BAU2, due to higher production volumes.

■ *Livestock production, nutrition and livelihoods:* Additional investment in green agriculture also leads to increased levels of livestock production, rural livelihoods and improved nutritional status. An increase in investment in green agriculture is projected to lead to growth in employment of about 60 per cent compared with current levels and an increase of about 3 per cent compared with the BAU2 scenario. The modelling also suggests that green agriculture investments could create 47 million additional jobs compared with BAU2 over the next 40 years. The additional investment in green agriculture also leads to improved nutrition with enhanced production patterns. Meat production increases by 66 per cent as a result of additional investment between 2010-2050 while fish production is 15 per cent below 2011 levels and yet 48 per cent higher than the BAU2 scenario by 2050. Most of this growth is caused by increased outlays for organic fertilisers instead of chemical fertilisers and reduced losses because of better pest management and biological control.

■ *GHG Emissions and biofuels:* Total CO<sub>2</sub> emissions to increase by 11 per cent relative to 2011 but will be 2 per cent below BAU2. While energy-related emissions (mostly from fossil fuels) are projected to grow, it is worth noting that emissions from (chemical) fertiliser use, deforestation and harvested land decline relative to BAU2. When accounting for carbon sequestration in the soil, under ecological practices, and for synergies

with interventions in the forestry sector, net emissions decline considerably.

We also specifically analyse the generation of agricultural waste, residues and biofuels in these models. In the green economy case, we assume that investment is allocated to second-generation biofuels, which use agricultural residues, non-food crops and are primarily grown on marginal land. On average we find that the total amount of fresh residues from agricultural and forestry production for second-generation biofuel production amounts to 3.8 billion tonnes per year between 2011 and 2050 (with an average annual growth rate of 11 per cent throughout the period analysed, accounting for higher growth during early years, 48 per cent for 2011-2020 and an average 2 per cent annual expansion after 2020). Using the IEA's conversion efficiency standards (214 litres of gasoline equivalent (lge) per tonne of residue) we project that additional green investments lift the production of second-generation biofuels to 844 billion lge, contributing to 16.6 per cent of world liquid fuel production by 2050 (21.6 per cent when first-generation biofuels are considered). This would cost US\$ 327 billion (at constant US\$ 2010 prices) per year on average and would require 37 per cent agricultural and forestry residues. The IEA estimates that up to 25 per cent of total agricultural and forestry residues may be readily available, and economically viable (IEA Renewable Energy Division 2010), for second-generation biofuel production. Residues not used for second-generation biofuels are expected to be returned to the land as fertilisers, and in other

cases may be used as livestock feed. More details on the projections on first- and second-generation biofuels production are available in the Modelling and Energy chapters.

Overall, combining these results with research from other sources we find the following results:

- Return on investments in BAU agriculture will continue to decrease in the long run, mainly owing to the increasing costs of inputs (especially water and energy) and stagnated/decreased yields;

- The cost of the externalities associated with brown agriculture will continue to increase gradually, initially neutralising and eventually exceeding the economic and development gains; and

- By greening agriculture and food distribution, more calories per person per day, more jobs and business opportunities especially in rural areas, and market-access opportunities, especially for developing countries, will be available.

While any of the proposed measures contributes to the shift towards a green agriculture sector, the combination of all these interacting actions together will yield positive synergies. For instance, the investment in more sustainable farming practices leads to soil conservation, which increases agricultural yield in the medium to longer term. This allows more land for reforestation, which in turn reduces land degradation and improves soil quality. The higher yield and land availability also benefits the promotion of second-generation biofuels, which may help mitigate the effects of climate change.

## 4 Getting there: Enabling conditions

Despite the clear logic and economic rationale for moving more rapidly towards greener agriculture, the transition will require a supportive policy environment and enabling conditions that could help level the playing field between conventional and green agricultural practices.

Environmental and economic performance in agriculture is most likely to be improved by employing a mix of policies. There needs to be a greater use of regulations and taxes that impose penalties for pollution in order to include externality costs into market prices for these inputs, as well as economic incentives that reward green practices. There are also opportunities for applying market solutions as alternatives to direct regulation, for example, by using tradable permits and quotas to reduce pollution from greenhouse gases and water-borne nutrients. In general, governmental subsidies for farmer (producer) support should be increasingly decoupled from crop production and alternatively be retargeted to encourage farmers' efforts and investments in adopting green agriculture practices.

In the absence of good governance, collusion and excessive profit taking are constant dangers for incentive programmes. Instilling greater levels of transparency could help reduce such abuses of public-support programmes. In this section we present some of the key conditions that will facilitate a transition to a green agriculture.

### 4.1 Global policies

At the global level, the enabling conditions are synonymous with improvements to the international trading system and economic development cooperation for promoting sustainable agriculture. An enabling environment for greening agriculture should include a range of interventions at various points along the entire agri-food supply chain:

#### **Elimination of export subsidies and liberalising trade in agricultural products**

Current multilateral trade policies at the global level have primarily focused on the gradual reduction and removal of national tariff barriers. While such policies aim at facilitating trade, many developing nations are concerned that they are not well positioned to benefit from such trade policies as are the more developed nations.

These concerns are particularly relevant while domestic subsidies and other producer-support programmes

remain in many developed countries. These measures effectively distort and diminish any competitive advantages that developing nations might have. In addition, subsidies have effectively reduced global commodity prices, making it frequently unprofitable to produce certain products in many developing countries, especially for smallholder farmers. This combination of international trade laws and national subsidies can impede development of commercial agriculture in many developing countries, negatively affecting their efforts to achieve economic growth and poverty reduction.

Such trade and subsidy policies need to be reformed to liberalise trade in environmentally- friendly products and services while allowing developing countries to protect some domestic food crops (special products) from international competition when they are particularly important to food security and rural livelihoods. The World Trade Organisation (WTO) already makes a dispensation for countries with a per capita GDP of less US\$ 1,000 (Amsden 2005). Furthermore, agricultural subsidies need to be redirected to encourage more diverse crop production with long-term soil health and improved environmental impacts. A major shift of subsidy priorities is needed in which governments would help reduce the initial costs and risks of farmers' transition efforts to implement sustainable farming practices.

#### **Market power asymmetry**

Asymmetric market power in trade is an important issue for WTO competition policy. Leading firms are predominantly located in industrialised countries and maintain significant control over the food system standards and regulatory processes at all stages of the supply chain (Gereffi et al. 2005). In such market conditions, primary producers generally capture only a fraction of the international price of the commodity. Thus, the degree of poverty reduction and rural development benefits of supplying global trade have been limited. A recent study (Wise 2011) shows that even in a resource-rich country like the United States, despite rapid increase in prices for food commodities since 2006, "small-to-mid-scale family farmers had lower farm incomes in 2009 than they did earlier in the decade when prices were lower". A green agriculture system would require trade policies that redress these chronic asymmetries.

#### **Food safety standards**

The already stringent food safety standards and verifiable logistics management systems that are



applied in international markets are likely to become more sophisticated over the next few decades. Currently, most domestic food supply chains in developing countries have relatively low levels of food safety and handling practices. Improving capacity to develop and implement sanitary and food safety standards that can ensure compliance with international requirements can increase prospects for small farmer communities to supply international markets (Kurien 2004). Furthermore, it is particularly important to support international efforts to harmonise the variety of sustainable and organic certification protocols and standards. Today's fragmented certification procedures impose high transaction and reporting costs on farmers and limit their access to international markets.

Another important issue is that the cost of certification and reporting is to be borne only by sustainable producers while polluters can market their products freely. The burden of proof must be shifted to the polluter through introduction of certification protocols and labeling schemes which, at a minimum, show the quantities of different agrochemical inputs used in the production and processing of a product, and whether the product contains GMOs or not.

### Intellectual property

The application of Intellectual Property (IP) regimes has, in some cases, restricted the results of agricultural research and development being made available as public goods. Private-sector and often public-sector IP rights restrict the access of many in developing countries to research, technologies and genetic materials. Supporting the implementation of the World Intellectual Property Organisation's (WIPO) Development Agenda and providing improved access to and reasonable use of IP that involves traditional knowledge, ecological agriculture techniques and

genetic resources in international IP regimes would help advance development and sustainability goals.

## 4.2 National policies

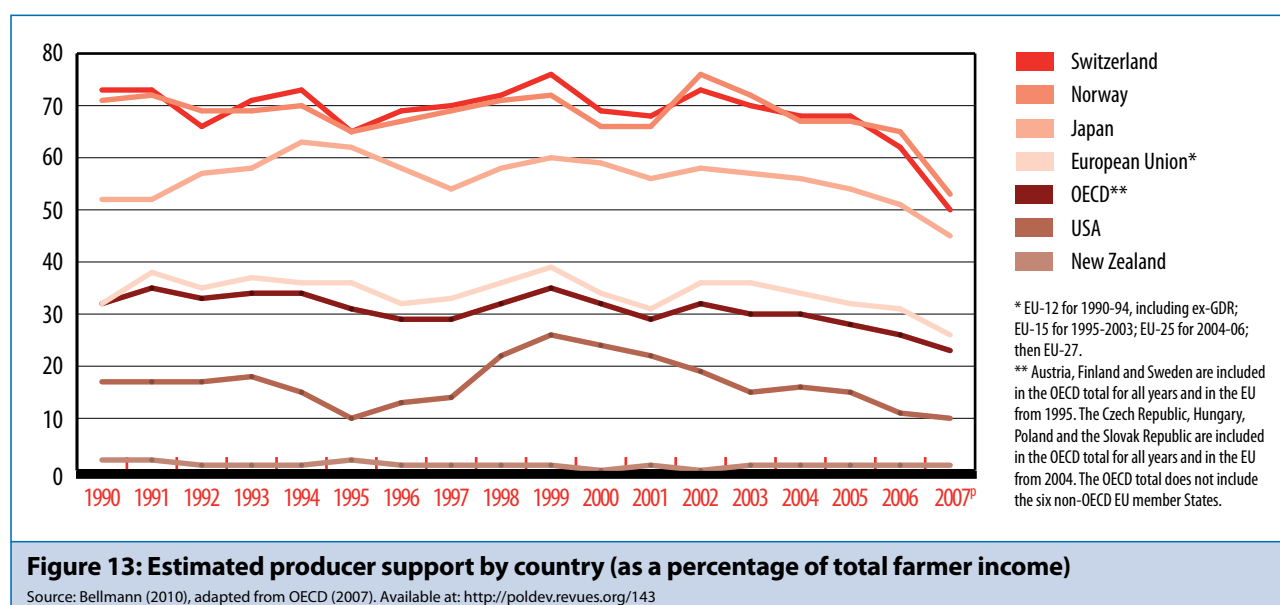
At the domestic public policy level, the key challenge is creating the conditions that would encourage more farmers to adopt environmentally sound agriculture practices instead of continuing to practice unsustainable conventional farming methods.

### Support for improved land tenure rights of smallholder farmers

In order for farmers to invest capital and more labour into the transition from brown to green agriculture, major land reforms will have to be implemented, particularly in developing countries. In the absence of more secure rights to specific plots of land for many years into the future, many poor farmers are unlikely to take on additional risks and efforts to gradually build up the natural capital of their farms beyond a one or two-year horizon.

### Targeting programmes for women smallholder farmers

Small-farm diversification often requires a division of labour at the household level that may result in gender-based distribution of management roles and responsibilities for both on and off-farm tasks. This has resulted in the majority of smallholder farms, especially in Africa, being run by women. Securing collective and individual legal rights to land and productive resources (e.g. water, capital), especially for women, indigenous people and minorities is important. Improving women's access to working capital through microfinance is an option that would allow much greater numbers of small-scale producers to procure green inputs and related mechanisation technologies (World Bank, IFAD and FAO 2009).



### **Public procurement of sustainably produced food**

Government-sponsored food programmes for schools and public institutions and public procurement policies should be encouraged to source foods that are sustainably produced. The Strategic Paper on Public Procurement, prepared by the UK Department for Environment, Food and Rural Affairs (DEFRA) in January 2008, provides a good example of how organic and sustainable products can be supported through public procurement policies.<sup>21</sup>

## **4.3 Economic instruments**

Agriculture's environmentally damaging externalities could be reduced by imposing taxes on fossil fuel inputs and pesticide and herbicide use; and establishing specific penalties for air emissions and water pollution caused by harmful farming practices. Alternatively, tax exemptions for investments in bio-control integrated pest management products; and incentives that value the multi-functional uses of agricultural land have proven effective in improving the after tax revenues for farmers that practice sustainable land management. The OECD countries have developed a wide range of policy measures to address environmental issues in agriculture, which include economic instruments (payments, taxes and charges, market creation, e.g., tradable permits), community based measures, regulatory measures, and advisory and institutional measures (research and development, technical assistance and environmental labelling).

In OECD countries, the partial shift away from production-linked support has enabled the agricultural sector to be more responsive to markets, thus improving growth. Importantly, some support measures have been linked to specific environmental objectives, research and development, information, and technical assistance, food inspection services, biodiversity, flood and drought control, and sinks for greenhouse gases and carbon storage. There is a need to strengthen these recent trends in developed countries and replicate them in those developing countries that offer farm subsidies in order to target these funds to specific objectives for greater and sustainable economic and environmental performance (OECD 2010).

Payment for Ecosystem Service (PES) can further incentivise efforts to green the agriculture sector. This is an approach that verifies values and rewards the benefits of ecosystem services provided by green agricultural practices (Millennium Ecosystem Assessment 2005; Brockhaus 2009). A key objective of PES schemes is to generate stable revenue flows that help compensate farmers for their efforts and opportunity costs incurred in

reducing environmental pollution and other externality costs that adversely impact the shared commons of the local, national and global environment. Such PES arrangements should be structured so that small-scale farmers and communities, not just large landowners, are able to benefit. Innovative PES measures could include reforestation payments made by cities to upstream communities in rural areas of shared watersheds for improved quantities and quality of fresh water for municipal users. Ecoservice payments by farmers to upstream forest stewards for properly managing the flow of soil nutrients, and methods to monetise the carbon sequestration and emission reduction credit benefits of green agriculture practices in order to compensate farmers for their efforts to restore and build SOM and employ other practices described in this chapter are important elements of PES programmes that have been implemented to date (Pagiola 2008; Ravnborg et al. 2007).

## **4.4 Capacity building and awareness-raising**

The availability and qualitative capabilities of rural labour are critical resources needed for implementing green agriculture practices. Green agricultural practices emphasise crop and livestock diversification; local production of natural fertiliser and other more labour-intensive farm operations. The seasonal variability of crop-specific farming tasks affects temporal labour surpluses and shortages, which must be managed throughout the year. Whether rural labour provides an advantage or a constraint for the adoption of green agriculture practices is highly contextual with specific regional and national conditions. The relative age and gender distribution of rural populations, their health, literacy and family stability, gender equity with respect to access to training and financial services, and other factors will determine the degree to which rural farming communities respond to public and private encouragement of their adoption of green agriculture (Foresight 2011).

### **Supply chains, extension services and NGOs**

Green farming practices in developing countries must be promoted and supported by information outreach and training programmes that are delivered to farmers and their supply-chain partners. These enhanced and expanded training programmes should build upon established agriculture extension service programmes in those countries where they are now functioning. However, in order to effectively use existing agriculture extension services, it should be recognised that some extension services over the past 50 years have failed due to a pervasive attitude that small farmers need to be "taught". The green agriculture paradigm requires participatory learning in which farmers and

21. The paper is available at <http://www.sustainweb.org/pdf2/org-238.pdf>.

professionals in agro-ecological sciences work together to determine how to best integrate traditional practices and new agro-ecological scientific discoveries. Efforts should also be made to partner with NGOs that support farmers, field schools, demonstration farms and other such initiatives. It is also important to support small and medium business enterprises that are involved in supplying agriculture inputs; particularly those firms that offer green agriculture products and services such as organic certification auditing and reporting.

#### **Integrating information and communications technologies with knowledge extension**

Support is needed to improve farmers' access to market information including through IT in order to enhance their knowledge of real market prices so that they can better negotiate the sale of their crops to distributors and end customers. There are also opportunities to support the construction of meteorological monitoring telemetry stations that could support national and regional weather forecasting capabilities that would help farmers determine best times for planting, fertiliser applications, harvesting and other critical weather-sensitive activities. Such networks could help support the introduction of innovative financial services such as

weather-indexed crop insurance that would help reduce risks associated with adopting new technologies and shifting to green practices and marketing methods.

#### **Better food choices**

In an era where global human health is undermined by malnourishment and obesity, there is an opportunity to guide and influence people's food consumption into a greater balance with sustainably produced and more nutritious foods. Raising awareness about better food and its availability at affordable prices can reduce and reshape food demand trends. In this regard, there is a need to invest in public education and marketing that would encourage consumers to adopt more sustainable dietary habits (OECD 2008).

Large-scale industrial farming practices, in many cases, pose enormous public health risks due to the overuse of inputs such as antibiotics, pesticides and synthetic growth hormones. There are neither policies nor any labels that transparently display the level of use and residues of these inputs. Introducing labelling schemes that can help consumers to make informed choices will dramatically shift the consumer behaviour towards safe and healthy food.

## 5 Conclusions

A transformation of today's predominant agriculture paradigms is urgently needed because conventional (industrial) agriculture as practiced in the developed world has achieved high productivity levels primarily through high levels of inputs (some of which have limited known natural reserves), such as chemical fertilisers, herbicides and pesticides; extensive farm mechanisation; high use of transportation fuels; increased water use that often exceeds hydrologic recharge rates; and higher yielding crop varieties resulting in a high ecological footprint. Similarly, traditional (subsistence) agriculture as practiced in most developing countries, which has much lower productivity, has often resulted in the excessive extraction of soil nutrients and conversion of forests to farmland.

The need for improving the environmental performance of agriculture is underscored by the accelerating depletion of inexpensive oil and gas reserves; continued surface mining of soil nutrients; increasing scarcity of freshwater in many river basins; aggravated water pollution by poor nutrient management and heavy use of toxic pesticides and herbicides; erosion; expanding tropical deforestation, and the annual generation of nearly a third of the planet's global greenhouse gas emissions (GHG).

Agriculture that is based on a green economy vision integrates location-specific organic resource inputs and natural biological processes to restore and improve soil fertility; achieve more efficient water use; increase crop and livestock diversity; support integrated pest and weed management and promotes employment and smallholder and family farms.

Green agriculture could nutritiously feed the global population up to 2050, if worldwide transition efforts are immediately initiated and this transition is carefully managed. This transformation should particularly focus on improving farm productivity of smallholder and family farms in regions where increasing population and food insecurity conditions are most severe. Rural job creation would accompany a green agriculture transition, as organic and other environmentally sustainable farming often generate more returns on labour than conventional agriculture. Local input supply chains and post-harvest processing systems would also generate new non-farm, value added enterprises and higher skilled jobs. Higher proportions of green agricultural input expenses would be retained within local and regional communities,

and the increased use of locally sourced farm inputs would substitute for many imported agri-chemical inputs, helping to correct developing countries' foreign trade imbalances.

Ecosystem services and natural capital assets would be improved by reduced soil erosion and chemical pollution, higher crop and water productivity, and decreased deforestation. A greener agriculture has the potential to substantially reduce agricultural GHG emissions by annually sequestering nearly 6 billion tonnes of atmospheric CO<sub>2</sub>. The cumulative effect of green agriculture in the long term will provide the adaptive resilience to climate-change impacts.

Investments are needed to enhance and expand supply-side capacities, with farmer training, extension services, and demonstration projects focusing on green farming practices that are appropriate for specific local conditions and that support both men and women farmers. Investments in setting up and capacity building of rural enterprises are also required.

Additional investment opportunities include scaling up production and diffusing green agricultural inputs (e.g. organic fertilisers, biopesticides, etc.), no-tillage cultivation equipment, and improved access to higher yielding and more resilient crop varieties and livestock. Investments in post-harvest storage handling and processing equipment, and improved market access infrastructures would be effective in reducing food losses and waste.

In addition to production assets, investments are required to increase public institutional research and development in organic nutrient recovery, soil fertility dynamics, water productivity, crop and livestock diversity, biological and integrated pest management, and post-harvest loss reduction sciences.

Secure land rights, and good governance, as well as infrastructure development (e.g. roads, electrification, the internet, etc.) are critical enabling conditions for success, especially in the rural sector and particularly in developing countries. These investments would have multiple benefits across a wide range of green economy goals and enable the rapid transition to greener agriculture.

Public policies are needed to provide agriculture subsidies that would help defray the initial transition costs

associated with the adoption of more environmentally friendly agriculture practices. Such incentives could be funded by corresponding reductions of agriculture related subsidies that reduce the costs of agricultural inputs, enabling their excessive use, and promote commodity crop support practices that focus on short-term gains rather than sustainable yields.

Public awareness and education initiatives are needed in all countries to address consumer demand for food. Investments in consumer-oriented programmes that focus on nutritional health and the environmental and social equity implications of dietary behaviours could encourage local and global demand for sustainably produced food.

# References

- ACDI/VOCA. (2009). "Smallholder Horticulture Outgrower Promotion (SHOP) Project Final Report to USAID." October, 2009. Washington D.C.
- Adeoti, A., Barry, B., Namara, R., Kamara, A. (2009). "The Impact of Treadle Pump Irrigation Technology Adoption on Poverty in Ghana." *Journal of Agricultural Education and Extension* 15(4) 357-369. Philadelphia: Routledge.
- Adeoti, A., Barry, B., Namara, R., Kamara, A., Titiati, A. (2007). "Treadle pump irrigation and poverty in Ghana." Colombo, Sri Lanka: International Water Management Institute. IWMI Research Report 117.
- Adrian et al. (2010). "Bulletin of the British Ecological Society" 41 (1): 10-13. (March 2010).
- Adrian, M.A., Norwood, S.H., Mask, P.L. (2005). "Producers' perceptions and attitudes toward precision agriculture technologies." *Computers Electron. Agric.* 48:256-271.
- African Development Bank Group. (2010). "Agriculture Sector Strategy 2010-2014." page 6. Available at: <http://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/Agriculture%20Sector%20Strategy%2010-14.pdf> (last accessed: 17th October 2011).
- Ahmed, M. A. M., Ehui, S. and Assefa, Y. (2004). "Dairy development in Ethiopia. Environment and Production." Technology Division Discussion Paper No. 123. Washington, D.C.: International Food Policy Research Institute. Department for International Development, Overseas Development Institute, and Netherlands Ministry of Foreign Affairs (DFID/ODI/NMFA).
- Ali, F.G. (1999). "Impact of moisture regime and planting pattern on bio- economic efficiency of spring planted sugarcane (*Saccharum officinarum* L.) under different nutrient and weed management strategies." Phd Thesis, Dept. of Agronomy, University of Agriculture, Faisalabad, Pakistan.
- Amsden, A. H. (2001). *The Rise of "The Rest": Challenges to the West from Late-Industrializing Economies*. Oxford: Oxford University Press.
- Amsden, A. H. (2005). "Promoting Industry under WTO Law." in K. P. Gallagher (ed.). *Putting Development First: The Importance of Policy Space in the WTO and Financial Institutions*. London: Zed Book, 221.
- Altieri, M. (2008). "Small farms as a Planetary Ecological Asset: Five Key Reasons Why We Should Support the revitalisation of Small Farms in the Global south." Penang: Third World Network.
- Asian Development Bank. (2010). "The costs of achieving the Millennium Development Goals through Adopting Organic Agriculture." Markandya, A., Setboonsarng, S., Yu Hui, Q., Songkranok, R., and Stefan, A. No. 193. February 2010.
- Baker, C.J., Saxton, K.E., Ritchie, W.R., Chamen, W.C.T., Reicosky, D.C., Ribeiro, F., Justice, S.E. and Hobbs, P.R. (2007). *No-tillage seeding in conservation agriculture*, 2nd edition. FAO & Cab International. Oxfordshire, UK.
- Balgopal, B., Paranikas, P., and Rose, J. (2010). "What's Next for Alternative Energy?" The Boston Consulting Group Inc. Boston, MA.
- Banerjee, Abhijit V., 1999. *Land Reforms: Prospects and Strategies*, Conference Paper, Annual World Bank Conference on Development Economics, Washington D.C.; and MIT Department of Economics Working Paper No. 99-24. Available at SSRN: <http://ssrn.com/abstract=183711> or doi:10.2139/ssrn.183711
- Baributsa, D., Lowenberg-De-Boer, J., Murdock, L. and Moussa, B. (2010). "Profitable Chemical-Free Cowpea Storage Technology for Smallholder Farmers in Africa." Fifth World Cowpea Research Conference. CGIAR. Dakar, Senegal.
- Baoua. (2008). "Activity Report: Integrated Management of Pearl Millet Head Miner." The McKnight Foundation, Collaborative Crop Research Program. March, 2008.
- Barrett, C. B. (1993). "On Price Risk and the Inverse Farm Size – Productivity Relationship." University of Wisconsin – Madison, Department of Agricultural Economics Staff Paper Series no. 369.
- Beintema, N. and Elliott, H. (2010). *Setting Meaningful Investment Targets in Agricultural Research and Development: Challenges, Opportunities and Fiscal realities*. Available at: <ftp://ftp.fao.org/docrep/fao/012/ak978e/ak978e00.pdf>
- Belder, P., Rohrbach, D., Twomlow, S., Senzanje, A. (2007). "Can drip irrigation improve the livelihoods of smallholders? Lessons learned from Zimbabwe." International Crops Research Institute for the Semi-Arid Tropics, Bulawayo, Zimbabwe. *Journal of SAT Agricultural Research*, 68.
- Bellarby, J., Foereid, B., Hastings, A., Smith, P. (2008). "Cool Farming: Climate impacts of agriculture and mitigation potential." Greenpeace.
- Bellmann, C., Biswas, T., Chamay, M. (2011). "Recent Trends in World Trade and International Negotiations." *Revue internationale de politique de développement*. Available at: <http://poldev.revues.org/143> (last accessed: 20 September 2011).
- Bennett E., Carpenter S., Caraco, N. (2001). "Human Impact on Erodable Phosphorus and Eutrophication: A Global Perspective." *BioScience* 51(3): 227.
- Bravo-Ortega, C. and Lederman, D. (2005). "Agriculture and national welfare around the world: causality and international heterogeneity since 1960." Policy Research Working Paper Series 3499, The World Bank.
- Brockhaus, M., and Botoni, E. (2009). "Ecosystem Services – Local Benefits, Global Impacts." *Rural* 21 01/2009: 8-11.
- Bruinsma, J. (2009). "The Resource Outlook to 2050: By How Much Do Land, Water and Crop Yields Need To Increase By 2050?" Expert Meeting on How to Feed the World in 2050. Food and Agriculture Organisation of the United Nations Economic and Social Development Department.
- CAADP. (2009). "How are countries measuring up to the Maputo declaration?" Policy Brief. June 2009.
- Calvert, G.M, Plate, D.K., Das, R., Rosales, R., Shafey, O., Thomsen, C., Male, D., Beckman, J., Arvizu, E. and Lackovic, M. (2004). "Acute occupational pesticide-related illness in the US, 1998-1999: surveillance findings from the SENSOR-pesticides programme." *American Journal of Industrial Medicine* 45: 14-23.
- Cassman, K.G., Dobermann, A., Walters, D.T. (2002). "Agroecosystems, nitrogen-use efficiency, and nitrogen management." *AMBIO* 31:132-140.
- Cervantes-Gody, D. and Dewbre, J. (2010). "Economic Importance of Agriculture for Poverty Reduction", OECD Food, Agriculture and Fisheries Working Papers No. 23.
- CGIAR. (2011). "Mapping Hotspots of Climate Change and Food Insecurity in the Global Tropics." Available at: [http://ccaifs.cgiar.org/resources/climate\\_hotspots](http://ccaifs.cgiar.org/resources/climate_hotspots).
- Cheng, C.-H. and Lehmann, J. (2009). "Aging black carbon along a temperature gradient." *Elsevier. Chemosphere: Environmental Chemistry* 75: 1021-1027.
- China's National Pollution Census. (2007). Embassy of the PRC in the USA. Available at: <http://www.china-embassy.org/eng/xw/t396330.htm>. 4 January 2008.
- Clark, S., Klonsky, K., Livingston, P. and Temple, S. (1999). "Crop-yield and economic comparisons of organic, low-input, and conventional farming systems in California's Sacramento Valley." *American Journal of Alternative Agriculture*. 14(3):109-121.
- Clark, S. and Alexander, C. (2010). "The Profitability of Transitioning to Organic Grain Crops in Indiana." *Purdue Agricultural Economics Report*.
- Comprehensive Assessment of Water Management in Agriculture. (2007). "Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture." London: Earthscan, and Colombo: International Water Management Institute.
- Cordell, D., Drangert, J.O., White, S. (2010). "The Story of Phosphorus: Sustainability Implications of Global Phosphorus Scarcity for Food Security." Institute for Sustainable Futures, University of Technology Sydney and Linköping University.
- Cornia, G. A. (1985). "Farm Size, Land Yields and the Agricultural Production Function: An Analysis for Fifteen Developing Countries." *World Development* 13(4):513-534.
- Daberkow, S.G., and McBride, W.D. (2001). "Adoption of precision agriculture technologies by U.S. farmers." in Robert, P.C. et al. (eds.) *Precision agriculture [CD-ROM]*. Proc. Int. Conf., Minneapolis, 16-19 July 2000. ASA- CSSA-SSSA, Madison, Wisconsin.
- DEFRA. (2008). "The Strategic Paper on Public Procurement." English Organic Action Plan Steering Group (OAPSG) January 2008. Available at: <http://www.sustainweb.org/pdf2/org-238.pdf>.
- Delgado, C. L., Hopkins, J. C. and Kelly, V. A. (1994). "Agricultural growth linkages in sub-Saharan Africa." Washington, DC: International Food Policy Research Institute (IFPRI).
- Delgado, C., Hazell, P., Hopkins, J. and Kelly, V. (1994). "Promoting intersectoral growth linkages in rural Africa through agricultural technology and policy reform." *American Journal of Agricultural Economics* 76: 1166-71.



- Dieu, D., Wandji, N., Lapbim Nkeh, J., Gockowski, J., Tchouamo, I. (2006). "Socio- Economic Impact of a Cocoa Integrated Crop and Pest Management Diffusion Knowledge Through a Farmer Field School Approach in Southern Cameroon." International Association of Agricultural Economists.
- Dimitri, C., Effland, A. and Conklin, N. (2005). "The 20th century transformation of U.S. agriculture and farm policy." Electronic Information Bulletin No. 3, June 2005.
- Dobbs, T.L. and Smolik, J.D. (1996). "Productivity and profitability of conventional and alternative farming systems: a long-term on-farm paired comparison." *Journal of Sustainable Agriculture* 9(1): 63–79.
- Dodds, W.K., Bouska, W.W., Eitzmann, J.L., Pilger, T.J., Pitts, K.L., Riley, A.J., Schloesser, J.T. and Thornbrugh, D.J. (2009). "Eutrophication of U.S. Freshwaters: Analysis of Potential Damages." *Environmental Science & Technology*, 43 (1): 12-19. American Chemical Society. Washington DC.
- Dreze, J. and Sen, A. K. (1989). *Hunger and public action*. Clarendon Press: Oxford.
- Drinkwater, L.E., Wagoner, P., and Sarrantonio, M. (1998). "Legume-based cropping systems have reduced carbon and nitrogen losses." *Nature* 396:262–265.
- Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J. Soussana, J.F. Schmidhuber, J. and Tubiello, F.N. (2007). "Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.), Cambridge University Press: Cambridge, UK, 273–313.
- Edwards, S. (2007). "The impact of compost use on crop yields in Tigray, Ethiopia." Institute for Sustainable Development (ISD). Proceedings of the International Conference on Organic Agriculture and Food Security. FAO, Rome. Available at: <ftp://ftp.fao.org/paia/organicag/ofs/02-Edwards.pdf>
- Ellis, F. (1993). *Peasant Economics: Farm Households and Agrarian Development*, 2nd edition. Cambridge: Cambridge University Press.
- Emmanuel, D.M., Violette, R. (2010). "Exploring the Global Food Supply Chain Markets, Companies, Systems." 3D publishing. Available at: [http://www.3dthree.org/pdf\\_3D/3D\\_ExploringtheGlobalFoodSupplyChain.pdf](http://www.3dthree.org/pdf_3D/3D_ExploringtheGlobalFoodSupplyChain.pdf).
- Ensor, J. (2009). *Biodiverse agriculture for a changing climate*. Practical Action Publishing: Rugby, UK.
- Erenstein, O., Sayre, K., Wall, P., Dixon, J. and Hellin, J. (2008). "Adapting No-Tillage Agriculture to the Conditions of Smallholder Maize and Wheat Farmers in the Tropics and Sub-Tropics. No-Till Farming Systems." World Association of Soil and Water Conservation. Special Publication 3, 263.
- Ericksen, P.J. (2006). "Conceptualizing food systems for global environmental change (GEC) research." GECAFS Working Paper 2. Environmental Change Institute, Oxford.
- Eyhorn F., Mader, P. and Ramakrishnan, M. (2005). "The Impact of Organic Cotton Farming on the Livelihoods of Smallholders." FIBL Research Report, October 2005.
- Eziakor, I. G. (1990) "Comparative analysis of the effectiveness of manual versus mechanized tillage among Third World smallholders: a case study in Bauchi State of Nigeria." *Agriculture, Ecosystems and Environment*. 31: 301-312 Elsevier Science Publishers B.V., Amsterdam.
- Falkenmark, M., and Rockström, J. (2004). "Balancing water for humans and nature." Earthscan, London.
- FAO. (1994). "Land degradation in south Asia: Its severity, causes and effects upon the people." FAO, Rome. Available at: <http://www.fao.org/docrep/V4360E/V4360E00.htm>
- FAO. (2002). "World Agriculture Towards 2015/2030." FAO, Rome.
- FAO. (2006). "World Agriculture: Towards 2030/2050 (interim report)." An updated version, with extension of projections to 2050, of two of the key chapters (2 and 3) of the study Bruijsma, J (ed.) (2003). "World Agriculture: Towards 2015/30." Earthscan, London.
- FAO. (2007). "Energy Use in Organic Food Systems by Jodi Zieseme" FAO, 2007." FAO International Conference on Organic Agriculture and Food Security. 3-5 May 2007. Rome. Available at: <ftp://ftp.fao.org/paia/organicag/ofs/OFS-2007-5.pdf>
- FAO. (2008). "Agricultural mechanisation in Africa: Time for action Planning investment for enhanced agricultural productivity." Report of an Expert Group Meeting, January 2008, Vienna, Austria.
- FAO. (2008). "Household Metal Silos: Key Allies in FAO's Fight Against Hunger." Agricultural and Food Engineering Technologies Service. FAO, Rome.
- FAO. (2009). "World Summit on Food Security Rome 16 – 18 November, 2009. Feeding the World, Eradicating Hunger." WSFS 2009.inf/2.
- FAO. (2010). "Climate Change Implications for Agriculture in Sub-Saharan Africa." Ching, L. and Jhamtani, H.
- FAO. (2010). "The State of Food Insecurity in the World: Addressing food insecurity in protracted crises." FAO, Rome. Available at: <http://www.fao.org/docrep/013/i1683e/i1683e.pdf>.
- FAO. n.d. Available at: <http://www.fao.org/investment/whyinvestinagricultureandru/en/>. Accessed on 18 October 2011.
- FAO and ILO. (2009). "Safety and Health."
- FAOSTAT, 2004: Food and Agriculture Organisation of the United Nations, Statistical Databases, Available at: <http://faostat.fao.org> and FAOSTAT, 2007: <http://faostat.fao.org/site/377/default.aspx#ancor>.
- Faruquee, R. and Carey, K. (1997). "Land Markets in South Asia: What Have We Learned." World Bank Research Paper # 1754, Washington D.C.
- Feder, G. (1985). "The Relationship between Farm Size and Farm Productivity," *Journal of Development Economics* 18: 297 –313.
- Foresight. (2011). "The Future of Food and Farming: Challenges and Choices for Global Sustainability." The Government Office for Science, London.
- Frear, C., Zhao, Q., Chen, S. (2010). "An Integrated Pathogen Control, Ammonia and Phosphorus Recovery System for Manure and/or Organic Wastes." Washington State University. Washington Bioenergy Research Symposium. Seattle, WA.
- Gaiha, R. (2006). "A Review of Employment Guarantee Scheme in Maharashtra," Chapter 13 in Islam, N., Reducing Rural Poverty in Asia: Challenges and Opportunities for Microenterprises and Public Employment Schemes. New York: Food Press Inc.
- Galea, S., Vlahov, D. (2005). *Handbook of Urban Health: Populations, Methods, and Practice*. Springer Science+Media Inc. NY.
- Galinato S. P., Yoderb, J.K., and Granatstein, D. "The Economic Value of Biochar in Crop Production and Carbon Sequestration." Working Paper 2010. Available at: <http://ideas.repec.org/p/wsu/wpaper/sgalinato-2.html>.
- García-Mozo, H., Mestre, A., Galán, C. (2010). "Phenological trends in southern Spain: A response to climate change." *Agricultural and Forest Meteorology* 150: 575–580.
- Gebregezabher, T., Nyssen, J., Govaerts, B., Getnet, F., Behailu, M., Haile, M., Deckers, J. (2009). "Contour furrows for in situ soil and water conservation, Tigray, Northern Ethiopia." *Soil & Tillage Research* 103: 257–264.
- Geneva International Programme on Chemical Safety/World Health Organisation (WHO). (2004). "Epidemiology of pesticide poisoning: harmonized collection of data on human pesticide exposure in selected countries." Geneva International programme on Chemical Safety/WHO.
- Gereffi, G., Humphrey, J. and Sturgeon, T. (2005). "The Governance of Global Value Chains." *Review of International Political Economy* 12: 78-104.
- Ghosh, P.K., Dayal, D., Bandyopadhyay, K.K., Mohanty, M. (2006). "Evaluation of straw and polythene mulch for enhancing productivity of irrigated summer groundnut." *Field Crops Research* 99, 76–86.
- Giampietro, M. and Pimental, D. (1994). "The Tightening Conflict: Population, Energy Use and the Ecology of Agriculture." Available at: <http://www.dieoff.com/page69.htm>.
- Gliessman, S. R. and Rosemeyer, M. (2009). *The Conversion to Sustainable Agriculture: Principles, Processes, and Practices (Advances in Agroecology)*. 21 December 2009.
- Glover, J.D., Reganold, J.P., Bell, L.W., Borevitz, J., Brummer E.C., Buckler, E.S., Cox, C.M., Cox, T.S., Crews, T.E., Culman S.W., DeHaan, L.R., Eriksson, D., Gill, B.S., Holland, J., Hu, F., Hulke, B.S., Ibrahim, A.M.H., Jackson, W., Jones, S.S., Murray, S.C., Paterson, A.H., Ploschuk, E., Sacks, E.J., Snapp, S., Tao, D., Van Tassel, D.L., Wade, L.J., Wyse, D.L. and Xu, Y. (2010). "Increased Food and Ecosystem Security via Perennial Grains." *Science* 328: 1638-1639 (2010)
- Godonou, I., James, B., Atcha-Ahowé, C., Vodouhè, S., Kooyman, C., Ahanchédé, A. and Korie, S. (2009). "Potential of Beauveria bassiana and Metarhizium anisopliae isolates from Benin to control Plutella xylostella L. (Lepidoptera: Plutellidae)." *Crop Protection* 28: 220–224.
- Godfray H.C.J., Beddington J.R., Crute I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010). "Food Security: The Challenge of Feeding 9 Billion People." *Science* 327, 812 (2010).
- Goldman Sachs. (2007). Dominic Wilson and Anna Stupnyska, "The N-11: More Than an Acronym." *Global Economics Paper* 153.
- Goskomstat [State Statistical Committee]. (2002). "Rossiyskiy statisticheskiy ezhegodnik [Russian statistical yearbook (in Russian)]." Moscow.
- Government of China. (2007). "Pollution Census 2007." Available at: <http://www.i-sis.org.uk/full/chinasPollutionFull.php>.

- Grabski, A., Desborough P. (2009). "The impact of 14 years of conventional and no-till cultivation on the physical properties and crop yields of a loam soil at Grafton NSW, Australia." *Soil and Tillage Research*, 104: 180-184.
- Granastein, D., Kruger, C., Collins, H., Garcia-Perez, M., Yoder, J. "Use of Biochar from the Pyrolysis of Waste Organic Material as a Soil Amendment." Available at: <http://www.ecy.wa.gov/biblio/0907062.html>.
- Hall, K.D., Guo, J., Dore, M., Chow, C.C. (2009). "The Progressive Increase of Food Waste in America and Its Environmental Impact." *PLoS ONE* 4(11): e7940. doi:10.1371/journal.pone.0007940.
- Hasan, R. and Quibria, M. G. (2004). "Industry Matters for Poverty: A Critique of Agricultural Fundamentalism." *Kyklos*, 57(2): 253-64.
- Henao S. and Arbelaez, M. P. (2002). "Epidemiological situation of acute pesticide poisoning in the Central American Isthmus, 1992-2000." *Pan American Health Organisation (PAHO). Epidemiology Bulletin* 23: 5-9.
- Herren, H. and Osman-Elasha, B. (2010). "Agriculture at a Crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development." (IAASTD).
- Hill, H. (2009). Comparing Energy Use in Conventional and Organic Cropping Systems. National Center for Appropriate Technology (NCAT). Butte, MT. (2009). Available at: [www.attra.ncat.org/attrapub/PDF/croppingsystems.pdf](http://www.attra.ncat.org/attrapub/PDF/croppingsystems.pdf).
- Hines, R. and Pretty, J. (2008). "Organic Agriculture and Food Security in Africa." New York and Geneva: UNEP-UNCTAD CBTF.
- Hines, R., Pretty, J., and Twarog, S. (2008). Organic Agriculture and Food Security in Africa. UNEP and UNCTAD Capacity-building Task Force on Trade, Environment and Development. United Nations. New York and Geneva.
- Ho, M. W. (2010). "China's Pollution Census Triggers Green Five-Year Plan." *Institute of Science in Society*.
- Howard. (2009). "Visualizing Consolidation in the Global Seed Industry: 1996–2008." *Sustainability* (2009) 1: 127.
- IAASTD. (2009). "International Assessment of Agricultural Knowledge, Science and Technology for Development. 2009." Agriculture at a Crossroads. IAASTD: Washington, D. C.
- IAASTD. (2009b). "International Assessment of Agricultural Knowledge, Science and Technology for Development. 2009." Agriculture at a Crossroads: Global Summary for Decision Makers. IAASTD: Washington, D. C.
- ICARDA Caravan. (2009). "Review of agriculture in the dry areas: Minimum tillage, Maximum benefits." 26: 19-21.
- ICROFS. (2010). "How Organic Agriculture Contributes to Economic Development in Africa." International Center for Research in Organic Food Systems. Fact Sheet 4, February 2010.
- IEA (International Energy Agency) Renewable Energy Division. (2010). "Sustainable Production of Second-Generation Biofuel: Potential and Perspectives in Major Economies and Developing Countries." OECD/IEA, Paris.
- IFAD (International Fund for Agricultural Development). (2001). "Rural poverty report 2001: The challenge of ending rural poverty." IFAD, Rome.
- IFAD. (2003). "IFAD Press Release 05/03." IFAD Governing Council Annual Meeting. Rome. Available at: <http://www.ifad.org/media/press/2003/5.htm>.
- IFAD. (2010a). "Land Conservation and Smallholder Rehabilitation in Ghana." Rural Poverty Portal.
- IFAD. (2010b). "Soaring food prices and the rural poor: feedback from the field." Available at: <http://www.ifad.org/operations/food/food.htm>.
- ILO. (2008). "Report IV Promotion of rural employment for poverty reduction." Geneva.
- IPCC (Intergovernmental Panel on Climate Change). (2007a). "Climate Change 2007: The Impacts, Adaptation and Vulnerability." Working Group II Fourth Assessment Report. Cambridge: Cambridge University Press.
- IPCC (Intergovernmental Panel on Climate Change). (2007b). "Climate Change 2007: The physical science basis: Summary for policy makers." Working Group I Fourth Assessment Report. Cambridge: Cambridge University Press.
- IPCC (Intergovernmental Panel on Climate Change). (2007c). IPCC Synthesis Report. Climate Change 2007. An Assessment of the Intergovernmental Panel on Climate Change. Valencia, Spain, 12-17 November 2007.
- Irz, X., Lin, L., Thirtle, C. and Wiggins, S. (2001). "Agricultural Growth and Poverty Alleviation." *Development Policy Review* 19 (4): 449–466.
- ISIS. (2010). ISIS Report. 24 March 2010. Available at: <http://www.isis.org.uk/full/chinasPollutionFull.php>
- ITC and FiBL. (2007). "Organic Farming and Climate Change." <https://www.fibl-shop.org/shop/pdf/mb-1500-climate-change.pdf> accessed on 18 October 2011.
- Shiva, Vandana and Kunwar, Jalees, 2006 *Farmers' Suicide in India*. New Delhi:
- Jayne, T. S., Yamano, T., Weber, M., Tschirley, D., Benfica, R., Chapoto, A. and Zulu, B. (2003). "Smallholder income and land distribution in Africa: implications for poverty reduction strategies." *Food Policy* 28: 253–275. Research Foundation for Science, Technology and Ecology.
- Burneya, J., Woltering, L., Burke, M., Naylora, R. and Pasternak, D. (2009). "Solar-powered drip irrigation enhances food security in the Sudano-Sahel." *Proceedings of the National Academy of Sciences of the United States of America*. Available at: <http://www.pnas.org/content/107/5/1848.full>. (last accessed 6 September 2010).
- Johansson, R.C., Tsur, Y., Roe, T.L., Doukkali, R. and Dinar, A. (2002). "Pricing irrigation water: a review of theory and practice." *Water Policy* 4 (2): 173-199.
- Johnson, K.A. and Johnson, D.E. (1995). "Methane emissions from cattle." *Journal of Animal Science* 73: 2483-2492.
- Kader, A and Rolle, R. (2004). "The role of post-harvest management in assuring the quality and safety of horticultural produce." FAO, Rome.
- Kar, G., Singh, R., Verma, H.N. (2004). "Alternative cropping strategies for assured and efficient crop production in upland rainfed rice areas of eastern India based on rainfall analysis." *Elsevier. Agricultural Water Management* 67: 47–62.
- Kasterine, A. and Vanzetti, D. (2010). "The Effectiveness, Efficiency and Equity of Market-based and Voluntary Measures to Mitigate Greenhouse Gas Emissions from the Agri-food Sector." in United Nations Conference in Trade and Development (UNCTAD). Trade and Environment Review 2010. Geneva, UNCTAD.
- Kay, M., Brabben, T. (2000). "Treadle Pumps for Irrigation in Africa." IPTRID. Knowledge synthesis report No. 1 – October 2000.
- Kerdchoechuen, O. (2005). "Methane emissions in four rice varieties as related to sugars and organic acids of roots and root exudates and biomass yield." *Agriculture Ecosystems & Environment* 108: 155-163.
- Khan, Z. R., Pickett, J. A., Wadhams, L. J., Hassanalia, A., Midegaa, C. A. O. (2006). "Combined control of Striga hermonthica and stem borers by maize–Desmodium spp. intercrops." *Elsevier. Crop Protection* 25: 989–995.
- Khan, Z. R., Midegaa, C. A. O., Amudavi, D. M., Njuguna, E. M., Wanyama, J. W., Pickett, J. A. (2008). "Economic performance of the 'push-pull' technology for stem borer and striga control in smallholder farming systems in western Kenya." *Crop Protection* 27: 1084-1097.
- Knudsen, M.T., Halberg, N., Olesen, J.E., Byrne, J., Iyer, V., and Toly, N. (2005). "Global trends in agriculture and food systems." in Halberg, N., Alroe, H.F., Knudsen, M.T. and Kristensen, E.S. (eds.) *Global development of organic agriculture: Challenges and promises*. CAB, UK.
- Kono, D. Y. (2009). "Protection for Whom? The Uses and Abuses of Sanitary and Phyto-sanitation Standards in the WTO." *Oxford-Princeton Conference on Global Trade Ethics and the Politics of WTO Reform*. 19 February 2009.
- Krishna, A., and Uphoff, N. (2002). "Mapping and Measuring Social Capital Through Assessment of Collective Action to Conserve and Develop Watersheds in Rajasthan, India." in Grootaert C. and van Bastelaer, T. (eds.) *The Role of Social Capital in Development: An Empirical Assessment*. Cambridge: Cambridge University Press.
- Kurien, V. (2004). "Chairman's Speech: 30th Annual General Body Meeting on 8th June 2004." Available at: <http://www.amul.com/kurien-annual04.html>.
- Küstermann B., Kainz M. and Hülsbergen K.J. (2008). "Modelling carbon cycles and estimation of greenhouse gas emissions from organic and conventional farming systems." *Renewable Agriculture and Food Systems* 23: 38-52.
- La Rovere, R., Kostandini, G., Abdoulaye, T., Dixon, J., Mwangi, W., Guo, Z., and Bänziger, M. (2010). "Potential impact of investments in drought tolerant maize in Africa." CIMMYT, Addis Ababa, Ethiopia.
- Lal, R. (2008). "Soil Science: Management and Conservation." in Pond, W.G., Nichols, B.L. and Brown, D.L. (eds.) *Food For All: Culture, Science and Technology of Food in the 21st Century*.
- Lal, R. (2009). "Ten tenets of sustainable soil management." *Journal of soil and water conservation*. Jan/Feb 2009—64 (1).
- LaSalle, T.J. and Hepperly, P. (2008). "Regenerative Organic Farming: A solution to global warming." Rodale Institute.
- Lele, U., and Agarwal, M. (1989). "Smallholder and large scale agriculture in Africa: Are there trade-offs between growth and equity?" MADIA Project. Washington, D.C., World Bank.

- Li X., Gong J., Gao Q., Li F. (2001). "Incorporation of ridge and furrow method of rainfall harvesting with mulching for crop production under semiarid conditions." *Agricultural Water Management* 50 (3): 173-183.
- Lipton, M. (1977). *Why poor people stay poor: urban bias in world development*. Cambridge: Harvard University Press.
- Lubilosa. (1999). "Biological Locust and Grasshopper Control Project." Green Muscle: User Handbook. Available at: <http://www.lubilosa.org/Userhb.pdf>
- Lyson, T.A. (2005). "Systems perspectives on food security." in *Proc. New Perspectives on Food Security*. 12-14 Nov. Glynwood Center, Cold Spring NY, 65-68.
- Lundqvist, J., de Fraiture, C., and Molden, D. "Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain." SIWI Policy Brief. SIWI, 2008.
- MacDonald D.M. (2004). "Agri Impact Assessment Study for Organic Cotton Farmers of Kutch & Surendranagar." Agrocet Industries Ltd. 14 September 2004.
- Machethe, C. L. (2004). "Agriculture and poverty in South Africa: Can agriculture reduce poverty?" Paper presented at the conference, Overcoming Underdevelopment, October 28–29, 2004, Pretoria, South Africa.
- Maisiri, N., Senzanje, A., Rockstrom J., Twomlow S.J. (2005). "On farm evaluation of the effect of low cost drip irrigation on water and crop productivity compared to conventional surface irrigation system." Elsevier. *Physics and Chemistry of the Earth* 30: 783–791.
- Major, J., Rondon, M., Molina, D., Riha, S. and Lehmann, J. (2010). "Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol." *Plant and Soil* 333 (1-2) August 2010: 117-128, Springer Netherlands.
- Marcoux, A. (1998). "Population Change - Natural Resources -Environment Linkages in East and Central Africa." Population programme Service (SDWP), FAO Women and Population Division.
- Markandya, A., Setboonsarng, S., Yu Hui, Q., Songkranok, R. and Stefan, A. (2010). "The Costs of Achieving the Millennium Development Goals through Adopting Organic Agriculture." February 9, 2010. ADBI Institute. Working Paper No: 193.
- Markheim, D. and Riedl, B. (2007). "Farm Subsidies, Free Trade, and the Doha Round." February 5, 2007. The Heritage Foundation. WEBMEMO #1337.
- McKinsey & Co. (2009). "Charting Our Water Future: Economic frameworks to inform decision-making." Available at: [http://www.mckinsey.com/App\\_Media/Reports/Water/Charting\\_Our\\_Water\\_Future\\_Exec\\_per\\_cent20Summary\\_001.pdf](http://www.mckinsey.com/App_Media/Reports/Water/Charting_Our_Water_Future_Exec_per_cent20Summary_001.pdf) page 19.
- McKnight Foundation CCRP. "Activity Report: Integrated Management of Pearl Millet Head Miner." The McKnight Foundation, March, 2008. Available at: [http://mcknight.ccrp.cornell.edu/programme\\_docs/project\\_documents/WAF\\_06-011\\_IPM/06-011\\_IPM\\_yr2\\_07-08\\_vweb\\_E.pdf](http://mcknight.ccrp.cornell.edu/programme_docs/project_documents/WAF_06-011_IPM/06-011_IPM_yr2_07-08_vweb_E.pdf).
- McKnight Foundation CCRP. (2010). "CCRP Quarterly Newsletter." The McKnight Foundation. Collaborative Crop Research programme. January-March 2010. Available at: [http://mcknight.ccrp.cornell.edu/programme\\_docs/QN/10/QN1\\_10\\_3jun10.pdf](http://mcknight.ccrp.cornell.edu/programme_docs/QN/10/QN1_10_3jun10.pdf)
- McNellis, P.E. (2009). "Foreign Investment in Developing Country Agriculture – The Emerging Role of Private Sector Finance." FAO Commodity and Trade Policy Research Working Paper No. 28, Rome.
- Mejía, D.J. (2003). "An overview of rice post-harvest technology." FAO Agriculture and Consumer Protection Department, Rome, Italy.
- Mendoza, T.C. (2002). "Comparative productivity, profitability and energy use: intensity and efficiency of organic, LEISA and conventional rice production in the Philippines." Proceedings of the 14th IFOAM Organic World Congress, "Cultivating Communities," Victoria Conference Centre, Canada, 21-24 August 2002.
- Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being*. Washington DC: Island Press.
- Millennium Project Task Force on Hunger. (2004). "Halving hunger by 2015: A framework for action." United Nations Millennium Project Interim Report. New York.
- Miller, N, Robertson, G.P., Grace, P., Gehl, R and Hoben, J. (2010). "Nitrogen fertiliser management for nitrous oxide mitigation in intensive corn production: an emissions reduction protocol for US Midwest agriculture." *Mitigation and Adaptation Strategies for Global Change*. Springerlink.com.
- Minami, K., and Neue, H.U. (1994). "Rice paddies as a methane source." *Climatic Change* 27(1):13-26. Available at: <http://www.springerlink.com/content/t74hvj70425426w4/>.
- MOI. (2005). Ministry of Information, Government of Malawi. Undated. "Agriculture." <http://www.sdn.org.mw/min-information/agri.htm>. Accessed June 2005.
- Moyo, R., Love, D., Mul, M., Mupangwa, W., Twomlow, S. (2006). "Impact and sustainability of low-head drip irrigation kits in the semi-arid Gwanda and Beitbridge Districts, Mzingwane Catchment, Limpopo Basin, Zimbabwe." *Phys Chem Earth A,B,C* 31:885–892.
- Mrabet. (2008). "No-Till Practices in Morocco. No-Till Farming Systems." Goddard (ed.) *World Association of Soil and Water Conservation*. Special Publication 3: 393.
- Mrabet, R. and El Brahli, A. (2001). "Soil and Crop Productivity under Contrasting Tillage Management Systems in Semiarid Morocco."
- De Groote, H., Muller, D., Gbongboui C., Langewald J. (2001). "Participatory development of a biological control strategy of the variegated grasshopper in the humid tropics in West Africa." Elsevier. *Crop Protection* 21: 265–275. available at <http://www.sciencedirect.com/science/article/pii/S0261219401000916>
- Nagayets, O. (2005). "Small Farms: Current Status and Key Trends." Information Brief Prepared for the Future of Small Farms, Research Workshop, Wye College, June 26-29, 2005. International Food Policy Research Institute (IFPRI), 2020 Vision Initiative and Overseas Development Institute (ODI).
- Narayanan, S., and Gulati, A. (2002). "Globalization and the smallholders: A review of issues, approaches, and implications." Markets and Structural Studies Division Discussion Paper No. 50. Washington, D.C.: International Food Policy Research Institute (IFPRI).
- Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A.G. and Kaltenborn, B.P. (eds). (2009). "The environmental food crisis – The environment's role in averting future food crises." A UNEP rapid response assessment. United Nations Environment programme, GRID-Arendal.
- Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., and Lee, D. (2009). "Climate Change Impact on Agriculture and Costs of Adaptation (IFPRI)"
- Nemes, N. (2009). "Comparative Analysis of Organic and Non-Organic Farming Systems: A Critical Assessment of Farm Profitability." Available at: <ftp://ftp.fao.org/docrep/fao/011/ak355e/ak355e00.pdf>.
- Neufeldt, H., Wilkes, A., Zomer, R.J., Xu, J., Nang'ole, E., Munster, C. and Place, F. (2009). "Trees on Farms: Tackling the triple challenges of mitigation, adaptation and food security." World Agroforestry (ICRAF) Centre Policy Brief 07. ICRAF. Nairobi, Kenya.
- New York Times. (2010). "China Report Shows More Pollution in Waterways." February 10, 2010. New York City.
- Niggli, U., Fließbach, A., Hepperly, P. and Scialabba, N. (2009). "Low greenhouse gas agriculture: Mitigation and adaptation potential of sustainable farming systems." Rev. 2. Rome, FAO, April 2009. <ftp://ftp.fao.org/docrep/fao/010/ai781e/ai781e00.pdf>.
- Nordpil, H. (2009). "Trends in food commodity prices, compared to trends in crude oil prices (indeces)." in UNEP/GRID- Arendal Maps and Graphics Library.
- Norgaard, R. B. (1988). "Economics of the cassava mealybug [ *Phaenacoccus Manihoti*; Hom.: *Pseudococcidae* ] biological control programme in Africa." *Biocontrol* 33 (1): 3-6.
- Norse D, Li, J. Jin, L., and Zhang, Z. (2001). *Environmental Costs of Rice Production in China*. Aileen Press, Bethesda.
- NRC. (2010). *Toward Sustainable Agricultural Systems in the Twenty-First Century*. The National Academies Press, Washington, DC, USA.
- Oberholtzer, L, Dmitri, C, Green, C. (2005). "Price Premiums Hold on as U.S. Organic Produce Market Expands." Electronic Outlook Report, Economic Research Service/USDA.
- OECD. (1997). "Helsinki Seminar on Environment Benefits from Agriculture." OECD/GD (97) 110, OECD Publishing, Paris.
- OECD. (2007). *Agricultural Policies in OECD Countries: Monitoring and Evaluation*. 213- 221, OECD, Paris.
- OECD. (2008). "Environmental Performance of Agriculture in OECD Countries Since 1990." OECD Publishing, Paris. Available at: <http://www.oecd.org/dataoecd/61/21/44254899.pdf>.
- OECD. (2008). "Household Behaviours and the Environment: Reviewing the Evidence." OECD Publishing, Paris.
- OECD. (2009). "Agricultural Policies in OECD Countries. Monitoring and evaluation." OECD Publishing, Paris.
- OECD. (2010). "Agricultural Policies in OECD Countries: At a Glance." OECD Publishing, Paris.
- Offenheiser, R. (2007). "Don't feed the greed: End subsidies to wealthy." Des Moines Register. November 8, 2007.
- Opschoor, J. B. (2007). "Environment and Poverty: Perspectives, Propositions and Policies." Institute of Social Studies, Working Paper No. 437, The Hague.



- Pagiola, S. (2008). "Payments for environmental services in Costa Rica." Elsevier. *Ecological Economics* 65 (4): 712-724. May.
- Panin, A. (1995). "Empirical Evidence of Mechanisation Effects on Smallholder Crop Production Systems in Botswana." Elsevier. *Agricultural Systems* 41: 199-210.
- Pauchard, A., Aguayo, M., Pena, E. and Urrutia, R. (2006). "Multiple effects of urbanization on the biodiversity of developing countries: The case of a fast-growing metropolitan area (Concepcion, Chile)." *Biological Conservation* 127: 272-28
- Perrings, C. (1999). "The Economics of Biodiversity Loss and Agricultural Development in Low Income Countries." University of York, UK.
- Pimentel, D., Berardi, G., Fast, S. (1983). "Energy Efficiency of Farming Systems: Organic and Conventional Agriculture." Elsevier. *Agriculture, Ecosystems & Environment* 9 (4) 358-372.
- Pimentel, D., Hepperly, P., Hanson, J., Douds, D., and Seidel, R. (2005). "Environmental, energetic, and economic comparisons of organic and conventional farming systems." *BioScience* 55: 573-582.
- Portmann, F., Siebert, S., and Döll, P. (2009). "MIRCA2000 – global monthly irrigated and rainfed crop areas around the year 2000: A new high-resolution data set for agricultural and hydrological modelling." *Global Biogeochemical Cycles*, in revision.
- Prebisch, R. (1962). "The Economic Development of Latin America and its Principal Problems," Economic Commission for Latin America, Santiago, Chile.
- Pretty, J. (2006). "Agroecological Approaches to Agricultural Development." Available at <http://www.rimisp.org/getdoc.php?docid=6440>
- Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, M., Van der Bilj, G. and Dobbs, T. (2001). "Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture." *Journal of Environmental Planning and Management* 44 (2): 263-283.
- Pretty, J., Ball, A., Lang, T., Morison, J. (2005). "Farm costs and food miles: An assessment of the full costs of the UK weekly food basket." *Food Policy*. Elsevier. Available at : [http://ernaehrungsdienkwerkstatt.de/fileadmin/user\\_upload/EDWText/Personen/Lang\\_Tim\\_Pretty\\_Food\\_Policy\\_Food\\_Miles\\_UK\\_2005\\_Final.pdf](http://ernaehrungsdienkwerkstatt.de/fileadmin/user_upload/EDWText/Personen/Lang_Tim_Pretty_Food_Policy_Food_Miles_UK_2005_Final.pdf).
- Pretty, J., Nobel, A.D., Bossio, D., Dixon, J., Hine, R.E., Penning De Vries, F.W.T., Morison, J.I.L. (2006). Resource conserving agriculture increases yields in developing countries. *Environmental Science and Technology* 40: 1114-1119.
- Rahman, S. (2009) "Whether crop diversification is a desired strategy for agricultural growth in Bangladesh?" Elsevier. *Food Policy* 34: 340-349.
- Postel, S. (2001). "Drip Irrigation for Small Farmers. A New Initiative to Alleviate Hunger and Poverty." *International Water Resources Association. Water International* 26 (1): 3-13, March 2001.
- Raj, D.A., Sridhar, K., Ambatipudi, A. and Brenchandran, S. (2005). "Case Study on Organic versus Conventional Cotton in Karimnagar, Andhra Pradesh, India." Second International Symposium on Biological Control of Arthropods Volume I. USDA Forest Service Publication FHTET-2005-08.
- Ravnborg, H., Damsgaard, M., and Raben, K. (2007). "Payments for Ecosystem Services: Issues and Pro-Poor Opportunities for Development Assistance." DIIS Report 2007: 6. Danish Institute for International Studies. Copenhagen.
- Reganold J.P. (1992). "Effects of Alternative and Conventional Farming Systems on Agricultural Sustainability." Washington State University, Department of Crop and Soil Sciences. Memo, Oregon State University.
- Rockstrom, J., Falkenmark, M., Karlberg, L., Hoff, H. Rost, S. and Gerten, D. (2009). "Future water availability for global food production: The potential of green water for increasing resilience to global change." *Water Resources Research* 45: 16.
- Rodulfo, V.A. Jr.; B.C. Geronimo. 2004. AMDP presents R&D prospects and SCU'S role in Philippine agriculture and fisheries modernization. *Philippine Agricultural Mechanisation Bulletin, Agricultural Mechanisation Development Program*. 10,2:3-6.
- Rosset, P. M., (1999). "The Multiple Functions and Benefits of Small Farm Agriculture in the Context of Global Trade Negotiations." Policy brief prepared for FAO/Netherlands Conference on Agriculture and Land, 12-17 September, 1999, Maastricht, Netherlands.
- Rost, S., Gerten, D., Bondeau, A., Lucht, W., Rohwer, J. and Schaphoff, S. (2008). "Agricultural green and blue water consumption and its influence on the global water system." *Water Resources Research* 44 (9).
- Rost, S., Hoff, D.G.H., Lucht, W., Falkenmark, M. and Rockström, J. (2009). "Global potential to increase crop production through water management in rainfed agriculture." *Environ. Res. Lett.* 4 044002 (9).
- Ruttan, V. (1977). "The Green Revolution: Seven Generalizations." *International Development Review* 19: 16-23.
- Sahota, A. (2009). The Global Market for Organic Food & Drink in Willer, H. and Kilcher, L. (eds.) *The World of Organic Agriculture: Statistics and Emerging Trends* 2009, IFOAM, Bonn; FiBL, Frick; ITC, Geneva.
- Scialabba, N. (2007). "Organic Agriculture and Food Security." Available at: <ftp://ftp.fao.org/docrep/fao/meeting/012/ah952e.pdf>.
- Scialabba, N. and Müller-Lindenlauf, M. (2010). "Organic agriculture and climate change." *Renewable Agriculture and Food Systems* 25(2): 158-169.
- Scialabba, N. et al. (2008). "Draft Project Proposal: Organic Research Centres Alliance." FAO. Rome, Italy.
- Seo, N. S. (2010). "Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture." *Food Policy* 35: 32-40.
- Shah, T. et al. (2005). "Social Impact of Technical Innovations. Study of Organic Cotton and Low Cost Drip Irrigation in the Agrarian Economy of West Nimar Region." *International Development Enterprises*.
- Sharma, N.K., Singh, P.N., Tyagi, P.C., Mohan S.C. (1998). "Effect of leucaena mulch on soil-water use and wheat yield." Elsevier. *Agricultural Water Management*. 35: 191-200.
- Sherwood, S., Cole, D., Crissman, C. and Paredes, M. (2005). Transforming Potato Systems in the Andes. in Pretty, J. (ed). *The Pesticide Detox*. Earthscan, London.
- Shiva, V. (1989). "The violence of the green revolution: Ecological degradation and political conflict in Punjab." Dehra Dun: Research Foundation for Science and Ecology.
- Singer, H. W. (1950). "The Distribution of Gains between Investing and Borrowing Countries." *American Economic Review* 40: 306-317.
- Singh, H. (2005). "Services, Institutions, Intermediation: New Directions." Prepared for the Future of Small Farms, Research Workshop, Wye College, June 26-29, 2005. International Food Policy Research Institute (IFPRI), 2020 Vision Initiative and Overseas Development Institute (ODI).
- Singh, H. (2005). "The Future of Small Farms in Services, Institutions, Intermediation: New Directions." *Proceedings of a Research Workshop Wye, UK, June 26-29, 2005*.
- Sivanappan, RK. (1994). "Prospects of micro-irrigation in India." *Irrigation and Drainage Systems* 8 (1): 49-58.
- Smith, D. (2008). "GPS sparks big changes." Available at: <http://www.allbusiness.com/agriculture-forestry/agriculture-crop-production-oilseed/10597000-1.html>.
- Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O. (2007). "Agriculture." in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Smith, V. H. and Schindler, D.W. (2009). "Eutrophication Science: Where do we go from here?" Elsevier Ltd. Available at: <http://www.jlakes.org/web/EutrophicationScience-TIEE2009.pdf>. (last accessed 21 January 2011).
- Smith, V. H. and Schindler, D. W. (2009). "Eutrophication Science: where do we go from here?" *Trends Ecol.* 24: 201-207.
- Spencer, D. (2002). "The future of agriculture in Sub-Saharan Africa and South Asia: W(h)ither the small farm?" in *Sustainable Food Security for All by 2020. Proceedings of an International Conference*, September 4-6, 2001, Bonn, Germany. Washington, D.C.: International Food Policy Research Institute.
- SRI Homepage. (2010). Available at: <http://ciifad.cornell.edu/sri/sripapers.html>.
- Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C. (2006). "Livestock's Long Shadow: environmental issues and options." FAO, Rome.
- Steen, I., Steen, P., 1998. Phosphorus availability in the 21st century: management of a nonrenewable resource. *Phosphorus Potassium* 217, 25-31.
- Stern, N. (2007). *The Economics of Climate Change : The Stern Review*. Cambridge Univ. Press. UK.
- Sur, S., Bothra, A.K. and Sen, S. (2010). "Symbiotic Nitrogen Fixation – A Bioinformatics Perspective." *Biotechnology* 9 (3): 257-273.
- Swinton, S.M., and Lowenberg-DeBoer, J. (2001). "Global adoption of precision agriculture technologies: Who, when and why." in *Third European conference on precision agriculture*. 557-562. Grenier, G. and Blackmore, S. (ed). (2005) "Agro Montpellier" ENSAM, Montpellier.
- Tegtmeier, E. M. and Duffy, M. (2004). "External Costs of Agricultural Production in the United States." *International Journal Of Agricultural Sustainability*. 2 (1).

- Tejada, M., Gonzalez, J.L., Garcia-Martinez, A.M., Parrado, J. 2008. "Effects of different green manures on soil biological properties and maize yield." *Bioresource Technology* 99: 1758–1767.
- The Economist. (2010). "Agricultural Subsidies: Ploughing on. The rich world's farmers are still reaping handsome subsidies." 1 July, 2010.
- Thepent, V. and Chamsing, A. (2009). "Agricultural Mechanisation Development in Thailand." The Fifth Session of the Technical Committee of APCAE, 14-16 October 2009, Los Banos, Philippines.
- Tillman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002). "Agricultural sustainability and intensive production practices." *Nature* 418: 671–677.
- Tomich, T.P., Kilby, P. and Johnston, B.F. (1995). "Transforming Agrarian Economies: Opportunities Seized, Opportunities Missed." Ithaca, N.Y.: Cornell University Press.
- UN. (2007). "World Urbanization Prospects 2007." UN, New York. Available online at: 2007WUP\_ExecSum\_web.pdf [last accessed on the 20 January 2009]. [http://www.un.org/esa/population/publications/wup2007/2007WUP\\_Highlights\\_web.pdf](http://www.un.org/esa/population/publications/wup2007/2007WUP_Highlights_web.pdf).
- UNESCO ECA. (2007). "Africa Review report on Agricultural and Rural Development." Fifth Meeting of the Africa Committee on Sustainable Development (ACSD-5)/ Regional Implementation Meeting (RIM) for CSD-16 Addis Ababa, 22-25 October 2007.
- UN ESA. (2004). "World Population to 2300." UN Department of Economic and Social Affairs, Population Division.
- UN WomenWatch. (2009). "Women, Gender Equality and Climate Change." Available at: [http://www.un.org/womenwatch/feature/climate\\_change/downloads/Women\\_and\\_Climate\\_Change\\_Factsheet.pdf](http://www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf).
- UN-DESA. (2008). "Don't Forget the Food Crisis: New Policy Directions Needed." Policy Brief 8, October, 2008. Available at: <http://www.un.org/esa/policy/policybriefs/policybrief8.pdf>.
- UNEP. (2009). "Agriculture: A Catalyst for Transitioning to a Green Economy: A UNEP Brief." Available at: [www.unep.org/greeneconomy](http://www.unep.org/greeneconomy).
- Upadhyay, B. (2004). "Gender aspects of smallholder irrigation technology: Insights from Nepal." *Journal of Applied Irrigation Science* 39(2):315-327.
- Velarde, S. and Tomich, T.P. (2006). "Sustainable Tree Crops programme (STCP)."
- Wade, R.H. (1996). "Japan, the World Bank, and the art of paradigm maintenance: The East Asian miracle in political perspective." *New Left Review* 217:3-36.
- Wade, R. H. (2004). *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*. Princeton University Press.
- Wall, E., Bell, M.J. and Simm, G. (2008). "Developing Breeding Schemes to Assist Mitigation." *Livestock and Global Climate Change*. British Society of Animal Science. Penicuik, U.K.
- Wandji Dieu ne dort, N., Lapbim Nkeh, J. and James, J. G. (2006). "Socio-economic impact of a cocoa integrated crop and pest management diffusion knowledge through a farmer field school approach in southern Cameroon." Sustainable Tree Crop programme, International Institute of Tropical Agriculture (STCP?IITA\_HFC).
- International Association of Agricultural Economists Conference. Australia. 2006. Available at: <http://ageconsearch.umn.edu/bitstream/25418/1/pp060058.pdf>.
- Wang, Y., Lin, M., Tian, Z., Elmerich, C. and Newton, W. (eds.). (2005). "Biological Nitrogen Fixation, Sustainable Agriculture and the Environment", Proceedings of the 14th International Nitrogen Fixation Congress. Springer. Dordrecht, Netherlands.
- Wani, S.P., Pathak, P., Sachan, R.C. and Sudi, R. (2009). "Opportunities for water harvesting and supplemental irrigation for improving related Agriculture in Semi-arid Areas." in *Rainfed Agriculture: Unlocking the Potential*. Reading, UK. 198.
- Weinberger, K., Lumpkin, T. (2007). "Diversification into Horticulture and Poverty Reduction: A Research Agenda." *World Development* 35 (8): 1464–1480.
- Wise, A.T., (2011). "Still Waiting for the Farm Boom: Family Farmers Worse Off Despite High Prices." *Global Development and Environment Institute*, Tufts University. Available at: <http://www.ase.tufts.edu/gdae/Pubs/rp/PB11-1FarmIncomeMarch2011.pdf>.
- Wiggins, S. (2009). "Can the smallholder model deliver poverty reduction and food security for a rapidly growing population in Africa?" FAC Working Paper No. 08, Available at: [http://www.future-agricultures.org/Documents/Smallholder\\_S-Wiggins\\_Jul-09.pdf](http://www.future-agricultures.org/Documents/Smallholder_S-Wiggins_Jul-09.pdf) (last accessed July 2010).
- World Bank. (2008a). *Global Monitoring Report 2008: MDGs and the Environment: Agenda for Inclusive and Sustainable Development*. World Bank, Washington D.C.
- World Bank. (2008b). *World Development Report 2008, Agriculture for Development*. World Bank, Washington D.C.
- World Bank. (2010). *World Development Report 2010, Development and Climate Change*. World Bank, Washington D.C.
- World Bank. (2010). *Agricultural Growth and Poverty Reduction: Additional Evidence*. World Bank, Washington D.C.
- World Bank. (2010). "Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits?" World Bank, Washington D.C.
- World Bank, IFAD and FAO. (2009). *Gender in Agriculture Sourcebook*. Washington, DC: World Bank. Available at: <http://siteresources.worldbank.org/INTGENAGRLIVSOUBOOK/Resources/CompleteBook.pdf>.
- WWAP. (2003). *Water for People, Water for Life - UN World Water Development Report*. (WWDR). UNESCO, Paris.
- Zarea, A., Koocheki A., and Nassiri, M. (2000). "Energy Efficiency of Conventional and Ecological Cropping Systems in Different Rotations with Wheat." in Alföldi, T., Lockeretz, W., and Niggli, U. (eds.) (2000). *IFOAM 2000—The world grows organic*, Proceedings at the 13th IFOAM Scientific Conference, 28 August 2000.
- Zhao, L., Wu, L., Li, Y., Lu, X., Zhu, D., and Uphoff, N. (2009). "Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates." *Experimental Agriculture*, 45(3): 275–286.
- Ziesemer, J. (2007). "Energy use in organic food systems." *Natural Resources Management and Environmental Department*. FAO, Rome. August 2007.







# Fisheries

Investing in natural capital



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## List of acronyms

BAU	Business-as-usual
CBD	Convention on Biological Diversity
CTQ	Community Transferable Quota
EC	European Commission
EEZ	Exclusive Economic Zone
EFR	Environmental Fiscal Reform
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GFF	Global Fisheries Fund
ITQ	Individual Transferable Quota
IUU	Illegal, unreported and unregulated
MCS	Monitoring, Control and Surveillance
MEY	Maximum economic yield
MPA	Marine Protected Area
MRA	Marine recreational activity
MSY	Maximum sustainable yield
NRC	National Research Council
OECD	Organisation for Economic Co-operation and Development
PPP	Public-private partnership
RFMO	Regional Fisheries Management Organization
SCFO	Standing Committee on Fisheries and Oceans
SSF	Small-scale fisheries
T21	Threshold 21 model
TAC	Total allowable catch
TURFs	Territorial rights in fisheries
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
WTO	World Trade Organization

# Key messages

**1. The world's marine fisheries are socially and economically vital, providing animal protein and supporting food security to over 1 billion people.**

An estimated half of these people live in close proximity to coral reefs, relying on them not just for fish, but also for livelihoods – from small-scale fishing to tourism. Currently, the world's fisheries deliver annual profits of about US\$ 8 billion to fishing enterprises worldwide and support 170 million jobs, directly and indirectly, providing some US\$ 35 billion in household income a year. When the total direct, indirect and induced economic effects arising from marine fish populations in the world economy are accounted for, the contribution of the sector to global economic output amounts to some US\$ 235 billion per year.

**2. Global marine fisheries are currently underperforming in both economic and social terms.**

Society at large receives negative US\$ 26 billion a year from fishing, when the total cost of fishing (US\$ 90 billion) and non-fuel subsidies (US\$ 21 billion) are deducted from the total revenues of US\$ 85 billion that fishing generates. This negative US\$ 26 billion corresponds roughly to the estimated US\$ 27 billion in subsidies a year (including US\$ 21 billion in non-fuel subsidies), the latter of which contributes directly to over-fishing and depletion of fish stocks.

**3. Investing to achieve sustainable levels of fishing will secure a vital stream of income in the long run.**

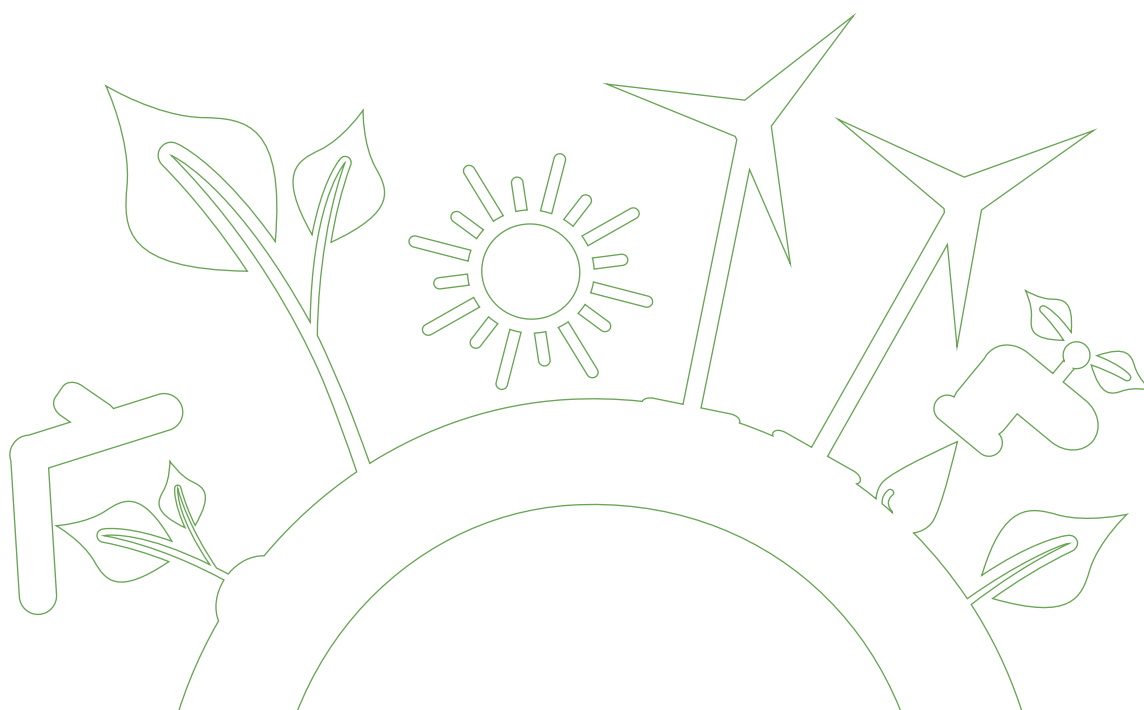
Greening the sector requires reorienting public spending to strengthen fisheries management, and finance a reduction of excess capacity through de-commissioning vessels and equitably relocating employment in the short-term. Thus, measures to green the sector will contribute to replenishing overfished and depleted fish stocks. A single investment of US\$ 100-300 billion would reduce excessive capacity. In addition, it should result in an increase in fisheries catch from the current 80 million tonnes a year to 90 million tonnes in 2050, despite a drop in the next decade as fish stocks recover. The present value of benefits from greening the fishing sector is about 3 to 5 times the necessary additional costs. In a scenario of larger and



deeper spending of 0.1 to 0.16 per cent of GDP over the period 2010-2050, to reduce the vessel fleet, relocate employment and better manage stocks to increase catch in the medium and longer term, 27 to 59 per cent higher employment would be achieved, relative to the baseline by 2050. In this same scenario, around 70 per cent of the amount of fish resources in 1970 would be available by 2050 (between 50 million tonnes and 90 million tonnes per year), against a mere 30 per cent under a business-as-usual (BAU) scenario, where no additional stock management activities are assumed.

**4. Greening the fisheries sector would increase resource rent from global fisheries dramatically.** Results outlined in this chapter indicate that greening world fisheries could increase resource rents from negative US\$ 26 to positive US\$ 45 billion a year. In such a scenario, the total value added to the global economy from fishing is estimated at US\$ 67 billion a year. Even without accounting for the potential boost to recreational fisheries, multiplier and non-market values that are likely to be realised, the potential benefits of greening fisheries are at least four times the cost of required investment.

**5. A number of management tools and funding sources are available that can be used to move the world's fisheries sector from its current underperforming state to a green sector that delivers higher benefits.** Aside from removing environmentally harmful subsidies, a range of additional policy and regulatory measures can be adopted to restore the global potential of fisheries. Economic studies generally demonstrate that marine protected areas (MPAs), for example, can be beneficial under specific conditions as an investment in the reproductive capacity of fish stocks. Currently, MPAs comprise less than 1 per cent of the world's oceans. To fully utilise MPAs as a management tool, the 2002 World Summit on Sustainable Development set a target to establish a global network of MPAs covering 10-30 per cent of marine habitats by 2012. This deadline was extended to 2020 and the target lowered to 10 per cent at the CBD meeting in Nagoya, Japan in late 2010.



# 1 Introduction

## 1.1 Objectives and organisation of the chapter

The aim of this chapter is to demonstrate the current economic and social value of marine fisheries to the world and, more importantly, estimate the sector's full potential economic and social value if it were managed within the framework of a green economy. Setting the conditions that will be needed to shift marine fisheries to a more sustainable future is crucial, and the chapter explores how best to provide appropriate incentives, engender reforms and channel investment.

Specific objectives of the chapter are to:

- Gain a better understanding of the contribution and impact of marine fisheries to the global economy;
- Demonstrate the potential benefits of sustainably managing the world's fisheries to national and regional economies and to the global economy;
- Estimate the financial requirements for investing in fisheries conservation and sustainable use, comparing these to long-term economic, social and environmental gains; and
- Demonstrate that the long-term economic benefit of investing in rebuilding fisheries and improving their management outweighs the short-term costs.

The fisheries sector consists of three main parts: 1) marine capture; 2) inland capture; and 3) aquaculture. This contribution focuses on marine fisheries. Inland fisheries and aquaculture are discussed with respect to how they relate to marine-capture fisheries.

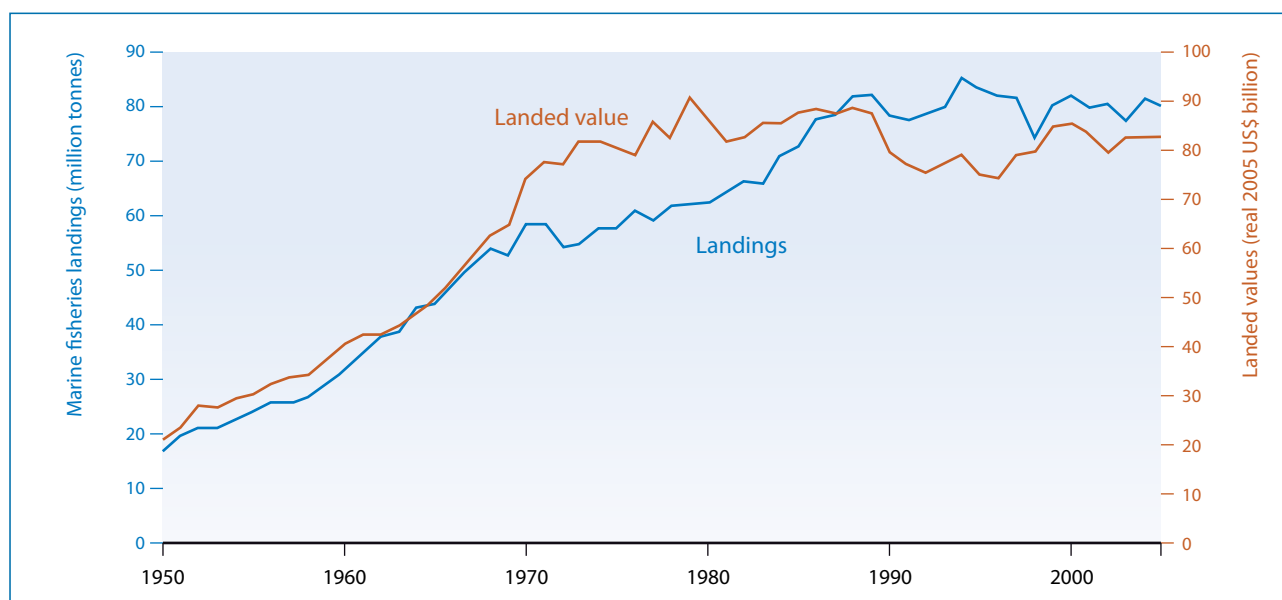
The prospects for greening the world's marine fisheries are explored in this chapter. For fisheries, we interpret greening as: 1) recognizing that there are limits to what the oceans can provide; 2) acknowledging that rebuilding overfished and depleted fish populations is needed to maximise sustainable yield, through time, for the benefits of both current and future generations; 3) essential habitats for living marine animals need to be protected and preserved; and 4) fishing and other activities involving ocean fish populations are organised to minimise the release of greenhouse gases. We will emphasise point 2) in this report because there is general consensus that many of the world's capture fisheries are in crisis. Overexploitation,

pollution and rising temperatures threaten 63 per cent of the world's assessed fisheries stocks (Worm et al. 2009). However, several fisheries are reasonably well managed, which provide important lessons for our effort to shift the world's fisheries to a greener, more sustainable state.

Fish are one of the planet's most important renewable resources. Beyond their crucial role in marine and freshwater ecosystems, fish make a vital contribution to the survival and health of a significant portion of the world's population. Marine fisheries provide nutrition and livelihoods for millions of people in coastal communities, notably in South and South-East Asia, West Africa and Pacific Island states. As coastal populations continue to grow, the future benefits these resources can provide will depend on how well fisheries can be greened. We present an estimate of the current economic and social contributions from marine fish populations, and what they could amount to if the sector were greened. We also state the institutional conditions under which we can increase economic benefits while conserving these vital renewable ocean resources for the benefit of all.

Often, fisheries managers and policy-makers are under pressure to sacrifice the long-term health of marine fish resources in favour of perceived short-term economic benefits to the fishing industry and consumers. Gaining a better understanding of the potential contribution and impact of marine fish populations on the global economy will provide broader, longer-term, economic and social perspectives. Our goal is to show policy-makers that a green economic approach will chart the course to balancing increasing demands for fish with the limits to the capacity of oceanic and coastal fish stocks.

We present the current status of global fisheries in the next section with an emphasis on catch and catch values, employment and the contribution of marine and coastal recreation and tourism to the global economy. The challenges and opportunities associated with establishing green fisheries are discussed in Section 2. In Section 3, we focus on scenarios of fleet adjustment, and estimate the potential costs and benefits of rebuilding depleted fisheries. Section 4 explores some of the conditions and the institutions, both national and international, that will be required to bring about the greening of the world's fisheries. We devote Section 4.6 to the discussion of how to finance the transformation.



**Figure 1: Landings and landed value of global marine fisheries (1950-2005)**

Source: Based on Sumaila et al. (2007) and Watson et al. (2004)

## 1.2 Review of the status of global fisheries

The total catch from the world's marine capture fisheries<sup>1</sup> rose from 16.7 million tonnes in 1950 to 80.2 million tonnes in 2005. It reached a peak of 85.3 million tonnes in 1994 (Figure 1). For these 56 years, fish comprised about 86 per cent of the total landings, with crustaceans and molluscs accounting for 6 per cent, and 8 per cent respectively. The

total landed value (gross output value) of the world's marine capture fisheries was about US\$ 20 billion<sup>2</sup> in 1950. It increased steadily to about US\$ 100 billion in the late 1970s and remained at that level throughout the 1980s despite further increases in the total landings (FAO 2005; *Sea Around Us project*<sup>3</sup>; Sumaila et al. 2007; Watson et al. 2004).

2. All values are expressed in real 2005 US\$.

3. The *Sea Around Us* project, compiles a global fishery database based on FAO reports and many other data sources (Pauly 2007).

1. Excluding catch of marine mammals, reptiles, aquatic plants and algae.

### Box 1: Inland capture fisheries

Around the world, inland fisheries are an increasingly important factor for communities because of increasing consumption per capita and the inability of people to purchase other animal protein. In a recent *State of World Fisheries and Aquaculture* report, the UN Food and Agriculture Organization (FAO) estimates that inland fisheries generate 10 million tonnes in landings annually; this amounts to about 11 per cent of the total capture fisheries catch from both inland and marine sources (FAO 2009). South-East Asia's Mekong river system, which is home to more than 850 freshwater species including many economically important species of catfish and carp, is estimated to provide fisheries landings worth around US\$ 2 billion per year (Barlow 2008).

Lake Victoria in Africa's rift valley, the world's second-largest inland body of water, contains more

than 500 species of freshwater fish. Of these, Nile perch, tilapia and dagaa (a small sardine-like fish) are highly sought-after in commercial fisheries, with landings totalling more than 1 million tonnes per year and a landed-value of US\$ 350-400 million.<sup>4</sup> Unfortunately, estimates of inland capture landings and value must be viewed with a high degree of uncertainty, owing to a lack of consistent data collection in many countries.

For this reason, it is inherently difficult to include inland capture fisheries into global analysis of the fisheries sector. Nevertheless, many concepts from marine capture fisheries such as over-capacity and subsidisation are also applicable to inland fisheries.

4. Lake Victoria Fisheries Organization, Available at: <http://www.lvfo.org>

	Fishing Effort (million kW sea days)	Landings (million t) <sup>2</sup>	Landed value (2005 real US\$ billion)*
Russia	432	3	3.2
Japan	398	4	14.4
China	301	10	15.2
Taiwan	261	1	2.7
USA	225	4.8	4.2
Spain	147	0.9	1.3
Korea Republic	138	1.6	2.5
France	116	0.6	1
New Zealand	115	0.5	1.1
Italy	100	0.3	1

\* Total world landings were 80.2 million tonnes in 2005 with an estimated landed value of US\$ 94.8 billion.

**Table 1: Top ten marine fishing countries/entities by fleet capacity**

Source: Based on Sumaila et al. (2007), Watson et al. (2004) and Anticamara et al. (2010)

Since the late 1980s, landed values have declined, falling from around US\$ 100 billion to almost US\$ 90 billion in 2005 (Figure 1). The decline in the landed value through the early 1990s corresponds to the increase in landings of low-valued Peruvian anchoveta, which accounted for over 10 per cent of the total landings from 1993 to 1996 and reached 15 per cent in 1994 (Sumaila et al. 2007; Watson et al. 2004). The top ten countries/political entities by fleet capacity are reported in Table 1. The fleet capacity indices in Table 1 are relative to

the estimated capacity for Spain. Hence, Russia, sitting at the top of the table is estimated to have nearly three times the fishing capacity of Spain, while the US has 30 per cent more capacity. The top ten countries/political entities captured about a third of the global annual catch in 2005, with an estimated landed value of nearly 50 per cent of the global total. This implies that for the world to succeed in greening the fishing sector, the ten countries listed in Table 1 will have to be committed participants.

## 2 Challenges and opportunities in global fisheries

### 2.1 Challenges

#### Overfishing

In the early 1970s, fishing activity expanded, particularly in Asia, but also along the Chilean coast, where large quantities of anchoveta were taken, and along the coast of West Africa. By 2005, there was a contraction of high-value areas. However, there has been a considerable expansion of fisheries into the high seas, most notably in the North Atlantic and South Pacific. The maps in Figure 2 represent the annual landed values of the world's fisheries by decade from 1950 to 2005. In all six maps, concentrations in catch value can be seen in the productive coastal areas of Europe and Asia, as well as areas characterised by the significant upwelling of nutrient-rich water, such as the western coast of South America.

The spatial expansion of marine fisheries around the world partially masks the extent to which fisheries have been overfished (Swartz et al. 2010). In fact, the FAO believes that only about 25 per cent of the commercial stocks, mostly of low-priced species, are currently underexploited, 52 per cent are fully exploited with no further room for expansion, 19 per cent overexploited and 8 per cent depleted (FAO 2009). Studies have estimated that by 2003, some 29 per cent of the world's marine fisheries had collapsed in the sense that their current catch level was less than one-tenth of the maximum registered catch (Worm 2006). In the business-as-usual (BAU) scenario, as presented in the Modelling chapter, half the amount of fish available in 1970 would be available by 2015 and only one-third in 2050. Practices such as "fishing down marine food web", where species are targeted and fished to depletion from largest to smallest species, can bring about significant changes to the balance of species in the ecosystem (Pauly et al. 1998; Hannesson 2002).

The collapse of cod stocks off Newfoundland in 1992 devastated local communities and the economic aftershock is still being felt far beyond Canada's Atlantic coast. Some 40,000 people lost their jobs, fishing towns shrank in population by up to 20 per cent and the Canadian taxpayer spent billions of dollars dealing with the aftermath of the collapse (Mason 2002; Rice et al. 2003; SCFO 2005). Despite a moratorium on fishing cod since 1992, the stock has failed to rebuild to pre-crash levels (Charles et al. 2009).

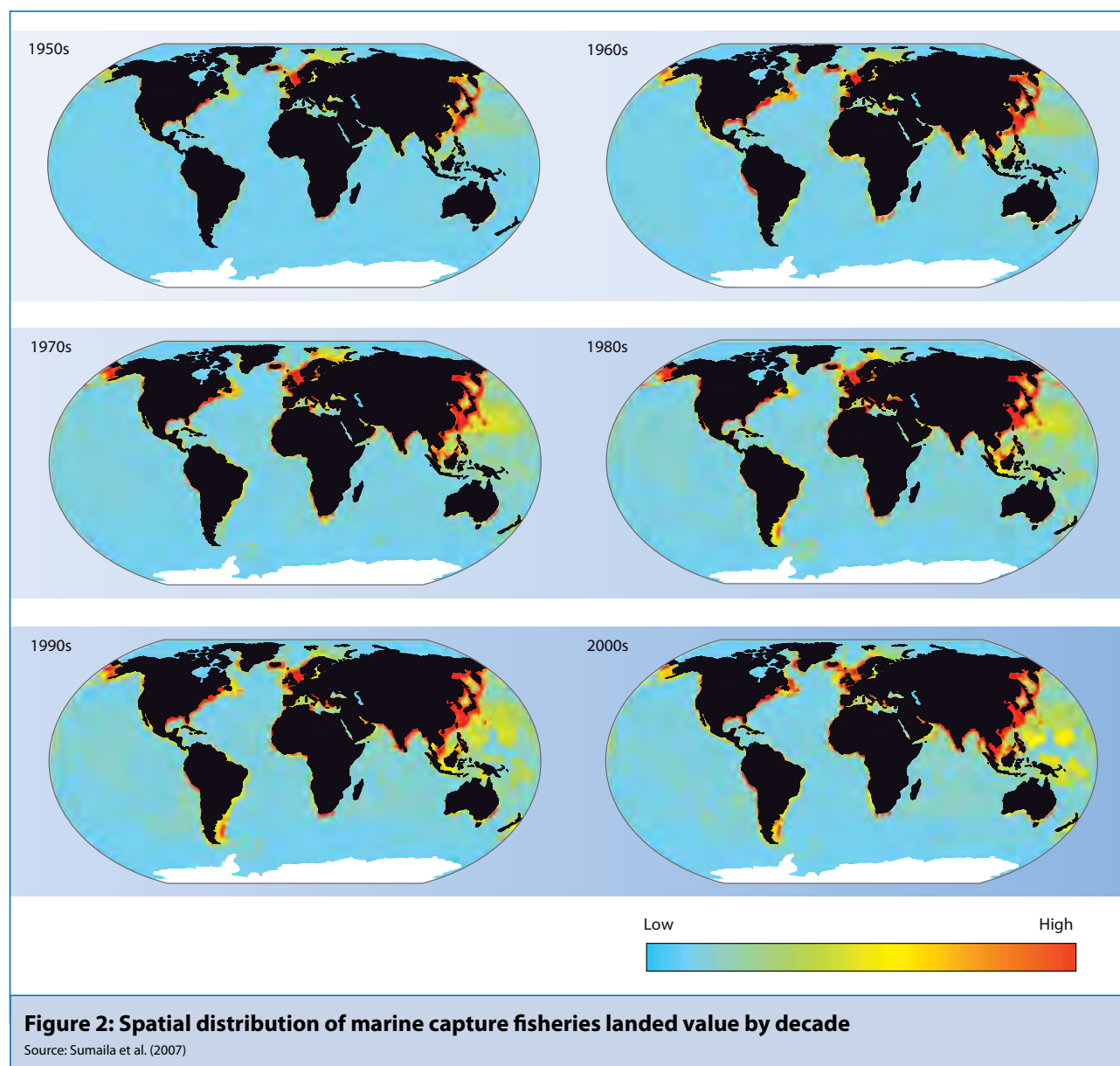
Halting the fishing of vulnerable, overexploited species and establishing conditions so that stocks can recover are clearly major challenges that have to be achieved despite demand for fish. Explaining the scale of the issue is a challenge in developed and developing countries and catalysing policy reform is particularly difficult when there are legitimate fears that fish stocks might not recover even if complete bans on fishing in certain areas are enforced.

#### Subsidies

Fisheries subsidies are defined here as financial transfers, direct or indirect, from public entities to the fishing sector, which help the sector make more profit than it would otherwise (Milazzo 1998). Such transfers are often designed to either reduce the costs of fishing or increase revenues. In addition, they may also include indirect payments that benefit fishers, such as management and decommissioning programmes. Subsidies have gained worldwide attention because of their complex role in trade, ecological sustainability and socio-economic development (UNEP 2003; UNEP 2004; 2005; 2011).

It is widely acknowledged that global fisheries are over-capitalised, resulting in the depletion of fishery resources (Hatcher and Robinson 1999; Munro and Sumaila 2002). There are many reasons for the decline of fishery resources, but the contribution of subsidies to the expansion of capacity and overfishing cannot be over-emphasised (Milazzo 1998; WWF 2001). Global fisheries subsidies have been estimated at US\$ 27bn in 2003 (Sumaila et al. 2010). Regional estimates of about US\$ 12 billion have been provided for the Asia Pacific Rim (APEC 2000) and around US\$ 2.5 billion for the North Atlantic (Munro and Sumaila 2002).

Khan et al. (2006), classified subsidies into three categories labelled "good", "bad" and "ugly" according to their potential impact on the sustainability of the fishery resource. Good subsidies enhance the conservation of fish stocks through time (for example subsidies that fund effective fisheries management or marine protected areas). Bad subsidies are those that lead to overcapacity and overexploitation, such as fuel subsidies. Ugly subsidies can lead to either the conservation or overfishing of a given fish stock, such as buyback subsidies, which, if not properly designed, can lead to overcapacity (Clark et al. 2005).



The challenge is that once subsidies are provided they become entitlements, which makes them politically difficult to remove. Only concerted action by groups such as civil society organisations, international bodies and governments can bring about the removal of such subsidies. Also, one strategy that may help is to keep the amount of the subsidy within the fishing community but divert it from increasing overfishing to enhancing fish stocks. This can be achieved by converting bad subsidies into good ones, using bad subsidies to fund transition programmes to help fishers move to greener fishing approaches and other non-fishing activities to support their livelihoods.

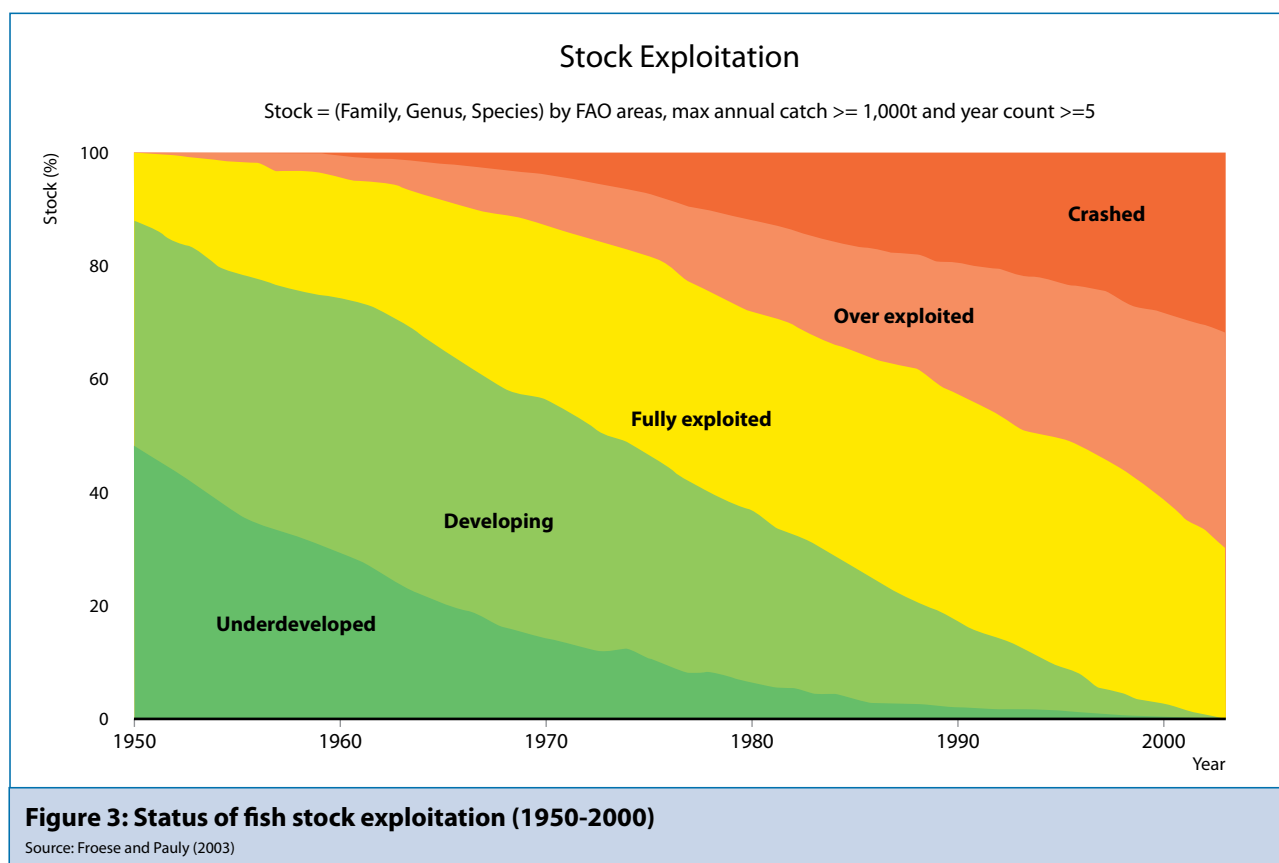
### Small-scale fisheries

A key issue along any coast is that of the local small-scale fisheries (SSF), which often provide crucial food supplies, sustain regional economies and support the social and cultural values of the areas, but are threatened as pressures on coastal areas are growing. This poses what is undoubtedly a major socioeconomic challenge: how to balance current and future needs for fishery resources.

There are many definitions of small-scale but such fisheries are usually characterised by being relatively more labour-intensive and less capital-intensive, more tied to coastal communities and less mobile (Berkes et al. 2001; Charles 2001; Pauly 2006). Other terms sometimes used for these fisheries are artisanal (versus industrial), coastal or inshore.

While all fisheries face a range of challenges, for SSF many of the challenges are related to factors that are external to the fisheries *per se* but within the broader social-ecological system (McConney and Charles 2009). These include (1) negative impacts of industrial and foreign fleets, depleting coastal fish stocks, and in some cases destroying coastal fishing gear; (2) degradation of coastal environments and fish habitat, through land-based sources of marine pollution, development of urban areas, shrimp farming, tourism, mangrove extraction, etc., leading in each case to reduced fish stocks; (3) infrastructure challenges, such as limitations on transportation of fish products; and (4) global forces,





such as climate change and globalisation of fish markets, that can negatively affect the small-scale fisheries. In addition, over-fishing by SSF contributes to the problem in many cases. It is important to recognise that given the above external factors, solving the sustainability challenge for SSF requires coordinated, multi-faceted approaches that aim to improve fishery governance at a local level – so that coastal fishers are involved in developing, and thereby support fishery management measures – while simultaneously dealing with other fleets, and market and infrastructure issues to improve coastal environmental quality. An integrated approach is thus unavoidable.

Certain realities of SSF pose challenges but also provide opportunities:

■ Small-scale fisheries are relatively immobile and are closely tied to coastal communities. This implies that fishers may have few other livelihood opportunities and may have high dependence on the fishery resources. Such a situation can lead, at times, to over-fishing, but alternatively this can lead to stewardship over local fish stocks that are so important to the community. The key is to discourage the former and encourage the latter;

■ Small-scale fisheries benefit a very large number of people, and the recognition of this reality can make it difficult to reduce fishing effort when that is needed to ensure ecological sustainability. On the other hand, the labour-intensive nature of SSF also means that there is

less sunk capital – the capitalisation, and consequent debt payments, that seriously limit flexibility in industrial fisheries. Furthermore, small-scale fisher organisations can be drawn upon to play a constructive role in policy actions (Salas et al. 2007). It should be noted that the high levels of employment provided by SSF may well help to limit resource exploitation elsewhere in coastal areas. Again, an integrated systems analysis is required to properly recognise these interactions (Garcia and Charles 2007); and

■ Many small-scale fishing fleets are capable of depleting fish stocks and damaging aquatic ecosystems. There is thus a direct challenge both to the aquatic ecosystem and to economic sustainability. Moving to sustainable paths for the future implies improving the ecological sustainability of SSF. At the same time, SSF also provide an opportunity for environmental improvement, one that arises in comparing such fisheries with the major alternative, namely, fuel-intensive industrial fishing. Industrial fisheries are not only a threat to coastal small-boat fishers, as discussed above, but also contribute most

Type	World total (US\$ billion)
Good	7.9
Bad	16.2
Ugly	3.0
Total	27.1

**Table 2: Global fisheries subsidies**

Source: Sumaila et al. (2010)

significantly to the negative climate externalities imposed by fisheries (due to their fuel-intensive nature) and to excessive high-seas resource exploitation. Furthermore, they receive the bulk of fishery subsidies globally. Given the above, there is an opportunity to move to a more sustainable model for the future, through an approach as in Indonesia, in which coastal waters are reserved for SSF. In this approach, industrial fleets are used only to catch fish that are beyond the reach of the SSF, and then only if such fishing is profitable from a full-cost accounting perspective (i.e., including the negative externalities resulting from such activity).

### Greening aquaculture

According to FAO (2009), aquaculture supplies around 50 per cent of the world's seafood. However, a close look at the total world fish supply from aquaculture reveals two disturbing issues. Firstly, as the supply from aquaculture increases, the supply from capture fisheries decreases. In fact, there is an almost one to one change in opposite directions. This means that aquaculture is not adding to the world supply of fish; rather it is displacing wild fish supplies. Secondly, aquatic plants account for about 23 per cent of the reported increase in aquaculture supply. Even in Japan, where aquatic plants are commonly eaten, these plants do not replace the need for real fish; they are used mainly as supplements. Deducting the 23 per cent of aquaculture supply that is aquatic plants reveals that the total supply of real fish from both the wild and farms is declining.

There are many challenges to aquaculture as a source of animal protein in a green economy. Many farms still rely

on wild caught fish as feedmeal and oil. The potential for disease from fish farms impacting wild populations is also an issue. Finally, there is the potential that fish farms can pollute the environment because of the waste they produce. Given these challenges, it is clear that current aquaculture practices need to be modified to make fish farming green.

The sector needs to 1) be organised to ensure minimal environmental degradation (Naylor et al. 1998); 2) stop the farming of carnivorous fish such as salmon, bluefin tuna and seabass until non-wild fish sources of fish meal are developed; 3) adopt integrated technologies that would make fish farming as self-contained as possible; and 4) develop reliable management systems for green aquaculture practices.

### Climate change and greenhouse gas emissions in fisheries

Climate change has begun to alter marine conditions, particularly water temperature, ocean currents, upwelling and biogeochemistry, leading to productivity shocks for fisheries (Diaz and Rosenberg 2008). Shifts in species distribution that appear to be caused by changes in sea temperature are well documented (Cheung et al. 2009; Dulvy et al. 2008; Perry et al. 2005), as are variations in growth rates (Thresher et al. 2007). Climate change may also alter the phenology of marine organisms, creating mismatches between the availability of prey and predator requirements and leading to coral bleaching and habitat loss for reef-associated fish species. These changes would affect the distribution and volume of

## Box 2: Subsidies and small-scale fisheries

Moves to shift to a green economy can provide opportunities to invest in SSF in a manner that enhances sustainability of the resource base as well as the coastal economy and society. The key lies in using the investments to build institutional strength and suitable incentives at a local scale. Measures such as subsidies and investment strategies can be used as incentives to change human behaviour positively, supporting long-term objectives in moving the fishery toward sustainability, without serious negative impacts. For example, this could involve providing funds to encourage certain actions such as conversion of fishing gear to less damaging choices, or a shift from fuel-intensive to more labour-intensive fishing methods.

In the context of SSF, this implies a careful examination of which subsidies are truly sustainable, equitable

and moving in the direction of conservation. For example, a fuel subsidy is common in fisheries, but this tends to promote more fuel-intensive and capital-intensive fleets, which leads not only to over-fishing, but also to inequitable expansion of catching power for some (those who can take advantage of the subsidy) at the expense of others (with less capital). On the other hand, a subsidy that is used to provide more secure livelihoods for coastal fishers, and one that leads to a shift of SSF, where necessary, to more ecologically suitable methods, may be very helpful. The subsidy issue also relates to the balance of small-scale and industrial fishing. Past subsidies on vessel construction and on fuel led to a favouring of industrial fleets that are too capital- and fuel-intensive. A better policy would be to orient subsidies as incentives to balance industrial and small-scale fisheries, thereby generating both human and ecological benefits.

catch worldwide, thereby affecting global fisheries socially and economically (Cheung et al. 2010). For instance, recent studies estimate that climate change may lead to significant losses in revenues, profits and/or household incomes, although estimates are considered preliminary (Cooley and Doney 2009; Eide, 2007; Sumaila and Cheung 2010; Tseng and Chen 2008).

It is estimated that the world's fishing fleet contributes 1.2 per cent of global greenhouse gas emissions (Tyedmers et al. 2005). The challenge is to find ways to reduce this contribution, such as by phasing out subsidised trawler fleets, which generate extremely high emissions per tonne of fish landed.

## 2.2 Opportunities

Greening the world's fisheries will help restore damaged marine ecosystems. When managed intelligently, fisheries will sustain a greater number of communities and enterprises, generating employment and raising household income, particularly for those engaged in artisanal fishing.

### Jobs supported by global fisheries

The world's fisheries provide livelihoods to millions of people in coastal regions and contribute significantly to national economies. They are relied upon as a safety net by some of the world's poorest, providing cash income and nutrition, especially during times of financial hardship. Healthy fisheries support the wellbeing of nations, through direct employment in fishing, processing, and ancillary services, as well as through subsistence-based activities. Overall, fish provides more than 2.9 billion people with at least 15 per cent of their average per capita animal protein intake (FAO 2009). The impact of the collapse of

fisheries would be devastating. Some 144 of the world's countries possess marine fisheries, which provide jobs for local and foreign workers alike. It is estimated that in 2006, about 35 million people around the world were directly involved, either part time or full time, in fisheries primary production.

When considering post-catch activities and workers' dependants, the number of people directly or indirectly supported by marine fisheries is about 520 million or nearly 8 per cent of the world's population (FAO 2009).

There has been a steady increase in fisheries employment in most low-and middle-income countries, while in most industrialised countries, the trend has been towards a decrease in the number of people employed in capture fisheries. For example, since 1970, the number of fishers has fallen by 61 per cent and 42 per cent in Japan and Norway, respectively (FAO 2009).

### Recreation and tourism

Marine recreational activities (MRAs) such as recreational fishing, whale watching and diving have grown in popularity in recent years and they have consequently come to the forefront of discussion and research on the ecological, economic and social impacts of more benign forms of interacting with the sea (Aas 2008; Hoyt 2001; Pitcher and Hollingworth 2002).

To estimate the value of MRAs, Cisneros-Montemayor and Sumaila (2010) first identified three indicators of socio-economic value in ecosystem-based marine recreational activities, which are 1) the level of participation; 2) the total employment in the sector; and 3) the sum of direct expenditure by users. A database of reported expenditure on MRAs was then compiled for 144 coastal countries. Using this

## Box 3: Small-scale fishing in Indonesia

Located at the north-eastern tip of Bali, Indonesia, is the fishing community of Les. Around 7,000 people live there, of whom some 1,500 make their living from fishing in coastal waters that have traditionally been rich in coral, fish and other marine organisms. Fishing for the aquarium trade has become one of the main sources of livelihood, with 75 households in the village now fully engaged in catching ornamental fish (UNEP 2006). Fishers in Les and neighbouring communities are switching from pelagic to ornamental fishing as the pelagic stocks become depleted in traditional fishing grounds, but ornamental fish are themselves threatened by damage to in-shore coral reefs caused by practices such as cyanide fishing. As a result,

villagers are being forced to fish for ornamentals further offshore and for longer periods.

Poison fishing has also led to substantial losses in revenue - estimated to amount to a net loss of as much as US\$ 476,000 per km<sup>2</sup> a year in Indonesia (Cesar 2002). The authors also estimate that the net loss from the deterioration of fisheries could be about US\$ 40,000 per km<sup>2</sup> a year. Given that Indonesia has the world's largest coral reef system, Wicaksono et al. (2001), estimate that the country could meet 60 per cent of global demand for ornamentals, compared with just 6 per cent currently, if its fisheries are managed effectively.

Item (units)	Recreational fishing	Whale watching	Diving and snorkelling	Total
Participation (million)	60	13	50	123
Expenditure (US\$ billion)	40	1.6	5.5	47.1
Employment (thousand)	950	18	113	1,081

**Table 3: Ecosystem-based marine recreational activities in 2003**

Source: Cisneros-Montemayor and Sumaila (2010)

database, the authors estimated the missing values and calculated the yearly global value for MRAs in terms of expenditure, participation and employment. They found that currently, recreational fishing occurs in 118 maritime countries and that country-level data on expenditure, participation and employment are available in 38 of these countries (32 per cent of total). The authors estimated that in 2003, nearly 60 million recreational anglers around the world generated a total of about US\$ 40 billion in expenditure, supporting over 950,000 jobs. In their analysis, countries with data account for almost 95 per cent of estimated total expenditure and 87 per cent of participation, so the authors argue that this estimate likely provided a close approximation to actual recreational fishing effort and expenditure.

Data on whale watching were found for a total of 93 territories (70 countries), mostly from 1994-2006 (Hoyt 2001; Hoyt and Iñiguez 2008). It is estimated that over 13 million people worldwide participated in whale watching in 2003, with expenditure reaching around US\$ 1.6 billion in that year (Cisneros-Montemayor and Sumaila 2010). It is also estimated that 18,000 jobs worldwide are supported by this industry each year. These numbers are only an indication of the potential economic contribution that can be expected from whale watching, given that the marine mammals are found in all of the world's oceans (Kaschner et al. 2006). Currently only a few countries have well-established whale watching industries.

There is limited country-level data on recreational diving outside of the USA, Australia, and to some extent, Canada and the Caribbean region. Using market surveys and other data on active divers, it is estimated that every year, 10 million active recreational divers (Cesar et al. 2003) and 40 million snorkelers generate over US\$ 5.5 billion globally in direct expenditure, supporting 113,000 jobs. In total, it is estimated that 121 million MRA participants generate US\$ 47 billion in expenditure annually and support over one million jobs (Cisneros-Montemayor and Sumaila 2010) (Table 3).

### Marine protected areas

Marine protected areas (MPAs) have been implemented in many countries and are regarded as a very important management instrument for fisheries. The assumption underlying the MPAs is that they can conserve the resources and increase the biomass therein, and consequently benefit surrounding areas through species migration and enhanced recruitment. Economic studies generally demonstrate that MPAs can be beneficial under specific conditions (Hannesson 1998; Sanchirico and Wilen 1999; Sumaila 1998). In addition, the MPA literature evaluates effectiveness of MPAs (Alder et al. 2002; Hockey and Branch 1997). In terms of policy design and implementation, many questions need to be addressed, including how to select MPA sites, how large should an MPA be, and how costly are MPAs, etc.

Marine Protected Areas will be a valuable management instrument for the greening of certain fisheries. There is growing consensus in the literature on the need to add MPAs in marine management plans (Costanza et al. 1998; Sumaila et al. 2000). Currently, MPAs comprise less than 1 per cent of the world's oceans (Wood et al. 2008). To fully utilise MPAs as a management tool, the Johannesburg Plan of Implementation adopted at the World Summit on Sustainable Development in 2002 aims to establish a global network of MPAs covering 10-30 per cent of marine habitats by 2012. This deadline was extended to 2020 and the target lowered to 10 per cent at the CBD meeting in Nagoya, Japan in late 2010.

### Consumer Awareness

In recent years, we have seen a relative explosion in the number of programmes that seek to help consumers make informed decisions in terms of sustainability about their consumption of fish products. Although such programmes are not without criticism, it is clear that consumer awareness of marine fishery issues, if properly designed and implemented, would be an important driver of greening world fisheries as such awareness programmes expand into more and more places around the world.

Examples of resources that consumers can use to inform their purchase of sustainably caught fish include:

- The Monterey Bay Aquarium's Seafood Watch, Available at: (<http://www.montereybayaquarium.org/cr/seafoodwatch.aspx>);
- The Marine Stewardship Council certification programme, Available at: <http://www.msc.org/>; and
- The U.S. National Oceanic and Atmospheric Administration's Fish Watch, Available at: <http://www.nmfs.noaa.gov/fishwatch/>

## 3 The economic case for greening fisheries

### 3.1 The contribution of fisheries to economic activity

Recent estimates of gross revenue from marine capture fisheries suggest that the sector directly contributes US\$ 80-85 billion to world output annually (Sumaila et al. 2007; World Bank and FAO 2009). However, this amount is by no means the total contribution from marine fish populations. As a primary industry (Roy et al. 2009), there are a vast number of secondary economic activities – from boat building to international transport – that are supported by world fisheries (Dyck and Sumaila 2010; Pontecorvo et al. 1980).

The weighted mean cost of fishing was estimated by Lam et al. (2010) to be US\$ 1,125 (range of US\$ 732 - US\$ 1,605) per tonne, which works out at about US\$ 90 billion for an annual catch of 80 million tonnes. The cost per tonne is split into the following cost components: 1) fuel cost (US\$ 216); 2) running cost, for e.g., cost of selling fish via auction, cost of treatment of fish (US\$ 162); 3) repair cost (US\$ 108); 4) payments to labour (US\$ 434); 5) depreciation (US\$ 101); and 6) payment to capital (US\$ 101).

Although the national contribution of fisheries to economic output is officially recorded as ranging between 0.5 per cent and 2.5 per cent for many countries (based on the total value of fish when they change hands for the first time after leaving the boat), the sector supports considerable economic activity by way of trickle-up linkages (Béné et al. 2007), also referred to as multipliers. The multiplier effect can be dramatic in coastal communities where small-scale fisheries not only generate direct revenues, but also represent the economic heart of coastal communities and the engine of the broader economy.

Dyck and Sumaila (2010) applied an input-output analysis to estimate the total direct, indirect and induced economic effects arising from marine fish populations in the world economy. Their results suggest there is a great deal of variation in fishing-output multipliers between regions and countries. When the output multipliers were applied at the global scale, the authors found that the contribution of the sector to global economic output amounted to some US\$ 235 billion per year (Table 4), close to three times the conventionally measured ex-vessel value of marine capture fisheries.

### 3.2 The potential contribution from rebuilding and sustaining fisheries

As discussed earlier, global ocean fisheries caught an estimated 80 million tonnes of fish with a total value of about US\$ 85 billion in 2005. The question we address in this section is: what are the potential gains, if any, from rebuilding marine fish stocks? We discuss this in terms of the potential increase in current catches, catch value, profits, resource rent and employment.

Using data from a recently published paper (Srinivasan et al. 2010), we assume that world fisheries landings could increase by 3.6 million tonnes-19.2 million tonnes per year if currently over-fished species are rebuilt to stock sizes allowing for maximum sustainable yield (MSY). This represents a potential to increase the value of landings by US\$ 6.4 billion-US\$ 36 billion per year. We nevertheless recognise the limitations of the MSY approach in global fisheries. However, since the approach involves rebuilding those fisheries currently classified as collapsed, we avoid issues involved when assuming all species can be fished at MSY.

For the further analysis, we make the following assumptions:

- The real price (nominal price adjusted for inflation) of fish is constant through time. There is evidence from historical data that real prices for fish have not changed much in the last few decades;

	Landed value (US\$ billion)	Indirect effect (US\$ billion)
Africa	2	5
Asia	50	133
Europe	12	36
Latin America & Caribbean	7	15
North America	8	29
Oceania	5	17
World Total	84	235

**Table 4: World marine capture fisheries output by region**

Sources: For landed values see Sumaila et al. (2007) and for multipliers see Dyck and Sumaila (2010)



	Current fisheries (US\$ billion)	Green fisheries (US\$ billion)
Value of landings	85	101
Cost of fishing	90	46
Non-fuel subsidies	21	10*
Rent**	-26	45
Wages	35	18
Profit	8	4
Total added-value	17	67

\* The estimated US\$ 10 billion in green subsidies would be to fund management programmes.

\*\* The rent is the return to owners of fisheries resources, which is the surplus from gross revenue after total cost of fishing is deducted and subsidies taken into account. Here, rent is total revenue (US\$ 85 billion) less total cost (US\$ 90 billion) less non-fuel subsidies (US\$ 21 billion). Note that fuel subsidies are usually in the form of rebates at the pump and therefore are already excluded.

**Table 5: Green fisheries – key figures**

■ As overfished stocks are rebuilt, there would be no substitution between capital and labour. That is, the various costs of fishing would stay in proportion to the current situation;

■ The practice of providing harmful subsidies to the fisheries sector is fundamentally at odds with green fisheries. Therefore, we assume that the estimated US\$ 16 billion per year in harmful subsidies are eliminated or re-directed toward aiding the transition to green fisheries. Similarly, we assume that the US\$ 3 billion per year in ambiguous subsidies, such as those for buybacks, would also be re-directed or eliminated;

■ The cost of fisheries management would increase by 25 per cent, from about US\$ 8 billion a year to US\$ 10 billion a year, to support better management under green fishing regimes;

■ Fisheries rent, that is, the return to owners of fisheries resources, would be US\$ 45 billion per year in a green economy scenario. This is based on evidence from a recent report showing that potential total rent in world fisheries is about US\$ 50 billion per year at Maximum Economic Yield (MEY), where the catch is about 10 per cent lower than our proposed scenario (World Bank and FAO 2009).

Given the above assumptions, global marine fisheries are projected to catch 90 million tonnes a year in a green economy scenario with lower and upper bounds of 84–100 million tonnes. The estimated value corresponding to this level of catch is about US\$ 101 billion per year (with a range of US\$ 91 billion–US\$ 121 billion). The total cost of fishing in a green economy scenario is estimated to be US\$ 46 billion, compared to US\$ 90 billion currently. Assuming that payments

to capital (normal profit) and labour (wages) remain proportionally constant in relation to total costs, the normal profit and wage income would amount to US\$ 4 billion and US\$ 17.8 billion, respectively. Resource rent for a green fisheries sector is assumed to be US\$ 45 billion per year based on recent research (World Bank and FAO 2009).

Total value added, or fisheries contribution to human welfare, in a green economy scenario is estimated at US\$ 67 billion a year (the sum of resource rent + payments to labour + normal profits). This represents a green economy improvement of US\$ 50 billion per year compared with the sector's existing contribution to human welfare (Table 5).

### Indirect benefits from rebuilding

As the value of the global marine catch increases from about US\$ 85 billion to US\$ 101 billion a year in a green-economy scenario, the total of direct, indirect and induced economic effects, arising from marine fish swells from US\$ 235 billion to US\$ 280 billion per year, assuming a linear relationship between catch and multiplier effects.

### Benefits from recreation and tourism

In general, recreational fishers do not necessarily fish for the catch but rather for experience. It should be reasonable to assume that a healthier ocean rich in biodiversity is likely to increase the utility and therefore the benefits derived by recreational fishers. However, owing to the lack of information, we refrain from doing so in this report.

## 3.3 The cost of greening global fisheries

A key element of greening the fisheries sector involves moving from the current situation where we are not fishing the resource in a sustainable manner to one where the fish we catch each year is equal to or less than the growth of wild stocks. To make the change from the current state of affairs would require some investment into adjusting fishing capacity, managing transitions in labour markets, management programmes and scientific research. Two modelling exercises were undertaken to estimate the cost of greening fisheries. A one time investment of US\$ 100–300 billion was calculated in this chapter to reduce excessive capacity, retrain fishers and improve fisheries management. Under the Green Economy Report T-21 modelling, a scenario of a larger and deeper spending of 0.1 to 0.16 per cent of GDP over the period 2010–2050 was considered to reduce the vessel fleet, relocate employment and better manage stocks to increase catch in the medium and longer term.<sup>5</sup>

5. See the Modelling chapter in this report.



### Identifying greening efforts

There is widespread agreement that the world's fisheries are currently operating at overcapacity. Advances in technology have made it possible for a much smaller global fleet to catch the maximum sustainable yield, but the global fishing capacity keeps on growing owing to the common property nature of fisheries and the provision of fishing subsidies by many maritime countries of the world. Also, the use of sometimes damaging fishing methods such as bottom-trawling, unselective fishing, pollution and human-induced variations in climate has changed the productivity of many aquatic environments.

The issue of overcapacity can be addressed by investigating some of the common sources of excess fishing capacity. In several places, fishing is considered employment of last resort, attracting people with few other job options. Investing in re-training and education programmes for fishers and creating alternative employment has been successful in reducing fishing pressure, especially in places that are known for artisanal fishing.

Fishing capacity can be curtailed by taking steps to decommission fishing vessels or by reducing the number of permits or licences. Much attention has been given to decommissioning programmes, which are intended to reduce effort by reducing the number of fishing vessels. Unfortunately, some research suggests that vessel buy-back schemes may actually increase fishing effort if not properly implemented (Hannesson 2007). This occurs when loopholes allow decommissioned vessels to find their way to other fisheries and increase their catching capabilities (Holland et al. 1999). Fishing enterprises may also act strategically in anticipation of a buy-back by accumulating more vessels than they would otherwise (Clark et al. 2005).

Many fishing grounds that have been over-exploited have suffered lasting damage to the sea bed by trawl nets, affecting the ability of certain species to reproduce (Morgan and Chuenpagdee 2003). In these cases, as well

as in instances where pollution or climate change have had an impact, mitigating investment in the natural environment is essential if ecosystems are to be brought back to past levels of health and productivity.

### The cost of fishing fleet adjustment

The world's current fishing capacity is widely estimated to be 2.5 times more than what is needed to land the maximum sustainable yield (MSY) (Pauly et al. 2002). This implies that in order to shift the fishing industry to MSY levels, we would need to trim excess fishing capacity. However, the cumulative power of the global fleet is presently increasing at a rapid rate, notably in Asia (Anticamara et al. in press).

It is estimated that some 4 million boats<sup>6</sup> are actively engaged in marine fisheries. If we assume that current fishing capacity is between 1.5 and 2.5 times the level needed to maximise sustainable catch, fishing effort would need to be reduced by between 40 and 60 per cent. This means that the active fishing fleet may need to be reduced by up to 2.4 million vessels. This calculation does not, however, account for differences in fishing capacity by vessel type. For instance, areas dominated by large-scale vessels (i.e., vessels larger than a given size, which varies from one country to another) may need to reduce fewer vessels than areas with more small-scale boats because large-scale operations represent greater fishing effort per unit.

It is estimated that the fishing industry employs more than 35 million people, which implies that between 15 and 22 million fewer fishers would be required in a green-fisheries scenario. However, research indicates that up to 75 per cent of fishers in Hong Kong would be willing to leave the fishing industry if suitable compensation were available (Teh et al. 2008). Alternative livelihood programmes that have been successful involve activities such as seaweed farming

6. Based on 2002 data and stagnant growth in fleet size as suggested by FAO trends. Available at <http://www.fao.org/fishery/topic/1616/en>.

## Box 4: How improvement in fishing gear can contribute to green fisheries

The potentially devastating impact of trawling, especially in terms of damage to the sea bed and bycatch, is well known (Hall 1996; NRC 1999; Watling and Norse 1998) and has given rise to legislation such as the mandatory use of turtle-excluder devices in shrimp trawls and bans of trawlers in the in-shore waters of many nations. In California, a shift from trawls to traps in the state's spot prawn fishery in 2003 resulted in a significant

reduction of rockfish bycatch (Morgan and Chuenpagdee 2003). Recent improvements to the design and use of fishing gear to minimise seafloor contact and to reduce bycatch, such as the use of the Nordmore grate in shrimp fishery (Richards and Hendrickson 2006) have been encouraging, but more investment is needed to address the impacts of large scale trawling and other high-impact fishing gear.

and recreational angling (Sievanen et al. 2005). Clearly, this is a difficult task for policy-makers to implement. Nevertheless, there are options:

#### **Scenario one: An across-the-board fishing capacity cut**

Assuming that the current global fishing fleet represents an average distribution of capacity throughout the world, we estimate that decommissioning of between 1.4 – 2.4 million vessels would be required. Similarly, between 15 million and 22 million workers would be removed from a green fishing industry. Based on vessel and crew data from the European Union (EC 2006), we calculate that the average cost of a vessel buyback is roughly equal to the average interest payments on a vessel for five years and the average cost of crew retraining is estimated as 1.5 years average annual crew wages. These values are estimated to be US\$ 15,000 per vessel buyback and US\$ 18,750 per crew retraining, respectively. Based on this information, we estimate that the total investment needed to reduce fishing capacity in this scenario to be between US\$ 290 billion and US\$ 430 billion worldwide. It should be noted that this total amount can be spread over time if necessary.

#### **Scenario two: Accounting for catch capacity distribution differences**

The above scenario assumes that, on average, vessels have similar catch capacity and impact ecosystems in similar ways. In fact, the distribution of fishing effort exhibits a great deal of variation around the globe (Anticamara et al. in press). Large-scale, high capacity vessels also tend to use more capital in place of labour so that the number of workers per weight of landings is lower than small scale fleets. For policy-makers concerned about reducing fishing effort while minimizing the impact on workers, it is probably prudent to focus on buybacks of large-scale fishing vessels.

The catching power of large-scale vessels implies that 160,000 of the world's 4 million fishing vessels catch the same amount of fish as the remaining 3.84 million vessels. Using data on fishing employment in small and large scale fleets (EC 2006), we calculate that, on average, large scale vessels employ about 3.6 times as many workers as small scale vessels. This implies that large scale fleets employ about 5 per cent of the world's 35 million fishers or 4.6 million workers. Combining these figures with our assumptions outlined above implies that cutting 130,000 – 160,000 large-scale vessels along with 1.4 – 1.7 million jobs supported by these vessels will achieve roughly the same green economy results as cutting 15 to 22 million fishing jobs across the board. In this scenario, the total cost of adjustment to green fisheries is between US\$ 115 and US\$ 175 billion since the high cost of worker retraining is minimised. The reason why the cost of greening world fisheries under this scenario is lower

than under scenarios one and three is that the cost of compensating, re-training and re-settling small scale fishers is much higher in those two cases.

#### **Scenario three: Global fleet capacity distribution**

If large and small scale fishing vessels were evenly distributed around the globe, scenario two would be an effective strategy to minimise the effect on employment numbers by decommissioning only the large scale vessels and affecting a smaller number of workers. However, many large-scale vessels are concentrated in developed countries while small-scale vessels are mostly found in developing countries. Although the same green economy result could potentially be achieved by making cuts to just large-scale vessels, this would be ineffective in areas dominated by small-scale fishing that are currently overfished, such as in India and Senegal.

In this scenario, we explore the possibility of putting three-quarters of the responsibility for cutting fishing effort on large-scale vessels, with the remaining quarter filled by small-scale vessels. In such a case, reducing a combination of 120,000 large-scale vessels and 960,000 small-scale vessels would halve the world's fishing capacity. However, unlike scenario one, the effect on workers in this scenario is greatly reduced, requiring provisions to deal with 1.3 million large-scale workers and 8.3 million small-scale fishers. Also, in this scenario, we allow for differences in the cost of decommissioning and re-training to vary between large and small-scale vessels. Using data from Lam et al. (2010), we calculate that large and small-scale crew workers earn average wages of US\$ 20,000 and US\$ 10,000 per year, respectively. Furthermore, we determine that large and small scale vessels pay an average of US\$ 11,000 and US\$ 2,500 per year in capital costs. This implies that, following the same assumptions as scenario one, the average cost of decommissioning for large and small-scale vessels is US\$ 55,000 and US\$ 12,500, respectively. Likewise, retraining efforts for large and small-scale crew members are estimated to be between US\$ 30,000 and US\$ 15,000 per worker.

By focusing effort reductions on large-scale vessels, the total cost of adjustment to green world fisheries in this scenario is much less costly than the first scenario, requiring a one-time total investment of between US\$ 190 billion to US\$ 280 billion with a mean of US\$ 240 billion to decommission vessels and provide for workers as they transition to other forms of employment. It would also be necessary to increase management expenditure by 25 per cent to US\$ 2 billion on an annual basis.

Given the current distribution of large and small-scale fishing vessels in the world, both scenarios one and two appear to be unrealistic. Therefore, we use the cost estimates in scenario three in the following cost-benefit analysis.

### 3.4 Cost-benefit analysis of greening fisheries

As presented earlier, greening the fisheries sector would lead to an increase in value added from fishing, globally, from US\$ 17 billion to US\$ 67 billion a year. This is a net increase of US\$ 50 billion a year. Given that the cost of restructuring the global fishing fleet under scenario three is a one-time investment of about US\$ 240 billion, benefits would be realised very quickly if fish stocks recover fast. Discounting the flow of US\$ 50 billion per year over the next 50 years at 3 per cent and 5 per cent, real discount rates represent a present value from greening ocean fisheries of US\$ 960 and US\$ 1,325 billion, which is between 4 and 5.5 times the mean estimate of the cost of greening global fisheries. This signals that there is potentially a huge green advantage. Although a variety of assumptions are needed to produce estimates in this section, it is clear that economic gains from greening world fisheries are substantial enough to compensate for even drastic changes in these assumptions.

### 3.5 Managing fisheries

Effective management is crucial for ensuring a green marine fisheries sector, although this has so far proved difficult to achieve. Research suggests that implementing a form of management known as individual transferable quotas (ITQs), also known as catch shares, can explain the improvement and rebuilding of many fish stocks around the world (Costello et al. 2008; Hannesson 2004). However, it has also been argued by many authors that ITQs are no panacea and need to be designed carefully (Clark et al. 2010; Essington 2009; Gibbs 2009; Hilborn et al. 2005; Pinkerton and Edwards 2009; Townsend et al. 2006).

Catch shares can be an effective tool in controlling fishing pressure. Because they are underpinned by Total Allowable Catch (TAC) limits, they can constrain catch to sustainable levels and, therefore, become valuable management tools (Arnason 1995). Individual transferable quotas do not confer full property rights to the ITQ owner, and furthermore, it is widely acknowledged that even if they were to provide such rights, there are still conservation and social concerns to worry about (Bromley 2009). Understanding these limitations to ITQs as a management regime, where this tool is implemented, must be part of a broader management system that ensures that these limitations are addressed appropriately. Measures are needed to ensure that ITQs work to improve economic efficiency, while ensuring the sustainable and equitable use of the fishery resources and the ecosystems that support them.

Below are some of the strategies that are needed as part of an ITQ management system if it is to achieve economically, ecologically and socially desirable outcomes (Sumaila 2010):

- Individual transferable quotas must be supported by an arm's-length stock assessment unit that is independent of industry and backed by strong monitoring, control and surveillance (MCS) to deal with the lack of full property rights, which can lead to "emptying" the ocean of fish under certain conditions;
- Some restrictions on the ownership of ITQs to people actively engaged in fishing may be needed to mitigate against diluting ITQ performance when quota owners are different from those who fish;
- Measures to ensure resource sustainability by taking an ecosystem-based management approach including

#### Box 5: Illegal, unreported and unregulated fishing and the greening of fisheries

The FAO identifies Illegal, Unreported and Unregulated (IUU) fishing as one of the major factors driving overexploitation of marine resources worldwide (FAO 2001). Based on case studies, MRAG (2005) estimate that the total loss due to IUU fishing is about 19 per cent of the total value of the catch. The commonly accepted economic reason for the persistence of IUU fishing is that detection rates and fines are too small relative to the catch value (Griggs and Lugten 2007; Kuperan and Sutinen (1998). In fact, Sumaila et al. (2006) suggest that the reported fines should be increased by at least 24 times to equalise the expected costs and benefits.

To green fisheries and prevent overexploitation, it is necessary to reduce IUU fishing. The direct way is to strengthen monitoring and control through strict policy enforcement, and the indirect way is through economic incentives, e.g., increasing fines or decreasing reporting costs. While reducing IUU fishing within a country using these direct and indirect ways is important, cooperation among countries is also very critical, since lots of IUU fishing occurs in the areas accessed by multiple countries.

Source: OECD (2004)

special attention to essential habitats, safe minimum biomass levels, input controls, etc.;

■ Networks of reasonably large marine protected areas may be needed to accompany the implementation of ITQs to deal broadly with the ecosystem effects of overfishing, to allow for recovery, and to recognise uncertainty in the performance of ITQs. Such a network would benefit greatly by ensuring that it is designed to be compatible with conservation and ITQ goals and objectives;

■ Imposing limits to quota that can be held by each quota owner, to mitigate social problems associated with the concentration of fishing power, although its effectiveness is very variable. It is worth noting that this is already a feature of many existing ITQ systems. In some fisheries, equity concerns may be alleviated by allocating quotas to communities or to residents of a territorial area in the form of community transferable quotas (CTQs) and territorial user rights in fisheries (TURFS), respectively (Christy 1982; Wingard 2000; Charles 2002). With such schemes in place, the economic efficiency benefits of ITQs may be captured while minimising negative social impacts; and

■ Auctioning of quotas can be used in some fisheries to deal with the problem of initial allocation of quota and its equity implications (Macinko and Bromley 2002; Bromley 2009).

There are several areas of management where increased investment can be extremely beneficial. These include:

- Stock-assessment programmes;
- Monitoring and control programmes; and
- Establishment of marine protected areas (MPA).

Stock assessment programmes are basic for fishery managers who require reliable statistics to inform them of the state of fish stocks so that they may keep a careful eye on whether fishing effort is appropriate for the sustainable use of the stock (Walters and Martell 2004).

Monitoring and control programmes are those that allow fisheries managers to determine whether fishers are acting in compliance with catch quotas or not. Such programmes are also necessary in terms of mitigating the impact of illegal and unreported fishing activities.

Historically, MPAs have not been used as a major tool in the management of the world's fisheries. However, their role as a management tool has become more popular in recent years. Marine Protected Areas attempt to maintain the health of fish stocks by setting aside an area of the ocean that is free from fishing activity – allowing mature fish in these areas to escape into unfished areas, thereby ensuring the future resilience of the fishery.

## 4 Enabling conditions: Institutions, planning, policy and regulatory reform and financing

### 4.1 Building effective national, regional and international institutions

The root cause of overexploitation of fish stocks is the lack of control over fish catches or fishing capacity, or both. Individual fishers competing with many others have an incentive to take as much fish as quickly as they can. If this incentive is not controlled, the result of such uncoordinated efforts of many competing fishers is the depletion of fish stocks to the point of harming future fish catches, raising the cost of catching fish, and possibly wiping out fish stocks once and for all (Hannesson 2004; Hardin 1968; Gordon 1954). Fortunately, it has been shown over the past several decades that very often communities or groups of fishers develop institutions that can regulate the incentives and create the conditions for sustainability (Dietz, T. et al. 2003). This is not guaranteed to occur, however, and it is unlikely in industrial or high-seas cases, where other measures are needed.

In this regard, note that privatising use of the fishery resource is not necessarily advisable. Even if a fish resource is privatised, there are conditions under which the private owner may find it optimal to overfish the stock, sometimes to extinction (Clark 1973; Clark et al. 2010). This happens when the stock in question grows very slowly compared to the rate of discount, so that the present value of future catches is low, compared to the once-and-for-all gain from depleting the stock. However, such restrictions are not necessarily best imposed by a governmental fisheries administration. Successful examples around the world of community-based or fisher-led restrictions are common, often in conjunction with spatial or territorial limits.

We need effective institutions at all levels of government, from the local to the provincial/state to the national, regional and international because of the migratory nature of many fish stocks. Many fish stocks spend their lives completely in the Exclusive Economic Zones (EEZ) of countries – they do not migrate across EEZs of other countries or straddle into the high seas. For these fish stocks, effective national institutions are all that is needed. Then we have fish stocks that are shared by two or more countries, the so-called transboundary fish stocks that live completely within the EEZs of more than one

country. For these fish stocks, participants in the fishery must agree on the management of the stock in order to make it effective (Munro et al. 2004). Then there are fish stocks that are partly or wholly located in what is left of the high seas. It has for a long time been a concern that the regulation of these fisheries is ineffective and that regulation of stocks that are governed by one or more coastal states but which straddle periodically into the high seas is undermined by the open access to the high seas. This prompted a conference on high seas fisheries in the 1990s under the auspices of the UN. This resulted in what is usually called the UN Fish Stocks Agreement, which vests the authority to regulate high seas fisheries in Regional Fisheries Management Organisations (RFMOs) (United Nations 1995), whose functioning was recently reviewed by Cullis-Suzuki and Pauly (2010b) and generally found wanting.

### 4.2 Regulatory reform

The basic requirement for a successful management of a fish stock is limiting the rate of exploitation to some sensible level. This necessitates 1) a mechanism to set such a target catch level and 2) a mechanism to monitor and to enforce it. The basic question to ask is whether the scientific, administrative and law-enforcing capability is in place to make this happen. The presence of strong social norms and cultural institution are great tools for enforcement where they work.

In practice, effective management institutions would have in place mechanisms for providing scientific advice, as well as a mechanism to set the rate of exploitation on the basis of that advice and in such a way that it maximises long-term benefits in the form of food supplies or fishing rent (difference between revenues and costs adjusted for subsidies). The latter requires an efficient and uncorrupted administration that strives for the best possible economic (or food supply) situation of the country in question (UNEP 2008).

As to the specific means by which the fisheries administration achieves its goals, these must be decided on a pragmatic basis. A limit on the total catch is perhaps the most obvious instrument to use, but there are



circumstances where it might not be adequate. Catch limits are notoriously difficult to monitor in small-scale fisheries, and even monitoring the boats and their use need not be much easier in that context. Yet, it is quantitative restriction of either kind that is needed in order to limit exploitation of fish stocks.

It has been pointed out repeatedly and supported by empirical evidence that limiting fish catches alone achieves very limited objectives in the fisheries (Costello et al. 2008; Hannesson 2004). It may, and it often has, succeeded in maintaining the fish stocks at healthy levels, while leaving the industry in shambles economically, with short fishing seasons, inferior products, low economic returns, and even threats to life and limb through undue risk-taking encouraged by narrow time opportunities to catch fish. One way to deal with this is to allocate the total fish quota among the vessels or fishing communities in the industry and make the quota allocations transferable, where feasible.

### 4.3 The economics of fishery management tools

The basic fishery management tools can be grouped into 1) output controls; 2) input controls; and 3) auxiliary measures. Both 1) and 2) control the rate of exploitation, which is the fundamental factor that needs to be controlled, as stated earlier.

Output controls mean limiting the total amount of fish that can be caught. We do not know what this means in terms of rate of exploitation unless we know what the size of the fish stock is. This can only be estimated with

a considerable and possibly high degree of imprecision. Nevertheless, catch quotas are often set on the basis of some target rate of exploitation, and to make any sense of them we must have a reasonably reliable idea about what the stock size is. This is admittedly an unlikely scenario in most fisheries of the world, which are small-scale and local in nature, and for which output controls may be of limited use. However, where feasible, the target output should be set on the basis of maximizing either food supply or fishing rent, depending on what is deemed most appropriate.

Where it is feasible to set a catch quota, and where there are strong monitoring and enforcement capabilities, it might be feasible to allocate the quota among the players in the industry, and make it transferable. This should help avoid wasteful competition for the largest possible share of a given catch and to achieve a reasonable correspondence between the fleet capacity and the available catch quotas. We stress reasonable, because there are several reasons why there is likely to be some mismatch between fleet capacity and catch quotas. One is variability of the fish stocks, another is the remuneration system used on the fishing boats. The optimal solution is ideal, but in practice we are unlikely to achieve anything better than getting closer to it.

Under some circumstances, effort controls could be better than quota controls. This can happen if quotas are difficult to monitor, or if the size of the fish stock cannot be estimated while we can be reasonably certain that it is always evenly distributed in a given area so that a unit of effort produces a given rate of exploitation. A problem here is technological progress by which a unit of effort (say, a boat-day) becomes more and more effective over

### Box 6: Updating international law on shared fish stocks

A shared fish stock is one that either 1) is a highly migratory species (i.e., tuna); 2) occurs in the EEZ waters of more than one political entity; 3) occurs in the high seas where it may be targeted by a multitude of fleets; or 4) any combination of the previous three. Often, the management of shared fish stocks is needed to counter what game theorists term the prisoner's dilemma, where parties sharing a stock would be better off cooperating on management initiatives but fail to do so because they are concerned other parties may free-ride on their investment in the resource.

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) was implemented to deal with some problems associated with shared fish stocks,

giving special rights and responsibilities over near-shore marine resources to coastal nations. However, this agreement and the 1995 United Nations Fish Stock Agreement, which was meant to reinforce UNCLOS, have left the management of shared and transboundary fish stocks open to management problems that game theorists have predicted (Munro 2007). It is suggested that, in order to green fisheries that are shared or transboundary in nature, the body of international law concerning access rights in fisheries must be re-examined with a focus on the establishment of RFMOs with the teeth to oversee the use of these fish stocks; for such laws to be effective, international law should be reviewed as soon as possible – before serious harm to shared fish stocks occurs.

time. Such increases in effectiveness usually reach 2–3 per cent per year, and hence can double the impact of a fleet after two decades (Pauly and Palomares 2010). In fact, this method of management encourages technological progress for the sole purpose of catching more fish, even to the point of exceeding the target rate of exploitation. Some efficiency gains are likely to be realised through allowing trade in effort. The total effort should be determined on the basis of the same principles as the total catch quota.

Then there are several measures which are termed auxiliary, as they do not primarily address the basic problem of controlling the rate of exploitation but promote greater yields from fish stocks in various ways. One is selectivity of fishing gear (mesh sizes, for example). Larger meshes allow young, fast growing fish to escape capture and to be caught at an age when they have grown to a more appropriate size. Closing off nursery areas serves the same purpose. Protecting the spawning stock could be desirable, if the extent the size of the spawning stock is critical for recruitment of young fish. Regulations such as mandatory discarding of marketable fish are highly doubtful, as is mandatory retention of unmarketable fish. The rationale for such measures is to discourage people from seeking fish that they are not authorised to take. While this is indeed desirable, such regulations are economically wasteful and one should look for ways to achieve the desired outcome in less wasteful ways.

## 4.4 Managing the transition process

This would be most challenging when we are dealing with depleted fish stocks that need to be rebuilt. This situation arises because the capacity of the fishing fleet has outgrown the available resource, and so the fleet would have to be downsized. Both of these necessitate a cutback in fishing activity. Fish quotas that are lower than contemporary and recent catches which have depleted the fish stock are necessary to rebuild the stock. Such small quotas mean that some of the fishing capacity is redundant, and even with rebuilt stocks it is highly likely to remain redundant if a repeated depletion of the stock is to be avoided.

All this implies investment in the fish stocks as it were, through foregone earnings in the short-term for the purpose of obtaining higher benefits in the future. Likewise, having some boat owners leave the fishery means that they would be foregoing earnings they otherwise would have obtained, and those who leave would in any case not share in the higher benefits to be realised in the future. Since the justification for rebuilding fish stocks is higher future benefits, it would in principle be possible for those who remain in the

fishery to buy out those who leave; in this way share the future income recovery with them (Martell et al., 2009). The problem is, however, that future income is an expected and not a certain variable, and the vagaries of nature could in fact greatly delay the realisation of any income recovery. Those who remain in the industry could, therefore, be reluctant to offer much of the income recovery they expect.

There is also a key issue in SSF, particularly a lack of access to capital, limiting the potential for this process. There is therefore a case for governments to come up with funds to finance the transition from overexploitation and overcapacity to an optimally exploited fishery with optimal fleet capacity. It should be stressed, however, that this is only bridge financing; in due course those who remain in the fishery should pay back the loans they got for the transition. Anything else could create the expectation that boat owners in an overexploited fishery will always be bought out, which could entice people to invest in overcapacity purely on the expectation of being bought out later.

## 4.5 Learning from successful international experience

There are a number of cases of successful transitions from an overexploited fishery, or a fishery with overcapacity, to a better managed fishery, albeit not fully optimal. Below is a non-exhaustive selection of these cases and their most salient features are mentioned.

### New Zealand

One of the early cases of control by ITQs is the bottom trawl fisheries in New Zealand. One interesting aspect of how that regime was implemented in the inshore fishery was how excess fishing capacity was bought out by having fishers tendering quotas. These buyouts were, however, financed with public money and never recovered; plans to charge resource rentals were abandoned early on. This case is well documented in a number of papers (Ackroyd et al. 1990; Batstone and Sharp 1999; Clark et al. 1989; Hersoug 2002).

### Pacific halibut

Individual transferable quotas were first introduced in the Canadian halibut fishery. One noteworthy feature is industry participation and payment for monitoring of quotas. Another lesson is how individual quotas provide economic benefits in the form of higher catch value due to longer fishing season and more leisurely fishing (Fox et al. 2003; Rice 2003; Turris 2000; Wilen 2005).

### Ayvalik-Haylazli Lagoon fishery

The Ayvalik-Haylazli Lagoon fishery, near a major agricultural and commercial centre city in Turkey, is an example of

successful community management (Berkes 1986). In this fishery, fishers from three neighbouring villages formed a cooperative in 1994. This cooperative organised fishers to cooperate in work to reduce fishing costs and restricted the resources access only to those members.

#### **Alaska Regional Fisheries Association**

This association, formed by fishers themselves to conserve and rebuild salmon stock in the middle of 1970s, is another successful case of fishery management. By self-imposing a tax of 3 per cent of the value of their catch, the association was able to increase salmon abundance and benefit the fishers (Amend 1989).

#### **Fisheries adjustments in Spain**

Starting in the mid-1970s, the extension of national fisheries jurisdiction into 200-nautical mile exclusive economic zones forced Spanish distant fishers were forced to depart from various fishing grounds where they had fished for decades, if not centuries. This resulted in a decline in employment by roughly a third over a few decades. However, government-supported unemployment subsidies, training programmes, public investment and transfers to new sectors, such as fish farming, fish processing and coastal tourism, enabled Spanish communities that were reliant on fishing to ensure a continued high standard of living and to avoid any major social crisis, despite a significant decline in fisheries employment (OECD 2000).

The lessons that can be learned from these cases are the following:

- It is important to find an initial allocation of a quota that is generally understood to be equitable and immune to challenge as far as possible (there might always be controversial cases, however);

- The allocation criteria should be fixed as quickly as possible, to avoid positioning such as participation in the fishery or investment in boats only to ensure inclusion in the system. The latter aggravates the overexploitation and overcapacity prior to establishing a quota system (bringing loans only);

- There may be a case for government to help with the provision of funds, to be paid back later, to buy out excessive fishing vessels;

- Equitable distribution of gains from individual transferable quotas is important, in order to avoid challenges on the grounds that the quotas make only a few people rich and leave little for the rest of society. Note that these challenges can emerge well after the quota system is established and even if the initial allocation of quotas was deemed acceptable, as gains from a quota regime take some time to emerge;

- There can be very substantial gains from individual quotas, in the form of lower fishing costs and a higher catch value. Not all these gains are due to rebuilding of fish stocks. Some are due to less fishing capacity used, others to longer fishing season and more leisurely fishing; and

- Under certain circumstances, fishing communities have the potential to maintain resources sustainably (Berkes et al. 2001; Ostrom et al. 1999).

## **4.6 Financing fisheries reform**

As shown earlier, green fisheries require accessing or raising the necessary funds to meet the economic, environmental and social goals in order to: ensure the long-term future of fishing activities and the sustainable use of fishery resources. Financing is required for measures to adapt the fishing fleet; promote the use of appropriate gear; strengthen markets in fishery products; promoting partnerships between researchers and fishers; diversify and strengthen economic development in areas affected by the decline in fishing activities; and provide technical assistance and (human) capacity building in developing countries.

Activities aimed at greening the fisheries sector are diverse and would take place at the local, national, regional and global levels. Financing arrangements or options would also have to be tailored to meet the needs at these levels. We must also keep in mind when considering options for financing fisheries reform that ample investment may not be sufficient for greening the fisheries sector if not combined with effective management regimes.

#### **Public investment in fisheries reform**

Since fisheries are considered by many to be a public resource and the public has much to gain through improved management, significant public investment in this industry can be justified. Public funding for fisheries sustainability includes direct funding from national budgets, contributions from multilateral funds, resources raised from capital markets backed by government guarantee and a share of government taxes, levies or revenues earmarked at a national level for a fisheries fund. A Global Fisheries Fund (GFF), run by the United Nations, along the lines of the Global Environmental Facility (GEF), can be set up. Funding from various public sources can be pooled for greening the fisheries sector. A high level forum on international fisheries finance can be established to bring together key decision makers from the public and private financial sector, as well as international financial institutions. It could regularly review funding availability and expenditure and provide recommendations for improvements.

### National fisheries reform funding opportunities

National fiscal incentives can be a powerful source of investments for green fisheries since political economy problems that would normally be encountered in trying to raise funds at the regional and/or global levels can be avoided. Such sources of investment may be most effective when the distribution of fishery resources is fairly well contained within national boundaries. However, given the transboundary nature of many marine species such as tunas that are targeted by many countries, national funding programmes may fail to generate adequate funding to green some fisheries. Two fiscal incentive programmes that can be effective for funding fisheries investment are Environmental Fiscal Reform (EFR) and the redirection of harmful subsidies to green activities. These are:

**Environmental Fiscal Reform** refers to a range of taxation and pricing measures which can raise revenue while furthering environmental goals (OECD 2005). In the absence of taxation, the financial benefit from exploiting fisheries resources are fully captured by the private sector, without compensation to society at large. Additionally, individual operators have little direct incentive to restrict their catch, since they do not, individually, derive any direct benefits from doing so while others continue to over-exploit. Imposing levies on the volume of catch, in combination with proper management measures – which may include restricting access to fishing grounds – can be effective in both generating revenue to compensate the owners of the resource, (i.e., the country whose fishing stocks are being exploited) as well as create a natural incentive to reduce fishing effort.

**Redirection of Subsidies** or elimination redirecting existing harmful subsidies in the fisheries sector globally can provide a significant additional source of financing for greening the fisheries sector. Fisheries subsidies have been estimated at some US\$ 25-30 billion annually (Sumaila et al. 2010). Limiting subsidies to those used for management, the so-called, beneficial subsidies, would generate savings of about US\$ 19 billion annually, which can be reallocated to finance green fisheries initiatives.

### Regional financing arrangements

A regional financing facility or mechanism is one in which:

- the activities it funds are limited to a given region (e.g., the Coral Triangle in the Western Central Pacific or West Africa); and
- the arrangement's member countries from within a given region have a substantial role in decision-making (Sharan 2008).

Regional financing of the greening of fisheries is important for a number of reasons. First, while the issue of fisheries sustainability is a global one, it has strong regional dimensions as well. Obstacles and measures required to adapt depend on regional biological and political landscapes and as such, would not be identical for all regions. The decline of the fish stock and its impacts is unlikely to be confined within any one country, and one country would not be able to address such impacts alone. Thus, regional financing arrangements would strengthen the overall global collective action for greening fisheries. A regional approach also offers proximity benefits such as closer interaction and learning, and lower transaction costs. A regional financing arrangement can also attract additional resources within the region as countries feel that they are in charge of decisions. In this regard, Regional Fisheries Funds can be set up in various regions of the world.

### Private investment in fisheries reform

*Venture capital and private equity* – Consumers are increasingly sensitive to the wider impacts of unsustainable fishing practices as they are with climate change. The result has been consumer pressure for products that are certified as environmentally friendly or consistent with sustainability. Emerging high growth sectors have traditionally been a target for venture capitalists, who invest in entrepreneurial activities and expect high returns for their risks. Markets for sustainable products and services such as eco-tourism and certified seafood can present attractive sources of income for the management of protected areas and their surrounding communities. Enabling productive projects for private sector actors in protected areas, with specific profit sharing agreements, have the potential to be an important potential source of financing.

### Public-private partnership

While the public and private sectors have important roles to play in generating new sources of funding for greening the fisheries sector, the mechanism of a Public Private Partnership (PPP) where the public sector's investment is leveraged to attain private sector participation in projects with public good characteristics can be applied in the fisheries sector.

### Evaluation of financing options

There are a myriad of financing options that have been outlined above ranging from those best implemented at national or global scales and those operated by public or private entities. Given the common property nature over much of the world's oceans living resources, which is detrimental to the success of private investment, it is unlikely that this avenue can be expected to fill much of the needed investment. That said, where sufficient access rights and regulations exist, this environment has the potential to spawn a great deal of innovative

private business activity that can be effective in both greening fisheries as well as driving new employment opportunities and wealth creation.

In regions of the world where rights are difficult to implement or communities prefer other forms of management, it is clear that the public has a large role in investing in green fisheries. This is an opportunity for public funds to be used in an area that will create jobs and yield benefits for public resource owners. National

strategies such as environmental fiscal reform are likely to be successful in cases where fish stocks remain within national boundaries. In other cases where stocks travel between the boundaries of two or more countries, regional or global strategies such as market based levies combined with international cooperation have a great deal of potential. Even in cases where green investment is to operate at the national level, international cooperation on topics such as the redirection of fisheries subsidies can be highly influential in driving change.



## 5 Conclusions

Our analysis confirms that global marine fisheries are underperforming both in economic and social terms. Greening the fisheries sector by rebuilding depleted stocks and implementing effective management could increase the overall marine fisheries catch, and raise the economic contribution of ocean fish populations to the global economy.

While important efforts have been made in national fisheries administrations around the world, and through regional fishery management organisations, more is needed to enhance the management of the resources in a green economy context.

In order to achieve sustainable levels of fishing from an economic, ecological and social point of view, a serious reduction in current excessive capacity is required. Given the wide difference in the catching power, the job creation potential, and the livelihood implications of large-scale versus small-scale fishing vessels, it appears that a reduction effort focused on large-scale vessels could reduce overcapacity at lower socio-economic costs to society.

This chapter demonstrates that greening the fisheries sector would cost billions of dollars. However, the gains

from greening would more than pay for the investments. Most of the cost involves helping the fisheries sector adjust to lower fishing capacity, which is a prerequisite for greening the fisheries sector and keeping it economically viable over the long-term.

The contribution revealed that there are successful experiences with mechanisms to manage the transition and adjustment within the fishing industry, through vessel buyback programmes, compensation, provision of social security and retraining programmes for fishers, to learn from and build upon.

More investment is required to improve fisheries management in most parts of the world. This would enable a more effective implementation of all management tools that have proven to be effective, including stock assessments, monitoring and controlling programs, transferable and non-transferable quota systems, and expanding marine protected areas. In addition, strengthening fishery institutions both in national administrations and regional fishery management organisations would allow a more effective governance and management of resources within and outside nations' Exclusive Economic Zones.

# References

- Aas, Ø. (Ed.). (2008). *Global challenges in recreational fisheries*. Blackwell Publishing. Oxford University Press.
- Ackroyd, P., Hide, R. P., and Sharp, B. M. H. (1990). "New Zealand's ITQ System: Prospects for the Evolution of Sole Ownership Corporations". Report to the Ministry of Agriculture and Fisheries. Wellington, Lincoln University.
- Alder, J., Zeller, D., Pitcher, T., and Sumaila, R. (2002). "A method for evaluating marine protected area management". *Coastal Management*, 30(2), 121–131.
- Amend, D. F. (1989). "Alaska's Regional Aquaculture Associations Co-Management of Salmon in Southern Southeast Alaska". In E. Pinkerton (ed.), *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*. The University of British Columbia Press.
- Anonymous. (2008). "Canada Closes Newfoundland Cod Fisheries". *Environment News Service*. Available at: <http://www.ens-newswire.com/ens/apr2003/2003-04-28-05.html>.
- Anticamara, J.A., Watson, R., Gelchu, A., and Pauly, D. "Global fishing effort (1950-2010): Trends, gaps, and implications". *Fisheries Research* [in press].
- APEC. (2000). *Study into the nature and extent of subsidies in the fisheries sector of APEC member economies*. PricewaterhouseCoopers Report No. CTI 07/99T. 1-228.
- Arnason, R. (1995). *The Icelandic fisheries: evolution and management of fishing industry*. Fishing News Books, Oxford University Press.
- Barlow, C. (2008). Inland Fisheries in the Lower Mekong Basin – Importance, Challenges and Mechanisms to meet those challenges. Paper presented at the "International symposium: Sustaining fish diversity, fisheries and aquaculture in the Mekong Basin." Ubon Ratchathani University, Thailand, 3-5 September.
- Batstone, C., and Sharp, B. (1999). "New Zealand's quota management system: the first ten years". *Marine Policy*, 23(2), 177-190.
- Béné, C., Macfadyen, G., and Allison, E. H. (2007). *Increasing the contribution of small-scale fisheries to poverty alleviation and food security* (Vol. 481). Rome: FAO.
- Berkes, F. (1986). "Local level management and the commons problem: a comparative study of Turkish coastal fisheries". *Marine Policy*, 10(3), 215-229.
- Berkes, F., Mahon, R., McConney, P., Pollnac, R., and Pomeroy, R. (2001). *Managing Small-Scale Fisheries: Alternative Directions and Methods*. Canada: International Development Research Centre (IDRC).
- Bonzon, A. (2000). "Development of economic and social indicators for the management of Mediterranean fisheries". *Marine and freshwater research*, 51, 493-500.
- Bromley, D. W. (2009). "Abdicating Responsibility: The Deceits of Fisheries Policy". *Fisheries*, 34(6), 280-290.
- Cesar, H., Burke, L., and Pet-Soede, L. (2003). *The economics of worldwide coral degradation*. Amsterdam: Cesar Environmental Economics Consulting. Available at: <http://www.icran.org/pdf/cesardegradationreport.pdf>
- Cesar, H. S. (2002). "Coral reefs: their functions, threats and economic value". In H. S. Cesar (ed.), *Collected Essays on the Economics of Coral Reefs* (pp. 14-39). CORDIO, Kalmar University, Sweden.
- Charles, A. T. (2001). *Sustainable fishery systems*. Oxford, UK: Blackwell Science.
- Charles, A.T. (2002). "Use Rights and Responsible Fisheries: Limiting Access and Harvesting through Rights-based Management". In: *A Fishery Manager's Guidebook. Management Measures and their Application*. (Cochrane, K. (ed.) FAO Fisheries Technical Paper, No. 424, Food and Agriculture Organization of the United Nations, Rome, 231p.
- Charles, A. T. (2006). "Subsidies in Fisheries: An Analysis of Social Impacts within an Integrated Sustainable Development Framework". AGR/FI(2004)6. OECD. Published with the title "Social Impacts of Government Financial Support of Fisheries" as Chapter 7 in (OECD, editor) "Financial Support to Fisheries: Implications for Sustainable Development". Organization for Economic Co-operation and Development, Paris France.
- Charles, A. T., Burbidge, C., Boyd, H., Lavers, A. (2009). *Fisheries and the Marine Environment in Nova Scotia: Searching for Sustainability and Resilience*. GPI Atlantic, Nova Scotia, Canada.
- Cheung, W. W. L., Lam, V., Sarmiento, J. L., Kearney, K., Watson, R., and Pauly, D. (2009). "Projecting global marine biodiversity impacts under climate change scenarios". *Fish and Fisheries*, 10(3), 235–251.
- Cheung, W. W. L., Lam, V., Sarmiento, J. L., Kearney, K., Watson, R., Zeller, D., and Pauly, D. (2010). "Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change". *Global Change Biology*, 16(1), 24–35.
- Christensen, V., Ferdaña, Z., and Steenbeek, J. (2009). "Spatial optimization of protected area placement incorporating ecological, social and economical criteria". *Ecological Modelling*, 220(19), 2583-93.
- Christy, Francis T., Jr. (1982). "Territorial Use Rights in Fisheries: Definitions and Conditions". FAO Fisheries Technical Paper No. 227.
- Cisneros-Montemayor, A. M., and Sumaila, U. R. (2010). "A global estimate of benefits from ecosystem-based marine recreation: potential impacts and implications for management". *Journal of Bioeconomics*, 12(3), 245-268.
- Clark, C. W., Munro, G. R., and Sumaila, U. R. (2005). "Subsidies, buybacks, and sustainable fisheries". *Journal of Environmental Economics and Management*, 50(1), 47–58.
- Clark, C. W., Munro, G. R., and Sumaila, U. R. (2010). "Limits to the privatization of fishery resources". *Land Economics*, 86(2), 209.
- Clark, C. W. (1973). "The Economics of Overexploitation". *Science*, 181(4100), 630-634.
- Clark, C. W., Munro, G. R., and Sumaila, U. R. (2007). "Buyback subsidies, the time consistency problem, and the ITQ alternative". *Land Economics*, 83(1), 50.
- Clark, I. N., Major, P. J., and Mollett, N. (1989). "The development and implementation of New Zealand's ITQ management system". In *Rights Based Fishing* (pp. 117–45).
- Commission of the European Communities. (2004). "Promoting more environmentally-friendly fishing methods: the role of technical conservation measures". Communication from the Commission to the Council and the European Parliament.
- Cooley, S. R., and Doney, S. C. (2009). "Anticipating ocean acidification's economic consequences for commercial fisheries". *Environmental Research Letters*, 4, 024007.
- Costanza, R., Andrade, F., Antunes, P., den Belt, M., Boersma, D., Boesch, D. F., Catarino, F., et al. (1998). "Principles for sustainable governance of the oceans". *Science*, 281(5374), 198.
- Costello, C., Gaines, S. D., and Lynham, J. (2008). "Can Catch Shares Prevent Fisheries Collapse?" *Science*, 321(5896), 1678-1681.
- Cullis-Suzuki, S., and Pauly, D. (2010a). "Marine Protected Area Costs as "Beneficial" Fisheries Subsidies: A Global Evaluation". *Coastal Management*, 38(2), 113.
- Cullis-Suzuki, S., and Pauly, D. (2010b). *Failing the high seas: a global evaluation of regional fisheries management organizations*. Marine Policy, 34:5, 1036-1042.
- Dietz, T., Ostrom, E. and Stern, P. C. (2003). The struggle to govern the commons. *Science* 302, 1907–1912 (2003).
- Diaz, R. J., and Rosenberg, R. (2008). "Spreading dead zones and consequences for marine ecosystems". *Science*, 321(5891), 926.
- Dulvy, N. K., Rogers, S. I., Jennings, S., Stelzenmüller, V., Dye, S. R., and Skjoldal, H. R. (2008). "Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas". *Journal of Applied Ecology*, 45(4), 1029–1039.
- Dyck, A. J., and Sumaila, U. R. (2010). "Economic impact of ocean fish populations in the global fishery". *Journal of Bioeconomics*, 12(3), 227-243.
- EC. (2005). "Economic performance of selected European fishing fleets". *Annual report 2004*.
- EC. (2006). "Economic performance of selected European fishing fleets". *Annual report 2005*.
- Eide, A. (2007). "Economic impacts of global warming: The case of the Barents Sea fisheries". *Natural Resource Modeling*, 20(2), 199–221.
- Essington, T. E. (2009). "Ecological indicators display reduced variation in North American catch share fisheries". *Proceedings of the National Academy of Sciences*, 107(2), 754-759.
- FAO. (1992). *Marine fisheries and the law of the sea: A decade of change* (No. FAO Fisheries Circular No. 853). FAO, Rome.

- FAO. (2001). *International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing*. FAO, Rome.
- FAO. (2005). "Review of the state of world marine fishery resources". FAO Fisheries Technical Paper 457. FAO, Rome.
- FAO. (2007). *The State of World Fisheries and Aquaculture 2006*. FAO, Rome.
- FAO. (2009). *The State of World Fisheries and Aquaculture 2008*. FAO, Rome.
- FAO (2009a). *Food and Agricultural Organization of the United Nations Yearbook: Fishery and Aquaculture Statistics 2007*. FAO, Rome.
- Fox, K., Grafton Q., Kirkley J., Squires, D. (2003). "Property rights in a fishery: regulatory change and firm performance". *Journal of Environmental Economics and Management*, 46(1), 156-177.
- Froese, R., Pauly, D. (2003). Warnsignale aus Nordsee und Wattenmeer – eine aktuelle Umweltbilanz. In: J.L. JLozán, E. Rachor, K. Reise, J. Sündermann and v.H. Westernhagen (ed.) "Warnsignale aus Nordsee und Wattenmeer – eine aktuelle Umweltbilanz". GEO, Hamburg.
- Gallic, B. L. (2002). *Fisheries Sustainability Indicators: The OECD experience*. Joint workshop EEA-EC DG Fisheries-DG Environment on "Tools for measuring (integrated) Fisheries Policy aiming at sustainable ecosystems", Brussels, Belgium.
- Garcia, S. M., and Charles, A. T. (2007). "Fishery systems and linkages: from clockworks to soft watches". *ICES Journal of Marine Science*, 64(4), 580-587.
- Gibbs, M. T. (2009). "Why ITQs on target species are inefficient at achieving ecosystem based fisheries management outcomes". *Marine Policy*, 34(3).
- Gordon, H. S. (1954). The Economic Theory of a Common-Property Resource: The Fishery. *Journal of Political Economy*, 62(2), 124.
- Griggs, L., and Lugten, G. (2007). "Veil over the nets (unravelling corporate liability for IUU fishing offences)". *Marine Policy*, 31(2), 159-168.
- Hall, M. A. (1996). On bycatches. *Reviews in Fish Biology and Fisheries*, 6(3), 319-352.
- Hannesson, R. (2002). "The economics of fishing down the food chain". *Canadian Journal of Fisheries and Aquatic Sciences*, 59, 755-758.
- Hannesson, R. (1998). "Marine reserves: what would they accomplish?" *Marine Resource Economics*, 13(3), 159-170.
- Hannesson, R. (2007). "Buyback Programs for Fishing Vessels in Norway". In R. Curtis and D. Squires (eds.), *Fisheries Buybacks* (pp. 177-190). Oxford: Blackwell.
- Hannesson, R. (2004). *The privatization of the oceans*. Boston, Mass: MIT Press.
- Hardin, G. (1968). "The Tragedy of the Commons". *Science*, 162(3859), 1243-1248.
- Hatcher, A., and Robinson, K. (Eds.). (1999). *Overcapacity, overcapitalization and subsidies in European fisheries*. Proceedings of the first workshop held in Portsmouth, UK, 28-30 October, 1998.
- Hersoug, B. (2002). *Unfinished business: The Netherlands' experience with rights-based fisheries management*. Eburon.
- Hilborn, R., Orensanz, J. M., and Parma, A. M. (2005). "Institutions, incentives and the future of fisheries". *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360, 47-57.
- Hockey, P. A. R., and Branch, G. M. (1997). "Criteria, objectives and methodology for evaluating marine protected areas in South Africa". *South African Journal of Marine Science*, 18, 369-383.
- Holland, S. M., Ditton, R. B., and Graefe, A. R. (1998). "An ecotourism perspective on billfish fisheries". *Journal of Sustainable Tourism*, 6(2), 97-116.
- Hoyt, E., and Iñiguez, M. (2008). *The state of whale watching in Latin America*. Chippenham, UK; Yarmouth Port, USA; London, UK: WDCC; IFAW; Global Ocean. Available at: [http://www.wdcs.org/submissions\\_bin/WW\\_Latinamerica\\_English.pdf](http://www.wdcs.org/submissions_bin/WW_Latinamerica_English.pdf)
- Hoyt, E. (2001). *Whale Watching 2001: Worldwide Tourism Numbers, Expenditures and Expanding Socio Economic Benefits*. Yarmouth Port, MA, USA: IFAW.
- Kaschner, K., Watson, R., Trites, A. W., and Pauly, D. (2006). "Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model". *Marine Ecology Progress Series*, 316, 285-310.
- Khan, A., Sumaila, U. R., Watson, R., Munro, G., and Pauly, D. (2006). "The nature and magnitude of global non-fuel fisheries subsidies". *Fisheries Centre Research Reports*, 14(6), 5.
- Kuperan, K and Sutinen, J. G. (1998). "Blue Water Crime: Deterrence, Legitimacy, and Compliance". *Fisheries Law and Society Review*, 32(2) 309-338.
- Lam, V., Sumaila, U.R., Dyck, A., Pauly, D. and Watson, R. (2010). *Construction and Potential Applications of a Global Cost of Fishing Database*. Fisheries Centre Working Paper #2010-13, The University of British Columbia, Vancouver, B.C., Canada.
- Lery, J., Prado, J., and Tietze, U. (1999). *Economic viability of marine capture fisheries*. FAO Fisheries Technical Paper No. 377. FAO, Rome.
- Macinko, S. and Bromley, D., (2002). *Who owns America's fisheries?* Pew Ocean Science Series (1st ed.). Island Press.
- Macher, C., Guyader, O., Talidec, C., and Bertignac, M. (2008). "A cost-benefit analysis of improving trawl selectivity in the case of discards: The Nephrops norvegicus fishery in the Bay of Biscay". *Fisheries Research*, 92(1), 76-89.
- Martell, S, Walters C.W., Sumaila, U.R. (2009). "Industry-funded fishing licence reduction good for profits and conservation". *Fish and Fisheries*, 10, 1-12.
- Mason, F. (2002). "The Newfoundland cod stock collapse: a review and analysis of social factors". *Electronic Green Journal*, 1(17).
- McAllister, M., Pikitch, E., and Babcock, E. (2001). "Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding". *Can. J. Fish. Aquat. Sc.*, 58, 1871-90.
- McConney, P., and Charles, A. (2008). "Managing small-scale fisheries: Moving towards people-centered perspectives". In R. Q. Grafton, R. Hilborn, D. Squires, T. Maree, and M. Williams (eds.), *Handbook of Marine Fisheries Conservation and Management* (p. 20). Oxford University Press.
- Milazzo, M. (1998). *Subsidies in world fisheries: a re-examination* (World Bank Technical Paper. No. 406. Fisheries series). The World Bank., Washington, D.C.
- Morgan, L. E., & Chuenpagdee, R. (2003). *Shifting gears: addressing the collateral impacts of fishing methods in US waters*. Pew Science Series. Washington, DC.
- MIRAG. (2005). *Review of impacts of Illegal, Unreported and Unregulated fishing on developing countries: synthesis report*. London: Marine Resources Assessment Group Ltd.
- Munro, G., and Sumaila, U. (2002). "The impact of subsidies upon fisheries management and sustainability: the case of the North Atlantic". *Fish and Fisheries*, 3, 233-250.
- Munro, G. R. (2007). "Internationally Shared Fish Stocks, the High Seas, and Property Rights in Fisheries". *Marine Resource Economics*, 22(4), 425.
- Munro, G. R., Van Houtte, A., and Willmann, R. (2004). *The conservation and management of shared fish stocks: legal and economic aspects*. FAO, Rome.
- Naylor, R. L., Goldburg, R. J., Mooney, H., Beveridge, M. C., Clay, J., Folke, C., Kautsky, N., et al. (1998). "Nature's subsidies to shrimp and salmon farming". *Science*, 282.
- NRC (National Research Council). (1999). *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*. Washington, D.C., National Academy Press.
- Obeng, V. (2003). *Towards an appropriate economic management regime of tuna fisheries in Ghana*. Master of Science Thesis. Department of Economics, Norwegian College of Fishery Science, University of Tromsø, Norway.
- OECD. (2000). "Transition to responsible fisheries: economic and policy implications". Organization for Economic Cooperation and Development, Paris.
- OECD. (2004). *Review of fisheries in OECD countries. Country statistics 2000-2002*. Paris: Organization for Economic Cooperation and Development.
- OECD. (2005). *OECD-DAC Development Cooperation Report 2005*. Organization for Economic Cooperation and Development, Paris.
- Ostrom, E., Burger, J., Field, C., Norgaard, R., and Policansky, D. (1999). "Revisiting the commons: Local lessons, global challenges". *Science*, (284), 278-282.
- Pauly, D. (2006). "Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences". *Maritime Studies (MAST)*, 4(2), 7-22.
- Pauly, D. (2007). "The Sea Around Us Project: documenting and communicating global fisheries impacts on marine ecosystems". *Journal Information*, 36(4).
- Pauly, D., and Palomares, M. L. D. (2010). *An empirical equation to predict annual increases in fishing efficiency* (Fisheries Centre Working Paper No. 2010-07) (p. 12). Vancouver, BC: UBC. Available at: [ftp://ftp.fisheries.ubc.ca/FCWP/2010/FCWP\\_2010-07\\_PaulyPalomares.pdf](ftp://ftp.fisheries.ubc.ca/FCWP/2010/FCWP_2010-07_PaulyPalomares.pdf)
- Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., and Torres, F. (1998). "Fishing down marine food webs". *Science*, 279, 860-63.

- Pauly, D., Christensen, V., Gu  nette, S., Pitcher, T., Sumaila, U. R., Walters, C. J., Watson, R., et al. (2002). "Towards sustainability in world fisheries". *Nature*, 418, 685-695.
- Perry, L. A., Low, P. J., Ellis, J. R., and Reynolds, J. D. (2005). "Climate change and distribution shifts in marine fishes". *Science*, 308, 1912-1915.
- Petersson, E. (2009). "Inland Fish and Fisheries". In *Fisheries Sustainability and Development* (pp. 147-168). Royal Swedish Academy of Agriculture and Forestry.
- Pinkerton, E., and Edwards, D. (2009). "The elephant in the room: the hidden costs of leasing individual transferable fishing quotas". *Marine Policy*, 33, 707-713.
- Pitcher, T. J., and Hollingworth, C. E. (2002). *Recreational fisheries: ecological, economic and social evaluation*. Blackwell Science, Oxford, UK.
- Pontecorvo, G., Wilkinson, M., Anderson, R., and Holdowsky, M. (1980). "Contribution of the Ocean Sector to the United States Economy". *Science*, 208(4447), 1000-1006.
- Rice, J. (2003). "The British Columbia rockfish trawl fishery". In *Report and documentation of the International Workshop on Factors of Unsustainability and Overexploitation in Fisheries* (Vol. 700, pp. 161-187). Presented at the International Workshop on Factors of Unsustainability and Overexploitation in Fisheries, Mauritius, FAO, Rome.
- Rice, J., Shelton, P., Rivard, D., Chouinard, G., and Fr  chet, A. (2003). "Recovering Canadian Atlantic Cod Stocks: The Shape of Things to Come?" In *The Scope and Effectiveness of Stock Recovery Plans in Fishery Management* (International Council for Exploration of the Sea, No. CM 2003/U:06)
- Richards, A., and Hendrickson, L. (2006). "Effectiveness of the Nordm  re grate in the Gulf of Maine northern shrimp fishery". *Fisheries Research*, 81, 100-106.
- Roy, N., Arnason, R., and Schrank, W. E. (2009). "The Identification of Economic Base Industries, with an Application to the Newfoundland Fishing Industry". *Land Economics*, 85(4), 675.
- Sainsbury, K., and Sumaila, U. (2003). "Incorporating ecosystem objectives into management of sustainable marine fisheries, including 'best practice' reference points and use of marine protected areas". In M. Sinclair and G. Valdimarson (eds.), *Responsible fisheries in the marine ecosystem*. CAB International.
- Salas, S., Chuenpagdee, R., Seijo, J., and Charles, A. (2007). "Challenges in the Assessment and Management of Small-scale Fisheries in Latin America and the Caribbean". *Fisheries Research*, 87(1), 5-16.
- Sanchirico, J. N., and Wilen, J. E. (1999). "Bioeconomics of spatial exploitation in a patchy environment". *Journal of Environmental Economics and Management*, 37, 129-150.
- SCFO. (2005). *Northern cod: a failure of Canadian fisheries management* (Report of the Standing Committee on Fisheries and Oceans). Ottawa, Canada: Standing Committee on Fisheries and Oceans.
- Sethi, S. A., Branch, T. A., and Watson, R. (2010). "Global fishery development patterns are driven by profit but not trophic level". *Proceedings of the National Academy of Sciences*, 107(27), 12163.
- Sharan, D. (2008). *Financing Climate Change Mitigation and Adaptation. Role of Regional Financing Arrangements* (Sustainable Development Working Paper Series). Asian Development Bank.
- Sievanen, L., Crawford, B., Pollnac, R., and Lowe, C. (2005). "Weeding through assumptions of livelihood approaches in ICM: Seaweed farming in the Philippines and Indonesia". *Ocean and Coastal Management*, 48(3-6), 297-313.
- Srinivasan, U. T., Cheung, W. W. L., Watson, R., and Sumaila, U. R. (2010). "Food security implications of global marine catch losses due to overfishing". *Journal of Bioeconomics*, 12(3), 183-200.
- Sumaila, U. R. (1998). "Protected marine reserves as fisheries management tools: A bioeconomic analysis". *Fisheries Research*, 37, 287-296.
- Sumaila, U. R., Alder, J., and Keith, H. (2006). "Global scope and economics of illegal fishing". *Marine Policy*, 30, 696-703.
- Sumaila, U. R., Gu  nette, S., Alder, J., and Chuenpagdee, R. (2000). "Addressing ecosystem effects of fishing using marine protected areas". *ICES Journal of Marine Science*, 57, 752-760.
- Sumaila, U. R. (2010). "A Cautionary Note on Individual Transferable Quotas". *Ecology and Society*, 15(3), 36.
- Sumaila, U. R., and Cheung, W. W. L. (2010). *Cost of adapting fisheries to climate change* (Discussion Paper No. 5). Development and climate change (p. 27). The World Bank, Washington, DC.
- Sumaila, U. R., Marsden, A. D., Watson, R., and Pauly, D. (2007). "A Global Ex-vessel Fish Price Database: Construction and Applications". *Journal of Bioeconomics*, 9(1), 39-51.
- Sumaila, U. R., Khan, A. S., Dyck, A. J., Watson, R., Munro, G., Tydemers, P., and Pauly, D. (2010). "A bottom-up re-estimation of global fisheries subsidies". *Journal of Bioeconomics*, 12(3), 201-225.
- Sumaila, U. R., and Pauly, D. (2006). *Catching more bait: a bottom-up re-estimation of global fisheries subsidies*. Fisheries Centre, University of British Columbia.
- Swartz, W., Sala, E., Tracey, S., Watson, R., and Pauly, D. (2010). "The Spatial Expansion and Ecological Footprint of Fisheries (1950 to Present)". (S. A. Sandin, Ed.) *PLoS ONE*, 5(12), e15143. doi:10.1371/journal.pone.0015143.
- Teh, L., Cheung, W. W. L., Cornish, A., Chu, C., and Sumaila, U. R. (2008). "A survey of alternative livelihood options for Hong Kong's fishers". *International Journal of Social Economics*, 35(5), 380-395. doi:10.1108/03068290810861620.
- Thresher, R. E., Macrae, C. M., Wilson, N. C., and Gurney, R. (2007). "Environmental effects on the skeletal composition of deepwater gorgonians (Keratois spp.; Isididae)". *Bulletin of Marine Science*, 81, 309-422.
- Townsend, R. E., McColl, J., and Young, M. D. (2006). "Design principles for individual transferable quota". *Marine Policy*, 30, 131-141.
- Tseng, W., and Chen, C. (2008). "Valuing the potential economic impact of climate change on the Taiwan trout". *Ecological Economics*, 65(2), 282-291.
- Turris, B. R. (2000). "A comparison of British Columbia's ITQ fisheries for groundfish trawl and sablefish: similar results from programmes with differing objectives, designs and processes". *FAO Fisheries Technical Paper*, 254-261.
- Tydemers, P., Watson, R., and Pauly, D. (2005). "Fuelling global fishing fleets". *Ambio*, 34, 59-62.
- UNEP. (2003). *Fisheries Subsidies and Marine Resource Management: Lessons learned from Studies in Argentina and Senegal* (UNEP report). Geneva: The United Nations Environment Programme.
- UNEP. (2004). *A UNEP Update on Fisheries Subsidies and Sustainable Fisheries Management*. Geneva: The United Nations Environment Programme.
- UNEP. (2005). *Reflecting Sustainable Development and Special and Differential Treatment for Developing Countries in the Context of New WTO Fisheries Subsidies Rules*. Geneva: The United Nations Environment Programme.
- UNEP. (2006). *Indonesia: Integrated Assessment of the Poverty Reduction Strategy Paper with a Case Study on Sustainable Fisheries Initiatives*. Geneva: The United Nations Environment Programme.
- UNEP. (2008). *Role of supply chains in addressing the global seafood crisis*. Geneva: The United Nations Environment Programme.
- UNEP. (2011). *Fisheries Subsidies, Sustainable Development and the WTO*. Earthscan, London and Washington, D.C.
- United Nations. (2002). "Report of the World Summit on Sustainable Development". Presented in Johannesburg, South Africa, 26 August-4 September 2002, New York, USA.
- United Nations. (1995). "Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks" [dated 8 September 1995]
- Walsh, S., Godo, O., and Michalsen, K. (2004). "Fish behaviour relevant to fish catchability". *ICES Journal of Marine Science*, 61(7), 1238-1239.
- Walters, C. J., and Martell, S. J. D. (2004). *Fisheries ecology and management*. Princeton University Press.
- Watling, L., and Norse, E. A. (1998). "Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting". *Conservation Biology*, 12(6).
- Watson, R., Kitchingman, A., Gelchu, A., and Pauly, D. (2004). "Mapping global fisheries: sharpening our focus". *Fish and Fisheries*, 5(2), 168-177.
- Whitmarsh, D., James, C., Pickering, H., and Neiland, A. (2000). "The profitability of marine commercial fisheries: a review of economic information needs with particular reference to the UK". *Marine Policy*, 24, 257-263.
- Wicaksono, A., Putrawidjaja, M., and Amin, I. (2001). "Overview of Indonesian Coral Trade: Importance to Coastal Communities, Health and Safety Issues, User's Conflicts and Illegal Trade Concerns". In A. Brucker (ed.), *Proceedings of the International Workshop on the Trade in Stony Corals: Development of Sustainable Management Guidelines*. Jakarta, Indonesia.



Wilen, J. E. (2005). "Property rights and the texture of rents in fisheries". In D. Leal (ed.), *Evolving Property Rights in Marine Fisheries* (pp. 49-67). Rowman and Littlefield, Oxford, UK.

Wilson, R. W., Millero, F. J., Taylor, J. R., Walsh, P. J., Christensen, V., Jen, and Grosell, M. (2009). "Contribution of Fish to the Marine Inorganic Carbon Cycle". *Science*, 323(5912), 359-362.

Wingard, J. D. (2000). "Community transferable quotas: internalizing externalities and minimizing social impacts of fisheries management". *Human Organization*, 59, 48-57.

World Bank/FAO (2009) "The Sunken Billions: The Economic Justification for Fisheries Reform", World Bank and Food and Agriculture Organization, Washington D.C., Rome.

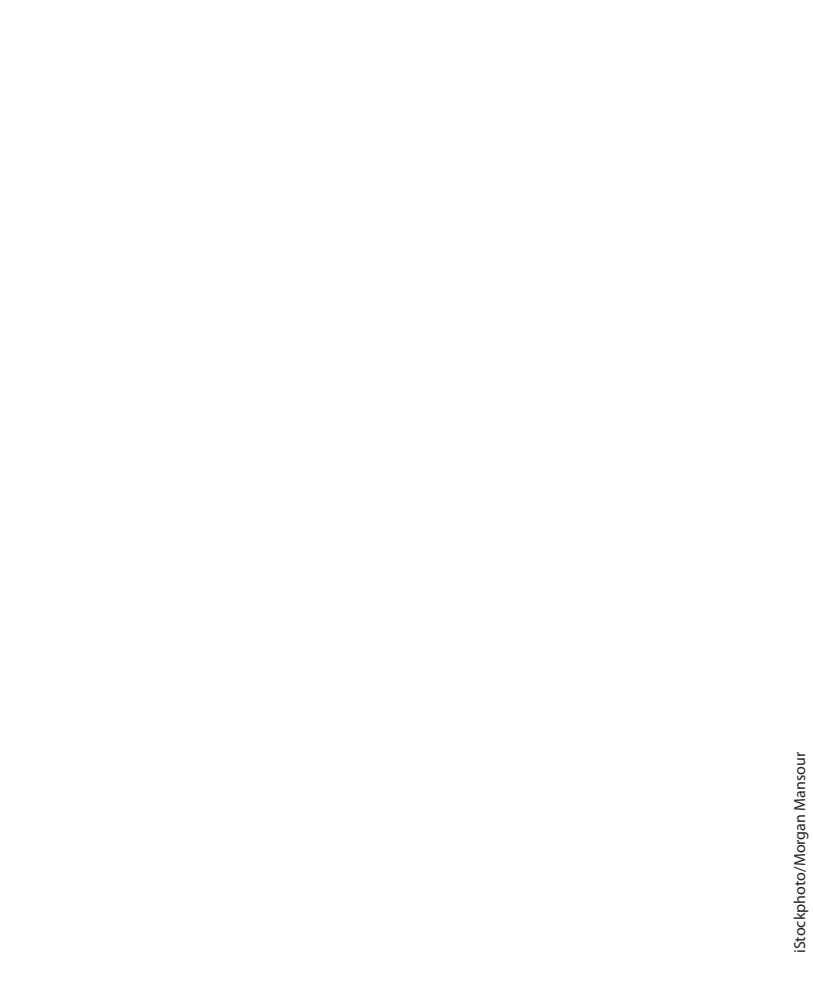
Wood, L. J., Fish, L., Laughren, J., and Pauly, D. (2008). "Assessing progress towards global marine protection targets: shortfalls in information and action". *Oryx*, 42(3), 340-351.

Worm, B., Hilborn, R., Baum, J. K., Branch, T., Collie, J. S., Costello, C., Fogarty, M. J., et al. (2009). "Rebuilding global fisheries". *Science*, 325, 578-585.

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., Jackson, J. B. C., et al. (2006). "Impacts of Biodiversity Loss on Ocean Ecosystem Services". *Science*, 314(5800), 787-790.

WWF. (2001). *Hard facts, hidden problems: A review of current data on fishing subsidies*. WWF, Washington, D.C.









# Water

Investing in natural capital



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## List of acronyms

BAU	Business-as-usual
BRIC	Brazil, Russia, India and China
CAGR	Compound Annual Growth Rate
CEWH	Commonwealth Environmental Water Holder
ESP	Environmental Service Program
FAO	Food and Agricultural Organization of the United Nations
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
IFPRI	International Food Policy Implementation
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
MDGs	Millennium Development Goals
MENA	Middle East and North Africa
OECD	Organization for Economic Co-operation and Development
PES	Payments for Ecosystem Services
RO	Reverse osmosis
RoW	Rest of the World
TEEB	The Economics of Ecosystems and Biodiversity
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USC	Ultra-Super Critical Technology
WHO	World Health Organization

# Key messages

**1. *Water, a basic necessity for sustaining life, goes undelivered to many of the world's poor.***

Nearly 1 billion people lack access to clean drinking water; 2.6 billion lack access to improved sanitation services; and 1.4 million children under five die every year as a result of lack of access to clean water and adequate sanitation services. At the current rate of investment progress, the Millennium Development Goal (MDG) for sanitation will be missed by 1 billion people, mostly in Sub-Saharan Africa and Asia.

**2. *The existing inadequacies in provision of water and sanitation services generate considerable social costs and economic inefficiencies.***

When people do not have access to water, either large amounts of their disposable income have to be spent on purchasing water from vendors or large amounts of time, in particular from women and children, have to be devoted to carting it. This erodes the capacity of the poor to engage in other activities. When sanitation services are inadequate, the costs of water-borne disease are high. Cambodia, Indonesia, the Philippines and Vietnam, for instance, together lose about US\$ 9 billion a year because of poor sanitation – or approximately 2 per cent of combined Gross Domestic Product (GDP). Access to reliable, clean water and adequate sanitation services for all is a foundation of a green economy.

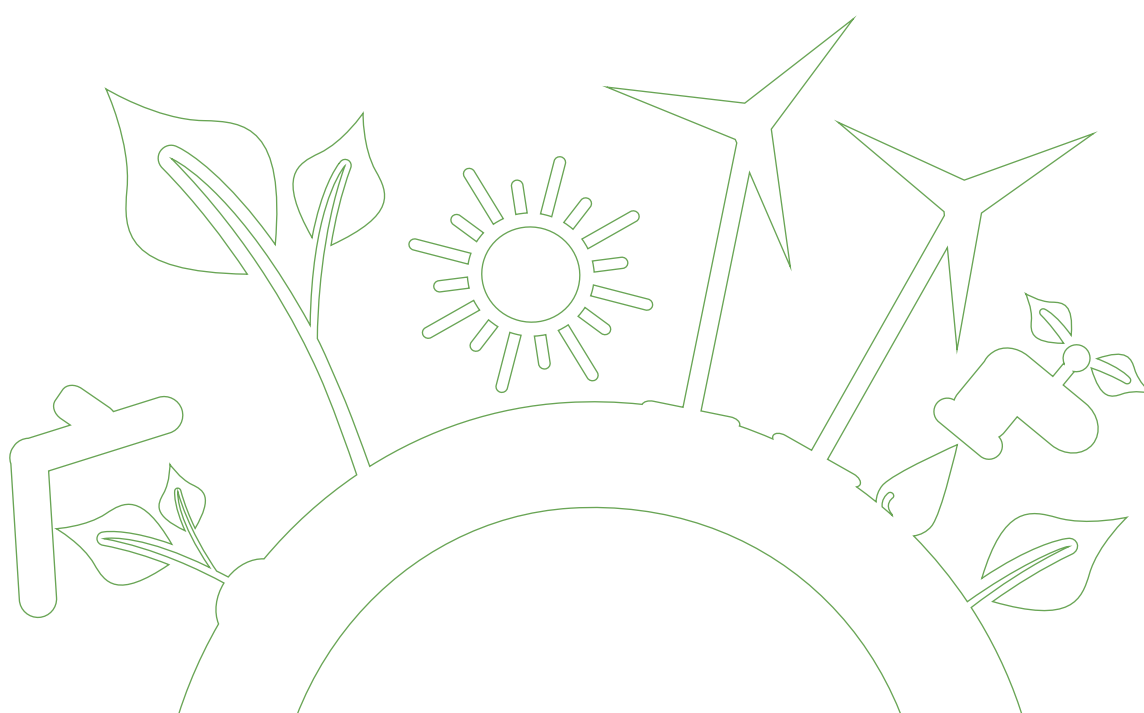
**3. *Continuing current practices will lead to a massive and unsustainable gap between global supply and demand for water withdrawal. This is exacerbated by failure to collect and treat used water to enable subsequent uses.***

With no improvement in the efficiency of water use, water demand is projected to overshoot supply by 40 per cent in 20 years time. Historical levels of improvement in water productivity, as well as increases in supply (such as through the construction of dams and desalination plants as well as increased recycling) are expected to address 40 per cent of this gap, but the remaining 60 per cent needs to come from investment in infrastructure, water-policy reform and in the development of new technology. The failure of such investment or policy reform to materialise will lead to the deepening of water crises.

**4. The availability of an adequate quantity of water, of sufficient quality, is a service provided by ecosystems.** The management of, and investment in, ecosystems is therefore essential to address water security for both people and ecosystems in terms of water scarcity, the over-abundance of water (flood risk) and its quality.

**5. Accelerated investment in water-dependent ecosystems, in water infrastructure and in water management can be expected to expedite the transition to a green economy.** Modelling suggests that, under the green investment scenario, global water use can be kept within sustainable limits and all the MDGs for water achieved in 2015. With an annual investment of US\$ 198 billion on average over the next forty years, water use can be made more efficient, enabling increased agricultural, biofuel and industrial production. By 2030, the number of people living in a water-stressed region is 4 per cent less than under BAU and up to 7 per cent less by 2050.

**6. When investment is coupled with improvements in institutional arrangements, entitlement and allocation system, the expansion of Payments for Ecosystem Services (PES), and the improvement of water charging and finance arrangements, the amount that needs to be invested in water can be reduced significantly.** Moreover, a significant proportion of water management policies and measures in other sectors such as input subsidies are undermining opportunities to improve water management. Resolving global water supply problems is heavily dependent upon the degree to which agricultural water use can be improved. Irrigated land produces 40 per cent of the world's food and, as populations grow, a significant proportion of this water will need to be transferred to urban, commercial and industrial uses.



# 1 Introduction

## 1.1 The aim of this chapter

This chapter has three broad aims. First, it highlights the need for providing all households with sufficient and affordable access to clean water supplies as well as adequate sanitation.

Second, it makes a case for early investment in water management and infrastructure, including ecological infrastructure. The potential to make greater use of biodiversity and ecosystem services in reducing water treatment costs and increasing productivity is emphasised.

Third, the chapter provides guidance on the suite of governance arrangements and policy reforms, which, if implemented, can sustain and increase the benefits associated with making such a transition.

## 1.2 Scope and definition

The scope of this chapter is restricted to freshwater ecosystems, the water supply and sanitation<sup>1</sup> sectors and the government and market processes that influence how and where this water is used.

The crucial contribution water makes to agriculture, fisheries, forestry, energy and industrial production is discussed in other chapters.

The perspective offered in this chapter is one that looks forward 20 years to 2030 and, where possible, to 2050. During the next 20 years, a considerable rise in demand for water of sufficient quantity and quality is expected and changes in local supply conditions are forecast.

The chapter builds on a substantial body of work undertaken in recent years by organisations and committees concerned about the way water resources are being managed.<sup>2</sup> To assist with its preparation, 11 background papers were prepared. References to these papers are marked in bold.

1. The World Health Organisation (WHO) defines "sanitation" as "the provision of facilities and services for the safe disposal of human urine and faeces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities. The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal." Available at <http://www.who.int/topics/sanitation/en/>

## Structure of the chapter

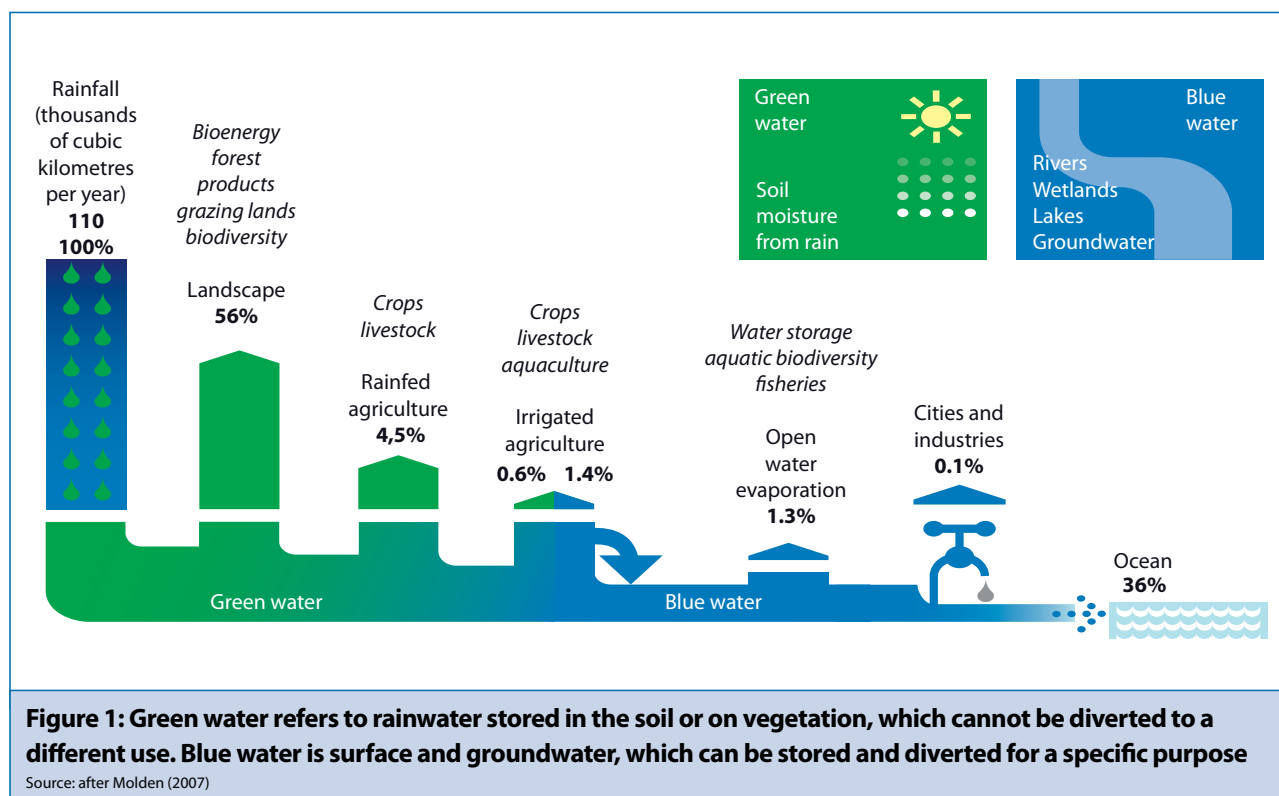
This chapter identifies the contribution that water can play in assisting a transition to a green economy. We first present a vision of the role that water ecosystems can play in the transition to a green economy and then provide an overview of the world's water resources and the services offered by the water supply and sanitation sector. After highlighting some of the more unique characteristics of water, we identify challenges and opportunities to make better use of water and water dependent ecosystems. Building on this knowledge base, the benefits of investing in the water supply and sanitation sector, as a means to assist with a transition to a green economy, are quantified. The chapter closes by identifying institutional reforms, which, if implemented, would increase the returns that could be gained from a commitment to a transition to a green economy.

## 1.3 Water in a green economy – A vision

As stressed in earlier chapters, in a green economy there is emphasis on the pursuit of opportunities to invest in sectors that rely upon and use natural resources and ecosystem services. At the same time, there is a transition to a suite of policy and administrative arrangements that neither degrade the environment nor impose costs on others. The interests of future generations are considered carefully. In the case of water, many of the potential gains are achieved simply by deciding to invest in the provision of water and sanitation services. Where water is scarce, this scarcity is acknowledged and managed carefully. Progress towards the pursuit of green objectives can be accelerated through the redesign of governance arrangements, the improved specification of property rights, the adoption of policies

2. The recommendations developed in this chapter have been significantly influenced by the:

- Development of the Dublin principles in 1992 which observes that "Water has an economic value in all its competing uses and should be recognized as an economic good" (Global Water Partnership 1992);
- Camdessus Report on financing water infrastructure that called for drastic improvements in accountability, transparency and capacity-building in the public utility sector coupled with a doubling of funding for the sector (Winpenny 2003);
- Guria Task Force Report on "Financing water for all", which recommends a transition to full cost recovery, the phasing out of subsidies and the devolution of responsibility for water supply and treatment to local government and municipalities (Guria 2006);
- World Commission on Dams (2000) which warned of the need to carefully assess the costs and likely benefits of major infrastructure investments;
- WHO's various reports on global water supply and sanitation; and
- 2030 Water Resources Group's report (2009) on ways to avoid water crises.



that reflect the full costs of use including the costs of adverse impacts on the environment, and through improved regulation. Use is kept within sustainable limits.

In green economies, the role of water in both maintaining biodiversity and ecosystem services and in providing water is recognised, valued and paid for. The use of technologies that encourage efficient forms of recycling and reuse is encouraged.

## 1.4 Measuring progress towards a green economy

In many countries, there is a lack of reliable data on the water-storage capacities of river basins, the condition of built infrastructure and the performance of the water supply and sanitation sector. One of the more significant opportunities to improve investment and management is to assemble data in a manner that enables water to be managed effectively and the performance of one region to be accurately compared with other regions.

Signposts of success in terms of progress towards a greener set of economic arrangements include:

- Recognition of the value of the benefits provided by good water management and costs (negative value) of not doing so;

- Evidence of increased investment in the water supply and sanitation sector that gives consideration to the environment;

- The formal definition of rights to use water and its allocation to users and the environment;

- Legislative recognition of the important role that ecosystem services can play in supporting an economy;

- Investment in the development of institutional capacity to manage ecosystems, including water, on a sustainable basis or using an ecosystem approach;

- The removal of policies that discourage ecosystem conservation and/or have perverse effects on water use and investment;

- Progress towards arrangements that reflect the full costs of resource use in ways that do not compromise the needs of disadvantaged people in a community; and

- Addressing ecosystem degradation by increasing efforts for restoring and protecting ecosystems critical to supply of water quantity and quality.

Indicators to be tracked include data on:

- The number of people without access to reliable supplies of clean water and adequate sanitation;



- The volume of water available per person in a region;
- The efficiency of water supply in the urban sector and water use;
- The efficiency of water use in the agricultural and industrial sectors; and
- The water use and water related impacts of companies and countries.

## 1.5 The world's water resources

Access to the world's water resources is heavily dependent upon the nature of the water cycle. While a massive amount of water reaches the earth's land surface, much less, around 40 per cent, makes its way into creeks, rivers, aquifers, wetlands, lakes and reservoirs, before cycling back into the atmosphere (see Figure 1). Of the water that is extracted for human purposes, on average, approximately:

- 70 per cent is used for agricultural purposes;
- 20 per cent is used by industry (including power generation); and
- 10 per cent is used for direct human consumption.

Given that the vast majority of usable fresh water is channelled towards agriculture, any global consideration of water allocation must consider the factors that determine the efficiency of water use in the sector. Irrigated land produces around 40 per cent of the world's food (Hansen and Bhatia 2004; **Tropp 2010**). One of the biggest challenges facing water managers is to find a way to significantly increase the productivity of irrigated agriculture so that water can be transferred to other sectors without adversely affecting the environment or food security. In many parts of the world there are few opportunities to enhance supplies at reasonable cost.

But general observations can be misleading. No two water bodies are the same. Managing large, complex, trans-boundary water systems typically requires a different approach to overseeing smaller water systems, where local issues are often all that need to be considered. In developing countries, water management and investment are typically geared towards reducing poverty and enabling economic development; the priority for developed nations tends to be maintaining infrastructure and supplying access to water at reasonable cost. In both cases, there is a need to focus more on long-term sustainability of the systems and services provided. Demand and supply also vary greatly. In Singapore, for example, almost all water is extracted for urban and industrial purposes, while in many other parts of the world, the majority of water is extracted for agricultural or mining purposes (Cosgrove and Rijsberman 2000).

## 2 Water: a unique natural resource

Unlike most other natural resources, water flows readily across and through landscapes in complex ways that affect its availability and opportunities to manage it. Understanding these water flows is critical to the design of investment programmes and policies necessary to support a transition to a green economy.

### 2.1 Services from natural infrastructure

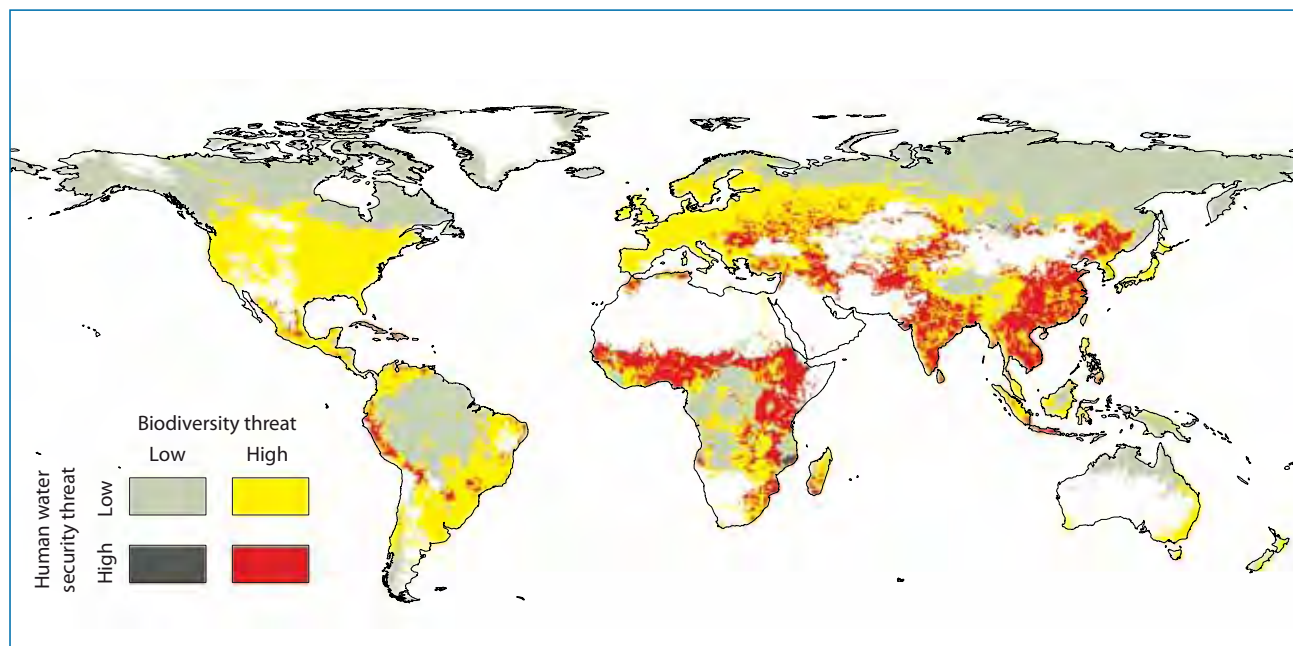
Water makes an irreplaceable contribution to ecosystem services that stem from the earth's natural capital and vice versa. Protecting the natural ecosystems of river basins and restoring degraded catchment areas is crucial to securing the world's water supplies, maintaining their quality, regulating floods and mitigating climate change (Khan 2010; TEEB 2008, 2009a, b, c). The role of other ecosystems, such as forests, wetlands and floodplains in providing access to water also needs to be recognised and quantified. Gauging the true value that these ecosystems provide is a key part of charting a course to a green economy.

Recent analysis is showing a close global correlation between the threats to biodiversity and threats to water security. As shown in Figure 2, regions where threats to

human water security is high, but the threat to biodiversity is low, are rare. When the threat to human water security is high, usually the threat to biodiversity is high. This suggests that there may be considerable opportunities for governments to improve biodiversity outcomes by investing in water security (Vörösmarty et al. 2010). Water-dependant ecosystems also play an important role in the provision of cultural benefits (Millennium Ecosystem Assessment 2005).

### 2.2 Water accounting

As water flows through and across land, it is used and reused. This makes information about water difficult to assemble and use for management. When, for example, a policy promotes a more efficient irrigation system, it is critical to decide whether or not the savings are to be used to expand irrigation or returned back to the river or aquifer from which the water was taken (Molden 1997). Gains in one area can be associated with losses in another area. When the savings are not returned back to the river or aquifer, the result can be a significant reduction in the quantity of water available to the environment and to other users (Independent Evaluation Group 2010).



**Figure 2: Prevailing patterns of threat to human water security and biodiversity. Adjusted human water security threat is contrasted against incident biodiversity threat. A breakpoint of 0.5 delineates low from high threat**

Source: Vörösmarty et al. (2010)

Another common water accounting error is to assume that ground and surface water systems are not connected to one another and to administer them separately. Many rivers play an important role in replenishing aquifers, while aquifers can provide much of a river's base flow (Evans 2007). Failing to account for these interactions can result in the serious problems of over-use and degradation. One administrative solution is to reverse the onus of proof and require managers to assume that ground and surface water resources are linked and manage them as a single connected resource until such time as disconnection can be shown (NWC 2009).

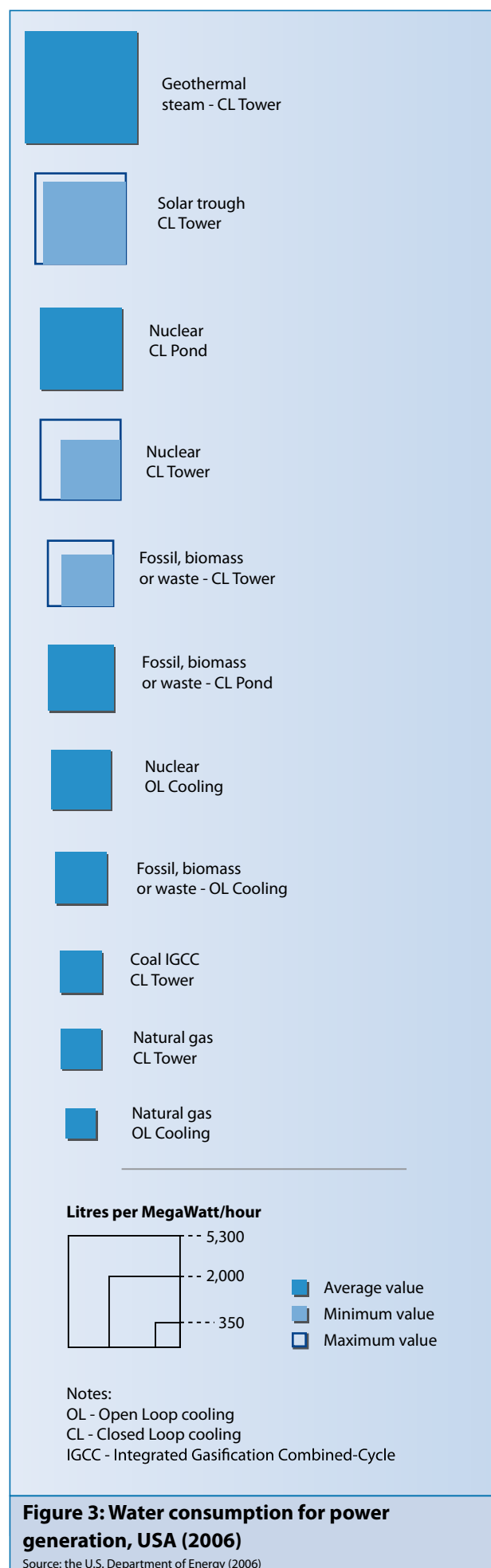
Land-use changes can have similar effects on the volume of water available for use. For example, whenever a plantation forest is established, a hillside is terraced, or a farm dam is constructed, run-off is usually reduced. As a result, the quantity of water available for extraction from a river or aquifer is less than it otherwise would be. Accounting for water in a way that is consistent with the hydrological cycle and that avoids double counting of its potential is critical to developing the robust allocation and management systems that underpin a green economy (Young and McColl 2008).

## 2.3 Water and energy

The interdependence of water and energy demands also needs careful attention as arrangements are put in place for a transition to a green economy. There are at least two dimensions to this relationship.

First, water plays an important role in energy generation, notably as a coolant in power stations. In the USA, for example, 40 per cent of industrial water-use is for power-station cooling (National Research Council 2010), although water-use efficiency varies with the technology used (Figure 3). By 2030, it is expected that 31 per cent of all industrial water-use in China will be for cooling power plants (2030 Water Resources Group 2009). Generally, as countries become wealthier and more populous, industrial demand for water is expected to increase. In China, more than half of the increase in demand for water over the next 25 years is expected to result from a significant expansion in its industrial sector (see Figure 10), which will need to be accommodated through a simultaneous reduction in the amount of water used for irrigation in the agricultural sector.

Second, the water supply and sanitation sector is a large consumer of energy. Relative to its value, water is heavy and in energy terms expensive both to pump over long distances and to lift. In California, USA, where large volumes of water are transported over long distances, the water sector consumes 19 per cent of the state's electricity and 30 per cent of its natural gas (Klein et al. 2005).



In developed countries, the relatively high energy costs of pumping and treating water for household, industrial or mining purposes are broadly accepted. In developing countries, great care must be taken to ensure that water treatment and distribution systems remain affordable. The relatively modest financial returns from food production in both developed and developing countries means it rarely pays to pump water over long distances for agricultural purposes. In recognition of this, Saudi Arabia has recently shifted its food security policy from one that subsidises water use at home to one that invests in the development of agriculture in other countries where water supplies are more abundant. This is enabling Saudi Arabia to access food at more affordable prices and use the revenue saved for other, more sustainable, purposes (Lippman 2010).

Appreciation of the nexus between water and energy highlights a set of green investment opportunities that are starting to emerge. In Durham, Canada, for example, a water efficiency field trial<sup>3</sup> was able to reduce water use by 22 per cent, electricity by 13 per cent and gas by 9 per cent, with a resultant annual reduction in CO<sub>2</sub> emissions of 1.2 tonnes per household – an 11 per cent reduction (Veritec Consulting 2008).

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3. The field trial took a sample of 175 households in the region of Durham, east of Toronto. The sample homes were given upgrades in efficient clothes washers, dishwashers, toilets, showerheads, fridges and landscape packages to quantify the potential water, energy, gas, and CO<sub>2</sub> savings from efficient fixtures, appliances and landscape design. To control and measure demand for each of the resources, sub-meters and data loggers were installed on fixtures and appliances within the home. The savings in resources could be attributed to both efficient fixtures and appliances and efficient water and energy use habits of the homeowners. The annual utility cost savings are expected to be more than US\$ 200 a year, which allows recovery of the additional installation cost in 3.4 years.

# 3 Challenges and opportunities

This section identifies the challenges associated with water scarcity and declining water quality in many parts of the world. It outlines opportunities for societies to manage their water resources more efficiently and to make the transition to a green economy. In doing so, societies can achieve the Millennium Development Goals.

## 3.1 Challenges

### Poverty, access to clean water and adequate sanitation services

Nearly 1 billion people lack access to clean drinking water and 2.6 billion lack access to improved sanitation services (WHO/UNICEF 2010).<sup>4</sup> As a direct result, every year,

4. WHO (2010) notes that rapid urbanization between 1990 and 2008 has led to an increased (urban) population of 40m not using water from improved sources and an increased (urban) population of 260m not using improved sanitation.

### Box 1: Economic impacts of poor sanitation

Together, Cambodia, Indonesia, the Philippines and Vietnam lose an estimated US\$ 9 billion a year because of poor sanitation (based on 2005 prices). This amounts to around 2 per cent of their combined GDP, varying from 1.3 per cent in Vietnam, 1.5 per cent in the Philippines, 2.3 per cent in Indonesia and 7.2 per cent in Cambodia.

The annual economic impact of inadequate sanitation is approximately US\$ 6.3 billion in Indonesia, US\$ 1.4 billion in the Philippines, US\$ 780 million in Vietnam and US\$ 450 million in Cambodia. In these four countries, the total value of this impact is US\$ 8.9 billion per year.

In 1991, a cholera epidemic swept through most of Peru<sup>6</sup> and cost US\$ 1 billion to control. If one tenth of this amount (US\$ 100 million) had been spent on the provision of sanitation services, the epidemic would not have occurred.

Source: World Bank – Water and Sanitation Program (2008) and Tropp (2010)

6. The epidemic also spread into several other countries in South, Central and North America.

1.4 million children<sup>5</sup> under the age of five die due to a lack of access to clean water and adequate sanitation services (UNICEF 2004). In east Nigeria and north Cameroon, every 1 per cent increase in use of unprotected water sources for drinking purposes is directly associated with a 0.16 per cent increase in child mortality (Ward et al. 2010).

Gleck (2004, 2009) argues that failure to provide people with affordable and reliable access to water and sanitation services is one of humankind's greatest failings. Lack of sanitation makes people sick. When water is unclean, water-borne diseases such as diarrhoea and water-washed diseases including scabies and trachoma are common (Bradley 1974). Diarrhoea is the third most common cause of child mortality in West Africa after malaria and respiratory infections (ECOWAS-SWAC/OECD 2008). New water-borne diseases such as the Whipple disease are still emerging (Fenollar et al. 2009).

The adverse impacts of water-borne disease on an economy can be large (Box 1). When people are sick, they cannot work and, among other costs, considerable expenditure on medical treatment is needed.

The adverse impacts of inadequate access to clean water, however, do not stop with water-borne disease. When water is not on tap, people (mainly women and children) must either spend a large amount of time fetching water or pay high prices for it to be carted to them. In Western Jakarta, Indonesia, the cost of water purchased from a water cart is ten to fifty times the full cost to a water utility of establishing a reliable mains water supply (Fournier et al. 2010). In certain circumstances, it is challenging to find a way to convince governments and private investors to go ahead despite a widespread perception that poor people are not able to pay for water (services) and that it is not cost-efficient to supply water to informal settlements. A lack of easy access to clean water also erodes the capacity of the poorest to engage in other activities. When children, for example, spend a large proportion of their days fetching water, they have less opportunity to attend school and obtain the education necessary to escape from poverty. When women are forced to spend time carting water, they have little opportunity for gainful employment elsewhere. More than a quarter of the population of East Africa live in conditions where every trip to collect water takes more than half an hour (WHO/UNICEF 2010).

5. 3,900 children per day.



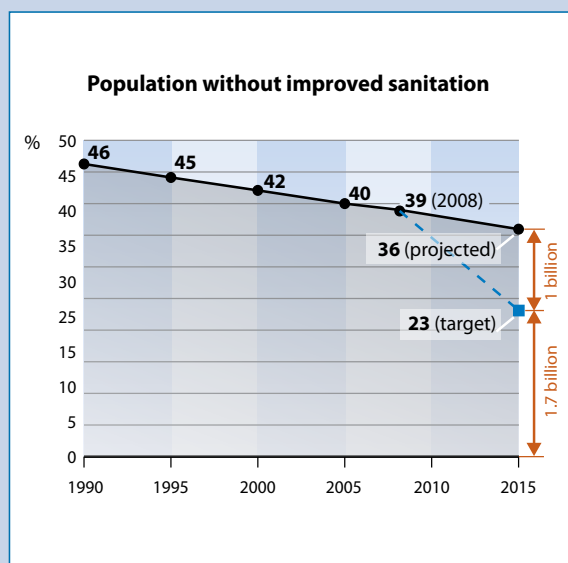
## Box 2: Millennium Development Goals and water

In 2000, governments committed to a wide range of Millennium Development Goals (MDGs) that rely upon access to water and made a specific commitment to halve the number of people without access to clean water and adequate sanitation by 2015.

The 2010 update on progress towards the water specific goals reports that 884 million – nearly 1 billion people – lack access to clean drinking water. When it comes to sanitation, 2.6 billion people do not have access to improved sanitation services. One in seven of those people without access to adequate sanitation services live in rural areas (WHO/UNICEF 2010).

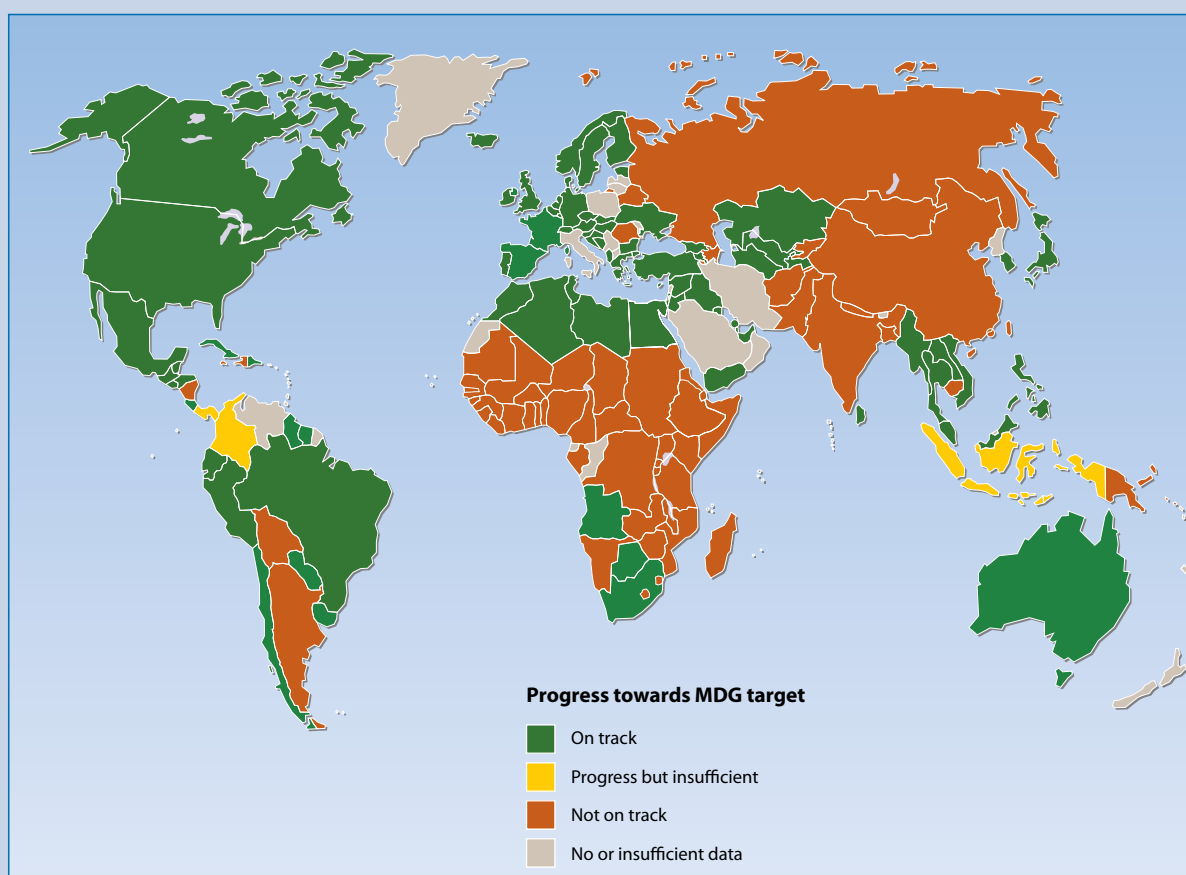
At the current rate of investment progress, the Millennium Development Goals for sanitation will be missed by 1 billion people (Figure 4). Most of these people live in sub-Saharan Africa and Asia (Figure 5).

Significant progress has been made in India and



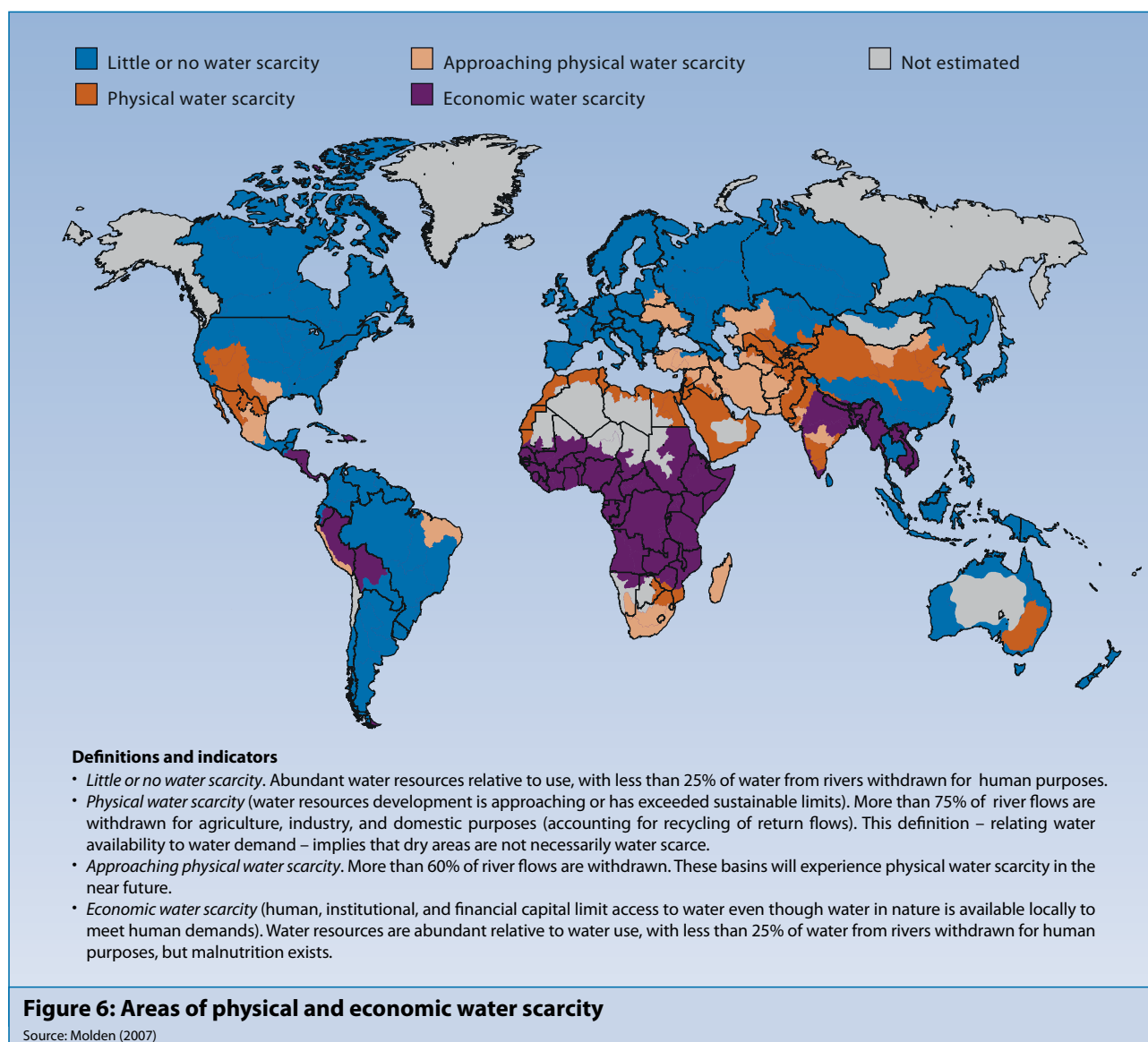
**Figure 4: Global progress towards MDGs' target to reduce the number of people without access to adequate sanitation services to 1.7 billion people by 2015**

Source: WHO/UNICEF (2010)



**Figure 5: Progress towards attainment of the MDGs' sanitation target to halve the number of people without adequate sanitation by 2015**

Source: WHO/UNICEF (2010)



From a government perspective, when water supply and sanitation services are inadequate, large amounts of revenue are spent dealing with the impacts of disease, rather than generating wealth (**Tropp 2010**).

In recognition of these fundamental and pressing challenges, governments have committed collectively to a set of MDGs, which, among other things, aim to halve the number of people without access to clean water and adequate sanitation services by 2015 (Box 2). By providing access to clean water and adequate sanitation services at an affordable price people can begin to save, invest and take a longer-term view of their future.<sup>7</sup> A transition to greener approaches to resource use and investment becomes possible.

### Water scarcity

Exploring opportunities to invest in the construction of dams, the International Water Management Institute

(IWMI) has identified two types of water scarcity: physical scarcity and economic scarcity (Figure 6). In regions where there is physical scarcity, the sustainable supply limit has been reached and little opportunity to construct more dams remains. In regions where the scarcity is economic, however, it is possible to increase supplies if the financial resources necessary to build a new dam can be found. The International Water Management Institute is of the view that economic scarcity is widespread in sub-Saharan Africa and in parts of South and South-East Asia (Molden 2007).

There is general consensus that when people have access to less than 1,700 cubic meters of water per year, a considerable proportion of them will be trapped in poverty (Falkenmark et al. 1989). Taking a different approach, the Organisation for Economic Cooperation and Development (OECD) defines water stress as “severe” when the ratio of total water use to renewable supply exceeds 40 per cent (OECD 2009). Using this measure, the OECD has estimated that by 2030 nearly half the world’s population (3.9 billion

7. In this context, Water, Sanitation and Hygiene (WaSH) initiatives, and specially the teaching of basic sanitation and hygiene to communities and school children will also prove critical.

people) will be living under conditions of severe water stress (Figure 7). The reasons for the emergence of this scarcity include:

■ **Population increase** – by 2030 the world's population will have increased by 2.4 billion people. All of these people will demand access to water for basic needs, to supply industrial goods and grow food;

■ **Increased living standards** – as countries develop and people become wealthier, they tend to consume more water and more water-intensive products such as meat;

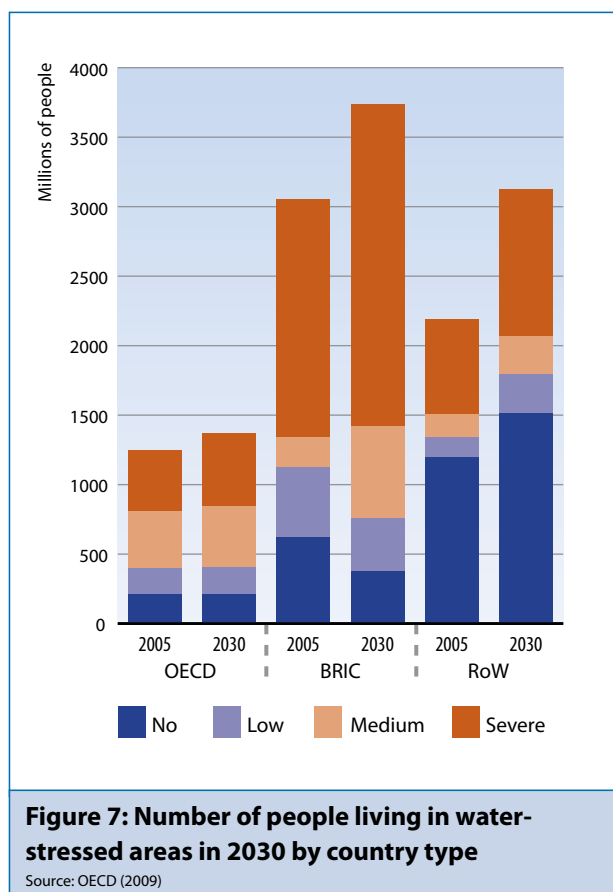
■ **Over-exploitation** – around the world a considerable proportion of aquifers and river systems are over-used. It has been estimated that 15 per cent of India's total agricultural production is being delivered via groundwater depletion – the situation that occurs when extraction exceeds replenishment (Briscoe and Malik 2006);

■ **Water pollution** – an increasing number of water supplies are becoming contaminated by pollutants, with the consequence that less water is available for use or it costs much more to make it usable;

■ **Ecosystem degradation** – over the last 50 years ecosystems have been degraded faster than ever before (Millennium Ecosystem Assessment 2005). Freshwater ecosystems, which provide critical services such as the purification of water by wetlands or forests are the most threatened and have been among the hardest hit, and;

■ **Adverse climate change**<sup>8</sup> – when combined with effects of climate change on dryland production systems, the International Food Policy Research Institute estimates that the aggregate effect of climate change is likely to be a significant reduction in total agricultural productivity. The greatest adverse impacts of climate change on people are expected in South Asia. In the next 40 years, child malnutrition is expected to increase by 20 per cent as a direct result of climate change (Nelson et al. 2009).

8. The IPCC Fourth Assessment Report lists 32 examples of major projected impacts of climate change amongst eight regions (covering the whole Earth). Of these: 25 include primary links to hydrological changes; of the other seven, water is implicated in four and two are general; only one refers to main impacts not obviously linked to the hydrological cycle: coral bleaching. The IPCC technical report (2008) underpinning this assessment report concludes unambiguously, inter alia, that: "the relationship between climate change and freshwater resources is of primary concern and interest". So far, "water resource issues have not been adequately addressed in climate change analyses and climate policy formulations"; and, according to many experts, "water and its availability and quality will be the main pressures, and issues, on societies and the environment under climate change". The Scientific Expert Group Report on Climate Change and Sustainable Development (2007) prepared for the 15th Session of the Commission on Sustainable Development came to similar conclusions.



### Balancing supply and demand

In an attempt to understand the magnitude of this emerging water-scarcity challenge, the 2030 Water Resources Group has projected global demand for water and, under different scenarios, compared it with likely supply. They concluded that if there is no improvement in the efficiency of water use, in 2030 demand for water could outstrip supply by 40 per cent (Figure 8). Clearly, a gap of this magnitude cannot (and will not) be sustained.

Figure 9 offers an alternative perspective on the magnitude of the emerging water-supply challenge. Under a business-as-usual scenario, improvements in water productivity can be expected to close around 20 per cent of the gap between global demand and supply. Increases in supply through the construction of dams and desalination plants, coupled with actions such as increased recycling, can be expected to close the gap by a similar amount. The remaining 60 per cent, however, must come from increased investment in infrastructure and water-policy reforms that improve the efficiency of water use. If the resources are not found to facilitate a significant increase in efficiency and if the water-policy reforms are not implemented, water crises must be expected to emerge. Figure 9 suggests that the average rate of improvement in water productivity and supply enhancement needs to increase at double the rate of improvement achieved in the past decade. Globally, the time for procrastination is past.

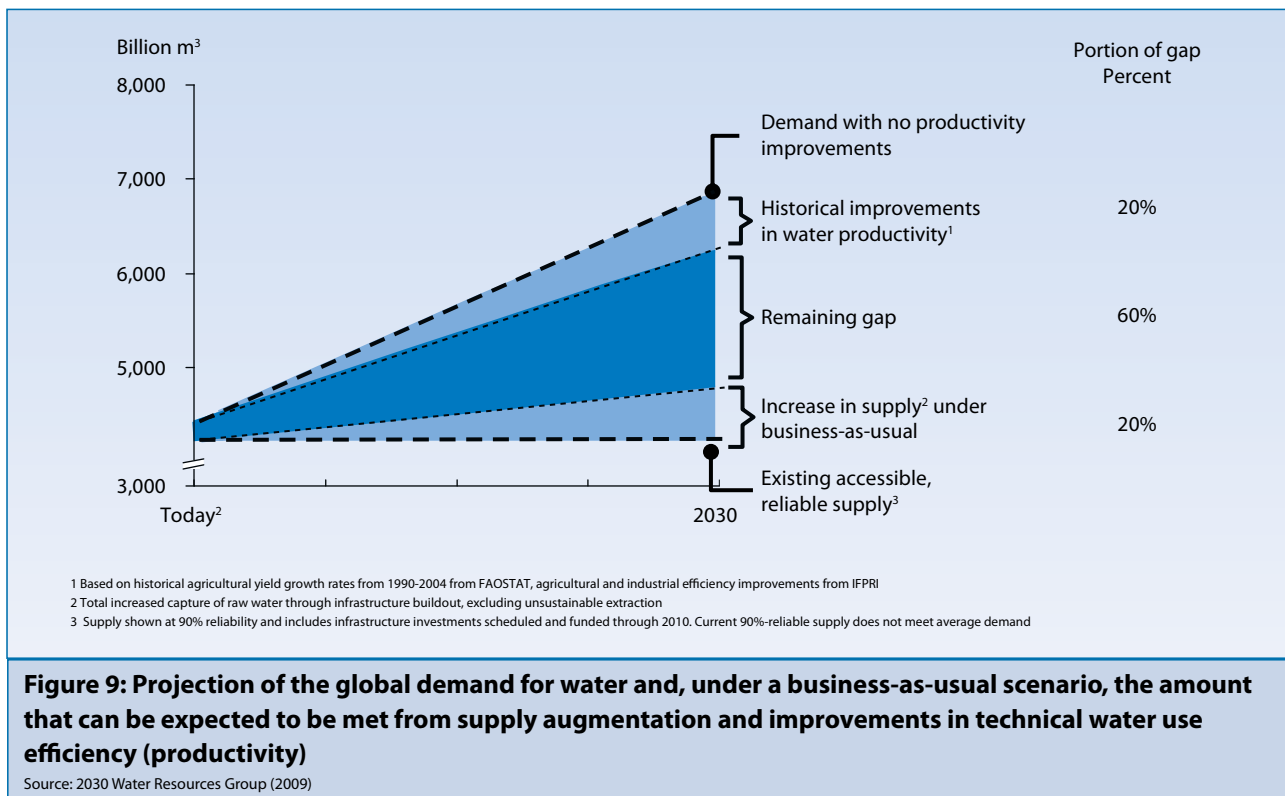
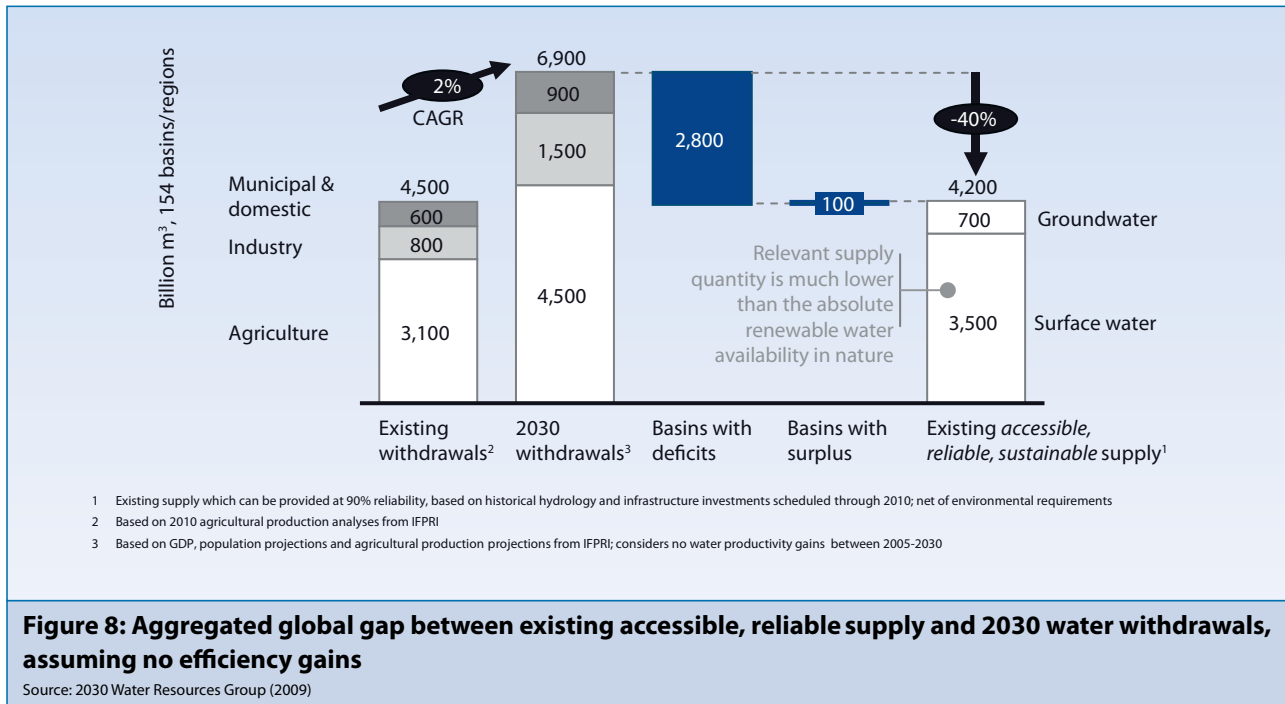


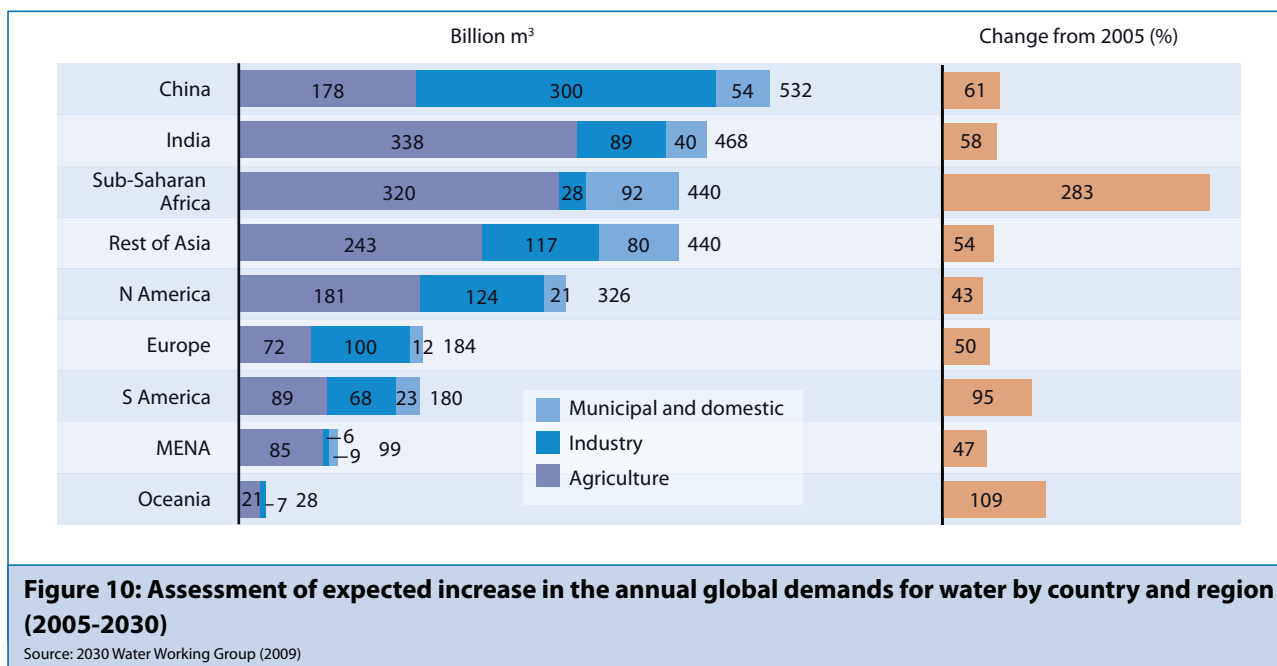
Figure 10 shows the nature of expected increase in demand for water throughout the world. As discussed, one of the more significant challenges is to find ways to supply more water to the industrial sector while increasing agricultural production. Significant transfers of water from rural areas to the industrial sector can be expected, especially in China and in North America (2030 Working Group 2009). In anticipation of the pressure that these shortages will place on water-dependent business, a number of large companies are beginning to quantify and account for their water use and water related impacts

and the nature of the water-related risks they face (Lloyds 2010; United Nations 2010a).

### 3.2 Opportunities

#### Investing in biodiversity and ecosystem services

In terms of ecosystem health and function, global assessments of the health of the world's water river systems and aquifers suggest that the aggregate trend



is one of decline (Millennium Ecosystem Assessment Report 2005; WWF's Living Planet Report 2010; the UN World Water Development Report 2010). Examples of this decline include:

■ Barriers have been laid across China's Taihu Lake to stop regular algal blooms reaching the water treatment plant that supplies water to over 2 million people (Guo 2007);

■ From October 2002 until October 2010, the absence of flow has meant that dredges have been used to keep the mouth of the Australia's River Murray open to the sea;

■ In Manila, the Philippines, groundwater extraction, primarily for industrial purposes, is lowering the water table at a rate of between 6 metres and 12 metres per year (Tropp 2010), and;

■ In 1997, China's Yellow River flowed all the way to the sea only for 35 days. For much of the year the river's last 400-plus miles were dry (Fu 2004).

There is a new recognition of the positive synergy that emerges between healthy environments and healthy communities. As documented by Le Quesne et al. (2010), some countries are now investing large amounts

### Box 3: Two examples of governments investing in river restoration

#### Korea

In July 2009, the Republic of Korea announced a Five-Year Plan (2009-2013) for Green Growth in order to implement the National Strategy for Green Growth. This includes a 22.2 trillion Korean Won (US\$ 17.3 billion) investment in a Four Major Rivers Restoration Project. The five key objectives of the project are as follows: (1) securing sufficient water resources against water scarcity, (2) implementing comprehensive flood control measures, (3) improving water quality whilst restoring the river-basin ecosystems, (4) developing the local regions around major rivers, and (5) developing the cultural and leisure space at rivers. Overall, it is expected that the project will create 340,000 jobs and generate an estimated 40 trillion Won (US\$ 31.1 billion) of positive economic effects as rivers are restored to health.

#### Australia

In January 2007, the Australian government announced a A\$ 10 billion (US\$ 10 billion) commitment to restore health to the seriously over-allocated Australia's Murray Darling basin and appoint an independent authority to prepare a new plan for the basin using the best available science. Some A\$ 3.1 billion is being spent on the purchase of irrigation entitlements from irrigators and the transfer of these entitlements to a Commonwealth Environmental Water Holder, A\$ 5.9 billion on the upgrade of infrastructure with half the water savings going to the environment, and A\$ 1 billion on the collection of the information necessary to plan properly.

Sources: Office of National River Restoration (under the Ministry of Land, Transport and Maritime Affairs) (2009); Korean Ministry of Environment and Korea Environment Institute (2009) and Murray Darling Basin Authority (2010). Available at <http://www.theaustralian.com.au/news/nation/prime-ministers-10-billion-water-plunge/story-e6frg6nf-1111112892512>



Biome/ecosystem	Typical cost of restoration (high-cost scenario)	Estimated annual benefits from restoration (avg. cost scenario)	Net present value of benefits over 40 years	Internal rate of return	Benefit/cost ratio
		US\$/ha	US\$/ha	%	Ratio
Coastal	232,700	73,900	935,400	11%	4.4
Mangroves	2,880	4,290	86,900	40%	26.4
Inland wetlands	33,000	14,200	171,300	12%	5.4
Lake/ivers	4,000	3,800	69,700	27%	15.5

**Table 1: Examples of the estimated costs and benefits of restoration projects in different biomes**  
Source: Adapted from TEEB (2009a)

of money in the restoration of degraded river systems and the development of policies and administrative arrangements designed to prevent degradation of these systems. Two examples are summarised in Box 3. Table 1 summarises the general nature of returns to investment in the restoration of ecosystems. When astute investments in the restoration of ecosystems are made, internal rates of return in excess of 10 per cent are attainable.

#### Investment in sanitation and drinking water supply

In many developing countries, one of the biggest opportunities to expedite a transition to a green economy is to invest in the provision of water and sanitation services to the poor.

A recent estimate puts the cost of achieving the 2015 MDGs at US\$ 142 billion per year for providing sanitation services and US\$ 42 billion per year for drinking water supply to households (Hutton and Bartram 2008b). More investment is required for sanitation services than drinking water as the number of households without access to adequate sanitation services is much higher (WHO/UNICEF 2010; **Tropp 2010**).

Although the amount of money needed to attain the MDGs for water is considerable, when spread over a number of years and divided by the number of people expected to benefit from such expenditure, the investment case is strong. In Ghana, for example, the OECD estimates that investment of US\$ 7.40 per person per year over a decade would enable the country to meet its MDG target (Sanctuary and Tropp 2005). Estimates of the required per capita expenditure in Bangladesh, Cambodia, Tanzania and Uganda range from US\$ 4 to US\$ 7 per capita per year (UN Millennium Project 2004; **Tropp 2010**).

Taking a different approach, Grey (2004) has estimated the amount that each sub-Saharan country would need to spend to achieve water supply and sanitation standards now achieved in South Africa. Depending on the country, the amount needed to be spent varied from US\$ 15 to

US\$ 70 per capita per year over the 10 years from 2005 to 2015.

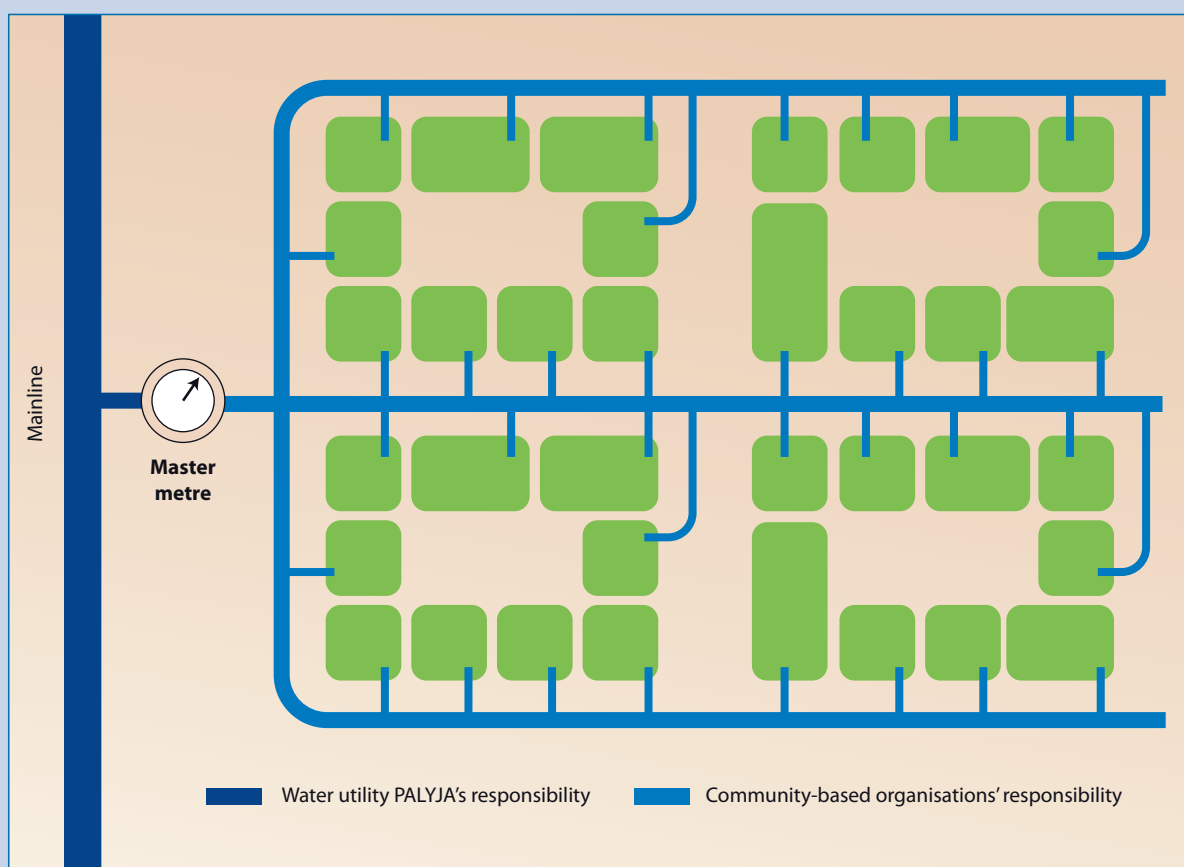
As shown later in this chapter, returns to investment in the provision of these services can be high. In particular, Sachs (2001) has found that the average rate of economic growth in developing countries where most of the poor have affordable access to clean water and adequate sanitation is 2.7 per cent greater than that attained in countries where these services are not well supplied.<sup>9</sup> This observation, reinforced by background papers prepared for this chapter (**Tropp 2010; Ward et al. 2010**), suggests that failure to invest adequately in the provision of affordable access to clean water and adequate sanitation acts as a barrier to development and that early investment in these areas is a necessary precondition to progress. Grey and Sadoff (2007) argue that a minimum amount of investment in water infrastructure is a necessary precondition to development; using a range of case studies, they identify a close association between adequate investment in infrastructure and environmental degradation.

#### Investing in smaller, local water-supply systems

As observed by **Schreiner et al. (2010)**, the presence of economic water scarcity should not be interpreted as a recommendation for the construction of large dams. In many cases, greater returns can be achieved from the construction of smaller storages that are built by and serve local communities. At this scale, community engagement and management of infrastructure is easier and adverse environmental impacts tend to be fewer in both urban and rural settings (Winpenny 2003).

In China's Gansu province, for example, investment in the collection of local rainwater at a cost of US\$ 12 per capita was sufficient to enable a significant upgrade of

9. Sachs (2001) estimated that the rate of growth in GDP per capita in countries where most of the poor had access to clean water and adequate sanitation services was 3.7 per cent. When these services are not available, however, he found that the average annual rate of growth in GDP per capita was 1.0 per cent.



**Figure 11: Schematic representation of a master meter system managed by a community-based organisation**

### Box 4: Micro-scale infrastructure provision in Western Jakarta

In Jakarta, Indonesia, a significant proportion of the population lives in informal settlements. While the government does not want to legitimise the unlawful occupation of land, it realises that the provision of access to safe water and sanitary conditions is necessary. A private water utility, PALYJA, is responsible for water supply in Western Jakarta and it is expected to supply water to all residents, including those in informal settlements. To this end, PALYJA has a water-supply contract with the government whereby they are paid for the cost of delivering water to users and for the cost of building and maintaining the necessary infrastructure.

As part of this process, PALYJA is trialling the provision of access to groups of informal houses by establishing

community-based organisations. Each organisation is given access to a single master water meter and is responsible for the management of the community's water-supply infrastructure as well as paying for the volume of water taken (Figure 11). MercyCorps has helped connect 38 households to a single meter, while USAID's Environmental Service Program (ESP) has brought 58 households together. Once established, the community signs a supply contract with PALYJA, with a special tariff arrangement to account for the fact that many households are using a single meter. Under this arrangement, both sides benefit: the community gets reliable access to an affordable waste supply, while PALYJA supplies a large number of houses with water at much lower overhead and administrative costs.

Source: Fournier et al. (2010)

domestic water supplies and to supplement irrigation. One project benefited almost 200,000 households (Gould 1999). At the micro-scale, it is possible to make much greater use of aid organisations and

local knowledge. In Western Jakarta, for example, the local water utility is working with non-government organisations to provide water to people in informal settlements in a manner that would be impossible

for a government utility to do so without being seen to sanction the presence of these settlements (see Box 4).

#### **Accessing new (non-traditional) sources of water**

One of the most common approaches to resolving water-supply problems is to build a large dam. Constructing them typically involves significant cost, the dislocation of many people and many adverse environmental problems.<sup>10</sup> **Schreiner et al. (2010)** observe that urban communities have historically relied on large dams for their water supplies. More recently, however, water-supply options have expanded to include the capture and storage of stormwater and desalination, fog interceptions in cloud forests (notably in the Andes mountains), transfers between islands, inter-basin water transfers, bulk transport such as by pipeline or Medusa bags (giant polyfibre bags holding up to 1.5 billion litres of potable water that are towed by ships). Other communities and countries are investing in sewage recycling. Singapore, for example, has invested in the development of systems that treat sewage to a standard allowing it to be used for drinking purposes. Most of these technologies, however, are reliant upon the use of increasing amounts of energy and, as a result, the costs of water provision are rising in most regions where there is physical water scarcity.

Desalination has the advantage that it is climate independent but, as with most of these alternative sources of supply, is disadvantaged by the fact that it requires access to large amounts of energy. Usually, sewage recycling is cheaper than desalination as it uses the same reverse osmosis technology, but requires about half as much energy per unit of water treated (Côté et al. 2005). Public opposition to household use of recycled sewage water, however, is strong (Dolnicar and Schäfer 2006). A careful assessment of the costs of these alternative sources of supply often reveals that

it is cheaper to invest in demand control (**Beato and Vives 2010; 2030 Water Working Group 2010**). In a green economy, there is much more attention to the long-term costs and impacts of resource use on the environment.

#### **Producing more food and energy with less water**

As the world's population increases, more water will be needed for household and industrial purposes with the consequence that in many areas, either more food will have to be imported, or more food produced with less water. When asked, "Is there enough land, water, and human capacity to produce food for a growing population over the next 50 years – or will we 'run out' of water?", analysis undertaken by the International Water Management Institute (IWMI) reveals that, "It is possible to produce the food – but it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world" (Molden 2007).

For example, in many developing countries, typical irrigated maize yields are in the vicinity of one to three tonnes per hectare, whilst they could be as high as eight tonnes per hectare. There is a significant opportunity to increase crop yields and avoid a global food security crisis. If this opportunity is realised, then not only will it also be possible to divert water to other uses, but it will also be possible for developing countries to produce a surplus for sale to others.

#### **Institutional reform**

When coupled with more traditional hard approaches to investment in built infrastructure, the softer approach of developing more effective administrative arrangements and policies that encourage private investment can significantly reduce the amount of money that governments need to invest in the water sector to achieve the same outcome. Opportunities of how to do this are developed in section 5. Typically, soft approaches focus on incentives and the factors that motivate consumers to manage their water use.

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10. For an authoritative response to the controversies surrounding large dams, see World Commission on Dams (2000).

## 4 The economics of greening water use

Research around the world suggests that there are no single-shot solutions to the world's mounting water access, sanitation and scarcity problems. Each circumstance has its own unique set of challenges and opportunities. At the most general level, it is becoming apparent that the best results come for the pursuit of mixed solutions. Simple single-shot solutions tend to be prohibitively expensive and, in many cases, are insufficient to solve known supply problems (**2030 Water Resources Group 2010**). In the Zambezi Basin, it has been estimated that even full development of the area's irrigation potential would benefit no more than 18 per cent of its rural poor (Björklund et al. 2009). A much more sophisticated investment strategy is needed (**Ménard and Saleth 2010**).

### 4.1 The economics of investing in water and ecosystems

Under the global model developed for the Green Economy Report by the Millennium Institute, the green investment scenario assumed investment in the water supply and sanitation sector would equal that estimated by Hutton and Bartram (2008b) as necessary to achieve the MDGs for water by 2015. Once this is achieved, it is assumed that governments will decide, once again, to halve the number of people without access to a reliable mains water supply and adequate sanitation. This new goal is achieved in 2030. Any funds left over during this second period are allocated to other water-related investments. In areas where there is economic water scarcity, priority is given to the construction of dams. In other areas, investment is channelled into making water-use more efficient. Where possible, and economically appropriate, desalination plants are constructed. These are assumed to supply water into the urban sector at a cost of US\$ 0.11/m<sup>3</sup> – in constant US\$ 2010, same unit for monetary values below.

Under the business-as-usual scenario, water use remains unsustainable and stocks of both surface and groundwater decline. Under the green investment scenario, global water use is kept within sustainable limits and all the MDGs for water are achieved in 2015. Water use is more efficient, resulting in increased agricultural, biofuel and industrial production. The number of people living in a water-stressed region is 4 per cent less under the green investment scenario by 2030 compared to business-as-usual, up to 7 per cent by 2050.

The results from this modelling are encouraging in terms of both economic terms and from the perspective

		2% GDP invested in green sectors	
	Unit	2030	2050
Additional investment in water sector	US\$ Bn/year	191	311
Additional water from desalination	Km <sup>3</sup>	27	38
Water from efficiency improvements (driven by green investments)	Km <sup>3</sup>	604	1,322
Total employment in the water sector	Mn people	38	43
Change in total employment in the water sector relative to BAU2*	%	-13	-22

\*The water-related investments are part of an integrated green investment scenario, G2, in which a total of 2 per cent of global GDP is allocated to a green transformation of a range of key sectors. The results of this scenario, in which the 2 per cent is additional to current GDP, is compared to a corresponding scenario in which an additional 2 per cent of global GDP is allocated following existing business-as-usual trends, BAU2 (see Modelling chapter for more detailed explanation of scenarios and results).

**Table 2: Modelled results of the Green Investment scenario**

of water management (Table 2). For 2050, total employment and income is greater under the green investment scenario, whereas the number of people working in the water sector is lower. This counter-intuitive finding occurs because the sector becomes much more efficient. Labour and other resources, which, under BAU2 would have been retained in the water sector, are freed for use in other sectors. In addition, as water is used more efficiently, more is available for manufacturing and other purposes with the result that more people are gainfully employed.<sup>11</sup>

The overall conclusion from this assessment is that, where there is water scarcity or when large proportions of a population do not have access to adequate water supply and sanitation services, early investment in water is a necessary precondition to progress.

### 4.2 Selecting projects and initiatives for investment

While it is useful and informative to examine the economics of investing in water at the global level, investments must be made primarily at the river basin, catchment and local level.

11. These findings are consistent with those of Hagos et al. (2008) who found that, as access to water improves, employment in other sectors expands.

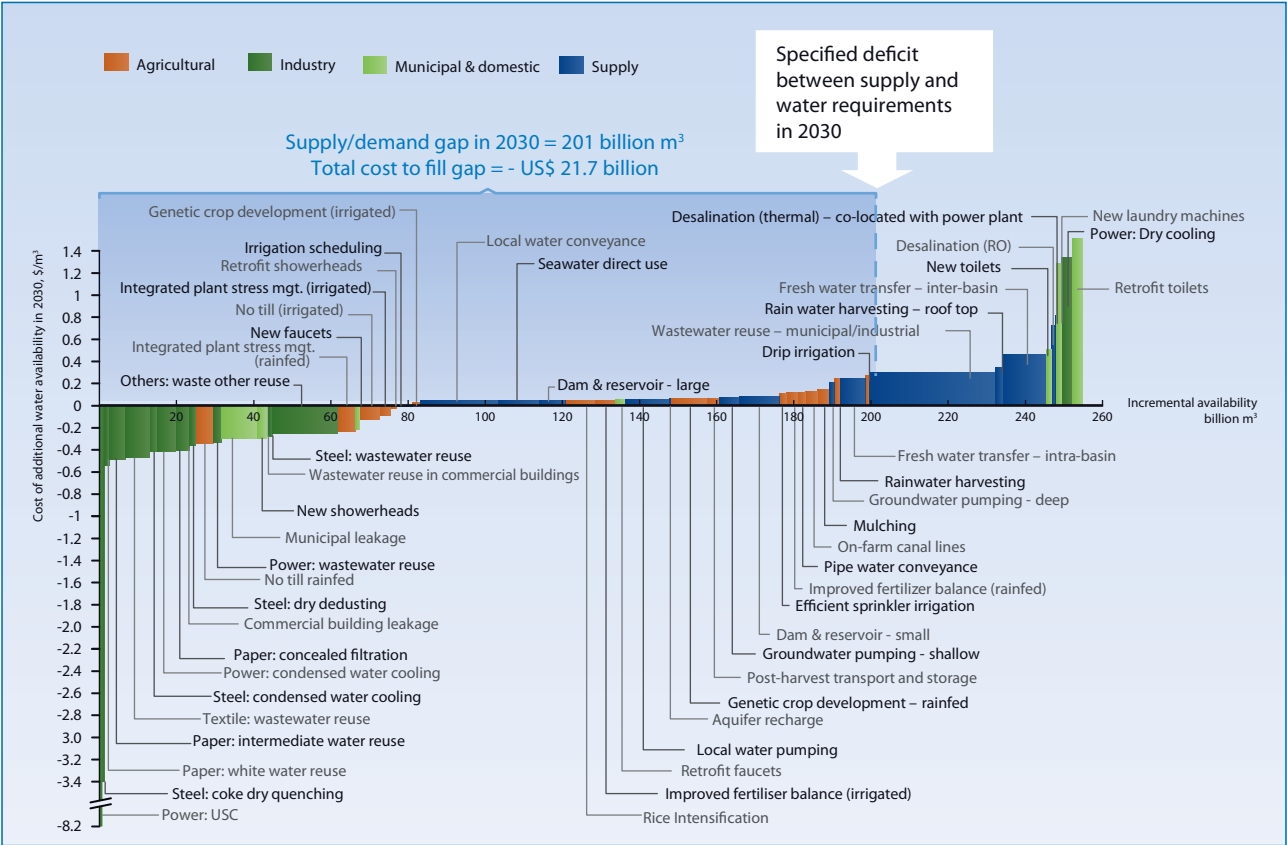


Figure 12: Relative costs of different methods of supplying water in China

Source: 2030 Water Working Group (2009)

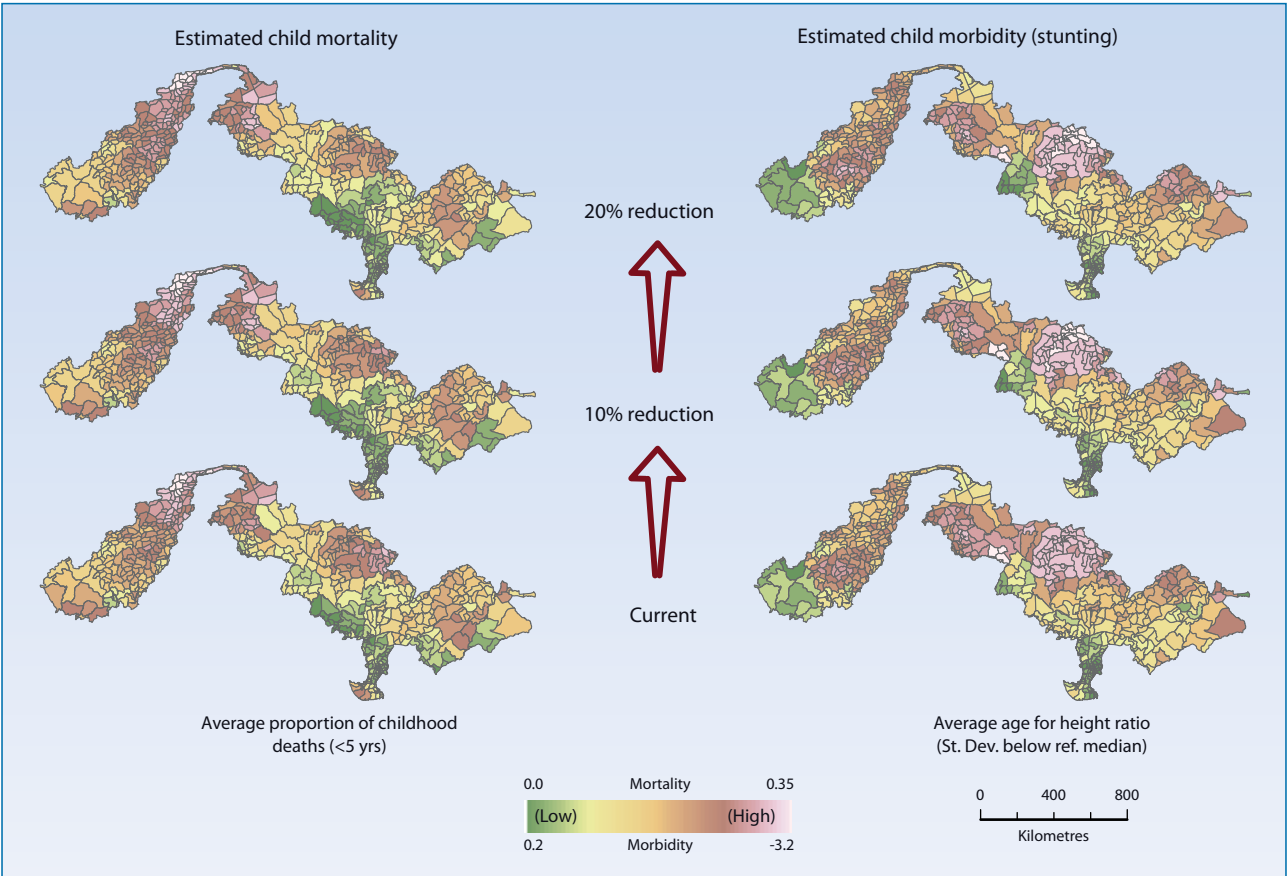


Figure 13: Predicted effect of a 10 per cent and 20 per cent reduction in the proportion of people obtaining their primary water supply from surface water or unprotected well water on child mortality and child morbidity (stunting), Niger River basin

Source: Ward et al. (2010)



In areas where the costs of enhancing water supplies from traditional sources are rising, the 2030 Water Working Group is recommending the preparation of formal costs curves similar to those shown in Figure 12. These cost curves rank each potential solution to a problem in terms of the relative cost per unit of desired outcome achieved and can be used to assess the likely costs and benefits of each solution. One of the most striking features of this approach is that one often finds solutions that both make more water available and cost less money. In China, for example, constructing water-availability cost curves identified 21 opportunities to make more water available for use and save money (Figure 12). These include increased paper recycling, investment in leakage reduction, wastewater reuse in power stations and commercial buildings and investment in water-efficient shower heads. All of these approaches are consistent with the development of a green economy, which seeks to minimise the impact of economic activity on the environment.

### 4.3 Flow of benefits from investment in the water supply and sanitation sector

Many returns to investment in the water sector are indirect. Build a toilet for girls in a school and they are more likely to go to school. This simple statement highlights the fact that investment in water opens up other opportunities for development. Assessing the case for more investment in water infrastructure in the Niger Basin, **Ward et al. (2010)** report that investment in providing access to potable water and in education are the only two variables that are consistently related to poverty reduction across the whole Niger River basin (Box 5).

Highlighting the complex spatial nature of responses to water investment, Figure 13 shows the predicted reductions in child mortality and morbidity from the protection of drinking water supplies.

#### Box 5: Empirical analysis of the relationship between poverty and the provision of access to water and sanitation in the Niger River basin

Ninety four million people live in the Niger River basin. The proportion living below the poverty line in Burkina Faso is 70.3 per cent, in Guinea 70.1 per cent and in Niger 65.9 per cent. Childhood mortality rates are up to 250 per 1000 live births. In 2004, only 53 per cent of those living in the Niger River basin were found to have access to a reliable and safe source of drinking water. Only 37 per cent had access to adequate sanitation facilities.

The quality of water used by households appears to be as important, or more so, than the total quantity of water available in the environment in predicting poverty levels. The use of unprotected well or surface water is generally positively correlated with increased child mortality and increased stunting.

In north-west Nigeria and east Nigeria, a 10 per cent decrease in the number of people using unprotected water is correlated with a decrease in child mortality of up to 2.4 per cent. Increased irrigation development is correlated with reductions in child stunting in central Mali, north-west Nigeria, central and eastern Nigeria and North Burkina Faso. Increased time spent in education is significantly correlated with a reduction in child mortality and child stunting. In much of the Mali Inner Delta, a one-year rise in the average level of education is associated with an approximate 3 per cent fall in child mortality.

The area of irrigated land was associated with decreases in poverty in only two cases, north-west

Nigeria and eastern Nigeria and northern Cameroon. This suggests that the contribution of irrigation to total rural welfare is low in the Niger River basin and that the levels of irrigation potential are too small at present to offer a discernable improvement in livelihoods at this scale of analysis. This is in contrast to the general literature on development in this region that suggests irrigation will be crucial for the future economic wellbeing of the basin, along with improvements in the productivity of rain-fed agriculture. However, it may be that the benefits of irrigation do not yet accrue to the people engaged in its practice or that they do so at levels too small to register in these statistics.

The data suggest poverty reduction initiatives that rely solely on hydrologic probabilities or fail to account for the different causal relationships of spatially-differentiated poverty are likely to be less effective than those that take a mixed approach.

Strong spatial patterning is evident. Education and access to improved water quality are the only variables that are consistently significant and relatively stationary across the Niger River basin. At all jurisdictional scales, education is the most consistent non-water predictor of poverty. Access to protected water sources is the best water-related predictor of poverty.

Source: Ward et al. (2010)

# 5 Enabling conditions – Overcoming barriers and driving change

The first half of this chapter focusses on the case for investing in the provision of ecosystems services and in the water supply and sanitation sector. In the second half, we focus on the institutional conditions, softer approaches, which have the potential to speed the transition to increase the return on investment and reduce the amount of money that needs to be invested in the water sector.

Without significant water policy reform to enable the reallocation of water from one sector to another, financially reward those who make water use more efficient and so forth, a global analysis by the **2030 Water Working Group (2010)** suggests that some nations will not be able to avoid the emergence of a water crisis in many regions. If wide ranging reforms are adopted, however, then the group's analysis suggests that most water crises can be averted. Investment in water policy reform and governance enables greater engagement and use of local knowledge and for investments to be made at a multitude of scales. When such approaches are taken, the 2030 Water Working Group estimates that the global amount of money that needs to be invested in the water sector can be reduced by a factor of four.

## 5.1 Improving general institutional arrangements

Arguably, the greatest impediment to investment in water infrastructure and management arrangements has been the difficulty in establishing high-level governance and political support for arrangements that support effective governance (Global Water Partnership 2009a). Problems range from a simple lack of institutional capacity to the presence of widespread corruption<sup>12</sup> and opportunities to gain political favour. Building upon these observations in a background paper prepared for this chapter, **Ménard and Saleth (2010)** report that governments are learning that improvement in arrangements for the administration of water resources offers one of the least-cost opportunities to resolve water-management problems in a timely manner. Long-

term solutions such as the establishment of reliable, stable governance arrangements for the supply of water are central to a green economy.

A parallel issue is the question of rights or entitlements to use land and water. When these rights are insecure, the incentive to take the long-term perspective necessary to encourage green approaches to investment is weak. When land tenure, water entitlements and other forms of property rights are well-defined, far more sustainable forms of resource use can be expected. Early investment in the development of land registers and other similar processes are simple ways to expedite the transition to a green economy.

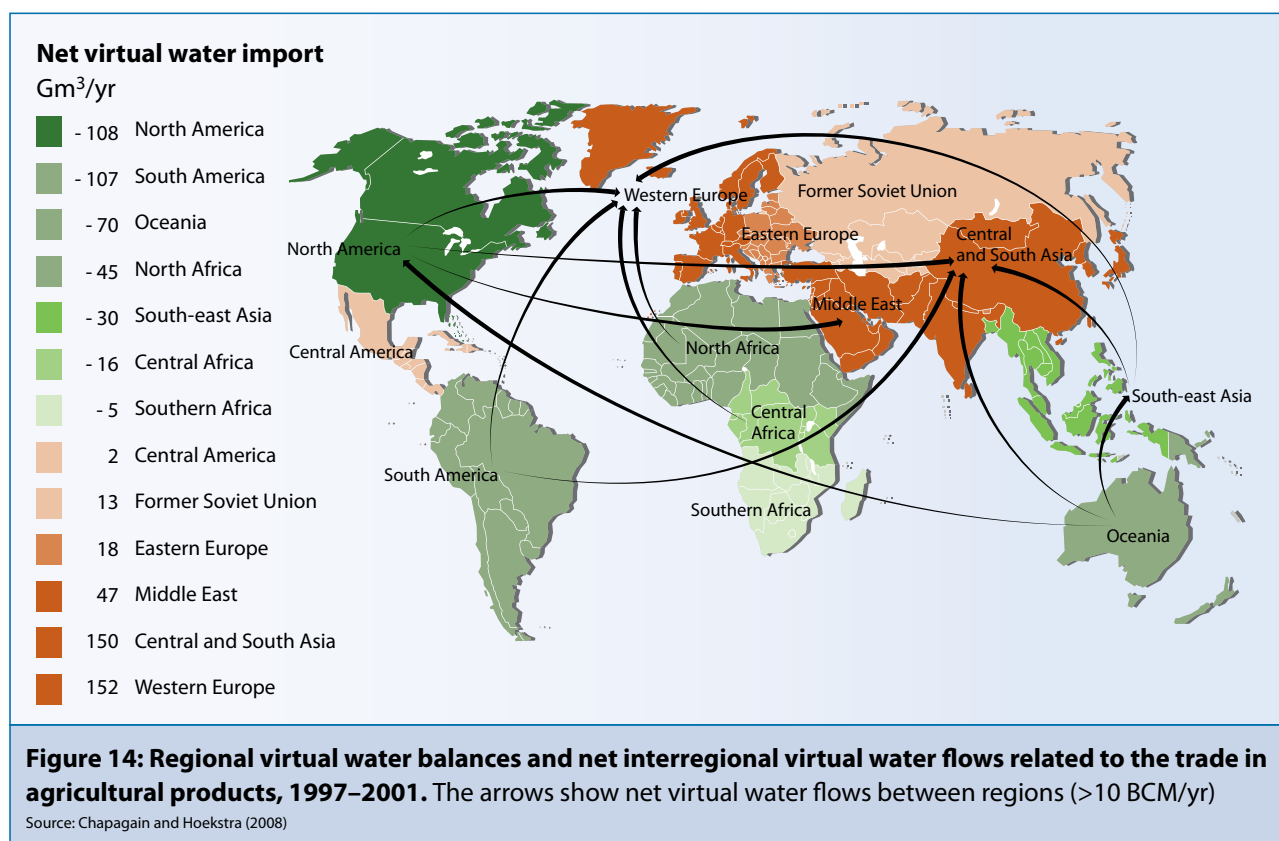
Increases in the capacity of a nation to collect taxes will clearly make it easier to move to full-cost pricing arrangements and, where appropriate, provide rebates and other forms of assistance to the most needy without having to resort to inefficient cross-subsidies.

Another example of an enabling condition is the use of education and information programmes designed to increase awareness of opportunities to act in an environmentally responsible manner. If members of a community feel obligated to look after the environment then they are more likely to do so.

## 5.2 International trade arrangements

The Enabling Conditions chapter discusses the role of international trade and trade-related measures in influencing green economic activity. Whether or not freer trading arrangements will ultimately be to the benefit of water users depends upon the degree of trade liberalisation that occurs and what exceptions are made. As agriculture uses around 70 per cent of all water extracted for consumptive purposes, and large amounts of water are embodied in many of the agricultural products traded (Figure 14), this policy option deserves careful consideration. When trade is unrestricted and all inputs priced at full cost, communities have the opportunity to take advantage of the relatively abundant sources of water in other parts of the world. When trade in agricultural products is restricted, water use is likely to be less efficient. Fewer crops can be grown per drop of available water. As a

12. The 2008 Global Corruption Report found that corruption in the water sector is likely to increase the cost of achieving the Millennium Development Goals by US\$ 50 billion (Transparency International 2008). US\$ 50 billion is about the same amount of money as the 2030 Water Resources Group's estimate of the annual cost of implementing the least-cost solution to the resolution of global water problems.



whole, the world is generally worse off. However, some countries strive for food sovereignty for various reasons including security.

In an attempt to understand the likely impacts of freer trading arrangements on water use, a background paper to this chapter uses a model to estimate the likely effects of agricultural trade liberalisation on water use (**Calzadilla et al. 2010**). The model used differentiates between rain-fed and irrigated agriculture and includes functions that take into account the effects of climate change on the volume of water available for extraction. The trade-liberalisation scenario is based on the proposals being developed as part of the Doha round of negotiations, which seek to move the world towards a regime where agricultural trade is less restricted. In particular, the analysis assumes that there is a 50 per cent reduction in tariffs, a 50 per cent reduction in domestic support to agriculture and that all export subsidies are removed. Given that progress towards such a regime will take time to implement, the scenario is examined with and without climate change. The climate-change scenarios are based on those developed by the International Panel on Climate Change (IPCC) (2008).

Table 3 presents a summary of the findings of this modelling exercise, presented in more detail in the background paper. The introduction of Doha-like freer trading arrangements increases global welfare by US\$ 36 billion. If strong climate change occurs, global welfare

is reduced by US\$ 18 billion. The model assumes no change to the policies that determine how the welfare benefits from increased trade are distributed. **Calzadilla et al.** conclude that trade liberalisation:

- Increases the quantity of agricultural products traded and the capacity of nations to trade with one another with the consequence that global capacity to adjust to climate change is greater than it otherwise would be;
- Tends to reduce water use in water-scarce regions and increase water use in water-abundant regions, even though water markets do not exist in most countries; and
- Makes each nation more responsive to changing conditions and, as a result, reduces the negative impacts of climate change on global welfare by 2 per cent. Regional changes, however, are much larger than this.

In summary, the modelling suggests that freer international trading arrangements for agriculture will significantly reduce the costs of facilitating adjustment and attaining MDG targets. Trade liberalisation can be expected to reduce water use in places where supplies are scarcest and increase water use in areas where they are abundant. Trade liberalisation increases the capacity to adapt to climate change and reduces its negative effects.

Regions	50% reduction in tariffs, no export subsidies and 50% reduction in domestic support to Agriculture	Strong Climate Change Scenario	Both scenarios combined (Free trade and strong climate change)
United States	-1,069	-2,055	-3,263
Canada	-285	-20	-237
Western Europe	3,330	1,325	4,861
Japan and South Korea	11,099	-189	10,970
Australia and New Zealand	622	1,022	1,483
Eastern Europe	302	538	883
Former Soviet Union	748	-6,865	-6,488
Middle East	2,104	-3,344	-1,213
Central America	679	-240	444
South America	1,372	805	2,237
South Asia	3,579	-3,632	-28
Southeast Asia	3,196	-3,813	-552
China	5,440	71	5,543
North Africa	4,120	-1,107	3,034
Sub-Saharan Africa	218	283	458
Rest of the World	285	-308	-17
Total	35,741	-17,530	18,116

**Table 3: Change in regional welfare over 20 years as a result of climate change and trade liberalisation, US\$ million (findings from a model developed by Calzadilla et al. 2010)**

### 5.3 Using market-based instruments

Market-based instruments that can be harnessed to foster a green economy include:

- Payments for Ecosystem Services (PES);
- Consumer-driven accreditation and certification schemes that create an opportunity for consumers to identify products that have been produced sustainably and pay a premium for access to them; and
- Arrangements that send a scarcity signal including the development of offset schemes, the trading of pollution permits and the trading of access rights to water.

Each of these approaches has direct application to the water sector and the degree to which communities are likely to become interested in maintaining and investing in the provision of ecosystem services.

#### Payments for Ecosystem Services

From a water perspective, there are two main types of payments for ecosystem services – those financed by the user of a service and those financed by a government or donor (Pagiola and Platais 2007; Engel et al. 2008). In either case, such schemes can be successful only when a secure source of money for the scheme has been identified and

committed. Arguably, the most efficient are operated by users who are able to identify which services they want and the price they are willing to pay for them. Most government-financed programmes depend on financing from general revenues and, because they typically cover large areas, they are likely to be less efficient. Moreover, because they are subject to political risk, they are less likely to be sustainable. When a government or financial conditions change, support for the scheme can collapse (Pagiola and Platais 2007; Wunder et al. 2008).

Payments for Ecosystem Services schemes are becoming common in Latin America and the Caribbean region. In Ecuador, Quito's water utility and electric power company pay local people to conserve the watersheds from which this company draws its water (Echavarría 2002a; Southgate and Wunder 2007). In Costa Rica, Heredia's public-service utility pays for watershed conservation using funds derived from a levy on consumers (Pagiola et al. 2010).

Many small Latin American towns have similar schemes, including Pimampiro in Ecuador; San Francisco de Menéndez in El Salvador and Jesús de Otoro in Honduras (Wunder and Albán 2008; Herrador et al. 2002; Mejía and Barrantes 2003). Hydroelectric producers are also becoming involved. In Costa Rica, for example, public-sector and private-sector hydro-electricity producers are paying for conservation of the watersheds from which they draw water. Pagiola (2008) reports that these companies now

contribute around US\$ 0.5 million per annum towards the conservation of about 18,000 ha. In Venezuela, CVG-Edelca pays 0.6 per cent of its revenue (about US\$ 2 million annually) towards the conservation of the Río Caroní's watershed (World Bank 2007). Some irrigation systems, such as those in Colombia's Cauca Valley, have participated in schemes like these (Echavarría 2002b).

More generally, and as explained in **Khan (2010)**, as countries shift to a greener set of economic arrangements, the costs of more traditional hard engineering approaches to water management involving the construction of treatment plants, engineering works to control floods, etc. become more expensive. In contrast, the cost of operating an ecosystem payment scheme is much less likely to increase. For this to occur, however, parallel investments in the development of property rights and governance arrangements may be necessary to ensure water-supply utilities can enter into contracts that maintain access to ecosystem services and expect these contracts to be honoured. Well-defined land tenure systems, stable governance arrangements, low transaction costs and credible enforcement arrangements are essential (**Khan 2010**).

As noted elsewhere in this chapter, early attention to governance arrangements is a necessary precondition to the inclusion of water in a transition strategy to a green economy.

### **Strengthening consumer-driven accreditation schemes**

Whilst rarely used in the water sector, in recent years there has been a rapid expansion in the use of a variety of product accreditation schemes that enable consumers to pay a premium for access to products that are produced without detriment to the environment including its capacity to supply water-dependent services. As observed by de Groot et al. (2007), these accreditation schemes rely on the self-organising nature of private market arrangements to provide incentives for the beneficiaries of the improved service to pay for it. Once established, these arrangements can play an important role in encouraging the restoration of natural environments.

Arguably, one of the better-known examples is the labelling scheme developed by the Forest Stewardship Council (FSC). The Council guarantees that any timber purchased with its label attached has been harvested in a manner that, amongst other things, seeks to maintain ecological functions and the integrity of a forest. Where appropriate, this includes recognition of the essential role that forests play in water purification and in protecting communities from floods.<sup>13</sup>

### **Increasing the use of tradeable permit, off-set and banking schemes**

A broad class of market-based instruments of relevance to a green economy are those that limit opportunity to pollute and / or use a resource. There are many variants of such schemes, but all work by using a market mechanism to reward people who are prepared to cease or reduce a water-affecting activity, thus allowing others to take up the same activity and thereby ensuring an overall controlled impact on the environment.

One such example is a mechanism whereby a water treatment plant can release more nutrients into a waterway by arranging for the reduction of nutrient pollution from a nearby dairy farm. In many cases, the result can be a significant improvement in water quality at a much lower cost if the water treatment plant is not allowed to increase its emissions. In rural areas, nitrate pollution charges and trading schemes are often suggested and are now operational in parts of the USA (Nguyen et al. 2006).

Another example, well developed in the USA, is the use of wetland banking schemes that require any person proposing to drain a wetland to first arrange for the construction, restoration or protection of another wetland of greater value (Robertson 2009). In these schemes, it is possible for a person to restore a wetland and then bank the credits until a third party wishes to use them. Three quarters of these wetland banking arrangements involve the use of third-party credits (U.S. Army Corps of Engineers 2006; Environmental Law Institute 2006).<sup>14</sup>

## **5.4 Improving entitlement and allocation systems**

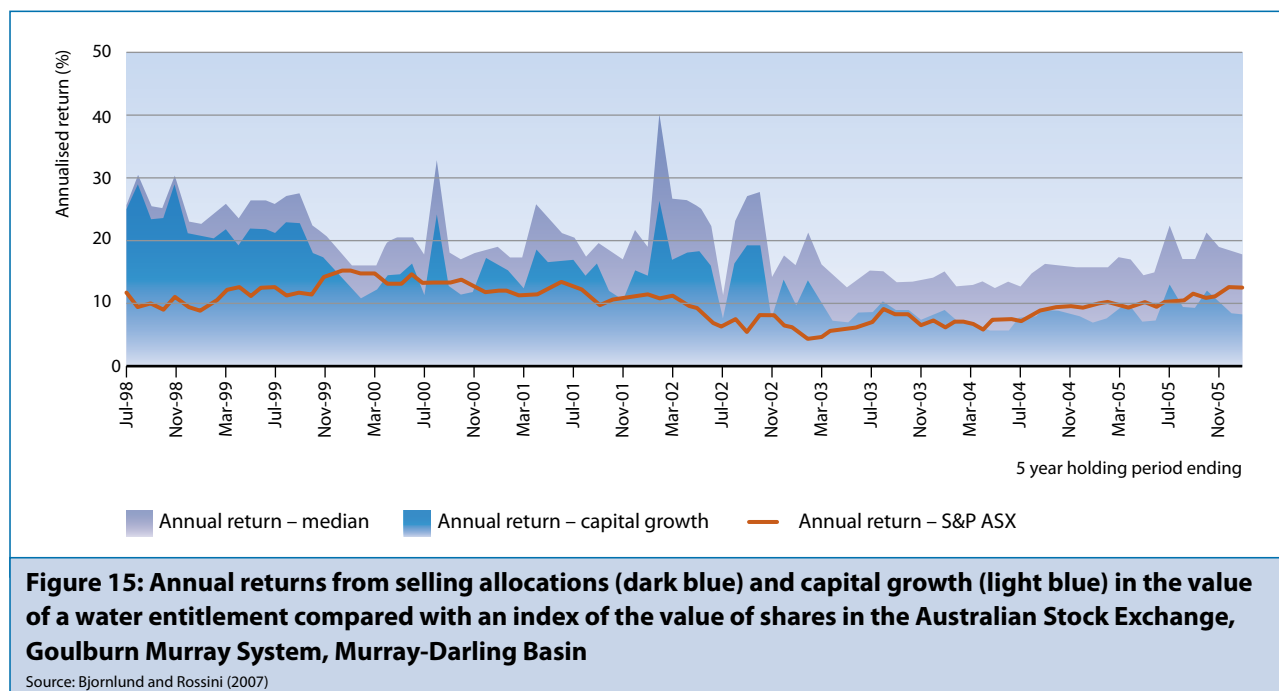
The last class of market-based instruments of particular relevance to water are those that use water entitlement and allocation systems to allow adjustment to changing economic and environmental conditions by allowing people to trade water entitlements and allocations.

In well-designed systems, water-resource plans are used to define rules for determining how much water is to be allocated to each part of a river or aquifer and a fully-specified entitlement system is then used to distribute this water among users. Under such an arrangement rapid changes in supply conditions can be managed efficiently (Young 2010). Australian experience in the development of fully-specified entitlement systems is described in Box 6. Among other things, the approach enables people to use bottom-up market based

14. In each of these schemes banking and trading is possible only because they involve the development of indices that enable wetlands of differing value per hectare to be compared with one another.

13. For more information see <http://www.fsc.org/pc.html>





approaches to respond rapidly to changes in water supply. Consistent with the notion of increased returns from taking a green approach to the development of an economy, the introduction of water markets in Australia has produced an estimated internal rate of return in excess of 15 per cent per year over the last decade (see Figure 15). The result has been a considerable increase in the wealth and welfare of those involved.

In a green economy, the environment is given rights that are either equal or superior to those of other users of a water resource. In countries where property right systems are robust and users comply with entitlement and allocation conditions, environmental managers are beginning to purchase and hold water entitlements for environmental purposes. In Oregon, USA, for example, the Oregon Water Trust has been buying water entitlements from irrigators since 1993 (Neuman and Chapman 1999) and then using the water allocated to them to maintain and improve the function of streams and water-dependent ecosystems (Scarborough and Lund 2007). In Australia, the Commonwealth Environmental Water Holder (CEWH) has recently acquired 705 GL of water entitlements from irrigators for similar purposes in the Murray Darling Basin and has announced its intention to continue to do this until it holds in the vicinity of 3,000 to 4,000 GL of water entitlements (Murray Darling Basin Authority 2010). If this process is completed, the CEWH will hold between 27 per cent and 36 per cent of all the Basin's water entitlements.

## 5.5 Reducing input subsidies and charging for externalities

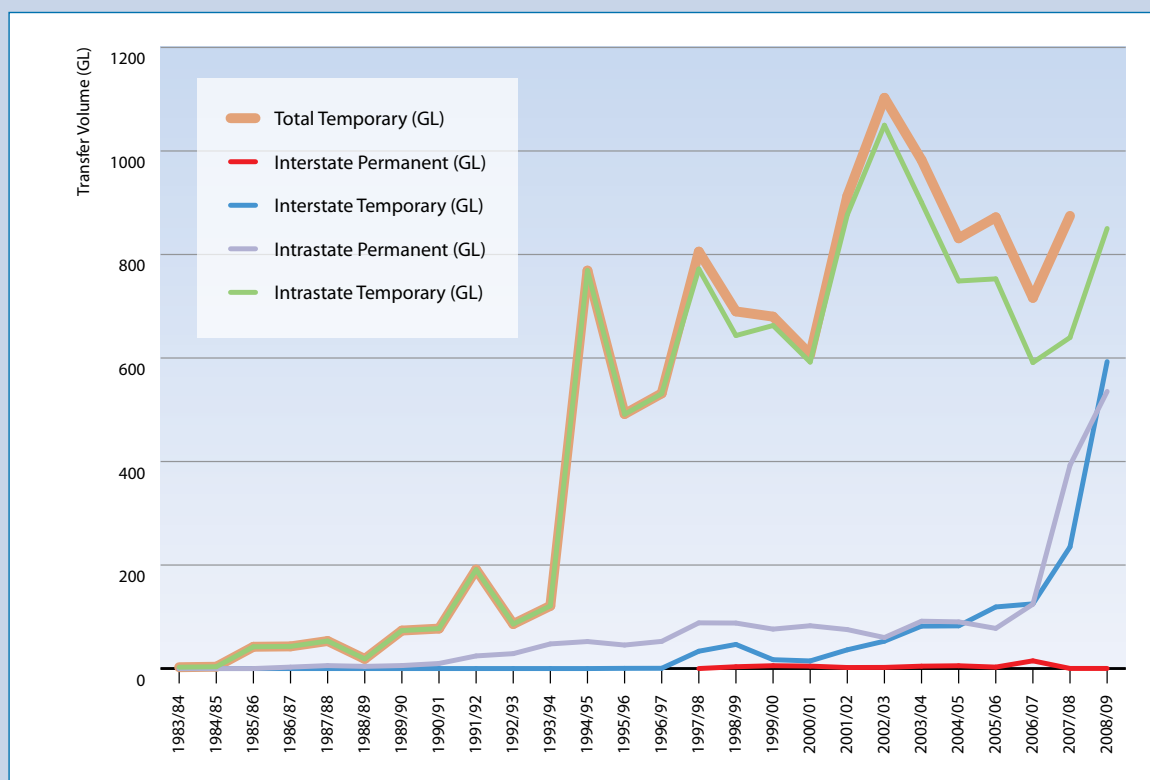
In some cases, subsidies can be justified but unless implemented with great care, they can have a perverse

effect on progress towards the greening of an economy. In most cases, subsidies encourage the exploitation of water at unsustainable rates. In India's Punjab Province, for example, electricity for groundwater pumping is supplied to farmers either at a heavily subsidised price or for free. Experience is now showing that these subsidies encourage farmers to pump much more water than otherwise would be the case and, as a result, water levels in 18 of Punjab's 20 groundwater districts are falling rapidly. Officials are aware of the adverse effects of subsidising electricity to this extent but have been unable to find a politically acceptable way to phase them out (The Economist 2009).

Processes that attempt to reflect the full cost of electricity use include funding research on the adverse effects of providing these subsidies and stimulating public debate about the wisdom of continuing to do so. If this research is rigorous and the communication strategies well developed, it is hoped that ultimately there will be sufficient political pressure to enable these subsidies to be removed (Ménard and Saleth 2010). As soon as this starts to happen, the money saved can be used to invest in other more sustainable activities. An alternative, much more expensive approach is to build a separate rural power supply system so that access to electricity can be rationed.

## 5.6 Improving water charging and finance arrangements

As noted by the OECD (2010), water-supply pricing policies are used for a variety of economic, social and financial purposes. Ultimately, water policies need mechanisms that distribute water to where it is needed, generate revenue and channel additional sources of finance.



**Figure 16: Development of Murray Darling Basin water entitlement transfers**

Source: Young (2010)

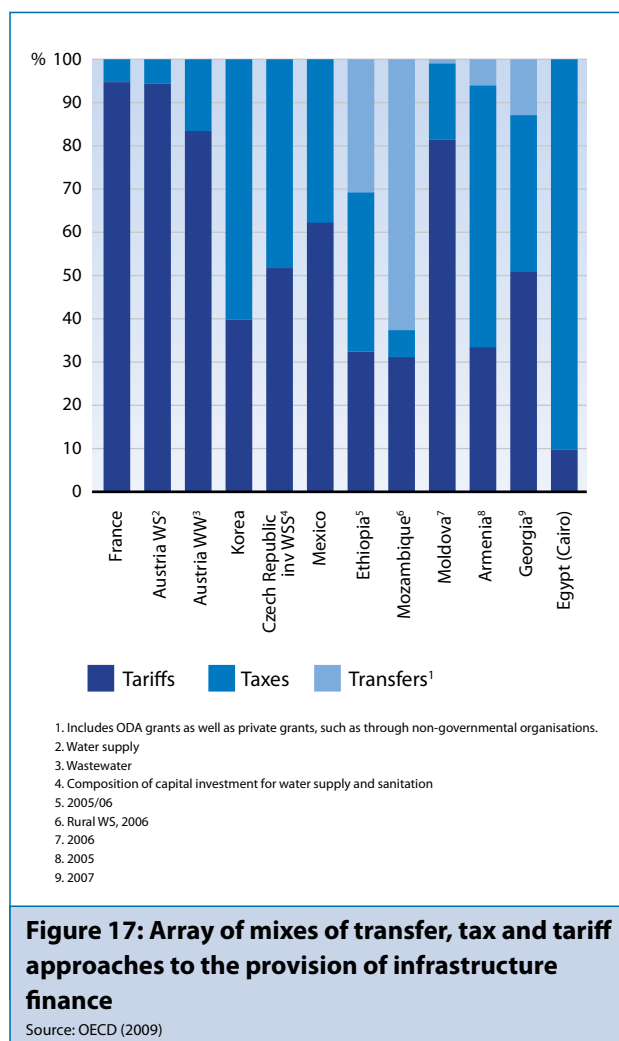
## Box 6: Australian experience in the role of water markets in facilitating rapid adaptation to a shift to a drier climatic regime

Recently, Australia's Southern Connected River Murray System experienced a rapid shift to a drier regime that has demonstrated both how difficult and how important it is to specify water rights as an entitlement only to a share of the amount of water that is available for use and not an amount. At the time that this shift occurred, the plans that were in place assumed that inflows would continue to oscillate around a mean and that known water accounting errors in the entitlement system could be managed. As a result, when a long dry period emerged, stocks were run down and managers decided to use environmental water for consumptive purposes on the assumption that more water could be made available to the environment when it rained again.

After four years of drought, and as the drought moved into its fifth, sixth, seventh and now eighth year, plans had to be suspended and new rules for the allocation of water developed (National Water Commission 2009). A new Basin Plan is now in the process of development and will seek, amongst other things, to deal with an acute over-allocation problem. In parallel with these changes,

considerable investment has been made in the development of the scientific capability to assemble the knowledge necessary to prevent these problems from re-emerging.

Another key feature of the system now being used in all Basin States is the definition of entitlement shares in perpetuity and the use of water markets to facilitate change. All water users now understand that they will benefit personally if they can make water use more efficient. As a result, a vibrant water market has emerged and significant improvements in the technical efficiency of water use have occurred. In this regard, Australia was lucky its entitlement system and the associated administrative processes had been developed in a manner that facilitated the rapid development of the water market possible (see Figure 16). Among other things, this included a much earlier commitment to meter use and established governance arrangements that prevent people from using more water than that allocated to them and the unbundling of water licences so that equity, efficiency and environmental objectives can be managed using separate instruments.



2. *Tax revenue* can be used to subsidise operating costs and cover capital costs; and
3. Grants and other forms of *transfer payment* can be sourced from other countries.

Figure 17 shows how different countries combine each of these approaches. Very few countries rely only upon tariffs to finance infrastructure investment, even though economic theory would suggest that charging people a tariff in proportion to the service provided is the most efficient option. Reliance on tax revenue is common and, when donors are willing, transfer payments (donations) can play a significant role. In OECD countries, it is now common for urban water-supply utilities to set a tariff that is sufficient to cover the full operating costs of supplying water (OECD 2010).

### Charging for access to water

Shifting to a green economy usually involves a commitment to begin charging for the full costs of resource use. With regard to water, however, there is a dilemma as access to clean water and adequate sanitation services is a human right (United Nations 2010a). In a green economy, the efficient use of resources is encouraged, as is investment in built infrastructure. There is also an emphasis on equity.

When considering the most appropriate charge to set, from an efficiency perspective, it is useful to distinguish between:

- The capture, storage, treatment and supply of water for public rather than private purposes;
- Situations where water supplies are abundant and when supplies are scarce;
- The supply of water to households, to industry and for irrigation;
- Regions where institutional capacity to collect charges is strong and when it is weak; and
- The need to recover daily operating costs and the need to make an adequate return on capital so that the supplier (whether public or private) can afford to maintain both natural and built infrastructure.

Complicating the issue, there is also a need to consider the implications of charging people for the full cost of providing sanitation services. First, sanitation service provision generally requires access to water. Second, there are important public health issues to consider. When, for example, one person defecates in the open, health risks are imposed on all who live nearby. In an attempt to avoid the emergence of such problems, governments

From a greening economy perspective, we recognise, however, that there is little agreement about the best way to charge for access to water and sanitation services. Three background papers were adapted to assist with preparation of this chapter – a primer on the economics of water use, a primer on financing and a paper on South African experience with the supply of free access to basic water (Beato and Vives 2010; Vives and Beato 2010; Muller 2010). Relevant insights can also be gained from the background paper on Indonesian experience with the provision of water to Western Jakarta (Fournier et al. 2010). The United Kingdom is pioneering various pricing arrangements that reflect the full costs of providing water. The approach emphasises the role of pricing and charging in catalysing innovation and in encouraging communities to share access to water resources.

### Sources of revenue

Known as the “3 Ts,” in essence, there are three ways to finance water infrastructure and the costs associated with operating that infrastructure (OECD 2009):

1. Users can be charged a *tariff* for the water provided to them;

normally set building standards that require the provision of toilets and connection either to a sanitation service or an appropriate on-site treatment of the waste. When there is no effective building control and, especially when informal settlements are involved, a way to efficiently engage with communities needs to be found.

When water is used for public purposes, such as the maintenance of a wetland for biodiversity or recreational benefits, access is usually provided for free and funded by the government through taxation. Usually, this is efficient as the beneficiaries are numerous and not easily identified. Moreover, there is no congestion problem; many people can benefit without detracting from the benefit received by others.

When water supply (consumption) is for private benefit, however, use by one person typically excludes use by another. In such situations, the efficient strategy is to make water available to those who want it – at least – the full cost of supply. Then, every water user has a greater incentive to use water efficiently. But this simple observation fails to consider important equity considerations that are discussed in the next section.

When water supplies are scarce, the efficient strategy is to price access to water at the marginal cost of supplying the next unit of water (**Beato and Vives 2010**). Costs increase as more and more water is produced. The efficient charge is equal to marginal cost – the cost of producing the next unit of water. Typically, this cost rises as more and more water is supplied.

When water supplies are scarce and no more water can be accessed by, for example, more desalination or recycling, economic theory would suggest the need for a scarcity charge.

When water supply is abundant, however, water pricing theorists face an interesting dilemma. As more and more water is supplied, the cost per unit of water supplied declines. Moreover, the cost of supplying the next unit of water is less than the average cost of supply. The result is a regime where, if water charges are set at marginal cost of supply, the revenue collected will not be sufficient to cover average costs – the water supply business will go bankrupt unless the supply charge is set above average long run cost of supply and/or a government makes up the shortfall (**Beato and Vives 2010**).

The question of whether or not a government should fund any revenue shortfall experienced by a water utility depends upon its capacity to collect revenue from other sources. When institutional capacity to collect revenue is strong, the most efficient charge is one that charges all users in proportion to the metered volume of water taken. When institutional capacity is weak, however,

it may not be possible to do this. Before volumetric charges can be introduced, meters must be installed and revenue collection procedures established.

Finally, it is necessary to differentiate between day-to-day operating costs and the cost of ensuring that sufficient money is set aside to fund infrastructure upgrades and maintenance, ecosystem restoration and to ensure an adequate return on capital. The former is sometimes known as the “lower bound cost” and the latter as the “upper bound cost”.

As a general rule, the faster any system shifts to lower bound cost and then onto upper bound cost, the more efficient, the more sustainable and more innovative water use will be. When institutional capacity is strong, the most efficient strategy is to set a price that is the greater of marginal cost and average cost. Mechanisms other than water pricing policies should be used to transfer income to disadvantaged households and businesses.

### Financing access for the poor

In an environment where a large number of children die as a result of lack of access to adequate water, what is the right tariff to set? Western Jakarta provides an illustrative case study. Some 37 per cent of the people living in Western Jakarta do not have access to a reliable mains water supply. Most of these people are poor and either buy water from carts operated by water vendors or collect it from an unhygienic source. Those forced to buy water from a cart pay up to 50 times the full cost of providing water access to a mains water supply. In addition, they incur the costs linked with poor quality and inadequate volumes of water. Government policy, however, requires the poor be provided access at a highly subsidised price so, in practice, those poor people who get access to mains water are supplied it at a price that is 70 times less than the price paid to water vendors. Since the government cannot afford to pay this subsidy, it is actively discouraging the water utility from making water available to these people (**Fournier et al. 2010**). The poor who receive access to reliable subsidised water benefit, but this assistance is of no benefit to the 37 per cent of people who do not have access to a reliable mains water supply. Table 4 shows the tariff structure used in Western Jakarta.

South Africa provides a different perspective on the question of what tariff to set. In 1996, South Africa devolved responsibility for water management to local government and then introduced a policy that required local governments to provide a basic amount of water to all people free of charge, using funds redirected from central government. As a result, the proportion of the population without access to a reliable water supply has dropped from 33 per cent to 8 per cent (**Muller 2010**). Whether or not the same, or more, progress could have been made if users had been required to pay the full cost

of supplying water to them is not known and probably cannot be determined reliably as water has played a central role in the political transformation of this country. Recently, the Constitutional Court of South Africa (2009) ruled that a local government could charge for access and use pre-paid meters as a means to do this.

Seeking empirical evidence in the Niger Basin, **Ward et al. (2010)** found that access to education and to clean water are the most consistent predictors of economic progress. Having analysed the data and, particularly, the high costs of delaying access because of revenue shortfall, one can observe that if countries cannot afford to make drinking water available at less than full cost of supplying it to all poor people, then an alternative approach is to focus on the efficient provision of water to all poor people at the cost of supply. From a green economy perspective, the strategy to pricing to adopt is the one that most speeds the transition.

#### Cross-subsidising (selectively taxing) water use

In many countries, the water tariff regimes are used to cross-subsidise the cost of supplying water to the poor. In Jakarta, this is achieved by charging wealthier households and/or those who use large volumes of water more than the cost of supply and then using the resultant revenue to enable water to be supplied to the poor at less than full cost (Table 4). As a transitional strategy in countries with little other capacity to transfer wealth from the rich to the poor, a case can be made for the use of cross-subsidies, even though this approach

Code	Customer Type	Volume of water used		
		0-10 m <sup>3</sup>	11-20 m <sup>3</sup>	>20 m <sup>3</sup>
K2	Low-Income Domestic	\$ 0.105	\$ 0.105	\$ 0.158
K3A	Middle-Income Domestic	\$ 0.355	\$ 0.470	\$ 0.550
K313	High-Income Domestic and Small Business	\$ 0.490	\$ 0.600	\$ 0.745
K4A		\$ 0.683	\$ 0.815	\$ 0.980
K413	Non-Domestic	\$ 1.255	\$ 1.255	\$ 1.255

Prices converted to US\$ and rounded to 3 decimal places

**Table 4: Water Tariff Structure in Western Jakarta, US\$ per m<sup>3</sup>**

Source: Adapted from **Fournier et al. (2010)**

distorts investment in water use. In developed countries, however, the use of a water charging regime to transfer income from one group of people or one region to another is extremely inefficient. For this reason alone, **Beato and Vives (2010)** conclude that subsidies should be targeted as tightly as possible and accompanied by a transparent strategy for their removal. The result is the emergence of a regime that encourages investment and innovation. Infrastructure is located in places where its

## Box 7: Recent experience of private companies providing water to households

Phnom Penh Water Supply Authority in Cambodia has seen major transformations between 1993 and 2009. The number of connections increased seven-fold, non-revenue water fell from 73 per cent to 6 per cent, collection efficiency rose from 48 per cent to 99.9 per cent, and total revenues increased from US\$ 300,000 to US\$ 25 million, with a US\$ 8 million operating surplus. After receiving initial grants and soft loans from international financial institutions, the utility is now self-financing. Tariffs increased steeply in the early years, but they have been held constant at around US\$ 0.24/m<sup>3</sup> since 2001, because the combination of service expansion, reduced water losses and high collection rates has guaranteed a sufficient cash flow for debt repayment as well as capital expenditure.

Balibago Waterworks Systems serves around 70,000 customers in a rural area of the Philippines. The business has grown by going out to adjacent towns and villages and asking each community whether they would like the Balibago to build a network that would enable them to supply piped water to it. When Balibago does this, it begins by showing the community its regulated schedule of tariffs. The community is then asked if they want access to piped water and are prepared to pay the scheduled price for access to it. Balibago is finding that in many cases, the result is judged as an attractive proposition for communities that might previously have relied on hand pumps and wells, and it makes good money for the company's investors.

Source: Adapted from Global Water Intelligence (2010)



use can be sustained. Sustainable jobs and more green growth follows.<sup>15</sup>

### Increasing private-sector participation

As a transition to efficient supply of water at full cost occurs, opportunities for the involvement of private enterprise in the provision of water supply and sanitation services increase. The main reason for considering such arrangements is that research is showing that private-sector engagement can help to deliver benefits at less cost and thereby release revenue for green growth in other sectors. Once again, this opportunity is controversial. Several private-sector participation arrangements have

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15. When water is supplied to businesses at less than full cost, businesses tend to locate in locations chosen on the assumption that subsidised access to water will continue. This, in turn, encourages people to live in and migrate to such places and locks an economy into a regime that becomes dependent upon the subsidy. As each of these steps occurs, opportunities for development are undermined.

failed. Nevertheless, there is little to suggest that the frequency with which these problems occur is less than that found among publicly-run systems (**Ménard and Saleth 2010**).

Closer analysis is showing that when contractual arrangements are well developed, use of the private sector can offer a wide range of benefits and, when well-designed contractual arrangements are in place, can outperform the public sector. For example, Galani et al. (2002) show that Argentina's temporary privatisation of approximately 30 per cent of its water supplies met with positive results. Child mortality was found to be 8 per cent lower in areas where water provision had been privatised. Moreover, this effect was largest (26 per cent) in the areas where people are poorest. The experience is equally positive in regions where businesses are allowed to supply water at full cost – operators are finding that many people are prepared to pay for the services they offer (Box 7).

## 6 Conclusions

Access to clean water and adequate sanitation services is critical to the future of each and every household. Water is clearly fundamental to food production and providing ecosystem services and vital for industrial production and energy generation.

Finding a way to use the world's water more efficiently and making it available to all at a reasonable cost, while leaving sufficient quantities to sustain the environment, are formidable challenges. In an increasing number of regions, affordable opportunities to access more water are limited. But progress has to be made to improve efficiency use and working within scientifically established and common practice limits. Direct benefits to society can be expected to flow both from increased investment in the water supply and sanitation sector, including investment in the conservation of ecosystems critical for water.

Research shows that by investing in green sectors, including the water sector, more jobs and greater prosperity can be created. Arguably, these opportunities are strongest in areas where people still do not have access to clean water and adequate sanitation services. Early investment in the provision of these services appears to be a precondition for progress. Once made, the rate of progress will be faster and more sustainable, thus making transition to a green economy possible.

Arrangements that encourage the increased conservation and sustainable use of ecosystem services can be expected to improve prospects for a transition to a green economy.

Ecosystem services play a critical role in the production of many goods and in many of the services needed by the world's human population but pressure on them is increasing. By investing in arrangements that protect these services and, where appropriate, enhance them there is opportunity to ensure that the greatest advantage is taken of these services. Often the most effective way forward is to invest first in the development of supply and distribution infrastructure so that pressure is taken off the systems that supply ecosystem services.

Significant opportunities for improvement include the development of arrangements that pay people who provide and do the work necessary to maintain access to ecosystem services.

Another opportunity is the formal allocation of water rights to the environment. Where water resources have

been over-allocated, there are significant opportunities to fund restoration at a reasonable cost before changes become irreversible.

The costs of achieving a transition will be much less if the increased investment is accompanied by improvements in governance arrangements, the reform of water policies and the development of partnerships with the private sector.

The opportunity to improve governance arrangements is one of the biggest opportunities to speed transition to a greener economy. In any area where there is water scarcity, it is critical that governance arrangements are put in place to prevent over-use and over development of the available water resource. Building administrative regimes that are respected and trusted by local communities and industry takes time; however, this is essential in ensuring a return on the investments suggested in this chapter. These new arrangements, among others, will need to be able to facilitate the transfer of water from one sector to another.

Individual decisions about how to use resources and where to invest are influenced by policy. From a green economy perspective, there are significant opportunities to reform policies in ways that can be expected to significantly reduce the size of the investment needed to facilitate progress. Phasing out subsidies that have a perverse effect on water use and adopting freer trading arrangements, brings direct benefits to many sectors. Other opportunities, such as the establishment of tradeable water entitlement and allocation systems, bring benefits initially to the water sector.

In green economies, there is a commitment to factoring social equity into the transition to arrangements, such as full cost accounting, that influence investment and decisions by people and industry. Ultimately, the question of how fast this transition should occur depends on a case-by-case assessment of the influence of the arrangement on the expected rate of progress. Where capacity exists, financial transfers and tax revenues collected from other sources can be used to fund the infrastructure necessary to provide households with access to services but, when this approach slows progress, tariffs should be raised to at least cover the full costs of service provision. Preference should go to the various pricing arrangements that enable most rapid progress.

# References

## Background papers prepared to underpin development of this chapter

### The macro-economic case for investment in water

2030 Water Resources Group 2010. *Charting our water future*. Adapted from a report of the same name.

Tropp, H. 2010. *Making water a part of economic development: The economic benefits of improved water management and services*.

Calzadilla, A., Rehdanz, K., and Tol, R.J.S. 2010. *The impacts of trade liberalisation and climate change on global agriculture*.

Khan, S. 2010. *The costs and benefits of investing in ecosystem services for water supply and flood protection*.

### Policy Guidelines for investment in water

Beato, P. and Vives, A. 2010. *A primer on water economics*. Vives, A. and Beato, P. 2010. *A primer on water financing*.

Ménard, C. and Saleth, R.M. 2010. *The effectiveness of alternative water governance arrangements*.

### Regional experience

Fournier, V., Folliasson, P., Martin, L., and Arfiansyah 2010. *PALJA "Water for All" programs in Western Jakarta*.

Muller, M. 2010. *Free basic water – a sustainable instrument for a sustainable future in South Africa*. Adapted from *Environment and Urbanization* 20(1):67–87.

Schreiner, B., Pegram, G., von der Heyden, C., and Eaglin, F. 2010. *Opportunities and constraints to development of water resources infrastructure investment in Sub-Saharan Africa*.

Ward, J., Kazcan, D., Ogilvie, A., and Lukasiewicz, A. 2010. *Challenging hydrological panaceas: evidence from the Niger River Basin*.

## Other references cited in chapter

2030 Water Resources Group. 2009. *Charting our water future: Economic frameworks to inform decision making*. McKinsey and Company, Munich.

Björklund, G., Bullock, A., Hellmuth, M., Rast, W., Vallée, D., and Winpenny, J. 2009. "Water's many benefits." In *The UN World Water Development Report 3: Water in a changing world*. Earthscan, London.

Björnlund, H. and Rossini, P. 2007. "An Analysis of the returns from an investment in water entitlements in Australia." *Pacific Rim Property Research Journal* 13(3):344–360.

Bradley, D.J. 1974. Chapter in "Human Rights in Health". *Ciba Foundation Symposium* 23:81–98.

Briscoe, J. and Malik, R.P.S. 2006. *India's water economy: Bracing for a turbulent future*. World Bank and Oxford University Press, Oxford.

Calzadilla, A., Rehdanz, K., Betts, R., Falloon, P., Wiltshire, A., and Tol, R. 2010. "Climate Change Impacts on Global Agriculture". *Kiel Working Paper*, 1617. Kiel Institute for the World Economy, Kiel.

Cave, M. 2009. *Independent Review of Competition and Innovation in Water Markets: Final report*. Office of Public Sector Information, Surrey. Available at [www.defra.gov.uk/environment/water/industry/cavereview](http://www.defra.gov.uk/environment/water/industry/cavereview)

Chapagain, A.K. and Hoekstra, A.Y. 2008. "The global component of freshwater demand and supply: an assessment of virtual water flows between nations as a result of trade in agricultural and industrial products." *Water International* 33(1):19–32

Constitutional Court of South Africa. 2009. Case CCT 39/09 2009 ZACC 28.

Cosgrove, W.J. and Rijsberman, F.R. 2000. *World water vision: making water everybody's business*. Earthscan, London.

Côté, P., Siverns, S., and Monti, S. 2005. "Comparison of membrane-based solutions for water reclamation and desalination." *Desalination* 182:251–257.

Credit Suisse Research Institute. 2009. *Water: the next challenge*. Credit Suisse. Available at <https://emagazine.credit-suisse.com/app/shop/index.cfm?fuseaction=OpenShopCategory&coid=254070&lang=EN>

Dolnicar, S. and Schäfer, A.I. 2006. *Public perception of desalinated versus recycled water in Australia*. Available at <http://ro.uow.edu.au/commpapers/138>

Echavarría, M. 2002a. "Financing watershed conservation: The FONAG water fund in Quito, Ecuador" in Pagiola, S., Bishop, J. and Landell-Mills, N. (eds.) *Selling Forest Environmental Services: Market-based Mechanisms for Conservation and Development*, pp. 91–102. Earthscan, London.

Echavarría, M. 2002b. "Water User Associations in the Cauca Valley: A Voluntary Mechanism to Promote Upstream-Downstream Cooperation in the Protection of Rural Watersheds." *Land-Water Linkages in Rural Watersheds Case Study Series*. Food and Agriculture Organisation, Rome.

ECOWAS-SWAC/OECD 2008. "Communicable Diseases". Atlas on Regional Integration in West Africa, population series. Available at <http://www.oecd.org/dataoecd/56/39/40997324.pdf>

Engel, S., Pagiola, S., and Wunder, S. 2008. "Designing payments for environmental services in theory and practice: an overview of the issues." *Ecological Economics* 65:663–674.

Evans, R. 2007. The Impact of groundwater use on Australia's rivers: Exploring the technical, management and policy challenges. Land and Water Australia, Canberra. Available at <http://lwagov.au/files/products/innovation/pr071282/pr071282.pdf>

Environmental Law Institute (ELI). 2006. 2005 *Status report on compensatory mitigation in the United States*. ELI, Washington, DC.

Falkenmark, M. 1989. "The Massive Scarcity Now Threatening Africa: Why Isn't it Being Addressed?" *Ambio* 18(2):112–118.

Fenollar, F., Trape, J.-J., Bassene, H., Sokhna, C., and Raoult, D. 2009. "Tropheryma whipplei in fecal samples from children, Senegal." *Emerging Infectious Diseases* 15(6).

Fu, G., Chen, S., and C. Liu. 2004. "Water Crisis in the Huang Ho (Yellow) River: Facts, Reasons, Impacts, and Countermeasures." Paper presented at the 7th International River Symposium 31 August – 3 September, Brisbane, Australia.

Galiani, S., Gertler, P. and Schargrofsky, E. 2002. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113:83–120.

Gleick, P. 2004. *The World's Water: The biennial report on freshwater resources 2004–2005*, Island Press.

Gleick, P. 2009. *The World's Water: The biennial report on freshwater resources 2008–2009*. Island Press, London.

Global Water Intelligence. 2010. "Five things I learned at the Global Water Summit". *Global Water Intelligence Newsletter* April 2010. Available at [www.globalwaterintel.com](http://www.globalwaterintel.com)

Global Water Partnership. 1992. Dublin statement and principles. Available at <http://www.gwpforum.org/servlet/PSP?iNodeID=1345>

Global Water Partnership. 2000. Integrated Water Resource Management: *TAC Background Paper No.4* Available at [www.cepis.ops-oms.org/bvsarg/i/fulltext/tac4/tac4.pdf](http://www.cepis.ops-oms.org/bvsarg/i/fulltext/tac4/tac4.pdf)

Global Water Partnership. 2009a. "Triggering change in water policies." *Policy Brief 8*. Global Water Partnership.

Global Water Partnership. 2009b. *A Handbook for Integrated Water Resources Management in Basins*. Global Water Partnership and the International Network of Basin Organizations.

Gould, J. 1999. "Contributions Relating to Rainwater Harvesting". Contribution to the *World Commission on Dams, Thematic Review IV.3: Assessment of Water Supply Options*.

Grey, D. 2004. "The World Bank and Water Resources: Management and Development". Presentation at World Bank Water Week 2004.

Grey, D. and Sadoff, C.W. 2007. "Sink or Swim? Water security for growth and development." *Water Policy* 9:545–571.

de Groot, R., de Wit, M., Brown Gaddis, E.J., Kousky, C., McGhee, W., and Young, M.D. 2007. "Making Restoration Work: Financial Mechanisms." In Aronson, J., Milton, S.J. and Blignaut, J.N. (eds.) *Restoring Natural Capital: Science, Business and Practice*. Island Press, London.

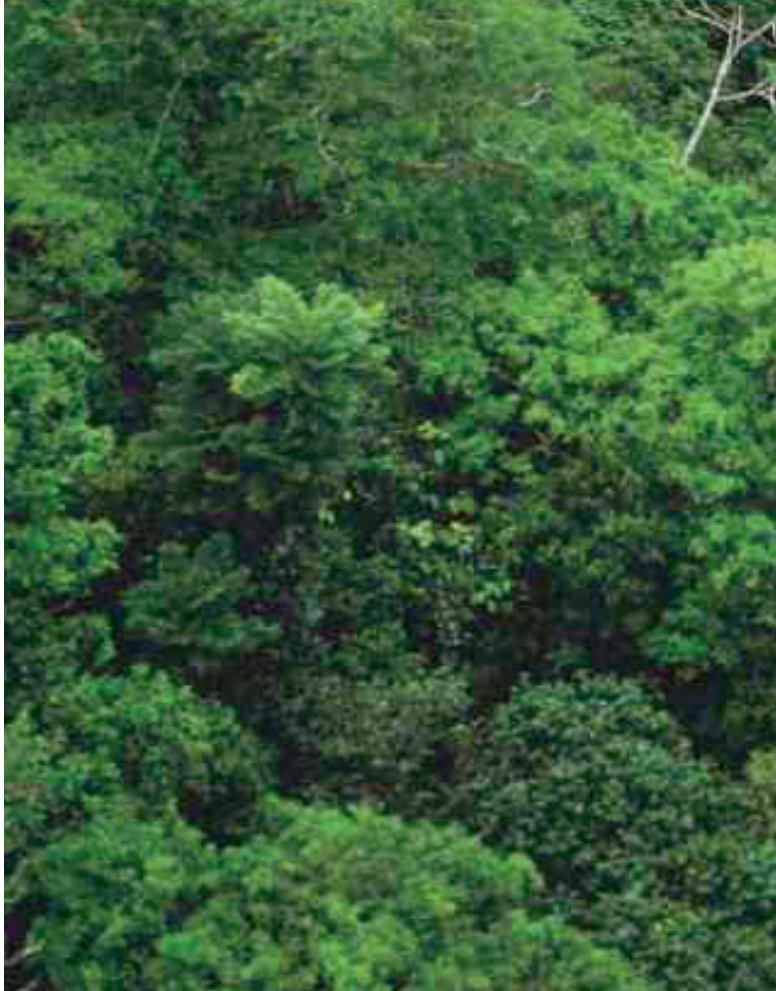
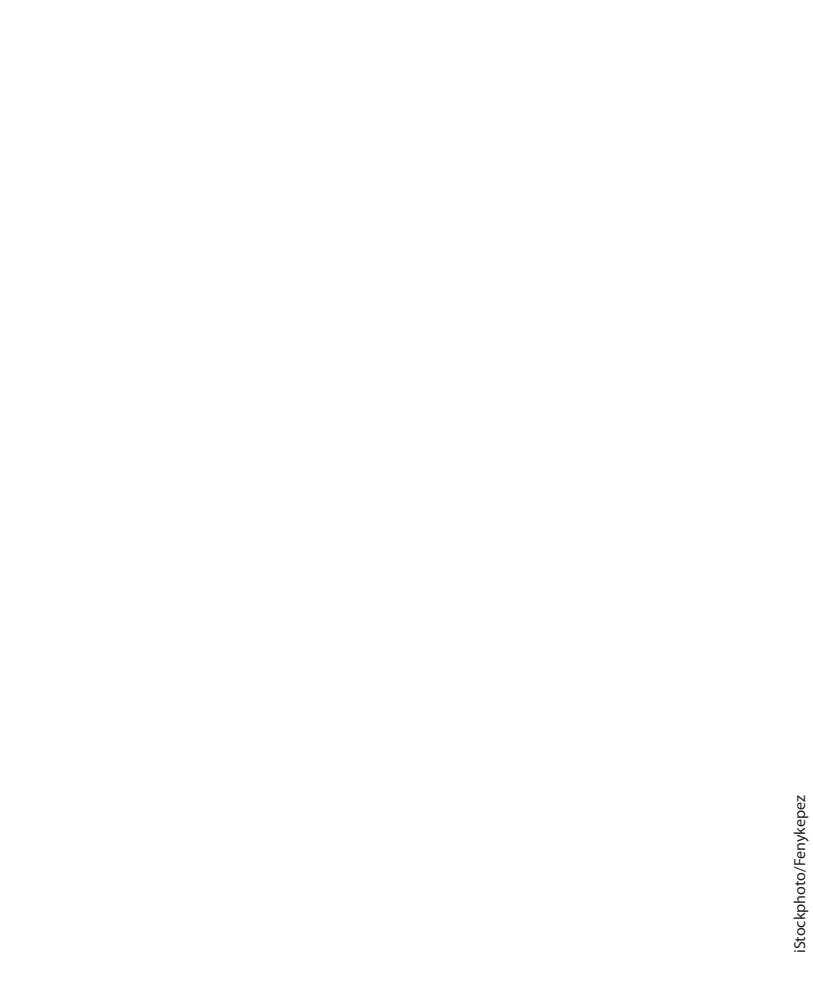
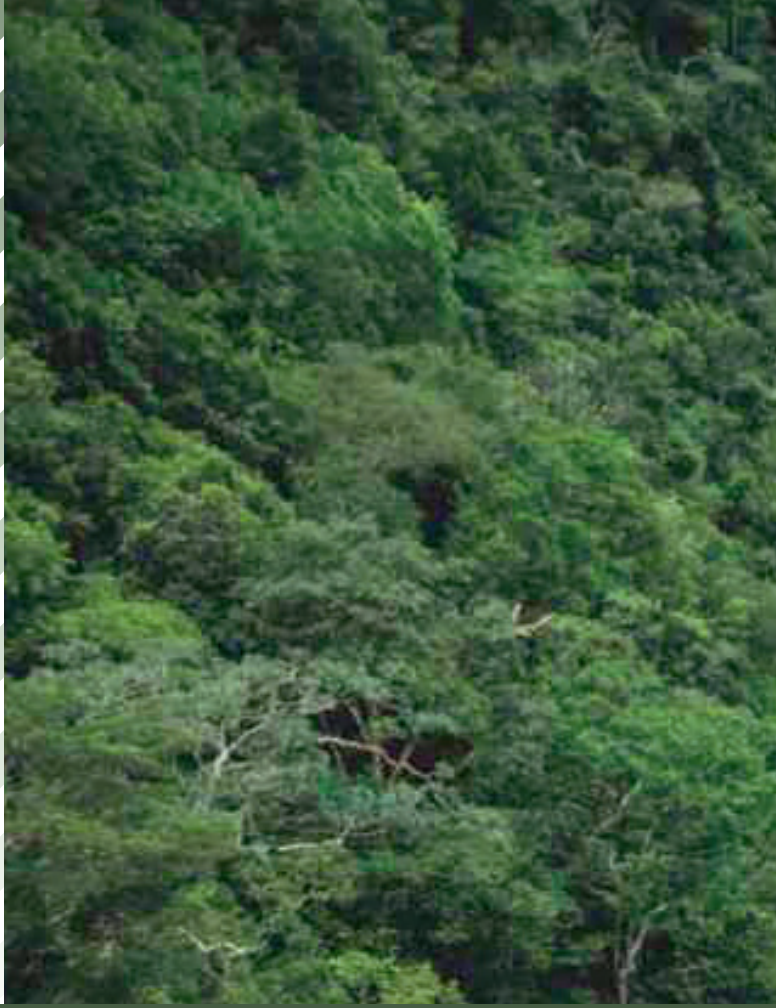
Guo, L. 2007. "Ecology: Doing battle with the green monster of Taihu Lake." *Science* 317(5842): 1166.

- Guria, A. (Chair). 2006. "Enhancing access to finance for local governments." *Financing Water for Agriculture: Report 1 of the Task Force on Financing Water for All*. World Water Council, Marseille.
- Hagos, F., Boelee, E., Awulachew, S.B., Slaymaker, T., Tucker, J., and Ludi, E. 2008. "Water supply and sanitation (WSS) and poverty micro-level linkages in Ethiopia." *RIPPLE (Research Inspired Policy and Practice Learning in Ethiopia and the Nile Region) Working Paper No 8*. Available at <http://www.rippleethiopia.org/library.php/files/file/20090121-wp8-wss-and-poverty>
- Hansen, S. and Bhatia, R. 2004. *Water and Poverty in a Macro-Economic Context*. Norwegian Ministry of the Environment.
- Herrador, D., Dimas, L. A., and Méndez, V. E. 2002. *Pago por servicios ambientales en El Salvador: Oportunidades y riesgos para pequeños agricultores y comunidades rurales*. San Salvador: Fundación PRISMA.
- Hutton, G. and Bartram, J. 2008a. *Regional and global costs of attaining the water supply and sanitation target (target 10) of the Millennium Development Goals*. World Health Organisation. [http://www.who.int/water\\_sanitation\\_health/economic/cba\\_interventions/en/index.html](http://www.who.int/water_sanitation_health/economic/cba_interventions/en/index.html)
- Hutton, G. and Bartram, J. 2008b. "Global costs of attaining the Millennium Development Goal for water supply and sanitation." *Bulletin of the World Health Organization* 86:13–19.
- Independent Evaluation Group. 2010. *Water and Development: An evaluation of World Bank Support, 1997–2007*. World Bank, Washington DC.
- Intergovernmental Panel on Climate Change (IPCC). 2008. "Climate Change and Water." *Technical Paper of the IPCC*. Document IPCC-XXVIII/Doc.13 (8.IV.2008), pp. 7–8.
- International Institute for Labour Studies. 2009. *World of Work Report 2009: The Global Jobs Crisis and Beyond*. International Labour Office, Geneva.
- Klein, G., Krebs, M., Hall, V., O'Brien, T., and Blevins, B.B. 2005. "California's Water – Energy Relationship. Californian Energy Commission." In *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington, DC.
- Korean Ministry of Environment and Korea Environment Institute. 2009. "Four major river restoration project of Republic of Korea." *Korea Environmental Policy Bulletin (KEPB)*, Issue 3, Volume VII.
- Le Quesne, T., Kendy, E., and Weston, D. 2010. *The implementation challenge: Taking stock of government policies to protect and restore environmental flows*. WWF Report. Available at [http://www.hydrology.nl/images/docs/alg/2010\\_The\\_Implementation\\_Challenge.pdf](http://www.hydrology.nl/images/docs/alg/2010_The_Implementation_Challenge.pdf)
- Lippman, T.W. 2010. "Saudi Arabia's quest for 'food security'." *Middle East Policy* 17(1):90.
- Lloyds 2010. *Global water scarcity: Risks and Challenges for Business*. Lloyds 360 Risk Insight Report. Available at <http://www.greenbiz.com/business/research/report/2010/04/27/global-water-scarcity-risks-and-challenges-business>
- Marin, P. 2009. "Public-private partnerships for urban water utilities – A review of experiences in developing countries." *Trends and Policy Options No. 8*. World Bank. World Bank Publications, Washington, DC.
- Mejía, M.A. and Barrantes, G. 2003. Experiencia de pago por servicios ambientales de la Junta Administradora de Agua Potable y Disposición de Excretas (JAPOE) de Jesús de Otoro, Intibucá, Honduras. Tegucigalpa: PASOLAC.
- Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.
- Molden, D. 1997. "Accounting for water use and productivity." *SWIM Paper 1*. Available at [http://www.iwmi.cgiar.org/publications/SWIM\\_Papers/PDFs/SWIM01.PDF](http://www.iwmi.cgiar.org/publications/SWIM_Papers/PDFs/SWIM01.PDF)
- Molden, D. (ed.) 2007. *Water for life, water for good: A comprehensive assessment of water management in agriculture*. International Water Management Institute, Colombo and Earthscan, London.
- Murray Darling Basin Authority. 2010. *Guide to the proposed Basin Plan*. Murray Darling Basin Authority, Canberra.
- Muller, M. 2008. "Free basic water – a sustainable instrument for a sustainable future in South Africa." *Environment and Urbanization* 20(1):67–87.
- National Research Council. 2010. *Electricity from Renewable Resources: Status Prospects and Impediments*. The National Academies Press, Washington, DC.
- National Water Commission. 2009. *Australian water policy reform 2009: Second biennial assessment of progress in implementation of the National Water Initiative*. National Water Commission, Canberra. Available at [http://www.nwc.gov.au/resources/documents/2009\\_BA\\_complete\\_report.pdf](http://www.nwc.gov.au/resources/documents/2009_BA_complete_report.pdf)
- Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringle, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., and Lee, D. 2009. *Climate Change: Impact on Agriculture and Costs of Adaptation*. International Food Policy Research Institute Food Policy Report, Washington, D.C.
- Neuman, J. and Chapman, C. 1999. "Wading into the water market: The first five years of the Oregon Water Trust." *Journal of Environmental Law and Litigation* 14:146–48. Available at [http://www.law.uoregon.edu/org/jell/docs/v14\\_1\\_con.pdf](http://www.law.uoregon.edu/org/jell/docs/v14_1_con.pdf)
- Nguyen, T.N., Woodward, R.T., Matlock, M.D., Denzer, A., and Selman, M. 2006. *A guide to market-based approaches to water quality*. World Resources Institute, Washington, D.C.
- OECD. 2009. *Managing water for all: An OECD perspective on pricing and financing*. OECD, Paris.
- OECD. 2010. *Pricing water resources and water sanitation services*. OECD, Paris.
- Office of National River Restoration (under Ministry of Land, Transport and Maritime Affairs). 2009. *Restoration of four major rivers – Revival of rivers: A new Korea*.
- Pagiola, S. 2008. "Payments for environmental services in Costa Rica." *Ecological Economics* 65(4):712–724.
- Pagiola, S. and Platais, G. 2007. *Payments for Environmental Services: From Theory to Practice*. World Bank, Washington, DC.
- Pagiola, S., Zhang, W., and Colom, A. 2010. "Can payments for watershed services help finance biodiversity conservation? A spatial analysis of Highland Guatemala." *Journal of Natural Resources Policy Research* 2(1):7–24.
- Parikh, S.K. (Chair) 2007. *Report of the Expert Group on "Groundwater management and ownership"*. Government of India Planning Commission, New Delhi, September.
- Robertson, M. 2009. "The work of wetland credit markets: two cases in entrepreneurial wetland banking." *Wetlands Ecology and Management* 17(1):35–51.
- Sachs, J.D. 2001. *Macroeconomics and health: Investing in health for economic development*. Report of the Commission on Macroeconomics and Health prepared for WHO.
- Sanctuary, M. and Tropp, H. 2005. *Making water a part of economic development: The economic benefits of improved water management services*. Stockholm International Water Institute, Stockholm.
- Scarborough, B. and Lund, H.L. 2007. *Saving our streams: harnessing water markets, a practical guide*. The Property & Environment Research Center, Bozeman, MT.
- Scientific Expert Group Report on Climate Change and Sustainable Development. 2007. *Confronting climate change: Avoiding the unmanageable and managing the unavoidable. Full Report*. Prepared for the 15th Session of the Commission on Sustainable Development. Scientific Expert Group on Climate Change (SEG), February 2007.
- Southgate, D. and Wunder, S. 2007. *Paying for watershed services in Latin America: A review of current initiatives*. Working Paper 07–07. Blacksburg, VA: SANREM CRSP.
- The Economics of Ecosystems and Biodiversity (TEEB). 2008. *The economics of ecosystems and biodiversity. An interim report*.
- The Economics of Ecosystems and Biodiversity (TEEB). 2009a. *The economics of ecosystems and biodiversity*. Climate Issues Update.
- The Economics of Ecosystems and Biodiversity (TEEB). 2009b. *The economics of ecosystems and biodiversity for national and international policy makers. Summary: Responding to the value of nature*.
- The Economics of Ecosystems and Biodiversity (TEEB). 2009c. *The Economics of Ecosystems and Biodiversity for National and International Policy Makers*.
- The Economist. 2009. "When rain falls". 12 September 2009, pp. 31–33.
- Transparency International. 2008. *Global Corruption Report 2008: Corruption in the Water Sector*. Cambridge University Press, Cambridge.
- UNESCO. 2006. *Water a shared responsibility: The United Nations World Water Development Report 2*. UNESCO Paris and Berghahn Books, New York.
- UNICEF. 2004. *State of the world's children 2005*. UNICEF, New York.
- United Nations Millennium Project. 2004. *Millennium development goals needs assessments for Ghana, Tanzania, and Uganda. Background paper*.



- United Nations. 2010a. "UN CEO Water Mandate: Framework for responsible business engagement with water policy." Available at [http://www.unglobalcompact.org/issues/Environment/CEO\\_Water\\_Mandate/](http://www.unglobalcompact.org/issues/Environment/CEO_Water_Mandate/)
- United Nations. 2010b. "The UN World Water Development Report: Water for people, water for life." Available at [http://www.unesco.org/water/wwap/wwdr/table\\_contents.shtml](http://www.unesco.org/water/wwap/wwdr/table_contents.shtml)
- United Nations Economic Commission for Africa (UNECA). 1999. *Global Economic Outlook 2000*. Earthscan, London.
- U.S. Army Corps of Engineers. 2006. *Draft environmental assessment, finding of no significant impact, and regulatory analysis for proposed compensatory mitigation regulation*. U.S. Army Corps of Engineers, Washington, DC. March 13, 2006.
- U.S. Department of Energy. 2006. "Energy Demands on Water Resources. Report to Congress on the Interdependency of Energy and Water." U.S. National Research Council, Washington, DC. Available at <http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAComments-FINAL.pdf>
- Veritec Consulting. 2008. "Region of Durham efficient community: Final report." Regional Municipality of Durham, Ontario. Available at <http://www.durham.ca/departments/works/water/efficiency/ECfinalReport.pdf>
- Vörösmarty, C.J., McIntyre, C.J., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C. A., Reidy Liermann, C., and Davies, P.M. 2010. "Global threats to human water security and river biodiversity." *Nature* 467:556–561.
- Ward, J., Kaczan, D., and Lukasiewicz, A. 2009. *A water poverty analysis of the Niger Basin, West Africa Niger Basin Focal Project: Work Package 1*. CSIRO Sustainable Ecosystems Report to the CGIAR Challenge Program on Water and Food.
- WHO/UNICEF. 2010. Progress on sanitation and drinking-water: 2010 Update. Available at [http://www.who.int/water\\_sanitation\\_health/publications/9789241563956/en/index.html](http://www.who.int/water_sanitation_health/publications/9789241563956/en/index.html)
- Winpenny, J. 2003. *Financing water for all: Report of the World Panel on Financing Water Infrastructure*. World Water Council, Marseille.
- World Bank. 2005. "Managing water resources to maximise sustainable growth: A country water resources assistance strategy for Ethiopia." World Bank, Washington, DC. Available at <http://www.worldbank.org/bnpp/files/TF050714Ethiopiafinaltextandcover.pdf>
- World Bank. 2007. Report No. 37502-VE. World Bank, Washington, DC.
- World Bank – Water and Sanitation Programme. 2008. *Economic Impacts of Sanitation in Southeast Asia: A four-country study conducted in Cambodia, Indonesia, the Philippines and Vietnam under the Economics of Sanitation Initiative (ESI)*. World Bank, Jakarta.
- World Commission on Dams. 2000. *Dams and development: a new framework for decision making*. Earthscan, London and Sterling, VA.
- World Health Organization. 2004. *Water, sanitation and hygiene links to health: Facts and figures*. WHO, Geneva.
- World Health Organization. 2008. Progress on drinking water and sanitation: Special focus on sanitation: WHO/UNICEF joint monitoring programme for water supply and sanitation. Available at [http://www.who.int/water\\_sanitation\\_health/monitoring/jmp2008/en/index.html](http://www.who.int/water_sanitation_health/monitoring/jmp2008/en/index.html)
- World Health Organization. 2010. UN-Water Global Annual Assessment of Sanitation and Drinking-Water (GLAAS) 2010: Targeting Resources for Better Results. WHO, Geneva. Available at [http://www.who.int/water\\_sanitation\\_health/glaas/en/](http://www.who.int/water_sanitation_health/glaas/en/)
- World Wide Fund for Nature (WWF). 2010. *Living Planet Report 2010: Biodiversity, biocapacity and development*. Available at [http://www.panda.org/about\\_our\\_earth/all\\_publications/living\\_planet\\_report/](http://www.panda.org/about_our_earth/all_publications/living_planet_report/)
- Wunder, S. and Albán, M. 2008. "Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador." *Ecological Economics* 65(4):685–698.
- Wunder, S., Engel, S., and Pagiola, S. 2008. "Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries." *Ecological Economics* 65(4):834–852.
- Young, M. and McColl, J. 2010. "A robust framework for the allocation of water in an ever changing world." Chapter 5 in Bjornlund, H. (ed.) *Incentive and Instruments for Sustainable Irrigation*. WIT Press, Southampton.
- Young, M.D. and McColl, J.C. 2008. "Double trouble: the importance of accounting for and defining water entitlements consistent with hydrological realities." *Australian Journal of Agricultural and Resource Economics* 53:19–35.
- Young, M.D. 2010. *Environmental effectiveness and economic efficiency of water use in agriculture: The experience of and lessons from the Australian water policy reform programme*. Consultant report prepared for the OECD, Paris.









# Forests

Investing in natural capital



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## List of acronyms

ABS	Access and benefit-sharing	IOE	International Organisation of Employers
AIDS	Acquired immune deficiency syndrome	IRR	Internal rate of return
AIJ	Activities implemented jointly	ITTO	International Tropical Timber Organization
BAU	Business-as-usual	ITUC	International Trade Union Confederation
BNDES	Brazilian National Development Bank	IUCN	International Union for Conservation of Nature
BOD	Biological oxygen demand	LDCs	Least Developed Countries
CDM	Clean Development Mechanism	LPG	Liquefied petroleum gas
CI	Confidence interval	NGO	Non-governmental organisation
CO <sub>2</sub>	Carbon dioxide	NPA	Natural Protected Areas
CPET	Central Point of Expertise on Timber	NPV	Net Present Value
EMBRAPA	Brazilian Agricultural Research Corporation	NWFPs	Non-wood forest products
ESC	Environmental Services Certificate	OECD	Organisation for Economic Co-operation and Development
EU	European Union	PEFC	Programme for the Endorsement of Forest Certification
FAO	Food and Agriculture Organization of the United Nations	PES	Payment for Ecosystem Services
FLEG	Forest Law Enforcement and Governance	PFE	Permanent Forest Estate
FLEGT	Forest Law Enforcement Governance and Trade	REDD	Reducing Emissions from Deforestation and Forest Degradation
FONAFIFO	Costa Rica's National Forestry Financing Fund	RIL	Reduced impact logging
FSC	Forest Stewardship Council	RUPES	Rewarding the Upland Poor in Asia for Environmental Services
G2	Green Scenario 2	SFM	Sustainable forestry management
G8	Group of Eight	SIEF	Solomon Islands Eco-Forestry
GDP	Gross Domestic Product	SSA	Sub-Saharan Africa
GEF	Global Environment Facility	UNEP	United Nations Environment Programme
GHG	Greenhouse gas	UNFCCC	United Nations Framework Convention on Climate Change
GIS	Geographic Information Systems	VETE	Village Eco-Timber Enterprises (Solomon Islands)
GPGs	Global public goods	VPAs	Voluntary Partnership Agreements
HIV	Human immunodeficiency virus	WRM	World Rainforest Movement
ICRAF	International Center for Research in Agroforestry		
IEA	International Energy Agency		
IFC	International Finance Corporation		
IIED	International Institute for Environment and Development		
ILO	International Labour Organization		

# Key messages

**1. Forests are a foundation of the green economy, sustaining a wide range of sectors and livelihoods.** Forest goods and services support the economic livelihoods of over 1 billion people, most of whom are in developing countries and are poor. While timber, paper and fibre products yield only a small fraction of global GDP, public goods derived from forest ecosystems have substantial economic value estimated in the trillions of dollars. Forests sustain more than 50 per cent of terrestrial species, they regulate global climate through carbon storage and protect watersheds. The products of forest industries are valuable, not least because they are renewable, recyclable and biodegradable. Thus, forests are a fundamental part of the earth's ecological infrastructure and forest goods and services are important components of a green economy.

**2. Short-term liquidation of forest assets for limited private gains threatens this foundation and needs to be halted.** Deforestation, although showing signs of decline, is still alarmingly high at 13 million hectares per year. Although net forest area loss amounts to five million hectares per year, this is a result of new plantations that provide fewer ecosystem services than natural forests. High rates of deforestation and forest degradation are driven by demand for wood products and pressure from other land uses, in particular cash crops and cattle ranching. This "frontier" approach to natural resources – as opposed to an investment approach – means that valuable forest ecosystem services and economic opportunities are being lost. Stopping deforestation can therefore be a good investment: one study has estimated that, on average, the global climate regulation benefits of reducing deforestation by 50 per cent exceed the costs by a factor of three.

**3. International and national negotiations of a REDD+ regime may be the best opportunity to protect forests and ensure their contribution to a green economy.** To date, there has been no clear and stable global regime to attract investment in public goods that derive from forests and to assure their equitable and sustainable production. Such a regime promises to tip the finance and governance balance in favour of longer-term sustainable forest management (SFM)<sup>1</sup> – which would be a real breakthrough where the viability of SFM has been elusive in many countries. Management for forest public goods would then open up the prospect of new types of forest-related jobs, livelihoods and revenues – where local people can be guardians of forests and forest ecosystem services. It will require REDD+ standards as well as effective systems for local control of forests, and transfer of revenue, to ensure these livelihood benefits are realised.

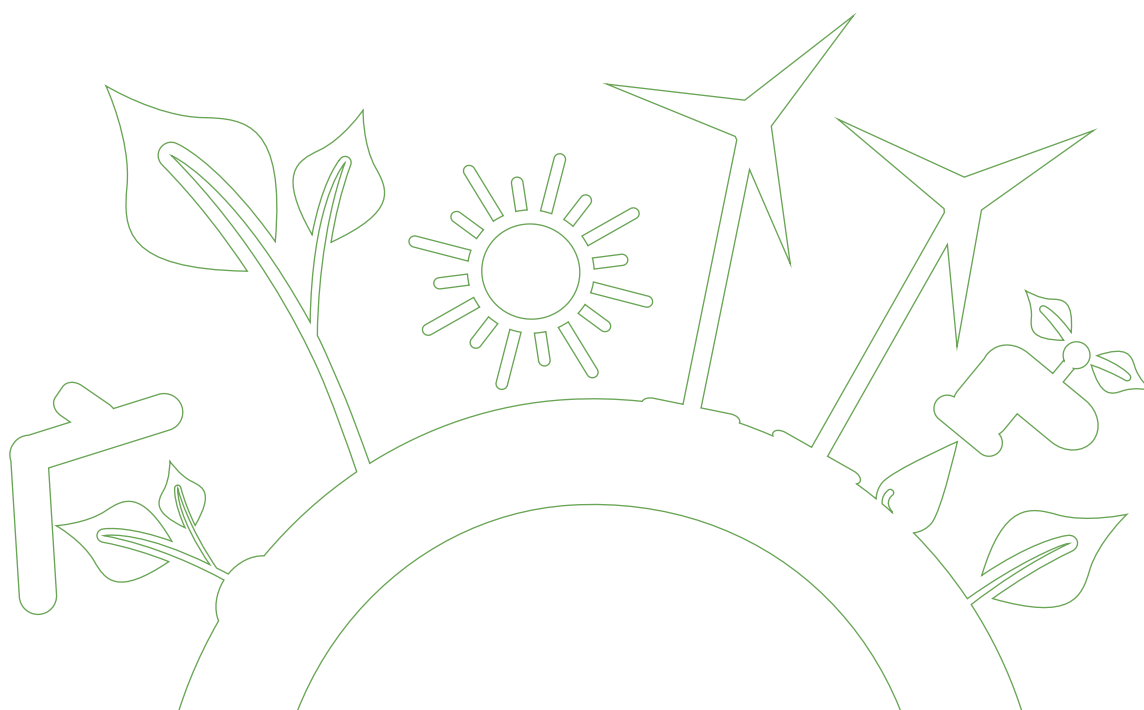
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1. Sustainable forest management may be defined as "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (FAO 2005b).

**4. Tried and tested economic mechanisms and markets exist which can be replicated and scaled up.** There are enough existing glimpses of green economy forestry to warrant more serious policy attention, including certified timber schemes, certification for rainforest products, payments for ecosystem services, benefit-sharing schemes and community based partnerships. They need to be catalogued, assessed for the ecosystem services they offer, promoted widely and scaled up. We contribute to that process in this chapter.

**5. Investments in natural forests and plantations can deliver economic benefits.** Modelling for the Green Economy Report (GER) suggests that an investment of just US\$ 40 billion per year over 2010 to 2050 in reforestation and paying landholders to conserve forests could raise value added in the forest industry by 20 per cent, compared to business-as-usual (BAU). In addition, it could increase carbon stored in forests by 28 per cent, compared with BAU. Provided investments are also made in sustainable productivity-enhancing improvements in agriculture (see Agriculture chapter), this expansion in forest plantations need not threaten food production. However, tree planting would have to be carefully targeted to ensure that it does not displace poor farmers, who have ill-defined tenure; tree planting should also provide another livelihood option in rural areas.

**6. Legal and governance changes are needed to tip the balance towards sustainable forestry, which is not yet at scale, and away from unsustainable practice, which is entrenched in both the forest sector and competing sectors.** Well-managed forests are the cornerstone of ecological infrastructure; as such, they need to be recognised as an “asset class” to be optimised for its returns. These returns are largely public goods and services, such as carbon storage, biodiversity and water conservation and need to be better reflected in national accounting systems. Private forest goods can also have significant economic and social benefits if sustainably produced. Yet, expansion of SFM and green investment face competition from unsustainable and illegally-sourced wood and fibre products, as well as policy biases towards competing land uses such as pasture, agriculture and mining. Both carrots (support for skills training, independent verification of SFM and preferential government procurement) and sticks (tightening up laws and enforcement against illegal logging and marketing) are needed. Also necessary is a revision of policies favouring other sectors, which can erode forest benefits, notably the costs and benefits of agricultural subsidies.



# 1 Introduction

This chapter makes a case for greening the forest sector. It does so by assessing the gap between BAU in the forest sector and the role of the sector in a green economy. To support that assessment, the chapter reviews the current range of green investments in forests and how they are likely to affect both the timber industry and ecosystem services on which the livelihoods of the poorest depend.

This section includes a description of the forest sector's current state and a vision for forests in a green economy. Section 2 presents the challenges and opportunities facing the sector. Section 3 identifies a number of green investments in forests of different types. It reviews the state of knowledge on their magnitude, private and social rate of return, and economic, social and environmental impacts. Section 4 presents the results of modelling the impacts of directing 0.035 per cent of global GDP to two particular green investments: a public-sector investment that pays landholders to conserve forests; and a private-sector investment in reforestation. Section 5 gives an overview of the enabling conditions for green investments in forests to be effective. Section 6 concludes the chapter.

## Box 1: Economic importance of the forest industry in sub-Saharan Africa (SSA)

While a figure of 6 per cent contribution to GDP is often quoted for the entire SSA, such a figure masks the disparities between tropical and non-tropical countries. For example, forests play a major role in the economies of Cameroon, the Central African Republic, Congo, the Democratic Republic of Congo, Equatorial Guinea and Gabon, and in the livelihoods of local people. The forest sector contributes, on average, between 5 and 13 per cent of the gross domestic product (GDP) of these countries. Up to 60 per cent of export earnings for Gabon are from timber products, while for the Central African Republic it is about 50 per cent. Gabon is the biggest exporter of industrial roundwood, exporting nearly 97 per cent of its total production. Export of medicinal plants is a significant foreign-exchange earner for Cameroon, amounting to around US\$ 2.9 million a year.

Source: Gumbo (2010)

## 1.1 Current state of the forest sector

In 2006, the forest industry (defined as roundwood production, wood processing, and pulp and paper) contributed approximately US\$ 468 billion or 1 per cent of global gross value added, of which pulp and paper represented about 40 per cent (FAO 2009). Although this was an increase in absolute terms from 1990, the share of the forest sector declined due to the much faster growth of other sectors (FAO 2009). Nevertheless, the forest industry is extremely important for some developing countries (Box 1). Not captured in these figures on GDP share are the contributions made by forest ecosystem services to human wellbeing and the role of forests in sustaining livelihoods. With a broader concept of GDP, such as the GDP of the poor, which captures the reliance of rural populations on nature, the contribution of the forest sector is greatly increased (TEEB 2009).

Besides wood products and paper, the world's forests also produce a large amount of the energy used in developing countries, particularly among low-income households. About half of the total roundwood removed from forests worldwide is used for energy, including traditional heating and cooking and for heat and power production in industrial operations (FAO 2009). More than 2 billion people depend on wood energy for cooking, heating and food preservation (UNDP 2000). Figures on biomass energy (wood plus crop residues and animal dung) from Openshaw (2010) give an indication of the economic and social importance of the energy derived from wood. According to the International Energy Agency (IEA) (2007), for the world as a whole, biomass energy accounted for an estimated 10 per cent of primary energy in 2005 (47.9 ExaJoule (EJ), of which 39.8 EJ were in Least Developed Countries (LDCs). But in many developing countries it dominates, with over 50 per cent of total energy use. Although much of it is used by the subsistence sector, in many countries biomass energy is the most important traded fuel, both in terms of employment and value. In sub-Saharan Africa, biomass fuels account for as much as 80 per cent of energy consumption.

Forests are also home to important non-wood forest products (NWFPs) that make a significant contribution to local economies and livelihoods; in some cases NWFPs are important exports. The main product categories are food from plant products, raw material for medicine and aromatic products and exudates such as tannin extract and raw lacquer (FAO 2009). It has been estimated that in 2005 the value of NWFPs extracted from forests worldwide amounted to US\$ 18.5 billion, but this was

Service	Estimates of value (US\$/ha)	Source
Genetic material	< 0.2 – 20.6	Simpson et al. (1996) Lower estimate: California Higher estimate: Western Ecuador
	0 – 9,175	Rausser and Small (2000)
	1.23	Costello and Ward (2006) mean estimate for most biodiverse region
Watershed services (e.g. flow regulation, flood protection, water purification)	200 – >1,000 (several services combined in tropical areas) 0 – 50 single service	Mullan and Kontoleon (2008)*
Climate regulation	650 – 3,500	IIED (2003)*
	360 – 2,200 (tropical forests)	Pearce (2001)*
	10 – >400 (temperate forests)	Mullan and Kontoleon (2008)*
Recreation/tourism	<1 – >2,000	Mullan and Kontoleon (2008)*
Cultural services – existence values	0.03 – 259 (tropical forests)	Mullan and Kontoleon (2008)*
	12 – 116,182 (temperate forests)	Mullan and Kontoleon (2008)*

\* Lowest and highest estimates from a review of valuation studies

**Table 1: Estimates of the value of forest ecosystem services**

believed to cover only a fraction of the total value because of incomplete coverage of the statistics (FAO 2010). Numerous studies have shown the importance of the subsistence use of NWFPs for people's livelihoods. In a review of 54 case studies, over half of which were from Eastern and Southern Africa, Vedeld et al. (2004) estimated that the average annual forest environmental income amounted to 22 per cent of household income. While a large part of this was from fuelwood, wild foods and fodder for animals were also important.

Forests, which sustain more than 50 per cent of terrestrial species (Shvidenko et al. 2005), play a vital role in protecting watersheds and regulating climate (ecosystem services) and they have great cultural and symbolic significance. Valuation studies of these services conducted in many different countries have shown a wide variation in results, reflecting the importance of location, the methodologies and assumptions about biophysical linkages, e.g. between forest cover and watershed services (Table 1). Studies that concentrate on the value of the climate-regulation services of forests associated with reducing deforestation also produce substantial estimates (Box 2).

Scaling up from such wide-ranging values is challenging, and estimations of values at a national or global scale have produced huge ranges. While there is still a high degree of uncertainty about the value of forest ecosystem services at a global level, even conservative estimates tend to be high, measured in trillions of US dollars. This indicates the importance of taking these services into account in decision-making on land and resource use.

Forests also provide significant employment, with the contribution of the formal sector greatly outweighed

by that of the informal sector. About 10 million people are employed in forest establishment, management and use worldwide (FAO 2010). Adding employment in primary processing, pulp and paper and the furniture industry brings the figure to about 18 million people (Nair and Rutt 2009). Despite growing informality and mechanisation, forestry is still a highly significant sector, with roughly 0.4 per cent of the global workforce (FAO

## Box 2: The value of forest ecosystem services – climate regulation

Hope and Castilla-Rubio (2008), contributing to the Eliasch Review (2008) estimated that the net present value of benefits in terms of reduced climate-change damage associated with reducing deforestation and hence emissions by 50 per cent each year from 2010 to 2100 would be US\$ 5.3 trillion (mean) with a 90 per cent confidence interval (CI) of US\$ 0.6 to US\$ 17 trillion. Reducing deforestation by 90 per cent from 2010 was estimated to yield benefits of US\$ 10 trillion (90 per cent CI of US\$ 1 trillion to US\$ 30 trillion). The mean benefits from reducing deforestation in both scenarios were found to greatly exceed the mean costs by a factor of approximately three (3.12 for a 50 per cent reduction and 2.86 for a 90 per cent reduction). In both cases there is a possibility that net benefits could be negative but the probability is very low.



Scope	Estimate	Source
Formal employment in forestry, wood processing and pulp and paper	14 million	FAO (2009)
Formal employment in furniture industry	4 million	Nair and Rutt (2009)
Informal small forest enterprises	30–140 million	UNEP/ILO/IOE/ITUC (2008), citing Poschen (2003) and Kozak (2007) for lower and higher estimate, respectively
Indigenous people dependent on forests	60 million	World Bank (2004)
People dependent on agroforestry	500 million–1.2 billion	UNEP/ILO/IOE/ITUC (2008)
	71–558 million	Zomer et al. (2009). For agricultural land with 10% tree cover up to 50%
Total	119 million–1.42 billion	Lower bound assumes overlap between indigenous people dependence and agroforestry

**Table 2: Forest-dependent employment and livelihoods**

2009). Outside of the formal sector there is greater uncertainty about the number of people dependent on forests for employment and livelihoods, as shown in Table 2. As a result, the estimate for the total number of people dependent on forests ranges from 119 million to 1.42 billion. But even conservative estimates of people engaged in informal forest enterprises, indigenous people dependent on forests and people dependent on agroforestry, greatly exceed employment in the formal forest sector.

There are regional variations, however. The employment role of the sector has been declining, particularly in Europe, East Asia and North America, most probably because of gains in labour productivity (FAO 2010). The only countries in Europe that have increasing employment in the forest industry sector are Poland, Romania and the Russian Federation. Latin America and the Caribbean and the developing Asia-Pacific region are the two regions where the forest industry sector has been expanding on all fronts over the last decade. This has been driven by various factors, including the abundance of low-cost, skilled labour, relatively abundant forest resources, a high rate of economic growth, specific policies to encourage development and investment in the sector and a general improvement of the investment climate (Lebedys 2007).

The production and trade of fuelwood is also important for employment. Openshaw (2010), while noting that there are no definite estimates, suggests that nearly 30 million people worldwide may be involved in the commercial production, transport and trade of biomass- energy products, generating around US\$ 20 billion annually. More specifically, a survey in Malawi in 1996/97 found that 56,000 people were involved in tree growing, fuelwood and charcoal production, transport and roadside and urban trading in the country's four principal towns. This was many times greater than the number employed in kerosene, liquefied petroleum gas (LPG) and electrical production, transport or transmission and trading for the household

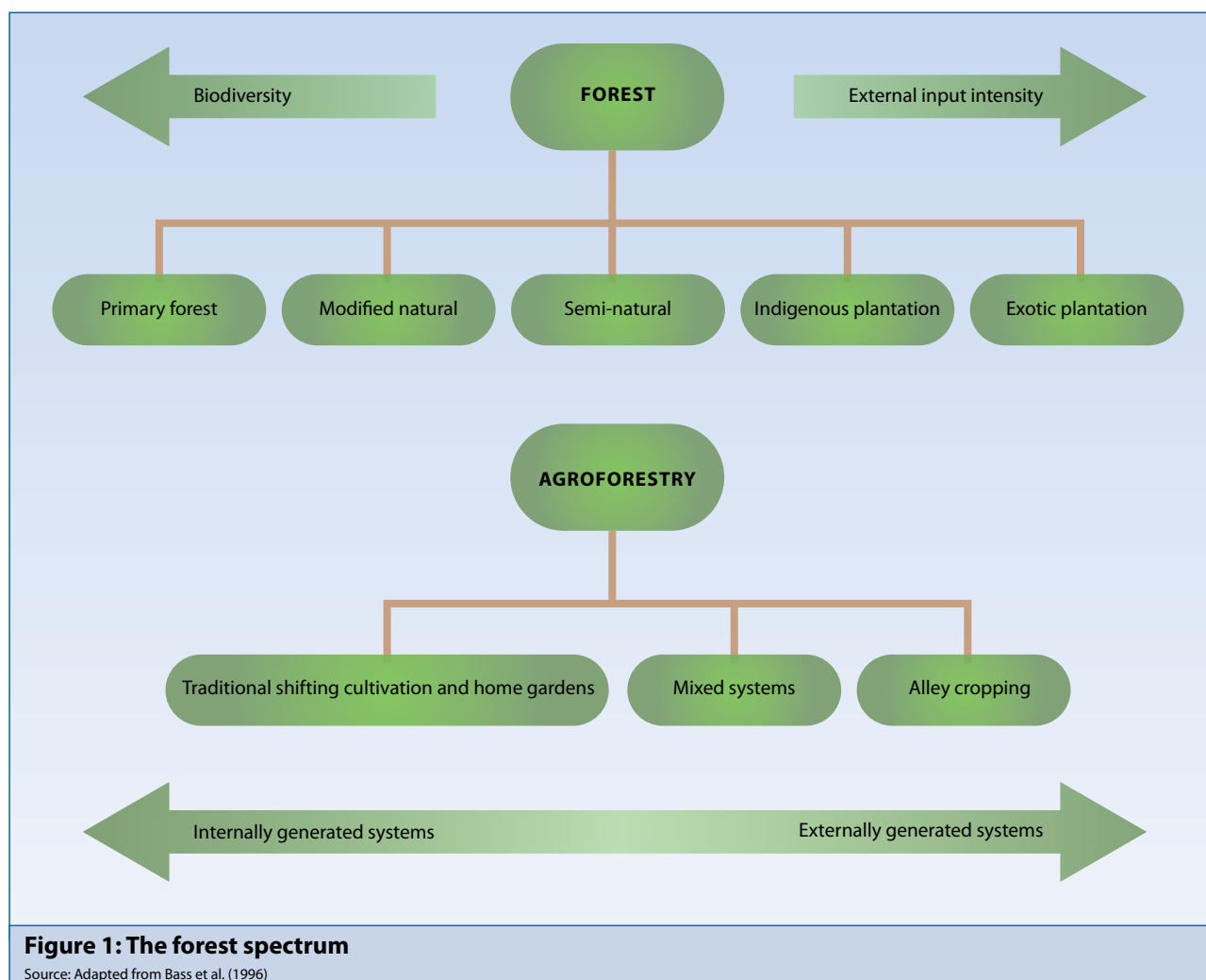
sector, estimated at 350 to 500 (Openshaw 2010 citing Openshaw 1997a and b). A repeat survey carried out in 2008 found that employment in growing, production, transport and trade of biomass energy had increased significantly to 133,000 (BEST 2009).

## 1.2 Scope of the forest sector

The forest sector can be considered in various ways: from merely forest management and primary production, to the whole supply chain of forest products and to the provision of ecosystem services. The focus of this chapter is on forests and the production and management of forest ecosystem services, including carbon management/climate regulation, water-quality management, energy provision and ecotourism. While issues of resource and energy efficiency and clean production are important in the manufacture of secondary wood-based and fibre-based products, they also apply to a number of other industrial sectors, and are therefore covered in the Industry and Energy chapters of this report.

The management of forest ecosystem services is unique to the forest sector (albeit influenced by other sectors) and we therefore give it priority here. The focus on forest ecosystem services also has the effect of widening the range of products and services that can be considered part of the downstream forest sector.

Confining the scope of the chapter to the production of forest ecosystem services simplifies matters but still leaves open the question of what types of forest to consider. FAO's official definition of forests covers a broad spectrum from pristine natural forests undisturbed by human intervention, often known as primary forests, to intensive high-yield plantations, as shown in Figure 1. In between, are natural forests with varying degrees of human modification, and various types of planted forests. We are interested in all of these forest types, in the



extent to which each of these are managed for a range of ecosystem services, and the balance between them. Not covered by FAO's definition are various agroforestry systems, including admixtures of tree, crop and livestock regimes at the field or landscape level, under the management of the farmer. We include them in this chapter because they often provide many, if not all, forest ecosystem services and are important for livelihoods.

### 1.3 Vision for the forest sector in a green economy

Greening the forestry sector implies managing it and investing in it as an asset class that produces a wide range of benefits to society. The wider economic roles of forests in a green economy include: as factories of production (producing private goods from timber to food), as ecological infrastructure (producing public goods from climatic regulation to water-resource protection) and as providers of innovation and insurance services (forest biodiversity being key to both).

The greening of the forest sector will be driven by societal demands for ecosystem services spread across several

sectors, encompassing the traditional industries of wood processing and paper manufacture as well as tourism, energy, water management, carbon trading and new forest-based products. Forestry in a green economy will also meet critical livelihood needs of local communities by providing a stream of fuelwood, construction materials, food sources and medicinal plants. Effective local control and management of forests need to be improved but governments, through access and benefit-sharing (ABS), and new markets, such as ecosystem services, will ensure there are greater economic incentives to do so. These incentives would emerge from a robust and fair international system that ensures forest-related public goods, notably carbon storage and biodiversity conservation, are transferred between nations. Forests would also attract interest from financial institutions opening up forests as a new economic asset.

With greater understanding and recognition of the public goods generated by forests, and the increasing financial rewards for producing them, it becomes critical for forest managers and governments to account more effectively and transparently for forest stocks and flows. This entails being able to measure and value the forest sector's contribution to societal wellbeing in

more sophisticated ways and capturing the full range of marketed and non-marketed goods and services, including the significant contribution they make to the livelihoods of the poor and marginalised.

### 1.4 Indicators

In order to assess how far the forest sector is shifting towards a green economy, it will be important to keep track of indicators that measure the following:

1) the changing proportion of consumption made

up by forest goods and services, and particularly the rate of substitution of carbon-intensive products with forest products; 2) changing markets for forest ecosystem services; 3) investments in sustainable forest enterprise and production, especially those which aim at several ecosystem services and include sustainability conditions; 4) the changing ownership of forest land and forest enterprise, notably the inclusion of local forest stakeholder groups; 5) forest governance improvements; and 6) the sustainability of forest management, from stand to landscape to national levels, in environmental, social and economic terms.

## 2 Challenges and opportunities

### 2.1 Challenges

The major challenges facing the forest sector include the loss of forest, competing land uses, market, policy and governance failures. These challenges are connected. Competing land uses, especially from agriculture, are immediate causes of forest loss. These competing land uses are, in turn, driven by market, policy and governance failures.

#### Trends in forest cover and deforestation

There are clear signs that forests are not being sustainably managed. Table 3 shows that the world's forested area is declining both in absolute terms (deforestation) and in net terms (taking account of forest planting and natural expansion), although at a slower rate than in previous decades. Changes in total forest area at the global level, however, mask regional variations. Forest cover stabilised in North and Central America and expanded in Europe and Asia, in the latter case mainly owing to large-scale afforestation in China, which offset continued deforestation in Southeast Asia. Africa and South America underwent the largest net loss of forests in this period (2000-2010) and Oceania also experienced net loss (FAO 2010).

In its latest Forest Resource Assessment, FAO (2010) revised upwards its deforestation estimate for the 1990s. In the Forest Resource Assessment 2005 (FAO 2005a), deforestation in the 1990s was estimated at 13 million hectares per year.

Trends for different types of forests are also important. Of most concern is the decline in primary forests, 40 million hectares of which have been lost or modified since 2000. In contrast, planted forests are expanding more rapidly, with a 50 per cent increase in the growth rate over the previous decade, and now account for 7 per cent of the total forest area worldwide (FAO 2010). This expansion – explained by the forest transition theory – is expected to continue (see Box 3). Carle and Holmgren (2008) predict that the area of planted forest in 2030 will reach between 302.7 million hectares and 345 million hectares, depending on assumptions about productivity increase. Three-quarters of all planted forests consist of native species, although introduced species are more common in a number of countries with large areas of planted forests across sub-Saharan Africa, Oceania and South America (FAO 2010).

#### Competing uses of land

Agricultural expansion, often combined with timber extraction and the expansion of infrastructure, which

facilitates access, has been found to be the main proximate cause of deforestation in tropical areas over the last two decades (Geist and Lambin 2002; Chomitz et al. 2006). Increasing population, increasing income and shifts in tastes to more meat-based diets are forecast to increase the demand for food by 70 per cent (in value terms) by 2050 (Bruinsma 2009). To meet this demand, further clearing of forest will be required unless agricultural productivity can continue to rise significantly. Increasing demand for biofuels means they will compete with food crops for land, putting further pressure on forests. Climate change, where it has an adverse impact on agricultural yields, will add to the pressure for converting forests to agricultural land. It also affects forests directly through changes in their growth rate or in fire propensity.

#### Market, policy and governance failures

Underlying the loss of forest and competing land-uses are governance and market factors that render deforestation a rational (and often legal) course of action, irrespective of the environmental and social costs. Governance drivers include the lack of forest rights for local stakeholders, which discourage local investment in intact forests and which enable appropriation of land and/or forest resources by more powerful outsiders. These are compounded by market failure, as not all of the important ecosystem services provided by forests are captured in markets. Those taking decisions on the practices used in timber extraction and conversion of forests to other land uses do not factor in the adverse effect on the provision of ecosystem services (Pagiola et al. 2002). Because maintenance of these other ecosystem services is not usually rewarded, there is very little incentive for forest managers to take them into account (De Groot et al. 2010).

	1990	2010
World forest area (hectares)	4.17 billion	4.03 billion
World planted forest area (hectares)	178 million	264 million
	1990-2000	2000-2010
Annual net forest loss (hectares/year)	8.3 million	5.2 million
Annual deforestation (hectares/year)	16 million*	13 million
Annual increase in planted forest (hectares/year)	3.6 million	4.9 million

**Table 3: Trends in forest cover and deforestation**

Source: Compiled from data in FAO (2010)

\* In its latest Forest Resource Assessment 2010 FAO revised upwards its deforestation estimate for the 1990s. In the Forest Resource Assessment 2005 (FAO 2005a), deforestation in the 1990s was estimated at 13 million hectares per year.

### Box 3: Forest transition theory

Globally, the area devoted to planted forests is growing. Planted forests are estimated to produce 1.2 billion m<sup>3</sup> of industrial roundwood, which amounts to about two-thirds of all production (Carle and Holmgren 2008). Further shifts in production to planted forests are expected. Improvements in technology mean that more and more can be produced per hectare of land. For example, eucalyptus plantings in Brazil have reached productivity levels exceeding 50 m<sup>3</sup> per hectare (FAO 2009). In view of such improvements, FAO predicts that growth in production from planted forests will keep pace with growth in demand for industrial roundwood. This can be expected to reduce the pressure on primary forest, although much of the latter could be lost by the time the switch to planted forest has taken place.

This growth of planted forests is explained by the forest transition theory (Mather 1992) and the stages of forest development (Hyde 2005, which draws on von Thunen's rent model; see also Angelsen 2007 who combines the von Thunen and forest transition theories). The theory suggests that countries start with high forest cover and as they develop, the forest is converted to other land uses, agriculture in particular. The process accelerates as infrastructure improvements open up frontier forest areas and makes timber extraction and agriculture economically viable. Over time, as timber becomes scarce, and as the economy develops, providing off-farm employment opportunities, a series of adjustments are made. It becomes profitable to manage forests and plant new ones. The area of forest cover starts to increase again.

This process has been followed by many developed countries and some developing nations, including Costa Rica, which is in the later stages of this transition. Similarly, Vietnam saw its forest cover decline from 43 per cent in 1943 to 20 per cent in 1993 as a result of agricultural expansion and migration

into forested areas. Since then, considerable efforts have been made to increase forest cover, an ambitious programme of reforestation. By 2009 forest cover had increased to 39 per cent of the land area (FCPF 2010). In Vietnam, while forest cover has increased as a result of reforestation programmes, the quality of natural forests continues to be more fragmented and degraded (FCPF 2010). This is where valuation is important, as it would show the economic consequences of letting the standard forest transition takes its course.

There are other market adjustments in response to increasing scarcity of wood, in particular, increasing use of wood-processing residues and recovered paper and wood products. While global demand for wood and fibre is expected to almost double by 2030, global production of industrial roundwood is projected to increase by a more modest 40 per cent (FAO 2009).

Thus, taking this longer-term perspective, the concern about forests is not so much about the ability to provide the world's increasing demand for timber and fibre but about the ability to continue providing livelihoods for forest-dependent people outside of the formal economy and to continue providing non-marketed ecosystem services. The latter are currently unpriced and therefore largely ignored in management decisions to date. This raises the question of how to change the shape of this forest transition (Angelsen 2007). Is it an inevitable pattern of development or can a combination of policies ensure the retention of greater areas of primary forest cover? Neither the forest transition theory nor the land-rent model distinguish between forest cover of different types – i.e. primary forest and secondary forest, degraded forest and planted forest. The provisioning services of forest, such as timber and fibre, may be maintained through market adjustments, but other valuable ecosystem services could be lost.

Governments have sought to secure these other ecosystem services of forests through designation of protected areas, restricting extraction of timber, or access or through regulations on timber harvesting and forest management. But these can be difficult to enforce, particularly when development through forest clearing is the norm. At the same time, these market failures can be exacerbated by policy failures or

intervention failures, which increase the private benefits of conversion through tax incentives and subsidies. The impact of subsidies for cattle ranching on deforestation in the Brazilian Amazon in the 1980s and 1990s has been well documented (Browder 1988; Binswanger 1991). Similarly, in Cameroon, incentives for plantation agriculture led to natural forests being cleared for commercial agriculture (Balmford et al. 2002).



## 2.2 Opportunities

Together with the challenges facing the forest sector, there are also opportunities for greening the sector. They include the establishment of sustainable forest management (SFM) criteria and indicators, the growth of protected areas, the concept of reducing emissions from deforestation and forest degradation (REDD+) and the growing acceptance of payments for ecosystem services (PES).

### Sustainable forest management (SFM)

Although there is no consistent, routine and comprehensive assessment of forest management globally, considerable effort has gone into developing SFM criteria and indicators to describe comprehensively the elements of good practice. They cover the economic, social/cultural, environmental and institutional dimensions of SFM, based on scientific and technical knowledge of forest systems. Regional criteria include those of the International Tropical Timber Organization (ITTO), which apply to all its member countries. Recent initiatives led by civil society groups and some forest companies and industry associations have developed voluntary SFM codes of practice and management guidelines. Certification schemes provide an independent assessment of adherence to the standards and statistics on them provide an indication of the extent of best practice, although lack of certification does not necessarily imply bad practice.

Currently over 5 per cent of the world's production forests are certified under the Forest Stewardship Council (FSC) standard, at 133 millions hectares certified in 79 countries, including 77.6 millions hectares of natural forests, 12.5 millions of hectares of plantations and 43.3 millions of hectares of mixed natural/plantation landscapes (FSC 2010 data as of 15/04/10). Over 80 per cent of FSC-certified forests are boreal and temperate. Tropical and subtropical forests account for 13 per cent of the total FSC-certified area, with 16.8 million hectares (FSC 2010).

The other major international forest certification scheme is the Programme for the Endorsement of Forest Certification (PEFC). Some 232 million hectares of forest are certified to PEFC's Sustainability Benchmark, nearly twice the area of FSC certification, although some forests are certified by the PEFC and FSC. Almost all the PEFC endorsed certified forests are in OECD countries, just under half in Canada with most of the rest in USA, Scandinavia and Brazil in the tropics (PEFC 2010). However, China is developing a national scheme and is expected to join the PEFC in 2011 (PEFC 2011).

In 2005, ITTO (2006) found that only 7 per cent of its member countries' production forests (25 million

	Africa	Asia and the Pacific	LA and the Caribbean	Total
Total closed natural forest (FAO 2001, thousand hectares)	208,581	226,984	788,008	1,223,573
Total area under permanent forest estate (PFE)	110,557	206,705	541,580	858,842
Percentage	53%	91%	69%	70%
Production PFE	71,286	135,726	190,331	397,343
	64%	66%	35%	46%
Natural production forests				
Total area	70,461	97,377	184,727	352,565
With management plans	10,016	55,060	31,174	96,250
Certified	1,480	4,914	4,150	10,544
Sustainably managed	4,303	14,397	6,468	25,168
Percentage sustainably managed	6%	15%	4%	7%
Planted production forests				
Total area	825	38,349	5,604	44,778
With management plans	488	11,456	2,371	14,315
Certified	-	184	1,589	1,773
Protection PFE	39,271	70,979	351,249	461,499
	36%	34%	65%	54%
With management plans	1,216	8,247	8,374	17,837
Sustainably managed	1,728	5,147	4,343	11,218
Percentage of PFE that is sustainably managed (excludes planted areas)	5%	12%	2%	4%

**Table 4: Management status in tropical permanent forest estate (PFE) (2005, thousand hectares)\***

Source: ITTO (2006). Includes forests in the tropical PFEs of all ITTO producer member countries except India

\* Permanent forest estate (PFE) refers to "certain categories of land, whether public or private, that are to be kept under permanent forest cover to secure their optimal contribution to national development" (ITTO 2006). Closed natural forests are defined by FAO (2001) as forests "where trees in the various storeys and the undergrowth cover a high proportion (>40 per cent) of the ground and do not have a continuous grass layer".

hectares) were being sustainably managed. Whilst every ITTO producer-country's policies promoted sustainable management of forests in 2005, management plans existed for only 27 per cent of the 353 million hectares of production forests, and just 3 per cent were certified (Table 4). Despite the low level of sustainable management, however, this is a huge improvement on the mere 1 million hectares of all tropical forests that ITTO had assessed as sustainable in 1988. Furthermore, ITTO noted that some countries have made notable improvements, including Bolivia, Brazil, the Republic of Congo, Gabon, Ghana, Malaysia and Peru. There is

still considerable room for improvement, in view of ITTO's conclusion that resources for enforcement and management are woefully and chronically inadequate, trained staff, vehicles and equipment are all in short supply, while systems for monitoring and reporting forest management are often limited or lacking.

In OECD countries, it is likely that there is a greater extent of sustainable management. The European Union estimates that 80 per cent of its forested area is under a management plan and 90 per cent of that area is managed sustainably: a large proportion of the area is managed by small private owners who have held the forest for generations. A majority of Canadian and many US production forests are certified. Although there are good examples of forest management in Russia, over-logging has occurred, especially in the Russian Far East, near the border with China (Sun et al. 2008).

It is also possible that a large proportion of small-scale informal forest enterprises (family forests, indigenous forests), which are beyond the scope of assessments like that of ITTO, are sustainably managed. This can be judged by the longevity of the forest resources, passed

from generation to generation, and evident production of multiple goods and services. However, there is little information to go on, apart from the minority of forests that are certified.

#### **Growth of protected areas**

One apparently positive trend from the environmental perspective is that the area of protected forests is increasing. About 13.5 per cent of the world's forests are protected according to IUCN categories I-VI and 7.7 per cent (about 300 million hectares) for categories I-IV, involving more restrictions on land use (Schmitt et al. 2009). The area of protected forests has increased by 94 million hectares since 1990, of which two-thirds has been since 2000 (FAO 2010).

In Latin America designation of protected forests has been one of the most used strategies for the sustainable management of forests. It is estimated that there are 100 million hectares under IUCN categories I, II and III (which are the most restrictive) in Latin America and the Caribbean (Robalino et al. 2010). Growth in protected areas has been particularly rapid since the 1980s. In sub-Saharan Africa, 32.5 million hectares of forests and

### **Box 4: The national PES scheme in Costa Rica**

The Costa Rican Payments for Ecosystem Services programme (PSA, in Spanish) was created in 1996, through the Forestry Law 7575, which recognises the provision of ecosystem services from forests. Based on the beneficiary pays principle, it suggests that forest owners should be compensated for the following services:

- Mitigation of greenhouse gases (GHG) (reduction, sinking, fixing and storing carbon);
- Protection of water for rural, urban or hydro-electric use;
- Protection of biodiversity for conservation, scientific and pharmaceutical use; and
- Landscape beauty for tourism.

Forest owners are currently paid for several land-management practices, and all except agroforestry are paid per hectare over five years: forest conservation (US\$ 320), offering higher payments in hydrologically-sensitive areas (US\$ 400), areas identified as "conservation gaps" (US\$ 375), reforestation (US\$ 980), forest management (active

before 2003 and again in 2010, receiving US\$ 250); forest regeneration, which could be in areas that meet the additionality criteria (US\$ 320), or not (US\$ 205); and agroforestry (US\$ 1.3 per tree, paid over three years).

In order to finance this program, FONAFIFO (Fondo Nacional de Financiamiento Forestal or National Forestry Financing Fund) receives funds from different funding sources: public funds in the national budget, donations, credits conceded by international organisms, private funds, own generated funds and timber and fuel taxes. Also, in 2001 FONAFIFO created the Environment Services Certificate (ESC), which is a financial instrument where FONAFIFO receives funds from companies and institutions interested in compensating forest owners for preserving forests.

Between 1997 and 2008 FONAFIFO distributed US\$ 206 million, an average of US\$ 17.2 million per year (Porras, 2010). The majority of funds were for forest protection (73 per cent), covering 460,000 hectares of forest, and almost 6,600 contracts were signed across the country.

Source: Robalino et al. (2010)

woodland, corresponding to 5 per cent of the total forest area, are formally protected (IUCN categories I-VI) and as much as 8 per cent, if forestry reserves are included (Gumbo 2010).

It should be noted, however, that although there has been a marked expansion in protected areas, there is no guarantee that they will be well-enforced. This is evidenced by the continuing loss of forests and other natural ecosystems within protected areas. Effectively enforcing the land and resource-use restrictions in protected areas is challenging and many are being encroached on, particularly in densely populated countries (Chape et al. 2005). Unsustainable land uses within protected areas are another cause (Cropper et al. 2001). Strassburg and Creed (2009), in a study of 133 countries in Latin America, Africa, the Middle-East, Asia and Eastern Europe, estimate that only one-third of the protected forest area is effectively legally protected, corresponding to 6 per cent of the total forested area in these countries. Of the five regions examined, Latin America has both the highest proportion of legally protected forests (24 per cent) and effective legal protection (9 per cent).

### **Payments for ecosystem services (PES) and REDD+**

New, incentive-based approaches to conserving forests have emerged over the last 10 to 15 years.<sup>2</sup> The most high-profile of such initiatives are PES, which pay forest landowners for providing watershed protection, carbon storage, recreation, biodiversity, etc. These range from local-level schemes, such as the local government in the town of Pimampiro in Ecuador, which makes payments ranging from US\$ 6-US\$ 12 per hectare per year to a small group of farmers (19 in 2005), to conserve forest and natural grassland in the area surrounding the town's water source (Wunder and Albán 2008; Echavarría et al. 2004), to national schemes such as in Costa Rica, where farmers are paid US\$ 64 per hectare per year in five year contracts (to protect biodiverse forests (see Box 4) and global schemes e.g. a range of voluntary carbon offset schemes for planting or conserving trees to fix CO<sub>2</sub> and store it. Some environmental payments schemes also factor in social needs, attempting to persuade poor and marginalised groups to become engaged in providing the service, for example the schemes developed under the RUPES programme in Asia (Rewarding the Upland Poor in Asia for Environmental Services they Provide).

One of the most long-standing global payment schemes is the Noel Kempff Mercado Climate Action project in Bolivia, which was developed as a pilot project in 1997 under the Activities Implemented Jointly (AIJ) programme of the UNFCCC. A consortium of international and local NGOs, some US energy companies and the

Bolivian Government bought out local timber concession holders and implemented a community development programme in order to extend the Noel Kempff Mercado Park. Through avoided deforestation the project was expected to avoid emissions of up to 3.6 million tonnes of carbon over 30 years (May et al. 2004).

While PES is primarily associated with developing countries, there are some well-known examples in industrialised countries. The New York City water utility – faced with the need to improve water quality – provides incentives to farmers and owners of forest land in the catchment areas to conserve the forest and adopt agricultural environmental management measures. This proved far less costly than building water-filtration systems (Landell-Mills and Porras 2002). In north-east France, the mineral-water producer, Vittel, paid local landowners to conserve the watershed (Perrot-Maitre 2006).

Until recently, the main driver of investment in PES schemes involving forest conservation was the need to protect watersheds. The rules of the Clean Development Mechanism (CDM) limited eligible forest carbon activities to afforestation and reforestation. This meant that carbon projects based on forest conservation were confined to the voluntary carbon market. But as the contribution of deforestation and forest degradation to GHG emissions has become recognised, this approach to mitigation has moved up the agenda in international climate negotiations, first as REDD (reducing emissions from deforestation and degradation) and more recently as REDD+, which adds conservation, sustainable management of forests and enhancement of forest carbon stocks to the list of eligible activities.<sup>3</sup> REDD+ has been likened to a multi-layer PES scheme, with transfers of finance between industrialised countries and developing countries in exchange for emission reductions associated with improvements in forest protection and management, and further transfers from the national level to forest landowners and communities (Angelsen and Wertz-Kanounnikoff 2008). Although PES will not be the only strategy used by governments to achieve forest-based emission reductions, it is likely to be important.

Unlike the project-based approach of international PES to date, REDD+ is likely to involve more national-level approaches, with finance being supplied by developed countries individually or as a bloc against the performance of national-level commitments to reduce deforestation and emissions. This is exemplified

2. PES has also been used to promote reforestation and agroforestry.

3. These are defined by Angelsen (2009). Angelsen also notes that REDD+ means different things to different people. The + sign captures the second part of UNFCCC Decision 2/CP.13-11 "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries". Addition of a further + to give REDD++ is being promoted by ICRAF to include agroforestry.

by Norway's contribution to the Amazon Fund in Brazil, which is conditional on the achievement of deforestation-reduction targets.<sup>4</sup> In 2010 Norway announced a grant of US\$ 1 billion to Indonesia in return for agreed measures to tackle deforestation and degradation. Indonesia, under the terms of the agreement, has accordingly announced a

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4. Available at <http://www.regjeringen.no/en/dep/md/Selected-topics/climate/the-government-of-norways-international-/norway-amazon-fund.html?id=593978>

2-year moratorium on new permits to clear natural forests and peatlands (Richardson 2010). The sums of money being estimated for full implementation of REDD+ amount to tens of billions of US\$ worldwide. Already, the financial support committed for preparation activities and bilateral programmes greatly exceed what has been provided so far in PES, providing grounds for optimism that this new mechanism can capture and transfer important new resources for ecosystem services provided by forests.

### 3 The case for investing in greening the forest sector

As indicated in the last section, there are promising developments such as certification of sustainable forest management, targets to increase protected areas and the growing momentum of PES and REDD+ schemes. But without a major change in the recognition given to the full suite of forest ecosystem services, in particular in climate negotiations, and in the absence of improvements in the agriculture sector, loss of primary forest is likely to continue. Protected areas will continue to expand but a large proportion will not be effectively enforced. The forest sector will meet the market demand for timber through planted forests and efficiency improvements in processing, but pressures on natural forests from other sectors, agriculture in particular, will continue, exacerbated by climate change. As a result, ecosystem services will continue to be lost.

Additional resources and policies are therefore needed to internalise the value of forest ecosystem services for forest landholders and ensure forests are worth more standing than cleared (Viana 2009). Investments targeted at increasing the profitability of sustainable harvesting techniques and making tree planting worthwhile can also make a contribution. This section reviews a range of investment options for greening the forest sector and identifies the economic, social, and environmental effects of these options.

#### 3.1 Options for green investment in forests

Some broad categories of green private and public investments can be distinguished for the main forest types, including agroforestry, as shown in Table 5. Green investment can be targeted at reversing the loss of forest area by conserving existing areas of primary forest or promoting expansion of forests through regeneration and reforestation. Green investment can also be directed to improving management in existing forests and agroforestry systems to ensure they continue to provide a wide range of ecosystem services. Such investment can only be considered green if it ensured that the forests conserved, established or restored meet principles of sustainable forest management, and balance the needs of different stakeholders. For example, creating a protected area that displaces forest-dependent communities would not meet the principle of supporting relevant socio-economic functions. Moreover, creating a protected area

does not guarantee enforcement. Similarly, extending the forest area through tree planting may be contentious if it uses a large amount of external inputs and directly or indirectly displaces local people from their land.

Some of the green investments listed in Table 5 are straightforward to quantify, although there will be considerable variation by location and species. Some of the public sector investments are not well-documented, in particular the amounts being spent on controlling illegal logging.

Because of the public-good nature of some forest ecosystem services, the private sector and holders of forested land are not always able to perceive a sufficient incentive to make green investments in forests, even

Forest type	Investment	
	Private*	Public**
Primary forest	Ecotourism development	Create new protected areas
	Private nature reserves	Improve enforcement of protected areas
	Pay landowners to protect watershed	Pay forest landholders to conserve forests
		Buy out logging concessions
Natural modified forest	Reduced impact logging and other forest management improvements	Incentives for improved forest management
	Certification to sustainable forest management standards	Support establishment of certification systems
		Control illegal logging
Planted forest	Reforestation and afforestation for production	Incentives for reforestation/afforestation
	Improve management of planted forests	Incentives to improve management
		Reforestation to protect ecological functions
Agroforestry	Extend the area with agroforestry systems	Incentives to landholders
	Improve management of agroforestry systems	Incentives to improve management Technical assistance

\* Private could also include investments made by communities

\*\* Some of the public investments listed here may also be made by the private sector, often on a more limited scale.

**Table 5: Green investment options for various forest types**



if such investments often involve a positive rate of return for society as a whole. Investment by the public sector is therefore needed in some cases to provide forest ecosystem services directly, to provide financial incentives to the private sector to make green investment competitive and to prevent unsustainable forest management, i.e. by controlling illegal logging. The return on investment for the public sector is measured in terms of social and environmental benefits. Research carried out as part of TEEB on the costs and benefits of investing in ecological infrastructure indicates that the rate of return could be very high, with a benefit cost ratio of over 13 to 1 in the case of active restoration of eucalyptus woodlands and dry forest in Australia, and over 30 to 1 for restoration of Atlantic forest in Brazil (Neßhöver et al. 2009).

### 3.2 Investing in protected areas

The creation of protected areas to restrict access and certain land-use practices has been the dominant approach used by governments to secure ecosystem services by controlling deforestation and forest degradation. In some cases the investment in protected areas may be made by NGOs. A well-known example is the conservation concessions whereby conservation organisations lease forest lands that would otherwise have ended up as logging concessions. Such concessions, mostly led by Conservation International but involving other major NGOs and donors, have been established in a number of countries, including Cambodia, China, Ecuador, Guyana and Madagascar (Rice 2002). Private companies do sometimes operate protected forest

areas, usually where there is a tourism interest or where the public sector is providing an incentive. In Brazil, for example, private landowners that set aside a protected area can receive a reduction in land tax (May et al. 2002).

The investment involved for the protected area authority, whether government, NGO or private sector, includes the administrative costs of demarcating and managing the area and keeping unauthorised users out. For the owners and users of the protected forest land it means forgoing timber royalties and giving up the net benefits from agriculture and other land uses that compete with forests. This latter cost has rarely been factored in, except where compensation schemes operate.

Balmford et al. (2002) estimated current expenditure on protected areas at US\$ 6.5 billion per year, of which half was spent in the USA. A more recent estimate suggests this could range from US\$ 6.5 to US\$ 10 billion per year (Gutman and Davidson 2007). These estimates do not distinguish between forest ecosystems and other ecosystems in the protected areas. For example Mullan and Kontoleon (2008) cite an estimate by Bruner et al. (2003) of US\$ 8 billion of total expenditure on protected areas, of which approximately 60 per cent covers forested land. This suggests a little under US\$ 5 billion per year or US\$ 16.7 per hectare (assuming IUCN categories I-IV) is being spent on protected forests.

Many protected areas do not receive adequate funds to ensure their effective management. Very little is spent on compensation to those local communities who lose access to land and resources when protected areas are created. Protected areas are a vital part of the management of forest ecosystem services, but they need to address concerns over ineffective enforcement and share benefits with local communities. Estimates made of the cost of effective enforcement of protected areas with compensation for local communities are two to three times the amount currently spent (Box 5). Increased investment is needed to ensure better integration of communities' interests and to improve effectiveness along with better buffer- zone management.

#### Box 5: Costs of effective enforcement of protected areas

The total annual cost of managing the existing network of protected areas effectively was estimated in 1999 to be around US\$ 14 billion per year. This included increasing management costs (then estimated at US\$ 6 billion) by over a third and introducing compensation payments to communities living in protected areas of some US\$ 5 billion (James et al. 1999). A later estimate of US\$ 20-28 billion (Balmford et al. 2002) added the cost of up-scaling protected areas to ensure protection of 15 per cent of land area in each region. Assuming that forests constitute 60 per cent of terrestrial protected areas, this would suggest a cost of US\$ 12-17 billion per year for effective management of protected forests.

Investing in protected areas may bring economic benefits to the national economy in the long term. Some countries have been able to build up a lucrative nature-based tourism industry, which has brought in foreign exchange and generated employment. For example Costa Rica, where protected areas received more than 1 million visitors per year in the five years up to 2006, generated entrance-fee revenue of over US\$ 5 million in 2005 and directly employed 500 people. Protected areas in Latin America receive large numbers of visitors and generate many associated jobs. For example, Mexican protected areas recorded 14 million visitors per year and 25,000 jobs (Robalino et al. 2010).

Nature-based tourism is also a major economic activity in sub-Saharan Africa and the number of tourist arrivals is growing faster than the global average (in 2004 at 14 per cent compared with 10 per cent worldwide). In the Great Lakes region, revenue from tourism based on gorilla viewing and other activities brings in about US\$ 20 million annually (Gumbo 2010). But the tourism industry in Africa also has human and environmental costs, contributing to the displacement of communities, thus undermining rights and livelihoods (Gumbo 2010).

Admittedly, setting aside forests as protected areas has often been controversial because it is seen as preventing more productive activities such as timber harvesting and agriculture and as being damaging to livelihoods and to human rights, particularly where indigenous people are involved (Coad et al. 2008). Adverse social impacts of protected areas identified by these authors include: displacement of local communities, changes in traditional land tenure, denied or restricted access to resources, loss of employment, crop damage and livestock predation.

Cost-benefit studies have been conducted for protected forests in different regions. These examine costs and benefits at local, national and global levels but are not able to monetise all of the social costs identified above (Balmford et al. 2002; Coad et al. 2008). While there is some variation, a number of the studies conclude that global benefits and sometimes national scale benefits outweigh the overall costs including the tangible opportunity costs to local communities. For example, the protection of the Virunga and Bwindi afro-montane forests of Eastern and Central Africa – home of mountain gorillas – show positive benefits as opposed to costs, but most of them accrue to the international community (Hatfield and Malleret-King, 2004). Overall, gorilla tourism generates US\$ 20.6 million per year in benefits, with 53 per cent accruing to the national level; 41 per cent to the international level, and only 6 per cent locally.

Another study (Ferraro 2002), one of six reviewed by Coad et al. (2008), examines the costs and benefits of the Ranomafana National Park in Madagascar, which was created in 1991. It finds that the opportunity costs to local communities amounted to US\$ 3.37 million or US\$ 39 per household per year, but were greatly exceeded by the global- and national-scale benefits. Earlier studies of the Mantadia National Park Madagascar (Kramer et al. 1995) and Mount Kenya National Park in Kenya (Emerton 1998) reached similar conclusions.

These studies indicate that, in theory, those gaining from the protected areas should be able to compensate

local communities and still be better off. Historically, this compensation to communities has rarely happened. This highlights a challenge and an opportunity in a green forest sector for capturing the global benefits and creating redistribution mechanisms that are able to compensate local communities and improve their livelihoods.

As far as environmental effects are concerned, although the creation of a protected area does not guarantee environmental effectiveness and many are being encroached on, there are positive examples suggesting that this investment option merits further attention. Protected areas are considered critical for conserving residual tropical-forest biodiversity (Lee et al. 2007; Rodrigues et al. 2004). Studies in South-East Asia show that parks and reserves consistently recorded larger numbers of endemic bird species and higher population densities than surrounding human-modified areas (Lee et al. 2007).

Figuerola and Sánchez-Cordero (2008) evaluated the effectiveness of Mexican Natural Protected Areas (NPAs) for preventing deforestation. They constructed an effectiveness index, based on the protected areas' percentage of transformed areas, the rate and absolute extent of change in these areas, the comparison between rates of change observed inside the protected area and in an equivalent surrounding area, and between the NPA and the state(s) in which it is located. They found that over 54 per cent of NPAs were effective in preventing land-use or land-cover change.

### 3.3 Investing in PES

There are no precise statistics on the amount of money currently channelled into PES schemes, but Canby and Raditz (2005) estimate this as being hundreds of millions of US\$. The majority of this money comes from governments directly or from international donor support. These funds cover two main types of cost: the payment to the landholder or forest concession holder, compensating for the opportunity cost of forgone land-use, along with the costs of any actions necessary for conservation such as fencing or employment of guards, and the transaction costs of designing, setting up and operating the payment scheme, including contract management, fund management, the transfer of funds and monitoring.

The evidence on the social and economic impacts of PES schemes is mixed, both in terms of the extent to which the poorest groups participate in the schemes and the extent of livelihood benefits for those who do (Engel et al. 2008; Porras et al. 2008). Evidence of impact on non-participants is particularly scanty, and largely confined to observations in Costa Rica where a high proportion of those receiving payments hire labour to carry out

conservation-related work (Ortiz Malavasi et al. 2003; Miranda et al. 2003).

The two national PES schemes involving forest conservation in Costa Rica and Mexico provide contrasting experiences in terms of the nature of participants, reflecting to some extent differences in land and forest-tenure regimes. In Costa Rica, where most land is held privately, small farmers have very little participation in the PES scheme in spite of efforts made to prioritise the poorest regions (Porrás 2010). In Mexico, a high proportion of forest land is held as common property by local communities and even though criteria for selecting priority areas were primarily biophysical, the poorest groups were fairly well-represented. In 2003 and 2004, 72 per cent and 83 per cent respectively of the total paid out went to forests associated with marginalised population centres (Muñoz-Piña et al. 2008).

Local schemes such as at Pimampiro in Ecuador and Los Negros in Bolivia have achieved a fairly wide participation of local forest landowners, albeit over a small area, partly because they have been able to adapt to local circumstances (Porrás et al. 2008). In Los Negros, for example, the majority of landowners did not have clear land title, but the scheme went ahead on the basis of local recognition of farmers' landholding (Robertson and Wunder 2005).

Analysis of the livelihood benefits of PES schemes in several Latin American countries has given varied results; in general they have been welcomed by participants. The cash payments, with some exceptions, appear to be

relatively insignificant when compared with opportunity costs and household income (Porrás et al. 2008). This has led some researchers to conclude that the payments function more as support, providing recognition of existing good practice, rather than constituting a real incentive for land-use change (Ortiz Malavasi et al. 2003; Kosoy et al. 2007).

Non-financial benefits, such as capacity building, strengthening of land and resource tenure are therefore often considered to be significant. For example, PES schemes have been found to strengthen resource management and social coordination capacities of the community institutions involved (Tacconi et al. 2009). Capacity building is commonly reported as a benefit from PES schemes (i.e. increasing agricultural productivity in Pimampiro, Ecuador (Echavarría et al. 2004); apicultural training in Bolivia measured at US\$ 35 per participant (Asquith and Vargas 2007). However, for Tacconi et al. (2009) there is little evidence available about the long-term impact of capacity-building activities, for instance whether new knowledge and skills were applied in practice.

The evidence on the effectiveness of PES in reducing deforestation is also mixed, reflecting difficulties in establishing a clear counterfactual of what would have happened in the absence of the scheme and in predicting the location of deforestation (Cropper et al. 2001; Nelson and Hellerstein 1997). The national scheme in Costa Rica reflects reductions in national deforestation rates after the scheme started, but much of the research on this scheme throws doubt on a causal link between the two (Box 6). The same can be said for the Mexico

## Box 6: Research on the impact of PES on deforestation in Costa Rica

In Costa Rica's Virilla watershed Miranda et al. (2003) asked PES participants about their motivations and found that many of them planned to retain their forests regardless of the scheme. But as forest clearance is prohibited by law, this may have influenced the responses of the landholders as they might not want to state openly that they would contemplate illegal activity. These responses only represent a snapshot in time. It is unclear how these motivations would change as macroeconomic and microeconomic conditions change. Another study examined the characteristics of land included in the PES scheme. In the isolated Peninsula of Osa, for example, it was found that land under protection contracts corresponds mainly to forest that may not be in direct danger of being converted because of its remoteness and difficult access (Sierra and Russman 2006).

Analysis by Sanchez-Azofeifa et al. (2007) at a national level found that although the average deforestation rate dropped from 0.06 per cent per year in 1986-1997, to 0.03 per cent per year in the first phase of the PES programme 1997-2000, there was no significant difference in the rate of deforestation between areas in the national PSA scheme and areas that were not. They suggest that this could reflect lack of targeting of areas under deforestation pressure and also the impact of previous forest conservation policies, including a 1997 legal restriction on forest clearing. Similar results were found in a more recent study by Robalino et al. (2008) i.e., the efficiency of PES in reducing deforestation between 2000 and 2005 was also low. Less than 1 per cent of the parcels of land enrolled in the programme each year would have been deforested without payments.

national scheme (PSAH). The only major study so far of this scheme, (Muñoz-Piña et al. 2008) found that much of the land being put under payments was not at risk of being converted because of its low opportunity costs. In 2003, only 11 per cent of the participating hectares in the scheme were classified as having high or very high deforestation risk. This increased to 28 per cent in 2004 but fell again to 20 per cent in 2005.

A common thread in this research is the importance of targeting specific areas in improving the effectiveness of PES. Robalino et al. 2010, noting that in Costa Rica there was improvement in 2000-05 compared with the 1997-2000 period, argue that targeting areas affected by some deforestation pressure and including spatially-differentiated payments are two plausible next steps to improve the effectiveness of the scheme. This also points to the importance of developing monitoring and verification schemes and data collection (including the use of easily available GIS databases) that can help identify additional areas.

The PES experience also shows that while challenges have been faced in achieving environmental objectives and ensuring the participation of small-scale forest owners and marginalised groups, there has been considerable learning and adaptation to make improvements. In particular, ways have been found of including landowners without formal land title in PES schemes. The most important actions appear to introduce environmental and social criteria for targeting, actively promoting the PES option amongst groups that would not otherwise get involved and/or to reduce transaction costs. The involvement of intermediaries or facilitating organisations that have a community development mission is also important (Grieg-Gran 2008).

The main constraint on the expansion of PES schemes has been the lack of funds to scale up from pilot projects. Even national-level schemes such that in Costa Rica have been constrained by lack of resources, with applications to enter the scheme greatly exceeding the funds available (Porrás et al. 2008). If a REDD+ mechanism is negotiated, there will be a step change in the amount of funds available: the sums currently involved in the readiness phase are already significant.

However, if payment schemes are implemented at much larger scales and in locations where governance is weak, facilitators will have to guard against elite capture and more attention will have to be given to strengthening the land tenure of local communities (Bond et al. 2009). Attention to such safeguards will need to be a part of any investment in scaling up PES under REDD+.

### 3.4 Investing in improved forest management and certification

This investment approach recognises the importance of the production of timber, fibre, and energy in natural forests; if managed well, they need not conflict with the provision of other ecosystem services. Moreover, the ability to generate returns from forests through timber harvesting that are high enough to compete with other land uses is an important factor preventing total conversion.

Since the early 1990s, various sets of timber-harvesting guidelines on Reduced Impact Logging (RIL) have been produced in different regions of the world, designed to reduce the adverse environmental impacts associated with tree felling, yarding and hauling (Putz et al. 2008). Some of the requirements of RIL imply higher costs for logging companies, in the form of new equipment, safety gear, technically qualified supervisors, reductions in the area harvested and/or the need to use helicopter

#### Box 7: Research on the profitability of Reduced Impact Logging (RIL)

Studies of the costs and benefits of improved forest management produce conflicting results. Two studies in the Brazilian Amazon, in Tapajos National Forest (Bacha and Rodriguez 2007) and Paragominas (Barreto et al. 1998) have concluded that RIL can be highly profitable. But Putz et al. (2008) highlight other studies that have shown conventional logging to be more profitable (Healey et al. 2000) or have given mixed results (Applegate 2002). They conclude that it is not possible to draw general conclusions about the financial viability of RIL because of the wide range of forest conditions and practices that influence profitability in the tropics.

An earlier review of cost information in over 250 RIL studies (Killmann et al. 2002) concluded that RIL does cost more, but not as much as expected. Activities where RIL involved higher costs included planning, where the median difference (10 observations) was US\$ 0.28 per m<sup>3</sup>, and felling, where RIL was US\$ 0.56 per m<sup>3</sup> higher than conventional logging or 48 per cent higher. It is possible that the experience gained with RIL techniques since this review was carried out has led to a reduction in costs and a greater chance of profitability, as reflected in the more recent studies from Brazil cited above.



or cable systems to log areas with steep slopes (Putz et al. 2008). Given the planning it entails, RIL should involve less wastage of saleable timber and there were high hopes when it was first promoted that it would be sufficiently financially attractive for logging companies to adopt it as part of their normal practice.

The evidence on its financial benefits is mixed though, reflecting the wide range of forest practices and conditions (see Box 7).

Reduced Impact Logging is just one aspect of SFM criteria and indicators used in national standards and in voluntary certification schemes which describe more comprehensively the elements of good practice. There are a number of cost-increasing requirements beyond RIL, which makes it unlikely that increased efficiency will be sufficient to offset these.

The experience from Africa and Gabon in particular has shown that meeting government SFM standards can be challenging (Box 8). SFM management plans are expensive and, as a result, there has been limited uptake.

Many schemes have emerged to certify forest management against SFM standards, as well as wood tracking systems to ascertain sustainable and/or legal

wood sources. Independent inspectors assess a mix of forest management documentation and actual field practice. There are two international approaches with widespread support: FSC and PEFC. Both also offer chain-of-custody certification, tracing products from SMFs and verifying they are not contaminated by other (potentially unsustainable) products. The logistics can be challenging, especially for pulp, where many wood sources are mixed. It usually operates through an electronic system of tagging logs with bar-codes and tracking subsequent products.

Companies opting for certification not only have to meet the costs of any improvements needed to meet the standards, but also the direct costs or transaction costs of the certification application. For small forest areas these can be relatively significant (Bass et al. 2001). The direct costs of FSC certification have been estimated to range between US\$ 0.06 and US\$ 36 per hectare certified, depending on the size of forest area, as unit costs decline with scale (Potts et al. 2010). In certification, links to markets and the possibility of premiums or improved access to high value markets provide the incentive for investment.

An analysis of the impact of forest certification by Cashore et al. (2006) used case studies from 16 countries in four regions (Asia-Pacific, Eastern Europe and Russia, Latin America and sub-Saharan Africa). Positive social effects were consistently reported, including improved pay and conditions for workers, the development of community infrastructure and the provision of training. There was less consistency in these case studies and other recent literature on the market benefits of certification for the companies concerned, raising concerns about its financial sustainability in some areas (Box 9).

While a niche market may exist for some certified timber, many companies (especially in developing and transitional countries) produce for local and national markets. In these cases, tools such as FSC certification will not provide a significant impact on prices received (Cashore et al. 2006). Studies of certification in Africa, Eastern Europe and Latin America provide support for this finding. Nevertheless, in three tropical-forest countries in Asia and the Pacific, there is some evidence of positive market benefits from certification. In other cases, in South Africa and Finland, certification is found to be beneficial in maintaining existing market share (Box 9).

Box 9 provides examples of both positive and negative cost-benefit ratios related to the uptake of certification.

Certification has so far been taken up by forest operations of all sizes in developed countries, as well as by larger companies (often plantation companies) in developing nations. None of the ten largest certified forests are in the tropics and few certified forests are

### Box 8: The high cost of SFM plans in Gabon

Rough calculations show that to invest in a 15,000 hectare concession (for locals) a sum of US\$ 4,505,000 is needed, of which US\$ 2,850,000 (63 per cent) will go towards the development of a management plan and the rest into various associated studies and impact assessments, the most costly being those of fauna. These figures do not include management training and other costs such as licenses. Sustainable forest management has complex requirements. To formulate a Sustainable forest management (SFM) plan for a concession, an inventory of forest resources is needed and funds are required for associated mapping, in-forest measurement and assessment, and development of the plan and a process for implementation. These actions alone entail heavy investments. In addition, the Forestry Code for Gabon calls for low-impact logging practices; workers' compounds must be established for at least 25 years, and associated agricultural sites must be taken into account and studied in advance.

Source: Gumbo (2010)



## Box 9: Costs and benefits of certification for producers

In Uganda, there is no internal market for certified products and most exports are destined for other African countries that do not require certification (Gordon et al. 2006). Paschalis-Jakubowicz (2006) reported that although FSC certification increased costs for private producers, this was not reflected in the price of lumber in Polish markets. In Guatemala and Mexico, economic benefits of certification have generally not lived up to expectations, despite major government initiatives encouraging its use in communities and industry (Carrera Gambetta et al. 2006; Anta Fonseca 2006). In Guatemala, the direct and indirect costs of certification in the Maya Biosphere reserve have been estimated to range between US\$ 0.10 and US\$ 1.90 per certified hectare per year, US\$ 8-107 per hectare harvested per year, and US\$ 4.2-52.9 per m<sup>3</sup> of harvested round timber. This indicates considerable variation but suggests that for some forest owners the costs are very high. While premiums have been obtained, they are not high (in the case of certified mahogany, US\$ 0.05-0.10 per board feet, equivalent to less than 10 per cent of the sales price), and it was found that prices for non-certified wood soon caught up (Carrera Gambetta et al. 2006).

Malaysia has benefited from an average premium of 37 per cent on sawn timbers (see Shahwahid et al. 2006). Muhtaman and Prasetyo (2006) found that Perum Perhutani in Indonesia received a 15 per cent price premium, and Wairiu (2006) reported an increase in price per cubic metre for Solomon Islands Eco-forestry (SIEF) timber marketed through Village Eco-Timber Enterprises (VETE) in the Solomon Islands.

A survey of the furniture industry in South Africa found that although FSC certification does not lead to price premiums, there are other benefits in maintaining existing markets and contributing to quality control (Morris and Dunne 2003) cited in Blackman and Rivera 2010).

In Finland, a survey of perceptions of certified and non-certified wood products companies found that certification was not considered to improve financial performance or to result in premiums but was important for signalling environmental responsibility and maintaining market share (Owari et al. 2006 cited in Blackman and Rivera 2010).

community-run (FSC 2010). This reflects challenges in interpreting and meeting social standards locally, addressing insecure rights and assets of tropical forest land-holders and managers, and poor access to capital, skills and markets (Bass 2010).

However, there are some important exceptions that suggest these challenges could be overcome. Mexico contains more than 700,000 hectares of community-managed FSC-certified natural forest, spanning 33 communities with stands ranging from 56 hectares to 252,000 hectares. Most of these (26 out of 33) cover less than 20,000 hectares (Robalino et al. 2010). The Mpingo Conservation Project in Tanzania was awarded an FSC group certification for its community forests in 2009 and Kikole village, one of the project's constituent rural communities, sold the world's first harvest of FSC-certified African blackwood in January 2010 (FSC 2009).

In terms of the environmental impacts of certification, there is a general perception that certification has been taken up by forest enterprises that were already practising good forest management. Some support to this perception is given by the geographic pattern of the uptake of certification, which is heavily concentrated (80 per cent

in the case of FSC) in temperate and boreal areas (FSC 2010). The evidence on the impact of forest certification on biodiversity has been reviewed by van Kuijk et al. (2009) who concluded that while there is no conclusive quantitative evidence about the effects, the good forest-management practices associated with certification are beneficial for biodiversity. These include reduced impact logging, riparian buffer zones, green tree retention in clearcuts, protected areas within forest management units and biodiversity corridors. The review also showed that many species and ecosystems are negatively affected by any form of logging, highlighting the need for a mix of conservation areas and production areas of forest.

A more recent review and expert survey (Zagt et al. 2010) draws a heavily qualified conclusion that certification has helped reduce biodiversity loss in the tropics. The caveats to this conclusion relate to the limited area of certified natural forest in the tropics and the range of extra-sectoral threats to tropical forests which certification can do little to address.

In short, while there are some positive examples of premiums being received by developing country producers, and good evidence of positive social impacts, the slow pace of expansion of forest certification in

tropical and sub-tropical areas suggests that more proactive support is needed for scaling up. The evidence on environmental impact shows that there is potential, but that investment in certification needs to be accompanied by other measures aimed at protecting high conservation-value forest, controlling illegal logging and policies directed at other sectors.

### 3.5 Investing in planted forests

Investment in planted forest can take a number of forms. It can be for productive purposes and range from systems using native species to high-yield plantations. Alternatively, trees can be planted to promote ecological restoration and ecosystem services, as in the case of China (Box 10), although use of timber and fuelwood in such cases is often not precluded. A distinction is often made between reforestation and afforestation.<sup>5</sup>

Historically, governments have played a strong role in subsidising plantations, often providing as much as

75 per cent of total costs (Canby and Raditz 2005). This has been particularly significant in low- and middle-income countries, where governments have justified large subsidies in order to increase domestic timber supplies, supply industry with low-cost wood, and even to relieve pressure on natural forests (Canby and Raditz 2005). Global subsidies for plantations between 1994 and 1998 totalled US\$ 35 billion, of which US\$ 30 billion went to non-OECD countries (van Beers and de Moor 2001; Canby and Raditz 2005).

In Brazil, for many years, industrial forest plantations were promoted for production purposes (fibre for pulp and charcoal) through national government financial incentives (Viana et al. 2002). But several programmes now promote reforestation for ecosystem services. For example, in Piraçicaba in Sao Paulo state, the local authorities in charge of water supply provide assistance to farmers in the form of seedlings and technical assistance to restore riparian forests (Porrás et al. 2008). A number of countries have invested in mangrove restoration in order to improve sea defences.

5. Afforestation refers to planting of trees on land that has not had forest cover for many years (for more than 50 years under the rules of the Clean Development Mechanism) and that is therefore not considered forest land. Reforestation refers to planting of trees on land that has had forest cover removed recently (e.g. within the last 50 years) and that therefore can be considered as forest land.

#### Box 10: Afforestation in China: The Sloping Land Conversion Programme

The Sloping Land Conversion programme (or Grain for Green programme) started in 1999 with a goal to convert around 14.7 million hectares of erosion-prone farmland to forest within critical areas of the watershed of the Yangtze River and Yellow River in China by 2010 (Bennett 2008). This includes 4.4 million hectares of farmland on slopes greater than 25 degrees (Ibid.). There was also a goal to afforest a similar area of wasteland (Ibid.). Total investment has been US\$ 4.3 million per year (Porrás et al. 2008). By the end of 2003, 7.2 million hectares of cropland had been converted and 4.92 million hectares of barren or wasteland had been afforested (Xu et al. 2004). By the end of 2006, the area of cropland converted had reached 9 million ha (Chen et al. 2009). This was a considerable increase over previous trends for conversion of cropland to forests, estimated at just 1.2 million ha from the late 1980s to 2000 (Bennett 2008).

The cost of planting forests and the rate of return on investment varies according to the species, location, and whether planting is for productive or protective purposes. Differences in assumptions about the inclusion of opportunity costs of the land or the land price also lead to variations in reported costs (van Kooten and Sohngen 2007). Table 6 gives an indication of the variation in costs. Taking the range of costs in Table 6 and an annual increase of 5 million hectares, the current level of investment in extending the forest area could range from US\$ 1.25 billion to over US\$ 40 billion per year.

The rate of return on private investment in planted forest for productive purposes can be very high. Estimates made by Cubbage et al. (2009) of the financial viability of industrial plantations based on exotic species indicate that excluding land costs, returns for exotic plantations in almost all of South America – Brazil, Argentina, Uruguay, Chile, Colombia, Venezuela, and Paraguay – could be substantial, with an internal rate of return (IRR) of 15 per cent or more. Yet the record of public incentives in plantations has been poor, with the wrong choice of sites, poor genetic material, poor maintenance and location too far from markets (Bull et al. 2006; Cossalter and Pye Smith 2003). Changes in local and global markets are also a major factor affecting rate of return. The depressed timber prices on world markets at the end of the 1990s and the early years of the last decade led to smallholder plantations in the Philippines becoming unprofitable (Bertomeu 2003).

The social impacts of reforestation can be very controversial, particularly where it involves large-scale plantations run by private companies because

Activity	Location	Cost/ha	Reference
Restoring eucalyptus woodlands	S.E Australia	€ 285–(passive i.e. natural regeneration) –€ 970 (active i.e. replanting)	Dorrrough and Moxham (2005) <i>in</i> Neßhöver et al. (2009)
Restoration of degraded stands	Atlantic forest, Brazil	€ 2,600	Instituto Terra (2007)
Replanting of mangroves	Thailand	US\$ 8,240 plus US\$ 118/ha per year for maintenance	Sathirathai and Barbier (2001)
Reforestation for carbon sequestration and wood	Costa Rica	US\$ 1,633	Based on payment in national PES scheme of US\$ 980/ha (Robalino et al. 2010) which covers 60% of costs (Miranda et al. 2004)
Reforestation for carbon sequestration and wood	Ecuador	US\$ 1,500	Wunder and Albán (2008)
Afforestation	India various regions	US\$ 413 (2001 prices). Mean of 25 estimates from 21 studies ranging from US\$ 12 to US\$ 755	Balooni (2003)
Industrial forest plantation	Sabah, Malaysia (Acacia mangium)	US\$ 921–1,052 (2001 prices)	Chan and Chiang (2004)
Industrial forest plantations	Average for Southern hemisphere, USA and China – main species	US\$ 957	Cubbage et al. (2009) excludes land costs, and uses 8% discount rate.
	Uruguay (Eucalyptus globules)	US\$ 500	
	US (Douglas fir)	US\$ 1,300	
	Colombia (Pinus tecunumani and Eucalyptus)	US\$ 1,800	

**Table 6: Costs of reforestation and afforestation**

of concerns about land grabs, withdrawal of access to local communities to common-property forest resources and replacement of perceived degraded or low-value common property forest, or land important for food production, by forest plantations (WRM 2008a). Other reviews acknowledge these issues but point out that in some areas plantations can provide benefits to the local poor. Garforth, Landell-Mills and Mayers (2005) highlighted the employment generated by the plantation sector in South Africa, directly and indirectly in small-scale processing and retailing and supporting industries, estimating that about 7 per cent of the population depend on the sector. Bull et al. (2005) pointed to extensive outgrower schemes and social programmes of HIV AIDs, education and job training as benefits from plantations in the Southern Hemisphere. But Garforth et al. (2005) stressed that significant investment in local bargaining power is needed for outgrower schemes to offer routes out of poverty.

Small-scale reforestation on the part of communities or small farmers has been less controversial because it is often an important livelihood option introduced with a poverty- reduction aim. Farmers in India have become important suppliers of wood as a result of such programmes (Saigal 2005). A number of reforestation schemes have been targeted at the provision of ecosystem services, notably carbon sequestration. While some case studies have been generally positive, e.g. Miranda et al. 2004, on Costa Rica and Wunder and Albán (2008) on PROFAFOR in Ecuador, concerns have

been raised about the long time scales involved for benefits to accrue to farmers and the need for capacity building. The Sloping Land Conversion Programme in China was welcomed by farmers in its early years because the compensation offered outweighed the loss of agricultural return (Xu et al. 2004). However, surveys in five provinces found that there were shortfalls for a significant proportion of farmers from 7 per cent to 77 per cent (Uchida et al. 2005; Xu et al. 2004).

The environmental impacts of reforestation and afforestation vary considerably. Plantations can be contentious owing to their more intensive use of water and chemicals, as well as introduction of exotic and genetically modified tree species. There has been much criticism of monoculture plantations of exotic species (WRM 2008b). Recognising plantations' high potential to produce wood, potentially taking pressure off natural forests, their sustainability is often conferred at the landscape level rather than within the plantation – siting plantations on less biologically and culturally important land within a land-use mosaic, so that the landscape as a whole provides the range of goods and services required.

Even where tree planting is for protective purposes rather than production, much depends on the way programmes are carried out. The mangrove-planting programme in Vietnam has been widely hailed for its environmental benefits. It involved an investment of US\$ 1.1 million in planting (carried out by volunteers) and protecting 12,000 hectares of mangroves but

Type of agroforestry system	Location	Rate of return/comparison with conventional farming	Reference
Silvo-pastoral	Central and South America	4–14%	Pagiola et al. (2007)
	Peruvian Amazon	Lower return than shifting agriculture with short time horizon but higher return over a longer period	Mourato and Smith (2002)
Three strata: 1) fruit trees, 2) banana, papaya, lemon 3) spices	Northern Bangladesh	Agroforestry is more profitable than conventional farming with or without the inclusion of family labour costs and less risky	Rahman et al. (2007)
Mixed agroforestry, timber, horticulture, agriculture – timber harvested after 15 years	Chittagong Hill Tracts, Southern Bangladesh	Agroforestry gives lower annual return per land unit than shifting cultivation in year 1, 5, 9 and 13 and higher in other years. Agroforestry has a higher NPV over 15 years at 10% discount rate	Hossain et al. (2006)
Contour hedgerows	Eastern Visayas, Philippines	Through soil conservation and improved yields increases agricultural profits by average US\$ 53/household or 6% of total income but outweighed by opportunity costs of land and labour. Excludes on-farm benefits such as fuelwood and fodder as well as long run and external benefits	Pattanayak and Mercer (1998)
Fertiliser tree fallows	Zambia	Over 5 years at 30% discount rate, agroforestry is more profitable than continuous maize with no mineral fertilisers	Ajayi et al. (2006)
Rotational woodlots	Tanzania	Agroforestry has an NPV of US\$ 388/ha, six times that of conventional maize	Franzel 2004 cited in Ajayi et al. (2006)

**Table 7: Rate of return of agroforestry compared with conventional farming**

saved US\$ 7.3 million per year on dyke maintenance (Neßhöver et al. 2009). In contrast, mangrove restoration in the Philippines produced poor results because trees were planted in the wrong places leading to low survival rates (Neßhöver et al. 2009).

Similarly, the Sloping Land Conversion Programme in China, although effective in bringing about tree planting on large areas of land, has problems of low survival rates and lack of technical support (Bennett 2008). The suitability of this approach for drier regions of China has also been questioned, for example by Zhang et al. (2008), who estimated that in the sub-alpine region of south-western China, afforestation would reduce water yield by 9.6 - 24.3 per cent, depending on the type of species and the climatic conditions. Another study (Sun et al. 2006) which applied a simplified hydrological model across the diverse regions of China, estimated higher annual water yield reductions from afforestation from 50 per cent in the semi-arid Loess Plateau region in the north to 30 per cent in the tropical south.

To conclude, private investment in reforestation has a place in a green forest sector to ensure sufficient supplies of wood. But it needs to take place within management of the landscape and should not replace natural forests, nor land that is important for subsistence food production. The economies of scale of planted forests, particularly high-yield, fast-growing, single-species plantations are such that market forces will drive expansion. But incentives are often given in forms that lead to their replacing natural forests. The CDM also was restricted to reforestation and afforestation, putting natural forest management at a further disadvantage in developing

countries. As stressed by Bull et al. (2005) incentives to plantations should be directed instead at promoting forest ecosystem services and social development. Governance conditions are also required that will tilt the balance away from those planted forests that do not support many ecosystem services towards those that do. It is important that certification schemes continue to provide criteria for planted forests, including high-yield plantations, to encourage best practice while not putting sustainable timber harvesting from natural forest at a disadvantage.

### 3.6 Investing in agroforestry

Agroforestry encompasses a wide range of practices as demonstrated by a definition given in a recent assessment (Zomer et al. 2009): "Agroforestry systems range from subsistence livestock silvo-pastoral systems to home gardens, on-farm timber production, tree crops of all types integrated with other crops, and biomass plantations within a wide diversity of biophysical conditions and socioecological characteristics. The term has come to include the role of trees in landscape level interactions, such as nutrient flows from forest to farm, or community reliance on fuel, timber, or biomass available within the agricultural landscape."

Zomer et al. (2009) estimate that as much as 1 billion hectares of agricultural land could currently be considered as agroforestry if a threshold of 10 per cent tree cover is taken. With a higher threshold of 30 per cent tree cover, the area of agroforestry would be considerably lower at 375 million hectares, but still

significant. They conclude that trees are an integral part of the agricultural landscape in all regions except North Africa and West Asia. Agroforestry is relatively important in Central America, South America and South-east Asia, where there are many long-standing management traditions as well as new scientific forms of agroforestry, but agroforestry is also practiced on large proportion of Africa's land area.

As with reforestation, the costs and rates of return of agroforestry systems vary considerably depending on location, species and management type. FAO (2005b) cites a review by Current and Scherr (1995) of agroforestry practices in Central America and the Caribbean which found that in 2/3 of the cases, Net Present Value (NPV) and returns to labour were higher than for the main alternative practices. Some more recent studies in different locations that have compared the profitability of agroforestry systems with conventional farming systems are shown in Table 7. They are generally consistent with the conclusions in Current and Scherr (1995) but show the importance for the results of time horizons, discount rates and the range of benefits included. A common conclusion of the studies that find in favour of the profitability of agroforestry is that it requires considerably higher investment in the early years. This constitutes a major obstacle to its adoption.

The Food and Agriculture Organization of the United Nations' review of the benefits of agroforestry (FAO 2005b) cited a number of positive impacts for farmers, an additional source of cash income, provision of products such as fodder for livestock, fuelwood and fertiliser in the form of nitrogen-fixing trees, that the

farmer would otherwise have to buy, decreased risk because of the wider range of products on the farm, and the ability to earn income throughout the year and accrue benefits at different times, over the short, medium and long term.

Research on the payments for agroforestry scheme introduced in Costa Rica in 2004 as an additional eligible activity in the national PES scheme, provides some evidence on the social impact of providing incentives for agroforestry (Cole 2010). A high proportion (78 per cent) of the farmers interviewed reported an increase in income. This was not from sale of harvested timber but from money left over after planting and maintenance costs were covered. This was particularly important in indigenous communities because of their strong dependence on subsistence farming and little other opportunity for outside income. However, farmers commonly viewed the plantings as a savings account for future generations and saw little short-term benefit. While the payments were concluded to be effective in overcoming initial economic and technical obstacles, the need for ongoing capacity building and support from strong local organisations was highlighted.

A number of projects and programmes have promoted the wider adoption of agroforestry on the basis of its significant on-site and off-site environmental benefits. The Alternatives to Slash and Burn programme showed that tree-based farming systems, whether mixed or monocultural, had significant carbon storage benefits, in part due to its limited soil cultivation and consequent oxidation of soils, in part due to making use of many vertical layers of vegetation. It has been estimated that in Sumatra, Indonesia,

### Box 11: Evidence on the impact of incentives for silvo-pastoral practices

Around US\$ 4.5 million was invested in payments to farmers in Central America and Colombia to fund a transition to greater use of silvo-pastoral practices in cattle ranching. The payments to farmers were based on a scoring system for environmental services.

Research on the implementation of this scheme in Quindío, Colombia (Rios and Pagiola 2009) shows a significant difference between participants and the control group after four years of payments. Only 13 per cent of the land area in the control group experienced any change in land use and the effect of this change was to increase the environmental service score by 7 per cent. In contrast, changes in land-use practices extended to 44 per cent of

the area occupied by participants in the payment scheme and the environmental service score increased by 49 per cent. Similar conclusions based on casual observation of neighbouring areas are drawn for the silvopastoral scheme in Matiguás-Rio Blanco, Nicaragua (Rios and Pagiola 2009).

Although water-related services were not a focus of the payment scheme, some positive impacts were also found. The silvo-pastoral scheme in Quindío, Colombia monitored water quality upstream and found a rapid drop in turbidity, biological oxygen demand (BOD) and coliforms after measures had been taken to reforest riverbanks and protect them from livestock entry (Pagiola et al. 2007).



rubber agroforestry systems store about 116 tonnes of carbon per hectare, 45 per cent of the amount stored by undisturbed natural forests (254 t/C per ha), whereas continuous cultivation of cassava stores only 39 tonnes of carbon per hectare (Tomich et al. 2001). The Food and Agriculture Organization of the United Nations (2005b) cites evidence of various types of environmental benefits from agroforestry. In Sumatra (Murniati et al. 2001) showed that households with diversified agroforestry systems depend less on gathering forest products from protected areas than farmers cultivating wetland rice. In the USA, trees planted as wind breaks have been estimated to increase crop yield significantly, for example, by 23 per cent for winter wheat (Kort 1988). More recently, the GEF-funded Silvopastoral project in Colombia,

Costa Rica and Nicaragua, which targeted areas of degraded pasture, provides some rigorous evidence of the environmental benefits of creating incentives for agroforestry (Box 11).

In general, agroforestry has potential to be both beneficial to farmers and to provide offsite-benefits in the form of carbon sequestration, reduced sedimentation in surface water, and maintenance of a wider basis of biodiversity than agriculture. But the economic evidence shows that farmers need both financial assistance and technical assistance in making the transition to modern forms of agroforestry. Investment in incentive schemes combined with longer-term technical support can be effective in promoting its expansion.

## 4 Modelling green investment in forests

In this section we examine the impacts at a global level of increasing investment in two of the options discussed in the previous section: private investment in reforestation and public investment in payments to avoid deforestation. This is because both are highly likely to play a role in climate-change mitigation and will form part of a post-2012 international climate agreement.

### 4.1 The green investment scenario

Under the global model developed for the Green Economy Report by the Millennium Institute, the green investment scenario (G2) allocates 0.034 per cent of global GDP to reforestation and incentives for avoiding deforestation/forest protection between 2011 and 2050.<sup>6</sup> This equates to US\$ 40 billion (in constant 2010 US dollar prices) per year on average, with 54 per cent or US\$ 22 billion directed to reforestation and 46 per cent or US\$ 18 billion per year to avoided deforestation.

This is similar in order of magnitude to estimates made in the 1990s of the amount of investment needed for sustainable forest management in production forests of US\$ 33 billion per year (Tomaselli 2006) and estimates made in recent years for the cost of avoiding deforestation, which range from US\$ 5 billion to US\$ 15 billion per year (Stern 2007; Grieg-Gran 2006) to US\$ 17–28 billion (Kindermann et al. 2008). The amount indicated for avoiding deforestation also compares well with the estimate of US\$ 12–17 billion per year made in Section 3.2 of the investment needed for effective management of protected forests (based on Balmford et al. 2002).

### 4.2 The baseline scenario: business-as-usual

In the model, the baseline scenario or business-as-usual (BAU) for the forest sector replicates the historical trend from 1970 and assumes no fundamental changes in policy or external conditions going forward to 2050.

6. The 0.034 per cent of GDP for forest-related investments is part of an integrated green investment scenario, G2, in which a total of 2 per cent of global GDP is allocated to a green transformation of a range of key sectors. The results of this scenario, in which the 2 per cent is additional to current GDP, is generally compared to a corresponding scenario in which an additional 2 per cent of global GDP is allocated following existing business-as-usual trends, BAU2. In the case of the forestry sector, there is no significant difference between the BAU2 scenario and the BAU scenario, which also projects a business-as-usual path but without additional investments (see the Modelling chapter for more explanation of the scenarios). Hence the green investment scenario (G2) can be compared to the BAU which also represents the model's projections of future trends on a business-as-usual path.

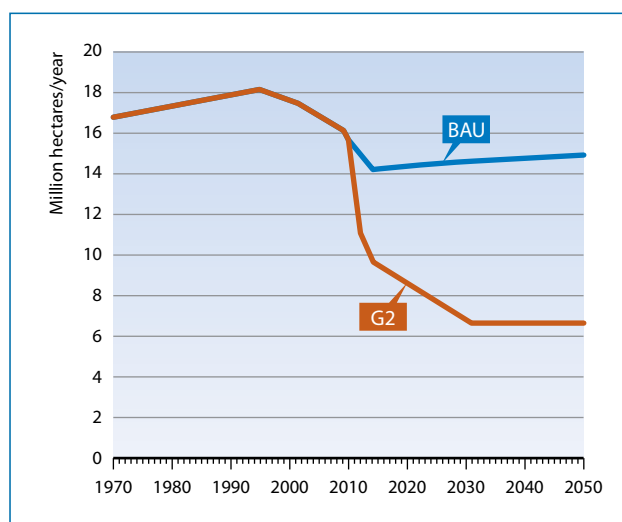
Under business-as-usual, the projection is for a steady decrease in forest cover from 3.9 billion hectares in 2010 to 3.7 billion hectares by 2050. As a result, carbon storage in forests will decline from 523 Gt in 2009 to 431 Gt in 2050. The contribution of the forest sector to global GDP and employment is projected to grow at 0.3 per cent per year between 2010 and 2050 to reach US\$ 0.9 trillion and 25 million jobs by 2050. This is in line with growth rates in the sector between 1990 and 2006 (FAO 2009).

### 4.3 Investing to reduce deforestation

The cost of avoiding deforestation is assumed to start at US\$ 1,800 per hectare, increasing to US\$ 2,240 per hectare by 2050. This is based on the global average value added per hectare of crop production plus the value added of forest products per hectare (measured in constant 2010 US\$ prices), which is taken to represent the opportunity cost if forests are conserved with no extraction of forest products or clearing. This approach to estimating opportunity cost is somewhat different from that taken in a number of studies on this topic (e.g. Grieg-Gran 2006; Börner et al. 2010), which add together the present value of agricultural revenues net of cost discounted over several years and the stumpage fees for timber, but the result is within the range of most such estimates.<sup>7</sup> It can be considered a generous estimate of the opportunity cost as in many locations the returns to converting forests to smallholder agriculture, subsistence and cash crops and to cattle ranching are considerably lower than US\$ 1,800 per hectare. This figure is more representative of higher-value land uses such as oil palm (see Grieg-Gran 2006; Chomitz et al. 2006; Börner et al. 2010).

Nevertheless, the cost of designing and administering a payment scheme, the so-called transaction costs, can be considerable, particularly in developing countries and in remote forest areas. While existing national-level PES schemes in Costa Rica and Mexico have administration costs of well below 10 per cent of the overall amount spent (Wunder et al. 2008), analysis of the Bolsa Floresta scheme in Amazonas state in Brazil indicates a much higher proportion, around 40 per cent (Viana et al. 2009). The cost figure used in this model is high enough to incorporate some provision for transaction costs.

7. It is equivalent to the cost of purchasing the land or the cost of making annual payments (as in PES schemes) to compensate for forgone annual returns to land over an appropriate time period (30–50 years) discounted at an appropriate rate.



**Figure 2: Deforestation reduction under the green investment scenario (G2)**

The investment would enable payments to be made to forest landholders over a steadily expanding area, with the yearly increase reaching 6.76 million hectares by 2030 and then decreasing to 6.66 million hectares by 2050, in effect reducing the annual rate of deforestation by just over 50 per cent, as shown in Figure 2. This is consistent with other studies, which have predominantly estimated the cost of reducing deforestation by 50 per cent (Stern 2007; Eliasch 2008; Kindermann et al. 2008).

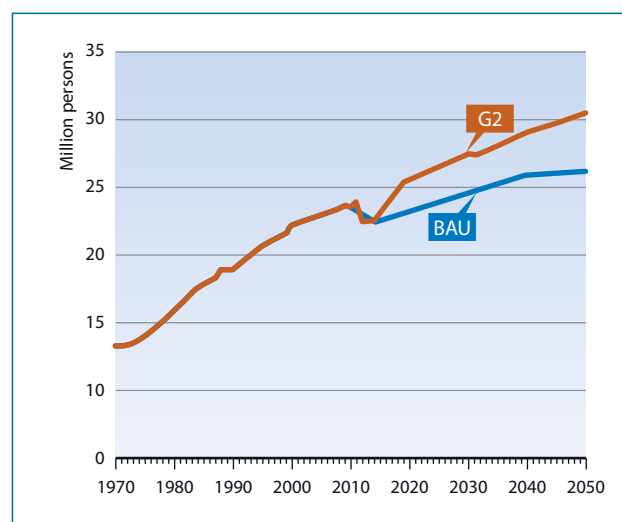
#### 4.4 Investing in planted forest

The cost of planting forests is assumed to be US\$ 1,630 per hectare based on the costs of reforestation in Costa Rica's national PES scheme, which pays farmers US\$ 980 per hectare (Robalino et al. 2010) to cover 60 per cent of the costs of establishment (Miranda et al. 2004). As shown in Table 6, this is within the range of costs estimated for production planted forests, which is the type of reforestation under consideration here.

Key forest-sector indicators in 2050	BAU	Green investment scenario (G2)
Natural forest area	3.36 billion ha	3.64 billion ha
Deforestation rate ha/year	14.9 million ha	6.66 million ha
Planted forest area	347 million ha	850 million ha
Total forest area	3.71 billion ha	4.49 billion ha
Carbon storage in forests	431 billion tonnes	502 billion tonnes
Gross value added	US\$ 0.9 trillion	US\$ 1.4 trillion
Employment	25 million	30 million

**Table 8: Forests in 2050 under the green investment scenario and business-as-usual (BAU)\***

\* See footnote 6.



**Figure 3: Employment under the green investment scenario (G2) and business-as-usual (BAU)**

The modelling examines the full cost to a landowner of establishing a planted forest rather than the incentive payment that might make such a land use competitive. On average, the investment allocated will cover the cost of reforesting an additional 9.6 million hectares per year or 386 million hectares over the 40-year period.

#### 4.5 Impacts of investment in reducing deforestation and in planted forest

The economic and environmental impacts of the green investment scenario are shown in Table 8. In the short term the reduction in deforestation leads to a decrease in the value added of the forest sector (wood, wood processing and pulp and paper) so that it is 1.7 per cent below the baseline in 2013. Similarly, employment is 2 per cent below the baseline level in 2013. However, this does not take account of the economic impacts on other sectors such as tourism, which may benefit from the reduction in deforestation and also the economic value of the reductions in carbon emissions. In the longer term, as the area of planted forest increases, value added in the conventional forest-based industries rises to US\$ 10.4 trillion, some 19 per cent above BAU. The increase is accompanied by growth in employment from 25 million to 30 million worldwide, or 20 per cent above business-as-usual (Figure 3).

The main environmental impact is on the area of natural forest, which in 2050 is 8 per cent more extensive in the green investment scenario than under BAU, and on the total area of forest (natural and planted) which in the green investment scenario is 21 per cent more extensive in 2050 than under BAU and 14 per cent higher than the current forest area. This has positive implications for biodiversity and carbon storage and results in reduced greenhouse gas emissions. The increase in the forest

area is made possible by the investments in improved agricultural productivity (see the Agriculture chapter). This means that demand for agricultural production can be met from a smaller area of land, freeing up land for reforestation or afforestation. It also means that there is less pressure on natural forest.

These projections indicate the potential of increasing green investment in the forest sector. But much depends on how the investment is made and in what policy and institutional context. As discussed above, reforestation programmes do not always work financially, socially or environmentally, and the small amount of investment

in avoiding deforestation so far, mainly in the national PES schemes in Costa Rica and Mexico, has struggled to demonstrate cost-effectiveness. Large investment programmes on the scale modelled here will be more challenging although they can draw lessons from the existing experience. Global aggregate projections of this nature cannot, owing to limitations of their design, capture the differences in response between tropical countries and non-tropical countries, or between countries with high forest cover and low forest cover, or between high income and low income countries. They do, however, indicate what can be achieved at a global level in the appropriate policy and institutional conditions.

## 5 Enabling conditions

Increased investment needs to be catalysed and backed up by improvements in forest governance, institutions and policy (UNFF 2009). Enabling conditions are needed to motivate the private sector and forest communities to make investments in sustainable forest management and downstream activities, and to support public-sector investments and ensure they realise value.

This section discusses important enabling conditions, including: forest governance and policy reform, actions to tackle bad practice in forestry and extra-sectoral drivers of forest loss, and information technology to characterise forest assets.

### 5.1 Forest governance and policy reform

An overarching requirement is to ensure that good forest governance is in place at the national level based on specific, country-led analysis of the economic, social and institutional drivers of forest loss. This good governance includes a vision for the future of a country's forests, and of forest-based economies, which addresses the sustainable and equitable provision of all forest ecosystem services. It also includes a policy framework that balances global and national public goods with private goods and community requirements, captures the value of forest ecosystem services in private and public decision-making, and creates clear incentives for good practice and disincentives for bad practice. In addition, it includes transparent, secure and fair rights to forest resources and allocation mechanisms especially for forest-dependent groups such as indigenous peoples. The fundamentals of good governance in a country (rule of law, freedom of association, respect for property rights, accountable legislature, etc.) will be critical.

At an operational level, good forest governance includes forest management principles, and a related hierarchy of criteria, indicators and standards that support progress from mere legality to SFM. It also includes participation of forest stakeholders – with special support to poor communities and indigenous peoples. Furthermore, it includes transparent and accessible databases and accountability mechanisms that record forest use by stakeholders and are linked to incentives and sanctions. Subsidies, fiscal instruments and other means to get the price right for given forest ecosystem services should also be covered, ensuring that externalities are reflected in payments for services. Finally, good forest governance

should include a capacity-developing, step-wise approach, helping stakeholders to continually improve forest management.

### 5.2 Tackling illegal logging

Illegal logging is a serious problem. The international trade in illegally sourced wood products was estimated to be worth US\$ 8.5 billion in 2008. Sustainably produced wood products will not be able to compete if large volumes are produced illegally or unsustainably, with low production costs, unreported taxes and royalties and unfair prices below market price. Because there are even larger volumes of illegal wood products that do not enter international trade and are consumed within the producing country, the actions that the governments of producing countries take to tackle illegal logging are likely to have leverage effects. However, the governments of countries that import wood products and the financial institutions that back forestry and manufacturing of wood products can also play an important role.

The 1998 G8 meeting was catalytic in drawing attention to illegal logging and setting in motion a significant international policy process – one that is increasingly influential and has recently reduced illegality, although has not yet stopped it. Subsequent intergovernmental agreements, in particular the Forest Law Enforcement and Governance (FLEG) processes coordinated by the World Bank, have helped to raise awareness of the issue and have resulted in agreements that “all countries that export and import forest products have a shared responsibility to undertake actions to eliminate the illegal harvesting of forest resources and associated trade”.<sup>8</sup>

The initiatives involve governments of importer countries increasingly excluding illegal products from their markets: by setting up border mechanisms to prohibit imports; by using public procurement policy to create protected markets for legal products; by using their own legal systems more aggressively to target companies involved in importing illegal goods; and by offering information and encouragement to importing, processing and retailing companies to control their supply chains. The USA became the first country to ban the import and sale of illegally harvested wood, and to require declaration of species and country of

8. Europe and North Asia FLEG Ministerial conference, 2005 St. Petersburg Declaration. Available at [http://194.84.38.65/files/specialprojects/enafleg/25dec\\_eng.pdf](http://194.84.38.65/files/specialprojects/enafleg/25dec_eng.pdf)



origin, extending the Lacey Act to wood products. The European Union has established a licensing system based around Voluntary Partnership Agreements (VPAs), which are negotiated with cooperating exporter countries (Box 12) under the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan.

The success of these tools will depend upon how extensive the uptake is and how well they close off the opportunities for circumvention by e.g. trade through third countries. This is highlighted in a recent study of illegal logging trends up to 2008 (Lawson and MacFaul 2010), which notes that there has been a reduction in illegal logging and in trade of illegally sourced wood products – although importing country measures had played a relatively small role in this. While FLEGT and the Lacey Act can be expected to have an impact in the future, the main challenge is the arrival of illegally-sourced wood via third party processing countries, notably China. The authors note that governments in processing countries are not taking adequate action to address illegal logging (Lawson and MacFaul 2010).

Further and more widespread improvement requires a transformation of forest governance in producing countries with wider stakeholder participation in the allocation of forest resources, and the determination of laws so that there is greater legitimacy for laws relating to forests and timber harvesting (as emphasised in 5.1). Both carrots (support for skills training in SFM, independent verification of SFM, and preferential government procurement for SFM) and sticks (tightening up laws and enforcement against illegal logging and marketing) are needed. The measures taken by consuming countries may help to promote this broader governance improvement, as the process of negotiating the VPAs has involved the inclusion of partner-country civil society in the negotiations (Brack 2010).

### 5.3 Mobilising green investment

Investment in forests can target conserving existing areas of primary forest, promote expansion of forests through regeneration and reforestation, improve forest management in existing forests of different types, and increase the number of agroforestry systems. Each of these will have different attractions for specific investors, e.g. agroforestry for agricultural investors aiming for long-term resilience in food and other markets. There is increasing evidence that private investments that seek long-term growth and security are attracted to well-managed forestry (such as pension funds, as well as specialist vehicles such as forest bonds). More recently, social stock exchanges and partnerships with corporations and government have revealed significant scope for social investments in locally-controlled forestry.

Because of the public-good nature of some forest ecosystem services, however, businesses and forest landholders usually do not perceive a sufficient incentive to make green investments in forests. Where such investments indicate a positive rate of return for society as a whole, investment by the public sector can be warranted: to provide forest ecosystem services directly; to provide financial incentives to the private sector to make green investment competitive; and/or to prevent unsustainable forest management. Central to this will be a hard-headed examination of national competitiveness in sustainable forest management, and effective regimes supporting financial rewards for producing forest ecosystem services, and notably Global Public Goods (GPGs).

A major incentive measure is public wood procurement, which has had a significant impact in a few importing countries and can have a knock-on effect on private procurement policy. Six EU countries including the UK (Box 13) have established procurement policies. These public procurement systems are driven by the power of public spending in the EU (which accounts for 16-18 per cent of GDP). They differ in some aspects, e.g.: whether they separate out legal and sustainable categories; whether they include social norms; and how they verify

#### Box 12: The EU licensing system for legal wood products

The EU's licensing system is based on VPAs with producing countries. These VPAs put in place a licensing system in each country, to identify legal products and license them for import to the EU. Unlicensed, and therefore possibly illegal, products will be denied entry to the EU. The agreements include: capacity-building assistance to set up the licensing scheme, improved enforcement and, if necessary, reform laws; and provisions for independent scrutiny of the validity of the issue of the licenses, as well as verifying legal behaviour through the chain of custody of the timber. The VPAs' impact is as yet unknown: the first two agreements with Ghana and Republic of Congo were signed too recently (September 2008 and March 2009, respectively) for any impact to be discernible. As developing a licensing system is estimated to take two years, the first FLEGT-licensed timber will not enter the market until late 2010. Negotiations are also underway with Cameroon, Central African Republic, Indonesia, Liberia and Malaysia (Brack 2010).

## Box 13: Wood procurement policy in the UK

The UK central government's wood procurement policy started with a requirement to source only legally-produced forest products (compulsory for all government contracts). A requirement for sustainable forestry was originally optional, but became mandatory from 2009, albeit with a six-year exemption for FLEGT countries (CPET 2010).

The UK policy recognises FSC and PEFC, and includes an independent Central Point of Expertise on Timber (CPET) to advise specifiers, contractors, etc.<sup>9</sup>

non-certified imports. Public procurement policies for timber also exist for Japan and New Zealand, as well as some local authorities in the EU and USA. There is clearly room for improvement but a good start has been made.

Another incentive is in the hands of key investors, such as the IFC and major private banks, which operate coherent controls and have specific policies for sustainable forest investment. Most of them have already stopped investing in unsustainable forestry and forest industry, and require certification associated with all forest investment (HSBC 2008). Some financial institutions have followed the lead of NGOs such as Tropical Forest Trust, Rainforest Alliance and Woodmark in promoting a step-wise approach to improving practice that culminates in full certification. A stepwise approach presents less of a challenge – and possibly more of an attractive business proposition – than the big stretch that is often required to move straight to full SFM certification. HSBC for example, is allowing five years to progress to certification (HSBC 2008).

## 5.4 Levelling the playing field: Fiscal policy reform and economic instruments

Forests are not so much a sector as a resource, which other sectors and livelihood systems use, e.g. the energy sector (low-cost wood can move in and out of energy markets) and the agriculture sector (forests can be a continuing source of food and an asset to be liquidated for farming). Policy measures which favour competing activities for

forest land and demand for the products derived from these activities can undermine efforts to conserve and sustainably manage forests. Mining and infrastructure projects, often prioritised for their contribution to government revenue, can have destructive direct impact on forests and indirect impacts through opening up remote areas. Government regulation of such projects and the due diligence procedures of financial institutions that back these projects provide important levers for good practice in siting, construction and operation to mitigate impacts on biodiversity.

Some governments and financial institutions are actively promoting biodiversity offsets to ensure that areas of rich biodiversity such as tropical forest that are unavoidably lost through capital development projects are offset through conservation actions to restore forest elsewhere or reduce risks. Engaging with a wide range of stakeholders is also critical, asking the question: which supply or demand factors (including particular specific goods and services) are tipping markets and governance regimes towards environmentally-sound, fairer, and more competitive outcomes? Which factors are mutually supportive and could lead to leveraged outcomes if more widely applied? The ecosystem approach can be used as a common framework for assessing potential trade-offs and synergies between sectors and stakeholders.

The most significant driver in terms of forest area is agriculture. For much of the 1980s and 1990s, the subsidies given to agriculture resulted in farming being the biggest cause of deforestation, and often also of inequity between farmers, where subsidies tend to be captured by larger farmers. With the onset of structural adjustment programmes, subsidies for key agricultural inputs such as fertiliser were reduced or phased out altogether in many developing countries. However, agriculture remains the engine of development of most low-income countries and is the focus of national and international efforts to ensure food security, particularly in response to the recent food price spike. Thus, it is not surprising that agriculture remains favoured over forests, if by means other than input subsidies – in particular, through water allocation systems, artificially low irrigation charges and infrastructure expansion, and roads. Today, the drive for biofuels expansion, often with substantial government support, is a new source of unequal competition and pressure on natural forests.

It is unrealistic to expect support to agriculture to be removed altogether if development and food security objectives are to be met. Agroforestry is one means to increase synergies between the two sectors. Mechanisms such as REDD provide incentives for forest conservation but will be undermined if agriculture is still subsidised in ways that are not coordinated with forest policy. Ways

9. Available at <http://www.cpet.org.uk/evidence-of-compliance/category-a-evidence/approved-schemes>.

should be sought for them to be mutually reinforcing (See Box 14). The chapter on Agriculture sets out the types of investment in sustainable agriculture that can meet world food needs and support conservation of natural forests and expansion of forest area.

## 5.5 Improve information on forest assets

In determining the relative priority to give to the forest sector versus agriculture and other sectors and to the range of forest ecosystem services, governments need to have better information on forest stocks, flows and cost-benefit distribution. This should go beyond counting trees and measuring area to assessing the magnitude, value and quality of forest ecosystem services. To do this requires information technology that can handle complexity. Geo-referenced information is needed on forest resources and the ecosystem services they provide. The associated economic, social and environmental benefits of forest ecosystem services also need to be captured in monitoring and economic statistics and included in multi-criteria analysis as basis for decision-making. There is adequate experience to take this to scale, so that countries have an accurate assessment of the stocks and flows of ecosystem services and who benefits from them. This is also needed to access ecosystem services markets that demand verification, and to improve the case made in public expenditure reviews.

At present, there are considerable uncertainties in estimating the value of ecosystem services at the local, national and particularly at the global level, reflecting gaps in information on biophysical linkages and how they depend upon both the type of forest and its management, and the site-specific nature of much of the research done to date. Publicly supported research on ecosystem services is needed to reduce the gaps in information and to document more fully the contribution made by the forest sector to the economy, livelihoods and social development in different downstream sectors. Improved knowledge of ecosystem services is essential for ensuring the full value of forests is acknowledged in wider development decisions. The link between forests and water supply particularly requires better information.

## 5.6 Making REDD+ a catalyst for greening the forest sector

There is no clear and stable global regime to attract investment in Global Public Goods (GPGs), and to assure their production in ways that are effective, efficient and equitable. Yet such a regime is essential to tip the

### Box 14: The effect of financial support to livestock in Brazil

A study of the livestock sector in Brazil highlights the challenges for policy coordination with forestry. Financial support from the Brazilian National Development Bank (BNDES) has played a significant role in the expansion of the livestock sector. The major part of this support has been targeted at purchase of stock, with less than 6 per cent of the funds being used to promote improvement of pastures. However, studies made by EMBRAPA, the Brazilian government agricultural research agency indicate that, with improvements in livestock, feed and management, it would be possible to increase the number of livestock by 42 per cent, while reducing the area of pasture by 35 per cent from its 2006 level. As the area of pasture in the Brazilian Amazon increased by 44 per cent between 1985 and 2006, driving much of the deforestation there, this has important implications for REDD: redirecting government support to improve pastures could reinforce efforts to control deforestation and restore forest cover.

Source: Smeraldi and May (2009)

finance and governance balance in favour of longer-term, sustainable forest management. Management for GPGs, as opposed to wood production alone, also opens up the prospect of new types of forest-related employment, livelihoods and revenues, including management partnerships with local communities. However, standards that support the co-production of local benefits with global benefits will be needed, as well as effective systems for local control of forests, to ensure livelihood benefits are realised and an equitable distribution of costs and benefits.

Payments for the climate regulation services of forests through the CDM and REDD+ mechanisms offer perhaps the greatest opportunity for countries and landholders to capture the value of their forest ecosystem services. The experience with PES provides valuable lessons for developing effective and equitable REDD+ mechanisms. Considerable work needs to be done, however, to resolve the issue of additionality<sup>10</sup>, that is to ensure that payments are targeted at forest conservation and enhancement activities which would not otherwise take place. This has proved challenging for existing PES schemes.

10. Additionality is aimed at improving efficiency.

However, this appears to discriminate against countries and forest landholders who have already conserved forests or taken early action. Determining the counterfactual or reference level of forest-related emissions – from forests that would otherwise not be conserved – is also challenging, as this is not necessarily the same as the formal development plans laid out by the country concerned; neither is it necessarily determined by whether forest conversion is permitted by national law. While there is scope for technical improvements in assessing deforestation and degradation and measuring forest carbon, determining reference emission levels into the future requires political negotiation (Bond et al. 2009).

The methodological guidance that came out of the Copenhagen COP was for reference emission levels in REDD+ to be based on historical rates adjusted for national circumstances (UNFCCC 2010). Reaching agreement on how these adjustments will be made will require both better understanding on the part of forest countries of how different rules on adjustment will affect them, and a pragmatic approach that recognises existing efforts to conserve forests and improve forest management.

Safeguards are also needed to protect the rights of forest-dependent people, particularly when these rights derive from traditional systems, rather than formal legal systems and to ensure that those who bear the costs of REDD+ schemes, in terms of land and resource restrictions, receive an appropriate share of the benefits. Specific models need to be developed for small-scale producers and local communities. As with protected areas, long-term effectiveness and efficiency of REDD+ schemes may often depend critically on ensuring these benefits for local stakeholders. Some projects in the voluntary carbon market, or as part of readiness activities and project design standards such as those of the Climate Community and Biodiversity Alliance, are showing how these equity issues can be addressed at the project level. At the national and international levels, the payment against performance approach being promoted in some bilateral deals could employ a broader concept of performance – one that incorporates not only emission reductions, but also considerations of equity and local co-benefits.

## 6 Conclusions

Understanding and accounting for the full range of services provided by forests is the most important task for the sector in a green economy. The active protection of tropical forests, for example, is now widely perceived as a crucial ecosystem management priority and a cost-effective way to reduce global carbon emissions. While the loss of forest carbon can be offset by planting trees, and some growing timber demand can be met by plantations, the loss of primary forest is often irreversible. Competing demand for forest land, especially from agriculture, is likely to continue driving deforestation. Policy measures beyond the forest sector, such as agricultural subsidies, are therefore at least as important as policies within the forest sector and innovative policies that exploit synergies between the two sectors will be especially valuable.

There are reasons for optimism, but greening the forest sector requires a sustained effort. Various standards and certification schemes have provided a sound basis for practising sustainable forest management, but their widespread uptake requires a strong mandate and consistent policies and markets. Protected areas, although controversial from the beginning, remain an important option for preventing the permanent loss of critical ecosystems and biodiversity. Their effective and equitable enforcement remains a challenge. The emerging PES and REDD+ schemes are ambitious and innovative avenues for funding the greening of the forest sector. Their interface with existing standards, certification schemes and networks of protected areas, however, needs to be monitored to ensure they build on or learn from earlier experiences.

Investment in greening the forest sector should consider sustainable forest management, PES and REDD+, planted forest, agroforestry, and indeed protected areas, although the modelling exercise – for illustrative purposes – focused only on reducing deforestation and increasing the area of planted forest.

Investing in greening the sector may involve short-term sacrifices in terms of income and jobs, as the forest stock in general requires time to grow or recover. This is why compensation schemes – whether national or international – are essential for communities.

Countries face a choice, whether to allow the prevailing forest transition to take its course or to change their forest economy to sustain a mix of forest goods and services that adds value and confers long-term resilience. Forests have tended to be associated with benefiting only the early phases of the development transition, where their intentional liquidation produces other forms of capital. Yet Sweden, Finland, Canada and other countries demonstrate how forests can play a sustained role in high-income countries, too. Maintaining forests in such countries has not inhibited wealth creation or labour markets; rather, there are significant forward linkages to many economic sectors with real opportunities for investment and related growth in wealth and jobs. These sectors could in turn, benefit from the renewable, recyclable, and biodegradable inputs that forests can provide. There are also highly significant public benefits in terms of biodiversity, health and recreation that are provided at relatively low cost.

The prospect of payments for ecosystem services such as carbon and biodiversity extends this practical proposition to those countries – notably low and middle-income – that are bold enough to make policy choices in favour of investing in the ecological infrastructure of forests, but that do not yet have the resources to invest in a modern forest industry. Protecting forests to maintain biodiversity and reduce carbon emissions do not require intensive management inputs, although they do require scrutiny and protection, and stable financial mechanisms. The alternative, a steady stripping of forest assets where the wider costs are unsupportable and the benefits are often uncertain, is no longer tenable.



# References

- Ajayi, O.C., Akinnifesi, F.K., Mullila-Mitt, J., DeWolf, J.J., and Matakala, P.W. (2006). "Adoption of agroforestry technologies in Zambia: Synthesis of key findings and implications for policy". Paper presented at the Agricultural Consultative Forum (ACF) Policy and Stakeholders' Workshop, 7 December 2006, Lusaka, World Agroforestry Centre.
- Angelsen, A. (2007). *Forest cover change in space and time: Combining the von Thünen and forest transition theories*. World Bank Policy Research Working Paper 4117, February.
- Angelsen, A. and Wertz-Kanounnikoff, S. (2008). "What are key design issues for REDD and the criteria for assessing options?" in A. Angelsen (ed.) *Moving ahead with REDD: Issues, options and implications*. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
- Angelsen, A. (2009). Introduction in Angelsen, A. with Brockhaus, M., Kanninen, M., Sills, E., Sunderlin, W. D. and Wertz-Kanounnikoff, S. (eds.) *Realising REDD+ national strategies and policy options*. CIFOR, Bogor, Indonesia.
- Anta Fonseca, (2006). "Forest certification in Mexico." in Cashore, B. et al., (eds.) *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Applegate, G.B. (2002). "Financial costs of reduced impact timber harvesting in Indonesia: Case study comparisons." in Enters, T., et al. (eds.), International conference proceedings on applying reduced impact logging to advance sustainable forest management, Kuching, Sarawak, Malaysia. Food and Agriculture Organization of the United Nations (FAO), Regional Office for Asia and the Pacific, Bangkok, Thailand.
- Asquith, N. and Vargas, M.T. (2007). "Fair deals for watershed services in Bolivia". *Natural Resource Issues*, No 7. International Institute for Environment and Development. London.
- Bacha, C.J.C. and Rodriguez, E.L.C. (2007). "Profitability and social impacts of reduced impact logging in the Tapajós National Forest, Brazil – A case study". *Ecological Economics*, 63, pp. 70-77.
- Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R. E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., and Turner, R. K. (2002). "Economic reasons for conserving wild nature". *Science*, 297, pp. 950-953.
- Balooni, K. (2003). "Economics of wastelands afforestation in India, a review". *New Forests*, 26, pp. 101-136.
- Barreto, P., Amaral, P., Vidal, E., and Uhl, C. (1998). "Costs and benefits of forest management for timber production in eastern Amazonia". *Forest Ecology and Management*, 108, pp. 9-26.
- Bass, S. (2010). Global overview of sustainable forest management approaches. Background paper for the Forests chapter, Green Economy Report.
- Bass, S., Nussbaum, R., Morrison, E. and Speechly, H. (1996). Paper farming: The role of plantations in the sustainable paper cycle. No. 5, Towards a Sustainable Paper Cycle Sub-Study Series, IIED, London.
- Bass, S., Thornber, K., Markopoulos, M., Roberts, S., and Grieg-Gran, M., (2001). Certification's impacts on forests, stakeholders and supply chains. Instruments for sustainable private sector forestry series. IIED, London.
- Bennett, M.T. (2008). "China's sloping land conversion program: Institutional innovation or business-as-usual?" *Ecological Economics*, Vol. 65, Issue 4, pp. 699-711.
- Bertomeu, M.G. (2003). "Smallholder maize-timber agroforestry systems in Northern Mindano, Philippines: Profitability and contribution to the timber industry sector". Paper presented at the International Conference on Rural Livelihoods, Forests and Biodiversity, 19-23 May, Bonn, Germany.
- BEST. (2009). Malawi: Biomass energy strategy study. A report prepared for the Government of Malawi (GoM). The EU, Brussels, Belgium.
- Binswanger, H.P. (1991). "Brazilian policies that encourage deforestation in the Amazon". *World Development*, Vol. 19, Issue 7, pp. 821-829.
- Blackman, A. and Rivera, J. (2010). The evidence base for environmental and socioeconomic impacts of 'sustainable certification'. Discussion Paper 10-17, Resources for the Future, Washington D.C., USA.
- Bond, I., Grieg-Gran, M., Wertz-Kanounnikoff, S., Hazlewood, P., Wunder, S., and Angelsen, A. (2009). "Incentives to sustain forest ecosystem services: A review and lessons for REDD". *Natural Resource Issues*, No. 16. International Institute for Environment and Development (IIED), London, with CIFOR, Bogor, Indonesia, and World Resources Institute, Washington D.C.
- Börner J., Wunder S., Wertz-Kanounnikoff, S., Rüginitz Tito, M., Pereira, L., and Nascimento, N. (2010). "Direct conservation payments in the Brazilian Amazon: Scope and equity implications". *Ecological Economics*, Vol. 69, Issue 6, pp. 1272-1282.
- Brack, D. (2010). Controlling illegal logging: Consumer-country measures. Briefing paper. Chatham House, London.
- Browder, J.O. (1988). Public policy and deforestation in the Brazilian Amazon in Repetto, R. and Gillis, M. (eds.), *Public policies and the misuse of forest resources*. Cambridge University Press. pp. 247-297.
- Bruinsma, J. (2009). "The resource outlook to 2050. By how much do land, water use and crop yields need to increase by 2050?" Technical paper from the Expert Meeting on How to Feed the World in 2050. Food and Agriculture Organization of the United Nations (FAO), Rome.
- Bruner, A., Hanks, J. and Hannah, L. (2003). "How much will effective protected area systems cost?" Presentation to the Vth IUCN World Parks Congress, 8-17 September, Durban, South Africa.
- Bull, G.Q., Bazett, M., Schwab, O., Nilsson, S., White, A., and Maginnis, S. (2006). "Industrial forest plantation subsidies: Impacts and implications". *Forest Policy and Economics*, Vol. 9, No. 1.
- Canby, K. and Raditz, C. (2005). "Opportunities and constraints to investment: Natural tropical forest industries". *Forest Trends*, Washington D.C.
- Carle, J., and Holmgren, P. (2008). "Wood from planted forests a global outlook 2005-2030". *Forest Products Journal*, Vol. 58, Issue 12, pp. 6-18.
- Carrera Gambetta, F., Stoian, D., Campos, J.J., Morales, J., and Pinelo, G. (2006). "Forest certification in Guatemala" in Cashore, B. et al. (eds.) *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Cashore, B., Gale, F., Miedinger, E., and Newsom, D. (eds.) (2006). *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Chan, H.H. and Chiang, W. C. (2004). Impact of incentives on the development of forest plantation resources in Sabah, Malaysia in Enters, T., and Durst, P. (eds.) *What does it take? The role of incentives in forest plantation development in Asia and the Pacific*, RAP Publication 2004/27, Asia-Pacific Forestry Commission, Food and Agriculture Organization of the United Nations (FAO), Regional Office for Asia and the Pacific, Bangkok, Thailand.
- Chape, S., Harrison, J., Spalding, M., and Lysenko, I. (2005). "Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets". *Phil. Trans. R. Soc. B*, Vol. 360, pp. 443-455.
- Chen, X. D., Lupi, F., He, G.M. and Liu, J.G. (2009). "Linking social norms to efficient conservation investment in payments for ecosystem services". *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, Vol. 106, pp. 11812-11817.
- Chomitz, K., Buys, P., De Luca, G., Thomas, T.S., and Wertz-Kanounnikoff, S. (2006). At loggerheads? Agricultural expansion, poverty reduction and environment in tropical forests. The World Bank, Washington, D.C.
- Coad, L., Campbell, A., Miles, L. and Humphries, K. (2008). The costs and benefits of forest protected areas for local livelihoods: A review of the current literature. Working Paper, revised 21 May, UNEP-WCMC.
- Cole, R.J. (2010). "Social and environmental impacts of payments for environmental services for agroforestry on small-scale farms in southern Costa Rica". *International Journal of Sustainable Development & World Ecology*, Vol. 17, No. 3, pp., 208-216.
- Cossalter, C. and Pye-Smith, C. (2003). Fast-wood forestry – myths and realities. Center for International Forestry Research, Jakarta, Indonesia.
- Costello, C. and Ward, M. (2006). "Search, bioprospecting and biodiversity conservation". *Journal of Environmental Economics and Management*, Vol. 52, Issue 3, pp. 615-626.
- CPET. (2010). "Executive summary of UK government timber procurement advice note." Central Point of Expertise on Timber. Available

at: <http://www.cpet.org.uk/files/TPAN%20April%2010.pdf>.

Cropper, M., Puri, J. and Griffiths, C. (2001). "Predicting the location of deforestation: The role of roads and protected areas in North Thailand", *Land Economics*, Vol. 77, No. 2.

Cubbage F., MacDonagh, P., Balmelli G., Rubilar, R., de la Torre, R., Hoeflich, V., Murara, M., Kotze, H., Gonzalez R., Carrero, O., Frey, G., Koesbandana, S., Morales Olmos, V., Turner, J., Lord, R., Huang, J., and Abt, R. (2009). Global forest plantation investment returns. XIII World Forestry Congress, Buenos Aires, Argentina, 18-23 October.

Current, D. and Scherr, S. (1995). "Farmer costs and benefits from agroforestry and farm forestry projects in Central America and the Caribbean: Implications for policy". *Agroforestry Systems*, 30, pp. 87–103.

De Groot, R. et al. (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation in TEEB – The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations.

Dorrrough, J. and Moxham, C. (2005). "Eucalypt establishment in agricultural landscapes and implications for landscape-scale restoration". *Biological Conservation*, 123, pp. 55–66.

Echavarría, M., Vogel, J., Albán, M., and Meneses, F. (2004). *The impacts of payments for watershed services in Ecuador. Emerging lessons from Pimampiro and Cuenca*. Markets for Environmental Series Report No. 4. IIED, London.

Eliasch, J. (2008). *The Eliasch Review – climate change: Financing global forests*. UK Office of Climate Change.

Emerton, L. (1998). Mount Kenya: The economics of community conservation. Community conservation in Africa Paper No. 6, Institute for Development Policy and Management, University of Manchester.

Engel, S., Pagiola, S., and Wunder, S. (2008). "Designing payments for environmental services in theory and practice: An overview of the issues". *Ecological Economics*, Vol. 65, No. 4, pp. 663–674.

FAO. (2001). Global forest resources assessment 2000, Food and Agriculture Organization of the United Nations, Rome.

FAO. (2005a). *Forest resources assessment 2005*, Food and Agriculture Organization of the United Nations, Rome.

FAO. (2005b). *State of the world's forests 2005*, Food and Agriculture Organization of the United Nations, Rome.

FAO. (2009). *State of the world's forests 2009*, Food and Agriculture Organization of the United Nations, Rome.

FAO. (2010). *Global Forest Resources Assessment 2010*, Food and Agriculture Organization of the United Nations, Rome. Available at: [www.fao.org/forestry/fra2010](http://www.fao.org/forestry/fra2010)

FCPF. (2010) Readiness Preparation Proposal (R-PP) Socialist Republic of Vietnam. Forest Carbon Partnership Facility, World Bank, Washington D.C. Available at: <http://www.forestcarbonpartnership.org/fcp/sites/forestcarbonpartnership.org/files/Documents/PDF/Oct2010/Viet%20Nam%20draft%20R-PP%20Oct%202010.pdf>

Ferraro, P. (2002). "The local costs of establishing protected areas in low income nations: Ranomafana National Park, Madagascar", *Ecological Economics*, Vol. 43, Issue 2, pp. 261–275.

Figueroa, F., and Sánchez-Cordero, V. (2008). "Effectiveness of natural protected areas to prevent land use and land cover change in Mexico". *Biodiversity Conservation*, 17, pp. 3223–240.

Franzel, S. (2004). "Financial analysis of agroforestry practices." in Alavalapati, J.R.R., and Mercer, D.E. (eds.), *Valuing Agroforestry Systems*. Kluwer Academic Publishers, Netherlands, pp. 9–37.

FSC. (2009). Forest stewardship council milestones annual report 2009. Forest Stewardship Council, Bonn, Germany.

FSC. (2010). Global FSC certificates: Type and distribution. Forest Stewardship Council, Bonn, Germany.

Garforth, M., Landell-Mills, N. and Mayers, J. (2005). "Plantations, livelihoods and poverty" in Garforth, M. and Mayers J. (eds.) *Plantations, privatization, poverty and power: Changing ownership and management of state forests*. Earthscan, UK and USA.

Geist, H.J., and Lambin, E.F. (2002). "Proximate causes and underlying driving forces of tropical deforestation". *Bioscience*, Vol. 52, Issue 2.

Gordon, E., Eba'a Atyi R., Ham, C., Polycarp Musimani Mwima, Eilu, G., Biryahwaho, B., Gombya-Ssembajjwe, B., Njovu, F. and Cashore, B. (2006). Forest certification in Sub-Saharan Africa in Cashore, B., Gale, F., Miedinger, E., and Newsom, D. (eds.) *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.

Grieg-Gran, M. (2006). The cost of avoiding deforestation. Background paper for the Stern Review of the Economics of Climate Change. IIED, London.

Grieg-Gran, M. (2008). Equity considerations and potential impacts on indigenous or poor forest-dependent communities. Background Paper No.9 for Bond et al. 2009 *op cit*.

Gumbo, D. (2010). Regional review of SFM and policy approaches to promote it – Sub-Saharan Africa. Background Paper for the Forests chapter, Green Economy Report.

Gutman, P. and Davidson, S. (2007). *A review of innovative international financial mechanisms for biodiversity conservation – with a special focus on the international financing of developing countries' protected areas*. WWF-MPO Washington D.C., October 2007. Available at: <http://www.cbd.int/doc/meetings/pa/wgpa-02/information/wgpa-02-inf-08-en.pdf>

Hatfield, R. and Malleret-King, D. (2004). "The economic value of the Virunga and Bwindi Mountain Gorilla protected forests: Benefits, costs and their distribution amongst stakeholders". Paper presented at the "People in Parks: Beyond the Debate" conference, March 2004. International School of Tropical Forestry, Yale University.

Healey, J.R., Price, C., Tay, J. (2000). "The cost of carbon retention by reduced impact logging", *Forest Ecology and Management*, 139, pp. 237–255.

Hope, C., and Castillo-Rubio, J. (2008). A first cost benefit analysis of action to reduce deforestation. Background paper for Eliasch Review, *op cit*.

Hossain, M.A., Alam, M.A., Rahman, M.M., Rahaman, M.A., and Nobi, M.N. (2006). "Financial variability of shifting cultivation versus agroforestry project: A case study in Chittagong Hill Tracts." *International Journal of Agriculture and Biology*, Vol. 8, No. 1.

HSBC. (2008). Forest land and forest products sector policy. HSBC, Available at: [http://www.hsbc.com/1/PA\\_1\\_1\\_S5/content/assets/csr/080905\\_forest\\_land\\_and\\_forest\\_products\\_sector\\_policy\\_summary.pdf](http://www.hsbc.com/1/PA_1_1_S5/content/assets/csr/080905_forest_land_and_forest_products_sector_policy_summary.pdf)

Hyde, W.F. (2005). Limitations of sustainable forest management: In an economics perspective. Chapter 9. in Kant, S. and Berry, R. (eds.) *Institutions, Sustainability, and Natural Resources*. Vol. 2 *Institutions for Sustainable Forest Management Series*, Springer, The Netherlands.

IEA. (2007). *Key world energy statistics 1973 & 2005*. International Energy Agency, Paris.

IIED. (2003). *Valuing forests: A review of methods and applications in developing countries*. Environmental Economics Programme, International Institute for Environment and Development, London.

Instituto Terra. (2007). *Restoration of the Atlantic Forest (Mata Atlântica)*, cited in Neßhöver et al. 2009.

ITTO. (2006). Status of tropical forest management 2005. ITTO Technical Series No. 24. *International Tropical Timber Organization*, Yokohama, Japan.

James, A.N., Gaston, K.J., and Balmford, A. (1999). "Balancing the earth's accounts. Commentary". *Nature*, Vol. 401, September.

Killmann, W., Bull, G.Q., Schwab, O., and Pulkki, R.E. (2002). Reduced impact logging: Does it cost or does it pay? in Enters, T., Durst, P.B., Applegate, G.N., Kho, P.C.S., and Man, G. (eds.) *Applying Reduced Impact Logging to Advance Sustainable Forest Management: International Conference Proceedings* (26 February to 1 March 2001, Kuching, Malaysia), Food and Agriculture Organization of the United Nations (FAO). Available at: <ftp://ftp.fao.org/docrep/fao/005/AC805E/AC805E00.pdf>

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrakso, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., and Beach, R. (2008). "Global cost estimates for reducing carbon emissions through avoided deforestation", *Proceedings of the National Academy of Science (PNAS)*, Vol. 105, No. 30, pp. 10302–10307.

Kort, J. (1988). "Benefits of windbreaks to field and forage crops". *Agriculture, Ecosystems and the Environment*, 22/23, pp. 165–190.

Kosoy, N., Martinez-Tuna, M., Muradian, R. and Martinez-Alier J. (2007). "Payments for environmental services in watersheds: Insights from a comparative study of three cases in Central America." *Ecological Economics*, 61, pp. 446–455.

Kozak, R. (2007). Small and medium forest enterprises: Instruments of change in the developing world. Rights and Resources Initiative, Washington, D.C.

- Kramer, R.A., Sharma, N., and Munasinghe, M. (1995). Valuing tropical forests: Methodology and case study of Madagascar. Environment Paper No. 13, The World Bank: Washington, D.C.
- Landell-Mills, N., and Porras I. (2002). Silver bullet or fools' gold: A global review of markets for forest environmental services and their impacts on the poor. International Institute for Environment and Development (IIED), London.
- Lawson, S., and MacFaul, L. (eds.) (2010). *Illegal logging and related trade: Indicators of the global response*. Chatham House, London.
- Lebedys, A. (2007). Trends and current status of the contribution of the forestry sector to national economies. A paper prepared for the FAO work programme component on financing sustainable forest management. 1990-2006 Working paper: FFSM/ACC/08.
- Lee, T. M., Sodhi, N. and Prawiradilaga, D. (2007). "The importance of protected areas for the forest and endemic avifauna of Sulawesi (Indonesia)". *Ecological Applications*, Vol. 17, Issue 6, pp. 1727-41.
- Mather, A. (1992). "The forest transition". *Area*, 24, pp. 367-379.
- May, P.H., Veiga, F., Denardin, V., and Loureiro, W. (2002) in Pagiola, S., Bishop, J. and Landell-Mills, N. (eds.), *Selling forest environmental services market-based mechanisms for conservation and development*. Earthscan Publications, London.
- May, P.H., Boyd, E., Veiga, F., and Chang, M. (2004). *Local sustainable development effects of forest carbon projects in Brazil and Bolivia. A view from the field*. International Institute for Environment and Development (IIED), London.
- Miranda, M., Porras, I.T., and Moreno, M.L. (2003). The social impacts of payments for environmental services in Costa Rica. A quantitative field survey and analysis of the Virilla watershed, IIED, London.
- Miranda, M., Porras, I.T., and Moreno, M. (2004). The social impacts of carbon markets in Costa Rica: A case study of the Huetar-Norte region, IIED, London.
- Morris, M., and Dunne, N. (2003). "Driving environmental certification: Its impact on the furniture and timber products value chain in South Africa". *Geoforum*, Vol. 35, Issue 2, pp. 251-266.
- Mourato, S. and Smith, J. (2002). Can carbon trading reduce deforestation by slash-and-burn farmers? Evidence from the Peruvian Amazon in Pearce, D.W., Pearce, C., and Palmer, C. (eds.), *Valuing the environment in developing countries: Case studies*. Cheltenham: Edward Elgar: 358-376.
- Muñoz-Piña, C., Guevara, A., Torres, J.M., and Braña, J. (2008). "Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results." *Ecological Economics*, Vol. 65, Issue 4, pp. 725-736.
- Muhtaman, D., and Prasetyo, F. (2006). "Forest certification in Indonesia." in Cashore, B. et al. (eds.), *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Mullan, K., and Kontoleon, A. (2008). Benefits and costs of forest biodiversity: Economic theory and case study evidence. Final Report, June.
- Murniati, Garrity, D.P., and Gintings, A.N. (2001). "The contribution of agroforestry systems to reducing farmers' dependence on the resources of adjacent national parks". *Agroforestry Systems*, 52, pp. 171-184.
- Nair, C.T.S., and Rutt, R. (2009). "Creating forestry jobs to boost the economy and build a green future", *Unasylva*, Vol. 60, No. 233. pp. 3-10. Available at: <ftp://ftp.fao.org/docrep/fao/012/i1025e/i1025e02.pdf>
- Nelson, G.C., and Hellerstein, D. (1997). "Do roads cause deforestation? Using satellite images in econometric estimation of land use." *American Journal of Agricultural Economics*, Vol. 79, Issue 2.
- Neßhöver, C., Aronson, J. and Blignaut J. (2009). Investing in ecological infrastructure in TEEB – The Economics of Ecosystems and Biodiversity for National and International Policy Makers.
- Openshaw, K. (1997a). Malawi: Woodfuel Production, Transport and Trade; A Consolidated Report. Report prepared for the Government of Malawi. Alternative Energy Development (now part of the International Resources Group), Washington, D.C.
- Openshaw, K. (1997b). Malawi: Biomass Energy Strategy Study. Report prepared for the World Bank by Alternative Energy Development (now part of International Resources Group), Washington, D.C.
- Openshaw, K. (2010). "Can biomass power development?" *Gatekeeper*, 144, April, International Institute for Environment and Development (IIED), London.
- Ortiz Malavasi, R., Sage Mora, L.F., and Borge Carvajal, C. (2003). *Impacto del programa de pago por servicios ambientales en Costa Rica como medio de reducción de pobreza en los medios rurales*. RUTA, San José, Costa Rica.
- Owari, T., Juslin, H., Rummukainen, A., and Yoshimura, T. (2006). "Strategies, functions and benefits of forest certification in wood products marketing: Perspectives of Finnish suppliers", *Forest Policy and Economics*, Vol. 9, No. 4, pp. 380-91.
- Pagiola, S., Bishop J., and Landell-Mills, N. (2002). "Market-based mechanisms for conservation and development." in Pagiola, S., Bishop, J. and Landell-Mills, N. (eds.), *Selling Forest Environmental Services Market-Based Mechanisms for Conservation and Development*. Earthscan Publications, London, UK.
- Pagiola, S., Ramírez, E., Gobbi, J., De Haan, C., Ibrahim, M., Murguetio, E., and Ruiz J.P. (2007). "Paying for the environmental services of silvopastoral practices in Nicaragua", *Ecological Economics*, Vol. 64, Issue 2, pp. 374-385.
- Paschalis-Jakubowicz, P. (2006). "Forest certification in Poland." in Cashore, B. et al., (eds.), *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Pattanayak, S., and Mercer, D. E. (1998). "Valuing soil conservation benefits of agroforestry: Contour hedgerows in the Eastern Visayas, Philippines." *Agricultural Economics*, 18, pp. 31-46.
- Pearce, D.W. (2001). "The economic value of forest ecosystems." *Ecosystem Health*, Vol. 7, Issue 4, pp. 284-296.
- PEFC. (2010). Statistical figures on PEFC certification. Information updated on 31 December 2010, Available at: <http://register.pefc.cz/statistics.asp>.
- PEFC. (2011). Forest certification progresses in China. Available at: <http://www.pefc.org/news-a-media/general-sfm-news/news-detail/item/695-forest-certification-progresses-in-china>
- Perrot-Maitre, D. (2006). *The Vittel payments for ecosystem services: a "perfect" PES case?* International Institute for Environment and Development (IIED), London.
- Porras, I., Grieg-Gran, M., and Neves, N. (2008). *All that glitters: A review of payments for watershed services in developing countries*. International Institute for Environment and Development (IIED), London.
- Porras, I. (2010). *Fair and green? The social impacts of payments for environmental services in Costa Rica*. International Institute for Environment and Development (IIED), London.
- Poschen, P. (2003). "Globalization and sustainability: The forestry and wood industries on the move - social and labour implications," European Tropical Forest Research Network News, Autumn/Winter pp. 43-45.
- Potts, J., van der Meer, J., and Daichman, J. (2010). *The state of sustainability initiatives review 2010: Sustainability and transparency*. International Institute for Sustainable Development (IISD), Winnipeg, Canada and the International Institute for Environment and Development, (IIED), London.
- Putz, F.E., Sist, P., Fredericksen, T., and Dykstra, D. (2008). "Reduced-impact logging: Challenges and opportunities". *Forest Ecology and Management*, 256, pp. 1427-1433.
- Rahman, S.A., Farhana, K.M., Rahman, A.H.M.M., and Imtiaj, A. (2007). "An economic evaluation of the multistrata agroforestry system in Northern Bangladesh". *American-Eurasian Journal of Agricultural & Environmental Sciences*, Vol. 2, Issue 6, pp. 655-661.
- Rausser, G. and Small, A. (2000). "Valuing research leads: Bioprospecting and the conservation of genetic resources". *Journal of Political Economy*, Vol. 108, Issue 1, pp. 173-206.
- Rice, R. (2002). Conservation concessions: our experience to date. Conservation International. Presented at the annual meetings of the Society for Conservation Biology, Canterbury, UK.
- Richardson, M. (2010). "Indonesia moving to reduce forest loss, warming emissions". *Japan Times*, 21 June. Available at: <http://search.japantimes.co.jp/cgi-bin/ea20100621mr.html>
- Rios, A., and Pagiola, S. (2009). Poor household participation in payments for environmental services in Nicaragua and Colombia, MPRA Paper No. 13727, Available at: <http://mpra.ub.uni-muenchen.de/13727/>
- Robertson, N., and Wunder, S. (2005). Fresh tracks in the forest: Assessing incipient payments for environmental services initiatives in Bolivia. CIFOR.
- Robalino, J., Pfaff, A., Sanchez, F., Alpizar, C. L. and Rodriguez, C.M. (2008). Deforestation impacts of environmental services payments: Costa Rica's PSA program 2000-2005. Presented at the World Bank workshop on the economics of REDD, 27 May. Discussion Paper Series. Environment for Development and Resources for the Future, Washington, D.C.
- Robalino, J., Herrera, L.D., Villalobos, L. and Butron, S. (2010). Forest management and policies in Latin America, Background paper for the Forests Chapter, Green Economy Report.



- Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Robert, L., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J. and Yan, X. (2004). "Effectiveness of the global protected area network in representing species diversity", *Nature*, Vol. 428, Issue 8, pp. 640–43.
- Saigal, S. (2005). Joint management of state forest lands: Experience from India in Garforth, M. and Mayers, J. (eds.), *Plantations, Privatization, Poverty and Power: changing ownership and management of state forests*. Earthscan, UK and USA.
- Sanchez-Azofeifa, G.A., Pfaff, A., Robalino, J.A., and Boomhower, J.P. (2007). "Costa Rica's payment for environmental services program: Intention, implementation, and impact", *Conservation Biology*, Vol. 21, Issue 5, pp. 1165–173.
- Sathirathai, S., and Barbier, E. (2001). "Valuing mangrove conservation in Southern Thailand." *Contemporary Economic Policy*, Vol 19, No. 2, pp. 109–122.
- Schmitt, C. B. *et al.* (2009). "Global analysis of the protection status of the world's forests." *Biological Conservation*, Vol. 142, Issue 10, pp. 2122–2130.
- Shahwahid, H.O., Awang Noor, A.G., Ahmad Fauzi, P., Abdul Rahim N., and Salleh Shahwahid, M. (2006). "Forest certification in Malaysia" in Cashore, B. *et al.*, (ed.) *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- Shvidenko, A., Barber, C.V., and Persson, R. (2005). "Forests and woodland systems." Chapter 21 in Hassan, R., Scholes, R., and Ash, R. (eds.) *Ecosystems and human well-being : Current state and trends : Findings of the Condition and Trends Working Group*. Island Press, Washington, D.C.
- Sierra, R. and Russman, E. (2006) "On the efficiency of the environmental service payments: A forest conservation assessment in the Osa Peninsula, Costa Rica." *Ecological Economics* 59: 131–141.
- Simpson, R.D., R.A. Sedjo and Reid, J.W. (1996). "Valuing biodiversity for use in pharmaceutical research". *Journal of Political Economy*, Vol. 104, Issue 1, pp. 163–183.
- Smeraldi, R. and May, P. (eds.) (2009). *A hora da conta Pecuária Amazônia e Conjuntura, Amigos da Terra, Amazônia Brasileira*.
- Stern, N. (2007). *The Stern Review: The economics of climate change*. Cambridge University Press. Cambridge, UK.
- Strassburg, B., and A. Creed (2009). Estimating terrestrial carbon at risk of emission. Applying the terrestrial carbon group 3 filters approach. Policy Brief 6 Discussion Draft. Terrestrial Carbon Group.
- Sun, G., Zhou, G., Zhang, Z., Wei, X., McNulty, S.G. and Vose, J.M. (2006). "Potential water yield reduction due to forestation across China." *Journal of Hydrology*, Vol. 328, No. 3–4.
- Sun, C., Liqiao Chen, L., Chen, L., Han, L., and Bass, S. (2008). *Global forest product chains: Identifying challenges and opportunities for China through a global commodity chain sustainability analysis*. IISD.
- Tacconi, L., Mahanti, S. and Suich, H. (2009). Assessing the livelihood impacts of payments for environmental services: Implications for avoided deforestation. Presented at the XIII World Forestry Congress. Buenos Aires, Argentina, 18–23 October.
- TEEB (2009). *The Economics of Ecosystems and Biodiversity for National and International Policy Makers*.
- Tomaselli, I. (2006). Brief study on funding and financing for forestry and forest-based sector, United Nations Forum on Forests (UNFF).
- Tomich, T.P., van Noordwijk, M., Budidarsono, S., Gillison, A., Kusumanto, T., Murdiyarso, D., Stolle, F., and Fagi, A.M. (2001). Agricultural intensification, deforestation and the environment: Assessing tradeoffs in Sumatra, Indonesia in Lee, D.R. and Barrett, C.B. (eds.), *Tradeoffs or synergies: Agricultural intensification, economic development and the environment*. CAB International, Wallingford, UK.
- Uchida, E., Jintao X., and Rozelle, S. (2005). "Grain for green: Cost-effectiveness and sustainability of China's conservation set-aside program." *Land Economics*, Vol. 81, No. 2, pp. 247–264.
- UNDP. (2000). *World Energy Assessment. Energy and the challenge of sustainability*. United Nations Development Programme, United Nations Department of Economic and Social Affairs and World Energy Council. United Nations Development Programme, New York. Available at: <http://www.undp.org/energy/activities/wea/drafts-frame.html>
- UNEP/ILO/IOE/ITUC. (2008). *Green jobs: Towards decent work in a sustainable, low-carbon world*. United Nations Environment Programme (UNEP), Nairobi.
- UNFCCC. (2010). Decision 4/CP.15 in Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum 30 March.
- UNFF. (2009). Report of the Secretary-General on Finance and other means of implementation for sustainable forest management (E/CN.18/2009/9), United Nations Forum on Forests Eighth Session, New York, 20 April–1 May. Available at: <http://www.un.org/esa/forests/documents-unff.html#8>.
- van Beers, C. and de Moor, S. (2001). *Public subsidies and policy failures: How subsidies distort the natural environment, equity and trade and how to reform them*. Cheltenham: Edward Elgar.
- van Kooten, G.C. and Sohngen, B. (2007). "Economics of Forest Ecosystem Carbon Sinks: A Review," Working Papers 2007-02, University of Victoria, Department of Economics, Resource Economics and Policy Analysis Research Group.
- van Kuijk, M., Putz, F.E., and Zagt, R. (2009). *Effects of forest certification on biodiversity*. Tropenbos International, Wageningen, the Netherlands.
- Vedeld, P., Angelsen, A. Sjaastad, E., and Kobugabe Berg, G. (2004). Counting on the environment forest incomes and the rural poor. Environmental Economics Series, Paper No. 98, World Bank Environment Department, World Bank, Washington, D.C.
- Viana, V.M., May, P., Lago, L., Dubois, O., and Grieg-Gran, M. (2002). *Instrumentos para o manejo sustentável do setor florestal privado no Brasil (Instruments for Sustainable Private Sector Forestry in Brazil)*, International Institute for Environment and Development (IIED), London.
- Viana, V.M. (2009). Financing REDD: Meshing markets with government funds. IIED briefing, March. International Institute for Environment and Development, London.
- Viana, V.M., Grieg-Gran, M., della Mea, R. and Ribenboim, G. (2009). The costs of REDD: lessons from Amazonas. IIED briefing, November. International Institute for Environment and Development, London.
- Wairui, M. (2006). Forest certification in Solomon Islands in Cashore, B. *et al.*, (eds.), *Confronting sustainability: Forest certification in developing and transitioning countries*. Report Number 8. Yale School of Forestry and Environmental Studies.
- World Bank. (2004). *Sustaining forests: A development strategy*, Washington, D.C.
- WRM. (2008a). Oil palm and rubber plantations in Western and Central Africa: An overview, WRM Briefing, December. World Rainforest Movement.
- WRM. (2008b). Regional perspectives on plantations, an overview on the Mekong basin WRM Briefing, December. World Rainforest Movement.
- WRM. (2008c). Regional Perspectives on Plantations, An Overview on Western and Central Africa; WRM Briefing, December. World Rainforest Movement.
- Wunder, S., and Albán, M. (2008). "Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador", *Ecological Economics*, Vol. 65, Issue 4, pp. 685–698.
- Wunder, S., Engel, S., and Pagiola, S. (2008). "Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries", *Ecological Economics*, Vol. 65, Issue 4, pp. 834–852.
- Xu, Z., Bennett, M., Tao, R., and Xu, J. (2004). "China's sloping land conversion program four years on: Current situation, pending issues." *The International Forestry Review* (Special Issue: Forestry in China – Policy, Consumption and Production in Forestry's Newest Superpower), Vol. 6, Issues 3–4, pp. 317–326.
- Zagt, R.J., Sheil, D., and Putz, E. (2010). Biodiversity conservation in certified forests: An overview in Sheil, D., Putz, F.E. and Zagt, R.J. (eds.), *Biodiversity conservation in certified forests*. Tropenbos International, Wageningen, the Netherlands.
- Zhang, Y., Liu, S., Wei, X., Liu, J., and Zhang, G. (2008). "Potential impact of afforestation on water yield in the subalpine region of Southwestern China", *Journal of the American Water Resources Association*, Vol. 44, No. 5, pp. 1144–1153.
- Zomer, R., Trabucco, A., Coe, R. and Place, F. (2009). Trees on farm: Analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper no. 89. World Agroforestry Centre, Nairobi.

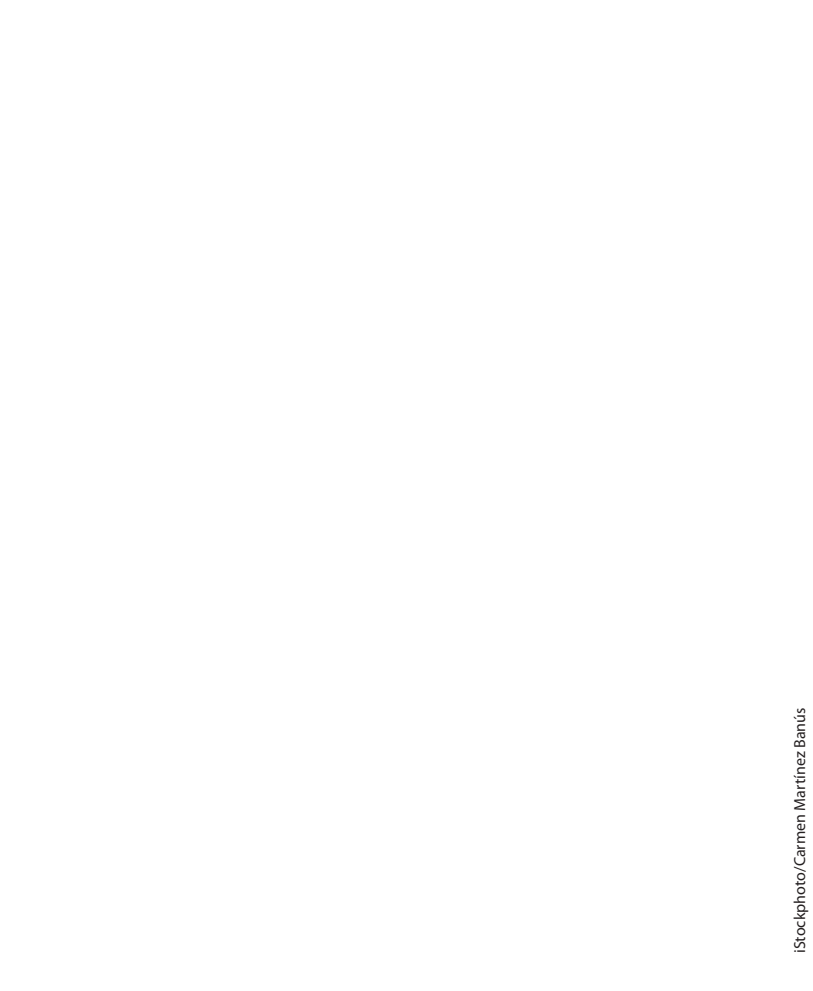






# Part II

Investing in energy and resource efficiency



!Stockphoto/Carmen Martínez Banús





# Renewable energy

Investing in energy and resource efficiency





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## List of acronyms

AGECC	Advisory Group on Energy and Climate Change	NH <sub>3</sub>	Ammonia
BAU	Business-as-usual	NMVOCs	Non-Methane Volatile Organic Compounds
CCS	Carbon capture and storage	NO <sub>x</sub>	Nitrogen oxides
CDM	Clean Development Mechanism	NRC	National Research Council
CENBIO	Brazilian Reference Center on Biomass	NREL	National Renewable Energy Laboratory
CO <sub>2</sub>	Carbon dioxide	OECD	Organisation for Economic Co-operation and Development
DEFRA	Department for Environment, Food and Rural Affairs (UK)	OPEC	Organization of the Petroleum Exporting Countries
ECN	Energy Research Centre of the Netherlands	PFM	Public Finance Mechanism
EEA	European Environment Agency	PM10	Particulate matter of 10 microns in diameter or smaller
EIA	Energy Information Administration	PV	Photovoltaic
ELI	Environmental Law Institute	R&D	Research and development
EREC	European Renewable Energy Council	REN	Renewable energy
ESMAP	Energy Sector Management Assistance Programme	RPS	Renewables portfolio standard
EU	European Union	SHSs	Solar household systems
EU ETS	European Union Emissions Trading Scheme	SO <sub>2</sub>	Sulfur dioxide
GDP	Gross domestic product	SRREN	Special Report on Renewable Energy Sources and Climate Change Mitigation (IPCC)
GER	Green Economy Report	T21	Threshold 21 model (Millennium Institute)
GHG	Greenhouse gas	UN DESA	United Nations Department of Economic and Social Affairs
GNESD	Global Network on Energy for Sustainable Development	UNCTAD	United Nations Conference on Trade and Development
GSI	Global Subsidies Initiative	UNDP	United Nations Development Programme
HRS	High Road Strategies	UNEP	United Nations Environment Programme
IEA	International Energy Agency	UNEP SEFI	United Nations Environment Programme Sustainable Energy Finance Initiative
IIASA	International Institute for Applied Systems Analysis	UNFCCC	United Nations Framework Convention on Climate Change
ILO	International Labour Organization	UNIDO	United Nations Industrial Development Organization
IOE	International Organisation of Employers	WEO	World Energy Outlook
IPCC	Intergovernmental Panel on Climate Change	WHO	World Health Organization
IQ	Intelligence quotient	WMO	World Meteorological Organization
IRENA	International Renewable Energy Agency	WTO	World Trade Organization
ITIF	The Information Technology and Innovation Foundation	WWEA	World Wind Energy Association
ITUC	International Trade Union Confederation		
LCOE	Levelised cost of energy		
MDGs	Millennium Development Goals		
MI	Millennium Institute		

# Key messages

**1. Investments in renewable energy have grown considerably with major emerging economies taking the lead.**

For 2010, new investment in renewable energy is estimated to have reached a record high of US\$ 211 billion, up from US\$ 160 billion in 2009. The growth is increasingly taking place in non-OECD countries, especially the large emerging economies of Brazil, China and India.

**2. Renewable energy can make a major contribution to the twin challenges of responding to a growing global demand for energy services, while reducing the negative impacts associated with current production and use.**

Investments in renewable energy are making a growing contribution towards mitigating climate change, but to stay below a 2°C increase in average global temperature, these developments need to be significantly enhanced. Renewable energy has other social and environmental benefits, including mitigating or avoiding many health problems and impacts on ecosystems caused by the extraction, transportation, processing and use of fossil fuels.

**3. Renewable energy can help enhance energy security at global, national and local levels.**

Most of the future growth in energy demand is expected to occur in developing countries, and against a background of rising fossil fuel prices and resource constraints; this raises serious concerns about energy security. In off-grid areas, renewable energy sources can ensure a more stable and reliable supply of energy. Examples include local mini-grids and household level photovoltaic or biogas systems.

**4. Renewable energy can play an important role in a comprehensive global strategy to eliminate energy poverty.**

In addition to being environmentally unsustainable, the current energy system is also highly inequitable, leaving 1.4 billion people without access to electricity and 2.7 billion dependent on traditional biomass for cooking. Many developing countries have a rich endowment of renewable energy that can help meet this need.

**5. The cost of renewable energy is increasingly competitive with that derived from fossil fuels.**

Improved cost-competitiveness is due to rapid R&D progress, economies of scale, learning effects through greater cumulative deployment and increased competition among suppliers. In the European context, for example, hydro and on-shore wind can already compete with fossil fuel and nuclear technologies, and off-shore wind will soon be competitive with natural gas technologies. Solar energy for water heating purposes (low temperature solar thermal) is commercially mature and commonly used in China and many other parts of the world.

**6. Renewable energy services would be even more competitive if the negative externalities associated with fossil fuel technologies were taken into account.**

These include both the current and future health impacts of various air pollutants, as well as the costs necessary to adapt to climate change and ocean acidification resulting from CO<sub>2</sub> emissions. The existing evidence clearly shows that the external costs from fossil fuel technologies are substantially higher than those of most renewable energy alternatives.

**7. Substantially increasing investments in renewable energy can be part of an integrated strategy to green the path of global economic development.**

Modelling studies carried out for the Green Economy Report (GER) project that an average annual investment of approximately US\$ 650 billion over the next 40 years in power generation, using renewable energy sources and second-generation biofuels for transport, could raise the share of renewable energy sources in total energy supply to 27 per cent by 2050, compared with less than 15 per cent under a business-as-usual (BAU) scenario. Increased use of renewable energy sources could contribute more than one-third of the total reduction in greenhouse gas emissions (GHG) of 60 per cent achieved by 2050, relative to BAU.

**8. A shift to renewable energy sources brings many new employment opportunities, but not without transitional challenges.**

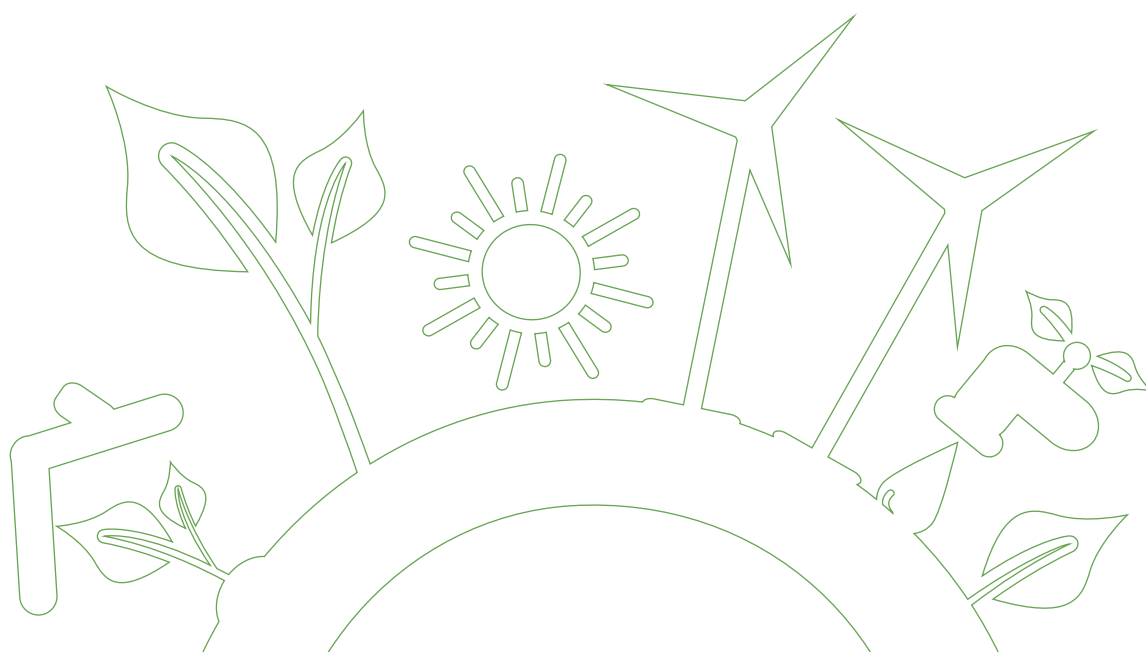
Due to the higher labour intensity of various renewable energy technologies compared with conventional power generation, increased investment in renewable energy will add to employment, especially in the short-term, according to modelling conducted for the GER. Overall impacts on employment of investing in renewable energy, taking into account possible effects in fossil fuel-related sectors, will vary by national context, depending on supportive policies, available resources and national energy systems.

**9. Policy support will need to be expanded considerably to promote accelerated investment in renewable energy.**

These investments carry enhanced risks, such as those typically associated with the development and diffusion of new technologies, exacerbated by high upfront capital costs. A range of public support mechanisms have been developed to mitigate risks and to enhance returns. The growing competitiveness of renewable energy has been achieved in part due to policy support to overcome barriers.

**10. Government policy to support increased investment in renewable energy needs to be carefully designed in an integrated manner; there is no one-size-fits-all approach.**

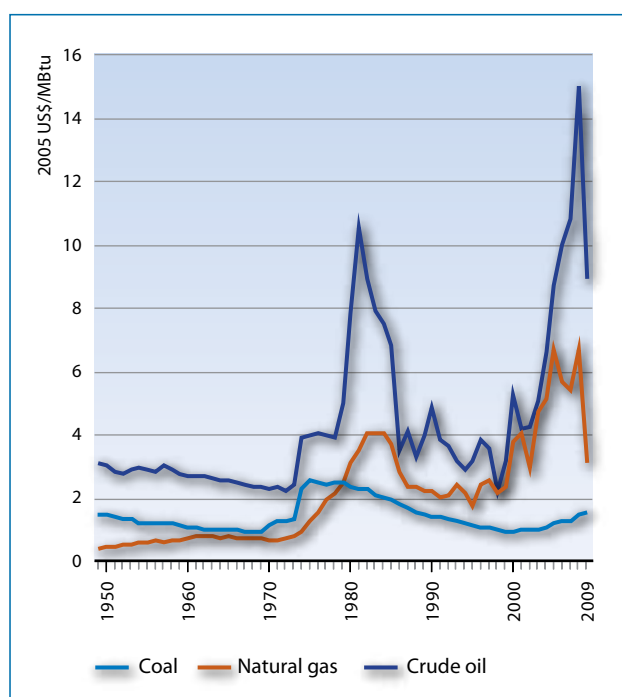
The range of regulatory policies, fiscal incentives and public financing mechanisms to support renewable energy is broad and can be complemented with support to R&D as well as other measures, such as those to stimulate investments in adapting grid infrastructure. The diversity of circumstances among countries, including existing energy systems and potential renewable development, requires that policy frameworks be carefully designed and tailored to specific situations.



# 1 Introduction

This chapter assesses the options for increasing investment in greening the energy sector by increasing the supply from renewable energy technologies.<sup>1</sup> The current highly carbon-intensive energy system depends on a finite supply of fossil fuels that are getting harder and more expensive to extract leading to concerns about national energy security in many countries. The challenges are compounded by the need to provide clean and efficient energy services to the 2.7 billion people without access. It is, thus, not sustainable in economic, social, and environmental terms. Furthermore, the current state of the energy sector leaves many countries exposed to large swings in oil import prices and also costs billions in public subsidies.

Greening the energy sector will require improvements in energy efficiency and a much greater supply of energy services from renewable sources, both of which will lead to reducing greenhouse gas emissions (GHG) and other types of pollution. In most instances, improvement in energy efficiency has net economic benefits. Global energy demand is still likely to grow in order to meet development needs, in the context of growing populations and income levels. Greening the sector also aims to end “energy poverty” for the estimated 1.4 billion people who currently lack access to electricity. Moreover, 2.7 billion people who are dependent on traditional biomass for cooking need healthier and



**Figure 1: Evolution of fossil fuel prices**

Source: Energy Centre the Netherlands (ECN)

	Total energy demand [Mtoe] <sup>a</sup>		Growth rate [%]	Share in total energy demand [%]	
	2008	2035	2008-2035 <sup>b</sup>	2008	2035
<b>OECD</b>	<b>5,421</b>	<b>5,877</b>	<b>0.3</b>	<b>44.2</b>	<b>32.6</b>
<b>Non-OECD</b>	<b>6,516</b>	<b>11,696</b>	<b>2.2</b>	<b>53.1</b>	<b>64.8</b>
Europe/Eurasia	1,151	1,470	0.9	9.4	8.1
Asia	3,545	7,240	2.7	28.9	40.1
China	2,131	4,215	2.6	17.4	23.4
India	620	1,535	3.4	5.1	8.5
Middle East	596	1,124	2.4	4.9	6.2
Africa	655	948	1.4	5.3	5.3
Latin America	569	914	1.8	4.6	5.1
<b>World<sup>c</sup></b>	<b>12,271</b>	<b>18,048</b>	<b>1.4</b>	<b>100.0</b>	<b>100.0</b>

a. Million tons of oil equivalent. b. Compound average annual growth rate. c. World includes international marine and aviation bunkers (not included in regional totals), and some countries/regions excluded here.

**Table 1: Primary energy demand by region in the IEA Current Policies scenario**

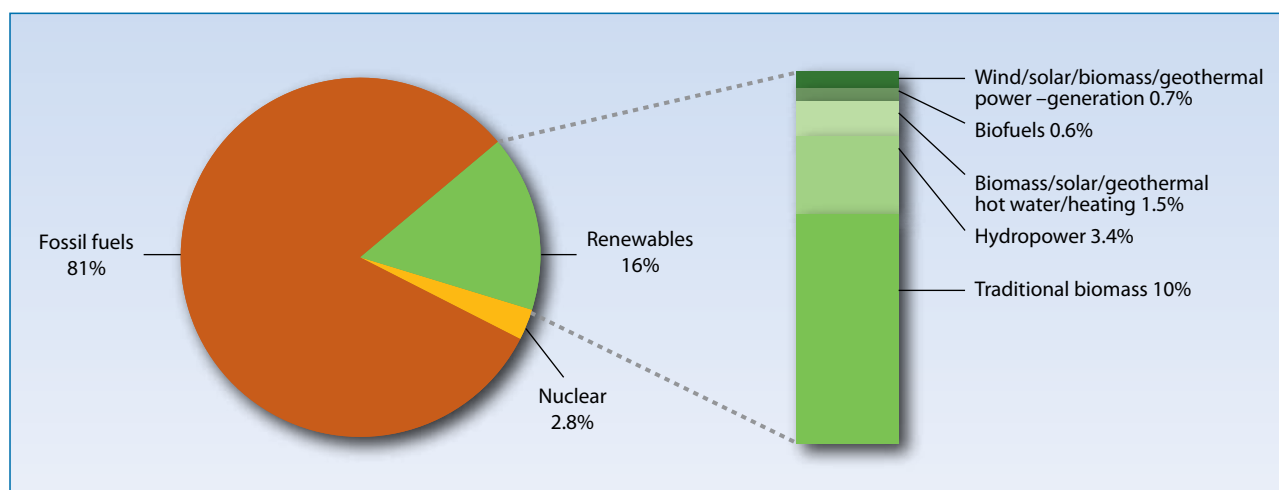
Source: IEA (2010d)

more sustainable energy sources (IEA 2010a). Modern renewables offer considerable potential for enhancing energy security at global, national and local levels. In order to secure all these benefits, enabling policies are required to ensure that the investments are made for greening the energy sector.

This chapter is structured as follows: Section 1 briefly describes features of world energy supply and the growing role of renewable sources of energy within it. Section 2 discusses the challenges and opportunities related to the energy sector, and the potential contribution of renewable energy. Section 3 reviews investments in renewable energy, covering recent trends, developments in cost-competitiveness, the importance of externalities, employment effects and expected investment needs. Section 4 presents the results of green investment scenarios (from the GER modelling chapter), in which investments in renewable energy are considerably expanded, as part of an integrated strategy also addressing energy efficiency and other aspects of demand. Section 5 discusses the barriers to increasing investments in the renewable energy sector and the policies to address these. Section 6 concludes the chapter.

1. The demand issue of energy efficiency is comprehensively covered in other chapters such as those on buildings, transport and manufacturing.





**Figure 2: Renewable energy share of global final energy consumption, 2009**

Source: REN21 (2011)

## 1.1 The energy sector<sup>2</sup> and the position of renewable sources of energy

World primary energy demand<sup>3</sup> is expected to continue growing. The International Energy Agency's (IEA) Current Policies scenario, which assumes no major change in policies as of mid-2010, projects a growth rate of 1.4 per cent per year up to 2035 (Table 1). The fastest growth is expected in non-OECD countries with a projected rate of 2.2 per cent per year, particularly in China and India and other emerging economies in Asia and the Middle East. Many non-OECD countries are also expected to see large increases in imports of oil or gas or both.

Energy demand is growing against the backdrop of fluctuating, but generally increasing fossil-fuel prices (see Figure 1). Expenditure on oil alone increased from 1 per cent of global GDP in 1998 to around 4 per cent at the peak in 2007, and is projected to remain high in the period to 2030 (IEA 2008b).

2. While comprehensive figures are lacking, the energy sector comprises somewhat more than 5 per cent of world GDP, indicating its importance for the economy as a whole.

3. Primary energy refers to the energy contained in an energy resource before it is subject to transformation processes, where losses – sometimes substantial – always take place.

Findings from this chapter indicate that the share of renewables in total energy supply is expanding and that the greening of the energy sector can contribute to the growth of income, jobs and access by the poor to affordable energy, which are other objectives of sustainable development. Worldwide investment in renewable energy assets – without large hydropower – grew by a factor of seven from US\$ 19 billion in 2004 to US\$ 143 billion in 2010. For OECD countries the share of renewable energy sources in total primary energy demand has risen from 4.6 per cent in 1973 to 7.7 per cent in 2009 (IEA 2010d).

This chapter follows the IEA definition of renewable energy:

*Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly or indirectly from the sun, or from heat generated deep within the earth. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and biofuels and hydrogen derived from renewable resources (IEA 2008a).*

Figure 2 indicates the share of renewable energy in global final energy consumption in 2009 at 19 per cent.

## 2 Challenges and opportunities

The global community and national governments are faced with four major challenges with respect to the energy sector: 1) concerns about energy security; 2) combating climate change; 3) reducing pollution and public-health hazards; and, 4) addressing energy poverty. Greening the energy sector, including by substantially increasing investment in renewable energy, provides an opportunity to make a significant contribution to addressing these challenges.

### 2.1 Energy security

Increasing energy demand together with rising energy prices raise concerns about energy security, a topic which covers a range of issues but primarily is associated with the reliability and affordability of national energy supply. Such concerns are particularly relevant for low-income countries, but also for emerging and developed economies, where a relatively high dependence on a limited range of suppliers can mean higher risks to the security of national energy supply due to geo-political and other developments. Risks to national energy security can also carry downwards to impinge on energy security at local levels.

The IEA's Reference Scenario, the trends of which are depicted in Tables 1 and 2, represent a baseline of how global energy markets would evolve without policy changes (IEA 2009a). In the scenario, oil importing countries (especially developing countries and emerging economies) are expected to become increasingly dependent on OPEC countries for oil. While total non-OPEC output is expected to remain about constant until 2030, production in OPEC countries is projected to increase, especially in the Middle East. OPEC's share in the world oil market consequently rises from 44 per cent in 2008 to 52 per cent in 2030, above its historical peak in 1973. For natural gas, increases in exports are mainly projected to come from Russia, Iran and Qatar, which would increase the world economy's energy dependency on these countries (IEA 2009a).

The increase in oil prices since 2002 has increased pressure on the balance of payments of developing countries (Figure 1). To protect consumers from increased fossil-fuel prices, some countries have increased their fuel subsidies putting additional strain on government budgets, and underpinning the demand for fossil fuel imports. Oil accounts for 10 to 15 per cent of total imports for oil-importing African countries and absorbs over 30 per cent of their export revenue on average

(UNCTAD 2006, ESMAP 2008a). Some African countries, including Kenya and Senegal, devote more than half of their export earnings to energy imports, while India spends 45 per cent. Investing in renewable sources that are available locally – in many cases abundantly – could enhance energy security for such countries (GNESD 2010). Energy security would then be influenced more by access to renewable technologies, including both their affordability as well as the capacity to adapt and deploy those technologies. Diversifying the energy matrix thus presents both a considerable challenge and opportunity for oil importing countries.

### 2.2 Climate change

The Intergovernmental Panel on Climate Change's (IPCC) fourth assessment report (IPCC 2007) underscored the importance of mitigating future human-induced climate change – mostly driven by the combustion of fossil fuels – and adapting to the changes that occur. Estimates of the damages of climate change and costs of mitigation and adaptation vary widely. Substantial damages will occur even with a rapid greening of the energy system, but will be much higher if no action is taken. The annual global costs of adapting to climate change have been estimated by the United Nations Framework on Climate Change Convention (UNFCCC 2009) to be at least US\$ 49 - US\$ 171 billion by 2030.<sup>4</sup> About half of these costs will be borne by developing countries. Moreover, climate change is likely to worsen inequality because its impacts are unevenly distributed over space and time and disproportionately affect the poor (IPCC 2007).

The Intergovernmental Panel on Climate Change (2007) and International Energy Agency (IEA) (2008c) estimate that in order to limit the rise of average global temperature to 2°C, the concentration of GHGs should not exceed 450 parts per million (ppm) CO<sub>2</sub>-eq. This translates to a peak of global emissions in 2015 and at least a 50 per cent cut in global emissions by 2050, compared with 2005. In 2009, the G8 committed to an 80 per cent cut in their emissions by 2050 in order to contribute to a global 50 per cent cut by 2050, although a precise baseline was

4. This estimate is very rough, approximate and conservative; it does not include key sectors of the economy such as energy, manufacturing, retailing, mining, and tourism, nor the impacts on ecosystems and the goods and services they provide. Other studies that take into account additional direct and indirect impacts of climate change related to water, health, infrastructure, coastal zones, ecosystems, etc., have assessed that cost of adaptation to be 2-3 times greater than that put forward by the UNFCCC (IIED 2009). In general, adaptation costs should only be interpreted as lower-bound estimates of the possible economic impacts of climate change (see also Stern 2006).

not specified. The 80 per cent reduction would yield some space for developing countries to have a less stark reduction trajectory while reaching the global 50 per cent target. There are still large uncertainties, however, concerning how to reach the emission reduction goals and the two-degree target agreed by most countries at the UN Climate Change Conference in Copenhagen in 2009. If pledges made subsequent to the conference were implemented together with other policy options under consideration in the negotiations,<sup>5</sup> emissions in 2020 are projected to reach 49 GtCO<sub>2</sub>-eq, which leaves a gap of at least 5 GtCO<sub>2</sub>-eq relative to the projected level required for the two-degree target of 39–44 GtCO<sub>2</sub>-eq (UNEP 2010b). In the IEA Current Policies Scenario, fossil fuels are projected to continue dominating energy supply in 2030 (see Table 2). Additionally, several models project that GHG emissions will rise fastest in high-growth countries such as China and India (IEA 2010b, 2010d).

A shift from fossil fuels to renewable energy in the energy supply can contribute to achieving ambitious emissions-reduction targets, together with significant improvements in energy efficiency. To reduce emissions to a level that would keep the concentration of GHGs at 450 ppm in 2050, the IEA projects that renewable energy would need to account for 27 per cent of the required CO<sub>2</sub> reductions, while the remaining part would result primarily from energy efficiency and alternative mitigation options such as carbon capture and sequestration (CCS) (IEA 2010b). A major part of the CO<sub>2</sub> reductions resulting from the promotion of renewables would take place in developing countries.

## 2.3 Impacts of energy technologies on health and ecosystems

There are high indirect costs associated with the pollution arising from combustion of fossil and traditional fuels. The release of both black carbon particles (from incomplete combustion of fossil fuels) and other forms of air pollution (sulphur and nitrogen oxides, photochemical smog precursors, and heavy metals, for example) have a detrimental effect on public health (UNEP and WMO 2011). Indoor air pollution from burning solid fuel accounted for 2.7 per cent of the global burden of disease in 2000 and is ranked as the largest environmental contributor to health problems after unsafe drinking water and lack of sanitation (WHO

5. These options include countries moving to higher ambition, conditional pledges; and the negotiations adopting rules that avoid a net increase in emissions from (a) "lenient" accounting of land use, land-use change and forestry activities, and (b) the use of surplus emission units (UNEP 2010b).

6. The IEA calculation includes international costs of pollution control equipment and has been done using a 4 per cent (social) real discount rate. All costs and prices are expressed in constant 2005 € and include "current policy" pollution control legislation.

	Total energy use [Mtoe]		Growth rate 2008–2035 <sup>a</sup> [%]	Share in total energy mix [%]	
	2008	2035		2008	2035
Coal	3,315	5,281	1.7	27.0	29.3
Oil	4,059	5,026	0.8	33.1	27.8
Gas	2,596	4,039	1.7	21.2	22.4
Nuclear	712	1,081	1.6	5.8	6.0
Hydro	276	439	1.7	2.2	2.4
Biomass and agricultural waste and/or residue <sup>b</sup>	1,225	1,715	1.3	10.0	9.5
Other renewables	89	468	6.3	0.7	2.6
Total	12,271	18,048	1.4	100.0	100.0

a. Compound average annual growth rate. b. Includes traditional and modern uses.

**Table 2: World primary energy mix in the IEA Current Policies scenario**  
Source: IEA (2010d)

2006). Burning fossil fuels costs the United States about US\$ 120 billion a year in health costs, mostly because of thousands of premature deaths from air pollution (NRC 2010). This figure reflects primarily health damage from air pollution associated with electricity generation and motor vehicle use. According to the IEA, the costs of air pollution controls worldwide amounted to about € 155 billion in 2005 and are estimated to triple by 2030 (IIASA 2009; IEA 2009a).<sup>6</sup> Renewable energy can mitigate or avoid many of these public health risks caused by the mining, production and combustion of fossil fuels.

The use of fossil and traditional energy sources in both developed and developing countries also impacts global biodiversity and ecosystems through deforestation, decreased water quality and availability, acidification of water bodies, and increased introduction of hazardous substances into the biosphere (UNEP 2010a). These impacts also reduce the natural capabilities of the planet to respond to climate change.

Renewable energy technologies are not without impacts and careful planning to address possible environmental and social impacts are essential. Production of biofuels, for example, can have negative impacts on biodiversity and ecosystems, while the environmental and social impacts of large-scale hydropower can be significant. The World Commission on Dams has provided guidelines for reducing possible negative impacts of hydropower development. First-generation biofuels have also received substantial attention for their impacts due to land-use change and agricultural production practices, leading to the development of biofuel sustainability standards (see Section 5.7). Increased mining activity and deforestation could result from increased use of renewable energy sources requiring rare earth elements,

Millennium Development Goal		How modern energy will help attain the MDGs
1	Eradicate extreme poverty and hunger by reducing the proportion of people whose income is less than US\$ 1 per day (in US\$ PPP)	Increases household incomes by improving productivity in terms of time saving, increasing output, and value-addition, and diversifying economic activity. Energy for irrigation increases food production and access to nutrition.
2, 3	Achieve universal primary education and promote gender equality	Provides time for education, facilitating teaching and learning by empowering especially women and children to become educated on health and productive activities, instead of traditional energy related activities.
4, 5, 6	Reduce child and maternal mortality and reduce disease	Improved health through access to clean water, cleaner cooking fuels, heat for boiling water, and better agricultural yields. Health clinics with modern fuels and electricity can refrigerate vaccines, sterilise equipment, and provide lighting.
7	Ensure environmental sustainability	Cleaner fuels, renewable energy technologies, and energy efficiency can help mitigate environmental impacts at the local, regional and global levels. Agricultural productivity and land-use can be improved to run machinery and irrigation systems.

**Table 3: Millennium Development Goals and links to energy access**  
Source: based on GNESD (2007) and Modi et al. (2006)

and this is an area getting increased attention to reduce possible negative impacts as much as possible (IPCC 2011).

## 2.4 Energy poverty

Expanding access to energy is a central challenge for developing countries. Reliable and modern energy services are needed to facilitate poverty reduction, education and health improvements, as reflected in a number of studies (GNESD 2007, 2010; Modi et al. 2006) identifying access to energy services as crucial for the achievement of most of the Millennium Development Goals (MDGs). Table 3 shows the link between various MDGs and modern energy access.

The scale of the challenge is massive with 1.4 billion people currently lacking access to electricity, and 2.7 billion depending on traditional biomass for cooking in developing countries as calculated by IEA, UNDP and UNIDO (IEA 2010a). In Sub-Saharan Africa 80 per cent of people rely on traditional use of biomass for their cooking, making it the region with the highest dependence on this energy source. While 53 per cent of urban populations in sub-Saharan Africa have access to electricity, the figure for the rural population is only 8 per cent (UNDP 2007). This rural-urban electrification imbalance contributes to a highly uneven spatial distribution of economic activity, encouraging larger and more rapid rural-urban migration. On average, 26 per cent of people have access to electricity in sub-Saharan Africa, ranging from 3 per cent in Burundi, Chad and Liberia, to 75 per cent in South Africa and to 92 per cent in Togo at the top (UNDP and WHO 2008). Unless dedicated new efforts are implemented, the IEA estimates that by 2030 1.2 billion people will still lack access to electricity and the number relying on biomass will even rise slightly to 2.8 billion. In some African countries, the share of the population without access to electricity might even increase. Renewable energy sources offer some cost-effective solutions to solving

energy poverty; one of the opportunities is explored in the next section.

### Solutions for energy access

There are various technological options to addressing the energy-poverty challenge described above. Implementing most of these options requires additional, publicly-financed investment, including development assistance, as the commercial market potential is likely to remain limited in some cases. Public-private partnerships may be one option along with promising alternative financing mechanisms, including cost-recovery from users, and are discussed in section 4 of this chapter.

In terms of technologies for electricity delivery, there are potentially three broad options for expanding access. First, existing centralised grids can be expanded to non-served areas, potentially based on new renewable sources of energy. Second, decentralised mini-grids can be installed to link a community to a small generating plant. Third, off-grid access can be facilitated by producing electricity for a single point of demand. The optimal mix of these options for any given country is determined by the availability of energy resources, the regulatory and policy environment, the institutional and technical capacity, geographic considerations, and relative costs (AGECC 2010). Intelligent planning should allow for the flexibility to integrate these systems as countries develop.

Grid expansion is generally the lowest-cost option in urban areas and in more densely populated rural areas. Successful expansion has been achieved recently on a large scale in China, South Africa and Vietnam. Grid expansion at a regional level in Africa could facilitate hydropower trading among countries, thereby supplying low-cost power while reducing the continent's vulnerability to varying oil prices and its carbon emissions (World Bank 2009).

In remote locations, off-grid and mini-grid options tend to be more cost effective than expanding existing

electricity grids. Renewable off-grid solutions – small hydro, mini-wind, bio-energy, and the increasingly popular solar household systems (SHSs) – have the potential to alleviate rural energy poverty and even to displace costly diesel-based power generation (GNESD 2010; IEA 2010a; REN21 2011). Furthermore, they can contribute to the decoupling of energy supply and GHG emissions, and avoid increasing fuel imports for low-income countries. SHSs typically generate around 30 to 60 watts from a photovoltaic (PV) module and include a rechargeable battery to power, for example, 4 to 6 compact fluorescent lamps, a TV, and potentially a mobile-phone charger. The technology is also useful for providing clean drinking water. The price in Asia for an average system ranges from US\$ 360 – 480 for 40 peak watts, thus US\$ 8–11/watt, while in Africa it is higher at US\$ 800 (e.g. in Ghana) for 50 watts, thus US\$ 16–17/watt (ESMAP 2008b). The main advantage of renewable off-grid solutions is that running costs are very low, although upfront investments are still high.<sup>7</sup>

The availability and diffusion of clean biomass technologies, such as improved and alternative

cook stoves and biogas systems, which reduce unsustainable and inefficient use of firewood and hazardous air pollution, can constitute an intermediate step to the provision of modern energy services for rural populations dependent on biomass. In fact, some have singled out clean biomass technologies for households and small industries as a priority for Africa, with the potential of developing industries suitable for rural areas and to leap-frog development of energy technologies (Karekezi et al. 2004). Projections by the IEA, UNDP and UNIDO (IEA 2010a) for ensuring universal access to modern cooking facilities by 2030 recognise this potential and include 51 per cent of the investment target of US\$ 2.6 billion per year allocated to biogas systems and 23 per cent to advanced biomass cooking stoves, both in rural areas.

For many remote rural areas and for a large proportion of the 1.4 billion who lack access to energy, renewable energy sources thus present an increasingly viable option for addressing their unmet demand. IEA, UNDP and UNIDO (IEA 2010a) estimated investment to ensure access to electricity for all by 2030 at US\$ 756 billion, corresponding to a relatively modest sum of US\$ 36 billion per year, the bulk of which would be for off-grid systems, including various renewable options, in addition to conventional diesel generation.<sup>8</sup>

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7. Potential financing mechanisms are discussed in section 5.3.

8. The estimated investment needs are not broken down by IEA, UNDP and UNIDO (IEA 2010a) according to energy source, but in discussing opportunities for renewables, the potential promise of combining different sources of renewable energy in a power system supplying rural mini-grids is highlighted.



# 3 Investing in renewable energy

Both the challenges and opportunities facing the energy sector call for scaling up investment in renewable energy. This section summarizes recent investment trends in renewable energy and the associated evolution of the competitiveness of renewable energy technologies. This is followed by an analysis of how this competitiveness is distorted by the lack of mechanisms to account for the larger negative externalities associated with the use of fossil fuels, reviewed in Section 2. The section then discusses the potential employment potential offered by renewable energy. The section closes with a review of estimates of the future investment required to meet the challenges of growing energy demand and climate change mitigation, complementing needed investments to improve energy efficiency across sectors.

## 3.1 Recent trends in renewable energy investment

During the past 10 years the growth of investment in renewable energy has been rapid, albeit from a low base. From 2004 to 2010, total investments into renewable energy exhibited a compound annual growth rate of 36 per cent.<sup>9</sup> There were a number of reasons for this performance:

- The relatively easy access to capital for project developers and technology manufacturers in the developed world and major emerging economies and low interest rates supported the growth of renewable energy technologies;

- For some renewable energy technologies, technological developments have led to a significant decline in costs and increased reliability of the technology, which have made investments more attractive;

- High oil prices contributed to the interest in renewable energy investments; and

- Regulatory support for renewable energy technologies increased over the past 10 years. Between 2004 and early 2011, for example, the number of countries that have supportive renewable energy policies in place rose from about 40 to almost 120 (REN21 2011).

For 2010, Bloomberg New Energy Finance estimates that global new investment in renewable energy hit a new record of US\$ 211 billion. This is an increase of more than 30 per cent from the US\$ 160 billion invested globally in 2009 and the US\$ 159 billion in 2008 (UNEP SEFI 2011).

The global financial crisis that began in 2008 appears to have temporarily reduced investment in renewable energy, with growth in new investments slowing in 2008 and 2009 (see Figure 3). Despite more difficult access to capital, especially the availability of debt finance, the sector as a whole has so far proven to be fairly resilient.

This buoyancy may be due partly to the stimulus provided by discretionary fiscal packages in many countries (IEA 2009b) launched in 2008 and 2009, some of which included support for renewable energy (HSBC 2009). In the US, for example, there were two separate packages, with a total of around US\$ 32 billion allocated to renewable energy.<sup>10</sup> South Korea and China also included renewable energy investments in their stimulus spending programmes. An estimated US\$ 194 billion in green stimulus funding had been allocated to support clean energy globally, including renewable energy technologies, energy-smart technologies, carbon capture and storage, and transport (UNEP SEFI 2011). Less than 10 per cent had actually been spent by the end of 2009, and just under half by the end of 2010. The delay reflects the time it takes for spending to be approved through administrative processes, and the fact that some projects were only formally presented after the programmes were announced.

The investments in renewable energy in emerging economies have been growing rapidly since 2005 (UNEP SEFI 2011).<sup>11</sup> In that year OECD countries accounted for almost 77 per cent of global investment in renewable energy.<sup>12</sup> By 2007, however, the share of non-OECD countries had risen to 29 per cent and further increased to 40 per cent in 2008 (Bloomberg New Energy Finance database). In 2008, for example, China was the second-largest country for renewable energy investments after Spain, with the US ranking third. Brazil was ranked fourth and India seventh. China took the lead though in 2009, maintaining this position in 2010, with US\$ 49 billion in new investment in renewable energy. Overall, from 2005 to 2008, investments in renewable energy assets grew by more than 200 per cent in OECD countries, but

9. The Emergency Economic Stabilization Act and the American Recovery and Reinvestment Act; these included the extension of the Production Tax Credits for wind and the Investment Tax Credit for solar.

10. The Emergency Economic Stabilization Act and the American Recovery and Reinvestment Act; these included the extension of the Production Tax Credits for wind and the Investment Tax Credit for solar.

11. See also previous editions of the UNEP SEFI Sustainable Energy Investment Trends Report (UNEP SEFI 2008a, 2009, 2010).

12. New financial investment in renewable energy excludes small scale systems, as well as corporate and government investment in R&D, which are included in Figure 5 and accounted for US\$ 68 billion, or almost one-third, of the US\$ 211 billion total in 2010 (UNEP SEFI 2011).

by more than 500 per cent in non-OECD countries. In 2010, new financial investments in renewable energy by developing countries, at US\$ 72 billion, edged past the amount invested that year by developed countries, at US\$ 70.5 billion (UNEP SEFI 2011). This recent rapid growth has led to predictions that developing economies may well soon have larger installed renewable energy generating capacity than the OECD countries (ITIF 2009, Pew Charitable Trusts 2010).

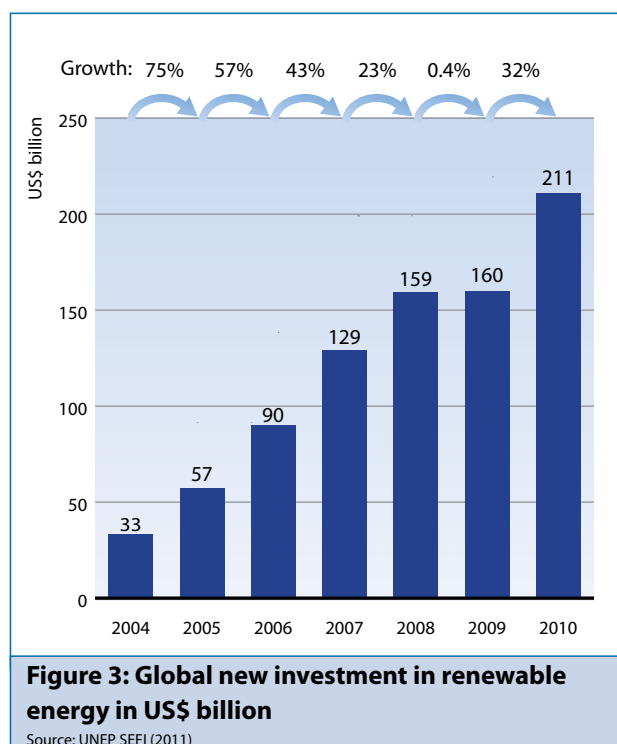
Among developing countries, by far the largest share of investments in renewable energy has been in the three large emerging economies of Brazil, China and India which together account for almost US\$ 60 billion, or 90 per cent. Other developing countries, while representing only 10 per cent of the total, are also experiencing accelerated growth, with Latin America (excluding Brazil) seeing investments almost tripling, Asia rising almost one-third, and Africa increasing five-fold in 2010 (UNEP SEFI 2011). These investments tend though to be concentrated still in a limited number of countries. For renewable energy investments to expand on a large scale in other developing countries, however, major efforts are needed to develop infrastructure such as transmission and distribution systems, improve the functioning of financial markets and other institutions, and provide a supportive incentive framework.

In addition to installing significant renewable energy capacity, fast-growing emerging markets have also built up large equipment manufacturing industries in the sector, both for export to the global market and for local use. China has, for example, become the world's largest producer of solar PV panels and solar water heaters. The government has supported investment in manufacturing capacity for renewable energies, for example, by establishing preferential electricity tariffs for the solar industry.

### 3.2 Technical advances and cost competitiveness

As renewable energy technologies have matured their costs have come down, making many of them increasingly competitive with other energy technologies. This section briefly reviews such developments, drawing on recent reviews of relative maturity and costs of different energy technologies (for example, IPCC 2011; IEA 2010b, c, d).

Overall, the IPCC (2011) review of renewable energy technologies concluded that technical potential, at a global level, does not present a constraint to continued



growth in the use of these technologies. In its assessment, the review also found that a growing number of these are technically mature and are being deployed at significant scale. Table 4 shows the stages of maturity of principal renewable energy technologies according to four stages of maturity: research and development; demonstration and deployment; diffusion; and commercially mature. The most mature technology is hydropower, which currently meets 16 per cent of the world's electricity demand. Many hydropower installations are large-scale where impacts potentially can be significant on livelihoods, biodiversity, water supply, etc. In order to address potential adverse impacts installations should follow sustainability guidelines as developed by the World Commission on Dams or other best practices.<sup>13</sup> Smaller-scale hydropower projects, by contrast, have fewer such impacts and have great potential in many developing countries. In terms of sustainable biomass applications, the production of sugarcane bioethanol-based transport fuels in Brazil is a commercially mature technology (see Box 3 in Section 5). Onshore applications of wind energy are also commercially mature, while offshore wind energy is in the diffusion phase and, in some situations, approaching the commercially mature phase.

Solar energy technologies for heating purposes (low temperature solar thermal), are commercially mature and commonly used in many parts of the world. Solar PV for electricity in small-scale applications is approaching commercial maturity, such as solar rooftop home systems or solar lanterns in off-grid areas, but is generally still dependent on subsidies or price support mechanisms. Concentrating solar thermal power has been in the demonstration and deployment phase for

13. For example, the International Hydropower Association's Hydropower Sustainability Assessment Protocol; available at: <http://hydrosustainability.org/>

	Research and Development	Demonstration and Deployment	Diffusion	Commercially Mature
<b>Hydropower</b>		Hydrokinetic turbines		Run-of-river Reservoirs Pumped storage
<b>Biofuels</b>	Aquatic plant-derived fuels	Pyrolysis-based biofuels Lignocellulose sugar-based biofuels	Gasification-based power Lignocellulose syngas-based biofuels	Traditional usage Cookstoves Domestic heating Small/large-scale boilers Anaerobic digestion Combined heat and power Co-firing fossil fuels Combustion-based power Sugar and starch-based ethanol Plant and seed oil-based biodiesel Gaseous biofuels
<b>Wind</b>	Higher-altitude wind generator	Wind kites	Offshore, large turbine	Onshore, large turbines Distributed, small turbines Turbines for water pumping
<b>Solar</b>	Solar fuels	Solar cooling	Solar cooking Concentrating PV Concentrating solar thermal power	Photovoltaic (PV) Low temp solar thermal Passive solar architecture
<b>Geothermal</b>	Submarine geothermal	Engineered geothermal systems		Direct use applications Geothermal heat pumps Hydrothermal, binary cycle Hydrothermal, condensing flash
<b>Ocean</b>	Ocean currents	Wave Tidal currents Salinity gradients Ocean thermal energy conversion		Tidal range

**Table 4: Stages of technological maturity**

Source: Based on Table 1.3 in IPCC (2011)

some time and diffusion has recently begun in a few locations. Geothermal energy can be harnessed for heat in almost any temperate climate, and in some locations also for power generation. It is mature in many countries, including among others Italy, Kenya, New Zealand, the Philippines and the United States; Iceland and El Salvador, for example, derive over 15 per cent of their electricity needs from geothermal sources (IPCC 2008).

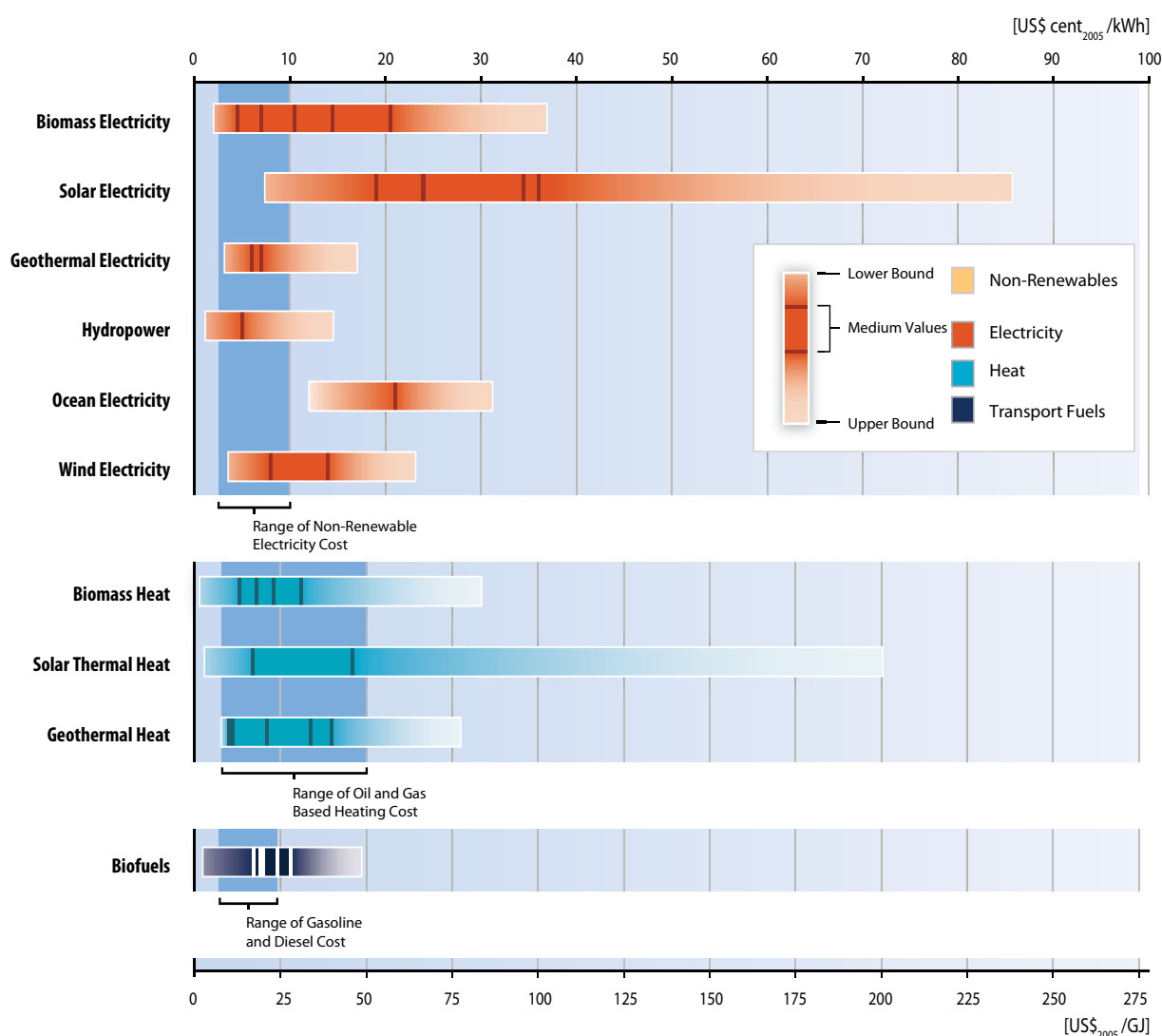
Diffusion and commercial maturity of many renewable energy technologies reflects ongoing, and in some notable cases rapid, improvements in their cost competitiveness. Figure 4 from the IPCC (2011) illustrates cost estimates (per kWh) under a levelised cost of energy analysis (LCOE) for principal renewable energy technologies, grouped according to three principal uses: electricity generation, heat and fuel for transport. The figure highlights the large range of variability of (unsubsidized) cost estimates for any given technology. For each of the three groups of technologies, the costs can be compared to a corresponding range from non-renewable technologies, which also depend on assumed prices for fossil fuels. Overall the IPCC review demonstrates that costs of renewable technologies are increasingly competitive with fossil fuel technologies,

though this is dependent on specific circumstances, such as locations with favourable resource conditions or without other low-cost energy options. The analysis also indicates though that further rapid deployment is dependent on supporting policies (discussed below in Section 5).

The IPCC (2011) review of renewable energy technologies also illustrates the pace at which costs have declined for some specific technologies. For example, average global PV module prices dropped from about US\$ 22 per watt in 1980 to less than US\$ 1.5 per watt in 2010 (IPCC 2011).<sup>14</sup> Cost reductions are driven by R&D, achieving economies of scale, learning effects through deployment and increased competition among suppliers, although the relative importance of individual factors is not always fully understood.

The importance of learning effects, which refers to the tendency for the costs of new technologies to decline as cumulative production or cumulative investment in R&D, and thus experience and know-how, increases is

14. The IPCC (2011) cites Bloomberg New Energy Finance as the source of these price estimates, which are calculated in US\$ with 2005 as the base year.



Notes: Medium values are shown for the following subcategories, sorted in the order as they appear in the respective ranges (from left to right):

Electricity	Heat	Transport Fuels
<b>Biomass:</b> 1. Cofiring 2. Small scale combined heat and power, CHP (Gasification internal combustion engine) 3. Direct dedicated stoker & CHP 4. Small scale CHP (steam turbine) 5. Small scale CHP (organic Rankine cycle) <b>Solar Electricity:</b> 1. Concentrating solar power 2. Utility-scale PV (1-axis and fixed tilt) 3. Commercial rooftop PV 4. Residential rooftop PV <b>Geothermal Electricity:</b> 1. Condensing flash plant 2. Binary cycle plant <b>Hydropower:</b> 1. All types <b>Ocean Electricity:</b> 1. Tidal barrage <b>Wind Electricity:</b> 1. Onshore 2. Offshore	<b>Biomass Heat:</b> 1. Municipal solid waste based CHP 2. Anaerobic digestion based CHP 3. Steam turbine CHP 4. Domestic pellet heating system <b>Solar Thermal Heat:</b> 1. Domestic hot water systems in China 2. Water and space heating <b>Geothermal Heat:</b> 1. Greenhouses 2. Uncovered aquaculture ponds 3. District heating 4. Geothermal heat pumps 5. Geothermal building heating	<b>Biofuels:</b> 1. Corn ethanol 2. Soy biodiesel 3. Wheat ethanol 4. Sugarcane ethanol 5. Palm oil biodiesel

The lower range of the levelised cost of energy for each RE technology is based on a combination of the most favourable input-values, whereas the upper range is based on a combination of the least favourable input values. Reference ranges in the figure background for non-renewable electricity options are indicative of the levelised cost of centralised non-renewable electricity generation. Reference ranges for heat are indicative of recent costs for oil and gas based heat supply options. Reference ranges for transport fuels are based on recent crude oil spot prices of US\$ 40 to 130/barrel and corresponding diesel and gasoline costs, excluding taxes.

**Figure 4: Range in recent levelised cost of energy for selected commercially available renewable-energy technologies**

Source: IPCC (2011)

Technology	Investment cost reduction (%)
Advanced coal	5-7
Natural gas combined cycle	10-15
New nuclear	4-7
Fuel cell	13-19
Wind power	8-15
Solar PV	18-28

**Table 5: Learning rates of electricity-generating technologies**

Learning rates of electricity-generating technologies in bottom-up energy system models (per cent)

Sources: Messner (1997), Seebregts et al. (1999), Kypros and Bahn (2003), and Barreto and Klaassen (2004)

illustrated by Table 5. This shows a range of percentage declines in the investment cost of various technologies associated with a doubling of cumulative production capacity.<sup>15</sup> Thus, the investment costs of solar PV decline, on average, by between 18 and 28 per cent as production capacity is doubled, compared to a lower decline of between 5 and 7 per cent for advanced coal. In general, the learning rates are higher for less mature energy technologies, such as wind and solar, whose cumulative production capacity or knowledge stock is usually much smaller than conventional technologies. Consequently, the investment costs – and, hence, total production costs – may decline much faster over time for renewable-energy technologies than for conventional technologies.

Most importantly, the analysis does not take two forms of market distortions into account: energy subsidies, which heavily favour fossil fuel technologies, and the differences in unaccounted external costs, which are generally larger for fossil fuel technologies. These are reviewed in the next section.

### 3.3 Externalities, subsidies and cost competition

The considerable externalities generated by fossil fuel energy sources include both the current and future health impacts of various air and other pollutants, as well as the costs necessary to adapt to climate change and ocean acidification resulting from CO<sub>2</sub> emissions. In many cases, there is a lack of political willingness to apply mechanisms to price these externalities. Failure to do so distorts the relative costs and returns of investing in renewable energy compared to fossil fuel alternatives.

The health externalities from fossil fuel energy usage are widespread and difficult to translate into monetary terms. In a recent study on global health, the World Health Organization found external environmental risks

accounted for up to 10 per cent of the global death and disease burden; over half of which is a direct result of fossil fuel use (WHO 2009). ExternE, a project funded by the European Commission, cites increased morbidity rates, congestive heart failure, and a loss of IQ in children among the many externalities readily assessed due to air particulate matter and byproducts of fossil fuel combustion.<sup>16</sup> A study from Harvard Medical School showed the true cost of energy from coal in the United States to include an externalised US\$ 0.27 per kWh (Epstein et al. 2011), compared to an average cost of energy production of US\$ 0.09 per kWh of electricity production (EIA 2011). By way of comparison, a study of government energy subsidies to the fossil fuel industry by the Environmental Law Institute demonstrates US subsidies for coal in the same year at US\$ 0.27 per kWh (ELI 2009).

Climate change-related externalities from fossil fuel combustion affect consumers directly through changes in weather patterns, loss of arable land/agricultural yield, increased water scarcity, and diminished ecosystems (NRC 2010). Largely a result of CO<sub>2</sub> emissions, these impacts are difficult to assess in monetary terms and require complex cost-benefit analysis compared with energy usage. A study of the external cost of electricity production in the EU by the European Environmental Agency (EEA 2008) examined the specific damage costs associated with emissions of CO<sub>2</sub>, as well as impacts associated with other air pollutants (NO<sub>x</sub>, SO<sub>2</sub>, NMVOCs, PM<sub>10</sub>, NH<sub>3</sub>); in 2008 traditional fossil fuel electricity-generation externalities were estimated to reach 25.9 Eurocent/kWh (in the EU-27).

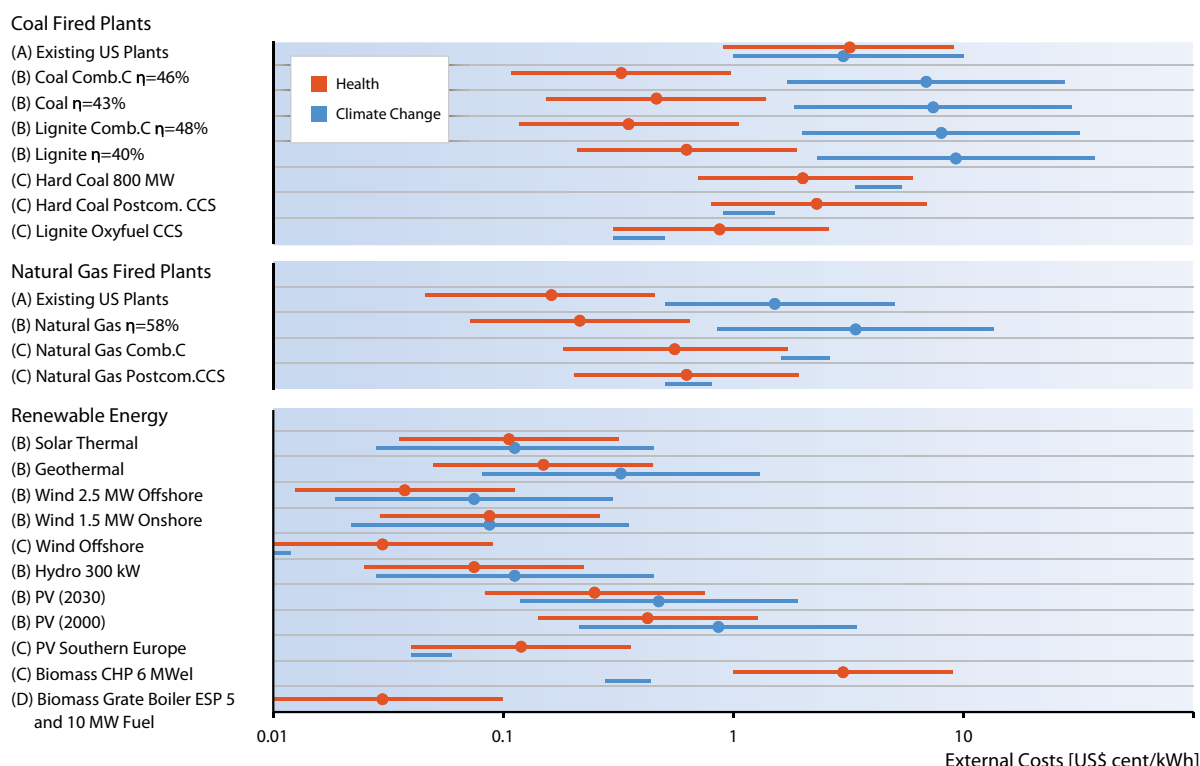
Figure 5, from the IPCC SRREN (2011), displays the additional cost (in US cents) per kilowatt hour of energy produced by the most common renewable and fossil sources over facility lifecycles, differentiating between costs in terms of health impacts and those due to climate change. The figure illustrates the wide range of estimates available for both categories of external costs. In general, external costs from generating electricity from coal or gas-fired plants produces higher externalities than renewable energy technology alternatives, with differences on the graph being larger than they appear due to the logarithmic scale. In addition, the median external costs of climate change impacts from the use of coal or gas for electricity generation exceed the health impacts by about one order of magnitude.<sup>17</sup> There is evidence, though, indicating that an integrated approach addressing both air pollutants and GHG emissions can be considerably less costly than dealing

15. These rates have been either assumed or estimated econometrically, based on expert knowledge or empirical studies. For a review of the literature on learning curves, including 42 learning rates of energy technologies, see McDonald and Schrattenholzer (2002) and Junginger et al. (2008).

16. See <http://www.externe.info/>

17. Except where carbon capture and storage (CCS) is potentially possible.





**Figure 5: External costs of energy sources related to global health and climate change (logarithmic scale)**

Source: IPCC (2011)

with those issues separately (IPCC 2007), strengthening the argument for taking measures to control air pollution.

The size of the externalities calculations indicates that various renewable technologies would already be competitive if important external costs were internalised to producers and consumers, but are primarily illustrative as there are acknowledged uncertainties in climate-change modelling and the calculation of the resulting damage costs. Because these external costs are not adequately reflected in energy prices, consumers, producers and decision-makers do not receive accurate price signals that are necessary to reach decisions about how best to use resources.

Governments should, though, consider these externalities in formulating policy and strategy for the energy sector. Table 6 by the European Commission (2008) is an example of how incorporating the external costs of

CO<sub>2</sub> emissions, together with expected cost reductions for various technologies can alter the competitiveness, in economic terms, of renewable energy technologies in the EU. The table, providing a range of estimates for various technologies, under a moderate fuel-price scenario illustrates how some sources of renewable electricity – in particular hydro and wind – can compete with fossil fuels and nuclear technologies in the EU. It also shows that in the EU the production cost of electricity from on-shore wind could soon be competitive with natural gas technologies. For biomass in the EU, the wide range reflects uncertainties in the costs of biomass. Costs of other renewable energy technologies, namely those for which only prototypes presently exist, are still significantly higher than conventional technologies.<sup>18</sup> The cost of electricity generated in the EU by solar PV is projected to fall by around a factor of three by 2030, but it is expected to remain considerably more expensive than that generated by other sources.

Table 6 also illustrates the important role played by the carbon price in assessing the cost-competitiveness of renewable energy generation compared with that derived from fossil fuels. The scenarios assume that each tonne of CO<sub>2</sub> directly emitted attracts a levy of € 0/ tCO<sub>2</sub> in 2007, € 41/tCO<sub>2</sub> in 2020 and € 47/tCO<sub>2</sub> in 2030. This assumes a relatively steep rise compared with the current (2011) levels of € 10–15, highlighting the potential of carbon markets (see Box 1).<sup>19</sup> If the

18. Note that steam cycle power plants require a reliable supply of water that in many areas is an increasingly valuable commodity subject to competing uses. Hence the analysis presented in Table 6 makes conservative assumptions concerning production costs of electricity from fossil fuels.

19. The Fourth Assessment Report of the IPCC (2007) reviewed damage cost estimates in peer-reviewed literature at the time of preparation of the assessment (up to 2005), reporting an average of US\$ 12 per tonne of CO<sub>2</sub> and an upper bound at US\$ 95 per tonne of CO<sub>2</sub>. As discussed below, a more recent review by the German Aerospace Centre and Fraunhofer Institute for System and Innovation Research (DLR/ISI, 2006) proposed a much higher range of € 15–280 per tonne of CO<sub>2</sub>, based primarily on a modelling report for the UK Department for Environment, Food and Rural Affairs (DEFRA).

Energy source	Power generation technology		Production cost of electricity (COE)			Net efficiency 2007	Life cycle GHG emissions			
			State-of-the-art 2007 € 2005/MWh	Projection for 2020 € 2005/MWh	Projection for 2030 € 2005/MWh		Direct (stack) emissions Kg CO <sub>2</sub> /MWh	Indirect emissions Kg CO <sub>2</sub> eq/MWh	Life cycle emissions Kg CO <sub>2</sub> eq/MWh	Fuel price sensitivity
Natural gas	Open cycle gas turbine (GT)	-	65-75 <sup>b</sup>	90-95 <sup>b</sup>	90-100 <sup>b</sup>	38%	530	110	640	Very high
	Combined cycle gas turbine (CCGT)	-	50-60	65-75	70-80	58%	350	70	420	Very high
		CCS	n/a	85-95	80-90	49% <sup>c</sup>	60	85	145	Very high
Oil	Internal combustion diesel engine	-	100-125 <sup>b</sup>	140-165 <sup>b</sup>	140-160 <sup>b</sup>	45%	595	95	690	Very high
	Combined cycle oil-fired turbine	-	95-105 <sup>b</sup>	125-135 <sup>b</sup>	125-135 <sup>b</sup>	53%	505	80	585	Very high
Coal	Pulverised coal combustion (PCC)	-	40-50	65-80	65-80	47%	725	95	820	Medium
		CCS	n/a	80-105	75-100	35% <sup>c</sup>	145	125	270	Medium
	Circulating fluidised bed combustion (CFBC)	-	45-55	75-85	75-85	40%	850	110	960	Medium
	Integrated gasification combined cycle (IGCC)	-	45-55	70-80	70-80	45%	755	100	855	Medium
		CCS	n/a	75-90	65-85	35% <sup>c</sup>	145	125	270	Medium
Nuclear	Nuclear fission	-	50-85	45-80	45-80	35%	0	15	15	Low
Bio-mass	Solid biomass	-	80-195	85-200	85-205	24%-29%	6	15-36	21-42	Medium
	Biogas	-	55-215	50-200	50-190	31%-34%	5	1-240	6-245	Medium
Wind	On-shore farm	-	75-110	55-90	50-85	-	0	11	11	Nil
	Off-shore farms	-	85-140	65-115	50-95	-	0	14	14	
Hydro	Large	-	35-145	30-140	30-130	-	0	6	6	Nil
	Small	-	60-185	55-160	50-145	-	0	6	6	
Solar	Photovoltaic	-	520-850	270-460	170-300	-	0	45	45	Nil
	Concentrating solar power	-	170-250 <sup>d</sup>	110-160 <sup>d</sup>	100-140 <sup>d</sup>	-	120 <sup>d</sup>	15	135 <sup>d</sup>	Low

a. Assuming fuel prices as in "European Energy and Transport: Trends to 2030 – Update 2007" (barrel of oil US\$ 54.5 (US\$-2005) in 2007 and US\$ 63 (US\$-2005) in 2030). b. Calculated assuming base load operation. c. Reported efficiencies for carbon capture plants refer to first-of-a-kind demonstration installations that start operating in 2015. d. Assuming the use of natural gas for backup heat production.

**Table 6: Energy technologies for power generation in the EU – moderate fuel price scenario**

Source: European Commission (2008)

full range of externalities from carbon emissions such as air pollution-related health hazards were included in carbon pricing, the relative position of renewable energy would be strengthened considerably. Minimum standards on fossil-fuel plants, which would raise the production costs of fossil fuels, could also increase the competitiveness of renewable energy.

The competitive position of renewable energy would be strengthened if subsidies for fossil fuels were also phased out. In many developing countries, government support to the energy sector is used to decrease the price of energy consumption to below market levels in the belief that this will reduce poverty and spur economic growth. Economically, the most efficient approach to making renewable energy attractive for large-scale market penetration is to remove all subsidies on fossil fuel and impose a price on carbon (for example through fossil-fuel taxes), and then to use the proceeds to subsidise renewable energy for a set duration and to

provide targeted subsidies to poor households. Phasing out fossil-fuel subsidies is difficult because doing so has impacts throughout the economy and affects those with vested interests. Any politically-viable reform would thus have to be well planned and probably phased in gradually.

Using a price-gap methodology, IEA estimated that fossil-fuel-related consumption subsidies amounted to US\$ 342 billion in 2007 (IEA 2010d), US\$ 557 billion in 2008 (IEA, OPEC, OECD and World Bank 2010), when fossil-fuel prices rose to particularly high levels, and US\$ 312 billion in 2009 (IEA 2010d). Subsidies for producers of fossil fuels are estimated to be in the order of US\$ 100 billion per year (GSI 2009). This support, totalling approximately US\$ 500-700 billion per year, for conventional energy (mostly fossil fuels) creates an uneven playing field for the adoption of renewable energy. By comparison, the IEA (2010d) estimated government support for electricity from renewables and

for biofuels at US\$ 57 billion in 2009. Realigning these subsidies is the most obvious way to alter the market advantage in favour of sustainable energy production, as was recognised by the G20 in 2009 when it pledged to phase out “inefficient and wasteful” fossil-fuel subsidies (Victor 2009; GSI 2009, 2010). The IEA has calculated that a complete removal of consumption subsidies would reduce CO<sub>2</sub> emissions by 5.8 per cent, or 2 Gt, in 2020 (IEA 2010d).

### 3.4 Employment potential in renewable energy

Employment in the renewable energy sector has become substantial – in 2010 more than 3.5 million people worldwide were estimated to be working either directly or indirectly in the sector. A small group of countries currently account for the majority of jobs,

especially Brazil, China, Germany, Japan and the United States (Table 8). China accounts for the largest number, with total employment in renewable energy in 2010 estimated at more than 1.1 million workers (Institute for Labor Studies et al. 2010). In Germany, the industry employed 278,000 people in 2008, with 117,500 new jobs having been created since 2004 (UNEP, ILO, IOE and ITUC 2008). These five countries are also those with the largest investments in renewable energy assets, R&D, and production.

Among technologies, wind energy generation has undergone particularly rapid growth, jobs having more than doubled from 235,000 in 2005 to 550,000 in 2009 (WWEA 2010). The most dynamic growth took place in Asia, where employment grew by 14 per cent between 2007 and 2009, followed by North America. Among power generation options, solar PV offers the higher employment rates, though this is likely to decrease

Typical project	Natural gas price		
	US\$ 2.00/MMBtu	US\$ 4.00/MMBtu	US\$ 8.00/MMBtu
Coal mine methane capture	US\$ 5.77	US\$ 0.79	Negative
Large-scale wind energy	US\$ 47.08	US\$ 8.50	Negative
Coal-to-gas fuel-switching*	US\$ 15.12	US\$ 72.44	US\$ 187.07
Pulverised coal CO <sub>2</sub> capture**	US\$ 279.99	US\$ 220.86	US\$ 102.59

\* Assumes coal prices stay constant. \*\* Lost electricity sales are assumed due to the energy penalty associated with CO<sub>2</sub> capture.

**Table 7: Mitigation project costs per tonne of CO<sub>2</sub> (US\$ at 2007 prices), given different values for natural gas prices**

Source: Ecorescurities Consulting (2009)

## Box 1: Carbon markets

Carbon markets are an instrument for reducing carbon emissions and targeting greenhouse-gas externalities from fossil-fuel use. They are essentially a group obligation to limit the total emissions of specified sources. A limited amount of tradable emission allowances are sold or given gratis, thus creating an artificial market from which a carbon price can emerge. This price imposes extra costs on the use of fossil fuels, making non-fossil based alternatives more competitive. These alternatives can include not only renewables, but also energy-efficiency measures, nuclear power generation, carbon capture and storage (CCS) and the reduction of non-CO<sub>2</sub> greenhouse gases. As of 2010, the two most prominent schemes for developing markets for carbon emissions are the EU Emissions Trading Scheme (EU-ETS) and the Clean Development Mechanism (CDM). These are actually

interlinked as the ETS is the principal market in which CDM credits are traded. Owing to the low current carbon prices and uncertainty about their future levels, however, carbon pricing mechanisms have not yet led to large-scale deployment of renewables.

The return on investment for renewable energy projects, relative to fossil fuel alternatives, is sensitive to both the carbon price and market power prices, in addition to the specific support measures for renewables. The carbon price is in turn sensitive to policy decisions. Table 7 illustrates, for example, that wind energy, assuming set capital and operating costs, can go from being an expensive carbon mitigation option at low natural gas prices, to a cost-effective technology in its own right at higher natural gas prices.

	Estimated employment worldwide	Selected national estimates								
		Denmark	Germany	Italy	Japan	Spain	US	Brazil	China	India
Technology										
Biofuels	> 1,500,000							730,000		
Wind power	~ 630,000	24,000	100,000	28,000		40,000	85,000	14,000	150,000	10,000
Solar hot water	~ 300,000					7,000			250,000	
Solar PV	~ 350,000		120,000		26,000	14,000	17,000		120,000	
Biomass power	-		120,000			5,000	66,000			
Hydropower	-					7,000	8,000			
Geothermal	-		13,000				9,000			
Biogas	-		20,000							
Solar thermal power	~ 15,000					1,000	1,000			
Total	> 3,500,000									

Notes:

&gt; : at least

~: approximately

Estimates are rounded to nearest 1,000 or 10,000 as all numbers are rough estimates and not exact. Estimates come from different sources, detailed in REN21 (2011), some of which have been calculated based on installed capacity. There are significant uncertainties associated with most of the numbers presented here, related to such issues as accounting methods, industry definition and scope, direct vs. indirect jobs, and displaced jobs from other industries. Despite the existence of some national estimates for employment in biomass power, hydropower and geothermal, there are no reliable estimates of worldwide employment.

**Table 8: Employment in renewable energy, by technology and by country**

Source: REN21 (2011)

	Average employment over life of facility (Jobs per megawatt of average capacity)		
	Manufacturing, construction, installation	Operating & maintenance/ fuel processing	Total
Solar PV	5.76-6.21	1.20-4.80	6.96-11.01
Wind power	0.43-2.51	0.27	0.70-2.78
Biomass	0.40	0.38-2.44	0.78-2.84
Coal-fired	0.27	0.74	1.01
Natural gas-fired	0.25	0.70	0.95

Note: Based on findings from a range of studies published in 2001-04. Assumed capacity factor is 21% for solar PV, 35% for wind, 80% for coal, and 85% for biomass and natural gas.

**Table 9: Average employment over life of facility (jobs per megawatt of average capacity)**

Source: UNEP, ILO, IOE and ITUC (2008)

alongside PV cost declines (Table 9) which does not incorporate more recent cost declines from the last 5 years.<sup>20</sup>

Further growth in employment in renewable energy generation will depend on such factors as the size of investment, the choice of available technologies to invest in, further maturing of technologies, overall progress in economic development, market size, national regulation, and the quality and cost of the labour force. The Green Jobs Report (UNEP, ILO, IOE and ITUC 2008) estimated that, with strong policy support, up to 2.1 million people could be employed in wind energy and 6.3 million in solar PV by 2030.

More recently, Bloomberg New Energy Finance conducted a green jobs analysis on the wind and solar

sectors in 2009. The findings were that the solar sector could expect significant net job creation between 2008 and 2025 (from 173,000 to 764,000), although the wind sector would only see modest gains (from 309,000 to 337,000). These more modest numbers for wind reflect the current policy environment, as well as ongoing technological developments, in particular sharp increases in productivity and thus lower demand for labour. Jobs created by the renewable energy sector can be safer, in terms of potential health risks, compared to employment within the fossil fuel energy sector, ensuring longer term employment periods and increased human capital (IPCC 2011).

Large-scale electricity technologies with high up-front investments are capital intensive, whether renewable or conventional (see Table 9). Biomass, as well as coal production and transport are, by contrast, labour intensive. Small-scale technologies tend to be labour intensive in manufacturing and installation. In general, for most renewable energy technologies, the manufacturing, construction and installation phases are the ones that offer the greatest job-creation potential. The opposite is true for fossil-fuels such as coal and natural gas.

In some cases, the growth of employment in the renewable energy industry may compensate for some job losses elsewhere in the energy sector, at least in aggregate terms if not for individual workers. A recent study in Aragon, Spain, for example, found that the renewable

20. More recent studies (for example, Wei et al. 2010), not captured in Table 9, show continued cost declines for renewable energy technologies, including lower employment factors.

energy industry generates between 1.8 and 4 times more jobs per MW installed than conventional sources (Llera Sastresa et al. 2010). China's growing labour force in renewable energy generation may be partially offset by job losses, estimated at more than half a million by the Chinese Academy of Social Sciences, resulting from the closing of more than 500 small inefficient power plants between 2003 and 2020 (Institute for Labor Studies et al. 2010). Presumably, labour retrenchment will take the form of not replacing workers that retire. In other cases, redeployment of workers to other sectors will be needed, accompanied by targeted retraining programmes.

### 3.5 Investment required for renewable energy

Forecasts for future investment needs are based on estimated costs of meeting climate change mitigation targets, while still satisfying the growing demand for energy. For the 450 ppm scenario, the IEA's World Energy Outlook 2010 (IEA 2010d) projects that a total additional investment in low-carbon technologies and energy efficiency (not only renewable energy) of US\$ 18 trillion is needed in the period 2010 to 2035.<sup>21</sup> Only US\$ 2.2 trillion (or 12 per cent) is incurred in the first 10 of these 25 years, but more than half in the second decade, 2020-2030. The World Energy Outlook 2010 does not specify the proportion or amount of these totals to be devoted only to renewable energy, but analysis in the previous year's Outlook estimated the needed investments in renewables by 2020 at US\$ 1.7 trillion under the 450 ppm scenario (IEA 2009a).

There are a number of other analyses with varying estimates of the investments required in renewable energy. The World Economic Forum (2010) suggests that to limit the global average temperature increase to 2°C, global investment in clean energy needs to reach US\$ 500 billion per annum by 2020, while current policies imply that this figure would likely only reach US\$ 350 billion per annum by 2020. Greenpeace and the European Renewable Energy Council (Greenpeace/ EREC 2010) estimate that a total additional investment in renewable energy over 2007-2030 of US\$ 9.0 trillion

21. These estimates are additional to investment costs projected under the Current Policies Scenario.

22. The total projected investment over 2007-2030 in renewable energy for the Reference scenario is US\$ 5.1 trillion and for the Advanced Energy [R]evolution, US\$ 14.1 trillion. The IPCC (2011) selected this scenario as one of four illustrative scenarios, out of its review of 164 scenarios from 16 different large-scale models. The Advanced Energy [R]evolution represents a scenario in which considerable investments are made in reducing growth in energy demand, and without the use of CCS to reduce GHG emissions.

23. The [R]evolution scenario has a similar target, but assumes a technical lifetime of 40 years for coal-fired power plants, instead of 20 years; the estimated additional investment needed for this scenario averages to US\$ 229 billion per year above the Reference scenario.

24. As quoted in UNEP SEFI (2009).

Infrastructure	Expected lifetime (years)
Hydro station	75++
Building	45+++
Coal station	45+
Nuclear station	30-60
Gas turbine	25
Aircraft	25-35
Motor vehicle	12-20

**Table 10: Lifespan of selected power and transportation assets**

Source: Stern (2006)

(averaging US\$ 390 billion per year) is required for the "Advanced Energy [R]evolution scenario".<sup>22</sup> The target of this scenario is the reduction of CO<sub>2</sub> emissions down to a level of around 10 Gt per year by 2050, and a second objective of phasing out of nuclear energy.<sup>23</sup>

New Energy Finance estimated that for CO<sub>2</sub> to peak before 2020, annual investments in renewable energy, energy efficiency and carbon capture and storage need to reach US\$ 500 billion by 2020, rising to US\$ 590 billion by 2030.<sup>24</sup> This represents an annual average investment of 0.44 per cent of GDP between 2006 and 2030. In summary, various sources estimate the capital investments into renewable energies required for mitigating climate change to be around US\$ 500 billion per year until 2020.

For climate mitigation, however, it is not only the scale of investments into renewable energy capacity that is crucial, but also the timing of these investments. This is due to the risk of locking-in a high-carbon power infrastructure because the energy sector is characterised by long life spans of power plants and distribution infrastructure (see Table 10). The carbon emissions in the decades to come are, therefore, determined by today's investment decisions. The early retirement or retrofitting of power assets, for example, tends to be very expensive and careful transition strategies are therefore needed (Blyth 2010).

Some studies also show that any significant delays in action by governments and the private-sector to move the energy sector onto a low-carbon growth path will lead to significantly higher costs to reach a given mitigation target. For example, the IEA (2009a) estimates that every year of delay in moving the energy sector onto the 450 ppm trajectory would add approximately US\$ 500 billion to the global costs for mitigating climate change. Such modelling is sensitive to assumptions about marginal abatement costs at different points in time, but the outcomes are broadly consistent with other studies. Another study (Edmonds et al. 2008) estimates that delaying mitigation actions in developing countries after 2012 could double the total discounted costs to



society by year 2020, with even greater cost increases by years 2035, and 2050, respectively.

It is important to note that the estimated costs of eliminating energy poverty are much smaller than estimates of energy investments to cope with growing energy demand or to address the challenge of mitigating climate change. In April 2010, the UN Secretary-General's Advisory Group on Energy and Climate Change (AGECC 2010) published a report, which estimates the required capital investment for universal modern energy access to meet basic needs<sup>25</sup> to be US\$ 35-40 billion per year

through 2030. For improving energy efficiency in low-income countries, the same report estimates the need for an average of US\$ 30-35 billion per year. A portion of these costs could be accounted for by renewable energy technologies (as discussed in section 2 above). A bigger push to invest in renewable energy more broadly need not, though, come at the expense of the relatively modest costs of ensuring universal access to modern energy.

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25. Energy required for cooking, heating, lighting, communication, healthcare and education.

## 4 Quantifying the implications of investing in renewable energy

To assess the implications of increasing investments in greening the world economy, including greening the energy sector, the Millennium Institute (MI) conducted a quantitative analysis based on its Threshold 21 national model (T21) adapted for the purpose of the global Green Economy Report (T21-Global). Described in more detail in the modelling chapter, T21-Global is a system dynamics model of the global economy in which the economic, social, and environmental spheres interact with each other.

This modelling exercise covers both energy supply and demand. Energy supply is broken down into electricity and non-electricity. It includes a variety of fossil-fuel sources as well as nuclear, biomass, hydro and other renewable sources. Fossil-fuel production is based on stocks and flows, including discovery and recovery processes. Fossil-fuel prices are endogenous in the model, i.e. determined as a result of the interactions between the forces of supply and demand considered within the model. Energy demand is determined by GDP, energy prices, and technology (i.e. level of energy efficiency), and is disaggregated by source according to the IEA classification. In the model, GDP is also dependent on energy demand, which implies a feedback mechanism that plays an important role in the various scenarios.

The scenarios modelled for the next few decades up to 2030 and 2050 include: 1) business-as-usual (BAU), which is based on the historical trajectory and assumes no major change in policy and external conditions; 2) allocating 1 or 2 per cent of the global GDP as additional investments into business as usual – BAU1 and BAU2 respectively; and 3) allocating 1 or 2 per cent of the global GDP as additional investments to green 10 economic sectors – G1 and G2, respectively. Under G2, the energy sector receives a much larger allocation, bringing the analysis closer to the policy targets of reducing GHG emissions to levels necessary to maintain atmospheric concentrations of CO<sub>2</sub> at 450 ppm. The presentation below focuses, therefore, on G2 and its comparison with BAU2.<sup>26</sup>

### 4.1 Business-as-usual (BAU)

The BAU scenario in the GER modelling analysis is similar to the WEO 2009 Reference Scenario<sup>27</sup> (IEA 2009a), in which world energy resources are generally adequate to meet demand in the foreseeable future. With respect to oil, however, the long-term picture is of serious concern, even with a peak of conventional oil projected to take place after 2035.

This BAU scenario should be interpreted as representing how energy use would evolve over the next 40 years if current trends were simply extrapolated. This assumption, however, ignores important potential consequences of climate change on economic activity or other aspects of human well-being, and is thus optimistic in terms of the likely implications of following a BAU path.

In the BAU scenario, the current growth (2.4 per cent annually) of world primary energy demand slackens between 2010 and 2050 to an average yearly increase of 1.2 per cent, due to slowing population growth and economic growth. Despite slower growth, however, global energy demand still increases by about one-third, from approximately 13,000 Mtoe today to almost 17,100 Mtoe in 2050. Similarly, world electricity demand would continue to grow, but at a much slower pace (from above 3 per cent now to 1.1 per cent per year by 2050).

Under BAU, fossil fuels remain the dominant source of energy, with a constant share of about 80 per cent through to 2050. Currently, renewable energy supplies some 13 per cent of world's energy demand, most of which is traditional biomass and large-scale hydropower. Under the BAU scenario, energy from modern renewables (excluding hydro, traditional biomass and agricultural waste and residues) would continue to register the strongest – but gradually reduced – growth rates (from around 3 per cent per year now to 1.1 per cent during 2030-2050).<sup>28</sup> Among the other sources in the energy mix, nuclear energy continues to expand, but the annual growth rate in supply drops from 1.3 per cent in short term to 0.6 per cent in the long run. Constant growth of coal and natural gas (1.3 per cent and 1.5 per cent annual growth respectively) and the projected decline in oil in the mid to longer term allows coal and natural gas to account for the largest shares of demand: 24 per cent for natural gas, 33 per cent for coal

26. More detail on the scenarios, including G1, is presented in the modelling chapter.

27. At the global aggregated level, this is also reasonably similar to the WEO 2010 (IEA 2010d) Current Policies Scenario.

28. Increases in the supply of energy from modern renewables are more modest than growth in total investments reviewed in Section 3.1, as the latter include total financial investments.

and 24 per cent for oil in 2050. The share of other sources of energy remains almost constant through to 2050.

With respect to energy end-uses, the transport sector surpasses industry under BAU to become the largest energy consumer (29 per cent) by 2050. The annual growth rates for transport and industry are 1.4 per cent and 1.0 per cent respectively. The residential sector, which is most directly influenced by population growth, is projected to exhibit the fastest growth throughout the simulation period (1.7 per cent per year) to reach 28.9 per cent of total energy demand in 2050. All these trends imply that under BAU, energy-related CO<sub>2</sub> emissions will grow from 28 Gt in 2007 to 41 Gt in 2030, and 50 Gt in 2050.

## 4.2 Green investment scenarios

The renewable energy subsector receives an additional 0.52 per cent of global GDP in the G2 scenario, on top of current investment and capacity trends in the sector.<sup>29</sup> These investments are mostly directed into the supply of renewable energy. A considerable portion of the remainder of the investment portfolios is also invested in energy efficiency, particularly in the transport, buildings and industry sectors. Such investments on the demand side interact with supply-side investments, particularly through the (endogenised) price for fossil fuels. The effects of investments in curbing the growth of demand are discussed in other chapters, but are also summarised in this section.

The following is a discussion on the different results from G2 and BAU, focusing on energy savings on the demand side, the penetration rate of renewable energy on the supply side, jobs and GHG emissions. The effects on GDP at the global aggregate level are covered in the modelling chapter of this report, as it is difficult to isolate such effects by inter-related sectors such as energy and manufacturing. As mentioned above, compared with G1 the allocation of additional investments under G2, with a heavy concentration on energy supply and use, is designed to achieve the maximum reduction in emissions, based on existing knowledge and assumptions.

### Effects on energy demand – achieving energy savings

Under the G2 scenario, additional green investments totaling US\$ 651 billion (at constant US\$ 2010 prices, same unit for monetary values below) per year over the next 40 years are allocated to improve efficiency for end-use energy demand.<sup>30</sup> These are concentrated in power use (across sectors) and in fuel use in both industry (see also HRS-MI 2009) and transport (transport investments are analysed in detail in the Transport chapter as funds are mostly allocated to the expansion of the public transport network as opposed to increased efficiency).

Under G2, these energy savings efforts curb total primary energy demand by 15 per cent by 2030 and by 34 per cent by 2050, compared with BAU, with demand reaching 14,269 Mtoe in 2030 and 13,051 Mtoe in 2050. Total fossil-fuel demand is 41 per cent lower than under BAU in 2050.<sup>31</sup> The lower energy consumption generates considerable savings on energy expenditure. Avoided capital and fuel costs in the power sector, for example, result in savings averaging US\$ 760 billion per year between 2010 and 2050. As explained above and in other chapters, these results are driven by the expansion of the public transportation network (rail and buses) and by improvements in energy efficiency (e.g., in the industrial and buildings sector), as well as the increased use of renewable energy and energy recovered from waste.

### Effects on energy supply – raising the penetration rate of renewable energy

In G2, the energy supply sector receives additional investments of US\$ 656 billion per year between 2010 and 2050 to expand biofuel production and power generation using renewables. The unit costs of investments applied in the simulations are based on estimates in the IEA's Energy Technology Perspectives 2010 (IEA 2010b) and a range of other published sources (detailed in the Modelling chapter and its technical annex).<sup>32</sup>

Additional investments in energy supply go to both the use of renewables in power generation and biofuel production. Fifty per cent of the additional investment (US\$ 327 billion (G2) per year over the 40-year period) is allocated to power generation.<sup>33</sup> The power-generation investment is further divided into nine areas: eight power-generation options plus carbon capture and storage (CCS). Two of the renewable power-generation options dominate:

■ **Solar power generation:** 35 per cent of power-generation investment (additional US\$ 63 billion in 2011 under G2) with an average additional investment of US\$ 114 billion per year over the 40-year period.

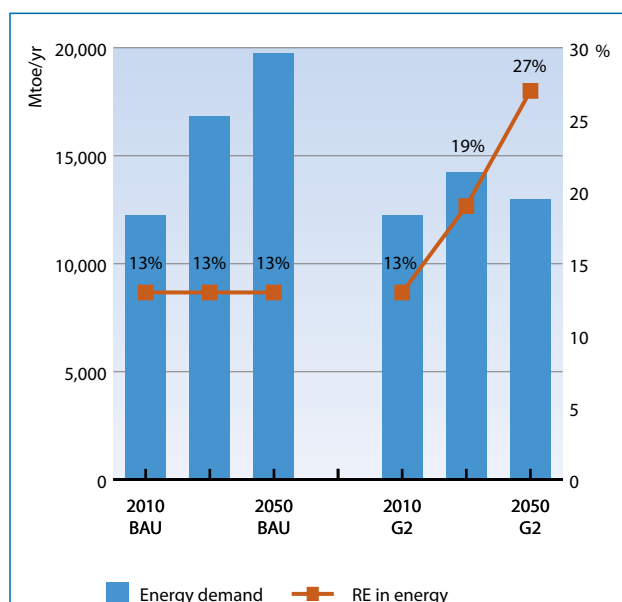
29. As published and projected by IEA (2010b, 2010d).

30. These are investments in the remainder of the G2 investment portfolio, as described above; i.e. G2 allocates 0.52 per cent of GDP of investments to renewable energy supply, and an additional portion of the total 2 per cent of GDP portfolio to energy efficiency in the sectors described.

31. Somewhat similarly, fossil fuel demand is 48 per cent lower under G2, compared to BAU2.

32. In general, the scenarios do not significantly alter current trends of development of nuclear energy, and the potential for developing carbon capture and storage (CCS) is kept fairly modest, in order to focus the analysis on renewable sources.

33. It is important to recall that the amounts of investment modeled in the G2 scenario (and also G1) are additional to existing investment trends in the energy sector, including in renewable energy sources. The amounts cited here for the investment scenario are therefore substantially lower than figures of total investment, for example, in renewable energy, as published by Bloomberg New Energy Finance, UNEP SEFI and others, that are elsewhere in this chapter.



**Figure 6: Trends in BAU and G2 scenarios in total energy consumption (left axis) and renewable penetration rate (right axis)**

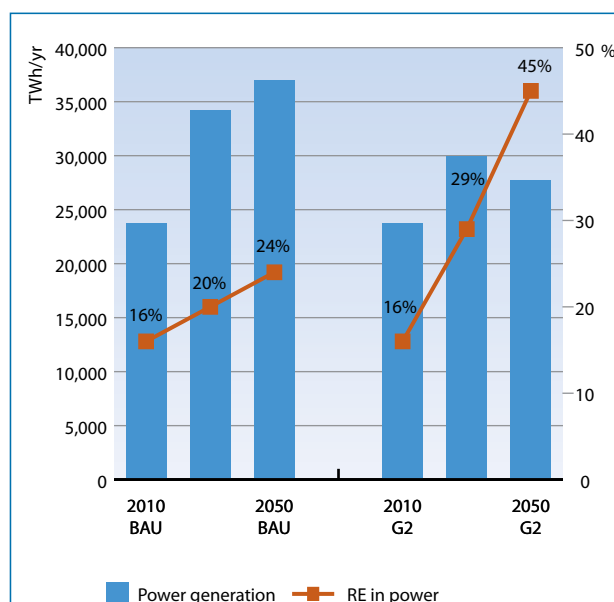
■ Wind power generation: 35 per cent of power generation investment in 2011, declining to 15 per cent in 2050 (additional US\$ 63 billion in 2011 under G2), with an average additional investment of US\$ 76 billion per year over the 40-year period.

Biofuel production accounts for the other 50 per cent of the energy investment, with an average additional investment of US\$ 327 billion per year over the 40-year period under G2. Increments in biofuel production are assumed to shift from first generation to second generation biofuels, using agricultural residues. In general, second-generation biofuels considerably reduce the pressure on diverting agricultural land from food production in the simulations.<sup>34</sup> In 2025 and 2050, the production of second-generation biofuels, from agricultural and forestry residues, is projected to reach 490 billion litres of gasoline equivalent (lge) and 844 billion lge, meeting 16.6 per cent of world liquid fuel consumption by 2050 (21.6 per cent when first generation biofuels are also considered). Around 37 per cent of agricultural and forestry residues would be needed in the G2 scenario. In case residues above 25 per cent are not available or usable (as indicated by the IEA 2010b), marginal land is assumed to be used for growing crops for biofuels.

The substitution of investments in carbon-intensive energy sources for investment in clean energy will

34. Note that investments in the agricultural sector, as part of the green investments scenarios, are also increasing the productivity of land, thus also reducing the potential conflict between biofuels and food production.

35. The IPCC (2011) review was conducted before the GER modelling results were published; see Krey and Clarke (2011) for more details of the IPCC review, which does cover studies published during or after 2006. Of the 164 scenarios reviewed, 26 (about 15 per cent) constitute baseline scenarios.



**Figure 7: Trends in BAU and G2 scenarios: power generation (left axis) and renewable penetration rate in power sector (right axis)**

increase the penetration rate of renewables to 27 per cent of total primary energy demand by 2050 under G2, compared with 13 per cent under BAU. In the power sector, renewables (including hydro, waste, wind, geothermal, solar, tidal and wave) will account for 45 per cent of total electricity generation by 2050, substantially higher than the 24 per cent under BAU. The share of fossil fuels, coal in particular, will decline accordingly to 34 per cent in 2050, compared with 64 per cent in the BAU scenario, mostly due to the expansion of renewables (Figure 6, Figure 7, and Table 11). Table 11 compares the resulting energy mix under G2 to the IEA's BLUE Map 450 Scenario as published in the ETP 2010 (IEA 2010b). The results are similar in terms of renewables penetration and differ primarily in terms of the lower share of nuclear energy in G2, as this technology is not targeted with additional investments. As discussed below, this partly explains the fact that the G2 scenario does not receive the same amount of emissions reduction as the BLUE Map 450 Scenario.

In general, G2 can be seen as conservative relative to some more ambitious scenarios that have been modeled by other. The results of G2 are relatively close, though, to the median found by the IPCC (2011) in their review of 164 global scenarios from 16 different large-scale integrated models.<sup>35</sup> These scenarios cover a wide range of renewable energy penetration rates, with the highest reaching approximately 43 per cent of primary energy supply in 2030 and 77 per cent in 2050. More than half of the reviewed scenarios resulted in the share of renewable energy in primary energy supply reaching at least 17 per cent by 2030, and at least 27 per cent by 2050, compared with 19 per cent and 27 per cent, respectively, under G2. On the other hand, most baseline scenarios reviewed by

%	2030				2050	
	*WEO	GER	*WEO	GER	*ETP	GER
Scenarios	Current Policies	BAU	450	G2	BLUE Map	G2
Coal	29	31	19	25	15	15
Oil	30	28	27	24	19	21
Gas	21	23	21	23	21	25
Nuclear	6	6	10	8	17	12
Hydro	2	2	3	3	29	4
Biomass and wastes	10	8	14	12		16
Other RE	2	3	5	5		8
Total	100	100	100	100	100	100

\*Additional sources: IEA (2010b, 2010d)

**Table 11: Comparison of energy mix in 2030 and 2050 in various GER and IEA scenarios**

the IPCC show moderately stronger deployment of RE than BAU from the GER modelling.

### Effects on employment – increasing jobs from greening the energy sector

The total employment in the energy supply sector is projected to decrease slightly over time in the BAU scenario, from 19 million in 2010 to 18.6 million in 2050, owing to increasing labour productivity in fossil-fuel extraction and processing. In the green investment scenarios, there is some short-term net job creation primarily because of the higher labour intensity of renewable energy generation compared with thermal power generation. In the longer term, increasing productivity also leads to a roughly comparable decline, reaching 18.3 million in 2050 in the G2 case. Between 330,000 and 1 million jobs would be created in the production and processing of biofuels and agriculture residues, which would rise to 3 million if a mix of agricultural residues and conventional feedstock is used. There is a major shift in employment, however, with growth in renewable power generation and biofuels production matched by a considerable decline in coal extraction and processing, and to some extent gas production (Figure 8). The additional investment in energy efficiency in the buildings sector<sup>36</sup> also included in the G2 scenario, however, leads to an additional 5.1 million jobs in 2050. The net effect is thus a projected increase in energy-sector employment of approximately 21 per cent over a comparable BAU scenario.<sup>37</sup>

It should be noted that the modelling of renewable-energy investment includes only “direct jobs” that will substitute new jobs from not expanding energy of other sources (in the case of increased demand) or even replace existing jobs in other energy technologies. It does not include “indirect jobs” – created or displaced – in sectors that supply energy industries. These are

	*WEO 450 Scenario	*ETP BLUE Map	G2	G2
	2030	2050	2030	2050
End-use electricity efficiency	49%	19%	22%	27%
Fuel efficiency		35%	23%	28%
Industry			7%	6%
Transportation		8%	16%	22%
Supply-side abatement	50%	46%	54%	46%
Power generation from low carbon sources (RE & Nuclear)	30%	27%	39%	33%
Biofuels	3%		6%	5%
CCS	17%	19%	9%	7%

NB: Columns may not add up to 100% due to rounding. \*Additional sources: IEA (2010b, 2010d)

**Table 12: Emission abatement shares from GER modelling compared with IEA**

the sectoral effects, whereas the wider effects on output and jobs in the rest of the economy<sup>38</sup> (covered in the Modelling chapter) depend on how the relative availability and price of capital, labour and energy are affected as a result of increased investment in renewable energy. It should also be pointed out that considerable net job creation can imply higher-cost energy, which can constrain economic growth and development. Finally, the global analysis does not capture effects on specific countries. Some of these, such as oil-exporting countries, may well see negative effects on employment in the energy sector.

### Effects on GHG emissions

Under the green investment scenarios, global energy intensity (in terms of Mtoe/US\$ billion GDP) declines by 36 per cent by 2030, and the cumulative global energy-related CO<sub>2</sub> emissions would be considerably mitigated by 2050 (Figure 9). Under G2, emissions are approximately 60 per cent lower in 2050 as compared to BAU. In absolute amounts, this corresponds to a decline from 30.6 Gt of energy-related CO<sub>2</sub> emissions in 2010 to about 20 Gt in 2050 (Figure 9).

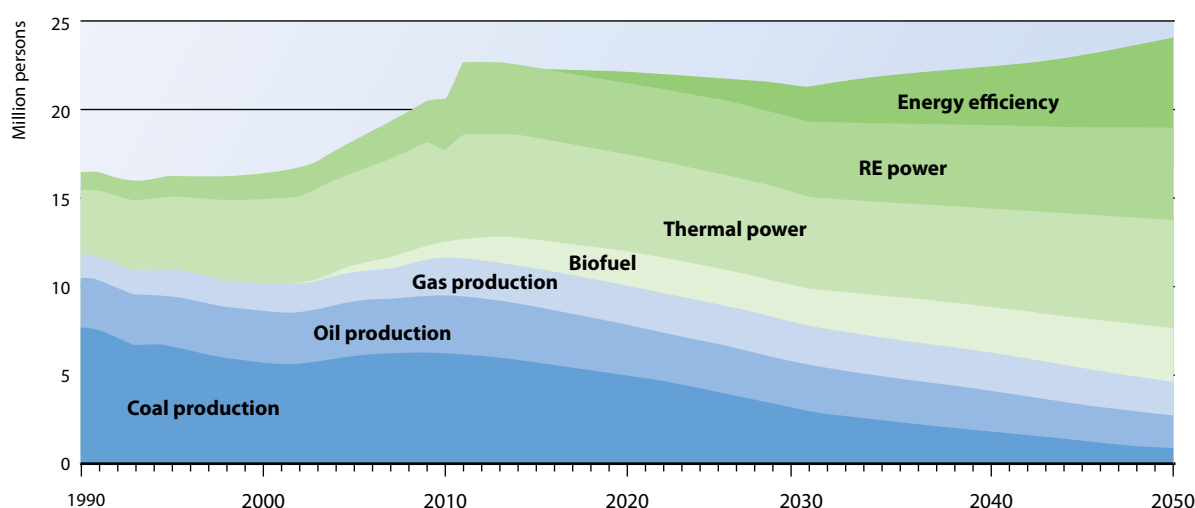
Table 12 compares the contribution to emissions reduction under G2 from both demand- and supply-side investments with those of the IEA's BLUE Map scenario. Both exercises project a contribution to emissions abatement of 46 per cent from supply-side investments. The green investment scenario G2, however, does not

36. These are essentially for the buildings sector, as potential job implications of investments in energy efficiency in industrial and transport sectors could not be captured.

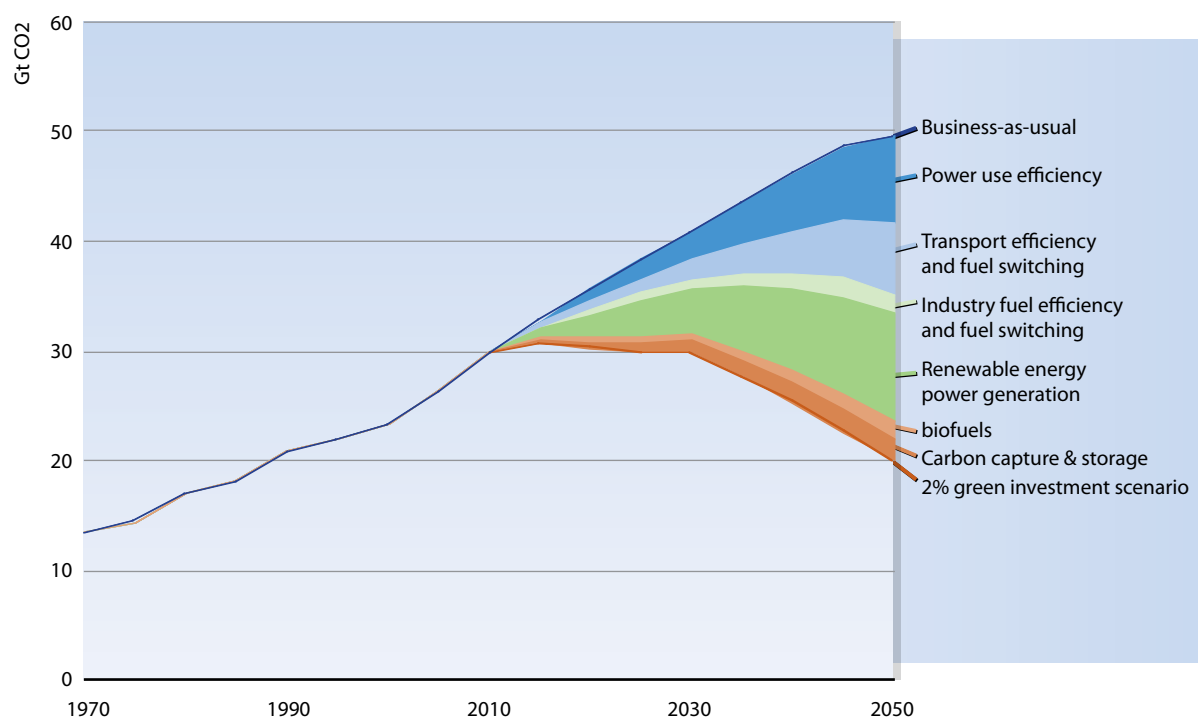
37. The point of comparison for employment generation is the simulated effects of an additional investment of 2 per cent of GDP in current investment patterns (see the Modelling chapter for more details).

38. Also sometimes referred to as “induced jobs” (NREL 1997).





**Figure 8: Total employment in the energy sector, and its disaggregation into fuel and power, and energy efficiency under the G2 scenario**



**Figure 9: Total energy-related emissions and reductions under G2 by source, relative to BAU**

fully achieve the emissions reductions projected by IEA as necessary for limiting atmospheric concentrations to 450 ppm.<sup>39</sup> Part of this difference is due to the positive effect of various green investments on overall economic growth (GDP) that, in turn, results in increased energy demand, a form of the rebound effect. In addition, the green investment scenarios do not include substantially

increased investments in nuclear power, nor in CCS, both major components of the IEA's BLUE Map 450 scenario (see Table 11 and Table 12). Note also though that only about a quarter of the scenarios reviewed for the IPCC (2011) SRREN result in a CO<sub>2</sub> concentration not exceeding 440 ppm by 2100, and more than half lead to concentrations by the end of the century in the range of 440 to 600 ppm. Thus, the G2 investment scenario constitutes a relatively conservative emissions reductions path, but one which is more feasible than more ambitious projections.

39. However, as explained in the Modelling chapter, with the potential carbon sequestration of the measures to green the agricultural sector, the G2 is expected to reduce the concentration of CO<sub>2</sub> to 450 ppm by 2050.

## 5 Overcoming barriers: enabling conditions

The preceding analysis has explored the results from increased investments in renewable energy, in terms of energy savings, penetration of renewable energy, increased jobs, and reduced GHG emissions. However, as noted in section 3, current levels of investment in renewable energy are still below what is needed to address the challenges facing the energy sector outlined earlier in the chapter. This section discusses the barriers to increasing investments in renewable energy and the measures that are needed to address these barriers.

The major barriers and respective policy responses may be grouped under the following headings: 1) energy policy framework; 2) risks and returns associated with renewable energy investments, including fiscal policy instruments; 3) financing constraints for renewable energy projects; 4) electricity infrastructure and regulations; 5) market failure related to investments in innovation and R&D; 6) technology transfer and skills; and 7) sustainability standards.

### 5.1 Policy commitment to renewable energy

In general, the growth in investment and deployment of renewable energy technologies, documented above, has been driven by an increasing number and variety of policies (IPCC 2011). These are reviewed below in the subsequent sub-sections. Individual policies to overcome various barriers to renewable energy development and deployment are most effective when they are part of a broad enabling policy framework, which builds on complementarity between a range of measures operating at multiple stages of the chain from research and development, through to deployment and diffusion. An enabling policy framework for renewable energy includes clear commitments to long-term development of the sector. Such commitment can be manifested by targets for investment in additional capacity and penetration rates within the energy mix. When supported by other enabling policies, setting targets to achieve these goals can send a strong signal to potential investors.

Important targets for energy access have been announced at the international level. The AGECC (2010) calls on the UN and its Member States to commit themselves to two achievable goals: universal access to

modern energy services and a global energy intensity reduction of 40 per cent by 2030. The report highlights that, “Delivering these two goals is key to achieving the [MDGs], improving the quality and sustainability of macroeconomic growth, and helping to reduce carbon emissions over the next 20 years”.

Many countries have already adopted targets for renewable energy. By early 2011, there were national policy targets in 98 countries, including all 27 EU member states (REN21 2011).<sup>40</sup> A large number of these targets concern renewables’ shares of electricity production, and generally fall in the range of 10-30 per cent within the next 1-2 decades. Targets are also set for the share of renewable energy in total primary or final energy supply, installed capacities of various specific technologies, the total amounts of energy production from renewables, or for the share of biofuels in transportation fuels. While earlier many targets were set for the 2010-2012 timeframe, targets set more recently concern the next decade to 2020 or beyond. For example, EU countries have set a target of 20 per cent of their final energy supply to be provided by renewable sources by 2020.

Policy targets for renewable energy have also been established in many developing countries. In fact, more than half of the national targets have been set by developing countries. Between 1997 and 2010, the number of developing countries with national targets doubled from 22 to 45. Developing countries with targets for 2020 or beyond include, among others, Brazil, China, Egypt, India, Kenya, the Philippines and Thailand. Box 2 illustrates the example of Tunisia, which has been encouraging the use of renewable energy since 2004. In addition to such national targets, there are many countries with sub-national targets at the state or provincial level.

The REN21 Global Status Report 2011 (REN21 2011) illustrates that a number of countries had either met their targets for 2011 or were about to do so. Finland and Sweden had already met their targets for 2020. The report also indicates though that some countries have not met their targets, while others have revised their targets downwards. For example, India missed its target for 2 GW of added wind power in 2010. The US reduced its target for

40. The following description and examples of policy targets here are based on information from the REN21 Global Status Report 2011 (REN21 2011).

about 950 million litres of advanced cellulosic biofuels by 2011 (as originally envisioned in the Energy Independence and Security Act of 2007) to about 25 million liters, due to difficulties in financing commercial production. The range of experience highlights the need to adjust targets according to evolving conditions. The achievement of targets requires a strategy of tailored policy measures, discussed in the further in the following sections.

## 5.2 Risks and returns

As is the case in other sectors, the nature of risks, relative to expected returns, influences the incentive to invest in renewable energy. If a project or company has an expected risk-adjusted rate of return on investment that is sufficiently high, it is considered an interesting opportunity for financing. Taking first the risks in renewable energy projects, these can be categorised as follows (UNEP SEFI, New Energy Finance and Chatham House 2009):

■ **Technical and project-specific risks**, including risks associated with lead times, construction costs, novelty of the technology, fuel and resources, and operations and management. Newer technologies have higher risks than traditional ones. As long as investors are unfamiliar with a technology and there is little in-country expertise, the perceived risk is high. Resource availability may also be an issue for specific technologies like geothermal where determination of good locations is costly and subject

to uncertainty. Some resource dependency also occurs with hydro, wind, and biomass-based technologies. Risks will therefore differ at regional or national levels.

■ **Country-specific institutional risks** such as stability of the government, reliability of the legal system, transparency of business dealings, currency risks, and general instability due to wars, famine and strikes. For large-scale investments in a specific country, a long-term stable policy regime with a sound legal basis is needed;

■ **Political risk and regulatory risks**, such as unexpected changes in policy or uncertainty about the future direction of policy. Given the long pay-back periods, the contribution of policies to predictability, clarity and long-term stability in the investment climate, are viewed as critical in being able to stimulate more investments;<sup>41</sup> and,

■ **Business and market risks**, including: 1) financial risks relating to the capital structure of the project such as high upfront capital intensity and the project's ability to generate enough cash flow; 2) economic risks relating to interest rates, exchange rates, inflation, commodity prices, counterparty credit risk; and 3) market risks associated with, for example, future electricity and carbon prices (which may also be influenced by political and regulatory risks). Most renewable energy technologies are less vulnerable to the price and availability of fuel during the operation of a project. Those technologies that are dependent on biomass, however, do face potential market-price risks if the opportunity cost of biomass production is related to agricultural commodity prices and also because a reduction in fossil-fuel prices can make renewable energy less competitive in fuel and

41. This includes either anticipating or being able to adapt to unanticipated adverse effects from the deployment of a new renewable energy project. A prominent example is the production of biofuels, in which the EU and the US have adjusted their respective policy support.

### Box 2: Tunisia's Solar Energy Plan

In order to become less dependent on energy imports and the volatile prices of oil and gas, the Government of Tunisia decided to develop the country's potential for renewable energy generation. A 2004 law on energy management provided a legal framework. In 2005, funding mechanisms such as the National Fund for Energy Management became available for deploying renewable energy technologies and increasing energy efficiency. Between 2005 and 2008, clean energy plans enabled the government to save nearly €900 million in energy expenditures (equivalent to 10 per cent of primary energy consumption), with an initial investment in clean energy infrastructure of only €260 million. The renewable energy supplies and energy efficiency measures are expected to have reduced total energy

consumption from conventional sources by about 20 per cent in 2011. In December 2009, the government presented the first national Solar Energy Plan and other complementary plans with the objective of increasing the share of renewable energy sources to 4.3 per cent of total energy generation in 2014, up from the current level of 0.8 per cent. The objective is to transform Tunisia into an international clean-energy hub. The Solar Energy Plan is based on three main technologies: solar PV, concentrating solar power and solar water heating systems, and comprises 40 renewable energy projects. The Plan's budget through to 2016 is €2 billion, while its savings on energy imports are expected to reach more than 20 per cent per year by the end of that year.

Source: Agence Nationale pour la Maîtrise de l'Énergie (2009)

power markets. Such risks may be reduced with second generation, relative to first generation biofuels.

Various government initiatives, including regulatory policies, fiscal incentives and public financing mechanisms, can reduce many of these risks and thus increase expected returns (Ecofys 2008). Such measures include offering long-term policy commitment to increased deployment of renewable energy investment, helping to mitigate political and regulatory risks. Shorter-term political commitment is similarly important. Owing to the long-lead times for project development, clarity over the development of regulation in support of renewable energy over a five-year horizon is desirable. Political and regulatory risks, as well as some country-specific risks, can also be reduced through government-sponsored initiatives to share risks, including through loan guarantees (discussed again under section 5.3) or public participation in the project or related infrastructure investments. Technical and project-specific risks can be addressed through action to improve permitting procedures, as well as grid connection procedures in the case of power generation projects. Well-designed measures to reduce the above risks have been estimated to decrease the production costs by as much as 30 per cent, in a European context (Ecofys 2008).

A range of further public support mechanisms can also enhance returns to investments in renewable energy, by either helping to lower costs or to enhance income. Measures to reduce costs include subsidies and fiscal measures, such as investment tax deduction, production tax deduction, and preferential depreciation schemes. Public finance mechanisms, such as loans, also lower risks to investors and this particular type of support is discussed in more detail in the next section.

Direct subsidies for renewable energy have been used to provide assistance in the early stages of market diffusion. In July 2009, for example, China initiated the Golden Sun Policy, which provides subsidies for 500 MW of PV projects until 2012 to temporarily support the domestic solar industry in response to reduced demand for PV panels in Germany and Spain. The policy supports large-scale PV, which complements the existing Solar Roofs Program that began in March 2009 (REN21 2010). Such subsidies can be in the form of investment support and grants to reduce capital costs, or in the form of operating support. Currently, they are estimated at US\$ 27 billion in 2007 for renewables (excluding hydroelectricity) and US\$ 20 billion for biofuels at the global level, clearly dwarfed by subsidies to fossil fuels.

Subsidies, however, need to be judiciously designed. Subsidies will most likely need to be adjusted over time in order to be efficient, and such changes are likely to be opposed by businesses or consumers who benefit

from them. Such support also needs to take into account requirements of international agreements, in particular the rules and regulations of the WTO. Box 3 gives the example of Brazil, which used taxes on petrol to cross-subsidise ethanol from sugarcane.

Taxes can be an alternative fiscal measure to subsidies (or used in combination) in order to shape the structure of incentives facing producers and consumers in energy markets. A tax is one of the most efficient measures for addressing the externalities of carbon emissions in energy production and use. Given the pervasiveness of energy use and, thus, the broad tax base, it may be desirable on both efficiency and equity grounds to embed such tax measures in a broader fiscal reform package with a view to offsetting a carbon tax with reductions in other taxes, especially those which distort markets; this would produce a win-win for society as a whole.

Renewable energy producers, for example, may be granted exemptions from general energy taxes. Such measures are potentially most effective where overall energy taxes are high, such as in Nordic countries (IEA 2008e). The United States and Sweden, for example, provide a 30 per cent tax credit for solar PV, France offers a 50 per cent income tax credit, and Australia provides rebates up to AUS\$ 8/watt (REN21 2010).

In addition to measures to reduce costs for renewable energy investments, governments employ a range of production support measures to enhance the income earned on such investments. These include obligation schemes, such as renewable portfolio standards for energy utilities mandated by government (discussed below under section 5.4) or feed-in tariffs.

Support mechanisms can elicit private investment in renewable energy, and while most support is implemented in high-income countries, incentives are becoming common place in developing countries. Currently 79 countries have at least some form of regulatory policy, such as a renewable quota, and 80 countries have at least one form of fiscal incentive in place (REN21 2011). Public finance and investment are being utilised, but at a slower rate than other mechanisms. In most support schemes the government must be actively involved to assure investment certainty.

Feed-in tariffs, much like preferential pricing, guarantee payment of a fixed amount per unit of electricity produced or a premium on top of market electricity prices. Feed-in schemes can be flexible and tailored; for example, tariffs can be based on technology-specific costs, possibly decreasing over time to follow actual cost reductions. This instrument is popular with project developers for the long-term certainty it can provide and, thereby, a considerable reduction of

market risk (IEA 2008e). To achieve the required returns, incentive mechanisms such as feed-in tariffs need to be guaranteed for 15-20 years, though the level of support can be expected to decrease.

By early 2011, feed-in tariffs had been implemented in more than 61 countries and 26 states/provinces, more than half of which have been enacted since 2005 (REN21 2011). Developing countries are increasingly employing feed-in tariffs, including 13 lower middle-income countries and three lower-income countries, as of early 2011. Ecuador, for example, adopted a new system of feed-in tariffs in early 2011, building on an earlier policy dating from 2005 (REN21 2011). Kenya introduced a feed-in tariff on electricity from wind, biomass and small- hydro power in 2008 and extended the policy in 2010 to include geothermal, biogas and solar-generated electricity (AFREPREN/FWD 2009).

As with any kind of positive support, the design of feed-in tariffs is crucial for their success. Important issues include tariff levels, graduated tariff decreases over time, time periods for support, the formula for cost-sharing among different groups of consumers, minimum or maximum capacity limits, payment for net versus gross generation, limitations based on type of ownership and differential treatment of technology sub-classes. For example, rates for solar PV feed-in tariffs have recently been (or are in the process of being) revised in various countries in reaction to price reductions of PV panels, and thus the declining cost of installations (REN21 2010, 2011).

Apart from feed-in tariffs, which are basically financed by cross subsidies among electricity users, the feebate has

also been proposed as alternative regulatory measure to enhance incentives to invest in renewable power generation. Feebates have been applied in the transport sector on vehicle emissions (Small 2010). In the power sector, feebates would impose a per kWh charge on generators in proportion to any difference between their average emissions per kWh and the industry as a whole, and a rebate to generators with below average emissions per kWh. Feebates could thus have little overall effect on energy prices, enhancing their overall feasibility and acceptability, and be revenue-neutral.

Initiatives to price carbon emissions would likely also have an important impact on the returns to renewable energy investments (see Box 1 in Section 3). At the international level, the most important policy initiative that would alter the relative profitability of renewables would be a framework agreement on carbon emissions that established a robust pricing mechanism for full cost accounting of health and climate externalities. With estimates reviewed by the IPCC (2007) ranging up to US\$ 95 per tonne of CO<sub>2</sub>, these additional costs of fossil fuels would make a variety of renewables attractive and spur wider investment and adoption over time. Accompanying measures would also be required though to minimise negative impacts on energy poverty.

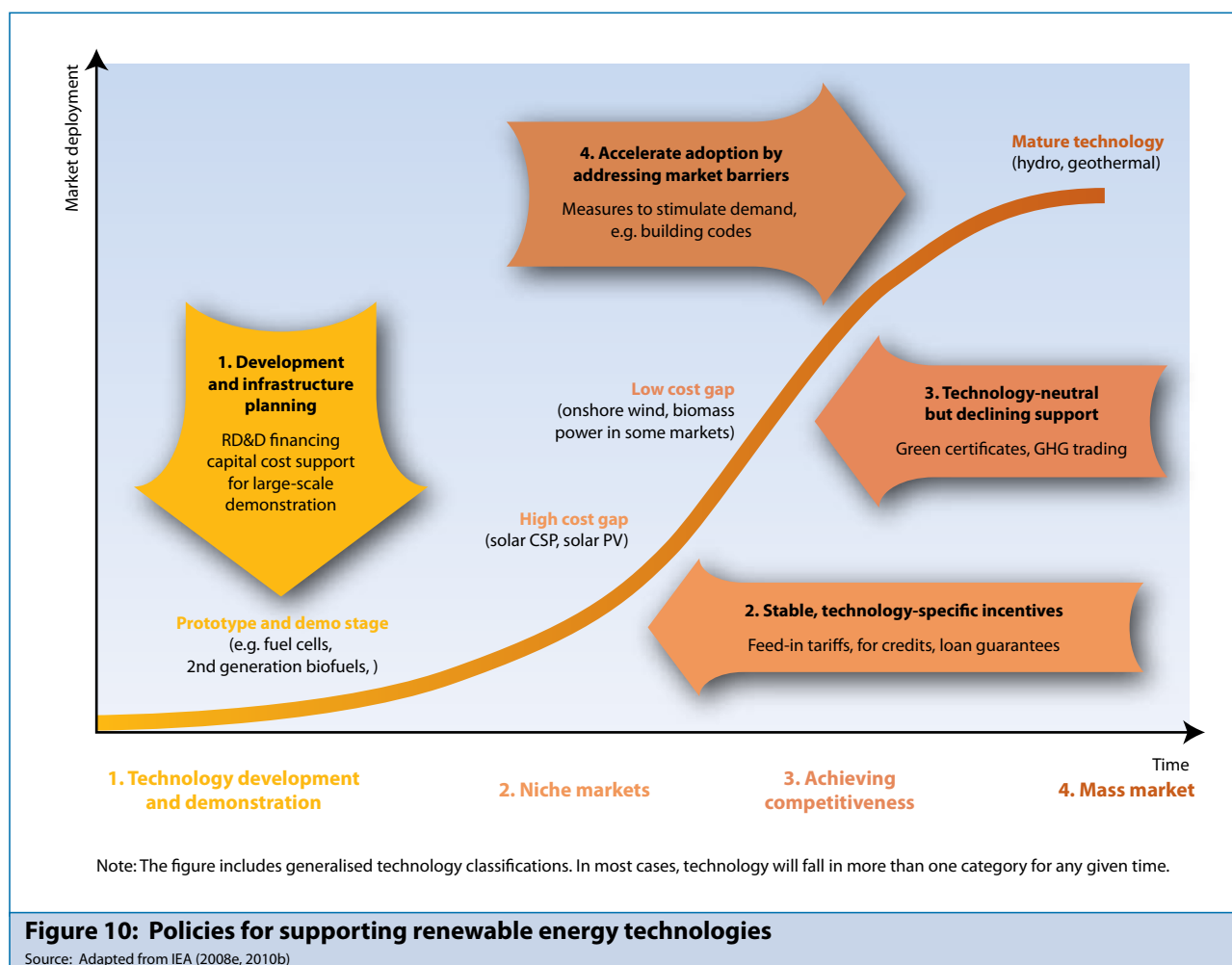
Some possibilities for selecting and adapting these various support measures to the level of technological maturity and market development is illustrated in Figure 10. Support to earlier stages of innovation and R&D is discussed further in section 5.5. Policies, incentives and mechanisms influencing risks and returns as discussed above generally contribute as deployment is initiated (in niche markets)

### Box 3: Brazilian ethanol

The Brazilian Alcohol Program (Proalcool) was established in 1975 for the purpose of reducing oil imports by producing ethanol from sugarcane. Incentives aimed at both production and consumption of ethanol, including vehicle technology advancement through flexible fuel engine development, made petroleum substitutes competitive on the Brazilian energy market (United Nations 2011). The ethanol costs declined along a "learning curve" as production increased at an average rate of 6 per cent per year, from 0.9 billion gallons in 1980 to 3 billion gallons in 1990 and to over 15 billion gallons by 2005 (IEA 2006). The unlevelised cost of ethanol in 1980 was approximately three times the cost of petrol, but cross-subsidies paid for the price difference at the pump. The subsidies came mostly from taxes on petrol and were thus paid by vehicle drivers. The democratization of Brazil

provided an increasingly deregulated ethanol market, culminating in the termination of Proalcool and the removal of all remaining ethanol subsidies in 1999. Cumulative subsidies to ethanol are estimated to have amounted to about US\$ 50 billion over the 20-year period ending in 1995, but were more than offset by a cumulative reduction of petroleum imports amounting to US\$ 100 billion by the end of 2006 (IEA 2006). As of 2006, Brazil accounted for over 50 per cent of the world's ethanol exports (IEA 2006). Other measures, such as the requirement that vehicle manufacturers provide so-called flex fuel vehicles that could operate on either ethanol or petrol, also supported the market for biofuels. These were introduced in 2003 to accommodate higher and fluctuating prices for sugar which had reduced the incentive to produce ethanol.





and as competitiveness improves. Measures targeting consumption and demand may be more relevant at later stages of diffusion and market development.

### 5.3 Financing mechanisms

As mentioned in the previous section, public finance mechanisms are one group of public support measures that governments can use or promote in order to influence the specific risk/ return profile of renewable energy technologies. These Public Finance Mechanisms (PFM, see Figure 11), can be categorised by stage of economic development, by stage of technological development, by type of investors, by type of risk to private investors, or by addressing specific barriers or constraints (UNEP SEFI 2005; UNEP/ Vivid Economics 2009; UNEP SEFI, New Energy Finance and Chatham House 2009). Public Finance Mechanisms vary from simple grants to complex conditional funding structures. As a general rule, PFMs aim at complementing the private sector and not substituting for it as part of an integrated and coherent enabling environment alongside regulations, taxes and subsidies. In high- and middle-income countries, one of the key aims of PFMs is to mobilise (or leverage) as much private capital for investments as possible (UNEP SEFI 2008b). Exceptions may occur in developing country contexts, where there is

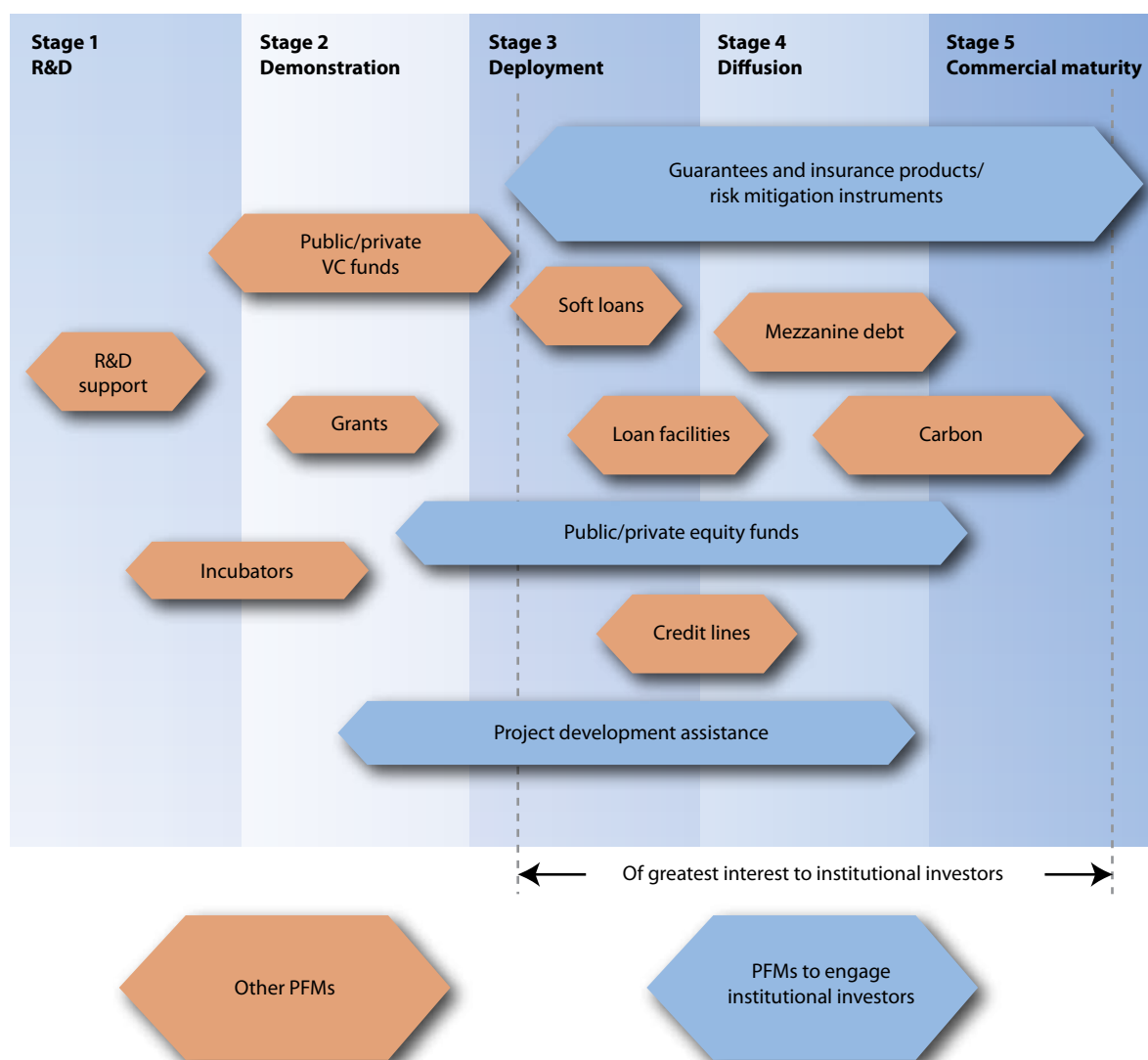
very limited private-sector involvement. Here, PFMs can be part of programmes to create and catalyse markets.

Even when risk-return ratios are favourable, one of the specific financing barriers that renewable energy projects may face can be due to high up-front capital costs or small project-size. Small-scale projects are at a disadvantage in attracting large mainstream investors such as pension funds. This can be a particularly relevant constraint in developing countries. Small project sizes also lead to planning and transaction costs that are high relative to the overall project cost.

Over the past decade, a variety of formal and informal financial institutions and financing arrangements have emerged that offer facilitate small-scale products for the energy-poor in rural areas. Figure 12 gives an overview of the various options available to the poor at different levels of poverty.<sup>42</sup>

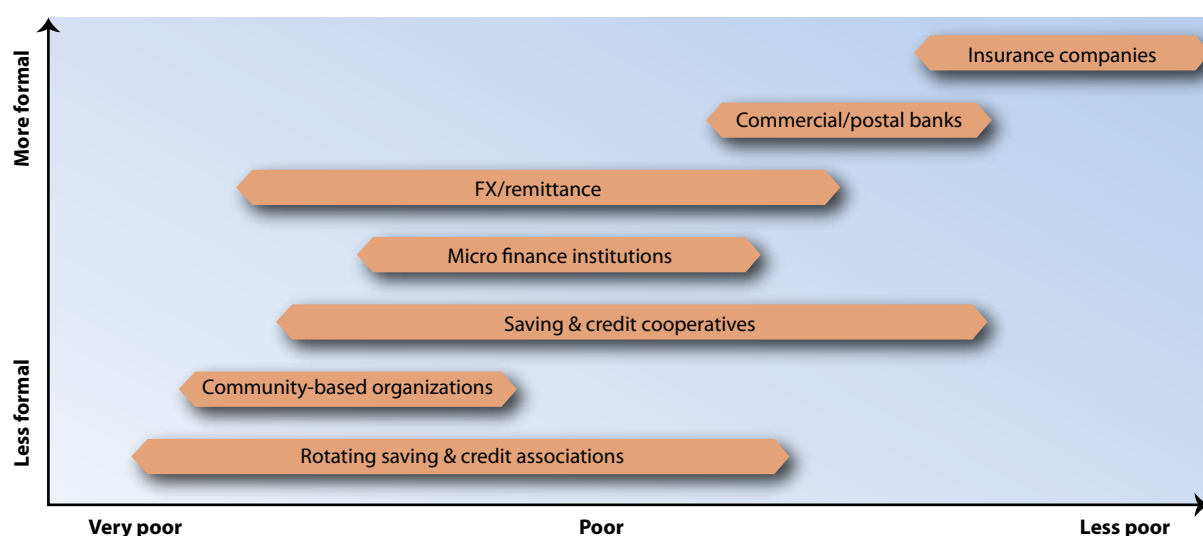
The smallest projects are found in consumer-driven renewable energy solutions in developing countries, such as solar home systems. The high transaction costs involved call for innovative consumer finance

42. A broader discussion of the role of the financial services and investment sector in supporting the greening of the energy sector is included in the finance chapter of this report



**Figure 11 : Public finance mechanisms across stages of technological development**

Source: UNEP SEFI (2009)



**Figure 12: Illustrative financing options for the poor**

Source: UNDP (2009)

mechanisms that address the particular needs of rural developing country customers. These mechanisms can make renewables attractive and cost effective for addressing energy poverty in off-grid situations (Box 4).

Beyond private companies and governments, however, bilateral and multilateral development assistance agencies are also expected to scale up funding while collaborating with existing energy programmes and funds<sup>43</sup> to administer and distribute resources (IEA 2010d). Engaging developing countries in the global mitigation challenge will require international funding and the agreement to establish the Copenhagen Green Climate Fund at the 2009 UNFCCC conference represents potentially significant progress in this area. Countries producing renewable energy may also benefit from increased revenues from selling emissions credits (through the CDM) or green certificates, and lower risk

## 5.4 Electricity infrastructure and regulations

The increased use of renewable energy in power generation faces specific barriers due to the demands it makes on existing electricity infrastructure. Electricity generation by wind and solar PV adds variability and lower predictability to the power system, requiring more attention to the design and regulation of energy

systems and markets (Owen 2006; Heal 2009; IEA 2008d). More reserve capacity, storage or increased trade between countries or regions is needed to provide the necessary flexibility to match demand with variability in supply. Smart grids with variable cost pricing and micro-metering is a new area of development with the potential to provide increased demand flexibility and enhance energy efficiency.

The additional investment costs for adapting the distribution and transmission systems, though substantial, should be manageable. For example, the ECF (2009) roadmap 2050 indicates that the investments required to expand the grid and effectively reduce intermittency challenges amount to around 10 per cent of overall investment in electricity generation.

In some situations, vested interests and control of access to the grid by incumbent power companies can pose barriers for independent providers of power from renewable sources. Similarly, oil companies may impede the distribution of biofuels through networks, such as pipelines, that they control. The construction sector may be reluctant to integrate renewable heating and cooling technology in their practices and building codes. Authorities have to be alert to signals from renewable

43. Such as the Climate Investment Funds, the Global Environment Facility and GTZ's Energising Development (IEA 2010d).

### Box 4: Grameen Shakti programme in Bangladesh

Grameen Shakti (or Grameen Energy in English), founded in 1996, provides electrification to rural communities in Bangladesh through a market-based approach: micro-credit. The experience of Grameen Shakti provides an example of successful entrepreneurship combined with effective energy policy. Capitalising on the network and experience of the Grameen Bank, Grameen Shakti provides soft credits through different financial packages to make solar-home systems (SHSs) available and affordable to rural populations. By creating a market for solar energy and providing multiple advantages over kerosene, Grameen Shakti succeeded in installing over 320,000 SHSs by December 2009.

One aspect that has been essential to the success of the program has been the creation of partnerships with indigenous organizations that have succeeded in cutting programme costs and increasing business development (United Nations 2011). Government financial and policy support provided

the coordination necessary for safe investments in renewable energy. Through effective policy guidelines, the industry had a greater potential for success and future growth (IPCC 2011). Grameen Shakti has also installed numerous improved cooking stoves and biogas plants that contribute to the reduction of woody biomass use and, in turn, decrease indoor pollution, while biogas technology further helps with sustainable waste management.

Grameen Shakti aims to install over 1 million SHSs by 2015, and simultaneously provide the necessary maintenance, while training the necessary technicians and users, thereby generating local employment, and generating social value through stakeholder engagement. Grameen Shakti demonstrates the potential that can be mobilised to reduce energy poverty efficiently, while also contributing to mitigate climate change, with innovative financing and business models in partnership with public support (Wang et al. 2011).

energy companies and move quickly to address such market entry barriers.

Regulations may thus be needed to promote the types of investments in infrastructure necessary for further development of electricity from renewable sources. In Europe, for example, the 2009 Renewable Energy Directive requires EU countries to provide acceleration of authorisation procedures for grid infrastructure, including coordinated approval of grid infrastructure with administrative and planning procedures.

Beyond regulations on electricity infrastructure, governments can establish obligations for renewable energy consumption or production more generally (as discussed in section 5.2). In an obligation system – also referred to as a renewables portfolio standard (RPS) or renewable energy target – a minimum amount or proportion from eligible renewable energy sources is prescribed. The obligation is typically imposed on consumption, often through supply or distribution companies. The implementation of an obligation system usually involves a penalty for non-compliance to ensure that the obligated parties meet their renewable energy purchase obligations (Gillingham and Sweeney 2010).

Obligations for renewables, however, can only be implemented when supply has developed sufficiently to ensure price competition among suppliers. They are typically used for mature technology and may be the successor of fiscal incentives or subsidies (see Figure 10). For investors, the perceived policy risks of obligations are smaller than those of subsidies, since they are not subject to government budget decisions. As of early 2011, there were 10 national and at least 30 state/provincial/regional jurisdictions with RPS policies (REN21 2011). Most of these require renewable power shares between 5 and 20 per cent.

## 5.5 Innovation and R&D

The technological development of renewable energy faces barriers due to the market failures inherent in innovation. Knowledge spillovers from research and development activities to create better products at lower costs benefit both consumers and other enterprises, but the potential innovator may not receive sufficient share of these to justify the investments (Gillingham and Sweeney 2010). Furthermore, new technologies can be intuitive and easily learned, which contributes to cost reductions, which others are also able to apply. Both situations result in a general under-investment along all stages of the innovation chain.

There is little systematic evidence quantifying the extent of this market failure in renewables and thus to

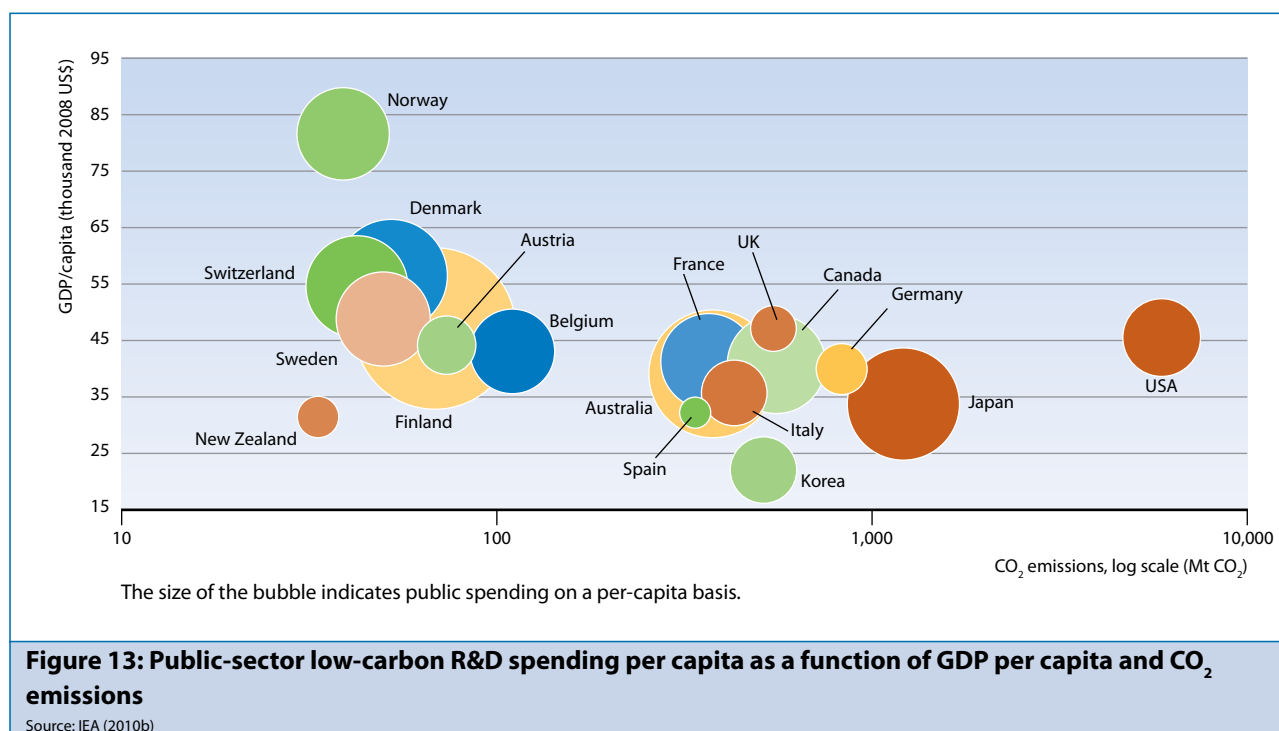
what extent investment and innovation in this sector would be higher if the market failure were eliminated. Nonetheless, the costs of some of the important technologies for renewable energy have declined steeply as installed capacity has increased, as seen above in section 3.3 in the discussion of learning effects for solar PV (IPCC 2011). These learning effects represent an important spillover benefit, as the cost reductions are generated and disseminated throughout the industry relatively “free-of-charge” (Jamasb 2007).

To achieve a socially optimal rate of innovation, therefore, policy support is needed (Tomlinson et al. 2008; Grubb 2004). In particular, public support for R&D is essential for supporting high-risk, fundamental research with a long-term perspective, whilst the private sector tends to focus on near-competitive technologies and shorter-term demonstration projects.

The public sector can support research institutes and academic institutions, fund research programmes targeted at specific technologies, and supply grants or use other means support to private-sector R&D efforts. Energy research has been found to be most effective when targeted R&D programmes, e.g. “technology push” projects, are joined seamlessly with “market pull” policies on deployment (IEA 2010b; IPCC 2011; United Nations 2011).

Research and development for the energy sector in the 28 IEA member countries has recently shown signs of growth, having been stagnant for some time. In 2006, when the share of renewables was just above 10 per cent, R&D spending in real terms was only slightly above levels registered 30 years earlier (IEA 2008e). In 2009, R&D and deployment in renewable energy by governments and business totalled US\$ 24.6 billion (UNEP SEFI 2010). Government support to R&D increased in that year by 50 per cent, accounting for US\$ 9.7 billion. Corporate spending, at US\$ 14.9 billion, declined somewhat, reflecting the economic recession. There are also many differences between countries in terms of public R&D expenditure (see Figure 13).

In developing countries, R&D for renewables may warrant specific attention, although there are many positive signs already. In many cases, local technical capabilities for developing or adapting technologies are virtually absent. The focus here should be on creating capacity to facilitate technology transfer, adapt technologies to local market conditions and support private-sector players that install, manufacture, operate and maintain the technologies. At the 2010 UNFCCC, COP16 in Cancun, Mexico countries agreed to establish a Climate Technology Mechanism. Its purpose is to accelerate the development and transfer of climate friendly technologies, especially to developing countries,



to address both climate mitigation and adaptation (UNFCCC 2010). However, the exact functioning of the mechanism's two components – the Technology Executive Committee and the Climate Technology Centre and Network – remains to be specified.

Market failures in innovation notwithstanding, considerable cumulative benefits can accrue to countries that generate first-mover advantages from leading development in the renewable energy sector. Simulation modelling has illustrated how overall economic competitiveness can improve when a country or region, in this case the EU, commits itself to unilateral climate-change mitigation action involving the penetration of renewables on a large scale (Barker and Scricciu 2009).

## 5.6 Technology transfer and skills

Technology transfer is the flow of knowledge, experience and equipment from one area to another. Often, technology transfer is exclusively seen as being from an industrialised country to a developing country, but it can also be between developing countries or even from urban areas to rural areas.

Like other new technologies, renewable energy faces barriers that relate to technology transfer. Before a technology can be transferred successfully, enabling conditions need to be fulfilled, such as institutional and adaptive capacity, access to finance, and both codified and tacit knowledge of the technology. In developing countries, especially in remote rural areas, however,

such conditions are often not present. Even when the economic feasibility of renewable energy options in those areas is favourable, these barriers can prevent their application.

Recent studies have argued that, in order to allow developing countries to adopt renewable energy technologies in the local and regional context, the capacity to maintain and operate the systems is not sufficient by itself; indigenous innovation capabilities also need to be addressed (Ockwell et al. 2009; Bazilian et al. 2008; United Nations 2011). The required capabilities to undergo the process of adaptive innovation are considerable and depend on a knowledge infrastructure usually encompassing centralised R&D and requiring higher levels of education. Indeed, the flows of technology and knowledge are of vital importance for technology transfer to developing countries (Ockwell et al. 2009).

A related issue is skill shortages. Employment in the renewable energy industry requires some skills that do not necessarily coincide with those found in the traditional energy industry. In Germany, for example, the renewable energy industry has recently experienced a shortage of skilled workers. Lehr et al. (2008) reported that almost all energy sub-sectors lack skilled workers, the most acute shortage being skills in hydro energy, biogas and biomass technologies. Wind-energy companies in Europe have also reported an acute shortage of highly-skilled workers. The shortage is most pressing for manufacturing and development, particularly engineering, operations and management, and site-management activities. The sector also needs skilled employees in R&D.



## 5.7 Sustainability standards

Renewable energy is not synonymous with sustainability. The term renewable refers largely to the naturally regenerative nature of the energy source, whereas sustainability has a broader scope, including economic, social and environmental considerations. Although renewable energy technologies are generally perceived as being more sustainable compared to nonrenewable sources, due to smaller environmental impacts, there is still a need to develop agreed standards to reduce and manage these impacts. The environmental and social impacts of large hydropower reservoirs are one prominent example, including their potential to release carbon dioxide and methane from decaying biomass in tropical locations. Concern about minimizing impacts has led to the development of policy principles and guidelines under the coordination of the World Commission on Dams. Biofuels are another example, as their production in some circumstances has been associated with unsustainable land use and land-use change, with potential consequences for GHG balances, biodiversity and food security; at the same time, there is also a risk of excessive water use and contamination (UNEP 2009).<sup>44</sup> Different renewable technologies may, therefore, rank differently according to

varying sustainability criteria. Methodologies to quantify effects and trade-offs are still under development.<sup>45</sup>

For biofuels, the sustainability challenge is slowly being addressed on the project and policy level. National biofuels policy, regulatory frameworks, international standards, and environmental impact assessment methodologies increasingly incorporate sustainability criteria and standards. For example, sustainability criteria for biofuels and bio-liquids were developed and adopted in the EU Renewable Energy Sources Directive (EU Directive 2009/28/EC), to be implemented by member states. Certification schemes can be used for validating the fulfillment of sustainability criteria. However, many countries lack the institutional capacity to effectively implement and enforce certification schemes, inhibiting the development and adoption of sustainability standards for biofuels.

Another challenge is balancing stringency and flexibility, as manifested in the introduction of sustainability standards for biofuels in the EU, which has led to trade disputes within the WTO. Overly rigid standards would be a disincentive for producers to enter the market and may limit investment, particularly in developing countries (Devereaux and Lee 2009). Policy makers, therefore, need to balance long-term sustainability concerns with shorter-term interests when promoting renewable energy.

44. Impacts on GHG balances vary depending on feedstock, location, input and production methods, previous land use, conversion technology, all throughout the life-cycle (UNEP 2009).

45. See for example ongoing climate policy planning guidance work by UNEP: <http://www.MCA4climate.info>.

## 6 Conclusions

The challenges posed to the global community and national governments, in terms of energy security, climate change, health impacts, and energy poverty are pressing, making the greening of the energy sector an imperative. The existing challenges are exacerbated by the expected growth in the global demand for energy, as population and incomes rise. Shifting from fossil fuels to renewable energy plays a critical role in greening the energy sector, along with other changes, in particular raising energy efficiency.

The cost effectiveness of renewable energy technologies has evolved considerably in recent decades. Many renewable energy technologies are maturing rapidly and their costs becoming competitive with fossil fuel alternatives. Consequently, the investments in deploying renewable energy increased dramatically in the last decade.

These developments have been driven by a range of policies. National targets for renewable energy are spreading. A number of governments have supported innovation to help reduce costs, while many more are increasingly putting in place regulations, fiscal incentives and financing mechanisms that mitigate risks and increase returns to investing in renewable energy. At the international level, the formal creation in 2011 of the International Renewable Energy Agency (IRENA) indicates a willingness of governments to work collaboratively in expanding the role of renewable energy.

Despite encouraging progress, a number of roadblocks still remain on the route towards a green energy sector. Most importantly, the overall incentive framework under which the energy sector operates has not yet been reconfigured to consistently support the development and deployment of renewable energy technologies and a managed phasing-out of emissions from fossil fuel sources. This is due to both vested interests and an energy system, comprised of both hardware, such as electricity infrastructure, and software, in the form of organisations and institutions, that are locked in to supporting conventional energy technologies. Although developing countries may have fewer cumulative investments in conventional energy systems, they face financial constraints and also a shortage of institutional and human capacity to acquire and manage new technologies.

To reduce such roadblocks, policymakers need to take an integrated approach that supports various stages of the development and diffusion of renewable energy technologies within an overall strategy that also addresses the rest of the energy system, on both supply and demand sides. In so doing, there is considerable scope for governments to work with market forces to create a level playing-field for the further growth of renewable energy. Phasing out subsidies for fossil fuels and pricing in health and environmental externalities from fossil-fuel combustion can speed up the transformation of the energy sector, though attention needs to be paid to impacts on low-income groups.

Increasing investments in renewable energy, as part of a green economy strategy spanning all major sectors, can contribute to reducing health and environmental impacts from energy production and use, while ensuring the basis for long-term economic growth. Such a strategy is based on the substitution of fossil fuel energy with renewable energy, savings from energy efficiency in manufacturing, buildings and construction, and transport, and behavioural change. Such an integrated strategy can increase national energy security and reduce carbon emissions while providing new employment opportunities that may, in global terms, more than compensate for jobs that disappear. This, however, should not prevent policymakers from recognising that in specific countries, depending on the extent to which fossil-fuel subsidies are phased out and negative externalities addressed, there could be net declines in employment, at least in the short term. The focus should be on specific countries and on practical ways of building capacity and skills to facilitate a transition to a green economy.

In order also to play a role as part of an integrated strategy to reduce energy poverty, specific aspects of renewable energy development needs to be tailored to the circumstances in rural areas where the majority of the poor in developing countries live. Mini-grids and off-grids may provide a cost-effective means of delivering electricity to the poor, while also reducing growth in GHG emissions. This requires additional financing flows, as well as continued development of new financing models.

# References

- AFREPREN/FWD Energy, Environment and Development Network for Africa. (2009). *The Role of Feed-in Tariff Policy in Renewable Energy Development in Developing Countries*. September 2009.
- AGECC. (2010). *Energy for a Sustainable Future, Summary Report and Recommendations*. The Secretary-General's Advisory Group on Energy and Climate Change (AGECC). Available at: <http://www.un-energy.org/publications/558-agecc-report-energy-for-a-sustainable-future>
- Agence Nationale pour la Maîtrise de l'Énergie. (2009). *Plan Solaire Tunisien*, Ministère de l'Industrie, de l'Énergie et des PME, Government of Tunisia, Tunis.
- Barker, T. and Scriciecu, S.S. (2009). "Unilateral Climate Change Mitigation, Carbon Leakage and Competitiveness: an Application to the European Union". *International Journal of Global Warming* 1(4): 405-417.
- Barreto, L. and Klaassen, G. (2004). Emission trading and the role of learning-by-doing spillovers in the "bottom-up" energy-system ERS model. *International Journal of Energy Technology and Policy*, 2(1), 70-95.
- Bazilian, M., de Coninck, H., Radka, M., Nakhooda, S., Boyd, W., MacGill, I., Amin, A.-L., von Malmborg, F., Uosukainen, J., and Bradley, R. (2008). *Considering technology within the UN climate change negotiations*. Energy Research Centre of the Netherlands (ECN), ECN-E-08-077, Petten, Netherlands.
- Blyth, W. (2010). "The economics of transition in the power sector", Information paper, International Energy Agency (IEA), Paris, January 2010.
- Devereaux, C. and Lee, H. (2009). *Biofuels and Certification: A Workshop at Harvard Kennedy School*. Discussion Paper 2009-07, Belfer Center for Science and International Affairs, June 2009, Cambridge, M.A.
- DLR-ISI. (2006). *External costs of electricity generation from renewable energies compared to electricity generation from fossil energy sources*, German Aerospace Centre (DLR) and the Fraunhofer Institute for System and Innovation Research (ISI).
- ECF. (2009). *Roadmap 2050, A practical guide to a prosperous low carbon Europe, Technical analysis*. European Climate Foundation (ECF), The Hague, The Netherlands.
- Ecofys. (2008). *Policy Instrument Design to Reduce Financing Costs in Renewable Energy Technology Projects. Report for the IEA Implementing Agreement on Renewable Energy Technology Deployment (RETD)*, Utrecht, the Netherlands, October. Available at: [www.ecofys.com/com/publications/documents/RETD\\_PID0810\\_Main.pdf](http://www.ecofys.com/com/publications/documents/RETD_PID0810_Main.pdf)
- EcoSecurities Consulting. (2009). *Assigning Carbon Price Estimates to Alternative Policy Scenarios*, January 30, 2009.
- Edmonds, J., Clarke, L., Lurz, J. and Wise, M. (2008). "Stabilizing CO<sub>2</sub> Concentrations with Incomplete International Cooperation." *Climate Policy* 8 (4): 355-76).
- EEA. (2008). "EN35 - External costs of electricity production", European Environment Agency (EEA). Available at: <http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production-1/en35>.
- EIA. (2011). *Electric Power Monthly with data for December 2010*, US Energy Information Administration (EIA), EIA report released March 11, 2011, Washington, D.C.
- ELI. (2009). *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008*, Environmental Law Institute (ELI), Washington, D.C.
- Epstein, P.R., Buonocore, J.J., Eckerle, K., Hendryx, M., Stout, B.M., Heinberg, R., Clapp, R.W., May, B., Reinhart, N.L., Ahern, M.M., Doshi, S.K. and Glustrom, L. (2011). "Full cost accounting for the life cycle of coal", in *Ecological Economics Reviews*. Robert Costanza, Karin Limburg & Ida Kubiszewski, Eds. *Ann. N.Y. Acad. Sci.* 1219: 73-98.
- ESMAP. (2008a). *Coping with Oil Price Volatility*. Energy Security, Energy Sector Management Assistance Program (ESMAP), World Bank, Washington D.C.
- ESMAP. (2008b). *Beyond the Grid: Innovative Programmes in Bangladesh and Sri Lanka*. Energy Sector Management Assistance Program (ESMAP) Knowledge Exchange Series. Available at: [http://www.esmap.org/esmap/sites/esmap.org/files/KES10\\_SriLanka\\_Electricity%20Beyond%20the%20Grid.pdf](http://www.esmap.org/esmap/sites/esmap.org/files/KES10_SriLanka_Electricity%20Beyond%20the%20Grid.pdf).
- European Commission. (2008). *Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport*, Commission Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Second Strategic Energy Review, An EU Energy Security and Solidarity Action Plan, SEC(2008)2872.
- Gillingham, K. and Sweeney, J. (2010). "Market Failure and the Structure of Externalities". In *Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy*, ed. Boaz M., A.J. Padilla, and R. Schmalensee, pp. 69-92, Earthscan Publications Ltd., London, U.K.
- GNESD. (2007). *Reaching the Millennium Development Goals and beyond – access to modern forms of energy as a prerequisite*. Global Network on Energy for Sustainable Development, Roskilde.
- GNESD. (2010). *Energy, Climate Change and Poverty Alleviation*, Global Network on Energy for Sustainable Development (GNESD) Policy Paper prepared by AFREPREN, ENDA-TM and Fundacion Bariloche.
- Greenpeace and European Renewable Energy Council (EREC). (2010). *Energy [r]evolution: a sustainable world energy outlook*, European Renewable Energy Council, Amsterdam. Available at: <http://www.erec.org/index.php?id=139>.
- Grubb, M. (2004). "Technology Innovation and Climate Change Policy: an overview of issues and options", *Keio Economic Studies* 41(2): 103-132.
- GSI. (2009). *Building Fossil-Fuel Subsidy Reform - Have we got all the blocks?* Global Subsidies Initiative (GSI) Policy Brief, Geneva, Switzerland.
- GSI. (2010). *Relative Subsidies to Energy Sources: GSI estimates*, Global Subsidies Initiative (GSI), Geneva, Switzerland.
- Heal, G. (2009). "The Economics of Renewable Energy". National Bureau of Economic Research (NBER) Working Paper No. 15081, Cambridge, M.A., June 2009.
- HRS-MI. (2009). *Climate Policy and Energy – Intensive Manufacturing: the Competitiveness Impacts of American Energy and Security Act of 2009*. High Road Strategies and Millennium Institute, Arlington, V.A.
- HSBC. (2009). *A Climate for Recovery The Colour of Stimulus Goes Green*, HSBC Global Research, February 2009.
- IEA. (2006) *The Energy Situation in Brazil: An Overview*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2008a). *Renewables Information 2008 edition*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2008b). *World Energy Outlook 2008*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2008c). *IEA Energy Technology Perspectives 2008*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2008d). *Empowering Variable Renewables: Options for Variable Electricity Systems*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2008e). *Deploying Renewables – Principles for Effective Policies*. Available at: <http://www.iea.org/textbase/nppdf/free/2008/DeployingRenewables2008.pdf>.
- IEA. (2009a). *World Energy Outlook 2009*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2009b). *The impact of the financial and economic crisis on global energy investment*. Paris.
- IEA. (2010a). *Energy Poverty: How to make modern energy access universal?* Special Excerpt from IEA *World Energy Outlook 2010*, by International Energy Agency (IEA), Organisation for Economic Co-operation and Development (OECD), United Nations Industrial Development Organization (UNIDO), and United Nations Development Programme (UNDP), 2010. Available at: [http://www.iea.org/speech/2010/jones/weo\\_poverty\\_chapter.pdf](http://www.iea.org/speech/2010/jones/weo_poverty_chapter.pdf).

- IEA. (2010b). *Energy Technology Perspectives 2010*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2010c). *Projected Costs of Generating Electricity 2010*, International Energy Agency, OECD Publishing, Paris.
- IEA. (2010d). *World Energy Outlook 2010*, International Energy Agency, OECD Publishing, Paris.
- IEA, OPEC, OECD and World Bank. (2010). *Analysis of the Scope of Energy Subsidies and Suggestions for the G-20 initiative*, joint report prepared for submission to the G20 Summit Meeting Toronto (Canada), 26-27 June 2010.
- IIASA. (2009). *Emissions of Air Pollutants for the World Energy Outlook 2009 Energy Scenarios Final Report*, (report prepared for the International Energy Agency using the GAINS model), IIASA, Laxenberg. Available at [www.worldenergyoutlook.org](http://www.worldenergyoutlook.org)
- IIED. (2009). *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*, International Institute for Environment and Development and Grantham Institute for Climate Change, London.
- Institute for Labor Studies and Ministry of Human Resources and Social Security, China. (2010). *Study on Green Employment in China*. International Labor Organization (ILO), March 2010.
- IPCC. (2007). *Climate Change 2007: Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Edited by B. Metz, O.R. Davidson, P.R. Bosch, R. Dave and L.A. Meyer, Cambridge University Press, Cambridge, UK and New York, USA.
- IPCC. (2008). *Scoping Meeting on Renewable Energy Sources, Proceedings*, Presented in Luebeck, Germany, 20-25 January 2008, 59-80. Available at: [http://www.iea-gia.org/documents/FridleifssonetalIPCCGeothermalpaper2008FinalRybach20May08\\_000.pdf](http://www.iea-gia.org/documents/FridleifssonetalIPCCGeothermalpaper2008FinalRybach20May08_000.pdf).
- IPCC. (2011). *Special Report on Renewable Energy Sources and Climate Change Mitigation*. Working Group III – Mitigation of Climate Change. Edited by O. Edenhofer, R. Pichs-Madruga, and Y. Sokoma. Published for the Intergovernmental Panel on Climate Change.
- ITIF. (2009). *Rising tigers, sleeping giant: Asian nations set to dominate the clean energy race by outinvesting the United States*, Information Technology and Innovation Foundation (ITIF) & The Breakthrough Institute.
- Jamasb, T. (2007). Technical change theory and learning curves: patterns of progress in electricity generation technologies. *Energy Journal* 28: 51-71.
- Junginger, M., Lako P., Lensink, S., Sark, W. van and Weiss, M. (2008). *Technological learning in the energy sector*, Utrecht University and Energy Centre of the Netherlands (ECN), Report No. 500102 017. Study performed within the framework of the Netherlands Research Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB). Available at: <http://www.rivm.nl/bibliotheek/rapporten/500102017.pdf>
- Karekezi, S., Lata, K. and Coelho, S.T. (2004). "Traditional Biomass Energy: Improving its Use and Moving to Modern Energy Use", thematic background paper for the International Conference for Renewable Energies, Bonn 2004. Available at: <http://www.ren21.net/Portals/97/documents/Bonn%202004%20-%20TBP/Traditional%20Biomass%20Energy.pdf>
- Krey, V. and Clarke, L. (2011). "Role of renewable energy in climate mitigation: a synthesis of recent scenarios", *Climate Policy*, 11, 1-28.
- Kypreos, S., and Bahn, O. (2003). "A MERGE model with endogenous technological progress", *Environmental Modelling and Assessment*, 8(3), 249–259.
- Lehr, U., Nitsch, J., Kratzat, M., Lutz, C. and Edler, D. (2008): "Renewable energy and employment in Germany", *Energy Policy*, 36, 108-117.
- Llera Sastresa, E., Aranda Usón, A., Zabalza Bribián, I. and Scarpellini, S. (2010). "Local impact of renewable on employment: assessment methodology and case study," *Renewable and Sustainable Energy Review*, 14 (2010), 689-690.
- McDonald, A. and Schrattenholzer, L. (2002). "Learning curves and technology assessment". *International Journal of Technology Management*. 23 (7/8), 718-745. Reprinted as RP-03-002. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. Available at: <http://www.iiasa.ac.at/cgi-bin/pubsrch?RR03002>.
- Messner, S. (1997). "Endogenized technological learning in an energy systems model", *Journal of Evolutionary Economics*, 7(3), 291-313.
- Modi, V., McDade, S., Lallement, D. and Saghir, J. (2006). *Energy and the Millennium Development Goals*. Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank, New York. Available at: [http://www.unmillenniumproject.org/documents/MP\\_Energy\\_Low\\_Res.pdf](http://www.unmillenniumproject.org/documents/MP_Energy_Low_Res.pdf)
- NRC. (2010). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Research Council (NRC), Washington, D.C.
- NREL. (1997). *Dollars from Sense: The Economic Benefits of Renewable Energy*. National Renewable Energy Laboratory (NREL) and U.S. Department of Energy.
- Ockwell, D.G., Watson, J., Mallett, A., Haum, R., MacKerron, G. and Verbeken, A.-M. (2009). *Scoping note on the difficulties developing countries face in accessing markets for eco-innovation*, Commissioned and published by Organization for Economic Development and Co-operation (OECD) Environment Directorate, Paris.
- Owen, A.D. (2006). "Renewable energy: externality costs as market barriers." *Energy Policy* 34: 632-642.
- Pew Charitable Trusts. (2010). *Who's Winning the Clean Energy Race?* Washington D.C.
- REN21. (2009). *Renewables Global Status Report 2009 Update*, Renewable Energy Policy Network for the 21st Century (REN21), Paris, June 2009.
- REN21. (2010). *Renewables 2010 Global Status Report*, Renewable Energy Policy Network for the 21st Century (REN21), Paris, July 2010.
- REN21. (2011). *Renewables 2011 Global Status Report*, Renewable Energy Policy Network for the 21<sup>st</sup> Century (REN21), Paris, July 2011.
- Seebregts, A. J., Kram, T., Schaeffer, G.J. and Bos, A.J.M. (1999). *Modelling technological progress in a MARKAL model for Western Europe including clusters of technologies*. Netherlands Energy Research Foundation (ECN).
- Small, K. A. (2010). *Energy Policies for Passenger Transportation: A Comparison of Costs and Effectiveness*. Discussion paper, University of California, Irvine.
- Stern, N.H. (2006). *Economics of Climate Change: The Stern Review*, Cambridge, UK, Cambridge University Press.
- Tomlinson, S., Zorlu, P. and Langley, C. (2008). *Innovation and Technology Transfer: Framework for a Global Climate Deal*, E3G/Chatham House, London.
- UNCTAD. (2006). *Meeting trade and development challenges in an era of high and volatile energy prices: Oil and gas in LDCs and African countries*, Report by the UNCTAD Secretariat, Geneva.
- UNDP. (2007). *Energizing the Least developed Countries to achieve the Millennium Development Goals: The Challenges and Opportunities of Globalization*, Issues paper prepared for UN Ministerial Conference of the Least Developed Countries, "Making Globalization work for the LDCs", Istanbul 9-11 July, 2007.
- UNDP and WHO. (2008). *The Energy Access Situation in Developing Countries, A Review Focusing On the LDCs and Sub-Saharan Africa*, United Nations Development Programme (UNDP), .New York.
- UNEP. (2009). *Towards Sustainable Production and Use of Resources: Assessing Biofuels*, United Nations Environment Programme (UNEP), Paris.
- UNEP. (2010a). *Advancing the Biodiversity Agenda: A UN System-wide Contribution*, United Nations Environment Programme (UNEP), Nairobi.
- UNEP. (2010b). *The Emissions Gap Report: Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2°C or 1.5°C? A preliminary assessment*. United Nations Environment Programme (UNEP), Nairobi.
- UNEP, ILO, IOE and ITUC. (2008). *Green Jobs: Towards Decent Work in a Sustainable, Low Carbon World*, United Nations Office at Nairobi (UNON), Nairobi.
- UNEP SEFI. (2005). *Public finance mechanisms to catalyze sustainable energy growth*, United Nations Environment Programme (UNEP) UNEP Sustainable Energy Finance Initiative (SEFI) and BASE, Paris.



UNEP SEFI. (2008a). *Global Trends in Sustainable Energy Investment 2008*. United Nations Environment Programme (UNEP) Sustainable Energy Finance Initiative (SEFI) and New Energy Finance: Paris.

UNEP SEFI. (2008b). *Public Finance Mechanisms to Mobilise Investment in Climate Change Mitigation*. United Nations Environment Programme (UNEP) Sustainable Energy Finance Initiative (SEFI), Paris.

UNEP SEFI. (2009). *Global Trends in Sustainable Energy Investment 2009*. United Nations Environment Programme (UNEP) UNEP Sustainable Energy Finance Initiative (SEFI) and New Energy Finance, Paris.

UNEP SEFI. (2010). *Global Trends in Sustainable Energy Investment 2010*. United Nations Environment Programme (UNEP) UNEP Sustainable Energy Finance Initiative (SEFI) and Bloomberg New Energy Finance, Paris.

UNEP SEFI. (2011). *Global Trends in Renewable Energy Investment 2011*. United Nations Environment Programme (UNEP) UNEP Sustainable Energy Finance Initiative (SEFI) and Bloomberg New Energy Finance, Paris.

UNEP SEFI, New Energy Finance and Chatham House. (2009). *Private Financing of Renewable Energy: A Guide for Policymakers*. United Nations Environment Programme (UNEP) UNEP Sustainable Energy Finance Initiative (SEFI), Paris; New Energy Finance, London; Chatham House, London.

UNEP/Vivid Economics. (2009). *Catalysing Low Carbon Growth in Developing Economies: public finance mechanisms to scale up private sector investment in climate solutions*, UNEP, Paris.

UNEP and WMO. (2011). *Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers*. United Nations Environment Programme (UNEP), Nairobi; World Meteorological Organization (WMO), Geneva.

UNFCCC. (2009). *Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention*, Report by the Chair of the Export Group on Technology Transfer (EGTT), FCCC/SB/2009/2, Bonn, Germany.

UNFCCC. (2010). *Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention*. United Nations Framework Convention on Climate Change (UNFCCC), 16th Conference of the Parties, Cancun, Mexico.

United Nations. (2011). *World Economic and Social Survey 2011: The Great Green Technological Transformation*, United Nations Department of Economic and Social Affairs (UN/DESA), New York.

Victor, D. (2009). *Untold billions: fossil-fuel subsidies, their impacts and the path to reform*, Global Subsidies Initiative (GSI) Paper GSI, Geneva, Switzerland.

Wang, L., Bandyopadhyay, S., Cosgrove-Davies, M. and Samad, H. (2011). *Quantifying Carbon and Distributional Benefits of Solar Home System Programs in Bangladesh*, Policy Research Working Paper 5545, The World Bank, Environment Department, Washington, D.C.. Available at: [http://www-wds.worldbank.org/servlet/WDSCContentServer/WDSP/IB/2011/01/24/000158349\\_20110124114152/Rendered/PDF/WPS5545.pdf](http://www-wds.worldbank.org/servlet/WDSCContentServer/WDSP/IB/2011/01/24/000158349_20110124114152/Rendered/PDF/WPS5545.pdf).

Wei, M., Patadia, S. and Kammen, D. (2010). "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy* 38:919-931.

WEF. (2010). *Green Investing 2010: Policy Mechanisms to Bridge the Public Financing Gap*, World Economic Forum (WEF).

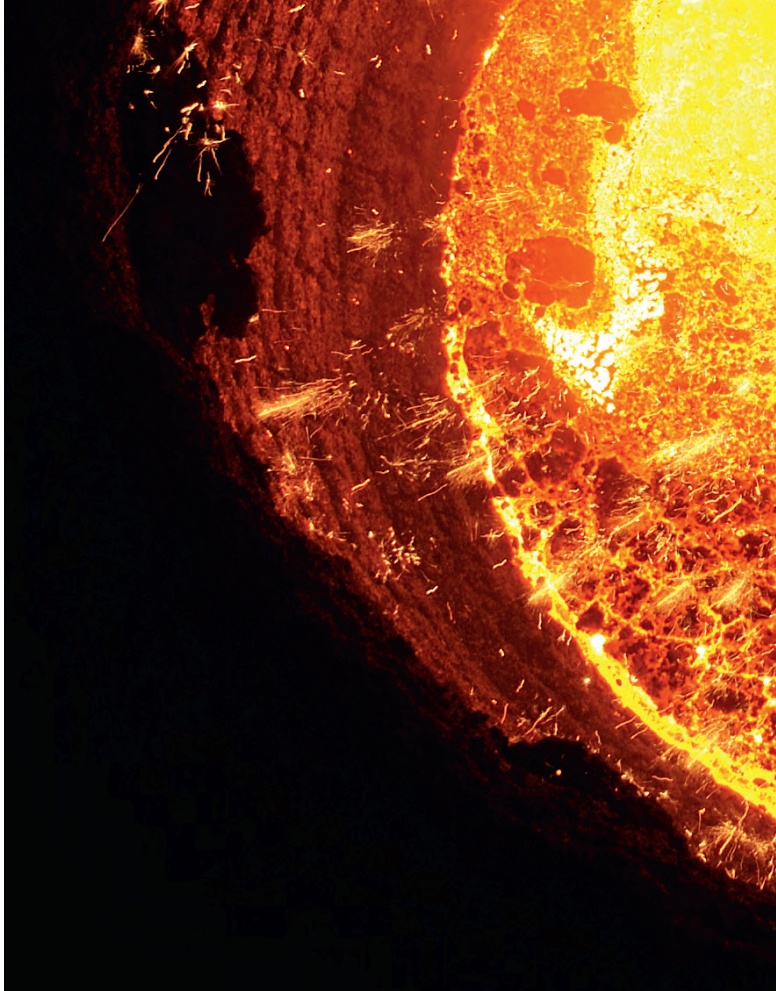
WHO. (2006). *Fuel for life: household energy and health*. World Health Organization, Geneva. Available at: <http://www.who.int/indoorair/publications/fuelforlife/>.

WHO. (2009). "The Poor man's fuel. The continued use of paraffin for domestic energy requirements in low income households" *Bulletin of the World Health Organization*; 87(9), doi: 10.1590/S0042-96862009000900014.

World Bank. (2009). "Africa's Development in a Changing Climate- Key policy advice from World Development Report 2010 and Making Development Climate Resilient: A World Bank Strategy for Sub-Saharan Africa". Available at: <http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1252586925350/Africa-WDR-2010-booklet.pdf>

WWEA. (2010). *World Wind Energy Report 2009*. World Wind Energy Association (WWEA), Bonn.



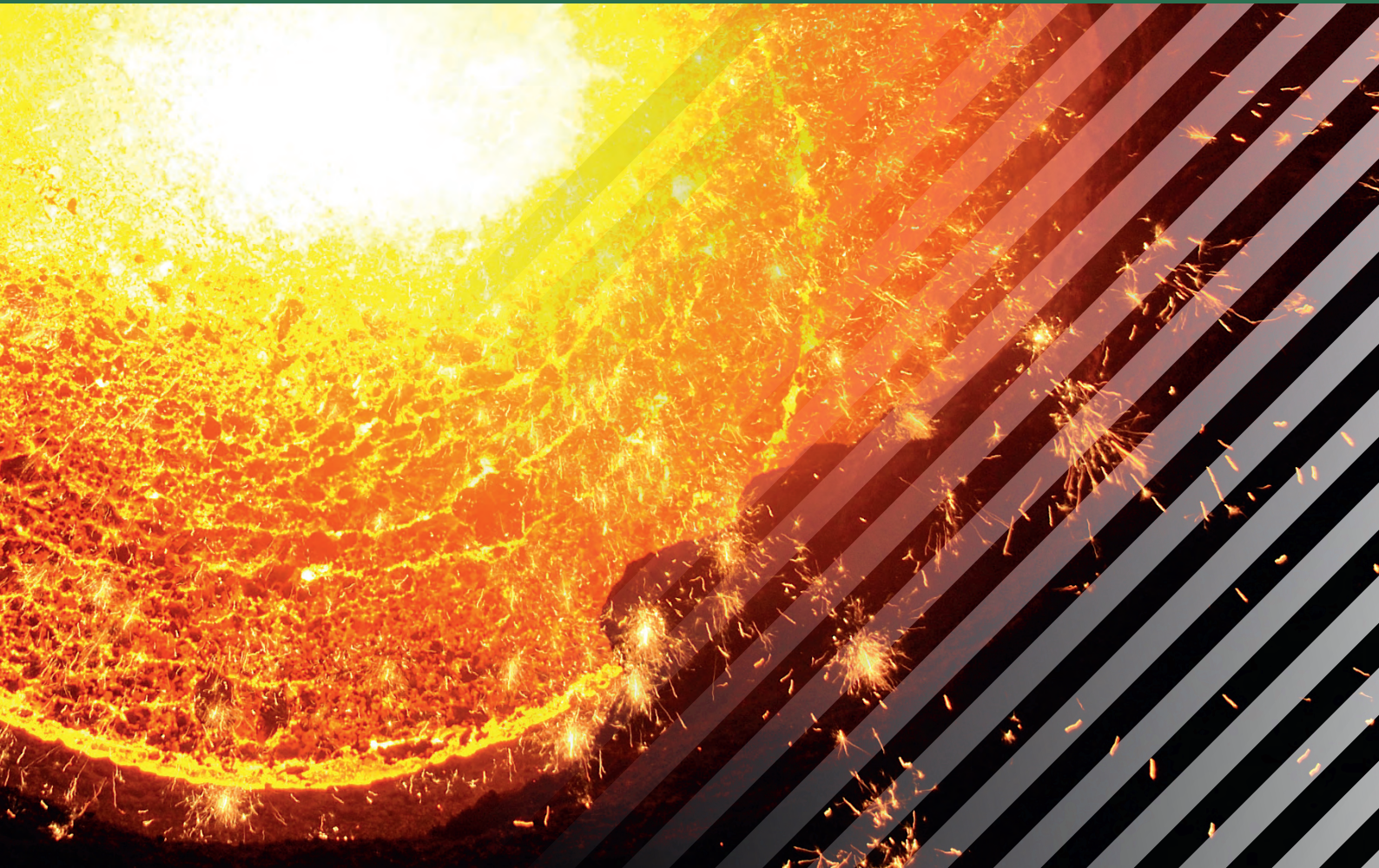






# Manufa**c**turing

Investing in energy and resource efficiency





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## List of acronyms

BAT	Best available technology
BAU	Business-as-usual
BPT	Best possible technology
BRIICS	Brazil, Russia, India, Indonesia, China and South Africa
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CHP	Combined heat and power
DMC	Domestic material consumption
EROIE	Energy return on investment in energy
ETFP	Ethical Trade Fact-finding Process
EU ETS	European Union Emissions Trading Scheme
EPR	Extended producer responsibility
FTE	Full-time equivalent
GHG	Greenhouse gas
GDP	Gross Domestic Product
HPV	High production volume
IWRM	Integrated water resource management
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
ISEAL	International Social and Environmental Accreditation and Labelling Alliance
ISIC	International Standard Industrial Classification of All Economic Activities
LCD	Liquid Crystal Display
LDCs	Least Developed Countries
OHS	Occupational Health and Safety
OECD	Organisation for Economic Co-operation and Development
ROI	Return on investment
REACH	Registration, Evaluation and Authorization of Chemicals
RoHS	Restriction of Hazardous Substances
SME	Small and medium-sized enterprise
WEEE	Waste Electrical and Electronic Equipment
WBCSD	World Business Council for Sustainable Development

# Key messages

**1. As currently configured, manufacturing has a large material impact on economy, environment and human health.** Manufacturing is responsible for around 35 per cent of global electricity use, over 20 per cent of CO<sub>2</sub> emissions and over a quarter of primary resource extraction. Along with extractive industries and construction, manufacturing currently accounts for 23 per cent of global employment. It also accounts for up to 17 per cent of air pollution-related health damage. Estimates of gross air pollution damage range from 1 to 5 per cent of global Gross Domestic Product (GDP).

**2. Key resource scarcities – including easily recoverable oil reserves, metal ores and water – will challenge the sector.** As industries resort to lower-grade ores, more energy is required to extract useful metal content. Improved recovery and recycling will increasingly become a decisive factor for both economic performance and environmental sustainability. The same applies to water use by industry, which is expected to grow to over 20 per cent of global total demand by 2030.

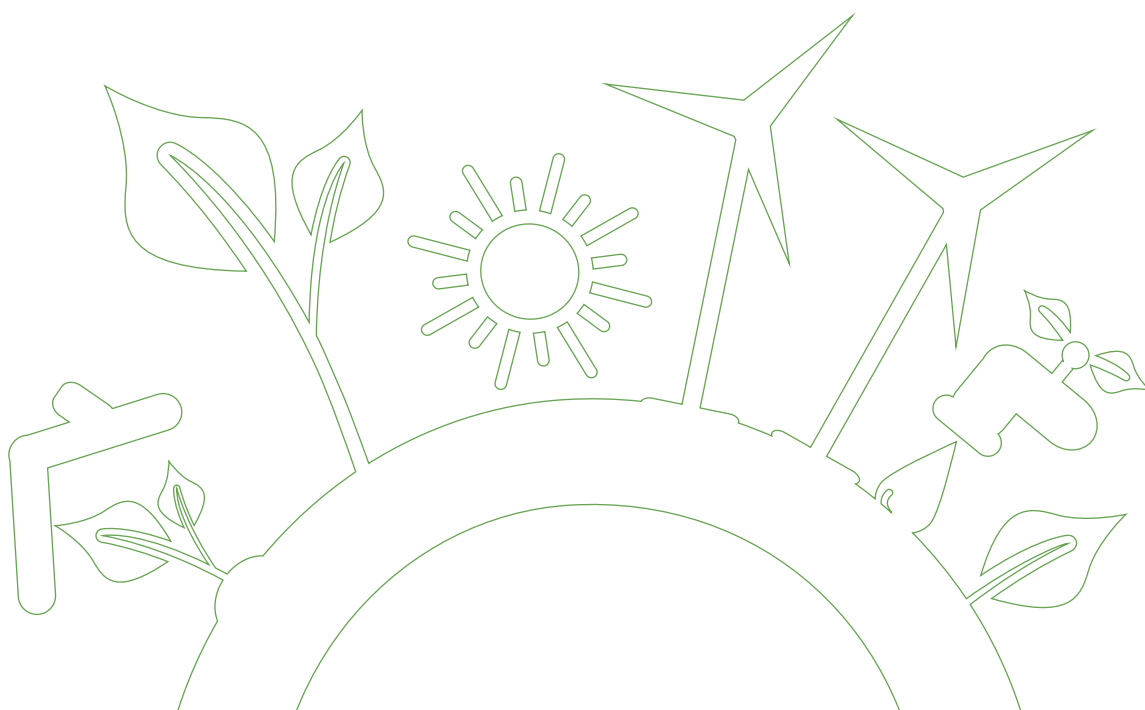
**3. Win-win opportunities exist, if manufacturing industries pursue life-cycle approaches and introduce resource efficiency and productivity improvements.** This requires supply and demand-side approaches, ranging from the re-design of products and systems to cleaner technologies and closed-cycle manufacturing. If the life of all manufactured products were to be extended by 10 per cent, for example, the volume of resources extracted could be cut by a similar amount. The costs of end-of-pipe pollution control can be reduced by cleaner production approaches in management, cleaner raw material selection, and cleaner technologies that reduce emissions and integrate by-products into the production value chain. With the use of alternative production equipment, processes and inputs, returns on investment can be substantial and with relatively short payback periods.

**4. Key components of a supply-side strategy include remanufacturing – for example of vehicle components – and the recycling of heat waste through combined heat and power installations.** Closed-cycle manufacturing extends the life-span of manufactured goods, making revamped goods available for re-use, and reduces the need for virgin materials. Repair, reconditioning, remanufacturing and recycling are fairly labour-intensive activities, requiring relatively little capital investment. Remanufacturing operations worldwide already save about 10.7 million barrels of oil each year, or an amount of electricity equal to that generated by five nuclear power plants.

**5. While direct job effects of greening manufacturing may be neutral or small, the indirect effects are significantly higher.** Manufacturing has become increasingly automated and efficient, which has been accompanied by job losses. This can be countered by life-cycle approaches and secondary production, for example, in the form of recycling, to secure jobs, for which safe and decent working conditions are of paramount importance.

**6. Green-investment-scenariomodelling for manufacturing suggests considerable improvements in energy efficiency can be achieved.** By 2050, projections indicate that industry can practically “decouple” energy use from economic growth, particularly in the most energy-intensive industries. Green investment will also increase employment in the sector. Tracking progress will require governments to collect improved data on industrial resource efficiency.

**7. Innovation needs to be accompanied by regulatory reform, new policies and economic instruments in order to enable energy and broader resource-efficiency improvements.** Environment-related levies, including carbon taxes, will be required to ensure producers include the cost of externalities in their pricing calculations. Mindful that manufacturing is not a uniform industry, governments need to consider approaches that meet the realities of specific industries and their value chains that often stretch across national economies. Governments are also challenged to find mixes of policies and regulatory mechanisms that best suit national circumstances. Developing countries have a strong potential to leapfrog inefficient technologies by adopting cleaner production programmes, particularly those that provide support to smaller companies, many of which serve global value chains. Of special importance to manufacturing is the introduction of recognised standards and labels, backed by reliable methodologies.



# 1 Introduction

Manufactured products are a key component of human consumption, whether as finished or semi-finished goods. Manufacturing processes are a key stage in the life-cycle of material use, which begins with natural resource extraction and ends with final disposal. Basic industries such as cement, aluminum, chemical and steel supply the semi-finished, or intermediate goods, used to build houses, cars, and other appliances used in daily life. Other industrial sectors produce finished goods such as clothing, leather, fine chemicals, electrical and electronic products.

In *Our Common Future* (1987), the Brundtland Commission foresaw industrial operations that are more efficient in resource use, generate less pollution and waste, are based on the use of renewable resources, and that minimise irreversible impacts on human health and the environment. This vision became the drive for concepts such as Cleaner Production promoted by UNEP and others since the 1980s. It remains a challenge for manufacturing industries world-wide, highlighting a need for more fundamental change in which the purpose of products and side-effects of manufacturing become a source of inspiration for re-design and beneficial output (Braungart and McDonough 2008).

In order to implement a strategy of sustainable use of natural resources based on integrated resource management and resource efficiency, policy interventions supplemented by voluntary initiatives are needed at each stage of the life-cycle of production and use. The balance between upstream and downstream interventions is up for policy debate. Upstream policy interventions, for example, at the stage of mineral extraction or forest harvesting, to minimise adverse environmental impacts or to charge users appropriately for depletion or appropriation of resource rents, would have the effect of raising input prices to manufacturing companies.

Policy interventions targeted at manufacturing companies with the aim of reducing pollution to air and water, safeguarding health from exposure to toxic chemicals, and emitting greenhouse gases can also have the effect of increasing the cost of using resource inputs. These, together with other measures, can be powerful drivers in encouraging manufacturing industries to become more efficient in their use of natural resources and energy. Measures intended to improve the performance of markets for secondary raw materials and to encourage recycling can help to improve the performance of manufacturing companies in reducing their use of virgin raw materials. These are all building

blocks for moving us closer to the vision described in *Our Common Future*.

## 1.1 Structure of the chapter

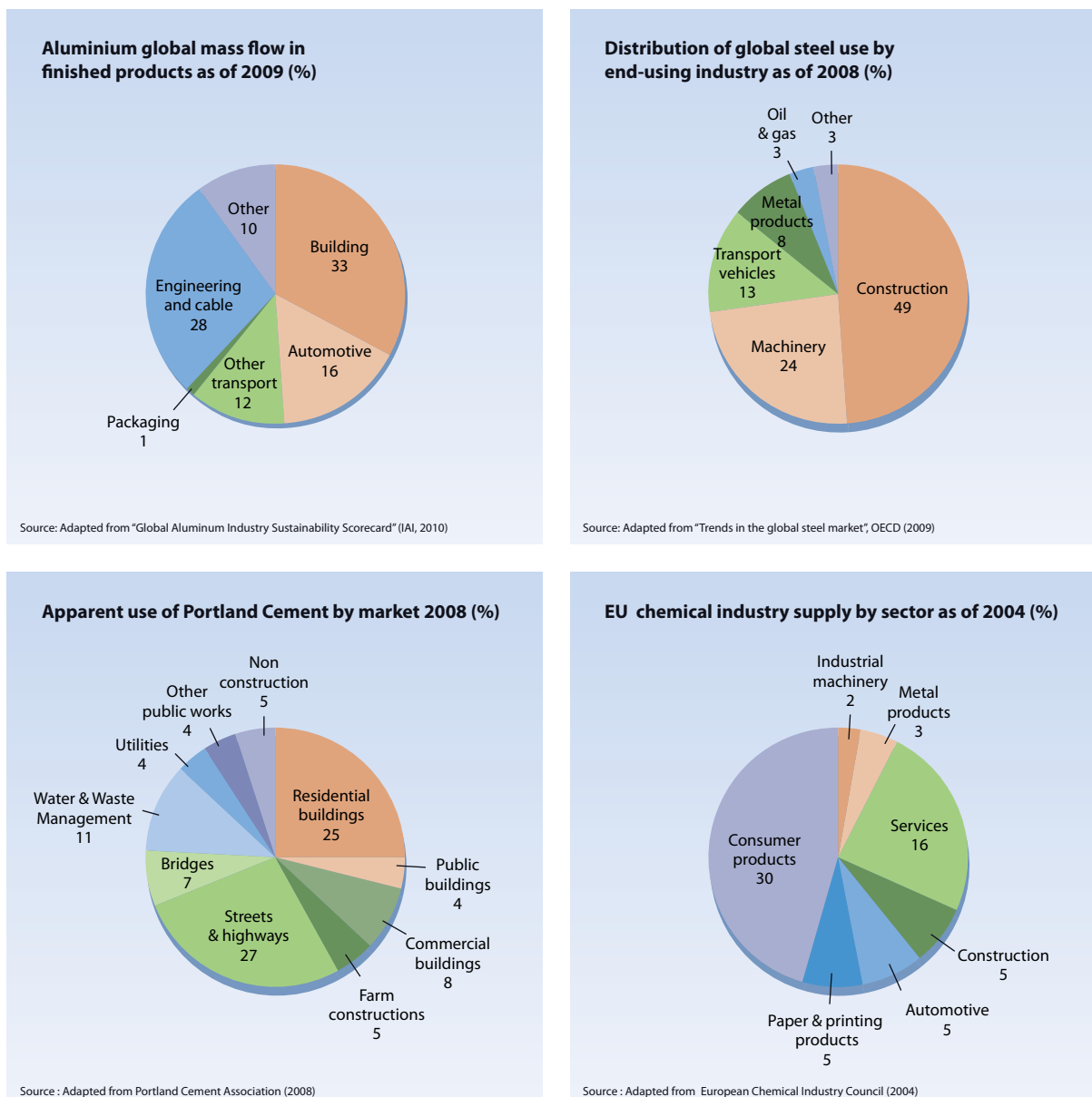
The chapter starts with a brief sketch of global manufacturing and its importance to developing economies. It then explains the choices of manufacturing branches, which are the main focus of the chapter, the environmental pressures associated with them, recent trends in decoupling economic growth from those pressures and a definition of green manufacturing.

*Section 2* describes the costs of failure to implement a strategy of greening manufacture. These relate to excessively rapid depletion of natural resources, which could adversely affect future economic growth, the negative externalities of industrial air pollution and the use of hazardous substances.

*Section 3* outlines a number of strategic approaches to encourage green manufacturing that involve investment in innovation, cleaner energy technologies, resource efficiency and a transition to green jobs. This includes a *supply-side strategy* involving the redesign of processes and technologies employed in the major materials-intensive subsectors of the manufacturing sector, including *closed-cycle* manufacturing where feasible. It also includes a *demand-side strategy* to change the composition of demand, both from within industry and from end-users.

*Section 4* argues that there are many opportunities for investments that can lower costs by using less material, energy and water. At the micro-level this can translate into an increase in profitability, if the rate of return on such investment is greater than that of an alternative investment. The section provides numerous examples of green investments highlighting, in particular, their impacts on energy savings and CO<sub>2</sub> emissions reductions, water savings and employment creation. However, the process of transition may be slowed by the problem of lock-in, owing to the capital-intensive nature of many manufacturing processes and long plant lives.

*Section 5* presents the results of model-based quantitative analysis done for this study that shows how investing to improve resource efficiency in manufacturing can often be profitable to business and increase employment while reducing environmental pressure. At the macro-level it can mean greater Gross Domestic Product (GDP) and a higher level of environmental services.



**Figure 1: Primary production supplies and their end products**

Section 6 discusses the enabling conditions for a green transformation in manufacturing. The various types of policy measures are discussed in some detail. These include regulatory and control mechanisms, economic or market-based instruments; fiscal instruments and incentives; voluntary action, information and capacity building.

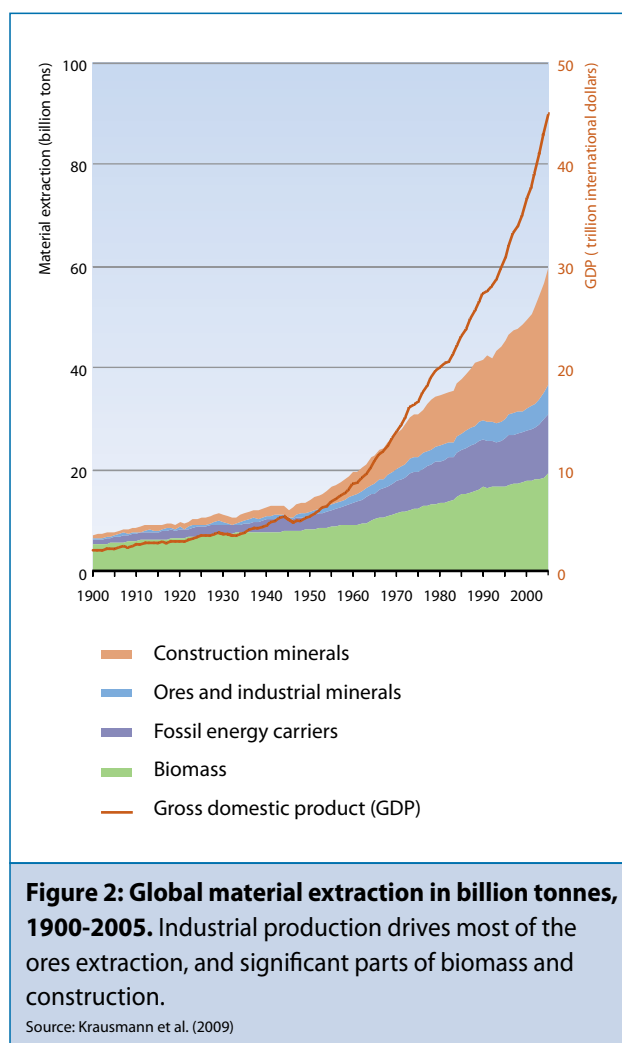
## 1.2 Manufacturing in the global economy

During the 20th century, the growth of manufacturing was phenomenal. World steel production, for example, rose by a factor of six between 1950 and 2000 to over 1.2 billion metric tonnes (World Steel Association, 2009).

Aluminum production doubled between 1980 and 2005 (USGS 2009). The growth of industrial production has also been accompanied by increasing pressure on the environment. Industry is responsible for over a third of global electricity use and over a fifth of CO<sub>2</sub> emissions (WRI 2007; IEA 2008).

Manufacturing has been a major driver of overall economic growth in developing countries since 1995. During this period, developing countries' GDP nearly doubled. In 2009, Manufacturing Value Added (MVA) grew by 2.5 per cent while in some major industrial countries it dropped by more than 10 per cent (UNIDO 2010). Following the start of the global financial crisis in 2008, a collapse in industrial production in 2009 was drastic in many countries dependent on manufacturing





exports. In a front-page article entitled “The collapse of manufacturing”, *The Economist* (2009), noted the challenges governments face in dealing with the varied and constantly changing difficulties in the world’s manufacturing industries. Governments are often slow to design and amend manufacturing programmes.

If anything, the recent financial crisis highlighted a broader shift in the location of centres of manufacturing that supply global value chains. The contribution of manufacturing to developing world GDP increased to almost 22 per cent by 2009, compared with 18 per cent in 1990 (UNIDO 2010). Broadly defined, industry (excluding agriculture and services, but including manufacturing, extractive industries and construction) accounted for about 23 per cent of global employment, representing over 660 million jobs in 2009, and grown by more than 130 million since 1999 (ILO 2011). In manufacturing, the chemical, iron and steel, and paper and pulp industries generate the highest revenues. However, in terms of employment, the textile sector (highly important for Lesser Developed Countries (LDC) and developing countries) and the basic metals sector (highly important for transition and developed countries) are leading, each accounting for 20-25 per cent of global employment in manufacturing (ILO 2010).

### 1.3 Scope and definition

This chapter focuses on those manufacturing sub-sectors that are energy-intensive or heavy users of natural resources. It excludes power generation as well as food and refined petroleum products, which are dealt with in the chapters on agriculture and energy. The following manufacturing sub-sectors are given special attention in this chapter:<sup>1</sup>

- Iron and steel (ISIC 241)
- Cement (ISIC 239)
- Chemicals and chemical products (ISIC 20)
- Pulp and paper (ISIC 17)
- Aluminum (ISIC 242)
- Textile and leather (ISIC 13 + 15)
- Electrical and electronic products (ISIC 26 + 27)

Throughout the analysis in the above subsectors, it should be noted that manufacturing is not a uniform sector and that geographic dispersion in its value chains is part of the complexity that the industry faces. Figure 1 illustrates where the products of some of the above-listed manufacturing industries go. The breakdown signals end products such as buildings, vehicles and consumer products that end-users are familiar with from their daily lives. It signals resource intensive consumption clusters related to housing and transport (cf the buildings and transport chapters). This is a reminder of insights from following a value-chain approach, considering green innovations upstream and downstream. Some would say the point of departure for green intervention needs to be design, since most of the business cost of production is determined during the initial design stage. A range of options, upstream and downstream, will be considered in this chapter.

In terms of CO<sub>2</sub> emissions, the branches of manufacturing covered in this chapter account for 22 per cent of global emissions. Emissions from the iron and steel, cement and chemical industries account for most of them, while industries such as textiles and leather can generate significant negative externalities if their effluents are not handled properly. The electrical and electronic goods

1. The *International Standard Industrial Classification of All Economic Activities* (ISIC), Revision 4 (United Nations 2008) divides manufacturing into 24 divisions, which are in turn divided into numerous groups and classes. The activities discussed in this chapter include those found in all or parts of eight of the ISIC divisions. Among the manufacturing industries not discussed explicitly in this chapter are glass, ceramics, wood products and machinery. This chapter needs to be read in conjunction with the Energy, Buildings, Forests, Waste and Water chapters of the Green Economy Report.

industries have a crucial role in the global economy, with 18 million jobs (ILO 2007), and account for most of the growth in manufacturing at present. They too have harmful environmental impacts if hazardous chemicals and metals in production and final disposal are not carefully managed.

Historically, GDP has grown more rapidly than material, energy and labour inputs required to produce it. This has been owing to a combination of structural change, as service consumption sectors have grown faster than material consumption, technical change, which, has reduced material and labour inputs (e.g. automation) per unit of production, and more stringent environmental policies, which have driven up the cost of using some pollution-intensive inputs. This resulted, among others, in *relative* decoupling of resource input from output and *absolute* decoupling of some of the associated environmental pressures. Yet resource- efficiency gains

have been offset by economic and population growth: overall emissions, energy use and material use continued to grow despite lower emissions, energy and material use per unit output (Figure 2). Without *absolute* decoupling, continuous economic growth implies continuously higher energy and resource demands, to levels that put the health of our natural resource base at risk.

The greening of manufacturing is essential to any effort to decouple environmental pressure from economic growth. Green manufacturing differs from conventional manufacturing in that it aims to reduce the amount of natural resources needed to produce finished goods through more energy- and materials-efficient manufacturing processes that also reduce the negative externalities associated with waste and pollution. This includes more efficient transport and logistics, which can also account for a significant percentage of the total environmental impact of manufactured products.

## 2 Challenges – the risks and costs of inaction

The new economic reality for manufacturing industries today include key structural changes such as the globalisation of production with transnational supply and demand, strong economic growth in Asia (notably China) and an increase of raw material prices. The following analysis focuses on the challenges of natural resource scarcity, the external costs of air pollution, as well as risks associated with hazardous substances and waste.

### 2.1 Natural resource scarcity

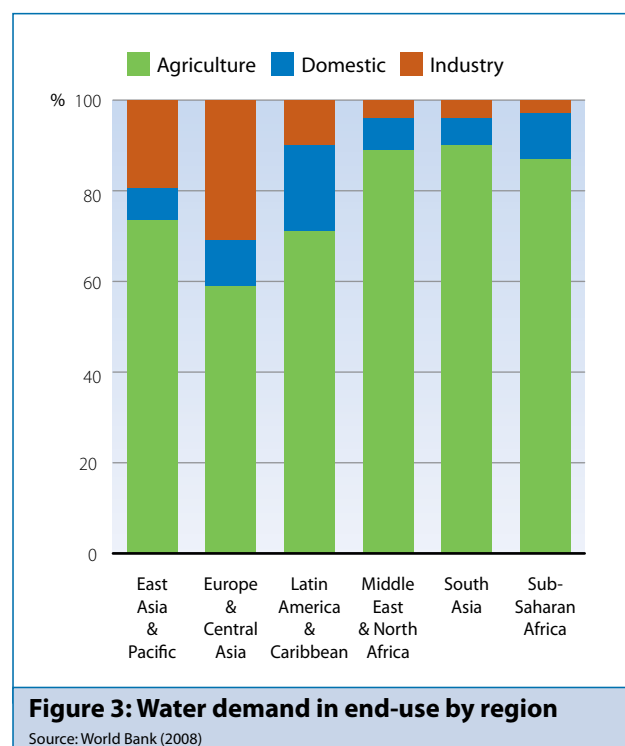
Resource scarcity is an increasing threat to future economic growth and a real challenge to the manufacturing industries, especially scarcity of fresh water, oil and gas, and some metals. Secure resource provision needs to be supported by healthy ecosystems, the vitality of which depends on biodiversity. The TEEB for business report (TEEB 2012) highlights what is called the “impacts and dependencies” of the manufacturing industry on biodiversity and ecosystem services, reflecting the footprint of facilities and the pollution arising from production processes, as well as the role of suppliers of raw materials or semi-finished goods. These linkages are often complex and sector- specific. In the case of direct impact and dependency on biodiversity,

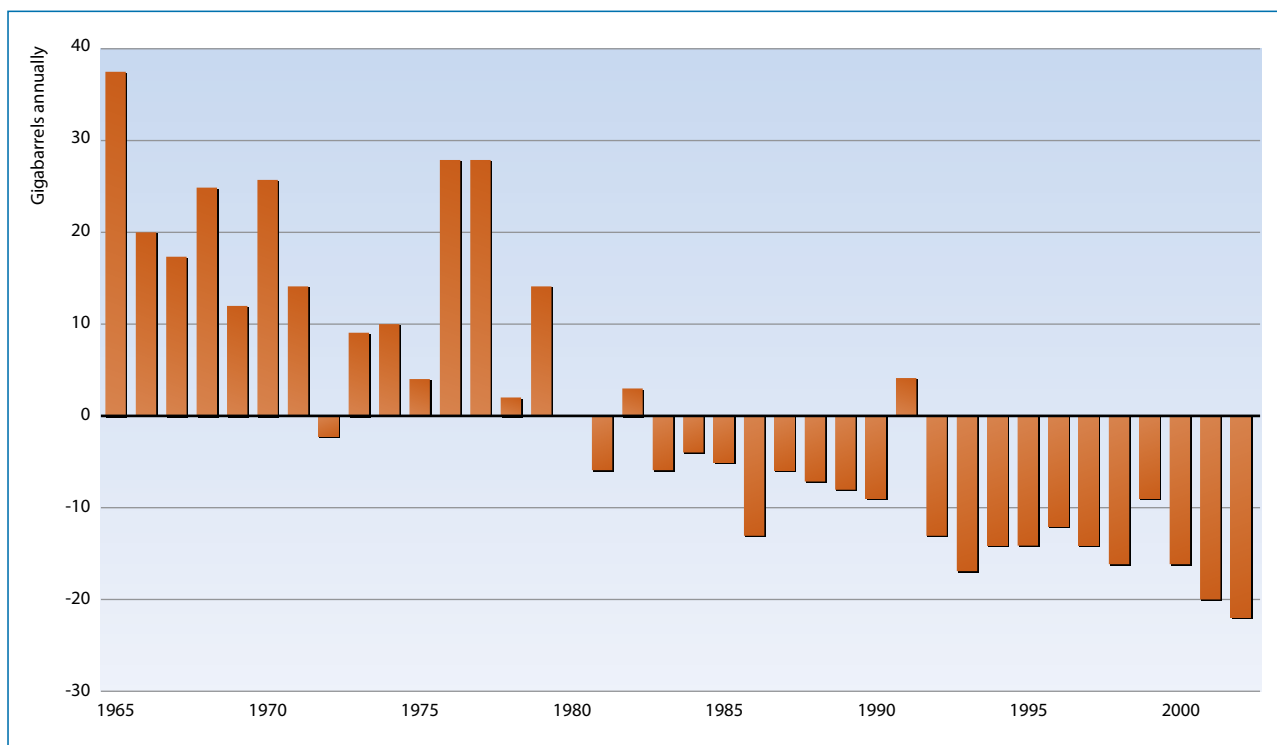
the industries most implied include the pulp and paper industry as well as the textile and leather industry. If one considers high dependence on specific ecosystem services, this points to a wider range of industries. What they face is dependencies that pose risks associated with operations, markets, finance, regulations and reputation. A clear operational risk is that of increased scarcity and cost of natural resources.

**Land use** is mainly a problem related to agriculture and food production, rather than industrial production (UNEP 2010a). The exception may be the future production of biomass for energy and feedstock purposes in industry. But industry is likely to face a significant challenge with regard to water in some countries or regions although it is responsible for less than 10 per cent of water use globally. Agriculture dominates with 70 per cent, followed by the energy sector and domestic uses, each with 10 per cent (UNESCO 2009).

Owing to expected high growth of industrial production, **water use** by industry is expected to grow to over 20 per cent of global total demand by 2030 (Water Resources Group 2009). At the same time, by 2030 a potential water shortage of 40 per cent of expected demand, compared to maximum sustainable supply, is projected at the global level. The extent to which industry drives water demand is highly differentiated by region and river basin (World Bank 2008; Figure 3). The implications of this are that industries operating in regions of high water stress, and regions where industrial water demand is relatively important compared with other water demand, must improve their water productivity greatly or relocate to more water-abundant locations. This is particularly true for industries with high water use, such as the paper and pulp, textiles and leather and the steel industries.

Demand for water by industry (and for the electric power sector) increasingly competes with water demand by agriculture and urban consumers. In addition, all of this needs to be balanced with water demand by ecosystems and biodiversity. Water treatment is a necessary precondition for industrial (or consumer) water use. About half of industrial water use is for cooling purposes, and about a fifth of this water is lost as vapor, but much of the other four-fifths can be used downstream for other purposes (although the discharge of heated water can be harmful to aquatic ecosystems). The best way to reduce water loss for cooling large central power





**Figure 4: Discovery rate of oil trend, 1965-2002**

Source: Heinberg (2004)

facilities is to find productive uses for the heat. This strategy, called co-generation or combined heat and power (CHP), is applicable in urban areas, industrial parks and in buildings generally, but its widespread application requires a major change in the structure of the electric power grid. Other industrial water uses include quenching of hot coke or red hot steel ingots, wood pulping, washing, rinsing and dyeing of textiles, tanning of leather and surface finishing of metals (including electroplating). These uses leave polluted and sometimes toxic waste streams that need treatment (which uses even more water), and whose costs in many instances are not reflected in the cost of production.

Reserves of easily recoverable oil are diminishing, stimulating technological innovation to extract oil from deep ocean underwater reservoirs and non-conventional sources, such as oil and tar sands, and natural gas from shale, as a close substitute for many uses of petroleum. Since the early 1980s the amount of new oil discovered each year has been less than the amount extracted and used (Figure 4). The overall peak is only a question of time. However, market forces including high prices may reduce demand and increase the use of substitutes, causing demand to peak before supply. Some think peak oil may still be 20 years in the future. Others think it has happened already (Campbell and Laherrère 1998; Campbell 2004; Heinberg 2004; Strahan 2007).

The energy and other costs of replacing oil exploration and development are rising. The energy return on investments in energy (EROIE) of oil discovered in the

1930s and 1940s was about 110, but for the oil produced in the 1970s it has been estimated at 23, while for new oil discovered in that decade it was only 8 (Cleveland et al. 1984). Decades ago, only 1 per cent of the energy in oil discovered was needed to drill, refine and distribute it, but since then the EROIE has declined drastically. In the case of deep-water oil, the EROIE is not above 10. For Canadian tar sands the EROIE appears to be only about 3, which means that a quarter of all the useful energy extracted is needed for the extraction itself. These costs are reflected in the rising price of oil (and gas, which is a partial substitute) and are a sign of increasing oil scarcity.

High quality metal ores are also gradually being depleted (OECD 2008). While absolute scarcity is not yet perceived as an immediate problem for most metals, the indicators on the life expectancy of reserves (cf Tables 1 and 2) show that lower grade ores must be used. However, in order to do so more energy is needed to extract the useful metal content, adding marginally to GHG emissions. And whilst metals appear above ground in our economies in increasing quantities, a UNEP Resource Panel report on metals has shown the opportunity for much improved recycling rates (UNEP 2010a). Metals such as iron and steel, copper, aluminum, lead and tin enjoy recycling rates that vary between 25 and 75 per cent globally, with much lower rates in some developing economies. Improved recovery and recycling rates are also important for high-tech specialty metals that are needed in manufacturing to make key components for products that range from wind turbines and photovoltaic panels to the battery packs of hybrid

	WORLD			OECD			BRIICS*			RoW**		
	Rate of change			Rate of change			Rate of change			Rate of change		
	2002	1980–2002	2002–2020	2002	1980–2002	2002–2020	2002	1980–2002	2002–2020	2002	1980–2002	2002–2020
<b>Amounts extracted (billion tonnes)</b>												
Total	55.0	36%	48%	22.9	19%	19%	17.7	67%	74%	14.4	35%	63%
Metal ores	5.8	56%	92%	1.8	41%	70%	2.2	110%	100%	1.9	30%	104%
Fossil energy carriers <sup>a</sup>	10.6	30%	39%	4.1	12%	6%	3.7	58%	59%	2.9	31%	60%
Biomass <sup>b</sup>	15.6	28%	31%	4.5	11%	6%	5.9	49%	33%	5.2	25%	50%
Other minerals <sup>c</sup>	22.9	40%	54%	12.6	21%	21%	5.9	81%	115%	4.4	58%	63%
<b>Per capita (tonne/capita)</b>												
Total	8.8	-4%	22%	20.0	0%	8%	6.0	19%	51%	6.7	-16%	20%
Metal ores	0.9	11%	58%	1.5	19%	54%	0.7	51%	73%	0.9	-19%	51%
Fossil energy carriers <sup>a</sup>	1.7	-8%	14%	3.6	-6%	-4%	1.3	13%	38%	1.3	-18%	18%
Biomass <sup>b</sup>	2.5	-9%	8%	3.9	-6%	-4%	2.0	7%	15%	2.4	-22%	11%
Other minerals <sup>c</sup>	3.7	-1%	27%	11.0	2%	10%	2.0	30%	86%	2.0	-2%	21%
<b>Per unit of GDP (tonne/1,000 US\$<sup>d</sup>)</b>												
Total	1.6	-26%	-14%	0.8	-33%	-24%	4.6	-35%	-32%	4.5	-21%	-26%
Metal ores	0.2	-15%	11%	0.1	-20%	9%	0.6	-18%	-23%	0.6	-24%	-8%
Fossil energy carriers <sup>a</sup>	0.3	-29%	-19%	0.1	-37%	-32%	1.0	-38%	-38%	0.9	-24%	-28%
Biomass <sup>b</sup>	0.4	-30%	-24%	0.2	-37%	-32%	1.5	-42%	-48%	1.6	-27%	-32%
Other minerals <sup>c</sup>	0.6	-24%	-11%	0.4	-32%	-22%	1.5	-29%	-17%	1.4	-8%	-26%

Notes: a. Crude oil, coal, natural gas, peat. b. Harvest from agriculture and forestry, marine catches, grazing. c. Industrial minerals, construction minerals. d. Constant 1995 US\$. \* BRIICS = Brazil, Russia, India, Indonesia, China and South Africa. \*\* RoW = Rest of the World

**Table 1: Global resource extractions, by major groups of resources and regions**

Source: (OECD 2008)

Metal ores <sup>a</sup>	1999 reserves (tonnes)	1997–99 average annual primary production (tonnes)	Life expectancy in years <sup>b</sup> , at three growth rates in primary production <sup>b</sup>			Average annual growth in production 1975–99 (%)
			0%	2%	5%	
Aluminium	25 x 10 <sup>9</sup>	123.7 x 10 <sup>6</sup>	202	81	48	2.9
Copper	340 x 10 <sup>6</sup>	12.1 x 10 <sup>6</sup>	28	22	18	3.4
Iron	74 x 10 <sup>12</sup>	559.5 x 10 <sup>6</sup>	132	65	41	0.5
Lead	64 x 10 <sup>6</sup>	3,070.0 x 10 <sup>3</sup>	21	17	14	-0.5
Nickel	46 x 10 <sup>6</sup>	1,133.3 x 10 <sup>3</sup>	41	30	22	1.6
Silver	280 x 10 <sup>3</sup>	16.1 x 10 <sup>3</sup>	17	15	13	3
Tin	8 x 10 <sup>6</sup>	207.7 x 10 <sup>3</sup>	37	28	21	-0.5
Zinc	190 x 10 <sup>6</sup>	7,753.3 x 10 <sup>3</sup>	25	20	16	1.9

Notes: a. For metals other than aluminium, reserves are measured in terms of metal content. For aluminium, reserves are measured in terms of bauxite ore.

b. With current production and consumption patterns, technologies and known reserves.

c. Life expectancy figures were calculated before reserves and average production data were rounded. As a result, the life expectancies in years (columns 4, 5, 6) may deviate slightly from those derived from reserves and average production (columns 2 and 3).

**Table 2: Life expectancies of selected world reserves of metal ores**

Source: OECD (2008)

cars, fuel cells and energy-efficient lighting systems. (UNEP 2010a). With respect to the availability of critical metals, the EU published in 2010 a list of 14 critical metals

or groups of metals that are important to its economy, where supplies may be adversely affected by shortages or political tension (Graedel 2009).



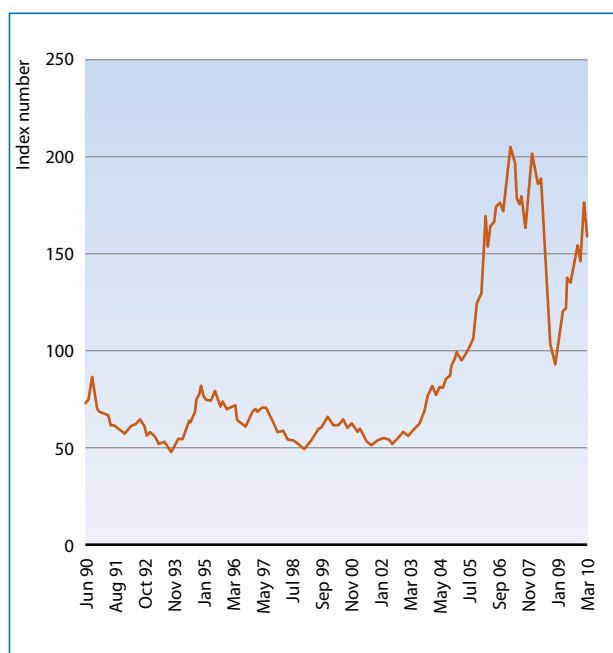
Against this background, resource-intensive sectors face a multitude of challenges. First, rapidly industrialising economies are building their infrastructure rapidly and requiring large amounts of resources. Competition over access to resources is likely to grow. Second, high quality metal ores are gradually being depleted. This leads to use of lower grade ores, which require much more energy to extract its useful metal component. Third, at local level resource extraction can have significant impacts on ecosystems and landscape. Mitigating these impacts through environmental policy or industry initiatives can also increase the cost of extraction. Fourth, there are risks of security of supply and price volatility.

Not all industrial production sectors are equally affected by these challenges, and not all materials are equally important in terms of economic or environmental impacts. This is illustrated by Figure 6 that combines information about physical material use in Europe with the life-cycle environmental impacts per kilogram of material (UNEP 2010b). Many minerals that dominate consumption by mass are of marginal importance for global warming, human toxicity, land use, or an integrated “Environmentally Weighted Material Consumption” index (van der Voet 2005). Indeed, environmental impacts are dominated by fossil fuels, their derivatives (such as plastics) and biotic materials (UNEP 2010b).

Resource scarcities – absolute or relative, actual or perceived – impact the prices of commodities and manufacturing inputs. Since the mid-2000s, commodity prices have shown an increasing volatility, which is mainly owing to a series of energy, financial and food crises. Economic recession, in turn, reduces demand for oil and can be followed by an equally drastic price decline that is further exaggerated by speculation. Thus, price volatility can seriously inhibit long-term green investment.

Since the early 2000s, other commodity prices, especially non-ferrous metals, have also been sensitive to short-term factors such as the boom in China coupled with recession in the US, depreciation of the US dollar (all commodities are priced in US\$) and speculative activity (Figure 5). In 2008, commodity prices exceeded previous records from the 1970s. Higher prices induce investment in alternatives, but excessive volatility tends to have the opposite effect, because it prevents rational planning.

It is important to differentiate between short and long-term impacts and trends. When prices for natural resources rise because long-term trends in demand begin to exceed long-term trends in supply, or when governments internalise some of the environmental costs of natural resource extraction or use to business, the response of market participants can facilitate the



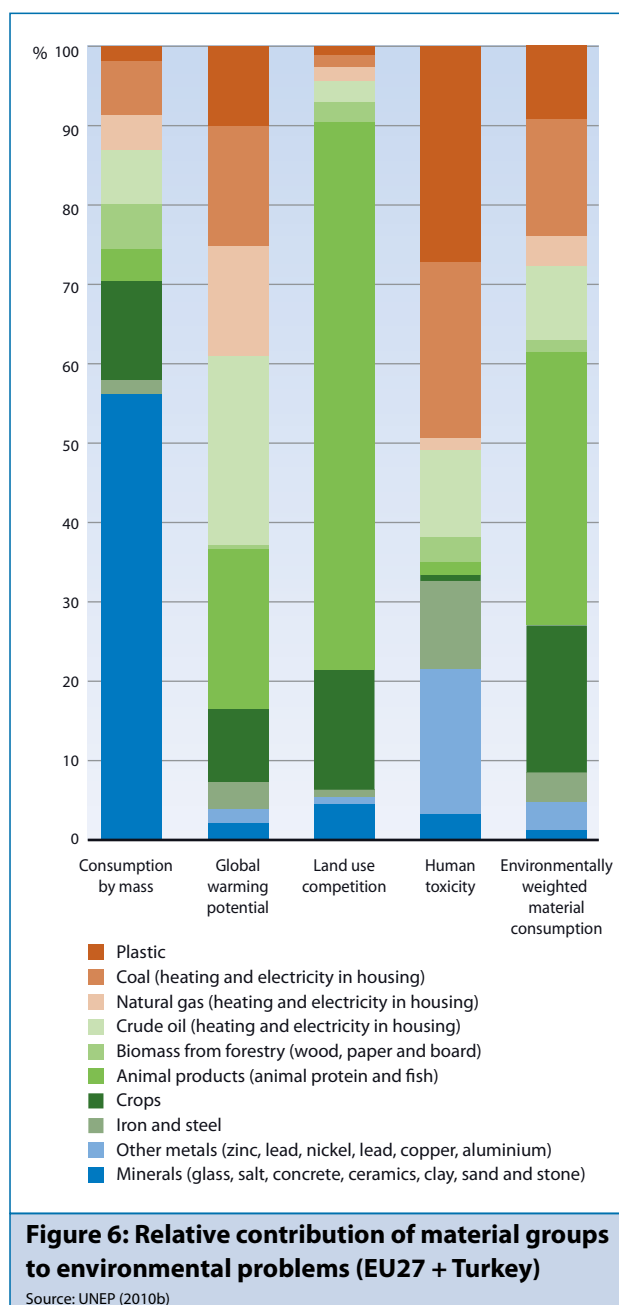
**Figure 5: Commodity metals price index, June 1990–May 2010 (2005 = 100), includes copper, aluminum, iron ore, tin, nickel, zinc, lead, and uranium price indices**

Source: Index Mundi (2010)

adjustment process. Manufacturers are more likely to adopt innovative technologies that can improve resource efficiency. To the extent that this is not fully sufficient to absorb the increase in costs, the selling price of their products will increase, providing an incentive for consumers to search for less costly substitutes in the market place. Meanwhile, exploration and development of additional resources will occur, and markets will reach a new equilibrium at a higher price that stimulates innovation.

## 2.2 The external costs of industrial air pollution

Most manufacturing processes cause, to varying degrees, air, water and soil pollution – costs to society and the environment that need to be accounted, or internalised, and reduced. In this section, the focus is on air pollution. Besides GHG emissions, industrial facilities release pollutants such as particulate matter, sulphur dioxide, nitrogen dioxide, lead, and chemicals that react to form ground-level ozone. These hazardous air pollutants can cause health and safety problems that are well known and degrade ecosystems. Some studies have sought to quantify the health and other costs of air pollution. For instance, the cost of air pollution in China, which was estimated in 2005 at 3.8 per cent of GDP, was found to be mainly driven by increasing industrialisation, which depends on coal-fired power plants and is led by an increasing urban population (World Bank 2007; Wan You and Qi 2005). Chinese coal on average contains 27 per cent ash and up to 5 per cent sulphur.



In the USA, damage from air pollution, mostly (95 per cent) in the form of health costs, is estimated to amount to between 0.7 per cent and 2.8 per cent of GDP. This estimate depends on assumptions about the value of life, as a function of age, and the relationship between exposure and mortality (Mendelsohn and Muller 2007). The USA data, taken from 10,000 locations, are consistent with European data. In Europe, the greatest contributors to emissions of particulate matter in 2000 were from the energy and electric power sectors (30 per cent), road transport (22 per cent), manufacturing (17 per cent) and agriculture (12 per cent) (Krzyzanowski et al. 2005).

The cost estimates presented in Table 3 are based on human health effects, including premature mortality, chronic illness, such as bronchitis and asthma, and several acute illnesses. Muller and Mendelsohn (2007) also measure the damages from reduced crop and timber

Country	Year	GDP (per cent)
China	2008	1.16-3.8
European Union	2005	2
Ukraine	2006	4
Russia	2002	2-5
USA	2002	0.7-2.8

**Table 3: Cost of air pollution from sulphur dioxide, nitrogen dioxide, and volatile organic compounds as a percentage of GDP**  
Source: Adapted from World Bank (2008); Markandya and Tamborra (2005); Strukova et al. (2006); Bobylev et al. (2002); Mendelsohn and Muller (2007).

yields, impaired visibility, deterioration of man-made materials, and diminished recreation services, although the health-related damages constitute 95 per cent of the total (not counting GHGs). Another 2009 assessment, by the U.S. National Research Council (2009), found that burning fossil fuels costs the USA about US\$ 120 billion a year in health costs, mostly because of thousands of premature deaths from air pollution.

The International Energy Agency (IEA) and the International Institute for Applied Systems Analysis (IIASA) have estimated the cost of control policies for air pollution caused by the combustion of fossil fuels to be US\$ 190 billion in 2005, some of it paid and some unpaid. This cost is projected to increase in a BAU scenario by a factor of three by 2030, owing to higher activity levels and increasingly stringent controls (IEA, IIASA 2009). However, the avoided costs to health and the environment are much greater, resulting in a highly favourable balance of benefits and costs. In addition, the costs of end-of-pipe pollution controls can be reduced by cleaner production approaches in management, cleaner raw material selection and cleaner technologies that reduce emissions and integrate by-products into a production value chain.

Air pollution and climate change are linked in several ways, and they could be beneficially addressed by integrated policy (Raes 2006). The analysis, using (IIASA) GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model, reveals that significant co-benefits on local air quality can be expected from reduced Greenhouse Gas Emissions (GHG) emissions and that climate change mitigation measures would cut SO<sub>2</sub>, NO<sub>x</sub> and particulate matter emissions at no extra cost and reduce local negative health impacts from fine particulate matter accordingly (IIASA 2009).

## 2.3 Hazardous substances and waste

Other significant environmental externalities at a global scale include impacts associated with hazardous

Location	Date	Cost (US\$)	Number of fatalities and injured
<b>Chemical industry</b>			
Bhopal, India	03/12/1984	US\$ 320 million in claims & compensation; US\$ 10 million in economic, medical, social, environmental rehabilitation. However, the Indian government estimated the cost of the Bhopal disaster at US\$ 3.3 billion.	2,800 fatalities and estimated 170,000 long-term adverse health effects
Toulouse, France	21/09/2001	€ 2 billion (environmental and social cost)	31 fatalities and 4,500 injured
<b>Oil &amp; Gas industry</b>			
North Sea	06/07/1988	US\$ 3.4 billion (mostly clean-up cost)	167 fatalities
Gulf of Mexico	20/04/2010	US\$ 6.1 billion (as of 09/08/2010), (containment, relief, grants to the US Gulf states, claims paid, and federal costs); creation of a US\$ 20 billion escrow account for clean-up and other obligations.	11 fatalities (oil platform workers)
<b>Table 4: Examples of major industrial accidents and related economic and social costs</b> <small>Source: Adapted from Mannan (2009), Grande Paroisse - AZF (2010), Kuriechan (2005) and BP (2010).</small>			

substances and waste. The waste sector produces pressure on the environment through releases from landfills, domestic and commercial waste-water treatment and industrial wastewater. According to Havranek (2009), the waste management sector in the EU in 2005 generated external costs of € 2.7 billion (assuming a low figure of € 21 per tonne of CO<sub>2</sub>eq emissions). A large component of this was owing to emissions of methane. For comparison, in the same year, the chemical industry in EU27 produced € 3.6 billion of external costs attributed to GHG emissions, which is a similar order of magnitude.

Releases of toxic substances cause health and safety problems and ecosystem degradation. Some countries have made significant progress by applying cleaner production, product substitution and end-of-pipe measures. In developed countries, toxic emissions have been one of the few success stories, with releases and exposure diminishing while production and GDP grew. This is related to the fact that most toxic substances are emitted as small mass flows, and for which substitution or emission reducing measures are relatively easy to achieve. Production patterns have changed radically, with industries based in developed countries focusing on high-value chemicals and pharmaceuticals. The manufacture of high production volume (HPV) chemicals, on the other hand, has been progressively migrating to developing countries, where regulatory frameworks are often lacking and where costs for the sound management of industrial (hazardous) waste are rarely internalised.

In the absence of good waste management, the following industries in particular may face toxicity challenges:

- Textile industry and leather industry in relation to dyeing and tanning products;
- Paper and pulp industry in relation to bleaching processes and related water emissions;

■ Chemical and plastics industry, depending on the type of chemicals produced; and

■ High-temperature processes such as in the cement and steel industry, where the formation of by-products or emissions of metals can be a problem.

Data provided by the International Council of Chemical Associations indicate that worldwide chemical sales in 2007 were € 1.8 trillion, a 28 per cent increase from 2000 (Perenius 2009). Over 60 per cent of these sales originated in Organisation for Economic Co-operation and Development (OECD) countries (€ 1.1 trillion). The BRIICS (Brazil, Russia, India, Indonesia, China, and South Africa) countries account for another 20 per cent of these sales (€ 400 billion in 2007). Of the hundreds of thousands of chemicals on the market, only a small fraction has been thoroughly evaluated to determine their effects on human health and the environment. Some chemicals that have been used in large quantities for many years are now suspected of carcinogenicity or teratogenicity. Some of the most toxic and dangerous chemical products (such as DDT) have been phased out, at least in the OECD countries. Adverse human health effects of chemicals include acute and chronic poisonings, neurodevelopmental disorders, reproductive/developmental disorders and cancer (WHO 2004). Preventing chemical pollution at the source avoids generating harmful wastes and emissions while reducing and eliminating costs of cleanup.

Gaps in applying standards for industrial safety and accidents give historical examples of the risks and societal costs that can be associated with industrial production, in particular where hazardous substances are involved. International Labour Organisation (ILO) global figures for 2003 indicated that there were about 358,000 fatal and 337 million non-fatal occupational accidents in the world; an additional 1.95 million died from work-related diseases. The number of deaths

caused by hazardous chemicals alone was estimated at 651,000. When taking into account compensation, lost working time, interruption of production, training and retraining, medical expenses, social assistance etc., these losses are estimated annually at 5 per cent of the global gross national product. Latest ILO estimates indicate that the global number of work-related fatal and non-fatal accidents and diseases does not seem to have changed significantly in the past ten years. One complication in manufacturing and ship-building is the distribution of occupational safety and health (OSH) obligations in the principal contractor–subcontractor relationship (ILO 2009).

The cost of industrial accidents represents a great source of public and private expenditure and social distress. Over the past three decades, a rough cost assessment of only a few of the major industrial accidents worldwide shows that a minimum of US\$ 40 billion have been spent on addressing the damages. If smaller incidents are taken into account, the real economic cost is likely to double, while deaths and injuries would be on the scale of several hundreds of thousands. Some major incidents are listed in Table 4. Clearly, there are global benefits in human and environmental health associated with cleaner and safer industrial production, which has to be part of a transition to green manufacturing.

### 3 Opportunities – Strategic options for the manufacturing sector

In its *Vision 2050* report, the World Business Council on Sustainable Development (WBCSD) (2010) describes a world in which the manufacturing industries follow life-cycle approaches that enable dematerialisation and expanded service systems. In a sustainable world of about 9 billion people by 2050, a complete range of new products and services is offered, based on high longevity, low embodied water, as well as low-energy and material content. This transition will not happen overnight, and it will require substantial investment. A major challenge is one of transition in industrial production, to become less carbon and material intensive while at the same time preserving jobs or reinvesting in completely new employment opportunities. This is particularly relevant for developing and emerging economies that currently invest heavily in conventional production infrastructure. Both at the country and industry sector level, improved resource-efficiency and decoupling offers the opportunity of competitive advantage and a sustainable future.

To what extent will green investments in efficiency have a more favorable payoff than conventional investments? Big companies normally set their hurdle Rate of Return on Investment (ROI) at around 25 per cent, pre-tax. There is overwhelming evidence of significant opportunities for efficiency investments that yield much higher rates of return, even under current economic conditions. The economic opportunities increase dramatically at higher carbon prices.

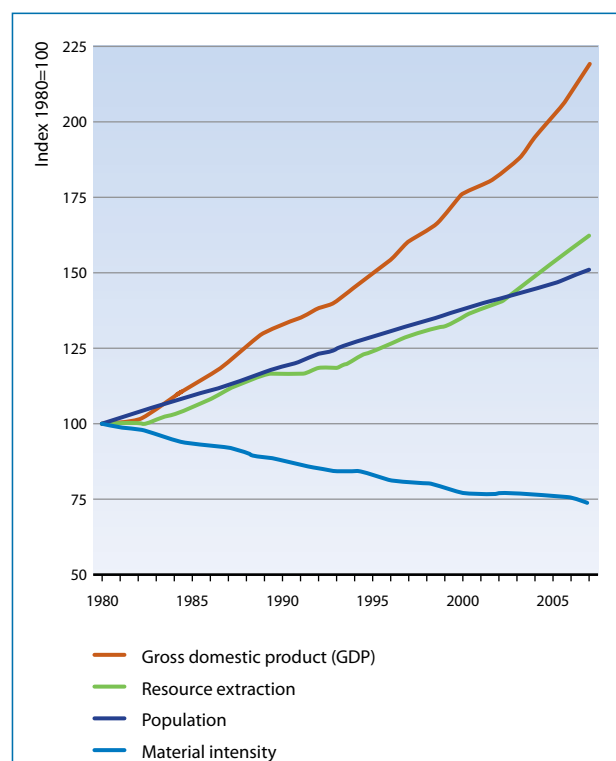
#### 3.1 Decoupling and competitive advantage

As indicated earlier, historical evidence shows that declining energy intensity in industry and relative decoupling have typically been offset by increases in energy demand associated with higher levels of GDP. In addition, there may have been additional demand for energy as an input owing to a decline in its relative price and to the increase in economic growth owing to the gain in resource efficiency itself; the two effects together are sometimes called the rebound effect. Overall emissions, energy use and material use have kept on growing despite lower emission, energy and material use per unit output as seen in Figure 7 (Krausmann et al. 2009). Resource extraction per capita has been stable or increasing only slightly. What economies world-wide need is absolute decoupling of the environmental

pressure associated with resource consumption from economic growth. This will be easier to achieve to the extent that resource use itself becomes more efficient.

In recent decades, OECD countries have decreased their extraction intensity per US\$ of GDP, reflecting some decoupling of primary resource extraction from economic growth. This trend is expected to continue. The main drivers are increased applications of more material-efficient technologies (technology effect), shifts from the primary and secondary sectors towards the service sector (structural effect), and associated increases in material-intensive imports (trade effect) owing to outsourcing of material-intensive production stages to other world regions (OECD 2008). For the world as a whole, of course, there is no trade effect because one country's imports are another country's exports.

The decoupling of material use from GDP growth has been less pronounced in fast-growing transition economies that need to build infrastructure, which requires more



**Figure 7: Global Relative Decoupling trends, 1980-2007**

Note: This figure illustrates global trends in resource extraction, GDP, population and material intensity in indexed form (1980 equals a value of 100).

Source: (SERI 2010)



resources (in mass terms) than in economies with low growth rates (Bleischwitz 2010). Similarly, the energy-intensive industrial sectors are not equally affected. The cement industry drives large material flows, but of relatively non-scarce resources such as limestone and clay. Iron ore and bauxite are not particularly scarce, and near substitutes are available. The paper and pulp and the natural fibre-based textile industry use renewable resources where the challenge is to avoid using them beyond the maximum sustainable yield. The challenges for the electrical and electronic industry may be more fundamental. High grade (>1per cent) and easy-to-refine copper ores are becoming scarcer and low-grade ores need more energy in the extraction and refining stages. Rarer metals such as silver, indium and tellurium are mostly extracted from other metallurgical wastes.

One of the major effects of the globalised nature of the world economy is the increasing shift of the manufacturing base from developed to developing and transition economies. This means that associated environmental damages from local pollution are also shifting. Accordingly, decoupling energy use and CO<sub>2</sub> emissions from GDP growth needs to be considered in the international context, rather than in terms of individual countries (see OECD 2008a). The relationship between Global Competitiveness Index ratings, material productivity and the introduction of leading technology strategies have been highlighted in recent research by Bleischwitz et al. (2009, 2010). A correlation was performed between resource productivity, Domestic Material Consumption (DMC) and competitiveness data by the World Economic Forum. Covering 26 countries, it showed a positive relationship between the material productivity of economies (measured by GDP in purchasing power parity US\$ per kg DMC) and their competitiveness index scores.

Improving the environmental efficiency of production at the global level can occur through technology and knowledge transfer from developed economies or through technology spillovers that occur as a result of international investment and globalised supply chains. With demand increasingly being driven from outside the advanced economies, these transfers and spillovers have dual benefits – not just reducing the extent of environmental damage exported from developed countries, but also helping developing economies shift to a more resource-efficient growth path (Everett et al. 2010).

### 3.2 Innovation in supply and demand

Making society more efficient with regard to the use of energy, water, land and other resources is a challenge that requires changes along the full chain of production and consumption. Authors such as Von Weizsäcker et

al. (1997, 2009) have suggested that one way to realise “Factor X”<sup>2</sup> improvements in resource productivity would be a radical change in end-use products, new ways of (e.g. shared) using products (e.g. sharing), and changes in consumption habits. This includes consideration of concepts such as “sufficiency” and asking critical questions about the function and service of proposed products.

It also requires a life cycle approach, which is what the WBCSD (DeSimone and Popoff 1997) has pursued in promoting the concept of eco-efficiency over the last decade. This concept focuses on those resource efficiency measures that also generate a positive rate of return to business on the required investments. Eco-efficiency provides a graphic tool for combining different measures, yet still has shortcomings in allowing quantification and comparison based on empirical indicators. The guidelines behind eco-efficiency include reducing the material and energy intensity of products, enhancing material recyclability, extending product durability and increasing the service intensity of products. Eco-efficiency in manufacturing can be measured through indicators related to resource-use intensity and environmental-impact intensity. Considering its application at national level, UNESCAP (2009) has defined the following as key indicators for manufacturing in the Asia Pacific Region:

<b>Resource-use intensity:</b>	<b>Environmental impact intensity:</b>
Energy intensity [J/GDP]	CO <sub>2</sub> intensity [t/GDP]
Water intensity [m3/GDP]	BOD intensity [t/GDP]
Material intensity [DMI/GDP]	Solid waste intensity [t/GDP]

Considering the full life-cycle and chain of supply and demand, Tukker and Tischner (2006) proposed a range of step-change measures along a full production-consumption chain, and speculated about their factor efficiency potential. Importantly, this reflects a full value-chain perspective, one that reflects product and service combinations as well as producer and user or consumer challenges. The entry point in this chapter is the upstream side and base industries such as steel and iron, cement, chemicals, paper and pulp and aluminum – industries that supply primary materials for the manufacturing of products such as cars, buildings and refrigerators that end-users know from daily life. Considering the full value chain can identify a range of areas for innovation and green investment, including product design and development (PD), material and

2. “Factor X” relates to a factor 4 or 10 improvement in energy and resource efficiency. Achieving factor X would in some cases require the application of disruptive new technologies. In addition, the concept of “exergy” promoted by Ayres (2010) and others focuses specifically on “useful energy” (as opposed to static energy and mass) and efficiency as a ratio of useful output compared to resource input.

energy substitution (MES), process modification and control (PM) and new, cleaner technologies and processes (CT). These become the building blocks in either a supply or demand-side strategy for improving resource efficiency in manufacturing.

A *supply-side strategy* involves redesign and improving the efficiency of processes and technologies employed in the major materials-intensive subsectors of the manufacturing sector (ferrous metals, aluminum, cement, plastics, etc.). On the other hand, if a green economy means improving not only productivity but also efficiency by a factor of four or more, a demand-side strategy is also required.

A *demand-side strategy* involves changing the composition of demand, both from within industry and from final consumption. This requires modifying output, i.e. to use final goods embodying materials and energy much more efficiently and/or to design products that require less material in their manufacturing. For instance, the need for primary iron and steel from energy-intensive integrated steel plants can be reduced by using less steel downstream in the economy (i.e. in construction, automobile manufacturing, and so on). Design for dismantling is a key step in advancing re-use and recycling of, for example, metals contained in the end-product.

The supply-side and demand-side approaches consist mainly of the following components:

■ **Re-design products** and/or **business models** so that the same functionality can be delivered with fundamentally less use of materials and energy. This also requires extending the effective life-time of complex products and improving quality, by incorporating repair and remanufacturing into a closed-cycle system;

■ **Substitute** green inputs for brown inputs wherever possible. For example, introduce biomass as a source of chemical feedstocks. Emphasise process integration and upgrade of process auxiliaries such as lighting, boilers, electric motors, compressors and pumps. Practice good housekeeping and employ professional management;

■ **Recycle** internal process wastes, including wastewater, high temperature heat, back pressure, etc. Introduce CHP if there is a local market for surplus electric power. Use materials and energy with less environmental impact, e.g. renewables or waste as inputs for production processes. Advance recyclability of materials used and find or create markets for process wastes such as organics;

■ **Introduce new, cleaner technologies** and improve the efficiency of existing processes to leapfrog and

establish new modes of production that have a fundamentally higher material- and energy efficiency. To start with, major savings potential in manufacturing lies in improving the resource efficiency of existing processes; and

■ **Redesign systems**, especially the transportation system and urban infrastructure down-stream, to utilise less resource-intensive inputs. The first target must be to reduce the need for and use of automotive vehicles requiring liquid fuels in comparison to rail-based mass transportation, bus rapid transit and bicycles.

Note that these transitional changes will occur automatically *only* to the extent that they are perceived by business managers and owners to increase competitiveness. Moreover, the manufacturing sectors are intermediates, which means that what they produce depends both on the availability and cost of raw materials and on the demand from downstream sectors, final consumers and governments. The latter can influence business decision-making by introducing new standards or subsidies. To ensure that a strategic transition to sustainable industrial production is realised in different parts of the world, both public and private investment in leap-frogging technologies would be highly desirable.

Despite technological advances, there will always be some inefficiency and waste. What is possible, however, is to use resources much more efficiently than it is used now. There is plenty of room for doing so. The USA's economy today converts primary energy into useful work – mechanical, chemical or electrical – with an aggregate efficiency of 13 per cent (Ayres and Warr 2009; Ayres and Ayres 2010). IEA data suggest that Russia, China and India remain less energy efficient than the USA (at least in the industrial sectors) (IEA 2009b). Japan, the UK and Austria are more efficient, overall, than the USA (20 per cent) (Warr et al. 2010). But this still means that *more than 80 per cent, or four-fifths, of the high quality energy extracted from the earth is wasted*. To cut that waste by only a quarter or a third could produce significant economic gains. From a macro-economic perspective, this is an enormous opportunity.

### **Closed-loop, circular systems in manufacturing**

Drawing on the principles of industrial ecology, *closed-cycle manufacturing* is a particularly ambitious approach to supply-side innovation. This concept refers to an ideal manufacturing system that maximises the useful life of products and minimises the waste and loss of valuable and scarce metals. At a broader systems level, another version of closed-cycle manufacturing is industrial symbiosis or eco-industrial parks. They are modeled on the Kalundborg (Denmark) example, within which wastes from certain manufacturing operations can be used as raw materials for others. In Kalundborg an oil refinery that produces

low temperature waste heat (warm water) is used for greenhouses supplying organic raw materials for a drug company that manufactures insulin. There is a coal-burning power plant from which desulfurization wastes are used by a wallboard manufacturer (Ehrenfeld and Gertler 1997). Although there have been a number of attempts to create eco-parks – there are now over a hundred around the world – it has been hard to reproduce such synergies elsewhere. One reason is the need for an eco-park to grow around a fairly large (and long-lived) basic industry that generates predictable wastes, with usable elements or components that smaller operations next door can utilise. And while policies should certainly promote the construction of more green factories and clusters of green factories, a greater challenge in developing economies today is how to retrofit, convert, and install more efficient and cleaner processes in existing factories.

At the product level, closed-cycle manufacturing achieves life-cycle efficiency by facilitating maintenance and repair, reconditioning and remanufacturing, with dismantling and recycling at the end, in contrast to today's linear throw-away paradigm. The usual one-way flow of products from the factory to the salesroom is changed to a two-way flow. If the useful life of all manufactured products (and buildings) were to be extended by 10 per cent, the volume of virgin materials (except fuels) extracted from the environment would be cut by a similar amount, other things being equal, and resource prices would tend to fall. This would eliminate jobs for miners, but it would employ more people in downstream stages – especially repair and renovation and recycling – and cut costs through the supply chain all the way to final consumers, who would then have more disposable income. It is important to recognise that radical change is seldom painless. Schumpeter's phrase "creative destruction" (1942) expresses this idea very well. Extending product life may also cut the rate of technological improvement. The lifetime extension of a product through increased reuse and recycling often results in relatively higher energy consumption levels because recent technological improvements have not been embodied in the reused products (such as cars and refrigerators). Life-cycle assessment of many products shows that most of the environmental pressure arises from their use and disposal rather than from the direct and indirect impacts of their production. The inability to capture technological improvements is especially acute in the area of electric power generation, where tough new source standards have inhibited the replacement of old generating facilities.

*Remanufacturing* is also becoming increasingly significant, particularly in areas such as motor-vehicle components, aircraft parts, compressors, electrical and data communications equipment, office furniture, vending machines, photocopiers and laser toner

cartridges. The Fraunhofer Institute (see UNEP et al. 2008) in Germany has calculated that remanufacturing operations worldwide save about 10.7 million barrels of oil each year, or an amount of electricity equal to that generated by five nuclear power plants. They also save significant volumes of raw materials. In the USA, it has been estimated that re-manufacturing is a US\$ 47 billion business that employs over 480,000 people (UNEP et al. 2008). In terms of employment and economic impact, the remanufacturing industry rivals such giants as household consumer durable goods, steel mill products, computers and peripherals, and pharmaceuticals.<sup>3</sup>

Some companies are now introducing specialised collection, sorting and dismantling plants around the world, either to save spare parts or to produce low-cost versions of their top-of-the line products. This encourages product redesign to facilitate the process. Caterpillar is probably the world's largest re-manufacturer, with a global turnover of US\$ 1 billion and plants in three countries. About 70 per cent of a typical machine (by weight) can be re-used as such, while another 16 per cent is recycled (Black 2008). Large diesel engines are routinely re-manufactured. Aircraft are essentially remanufactured continuously by replacement and reconditioning of most parts other than the body and frame (which is why some DC-4 and DC-6 aircraft manufactured in the 1930s or 1940s were still in use 50 years later.) Xerox and Canon, which began remanufacturing photocopiers in 1992, are among the companies that have pushed this concept.

The major obstacle to re-manufacturing is that strategies for extending the useful life of manufactured products depend upon active cooperation from original equipment manufacturers (OEM). The OEMs have resisted this approach to date. In fact, the current trend is exactly the opposite: products are increasingly being made as un-repairable as possible, so that old products are discarded and usually sent directly to landfills. Another barrier is the fact that most products are not sold directly by their manufacturers or agents. This makes collection and return difficult. Original equipment manufacturers would have difficulty providing warranties for products remanufactured by other firms. Also, some companies are reluctant to market re-manufactured products in competition with their own new machines. Instead, customers are encouraged to replace old, but still functioning products with new ones. This problem is less acute in product categories (such as computers) with rapidly changing technologies, where new products have much greater functionality than reconditioned or re-manufactured old ones. Most consumer product companies see repaired, renovated or remanufactured

3. For an analysis of over 7,000 remanufacturing firms in the USA, see the database and research by Lund (1996) and Hauser and Lund (2003) at Boston University, Available at [www.bu.edu/remman/](http://www.bu.edu/remman/)

products as directly competing with their new products and will continue to do so unless legislation is enacted or pricing differentials are introduced.

Three central components in the *waste minimisation* hierarchy are the 3Rs: reduce, re-use and recycle (see the Waste chapter). Following repair and remanufacturing to enable the re-use of products, *recycling* is a key step in the closed manufacturing system. This can support the use of the by-products of production processes, whilst also providing solutions in the substitution of inputs in manufacturing. The most important input substitution in the metals industry per se is the use of scrap in place of ore. In the US and Europe half or more of the carbon steel production is now based on scrap. Scrap is routinely sorted into grades, depending on the presence of contaminants. Research on ways to separate contaminant metals from the iron is needed, if only to facilitate recovery of the chromium, zinc, copper and so on. Yet, surprisingly, the recycling rate for iron and steel has dropped in recent years from a high of 60 per cent in 1980 to 35 per cent in 2006. The IEA projections assume that the decline will reverse and that a recycling rate of around 55 per cent will be achieved by 2050 (IEA 2009b). However, a significantly higher rate may be achieved by appropriate policy interventions, including measures to advance recyclability and design for dismantling.

Recycling is especially energy-efficient in the cases of aluminum and copper. Recycled aluminum requires only five per cent as much energy as primary production, but the recycled product, which often contains alloying elements, is not easy to roll into sheets or foil. Effective ways to purify the recycled metal (and to recover the alloying elements) would be very valuable. In the case of copper, a single tonne of metal requires the mining and processing of anywhere from 100 to 300 tonnes of ore (depending on the country), so the recycled copper requires much less energy than the virgin metal from ore (Ayres et al. 2003).

One of the most important (and under-exploited) near-term opportunities for improving energy efficiency in industrial processes lies in recycling high-temperature

waste heat from processes such as coke ovens, blast furnaces, electric furnaces and cement kilns, especially for electric power generation using combined heat and power (decentralised CHP). Virtually all of these examples are technically suitable for small combined heat and power plants with paybacks of the order of four years, providing only that the power can be utilised locally.<sup>4</sup> The pulp and paper industry has reported heavy investment in CHP technology to *reduce energy consumption*, noting that CHP installations allow savings of between 30–35 per cent of primary energy (UNEP 2006). Where CHP is not an option, the next example of input substitution is the use of waste fuel, such as biomass or municipal waste.

On the demand side, numerous measures can reduce absolute water use through efficiency and recycling measures. Recycling waste water from a variety of industrial processes is increasingly important because of the scarcity of fresh water in conjunction with growing demand for water in many parts of the developing world, such as northern China and India. The world market for water treatment in 2008 was US\$ 374 billion, of which US\$ 70 billion was in the US alone. Half of this market could be served by new modular systems using magnetic separation technology, which has been successfully applied to mining and industrial wastes as well as municipal wastewater (Kolm et al. 1975; Svoboda 2004).

Water used in chemical wood pulping is mostly recycled internally to recycle the chemicals. Metallurgical, chemical, textile and other surface-finishing operations generate polluted wastewater that must be treated before it can be re-used. In the longer term, there are numerous possibilities for reducing the need for water treatment after use by making the processes more efficient or cleaner. In particular, the need for industrial cooling water can and should be reduced dramatically by introducing co-generation of electricity to take advantage of high-temperature heat that is currently wasted.

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4. Under current rules in most countries, only electric power companies can sell electricity. This means that the utilities are also monopolist buyers. The price at which they are willing to buy electricity from other producers is often too low to make the investment worthwhile.



## 4 Investment and resource efficiency

Making the investment decision to pursue green manufacturing opportunities requires careful consideration of real net benefits and longer term consequences of decisions made today. This includes consideration of research, development and design options that enable users and consumers to move away from the throwaway consumption paradigm. Some technology innovations hold potential for drastic gains in resource efficiency, while others – such as carbon capture and storage (CCS) – may bring more costs than benefits. The cases of energy and water resources display the importance of having appropriate regulations and pricing in place. The area of human resources and employment highlights the importance of carefully considering direct and indirect impacts, as well as the role of taxes, price elasticity and rebound effects.

### 4.1 Investing in material and energy efficiency

To create a greener economy, many believe that fundamental changes are needed – changes which some have referred to as a social-technological transition (Geels 2002). The magnitude of the challenges is underscored by the fact that current unsustainable systems (socio-technical regimes) are locked-in by a multitude of demand- and supply-side-related factors. Yet, if the concept of closed-cycle manufacturing could be extended to mass-market products such as cars, washing machines, refrigerators and air-conditioners, the potential benefits to society would be significant. Firstly, by extending the average life-span of manufactured goods, the need for extracting virgin materials is correspondingly reduced. In the second place, repair, reconditioning, and remanufacturing are fairly labour-intensive activities, requiring relatively little capital investment. Thus, governments of developing countries have an interest in promoting imports of used goods that are capable of being remanufactured, not only in reducing global GHG emissions and resource consumption, but also in maintaining domestic employment and availability of modestly-priced goods for domestic consumption.

Most cleaner technology innovations will struggle to attract venture capital under current conditions, even in industrialised countries. Venture capital firms are looking for investment opportunities that offer high margins and require low capital expenditures and

low-cost testing of their market potential. Changing this situation to encourage innovation, especially in transitional and developing countries, depends on the enabling conditions (section 5). Those innovations that have attracted venture capital interest in recent years are mostly related to the Internet or renewable energy. While investment in core clean energy (including energy efficiency) decreased in 2009, owing to the global economic downturn, there was a record investment in wind power (UNEP SEFI 2010).

The field of electronics recycling is another promising area for research and development. Currently, there is some recycling of television sets to recover lead and glass, but e-recyclers mostly try to recover silver and gold, without recovering other scarce metals. New processes exist for recovering liquid crystal, indium metal and glass (LCD) from discarded flat-panel TV screens (Black 2008). These LCD panels constitute an increasing share of electronic waste, and the recovery process may be profitable enough to justify significant investment in a more structured approach to the electronic waste recovery problem as a whole.

Design initiatives in these areas are clearly within the scope and in the interests of manufacturers, because they contribute to competitiveness and cut costs. However there is another type of design innovation that is more directly relevant to overall resource efficiency, while being less profitable to manufacturers per se. This involves design changes to permit easier reconditioning, re-manufacturing and (finally) recycling of scarce metals. For example, it is important to facilitate the separation of electrical and electronic components from structural components of appliances and vehicles. This is important both to recycle rare metals (silver, gold, platinum, indium, etc.) that are increasingly being used in electronic products, and to reduce the extent to which these same metals (especially copper) become unwanted contaminants of secondary (recycled) aluminum and steel. Clearly, there is a huge opening for design-for-reparability, re-manufacturability and recyclability, i.e. for closed-loop manufacturing. In the case of used cars, open international markets currently provide incentives for material leakages that could be turned into business opportunities by using closed-loop systems.

A 2010 report from the Greco Initiative Regional Activity Centre for Cleaner Production (Greco Initiative)



Countries	Sector	Energy-efficiency initiatives	ROI	Payback	CO <sub>2</sub> savings
Bangladesh	Steel	Reparation of leaks and insulation of pipelines	260%	3.5 months	137 tons/year
China	Chemicals	Installation of a heat recovery system to recover heat for a CHP	96%	7 months	51,137 tons/ year
Ghana	Textiles	Installation of hi-tech de-scaling equipment for the boiler and steam pipes. Water conservation measures resulted in comparable savings.	159%	4 months	Not available
Mongolia	Cement	Improvements in the dust control system (filter bags) using new electric motors.	552%	2 months	11,007 tons /year
Honduras	Sugar	Replacement of steam turbines in the crushing mill with electric motors, powered by CHP; surplus electricity sold to the grid	Not available	1 year	Not available

See the following links accessed June 2010: <http://www.energyefficiencyasia.org/>, <http://www.ghanaef.org/publications/documents/2savingenergyindustry.pdf> and [http://www04.abb.com/global/seitp/seitp202.nsf/0/316e45d4d67ae21bc125751a00321e72/\\$file/Sugar+mill+case+study.pdf](http://www04.abb.com/global/seitp/seitp202.nsf/0/316e45d4d67ae21bc125751a00321e72/$file/Sugar+mill+case+study.pdf)

**Table 5: Examples of investment and environmental returns from energy-efficiency initiatives in developing countries**

Source: Adapted from Energy Efficiency Asia UNEP, SIDA, GERIAP, Energy Foundation Ghana, ABB Switzerland

described the effects of applying many of the strategies discussed here to a variety of manufacturing industries in the Mediterranean region. The study found that with the use of alternative machines and production input, ROI can be substantial. In the automotive industry ROI reached 250 per cent, in textiles 26 per cent, in chemicals 9 per cent, and in electronics 6 per cent, with payback periods varying between 3.4 and 11.3 months. However, the magnitudes of identified savings were not large. On the energy-efficiency front, case studies from around the world show similar levels of economic and environmental benefits from energy-efficiency initiatives (Table 5).

The IEA (2008, 2009b) scenarios – aimed at realising emission levels by 2050 that limits GHG concentrations to 450 ppm and average temperature rise to 2–3°C – imply high expectations of both technological innovation and regulation. It presents a BAU scenario that includes regular resource- and energy-efficiency improvements, implementation of best-practice technologies, and profitable recycling and valorization options that firms can implement profitably under existing market conditions<sup>5</sup>. The energy efficiency or carbon-reducing measures presented in the BLUE scenario would be more difficult to implement, and less likely to yield positive returns on investment<sup>6</sup>. For example, the scenario assumes the use of expensive forms of carbon-neutral electricity, including power plants equipped with CCS to achieve almost two-thirds of the required reductions of CO<sub>2</sub>. The IEA is frank in spelling out the cost implications, explaining that the drastic reductions in the BLUE scenario would require the widespread use of regulatory policy instruments, such as economic instruments, that

would gradually increase the price of carbon to US\$ 150 per tonne of CO<sub>2</sub> by 2050.

The case of CCS shows the advantage of an integrated resource-efficiency perspective, as opposed to pursuing investment decision-making focused on single measures (such as carbon emissions) at the cost of lower resource-efficiency and lower economic growth. CCS systems involve capturing, liquefying and injecting CO<sub>2</sub> deep into the earth's crust. CCS requires flue gases to be filtered and passed through a chemical process that dissolves the carbon dioxide in another chemical, then compresses and liquefies the carbon dioxide so that it can be pumped or shipped to a long-term storage site. The problem is that CCS requires a lot of energy. CCS systems being considered for cement plants today could double a current market price of US\$ 70 per tonne. In the case of electric power, a 500 megawatt power plant would need to use between 25 per cent and 40 per cent of its output to capture and store the CO<sub>2</sub> (Metz et.al. 2005). This would increase the number of power plants needed to supply the same amount of electric power to the rest of the economy by a factor of 4/3 to 5/3, adding significantly to the cost of electric power.

## 4.2 Investing in water efficiency

Water scarcity and hence the costs and benefits of reducing water scarcity are highly region-specific. Overall, by 2030 there is expected to be a water gap between potential demand and reliable supply (4,200 bio m<sup>3</sup>) of 40 per cent of potential demand (6,900 bio m<sup>3</sup>). Industry is currently responsible for an estimated 10 per cent of global water demand, the energy sector for an equivalent amount and agriculture for 70 per cent. The fraction used by industry will probably rise beyond 20 per cent in the next decades, in line with the growth of industrial production (Water Resources Group 2009; OECD, 2007; World Bank 2008; UNESCO 2009).

5. This includes resource-efficiency measures such as enhanced steel, paper and aluminum recycling, and the use of secondary fuels and solid waste as secondary raw materials in cement kilns.

6. Unfortunately, IEA (2009a) does not provide information on which energy efficiency measures presented in the BLUE scenario can be implemented with positive returns for industry.

In some countries with high water stress, such as Jordan, Egypt, Tunisia, and Turkey, it has been estimated that unsustainable use of groundwater now already reduces GDP by 1-2 per cent (World Bank 2007). For these countries alone, this would imply a GDP loss of around US\$ 10 billion. This report refrains from making extrapolations on a global scale owing to the strong regional character of the water gap problem. But since the physical water gap has to be closed, the question is how this can be done most cost-effectively.

The Water Resources Group (2009) has done probably the most comprehensive study globally into cost curves for measures that could close the water gap in four regions (China, India, South Africa and the Sao Paulo area in Brazil). Total costs of all measures (including in other sectors as industry) to close the water gap are US\$ 5.9 billion in India, US\$ 21.7 billion in China, US\$ 0.3 billion in Sao Paulo and negative in South Africa. These numbers typically represent 0.5 per cent or less of GDP.

The measures to be taken in the industries examined in this chapter show a mixed picture. In India, measures to close the water gap have to be taken predominantly in agriculture and to a lesser extent in industry. Most water conservation measures technically possible in industry would yield a positive social benefit-cost ratio. However, their commercial profitability at the enterprise level depends upon water-pricing policies. In China, the paper and pulp, steel and textile industries are well positioned to enhance water efficiency at a profit for themselves, whereas the picture is unclear in South Africa. The findings for the textile industry in China are in conformity with anecdotic case studies Turkey, where industrial users also pay for water supply and treatment, revealing a payback period of 3-5 years (Kocabas et al., 2009). However, in South Africa such investment would not seem to be profitable for industry because users do not pay a sufficiently high percentage of the costs of water supply and treatment.

Steel production facilities are often situated close to the ocean for shipping purposes and can use seawater for cooling purposes. A subsidiary of Arcelor in Brazil uses seawater for 96 per cent of total water used for its steel manufacturing. In South Africa, the proximity of a RAMSAR wetland has caused Saldanha Steel to build a zero-effluent plant, showing that it is possible for the steel industry to achieve zero water pollution levels (Von Weizsaecker 2009).

Improved monitoring of water use through emerging water accounting methods is an area where manufacturing companies can learn from agrifood industries. The Waterfootprint Network has highlighted, however, that the diversity of industrial products, the complexity of manufacturing production chains and

differences between countries and companies makes it more realistic to determine average amount of water used for industrial products per unit of value (e.g. 80 litres per US dollar) rather than per unit or by the weight of the product.<sup>7</sup> Faced with unpredictable climate conditions, manufacturing industries are starting to investigate this more closely. In a benchmark survey of reporting on water use by a hundred multinational corporations, CERES (2010) found that 10 of the 15 chemical companies examined disclosed market opportunities related to products intended to save water or improve water quality. Four companies disclosed new investments in research and development (R&D) to bring more water efficient products to the market. For example, Dow Chemicals reported on the construction of a new Water Technology Development Center to support its goal of driving a 35 per cent reduction in the cost of water reuse and desalination technologies by 2015.

### 4.3 Investing in a transition to green jobs

The industries analysed in this chapter employ more than 70 million workers<sup>8</sup>. During recent years these sectors have exhibited differing employment trends. Iron and steel, chemicals, pulp and paper and cement sectors have observed stagnating or declining levels of employment. Conversely, electrical and electronic products and textiles have experienced an expansion in their employment levels.

The manufacturing industries face serious deficits in decent work. From shortcomings related to occupational health and safety to rising informality, various dimensions of decent work are compromised. For example, operations in the iron and steel industry may expose workers to a wide range of hazards or conditions that could cause incidents, injury, death, ill health or diseases. The ship-breaking industry in Asia, a major supplier of recycled steel, is illustrative of poor health and safety conditions. In the textile sector, the need for greater flexibility is the root cause of relocations, a greater reliance on sub-contracting arrangements and consequent instability of employment.

Greening the manufacturing sector entails changes in the level and composition of jobs. In the metals value chain, for instance, significant green job creation opportunities are expected from the use and recycling of valuable byproducts and scraps. On the other hand,

7. The Waterfootprint Network has calculated industrial water uses that range from nearly 100 litres per US\$ in the USA to 20-25 litres per US\$ in China and India, Available at [www.waterfootprint.org/](http://www.waterfootprint.org/)

8. According to the ILO, the textiles industry employs 30 million workers; electric and electronic products 18 million; chemical industries 14 million, iron and steel 5 million, pulp and paper 4.3 million, aluminum 1 million, and cement 850,000. All figures are approximations.

efficiency improvements in manufacturing tend to reduce the need for workers in the same industry unless there is a resulting increase in demand (rebound). While the impact of greener practices on employment should not be overestimated, the empirical evidence supports positive effects of green practices on jobs. Direct effects of greening options may be neutral or small, but the indirect effects could be much larger (Lutz and Giljum 2009). This indicates that the economy would gain, especially in employment terms, from the introduction of greener production systems (Box 1). It must be noted that technological innovations are typically labour-saving and have often been accompanied by job losses.

After significant restructuring in the last century and increased automation and computerization in recent years, metals manufacturing is no longer the source of jobs it once was. Business-as-usual projections for the steel industry in Europe and the USA suggest job losses of 40,000-120,000 over the next two decades, faced with growing competition from Asia where production costs (wages) are lower. A BAU scenario in a study on climate action by the European Trade Union Confederation (ETUC et al. 2007) projected that up to 2030, the de-localisation of 50 to 75 MT of steel outside the EU, or the equivalent of 25- 37 per cent of current production, is possible. This would have an impact of 45,000 to 67,000 direct job losses, to which 9,000 to 13,000 outsourced direct jobs are to be added – resulting in a total loss of 54,000 to 80,000 jobs directly related to production. In an alternative scenario, where European authorities and industry were assumed to pursue a low carbon strategy, it is estimated that 50,000 direct jobs, internal and outsourced, could be saved in the European iron and steel industry. This strategy would involve investment in R&D, installing more efficient technologies and applying a tariff on steel imports based on carbon content, thus enabling steel production by low carbon processes to be competitive.

Similarly, the capital intensive aluminium industry cannot be expected to be a major source of green jobs. The same applies to the less labour-intensive cement industry, where the introduction of more energy-efficient plants in major producing countries such as China and India will lead to fewer workers required there as well. In this scenario, greening becomes a critical factor for competitive advantage (delivering low carbon products) and job *retention* rather than job *generation*.

Against this background, secondary production (recycling), therefore, becomes a proxy for a greener industry (UNEP et al. 2008). This requires appropriate processing equipment and recovery systems, supported by effective government regulations. Japan has largely abandoned domestic primary production and switched to secondary production and imports. In the EU,

secondary production of aluminum provided 40 per cent of total output by 2006. The world's largest producer of aluminum, China, is increasing its secondary production and faces shortages in availability of scrap metals. In the cases of India and Brazil, which has the highest recovery rate in the world for aluminum cans, endemic poverty is a key factor in driving recycling. This raises the challenge of ensuring decent work in an industry (recycling) where work can be dangerous, unhealthy and poorly paid.

Experience from the consumer electronics industry, producing products with increasingly short life-cycles, has shown how a growing problem of e-waste – going to destinations such as China, India, Pakistan and Bangladesh – results in environmental and health problems for both workers and society (owing to heavy metals and organic contaminants ending up in water and the food chain). While recycling is of great value in terms of resource conservation, it can entail dirty, undesirable and even dangerous as well as unhealthy work.

In the metals value-chains, there are significant job-creation opportunities to be found in the use and recycling of valuable byproducts and scraps. Around 21 million tonnes of ferrous slags were recovered from iron and steel mills in the USA in 2005 (van Oss 2006). This provided employment for over 2,600 people. Assuming comparable labour productivities in other countries, extrapolating USA data to other countries suggests that slag recycling worldwide might employ some 25,000 people (UNEP et al. 2008). Recycling of steel itself saves up to 75 per cent of the energy needed to produce virgin steel. In sectors such as the automotive industry and construction, steel recycling rates can reach up to 100 per cent. Less developed recycling systems and related infrastructure in developing countries result in lower recycling rates. A report by UNIDO (2007) has put the share of secondary (recycled) steel at 4 per cent in India, 10 per cent in China and 25 per cent in Brazil.

In the pulp and paper industry, where modernised and more efficient plants require fewer workers, recycling is the fastest growing source of substitute as well as new, green employment (UNEP et al. 2008). Recycling is labour-intensive and creates more jobs than incineration and land filling. This comes in addition to major savings in GHG emissions and landfill waste avoided. Paper comprises about a third of all municipal solid waste. Paper waste, growing faster than any other material in countries like China, is driven by increasing population growth, urbanisation and consumption patterns. For all materials considered here, studies have shown that recycling is preferable to landfills and incineration not only on an environmental basis but also since it creates more jobs. Related regulations on, for example, packaging will also impact job creation in the recycling industry.

## Box 1: Steel production with higher components of recycled materials – Direct and indirect impacts on jobs (in the EU27)

In a 2007 study (European Commission 2007), GHK Consultants evaluated the economic significance of the environment in terms of employment, output and value added associated with the range of activities that make use of, or contribute to, environmental resources in the EU27. Input-output tables for each Member State were used to estimate the indirect and hence **total economic impacts** of defined activities that are linked to environmental resources. The study also considered policy interventions directed to improve resource efficiency. One of the policy scenarios examined assumes a switch of 10 per cent by value in raw material inputs to steel production from virgin materials to recycled materials. As a result of the intervention, positive total impacts are reported for output and employment. The results can be summarised as follows:

The initial direct impact is neutral as the reduction in output from one sector is met by an increase in output from another sector. However, the net indirect (including induced) impact of this substitution leads

to an increase in output of nearly € 197 million and an extra 1,781 jobs. Adding the direct and indirect effects indicates that this substitution would add € 197 million of output and 3,641 (1,860 direct and 1,781 indirect) jobs.

The net positive impact on jobs and output is mainly owing to the supply-chain effect of the recycled materials sector. The recycled materials sector uses inputs from many other sectors, thus creating more jobs and wealth. If the substitution were to lead to an increase in the costs to the steel sector – since inputs of recycled materials cost more than virgin materials – this would be reflected in the cost of steel and paid by users of steel. Output and profits of the steel sector would be expected to fall due to higher costs of steel products. The ability to pass costs on to users will depend on factors such as the price elasticity of demand for steel. According to parameters of the model used, the steel sector could pass on 45 per cent of its unit costs to its customers and would have to absorb the rest as reduced profits.

	Output (million Euros)	Jobs (FTE)
<i>Direct impacts</i>		
Virgin material sector: loss of output and jobs	-489.0	-4,092.0
Recycled material sector: gain in output jobs	489.0	5,952.0
Net direct impact (1)	0.0	1,860.0
<i>Indirect impacts</i>		
Virgin material sector: fall in demand for inputs and subsequent fall in output from suppliers to the virgin material	-83.0	-753.0
Recycled materials sector: Increase in demand for inputs and subsequent increase in demand from various sectors	280.0	2,534.0
Net indirect impact (2)	197	1,781.0
Total impact (3)=(1)+(2)	197.0	3,641.0

Industries such as steel and aluminum can expect growing demand from new markets in the form of clean-tech such as solar technologies, being an important source of materials and components required for these. These potentials can be identified by considering industries not in isolation, but as part of a broader value-chain that contains possible hidden economic opportunities. Following this approach, a study by Gereffi et al. (2008) in the USA shows the example of how solar manufacturing can replace jobs lost in automotive manufacturing. Infinia Corporation has developed a concentrating solar-dish system specifically designed to be mass-produced by Tier 1 and Tier 2 auto manufacturers in the USA. Infinia

included US auto suppliers from the very beginning in product development and design. The product can be manufactured on existing auto production lines which have high surplus production capacity. Infinia estimates each unit of auto production capacity can be retooled to produce 10 units of their Solar Power System, producing 120,000 MW of solar capacity and securing as many as 500,000 manufacturing jobs. In cases like these, where certain jobs are potentially replaced with jobs in another sector, calls have emerged for a “fair and just transition” in which those harmed by the changes are adequately assisted and the new opportunities created shared by specific groups of worker constituencies.



As suggested by the US auto industry case, creating new job opportunities may lie in the introduction of new technologies, looking beyond just efficiency improvements, and considering possibilities that lie in diversification and in the value chains that provide green technologies such as solar and wind power. The IEA estimates that for every US\$ billion invested in clean-energy technology, 30,000 new jobs will be created. As indicated by Martinez-Fernandez et al. (2010) these figures must be dealt with cautiously, without ignoring job losses and social stress that will go with a period of transition.

Remanufacturing and recycling of scarce metals provide primary opportunities in the manufacturing sector per se. Significant opportunities may also lie in the area of industrial symbiosis (new products from old processes), highlighting also the importance of broader systemic (cross-sectoral) impacts as considered in the modelling (see next section) done for this report. Public policies, such as extended producer responsibility or returnable deposits, can help to promote closed cycle manufacturing and extend product life cycles, thereby saving resources and creating more jobs in maintenance, repair, remanufacturing and recycling. Collection and sorting of used or end-of-life products (reverse logistics) could be a significant employer. Shifting taxes away from labour on to waste emissions and/or materials extraction could also be an effective way of creating more jobs by cutting labour costs *vis a vis* direct energy costs, or capital costs.

#### 4.4 Growth and rebound – lessons for developing markets

The eventual advent of peak oil means that the supply of cheap oil and gas cannot be expected to continue in the future. Future economic growth will depend more than in the past on technological progress and capital deepening because growth in the world labour force is projected to slow gradually. The rate of energy efficiency increase has been slowing down since the 1960s. An acceleration of technological progress *vis-a-vis* resource efficiency seems possible, but it is unlikely to happen without an unprecedented global effort.

Future economic growth is expected to be driven by emerging countries, led by China and India. However, they are expected to shift away from their current emphasis on export-oriented growth to more domestic demand-driven growth, as growth of the labour force and rural-urban migration slows, leading to wage increases, and as social safety nets are put in place or strengthened. Increased consumption relative to savings will reduce global imbalances, but their GDP growth rates will also

slow. The greatest resource-efficiency effort is required in weaker developing country economies where most of the population increase will take place, and where the economic and social impacts of resource scarcity and commodity price volatility will probably be most severe (Shin 2004).

Economic growth is evidently the primary means of reducing global poverty, although it has a less direct impact on inequality. Increased demand from urbanising populations for products and services and productivity growth will be the basic drivers of economic growth. Increased resource efficiency can be expected to explain part of the future growth in productivity. This is the reason why some point to a likely rebound effect—usually on the basis of historical examples and evidence of the Jevons paradox—and question the extent to which investment in efficiency will really cut resource use. There is little doubt that technological innovations—by increasing efficiency, cutting the cost of basic materials and energy, and by increasing labour productivity—have been the main drivers of economic growth in the past. Lower cost of inputs generates increased demand for existing goods or for new products and services that did not exist previously.

There is not just one rebound channel or mechanism, but several, which include: more intensive use of energy-consuming equipment by current users because of a higher energy efficiency and thus a lower effective energy cost; purchase of larger units or units with more energy-consuming functions/services and consequently more energy use (e.g. vehicles with air-conditioning); more energy- and resource-efficient technologies diffuse to new sectors and applications (including households), which partly undoes savings resulting from per-unit improved efficiency; re-spending of money savings owing to energy conservation on other energy-intensive goods and services (income effect); creation of new demand (i.e. new users) owing to a lower market price of energy if initial energy savings are large; and diffusion of more energy-efficient general purpose technologies like batteries or computers (Van den Bergh 2008, 2011). These examples all depend ultimately upon price or cost reductions owing to efficiency gains. However, the next few decades are almost certainly going to experience significant energy prices increases, once the costs of CO<sub>2</sub> abatement have been set at levels sufficiently high to stabilise atmospheric CO<sub>2</sub> and have been fully internalised to users. In this case, greater take-up of more efficient technologies will help to abate the otherwise negative impacts on economic growth resulting from higher energy prices. Yet energy-efficiency proposals cannot rely on higher oil prices as such, with others alternatives like coal available. This reality underlines the need to have appropriate regulatory policies in place.



# 5 Quantifying the implications of greening

## 5.1 Business-as-usual trends

Summarising findings from the Millennium Institute's T21 model for investment scenarios up to 2050, we start with BAU in manufacturing. The IEA projects that under all scenarios, GDP will quadruple between 2010 and 2050<sup>9</sup> and manufacturing (as defined for purposes of this chapter) will contribute 27.6 per cent of GDP and 24.2 per cent of global employment in 2050. Yet, if peak oil occurs sooner than the IEA assumes, the global economic growth rate may be much lower than foresaw by the IEA (2009).

Heavy reliance on energy and manufacturing industries account for one-third of global energy use and 25 per cent (6.7 Gt) of total world emissions, 30 per cent of which comes from the iron and steel industry, 27 per cent from non-metallic minerals (mainly cement) and 16 per cent from chemicals and petrochemicals production. CO<sub>2</sub> emissions from fossil-fuel combustion in the industrial sector totaled 3.8 Gt in 2007, a 30 per cent increase since 1970. They are projected to continue increasing to reach 5.7 Gt in 2030 and 7.3 Gt in 2050 in the BAU case, primarily owing to increased consumption of coal.

The amount of water withdrawal for industrial production is expected to increase from 203 km<sup>3</sup> in 1970 to 1,465 km<sup>3</sup> in 2030 and 2,084 km<sup>3</sup> in 2050. Industrial water as a share of total water demand is expected to increase from 9.4 per cent in 1970 to 22 in 2030 and 25.6 per cent by 2050.

## 5.2 Trends under a green investment scenario

The Millennium Institute's T21 model uses IEA estimates selectively (among others) to simulate what the economy-wide effect of investments in the greening of sectors would be, using indicators such as industrial production and GDP growth, employment, resource consumption, and CO<sub>2</sub> from fossil-fuel use (Figure 8). These results

are presented in this section, covering six industry sub-sectors: steel, textile aluminum, leather, paper and pulp, and chemical and plastics products. Other industrial sectors are covered in the broader and aggregated industrial macro sector, presented in the modelling chapter. Energy intensive industries such as cement, the non-metallic mineral products and electrical and electronic products sub-sectors are not disaggregated in the model owing to lack of data.

In the T21 green economy model, the green investment scenario G2 in the industry sector assume the allocation of 3 per cent of the total additional green investment<sup>10</sup> to improvements in industrial energy efficiency. This translates into US\$ 79 billion per year on average between 2010 and 2050. Investments are allocated to both the broader industrial sector and to the selected subsectors) in more efficient, low carbon, development.<sup>11</sup> Faster growth, all else being equal, translates into higher demand for basic materials, resulting in higher energy demand and generation of greater CO<sub>2</sub> emissions in the industrial sectors.

Results of the simulation indicate that investing in the industry sector reduces energy consumption and emissions. This, in turn (other things being equal) helps to reduce the price of fossil fuels and yields higher value-added and employment (both within the industrial sectors analysed and across the economy). The total industrial employment is projected to be about 1.04 billion (people employed) in the G2 scenario (21 per cent of overall employment across all sectors) in 2050, 2.4 per cent lower than in BAU2. Concerning employment in the six manufacturing sectors analysed in more detail, the total number of jobs is 109 million in the G2 scenario in 2050, 15 per cent more than in BAU2 (Figure 9). The change (net reduction) in total employment is driven by the interaction of several factors: (1) higher demand for the industries analysed – increasing employment (the dominating factor making employment rise in the energy intensive sectors studied in more detail); (2) higher efficiency and capital intensity (as opposed to labour intensity, also due to the fact that running capital is cheaper in G2, for instance

9. The IEA economic model is typical of neo-classical growth models, in assuming that growth can and will continue at historical rates regardless of the availability or price of energy. This assumption has been strongly challenged by the econometric work of Ayres and Warr (Ayres et al. 2004, 2009a), who argue that growth is actually proportional to the output of "useful work" by the economy as a whole. Useful work is the product of energy consumption times conversion efficiency.

10. Additional green economy investments worth 2 per cent of GDP for G2.

11. This investment is estimated using the industrial CO<sub>2</sub> abatement cost published by the IEA in the WEO 2009 but with limited investment in CCS. See Modelling chapter.

due to lower energy costs) – reducing employment; and (3) higher productivity of work (driven by higher life expectancy and access to social services in G2). However, our calculation does not include potential employment creation from energy efficiency improvements (which is the case for end-use in the residential and commercial sectors), due to the lack of relevant literature.

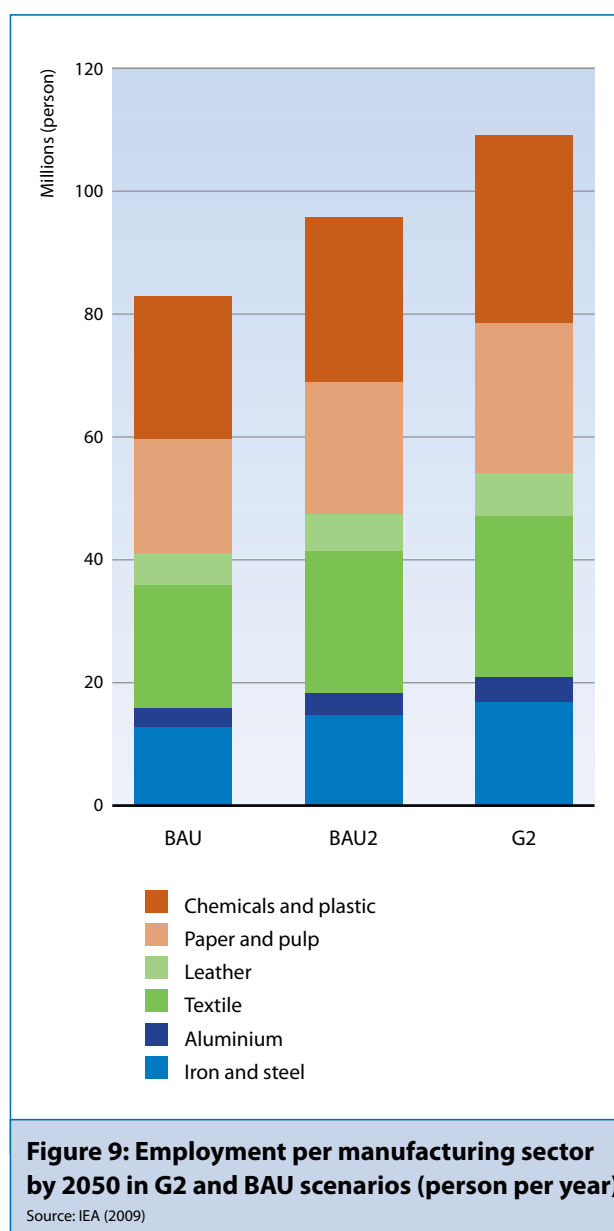
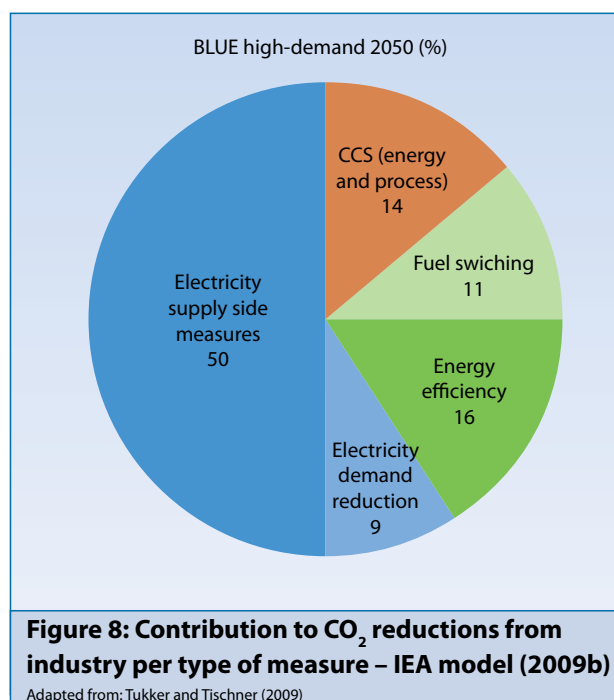
The green investment will lead to a considerable energy efficiency improvement by 2050, practically decoupling energy use and economic growth, particularly in the most energy-intensive industries. The improved energy efficiency is projected to mitigate total energy and process-related CO<sub>2</sub> emissions in the industrial sector by 51 per cent (3.7 Gt in the G2 case) by 2050, curbing the trend of growth as of 2025. Total emissions from the six selected manufacturing sectors would also decline to 1.3 Gt in the green case, from 2.7 Gt in the brown alternative (BAU 2) - (Figure 10).

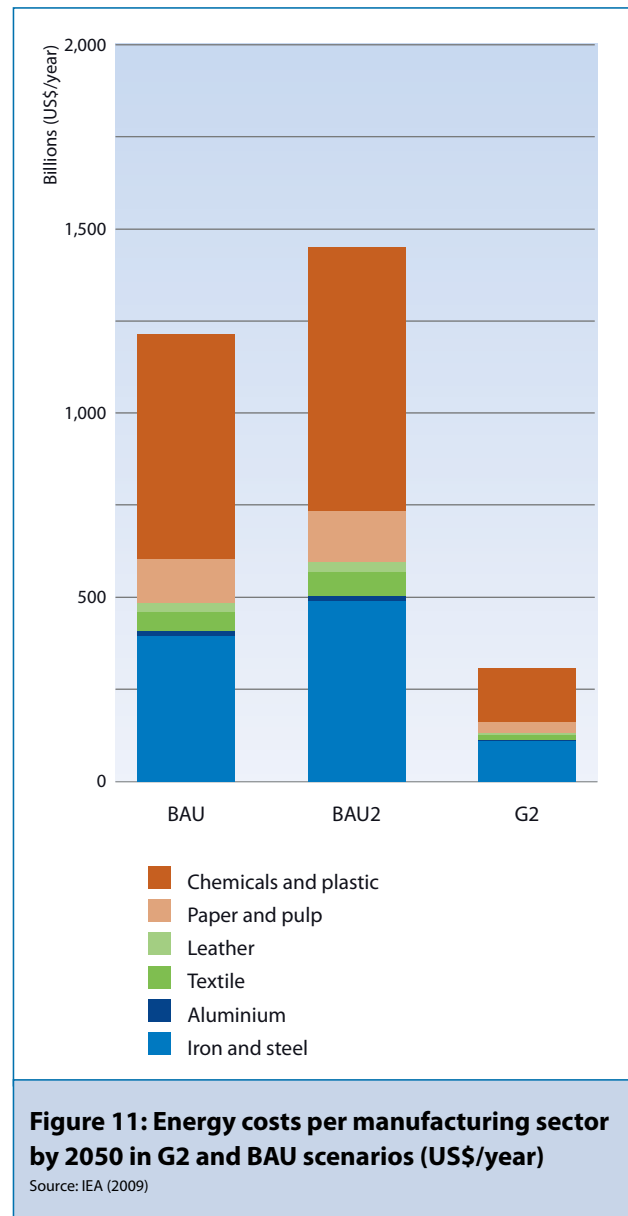
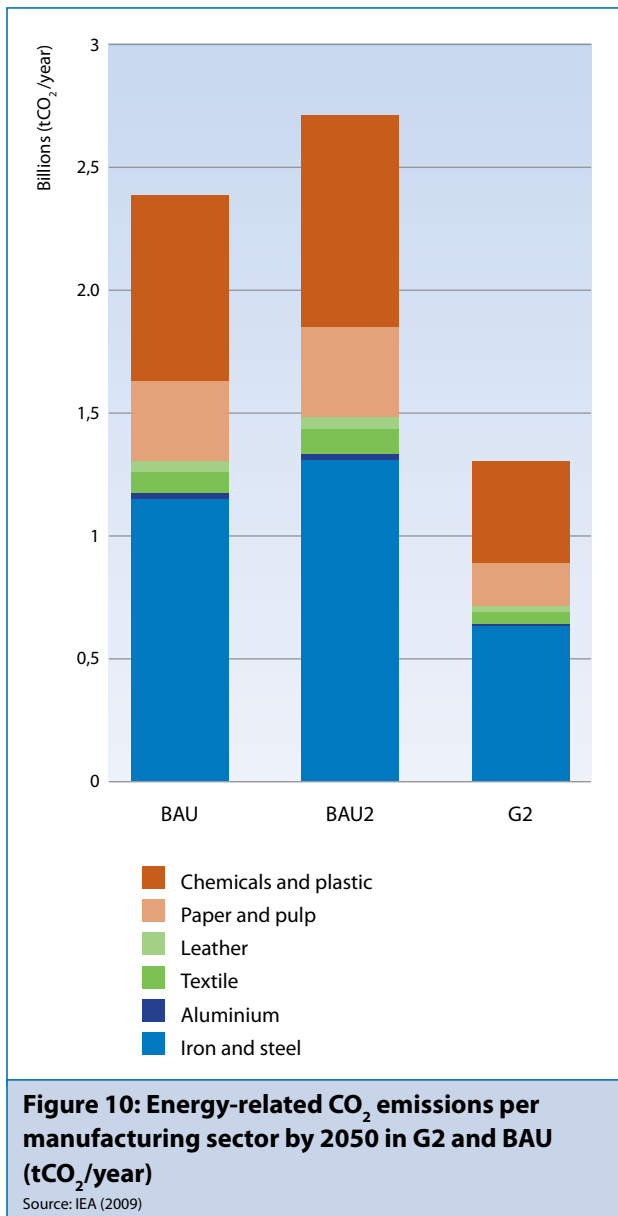
At the industry level, the avoided energy consumption averages 52 per cent by 2050 – comparing G2 to BAU2 – (or 52 per cent relative to BAU2), resulting in avoided costs of up to US\$ 193 billion relative to BAU 2 per year, on average, between 2010 and 2050 depending on the industry considered<sup>12</sup>. The chemical and plastics sector provides the greatest opportunity, with a potential of US\$ 193 billion relative to BAU2 in yearly avoided energy costs. Steel follows with an average US\$ 115-136 billion potential savings per year. Paper and pulp saves US\$ 37 billion, textiles US\$ 17 billion and leather US\$ 8 billion. Aluminum is the least promising, with US\$ 44 billion of yearly avoided energy cost in the G2 case. The above estimates are only proposed as examples, based on an assumed investment of US\$ 37.6 billion per year on average between 2011 and 2050 (Figure 11).

The model also assumes the same cost per tonne of emissions abatement for all industries, although in reality they rely on very different technologies. But the G2 model runs provide some insight into the aggregated potential opportunity cost of investment in low carbon technologies and efficiency improvements.

The average total cost of emissions in the BAU and green economy scenarios (based on IEA projections) would be US\$ 629 billion (BAU2) and US\$ 380 billion (G2). Assuming an emissions cap-and-trade mechanism with carbon prices aligned with the recent US domestic proposal, and no free allowances, the green economy investment would yield US\$ 264-US\$ 249 billion per year on average between 2011 and 2050 in avoided costs relative to corresponding brown scenarios (or US\$ 230-US\$ 195 billion from the BAU case).

12. Avoided costs are not pure economic gain, since they imply disinvestment and disemployment in the traditional energy sectors (the inverse of rebound).





It is worth repeating that the necessary simplifications in the model (indeed, any model) result in simulated outcomes that may be quite different from reality, inasmuch as they are unable to take into account a variety of cause-effect chains unrelated to the assumed investment-growth-employment relationships. However, the optimistic results of the simulation are realistic, at least in magnitude. The existing global economic system, and especially its industrial component, has been built upon a base of under-priced fossil energy and other ecosystem services. This has enabled grossly wasteful production and consumption practices in many parts of the world. For several reasons, the price of energy is probably going to rise significantly in the future. This will induce everyone in the system to seek energy-conserving products and services. The ultimate effect will be to enable existing goods and services to

be produced with much less energy. Whether increased efficiency will fully compensate for higher costs (thus permitting the same amount of economic growth or more) remains to be seen in practice, but a double dividend potential may well exist and is illustrated in the G1 and G2 scenarios.

Recent analysis for the US provided an assessment of the economic impact of the climate-energy legislation (APA-ACELA) pending in the US, together with a version with enhanced energy efficiency features, as compared to the reference forecast BAU in the 2010 International Energy Outlook, published by the Energy Information Administration (US, DOE). It covers the period 2013-2030. Its results tend to confirm that the results by the Millennium Institute reported here, especially as regards employment, are forecast accurately.

## 6 Enabling conditions for a green transformation in manufacturing

The manufacturing sector can make a significant contribution in greening national economies by producing goods that are more resource-efficient and have lower environmental impacts over their life-cycles. This applies, in particular, to the highly resource-intensive value chains such as metals and car manufacturing. But for the manufacturing industries to make this transition, they need to receive the appropriate policy and price signals. Under certain conditions it also needs institutional support from governments, in particular ensuring that supportive investments in physical infrastructure and education are sufficient to enable a transition that requires new systems and skills.

The past several decades have witnessed a major restructuring of the global economy, with the global manufacturing industry base shifting toward developing countries and emerging economies, and developed countries becoming ever more service-oriented. Globalization through increased cross-boundary trade and investment flows is driving this restructuring, along with technological and associated organizational changes. This transition process, driven by global factors of production and markets rather than local development factors, has resulted in significant capacity gaps in developing and transition economies in managing the structural transformation of their economy on a more sustainable basis. This situation is a handicap for small enterprises to adopt more resource-efficient technologies as they face growing demand to meet the new standards required to market their products through global supply chains.

With this background in mind, this section on enabling conditions focuses on actions that mainly governments can take to help induce the transition to green industrial production both through incremental and transformational changes. It is a transition that faces drivers such as resource scarcities and rising energy costs as well as barriers such as inefficient monopolies, outdated regulations that restrict new technological approaches and principle-agent conflicts. It is a transition in which, for example, power monopolies need to be challenged by government support for decentralised energy production and investment in smart grids that saves electricity transmission losses. It is also a transition in which governments need to consider the integrated resource efficiency perspective, avoiding technology policies (the example of Carbon Capture and

Storage) that focus on a single measure (such as carbon emissions) at the cost of increased fossil fuel extraction, lower resource-efficiency and lower economic growth.

Before reflecting on appropriate instruments for action, two key policy priorities for greening manufacturing are recommended and the promotion of closed cycle manufacturing and related life cycle approaches with supportive recovery and recycling infrastructure, and regulatory reform to enable factor efficiency improvements in energy use, for example through the introduction of co-generation and CHP technologies and the feed-in of decentralised power generated by use of renewables. The latter needs to be supported by investment in smart grids and approaches such as feed-in tariffs and time-of-day pricing (see Energy chapter).

### 6.1 Policy priorities

#### **Closed-cycle manufacturing and life cycle approaches**

Efforts to promote resource efficiency at the product, production process and company level need to be complemented by resource-efficiency innovations at the industrial cluster and systems level. At the company level, this starts with approaches such as eco-design, life-cycle management and cleaner production. At the industry and systems level, this implies innovations such as the greening of supply chains and clustering of industries in a given economic zone to become a platform for resource efficiency through optimised resource flows between industries. The industrial parks of the future could be eco-parks to maximise industrial symbiosis and secure green jobs.

The move toward a closed-cycle manufacturing through remanufacturing and reprocessing of post-consumption products and materials that are currently thrown away as a waste, represents an important opportunity for the transition toward a green economy. Two broad categories of post-consumption waste that could be the focus in such a transition are e-waste and materials such as metals, glass, plastics and paper products. The latter category constitutes the most diverse group of industrial products, which are already a target of some degree of recycling, albeit in varying degree of organisation and with an informal character in many developing societies. The policy focus would thus be

on formalising and structuring the waste recovery and recycling process in such a way that it will bring added economic, environmental and social benefits. In the case of e-waste, this implies a high-tech value chain where the production of electronic goods is done by multinational companies in developed and emerging economies. It is a value chain with labour-intensive disassembling work required for the recovering useful parts. The combination of these features could also serve as a basis for the evolution of a different form of symbiosis involving economic actors from developed and developing markets.

### **Co-generation: combined heat and power**

Most industrial applications have a need for heat, and most of the potential for co-generation applications can be found in energy-intensive industry sectors such as steel, aluminum, cement, chemicals, pulp and paper. It is technically and economically feasible to recycle high-temperature waste heat or other combustible wastes from industrial enterprises such as coke ovens, steel mills, cement plants, glass producers, brick and ceramic works. This provides the opportunity, should policy and regulation allow, to complement centrally-generated electricity networks with local heat and power systems where electricity is generated and heat re-used at the local industrial site level. It is an opportunity for significant factor-improvements in resource productivity, combined with investment in smart grids.

The world is undoubtedly electrifying, and demand for electric power continues to grow everywhere. Numerous industrial, commercial, and domestic users consume fossil fuel simply for purposes of cooking, hot water, heating air for space-heating, or producing industrial steam at moderate temperatures. There is no technical reason why most of these applications of low-temperature heat could not be supplied by means of small co-generation CHP facilities, based on diesel engines, small gas turbines, high-temperature fuel cells or even rooftop solar collectors. Small CHP systems remain a largely untapped market (Von Weizsaecker et al. 2009). Furthermore, a number of industry sectors have significant potential for generating electricity from waste heat, as in the case of steel mills.

In order to make effective use of such possibilities, it would be necessary for all of these electricity-producing units to be connected to the grid, both to sell their surplus and to buy during occasional periods of breakdown. However, in most countries the electric power industry is a legal monopoly, whether public or private, with exclusive rights of distribution. Besides the natural tendency of inducing inefficiencies across the whole chain of production, distribution and use, such monopolies are acting as major institutional barriers for the development of CHP facilities at different scales.

The primary problem faced by would-be CHP investors, according to the IEA (2009b), is difficulty in securing a fair market value for any electricity that is exported to the grid. Overcoming these barriers requires policy measures that encourage innovative technologies such as CHP, applied to industrial waste heat and waste biomass in particular.

## **6.2 Policy instruments to enable green manufacturing**

The spectrum of instruments available to governmental institutions to shape the enabling environment for greening industry and manufacturing can be categorised as follows:

- Regulatory and control mechanisms;
- Economic or market-based instruments;
- Fiscal instruments and incentives; and
- Voluntary action, information and capacity building.

An assessment of policy priorities and preferred instruments needs to consider that manufacturing is often dispersed across different countries and industry subsectors, as highlighted in the introduction of this chapter. The industries involved are likely to prefer holistic approaches that enable better sharing of costs, responsibilities, resources, and rewards across manufacturing value chains. This requires, among others, advances in corporate disclosure and governance, fiscal incentives to drive change in the design and take-back of products, policy support for the development of appropriate standards in sustainable manufacturing, and incentives and training to improve existing processes and the retrofitting of factories to be more resource efficient. It requires policy mixes the components of which are discussed below.

### **Regulatory and control mechanisms**

The major sources of significant quantities of emissions and effluents in manufacturing industries have traditionally been the initial targets for regulatory and control instruments. Legislation with clearly defined standards of technology and/or performance can drive green investment, encouraging industries to use natural resources more efficiently and create markets for green products and production. Regulatory requirements can build in cleaner technology standards in the licensing of new industrial operations. It can establish emission and discharge standards for industries with clear requirements for the best available or best possible technology (BAT, BPT). However, care needs to be taken that setting standards by regulation does not impede



innovation and fail to keep pace with technological progress. Experience in China has shown how eco-industrial development or industrial symbiosis can be held back by regulations that enforce too low fines on discharges and forbid or limit the exchange of by-products between companies (Geng et al. 2006).

Licensing of operations provides an opportunity to provide incentives, for example related to land-use planning, to encourage existing industrial estates and parks to move toward a more closed-loop manufacturing paradigm through materials recycling and exchange schemes. Policy and planning provisions can be used to ensure that the development and management of new industrial parks and estates are in accordance with the principles of industrial symbiosis and turn them into eco-industrial parks. This also requires governments to invest in supportive infrastructure for waste treatment and the conversion of wastes into resources. In addition, quota systems for resource (e.g. water) use can be set up in industrial parks, with a penalty mechanism that requires tenants to pay several times the normal rate for those resources they use whenever they exceed their allotted quota.

Regulatory and control mechanisms can promote principles such as Prevention (3P, 3R), Polluter Pays and Extended Producer Responsibility (EPR) to encourage large manufacturers with complicated supply chains to favour closed-cycle manufacturing and more efficient take back systems for remanufacturing and recycling. In recent years regulations such as the Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS), and Registration, Evaluation and Authorisation of Chemicals (REACH) directives of the EU have had impact world-wide on standards applied in the manufacturing and use of products.

Traditional command and control regulations introduced in many countries since the 1970s have tended to be technology-based or performance-based. They focused on end-of-pipe solutions, not considering more preventative approaches and ways to improve resource efficiency through more systemic changes to the production process or even product design. This left limited incentive for manufacturers to continually and fundamentally improve standards (dynamic efficiency), as opposed to economic instruments that put a price on emissions and effluents to create a permanent incentive for improvement. Whilst appearing simple to introduce, command and control regulations can be costly and inefficient in use.

The historical example of vehicle manufacturing shows how regulatory and control approaches can be combined with fiscal and voluntary instruments to bring about shifts in technological innovation. Mandatory

or voluntary standards and taxes can drive shifts in innovation *along* a technology frontier or shifts *of* the frontier (OECD 2010b). The type of changes described for the manufacturing industry in this chapter also require a shift of frontier, including redesign of products and the introduction of new production systems for closed-loop manufacturing. However, changes along the frontier for continual improvement remain important. In the case of vehicle manufacturing, these can involve innovation in end-of-pipe emission abatement, input substitution (e.g. of fuels), factor substitution (more efficient, redesigned engines) and output substitution (greater fuel efficiency of a redesigned vehicle). Analysis of invention and patents in car manufacturing over the period 1965-2005 by the OECD (2010b) has shown a strong positive effect of petrol taxes—combined with regulatory pressure—on engine redesign technologies, with factor-substitution showing the highest growth in patent applications over the period considered.

### **Economic or market-based instruments**

Economic instruments for pollution control and reducing other environmental pressures include charges and fees for non-compliance, liability payments as well as tradable permit systems targeting, for example, air pollution, water quality and land management. Instruments regulating price have the advantage of ensuring that the marginal cost of abatement is equalised among all polluters. Charges can target emissions and products (at the level of manufacturing, use or disposal), as well as byproducts such as packaging and batteries. The latter has also been addressed through deposit-refund systems, which can become of increasing significance world-wide for industries such as electronics and car manufacturing. New legislation can encourage recycling by mandating returnable deposits on recyclable products. Direct regulation on emissions can be complemented usefully by returnable deposit rules and end-of-life disposal rules.

To promote integrated water resources management amongst industrial water users, Government can either establish prices through taxes, fees and royalties or limit quantities through tradable permit schemes. In the case of the latter, a market for water use in a shared river basin can allow users with relatively high-valued water uses to purchase or lease water from users with relatively low-valued water uses. Similar to air-pollution credit schemes, the aim is to transfer reduction responsibilities to agents with the lowest costs of use reduction. In the USA, markets have been created in arid states to allocate water with relative success. Canada is an example of an industrialised country where power production and manufacturing are the principle water-using sectors. Most of the water used by manufacturing plants has traditionally been discharged directly into a receiving water body. Examination by Renzetti (2005) of the use

	Aluminium	Steel	Cement	Chemicals
Share in GHG emissions	0.8% of global emissions and 4% of manufacturing industries' emissions	3.2% of all global emissions and an estimated 4.1% of global CO <sub>2</sub> emissions; approx 15% of all manufacturing emissions – with 70% of emissions from direct fuel use and 30% emissions indirectly from electricity and heat	4 % of global emissions (process emissions and energy use) and 5% global CO <sub>2</sub> – this is expected to double in next 40 years, most of the increase in developing countries; 18% of all manufacturing emissions, emitted at various points in the production process	5% of global emissions, and 23% of emissions associated with manufacturing and construction industries
Concentration of actors	Twelve countries represent 82% global production; China, Russia, the EU, Canada and the US account for 61% of total production; ten leading companies (mostly multinationals) produce 55% of world's aluminum	Around 90% of total steel-making GHG emissions is produced by nine countries or regions. The top 25 steel-making companies collectively accounted for approx 43% of global production in 2006	Relatively low concentration, with the 16 largest companies accounting for around 25% of global output. About 81% of production takes place in 12 countries; China alone produces around half of the world's cement	Highly concentrated geographically – the EU, US, Japan and China account for 75% of global chemical production. Diversity of products means that overall there is a low concentration of actors in this subsector; small and medium-sized enterprises are common

**Table 6: Greenhouse gas emissions and structure of major manufacturing industries**

Source: UNEP (2009); WRI (2007)

of economic instruments for integrated water resource management (IWRM) in Canada has shown that the use of economic instruments can reduce monitoring costs, but designing them properly and setting them at appropriate levels requires that federal and provincial environmental regulators use economic analysis (such as cost-benefit or cost-effectiveness analysis).

In regulating acid-rain emissions, the US was a pioneer in introducing an emission-trading scheme to reduce SO<sub>2</sub> and NO<sub>x</sub> emissions (1990 Clean Air Act), whilst the EU introduced a regulatory approach through its Large Combustion Plant Directive (1989). In 2005, the EU activated the first region-wide emissions trading scheme (a cap-and-trade system) to meet its Kyoto commitments under the climate change convention (UNFCCC). The scheme has shown the complications regulators face in introducing emission trading schemes through either “grandfathering” (free allocation based on existing emissions by industries) or auctioning. Whilst initial over-allocation in the EU ETS resulted in a zero-carbon price, allocation rather than auctioning would tend to be preferred by heavy industries such as aluminum and steel that face direct international competition. Compared to command-and-control instruments such as licensing and technology standards, emissions trading can perform better in terms of criteria such as cost-effectiveness, long-term effects and dynamic efficiency, i.e. promoting ongoing improvement. Experience in the climate field has shown that the cost-effectiveness of trading systems can be determined by the visibility and robustness of the goal and the system, the effectiveness of the carbon price and the effectiveness of the constraint (Buchner et al. 2009).

Manufacturing industries based in developing countries can be introduced to credit and trading schemes through industry sector initiatives and project-based activities such as the Clean Development Mechanism (CDM) under

the UNFCCC. Provided that procedures under the CDM or similar type mechanisms are streamlined to reduce transaction costs, it can provide a promising avenue for greening manufacturing in developing countries. By 2010, many CDM projects involved investment in renewable energy technologies but a much smaller number involved investment in energy efficiency and fuel switching. These are important areas for transformative investments in manufacturing; these are areas where real opportunities can be taken, if technology standards are to be applied with reference not only to individual projects but also industry sector-wide best practice.

Sectoral approaches to climate action have received considerable attention as second best option (as opposed to global cap and trade) for introducing economic instruments and policies to reduce GHG emissions, in particular implying manufacturing industries world-wide. Economic factors to consider in the introduction of sector approaches in developing countries include the following (UNEP 2009):

- Nature of the adjustment costs associated with reducing emissions;
- Potential for avoiding capital lock-in;
- Nature of technical capacity within specific sectors and countries; and
- Availability of access to appropriate data and technology.

Some have argued (Bodansky 2007) that a few industry sectors stand out as ideal candidates for climate initiatives – being large, homogenous, highly concentrated and highly competitive (Table 6). These include aluminum, steel, cement, transport and power generation. The

cement industry, although also relatively homogenous and highly concentrated among countries, includes many smaller producers and is less subject to competitiveness issues than aluminum and steel. Emission targets could be defined for a given sector, with emissions allowances being allocated to individual emitters within that sector, and with trading allowed between countries participating in the agreement and/or with countries with economy-wide or other sectoral targets. Even if not introduced at international level, the debate on sector approaches provides important lessons for developing country governments in introducing climate policies with competitive, high impact industries in a step-by-step manner. This is particularly important to industrialising countries that host major emitting industries discussed in this chapter, notably China, India, Brazil, South Africa, Indonesia, Thailand, Chile, Argentina and Venezuela. The analysis of using market instruments through sector approaches also shows the flaws of introducing approaches that target only high emitting industries on a sector basis, as opposed to full value chains of supply and demand with these and other industries implied.

### **Fiscal instruments and incentives**

Fiscal policy, comprising public expenditure, subsidies and taxation, can provide powerful incentives that alter the basic cost-benefit calculation of producers and consumers, thus driving change in behavior from BAU. Taxes are unrequited in the sense that the benefits provided by government to taxpayers in exchange are not necessarily in proportion to their payments. Tax exemptions can be made for specific products or industry sectors. Tax revenues can be earmarked for a specific purpose, which may or may not relate to the field of activity that was taxed in the first place. An example would be a tax on landfills or plastic bags, the revenues of which is used for waste management infrastructure or other purposes. By 2009, the Government of South Africa was expecting revenue of US\$ 2.2 million from its plastic bag levy (Box 2), income that was due, among others, to support development of the local waste management industry. In 2010 the Government of India announced a carbon tax on coal production, from which it was expecting to raise US\$ 535 million and planning to use the revenue for investment in clean energy (Pearson 2010).

Historical research by the OECD has found that most of the taxes identified in member countries were levied on a specific tax base related to energy, transport and waste management. In designing different types of taxes, governments need to consider case-by-case the nature of the target industry involved. In its latest survey, the OECD (2010a) noted that taxes levied closer to the actual source of pollution (e.g. taxes on CO<sub>2</sub> emissions versus taxes on motor vehicles) leave a greater range of possibilities for innovation, mindful of complications where sources are dispersed and varied.

By the end of the 1990s, the OECD (1999) noted from a survey of its members an increasing use of environment-related taxes for pollution control, raising revenues of up to 3 per cent of GDP and a growing percentage of overall tax revenues. A decade later, the OECD (2010a) confirmed a growing movement towards environmentally related taxation and tradable permits in OECD economies, underlining the value of green taxes to boost innovation as could be seen in evidence of increased investment in R&D and registration of patents on new, cleaner technologies. In 2010, the OECD also reported that revenue from environmentally-related taxation has been gradually decreasing over the past decade relative to both GDP and total tax revenue. This trend is driven mainly by motor-fuel taxes, which still accounted for the vast majority of environmentally-related tax revenue. In many countries, these have increased fuel prices to sufficiently high levels to have greatly moderated the demand for motor fuels. It did foresee that additional revenue from carbon taxes and from the auctioning of tradable permits may increase the role of environmentally-related taxation in government budgets.

Stimulus packages introduced by governments following the global financial crisis have included new subsidies for greening industry and cleaner technologies. In addition to its total stimulus package of US\$ 586 billion, of which an expected 34 per cent was devoted to green investments, China announced solar subsidies to help local manufacturers which face a drop in international demand. The car industry worldwide has benefitted from US\$ billions of emergency bail-out loans, scrappage subsidies and consumer subsidies. In China, the world's largest car market today, the Ministry of Finance announced that it will offer substantial subsidies for the purchase of green cars and financing for the construction, in five cities, of the infrastructure for charging cars with electric power (Waldmeir 2010). It would offer up to Rmb 50,000 (US\$ 7,800) in subsidies for the purchase of plug-in hybrid electric vehicles and Rmb 60,000 (US\$ 9,400) for pure electric vehicles in cities such as Shanghai. The level of subsidy would be reduced after carmakers sold 50,000 green cars.

The subsidisation of green cars raises questions about its relative priority, compared with public transport vehicles and systems. A range of historical subsidies have prevented transformative investments in manufacturing since fuel prices did not reflect the cost of externalities and they resulted in a perverse principle of "the polluter being paid". Greening industry, therefore, also needs to involve the abolishment of perverse direct and indirect subsidies on resource use that allow favored groups access to free water, free use of the environment for purposes of waste disposal, or cheap electricity and fossil fuels well below regular market prices. It is increasingly important to reflect the full economic and social costs of such use. Where this is politically impossible or otherwise

## Box 2: Taxing plastic bags in an emerging market – The case of South Africa

Plastic bags have attracted increasing environmental concern over the last decade, visibly known for their role in littering roadsides, clogging sewer drains and getting ingested by animals and marine life. A number of countries have started to tax their usage or ban plastic bags. At a time when China decided to ban free plastic bags in 2008, the Worldwatch Institute reported that people in China used up to 3 billion plastic bags daily and disposed of more than 3 million tonnes of them annually. It signaled estimates that China refines nearly 5 million tonnes (37 million barrels) of crude oil each year to make plastics used for packaging.

In 2003, South Africa became one of the first countries to introduce a plastic bag levy that targets consumers directly. It addressed the thin plastic bags with handles typically distributed in retail outlets. The regulation tabled under the Environmental Conservation Act noted that the bags are indiscriminately dumped and not collected because the thin plastic film they are made of has little commercial value. It added that the problem is severe in low-income areas where waste collection services are inadequate. Since 2003, shoppers have to provide their own bags or pay for thicker, recyclable bags. Consumers wanting more information or report retailers who are not in compliance have the option of dialing a hotline number run by the Department of Environmental Affairs. Consumers could re-use the thicker plastic bags, paying up to 25 cents for the 10-litre plastic bag, 31 cents for the 12-litre bag and 49 cents for the 24-litre bag. The thickness of the bag was lowered in a compromise agreement with industry. Some retailers agreed to lower food prices in order to compensate poor consumers for the extra expense of the new bags.

The proposed regulation caused extensive debate, involving environmentalists, consumer organizations, industry and labour unions. Developmental considerations included the position of poor households in rural areas, who more typically use plastic bags available free of charge, and the concerns of workers involved in the manufacturing, packaging and retail industries. Business and unions raised concerns about jobs, income and equipment loss as well as the need to have a holistic approach to waste management rather than targeting a single product. Education, awareness and strong anti-litter penalties were proposed by industry and labour as appropriate responses to the problem of plastic shopping bags waste rather than regulation. A study commissioned by the National Economic Development and Labour Council examined possible impacts of the proposed regulation on investment, employment (including job losses or creation, shifts in skills profiles), distortions in the market (including supply and demand balances and between different products due to the focus on one part of the packaging industry), and industry (e.g. petrochemicals and plastics). The study warned of a possible close-down of the local plastic-bag manufacturing industry, with consequent job losses. It also showed, using recovery economics, that an effective stimulus to local recycling is dependent on addressing constraining factors such as the need to create additional demand in the local market for recycled polymer.

Debates emerged around the need to promote locally made facilities producing two alternatives, namely a Green Bag and Biodegradable Plastic Bag. The case showed the importance of finding reliable life cycle inventory data to compare the environmental impacts

not feasible, a distant second-best solution is to allow accelerated depreciation and relatively low taxes on investments in renewable energy and resource-efficient technologies. As a rule, subsidies should really only be used in case of the clear existence of positive externalities and possibly in support of infant industries.

Green manufacturing can also be supported by *financial instruments* such as revolving funds, green funds, insurance funds, soft loans and other forms of green subsidies. Providing rewards rather than penalties, green subsidies and feed-in tariffs can be important instruments to boost cleaner technologies and green products, as well as waste prevention and recycling schemes. Technology-specific instruments such as green subsidies can help

to unlock and guide alternative technology paths. This needs to be combined with appropriate regulation such as carbon taxes. Governments can also develop national financing mechanisms that would favour providing loans to those small and medium-sized enterprises (SME) that are willing to improve their resource efficiency but have limited access to financing from commercial banks. Such funding mechanisms could be operated using revenue generated through environmental taxes.

### **Voluntary action, information and capacity building**

In its analysis of environmental policy mixes, the OECD (2007) has argued that in the case of “multi-aspect” environmental problems, policy-makers should supplement instruments that address *total amounts* of pollution with instruments



of paper, plastic and cloth carrier bags. A factor in the analysis is different environmental criteria applied, criteria such as primary energy consumption, resource depletion, acidification, nutrient enrichment, ecotoxicity, air and water emissions. Those in favour of paper bags argue that while increased demand for paper bags could lead to more deforestation, paper grocery bags used in many countries today are increasingly made from recycled content.

The environmental levy is one way to make consumers more sensitive to the implications of excessive plastic bag consumption. The question is whether charges for the polluting product should be applied as producer taxes, as behavior-related charges (e.g. returning for recycling deposits) or as simple consumer charges. Experience shows that if, as was the case in Ireland, the levy on plastic bags was set high enough, success was more certain. If however, the levy was set too low, as happened in South Africa, it is not effective in the long term in promoting recycling. To be effective, changes in the price should be large, obvious increases and not small increments. This is the lesson Botswana learned in subsequently following the Irish example, having greater impact with an approach that ensured constant high prices of plastic bags, so that the initial significant decline in consumption continued.

Analyses of the results in South Africa suggest that plastic bag demand is relatively price inelastic, implying that instruments based on price alone would have limited efficacy. While the combination of standards and pricing successfully curbed plastic bag use in the short run, the effectiveness of the legislation may be declining over time. This does not imply that price regulation is necessarily less effective

than voluntary action by industry. Rather, the low recovery rate for plastic bags relative to the other packaging sectors can be explained by the differing characteristics of the plastic bags that make them less amenable to recycling. Factors such as their lower value per unit and relative lack of post-recycling applications, implies that they have a low recycling value relative to other waste streams. Regulation therefore has a special role in cases where the material in question has little inherent recycling value, leaving little incentive for industry to take the initiative. Where regulatory initiative is taken, the level of pricing and combination with other factors such as infrastructure and awareness-raising will be decisive.

South African government officials consider the regulation a success and have started implementing similar initiatives to regulate other waste products such as used tyres, oil and glass, confirming a trend towards waste product regulation. The example inspired other countries such as neighbouring Botswana. It also sparked debate about government use of the revenue, and how it could be used to boost the local waste management industry. In addition, it displayed the challenge government faces in introducing a common tax that impacts households of very different income levels. By 2009, in his budget review, the Minister of Finance announced an increase in the levy on plastic bags and the introduction of a levy on incandescent light bulbs targeting local manufacturing and imports. The plastic-bag levy was expected to generate US\$ 2.2 million while the incandescent light bulb levy was expected to generate US\$ 3 million.

Sources: Dikgang and Visser (2010); Fund for Research into Industrial Development, Growth and Equity (2001); Hasson, Leiman and Visser (2007); Nahman (2010); Nhamo (2005); and Yingling Liu (2008)

that address *the way* a certain product is used, *when* it is used, *where* it is used, etc. In these cases, regulatory and information instruments are often better suited than for example introducing taxes or credit trading systems. Information instruments can take a variety of forms, including product information, labeling and reporting.

Public institutions can support the validation and harmonization of eco-labeling schemes, and establish consumer awareness and education programmes to ensure consumers are able to make informed decisions and recognise newly introduced labeling and product information schemes. A recent study for the Ethical Trade Fact-finding Process (ETFP) Group including Consumers International, ISEAL and others, found that the

regulation of (environmental) marketing claims is, and self-regulation seems to be becoming, more common (Symbeyond Research Group, 2010).<sup>13</sup> In recent years, national eco-labelling schemes have been initiated in Brazil, China, India, South Africa, Indonesia, Thailand and Tunisia.<sup>14</sup> In addition to introducing such schemes

13. The Eco-label Index database keeps track of 373 eco-labels operating in 25 industry sectors and countries world-wide. Available at [www.ecolabelindex.com/](http://www.ecolabelindex.com/)

14. By 2000, 43 countries – mostly in Europe and Asia – had household appliance efficiency programmes in place, seven times as many as in 1980. Standards “push” the market by requiring manufacturers to meet minimum standards. They are well complemented by eco-labeling programmes, which “pull” the market by providing consumers with information to help them make responsible purchasing decisions, and hence encourage manufacturers to design and market more eco-friendly products (Worldwatch Institute 2004).



in collaboration with the private sector, the public sector can also lead by example and support recognised green labeling schemes and standards through its own sustainable public procurement programmes.

Governments can introduce support programmes with special focus on cleaner production or eco-efficiency, targeting specific sizes of companies or specific industries. An example is the provision of management and technology assistance to assist SMEs in exploiting opportunities for increased resource use efficiency and recycling.<sup>15</sup> Another example would be public-private partnerships for the disassembling and collection of e-waste in socially and environmentally beneficial ways in developing countries that have a comparative advantage in this industry. In addition to creating employment and decent work that meets recognised occupational health and safety standards, a formalised and advanced system of collecting and recycling e-waste can also boost the rate of recovery.

Public institutions can support R&D, revised educational curricula and training programmes to promote cleaner processes and systems, eco-design, products and services. Faced with possible job losses, training needs in the heavy manufacturing industries include training related to change in production processes (energy and resource efficiency, recycling, hazardous waste management), environmental impact assessments, skills upgrading for technicians and retraining into other heavy industries (Strietska-Illina et al. 2010); Martinez-Fernandez et al. OECD 2010).

Self-regulation in the form of voluntary initiatives by manufacturing industries includes longstanding initiatives such as Responsible Care by the chemicals industry, with participants from over 50 countries. As of 2004, the International Council of Chemical Associations and its members developed a Global Product Strategy to improve the global chemical industry's product stewardship performance. Since the 1990s, manufacturing industries have been involved in a range of voluntary initiatives started with the aim to fulfill or exceed standards set by legislation. The trigger for these has often been shock events such as industrial accidents during the 1980s. Voluntary initiatives by manufacturing industries can be complemented by public-private partnerships to facilitate dialogue with governmental bodies. A recent example is the Strategic Approach to International Chemicals Management (SAICM), a policy framework which promotes chemical safety around the world.

In the last decade, many industry voluntary initiatives introduced more systematic stakeholder engagement practices, monitoring and disclosure through reporting requirements. The reporting guidelines of the Global Reporting Initiative have been supplemented by sector specific guidance developed with the mining and metals, automotive manufacturing, telecommunications, apparel and footwear industries. Reporting on strategic management approach by these industries provide an opportunity for investors and other stakeholders to discuss with management what greening the relevant industry entails.

From an overview with 22 industry groups of progress made since the 1992 Rio Summit with sustainable business practices, UNEP (2002) among others recommended that voluntary initiatives be made more effective and credible as a complement to government measures. In an update of this review five years later, UNEP (2006) received report cards from 30 industry groups including the manufacturing sectors covered in this chapter. Industry groups reported voluntary initiatives for promoting awareness and integration of sustainability concepts into their daily operations as well as initiatives related sustainability reporting. Many industries reported the development of sector-specific voluntary standards. Some of these were developed in consultation with regulatory authorities (e.g. the automotive sector's fuel-efficiency standards in Europe). Few referred more specifically to certification and labelling initiatives, as was done by the pulp and paper industry.

The reporting process facilitated by UNEP (2006) showed growing interest in measurement of progress in greening industry. Use of and reporting against agreed indicators at industry sector level can help to fill the gap between national, macro level and company, micro level indicators. The Iron and Steel Institute, for example, reported agreement by its Board on the use of 11 indicators, which resulted in a collective report for which 44 member companies provided data.<sup>16</sup> The International Aluminium Institute reported agreement by its members to twelve sustainability objectives supported by 22 indicators. It developed a material resource mass-flow computer model to identify future recycling flows. The model projected that global recycled metal supply from post-consumer scrap will double by 2020 from a 2004 level of 6.7 million tonnes. It undertook to report annually on its global recycling performance.

15. UNEP and UNIDO have been supporting such approaches through a growing network of National Cleaner Production Centres in developing countries. Available at [www.unep.fr/scp/cp/network/](http://www.unep.fr/scp/cp/network/)

16. The four economic indicators were: investment in new processes and products, operating margin, return on capital employed and value-added. The five environmental indicators were: greenhouse gas emissions, material efficiency, energy intensity, steel recycling and environmental management systems. The two social indicators were: employee training and lost time injury frequency rates (UNEP 2006).

## 7 Conclusions

This chapter provides an overview of a number of greening opportunities in the manufacturing industries, focusing in particular on sub-sectors that are main contributors to GHG emissions globally and that have high impact by virtue of their broader contribution to global resource use, associated environmental impacts, GDP and employment. It notes the growing importance of manufacturing to developing countries, responsible for 22 per cent of global GDP by 2009.

*The analysis has shown challenges manufacturing faces, highlighting the costs and risks of inaction and an illustrative BAU scenario to 2050. In major economies, the external costs of air pollution—mainly in the form of health costs—could be well over 3 per cent of global GDP. The possible future scarcity of some natural resources, for example growing dependency on water, poses risks associated with operations, markets, finance, regulations and reputation. Reserves of easily accessible oil are being depleted. While global demand for metals such as copper and aluminium is increasing, high quality metal ores are gradually being depleted. Increasing resource scarcities put upward pressure on commodity prices and on the manufactured products for which they are used as inputs.*

While progress is being made in responsible chemicals management, concerns persist about the lack of thorough evaluation of the effects on human health and environment of thousands of chemicals on the market. The case of three toxic metals—mercury, lead and cadmium—show the challenges that globalisation and trade brings; metal is often sourced in one region of the world, refined in a second, incorporated into products in a third, and disposed of in yet another region. These realities challenge large corporations and their supply chains to improve traceability and safe management practices globally. Recent industrial accidents provide stern reminders of the costs of unsafe practices in the management of hazardous substances.

Real opportunities for manufacturing lie in taking a life cycle approach to its logical consequences and pursuing supply and demand side strategies to close the resource use cycle in manufacturing. Such strategies could enable even rapidly industrialising economies to decouple environmental damage from economic growth and improve their longer term competitiveness. At the industry level, the greening transformation involves a value chain that starts with the re-design of products, production systems and business models, and leads to extended producer responsibility in the form of take-back or reversed supplies, remanufacturing and

recycling on a scale not seen before. The case of metal stocks in our economies is illustrative. While only a few metals currently have an end-of-life recycling rate of above 50 per cent, many opportunities exist that can help to improve recycling rates and increase secondary production, which requires potentially only a fifth of the energy and causes up to 80 per cent fewer GHG emissions than primary production.

*Investment strategies for greening manufacturing highlighted investment in cleaner technologies and innovation, associated benefits in efficient use of energy and water, investment in a transition towards green jobs and likely prospects for resource efficient growth in developing markets. Following years of automation and related cuts in manufacturing jobs, the greening of manufacturing will not generate jobs in all sectors. However, recycling and re-manufacturing have considerable potential to create jobs. There will also be more skilled jobs in energy-service companies, in repair and maintenance and in recycling scarce materials. Government training programmes to upgrade skills will be needed in virtually all countries, but the kinds of skills required will vary according to the level of development of the local industry.*

Results of the simulations indicate that investing in greening the manufacturing industries will help reduce energy consumption and emissions, reduce the upward pressure on prices of fossil fuels and – through avoided energy costs – help boost productivity and profit whilst stimulating GDP and overall employment. From the sectors covered in this chapter, the chemical and plastics industry shows the greatest potential for energy savings. To track progress in how a green investment scenario evolves, governments need to begin to collect improved data on industrial resource efficiency.

Overall, there is abundant evidence that the global economy still has untapped opportunities to produce wealth using less material and energy resources. It is important to understand though that increasing resource efficiency is consistent with almost any definition of green, whereas cutting carbon or other GHG emissions per se may not be consistent with increased efficiency. An example of this is CCS technology, which is very energy intensive and resource inefficient. In sharp contrast, the wider implementation of comprehensive efficiency incentives, recycling, and CHP, together with closed-cycle manufacturing (repair, renovation, remanufacturing and recycling), will correspondingly increase resource efficiency. In many cases this could

reduce extraction and processing costs, thereby supporting economic growth.

*Discussion on the enabling environment highlight two recommended policy priorities, namely closed-cycle manufacturing with supportive infrastructure and regulatory reform to enable factor efficiency improvements in energy use through greater use of cleaner technologies like CHP. Governments should seek ways to encourage closed-cycle manufacturing, for example, by encouraging large multinational systems integrators which manufacture aircraft, automobiles, home appliances, electronic goods, etc. to be responsible for integrated materials management throughout the entire supply and demand chain– from the point of extraction to final disposal. The main objective must be to make manufactured goods last longer, by means of greater emphasis on re-design, repair, reconditioning, re-manufacturing and recycling. Extended producer responsibility (ERP) laws, refundable deposit schemes, and improving the functioning of markets for secondary raw materials are the most likely tools for getting started.*

*Each country will need to consider its appropriate policy mix of regulatory instruments and approaches to make the transition happen, mindful that basic physical processes and damaging impacts associated with pollution and unsustainable resource use are universal.<sup>17</sup> As major point sources of pollution, the manufacturing industries have traditionally been easy targets of command-and-control regulations. In some cases these need reform, in others new ones are required to scale up transformation. Command-and-control regulations need however to be better combined with market-based approaches, allowing appropriately structured markets to reflect the real price of energy and other resources and allowing*

manufacturing industries to innovate and compete on a fair basis. Recent history shows that the introduction of taxes can be a strong driver for technology innovation (petrol taxes and vehicle engine technology). Use of economic instruments can also reduce monitoring costs for regulators, but requires a willingness to undertake thorough economic analysis on their likely costs, benefits and effectiveness in order to design them correctly.

The concentration of certain heavy industries in some countries, as well as the dominance of their markets by a core group of corporations may point to opportunities for advancing climate mitigation strategies with an industry-sector approach, even if only on a national basis. This may be a way of addressing competition concerns and avoiding capital lock-in by industrialising countries in outdated technologies. At the same time, crediting and trading schemes is likely to offer greater economic efficiencies if introduced across industries. This can also be explored throughout global supply chains by using CDM-type projects to share cleaner technology applications among developed and developing markets.

Governments will also need to consider ways of supporting the greening of manufacturing through *institutional support and soft technology approaches*, for example, education and training in areas such as cleaner production and considering smaller, supplier enterprises in particular. Institutional support can vary from the financial, ensuring the provision of green subsidies and loans, to the provision of infrastructure, ensuring appropriate systems for deposit refunding, waste recovery, recycling and distribution. Scaled-up investment in establishing eco-industrial parks can be a key building block in this, an area open for public-private partnership. Voluntary initiatives by manufacturing industries over the last ten years have shown growing willingness to measure and communicate relevant performance and discuss with investors and other stakeholders what indicators to use in the process. Greening national economies and markets require reliable methodologies underlying these and similar efforts to communicate performance via green product labels and certification schemes.

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17. During the annual UNEP Business & Industry Global Dialogue on 11-12 April 2011, manufacturing industry representatives agreed on the need for a predictable regulatory framework, enabling long-term strategic thinking and longer-term investment, as precondition for business and industry to contribute to a “step” or transformative change that goes beyond existing voluntary industry initiatives. At the same time, it was stressed that regulation needs to be applied to local context, considering local approaches and social circumstances.

# References

- ABB Switzerland Ltd., Azucarera Hondurena S.A., (2008). "ACS 1000 variable speed drives help to increase revenues at sugar plant." Available at: [http://www04.abb.com/global/seitp/seitp202.nsf/0/316e45d4d67ae21bc125751a00321e72/\\$file/Sugar+mill+case+study.pdf](http://www04.abb.com/global/seitp/seitp202.nsf/0/316e45d4d67ae21bc125751a00321e72/$file/Sugar+mill+case+study.pdf).
- Austin, D. (1999). "Economic Instruments for Pollution Control and Prevention – A Brief Overview." World Resources Institute, Washington, D.C.
- Ayres, R.U. and Ayres, H. (2010). *Crossing the Energy Divide: Moving from Fossil Fuel Dependence to a Clean-Energy Future*. Wharton School of Publishing, Upper Saddle River, NJ.
- Ayres, R. U. and Warr, B.S. (2005). "Accounting for growth: The role of physical work." *Structural Change & Economic Dynamics*, 16, 2, 181-209.
- Ayres, R.U. and Warr, B.S. (2009a). *The economic growth engine: How energy and work drive material prosperity*. Edward Elgar Publishing, Cheltenham, UK; Northampton, MA.
- . 2009b. "Energy efficiency and economic growth: The "rebound effect" as a driver." in H. Herring and S. Sorrell (eds.). *Energy Efficiency and Sustainable Consumption*. Palgrave MacMillan, London.
- Ayres, R. U., Ayres, L.W. and Rade, I. (2003). *The Life Cycle of Copper, Its Co-Products, and Byproducts*. Kluwer Academic Publishers, Dordrecht.
- Ayres, R.U. , Ayres, L.W. and Warr,B.S. (2004). "Is the US economy dematerializing? Main indicators and drivers." in M. A. Janssen and J. C. J. M. v. d. Bergh (eds.). *Economics of industrial ecology: Materials, structural change and spatial scales*. MIT Press, Cambridge, MA.
- Black, A. (2008). Challenges, "Drivers and Barriers to Eco-Innovation – A UK context." Paper read at Eco-Innovation Workshop, 12 November 2008, Brussels.
- Bleischwitz, R. (2010). "International economics of resource productivity: relevance, measurement, empirical trends, innovation, resource policies." *International Economics and Economic Policy* 7, 2-3, 227-244.
- Bleischwitz, R. and Steger, S. (2010). "Drivers for the use of materials across countries" *Journal of Cleaner Production*, Vol 18 / 10.
- Bleischwitz, R. et al. (2009). "Outline of a resource policy and its economic dimension" in Bringezu, S. and Bleischwitz, R. (eds). *Sustainable resource management: trends, visions and policies for Europe and the World*, 216-296. Greenleaf, Sheffield, UK.
- Bobylev S., Avaliani S., Golub A., Sidorenko V., Safonov G., Strukova E. (2002). "Macroeconomic Assessment of Environment Related Human Health Damage Cost for Russia." A working paper, Moscow.
- Bondansky, D. (2007). *International Sectoral Agreements in a Post-2012 Climate Framework, A Working Paper*. Pew Center on Global Climate Change.
- Braungart, M and McDonough, W. (2008). *Cradle to Cradle. Re-making the way we make things*. Vintage Books, London.
- British Petroleum (BP). (2010). "BP Forms Gulf of Mexico Oil Spill Escrow Trust." 9 August 2010, Available at: <http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7064316>.
- Buchner, B. and Baron, R. (2009). "The cost-effectiveness of climate policy: beyond emissions trading" in *Climate Change: Global Risks, Challenges and Decisions*. IOP Conf. Series: Earth and Environmental Science 6 (2009) 232006.
- Campbell, Colin J. (2004). *The coming oil crisis*. Multi-Science Publishing Co., Brentwood, UK.
- Campbell, Colin Laherrere, J.H. (1998). The end of cheap oil. *Scientific American*, 278, 3, 60-65.
- Cleveland, C. J., Costanza, R., Hall, C. A. S., Kaufmann., R.K. (1984). Energy and the US economy: A biophysical perspective. *Science*, 255, 890-897.
- Coalition for Environmentally Responsible Economies (CERES) et al. (2010). Corporate Reporting on Water Risk. Ceres, Boston.
- DeSimone, L.D. and Popoff, F. (1997). *Eco-Efficiency: The Business Link to Sustainable Development*. MIT Press, Cambridge, MA.
- Dikgang, J. and Visser, M. (2010). "Behavioral Response to Plastic Bag Legislation in Botswana." Environment for Development Discussion Paper Series. Resources for the Future, May 2010, EFD, DP, 10-13, Washington, D.C.
- EEA, European Environment Agency. (2005). *The European environment: State and outlook*. European Environment Agency, Copenhagen.
- Ehrenfeld, J. R. and Gertler, N. (1997). "Industrial ecology in practice: the evolution of interdependence at Kalundborg." *Journal of Industrial Ecology*, 2, 1, 67-79.
- Energy Foundation Ghana, (1999). "Reducing Energy Cost through Integrated Energy Management: The Ghana Textile Printing Company Ltd." Available at: <http://www.ghanaef.org>.
- European Chemical Industry Council. (2004). "Chemical Industry 2015: Roads to the Future." Cefic, Brussels.
- European Commission (CEC) (2007). "Links between the environment, economy and jobs." GHK, London.
- European Commission DG Environment. (2008). "The use of differential VAT rates to promote changes in consumption and innovation." IVM Free University of Amsterdam et.al. 25 June 2008.
- European Trade Union Confederation (ETUC), ISTAS, SDA, Syndex and Wuppertal Institute. (2007). "Climate Change and Employment. Impact on employment in the EU-25 of climate change and CO<sub>2</sub> emission reduction measures by 2030." ETUC, Brussels.
- Everett, T., Ishwaran, M., Ansaloni, G.P., and Rubin, A. (2010). "Economic growth and the environment." in *MPRA Munich Personal Report Archive*. University of Munich, Munich.
- Fund for Research into Industrial Development, Growth and Equity (FRIDGE). (2001). "Socio-economic impact of the proposed plastic bag regulations." Report prepared by Bentley West Management Consultants for Nedlac, Johannesburg.
- Geels, F. W. (2002). "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study." *Research Policy*, 31, 8-9, 1257-1274.
- Geng, Y., Haight, M., and Zhu, Q. (2006). "Empirical Analysis of Eco-Industrial Development in China." *Sustainable Development (in press)*, Wiley InterScience Online ([www.interscience.wiley.com](http://www.interscience.wiley.com)) DOI: 10.1002/sd.306.
- Gereffi, G., Dubay, K. and Lowe, M. (2008). "Manufacturing Climate Solutions: Carbon- Reducing Technologies and US Jobs." Center on Globalization, Governance & Competitiveness, Duke University, Durham.
- Giuntini R. (2003) OEM Product-Services Institute (OPI). "Remanufacturing: The next great opportunity for boosting US productivity." Gaudette Kevin, Gaudette, K., November 2003, University of Indiana, Bloomington.
- Graedel, T. (2009). "Defining critical materials" in Bleischwitz, R., Welfens, P. and Zhang, Z. (eds). *Sustainable Growth and Resource Productivity*, 99-109. Greenleaf, Sheffield.
- Grande Paroisse - AZF, (2010). Available at: <http://www.azf.fr/nos-actions-apres-la-catastrophe/indemnisations-800240.html>, Accessed on 25 August 2010.
- Greco Initiative. (2009). "Green competitiveness in the Mediterranean; Finding business opportunities through cleaner production." Greco Initiative for Green Competitiveness, Regional Activity Centre for Cleaner Production, Barcelona.
- Government of Medhya Pradesh, Bhopal Gas Tragedy Relief and Rehabilitation Department, (2010). Available at: <http://www.mp.gov.in/bgtrdmp/profile.htm>, Accessed on 25 August 2010.
- Havranek, M. (ed.) (2009). *Urban metabolism - measuring the ecological city*. Charles University Environment Center, Prague.
- Hasson, R., Leiman, A. and Visser. M. (2007). "The Economics of Plastic Bag Legislation in South Africa." *South African Journal of Economics*, 75, 1, 66-83.



- Hauser, W. and Lund, R.T. (2003). "The Remanufacturing Industry: Anatomy of a Giant." Boston University, Boston. Available at: <http://www.bu.edu/reman/>
- Heinberg, R. (2004). *Powerdown: Options and actions for a post-carbon world*. Gabriola Island, B.C. Canada: New Society Publishers.
- International Aluminium Institute. (2010). *Global Aluminium Industry Sustainability Scoreboard*, IAI, London.
- International Energy Agency (IEA). *Annual World Energy Outlook*. Paris: OECD/IEA. Available at: <http://www.worldenergyoutlook.org>.
- International Energy Agency (IEA). (2008, 2010). *Energy Technology Perspectives*. OECD/IEA, Paris.
- International Energy Agency (IEA). (2009a). "The impact of the financial and economic crisis on global energy investment." Paper read at G8 Energy Ministers Meeting, Rome.
- International Energy Agency (IEA). (2009b). *Energy technology transitions for industry: Strategies for the next industrial revolution*. OECD/IEA, Paris.
- International Energy Agency (IEA) and International Institute for Applied Systems Analysis (IIASA). (2009). "Emissions of Air Pollutants for the World Energy Outlook 2009 Energy Scenarios," August 2009.
- International Institute for Applied Systems Analysis (IIASA) Press Release. (2009). "Current GHG emissions pledges leave climate targets in the red." IIASA, Laxenburg. Available at: <http://www.iiasa.ac.at/Admin/INF/PR/2009/2009-09-21.html>
- Index Mundi Commodity Prices. (2010). Available at: [www.indexmundi.com/commodities/?commodity=metals-price-index&months=300](http://www.indexmundi.com/commodities/?commodity=metals-price-index&months=300)
- International Labour Organization (ILO). (2007). "The production of electronic components for the IT industries: Changing labour force requirements in a global economy." Report TMITI/2007. International Labour Organization, Geneva.
- International Labour Organization (ILO). (2009). "General Survey concerning the Occupational Safety and Health Convention, 1981 (No. 155), the Occupational Safety and Health Recommendation, 1981 (No. 164), and the Protocol of 2002 to the Occupational Safety and Health Convention, 1981 - Report of the Committee of Experts on the Application of Conventions and Recommendations." International Labour Organization, Geneva.
- International Labour Organization (ILO). (2010). *Statistical Database*. International Labour Organization, Geneva.
- International Labour Organization (ILO). (2011). *Global Employment Trends 2011: The challenge of a jobs recovery*. International Labour Organization, Geneva.
- Jaffee, A., Peterson, S., Portney, P., Stevens, R. (1995). "Environmental regulations and the competitiveness of US manufacturing." *Journal of Economic Literature*, 33, 1, 132-163.
- Kocabas, A. (2009). "Towards 'Green' Conservation Planning In Istanbul's Historic Peninsula." Mimar Sinan Fine Arts University, Istanbul.
- Kolm, H., Oberteuffer, J. and Kelland, D. (1975). "High-Gradient. Magnetic Separation," *Scientific American*, 233, 46-54.
- Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., Haberl, H. Fischer-Kowalski, M. (2009). "Growth in global materials use, GDP and population during the 20th Century." *Ecological Economics*, 10, 2696-2705.
- Kryzonawski, M., Kuna-Dibbert B. and Schneider J., (2005). *Health Effects of Transport-Related Air Pollution*. World Health Organization, Copenhagen.
- Kuriechan, S.K. (2005). *Causes and impacts of accidents in chemical process industries and a study of the consequence analysis software*, MPhil Thesis, Pondicherry University, India.
- Laitner, J., Gold, R., Nadel, S., Langer, T., Elliott, R.N., Trombley, D. (2010). "The American Power Act and Enhanced Energy Efficiency Provision: Impacts on the US economy." American Council for an Energy Efficiency Economy, Washington, D.C.
- Lund, R. T. (1996). *The remanufacturing industry: Hidden giant*. Boston University, Boston. ([www.bu.edu/reman/](http://www.bu.edu/reman/))
- Lutz, C. and Giljum, S. (2009). "Global resource use in a business-as-usual world up to 2030: updated results from the GINFORS model" in Bleischwitz, R., Welfens, P., and Zhang, Z.X (eds) (2009). *Sustainable Growth and Resource Productivity*. Productivity, 30-42. Greenleaf, Sheffield, UK.
- Mannan, S.P.E. (2009). "Lessons learned from past incidents shed light on present day needs and challenges in process safety." lecture, Available at: [http://chen.qatar.tamu.edu/assets/PDFs/Distinguished\\_Lecture\\_Series\\_-\\_TAMUQ.pdf](http://chen.qatar.tamu.edu/assets/PDFs/Distinguished_Lecture_Series_-_TAMUQ.pdf). Texas A&M University, College Station, TX, USA.
- Markandya and Tamborra, M. (2005). "Estimates of damage costs from air pollution to human health, crops and materials: in *Green accounting in Europe: A comparative study*, 2, 113-225.
- Martinez-Fernandez, C., Hinojosa, C. and Miranda, G. (2010). "Green Jobs and Skills – Labour market implications of addressing climate change (working paper)." OECD Local Employment and Economic Development (LEED) Programme, Paris.
- Mendelsohn, R. and Muller, N. (2007). "Measuring the Damages of Air Pollution in the United States." *Journal of Environmental Economics and Management*, 54, 1, 1-14.
- Metz, B. et al., (eds.). 2005. *IPCC Special Report on Carbon Capture and Storage*: Cambridge University Press, Cambridge, UK.
- Nahman, A. (2010). "Food Packaging in South Africa: Reducing, Re-using and Recycling" in *Government Digest*, February 2010. CSIR Environmental and Resource Economics Group, South Africa.
- Nhamo, G. (2005). *Environmental Policy Processes surrounding South Africa's Plastic Bags Regulation*. PhD thesis. Rhodes University, Grahamstown, South Africa.
- Organisation for Economic Co-operation and Development (OECD). (1999). "Economic Instruments for Pollution Control and Natural Resources Management in OECD Countries. A Survey for the Working Party on Economic and Environmental Policy Integration." OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2007). *Instrument Mixes for Environmental Policy*. OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2008). *Measuring material flows and resource productivity*. OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2008a). *Reconciling Development and Environmental Goals - Measuring the Impact of Policies*. OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2009). *Trends In the Global Steel Market*. OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2010a). *Taxation, Innovation and the Environment*. OECD, Paris.
- Organisation for Economic Co-operation and Development (OECD). (2010b). "Fuels taxes, motor vehicle emission standards and patents related to the fuel-efficiency and emissions of motor vehicles". Joint Meetings of Tax and Environment Experts. OECD, Paris.
- Pearson, N.O. (2010). "India to raise US\$ 535 million from carbon tax on coal." *Bloomberg Businessweek*, 1 July 2010. Available at: [www.businessweek.com](http://www.businessweek.com)
- Perenius, L. (2009). "Global chemical industry: profile and trends." CEFIC presentation of 26 June, UNEP Geneva, Available at: [www.chem.unep.ch/uneppsaimc/mainstreaming/Documents/GCO\\_SteerComm1/LenaPerenius\\_Assessment%20of%20Key%20Resources.pdf](http://www.chem.unep.ch/uneppsaimc/mainstreaming/Documents/GCO_SteerComm1/LenaPerenius_Assessment%20of%20Key%20Resources.pdf).
- Portland Cement Association. (2008). *The 2007 Apparent Use of Portland Cement by State and Market Group, U.S. Summary*. PCA, Skokie.
- Raes, Frank. (2006) *Global Change Newsletter* No. 65, March, 2006, International Biosphere Geosphere Programme.
- Renzetti, S. (2005). "Economic Instruments and Canadian Industrial Water Use" in *Canadian Water Resources Journal*, 30, 1, 21-30.
- Shin, D. (2004). "Price Volatility and LDCs. American Gas Association." Available at: <http://www.netl.doe.gov/publications/proceedings/04/LNG/Davidper cent20Shinper cent20AGA.pdf>
- Strahan, D. (2007). *The last oil shock: A Survival Guide to the Imminent Extinction of Petroleum Man*. John Murray Ltd., London
- Stietska-Ilna, O., Hofmann, C., Duran Haro, M., Jeon, S. (2010). *Skills for green jobs: Global Synthesis Report*. ILO, Geneva.
- Strukova, E., Golub, A. and Markandya, A. (2006). "Air Pollution Costs in Ukraine." FEEM Fondazione Eni Enrico Mattei Research Paper Series, Working Paper No 120.06, Sept, 2006.



- Sustainable European Research Institute (SERI), (2010). "Trends in global resource extraction, GDP and material intensity 1980-2007." Available at: [http://www.materialflows.net/index.php?option=com\\_content&task=view&id=32&Itemid=48](http://www.materialflows.net/index.php?option=com_content&task=view&id=32&Itemid=48)
- Svoboda, J. (2004). *Magnetic Techniques For the Treatment of Materials*. Kluwer Academic Publishing, Dordrecht.
- Symbeyond Research Group. (2010). "Assuring Consumer Confidence in Ethical Standards. Mapping of different initiatives." Report prepared for the Ethical Trade Fact-finding (ETFP) Steering Group. Symbeyond Research, Amsterdam.
- TEEB. (2012). *The Economics of Ecosystems and Biodiversity in Business and Enterprise*. Edited by J. Bishop. Earthscan, Abingdon and New York.
- Tilton, J. E. (2002). *On borrowed time: Assessing the threat of mineral depletion*. European Commission, Brussels.
- Tukker, A. and Tischner, U. (2006). *New Business for Old Europe*. Product Service Development, Competitiveness and Sustainability. Greenleaf Publishing, Sheffield, UK.
- United Nations Economic and Social Commission for Asia and the Pacific. (2009). *Economic and Social Survey of Asia and the Pacific 2009*. UNESCAP, Bangkok.
- United Nations Educational, Scientific, and Cultural Organization. (2009). *Water Development Report 3*. UNESCO, Paris.
- United Nations Environment Programme. (2002). *Industry as a Partner for Sustainable Development. Ten years after Rio: The UNEP Assessment*. Nairobi: UNEP.
- United Nations Environment Programme. (2006). *Class of 2006. Industry report Cards on Environment and Social Responsibility*. UNEP, Nairobi.
- United Nations Environment Programme. (2009). *Industry Sectoral Approaches and Climate Action: From Global to Local Level in a Post-2012 Climate Framework - A Review of Research, Debates and Positions*. UNEP, Nairobi.
- United Nations Environment Programme, Resource Panel. (2010a). *Metals Stocks in Society - Scientific Synthesis*. UNEP, Nairobi.
- United Nations Environment Programme, Resource Panel. (2010b). *Assessing the environmental impacts of consumption and production: Priority products and materials*. UNEP, Nairobi.
- United Nations Environment Programme (UNEP) Sustainable Energy Finance Initiative (SEFI) and Bloomberg. (2010). *Global Trends in Sustainable Energy Investment 2010*. UNEP, Nairobi; Bloomberg New Energy Finance, London.
- United Nations Environment Programme, International Labour Organization (ILO), ICFTU and IOE. (2008). *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*. UNEP, Nairobi.
- United Nations Industrial Development Organization (UNIDO). (2007). *Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies*. UNIDO, Vienna.
- United Nations Industrial Development Organization (UNIDO). (2010). *International Yearbook Of Industrial Statistics 2010*. UNIDO, Vienna.
- United States National Research Council. (2009). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. The National Academies Press, Washington, D.C.
- United States Energy Information Administration. (2009). *International energy outlook*. Washington DC: United States Department of Energy, Energy Information Administration. <http://www.eia.doe.gov/oiaf/ieo/>.
- USGS, United States Geological Survey. (2007). *Minerals yearbook: Volume I Metals and Minerals*. Vol. I. US Department of Interior, Washington, D.C.
- Van den Bergh, J.C.J.M. (2008). "Environmental regulation of households? An empirical review of economic and psychological factors." *Ecological Economics*, 66, 559-574.
- Van den Bergh, J.C.J.M. (2011). "Energy conservation more effective with rebound policy." *Environmental and Resource Economics*, 48, 1, 43-58.
- Van Der Voet, E., Moll, S. and De Bruyn, S. (2005). "Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU- 25 and AC-3 countries." European Commission, Brussels. Available at: [http://ec.europa.eu/environment/natres/pdf/fin\\_rep\\_natres.pdf](http://ec.europa.eu/environment/natres/pdf/fin_rep_natres.pdf).
- Van Oss, H. (2006). "Iron and Steel Slag." US Geological Survey, Reston, VA.
- Von Weizsaecker, E., Lovins, A. and Lovins, L.H. (1997). *Factor Four: Doubling wealth, halving resource use - A report to the Club of Rome*. Earthscan, London.
- Von Weizsaecker, E., Hardgroves, K.C., Smith, M.H., Desha, C., Stasinopoulos, P. (2009). *Factor Five - Transforming the Global Economy through 80 per cent Improvements in Resource Productivity*. Earthscan, London; The Natural Edge Project, Australia.
- Waldmeir, P. (2010). "China offers subsidies to accelerate green car sales" *Financial Times*, 2 June 2010.
- Wan You and Jianguo Qi. (2005). "Long-term Development Trend of China's Economy and Importance of the Circular Economy" *China & World Economy*: 13, 2, 16-25.
- Warr, B.S., Eisenmenger, N., Krausmann, F., Schandl, H., Ayres, R.U. (2010). "Energy Use and Economic Development: A comparative analysis of useful work supply in Austria, Japan, the United Kingdom and the US during 100 years of economic growth" *Ecological Economics*, 69, 10, 1904-1917.
- Water Resources Group. (2009). *Charting Our Water Future*. McKinsey & Company, New York.
- World Bank. (2007). *World Development Report*. World Bank, Washington, D.C.
- World Bank and State Environmental Protection Administration (SEPA), P. R. China. (2007). "Cost of pollution in China economic estimates of physical damages." World Bank, Washington, D.C.; SEPA, Beijing.
- World Bank. (2008). *World Development Indicators 2008*. World Bank for Reconstruction for Development, Washington, D.C.
- World Bank. (2009). *World Development Indicators 2009*. World Bank for Reconstruction for Development, Washington, World Business Council for Sustainable Development (WBCSD). (2010). *Vision 2050: The new agenda for business*. WBCSD, Geneva.
- World Commission on Environment and Development. (1987). *Our Common Future*. Oxford University Press, New York.
- World Health Organization. (2004). *The Global Burden of Disease: 2004 Update*. Available at: [http://www.who.int/healthinfo/global\\_burden\\_disease/2004\\_report\\_update/en/index.html](http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/index.html).
- World Resources Institute. (2005). *Navigating the Numbers*. WRI, Washington, D.C. Available at: [http://pdf.wri.org/navigating\\_numbers.pdf](http://pdf.wri.org/navigating_numbers.pdf).
- World Resources Institute. (2007). *Slicing the Pie: Sector-based Approaches to International Climate Agreements*. WRI, Washington, D.C.
- World Steel Association. (2009). *World Steel Figures*. WSA, Brussels. Available at: <http://www.worldsteel.org/pictures/publicationfiles/WSIF09.pdf>.
- Worldwatch Institute. (2004). *State of the World 2004*. Worldwatch Institute, Washington, D.C.
- Yingling, L. (2008). "China Watch: Plastic Bag Ban Trumps Market and Consumer Efforts". Available at: [www.worldwatch.org](http://www.worldwatch.org), 30 June 2008.







# Waste

Investing in energy and resource efficiency





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## List of acronyms

3Rs	Reduce, Reuse and Recycle	MLF	Multilateral Fund for the Implementation of the Montreal Protocol
ADB	Asian Development Bank	MRF	Material Recycling Facility
BAU	Business-as-usual	MSW	Municipal Solid Waste
BIR	Bureau of International Recycling	NGO	Non-governmental organisation
C&D	Construction and Demolition	NIMBY	Not in my back yard
CBO	Community-based organisation	NRDC	Natural Resource Defense Council
CDM	Clean Development Mechanism	ODS	Ozone depleting substance
CE	Circular economy	OEA	Waste and Resources Action Programme
CEIT	Countries with economies in transition	OECD	Organisation for Economic Co-operation and Development
CER	Certified Emission Reductions	OHS	Occupational Health and Safety
CO <sub>2</sub>	Carbon dioxide	PAYT	Pay-as-you-throw
DBOT	Develop, Build, Operate and Transfer	PFI	Private Finance Initiative
DfD	Design for Disassembly	PPP	Public-private partnership
DfE	Design for Environment	RCRA	Resource Conservation and Recovery Act
EAWAG	Swiss Federal Institute of Aquatic Science and Technology	RDF	Refuse Derived Fuel
EEA	European Environment Agency	RMB	Renminbi, currency in People's Republic of China
EoLV	End-of-life Vehicles	ROI	Return on investment
EPA	United States Environmental Protection Agency	SCRAP	School and Community Reuse Action Project
EPR	Extended Producer Responsibility	StEP	Solving the e-waste Problem
EU	European Union	SO <sub>2</sub>	Sulfur dioxide
E-waste	Electronic waste	TEAP	Technology and Economic Assessment Panel of the Montreal Protocol
FFTC	Food and Fertilizer Technology Center	THB	Thai Baht, currency in Thailand
CER	Certified Emissions Reductions	UNCTAD	United Nations Conference on Trade and Development
GDP	Gross Domestic Product	UNDP	United Nations Development Programme
GHG	Greenhouse gas	UNEP	United Nations Environment Programme
GIS	Geographic Information System	UNFCCC	United Nations Framework Convention on Climate Change
GMS	Greater Mekong sub-region	UNU	United Nations University
GPS	Geographic Positioning System	USGS	United States Geological Survey
HDPE	High Density Polyethylene	VBWF	Volume Based Waste Fee
HSWA	Federal Hazardous and Solid Waste Amendments (USA)	WEEE	Waste Electrical and Electronic Equipment Directive
ICC	International Coastal Cleanup	WtE	Waste to Energy
IFC	International Finance Corporation		
ILO	International Labour Organization		
ILSR	Institute of Local Self Reliance		
IPCC	Intergovernmental Panel on Climate Change		
ISWM	Integrated Solid Waste Management		
LDCs	Least Developed Countries		
LDPE	Low Density Polyethylene		
MBT	Mechanical and biological treatment		
MEA	Multilateral Environmental Agreement		
MIS	Management Information System		

# Key messages

**1. The increasing volume and complexity of waste associated with economic growth are posing serious risks to ecosystems and human health.** Every year, an estimated 11.2 billion tonnes of solid waste are collected worldwide and decay of the organic proportion of solid waste is contributing to about 5 per cent of global Greenhouse Gas (GHG) emissions. Of all the waste streams, waste from electrical and electronic equipment containing new and complex hazardous substances presents the fastest-growing challenge in both developed and developing countries.

**2. The growth of the waste market, increasing resource scarcity and the availability of new technologies are offering opportunities for greening the waste sector.** The global waste market, from collection to recycling, is estimated at US\$ 410 billion a year, not including the sizable informal segment in developing countries. Recycling is likely to grow steadily and form a vital component of greener waste management systems, which will provide decent employment. While currently only 25 per cent of waste is recovered or recycled, under the green investment scenario modelled in the Green Economy Report (GER), the amount of waste destined for landfills would be considerably reduced. These gains, implying the development and expansion of new market opportunities, would be achieved through the doubling of the recycling rate of industrial waste (an increase from 7 to 15 per cent), near full recycling of e-waste (from a current estimated level of 15 per cent), and an increase of about 3.5 times over the current recycling rate of Municipal Solid Waste – the principal source of recycled materials, from 10 to 34 per cent. Furthermore, by 2050, effectively all organic waste would be composted or recovered for energy, compared with 70 per cent under a business-as-usual (BAU) scenario.

**3. There is no one-size-fits-all when it comes to greening the waste sector, but there are commonalities.** Most of the waste management related standards are national or local; however, as a common feature, greening the waste sector includes, in the first instance, minimisation of waste. Where waste cannot be avoided, recovery of materials and energy from waste, as well as remanufacturing and recycling waste into usable products should be the second option. The overall goal is to establish a global circular economy in which material use and waste generation is minimised, any unavoidable waste is recycled or remanufactured, and any remaining waste is treated in a manner least harmful to the environment and human health, or even in a way which generates new value such as energy recovered from waste.

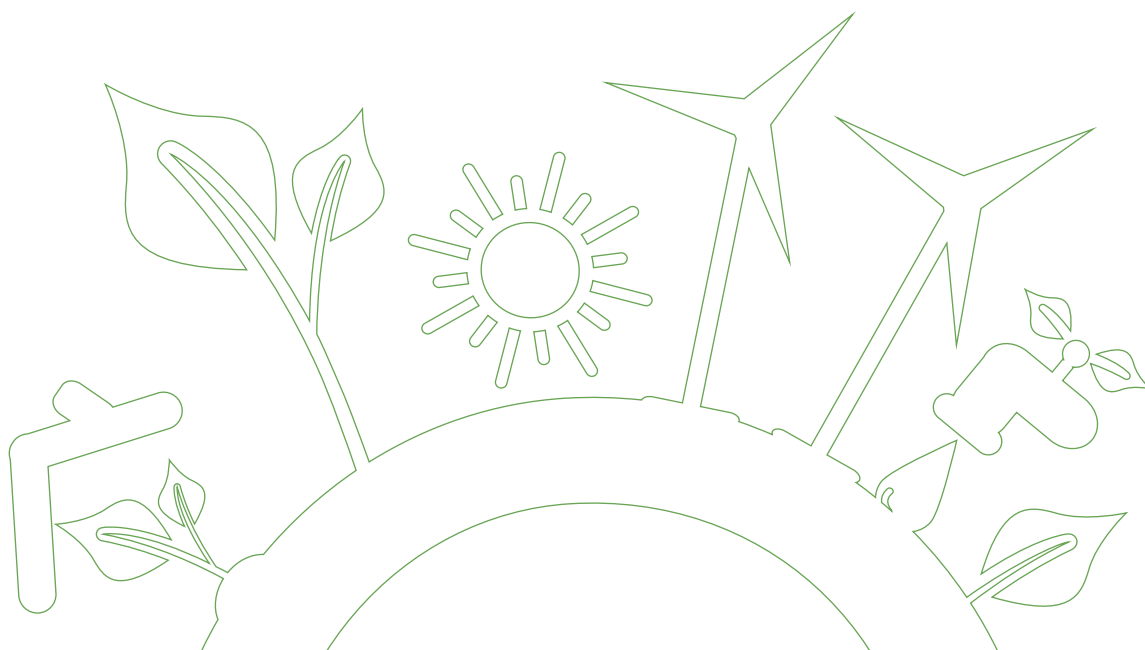
**4. Investing in greening the waste sector can generate multiple economic and environmental benefits.** Recycling leads to substantial resource savings. For example, for every tonne of paper recycled, 17 trees and 50 per cent of water can be saved. By recycling each tonne of aluminium, the following resource savings could be accrued: 1.3 tonne of bauxite residues, 15 m<sup>3</sup> of cooling water, 0.86 m<sup>3</sup> of process water and 37 barrels of oil. These are in addition to the avoidance of 2 tonnes of CO<sub>2</sub> and 11 kg of SO<sub>2</sub> released. In terms of new products, the Waste to Energy (WtE) market was already

estimated at US\$ 19.9 billion in 2008 and projected to grow by 30 per cent by 2014. In terms of climate benefits, between 20 to 30 per cent of projected landfill methane emissions for 2030 can be reduced at negative cost and 30 to 50 per cent at costs of less than US\$ 20/tCO<sub>2</sub>-eq/yr.

**5. Recycling creates more jobs than it replaces.** Recycling is one of the most important sectors in terms of employment creation and currently employs 12 million people in just three countries - Brazil, China and the United States. Sorting and processing recyclables alone sustain ten times more jobs than land filling or incineration on a per tonne basis. Estimations made in the context of this report suggest that with an average of US\$ 152 billion invested in waste collection as part of an overall green investment strategy over the period 2011 to 2050, global employment in waste collection activities by 2050 will be 10 per cent higher in a green economy scenario than projections under BAU. While higher rates of recycling may reduce employment opportunities in extraction of virgin materials and related activities, the overall net employment appears to be positive.

**6. Improving labour conditions in the waste sector is imperative.** The activities of collecting, processing and redistributing recyclables are usually done by workers with few possibilities outside the sector. Thus, despite the potentially significant contribution to employment creation, not all of the recycling and waste management related jobs can be considered green jobs. To be green jobs they also need to match the requirements of decent work, including the aspects of child labour, occupational health and safety, social protection and freedom of association.

**7. Greening of the waste sector requires financing, economic incentives, policy and regulatory measures and institutional arrangements.** Improved waste management and avoided environmental and health costs can help reduce the financial pressure on governments. Private sector participation can also significantly reduce the costs, as well as enhance service delivery. Micro-financing, other innovative financing mechanisms and international development assistance may, in addition, be tapped to support operational costs for waste treatment. A range of economic instruments can serve as incentives to green the sector (such as taxes and fees on waste, recycling credit and other forms of subsidies). Their use could be combined with policies and regulations such as targets for the minimisation, reuse, recycling and displacement of virgin materials in products; regulations relevant to the waste management market; and land-use policies and planning and regulations to set minimum safety standards that protect labour.



# 1 Introduction

This chapter seeks to make an economic case for investing in greening the waste sector and it aims to provide policy-makers with guidance on how to mobilise such investment. It demonstrates how green investment in the waste sector can create jobs and contribute to economic growth, while addressing environmental issues, in a pro-poor and equitable manner.

The environmental and social (including health-related) benefits from greening the waste sector have been stressed already for a long time. The impact of this has, however, been limited, as environmental and social concerns are often seen as competing with economic imperatives. Environmental and social aspects of greening the waste sector are discussed, but the emphasis is on making an economic case based on the available data.

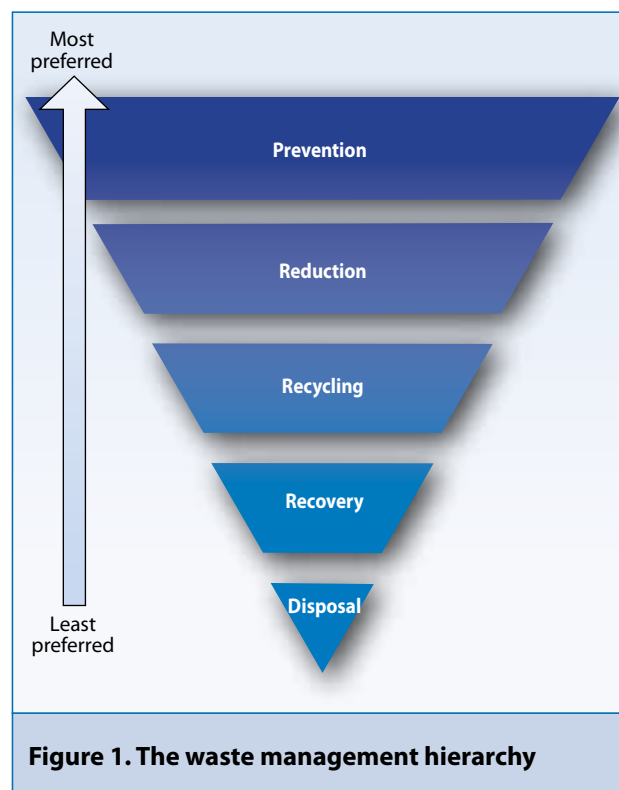
The chapter starts with an explanation of the scope of the waste sector and what is meant by the greening of the waste sector, followed by a discussion of the challenges and opportunities facing the sector. It then discusses the goals for greening the sector and the potential economic implications of additional green investment, including the results from a modelling exercise. Finally, the chapter presents conditions that are important for enabling the greening of the waste sector.

## 1.1 Scope of the waste sector

The waste sector has traditionally referred to municipal solid waste (MSW) and excludes wastewater, which tends to be categorised under the water or industry sectors. The scope of this chapter is therefore limited to management of MSW and special waste streams such as used electrical and electronic equipment as well as vehicles and vehicle parts, construction and demolition waste, health-care waste, and biomass waste or agricultural residues.

## 1.2 Greening the waste sector

Greening the waste sector refers to a shift from less-preferred waste treatment and disposal methods such as incineration (without energy recovery) and different forms of landfilling towards the three Rs: Reduce, Reuse and Recycle. The strategy is to move upstream in the waste management hierarchy, based on the internationally recognised approach of Integrated Solid Waste Management (ISWM) (Figure 1).



**Figure 1. The waste management hierarchy**

The ISWM is a strategic approach to managing all sources of waste; prioritising waste avoidance and minimisation, practicing segregation, promoting the 3Rs, implementing safe waste transportation, treatment, and disposal in an integrated manner, with an emphasis on maximising resource-use efficiency. This marks a departure from the usual approach where wastes are managed mainly from a compliance point of view characterised by end-of-pipe treatment such as incineration (without energy recovery) and landfilling.

Under ISWM, activities of greening the sector can include:

- Resource conservation, which avoids excessive resource consumption;
- Waste reduction through resource use optimisation that minimises resource wastage;
- Waste collection and segregation, ensuring appropriate waste treatment;
- Waste reuse, which circulates waste and avoids the use of virgin resources;
- Waste recycling, which converts waste into useful products;



- Energy recovery, which harnesses residual energy from waste;

- Landfill avoidance, which conserves land and avoids risks of contamination; and

- Construction and maintenance of infrastructure for waste collection, recovery of materials from waste streams (collection and segregation) and application of 3R technologies and associated activities.

Indicators to measure the progress of greening the sector can include:

- Resource consumption rate (material use in kg per capita);

- Waste generation rates (kg per capita/year, overall and by economic sector);

- Proportion of waste being collected and segregated;

- Proportion of materials in waste streams being reused or recycled;

- Proportion of virgin material displacement in production;

- Proportion of waste used for energy recovery;

- Proportion of materials in waste streams diverted from landfill;

- Reduction in greenhouse gas (GHG) emissions due to avoided landfilling;

- Proportion of total waste disposed in landfill; and

- Extent of capture, recovery and/or treatment of polluting emissions such as leachate and landfill gas.

In relation to an overall green economy, indicators of greening the waste sector can include the value of – and jobs related to – the goods generated through the greening of the waste sector such as remanufactured products, recovered energy, and the services in terms of waste collection, segregation, and processing. Economic and social benefits in terms of health, property values, tourism as well as direct and indirect job creation should also be included. Not all of these indicators may, however, be readily available. Proxies are used where possible in this chapter to gauge and estimate the economic significance of greening the sector.

### 1.3 A vision for the waste sector

The long-term vision for the waste sector is to establish a circular global economy in which the use of materials and generation of waste are minimised, any unavoidable waste recycled or remanufactured, and any remaining waste treated in a way that causes least damage to the environment and human health or even creating additional value by recovering energy from waste. To achieve this vision, radical changes to supply-chain management, especially to the product and industrial design part of the supply chain, are needed. Specifically, the 3Rs need to guide industrial design – with implications for materials at all stages – and be overlaid on the entire supply chain. This requirement is, in turn, expected to motivate innovation. The chapter on manufacturing further elaborates on life-cycle approaches, including closed loop and circular systems in manufacturing.

## 2 Challenges and opportunities in the waste sector

### 2.1 Challenges

The waste sector is facing three sets of challenges: 1) increasing growth in the quantity and complexity of waste streams associated with rising incomes and economic growth; 2) increasing risk of damage to human health and ecosystems; and 3) the sector's contribution to climate change.

#### The growing volume and complexity of waste

The exploitation of the earth's resources continues apace; material use increased eight-fold in the last century (Krausmann et al. 2009). According to the Wuppertal Institute, an average European consumes about 50 tonnes of resources a year, around three times the amount consumed per capita by emerging economies. Furthermore, on average, Europeans dispose twice as much as citizens from emerging economies (Bleischwitz 2009). Per-capita resource use in emerging economies is also increasing considerably while the world's Least Developed Countries (LDC) are beginning the transition towards an industrial type of societal metabolism, as incomes rise and purchasing power is deployed in consumer spending.

Currently, 3.4-4 billion tonnes of municipal and industrial waste are produced every year, of which non-hazardous industrial waste accounts for 1.2 billion tonnes (Chalmin and Gailllochét 2009). A major share of the waste generated is MSW originating from urban settlements (1.7-1.9 billion

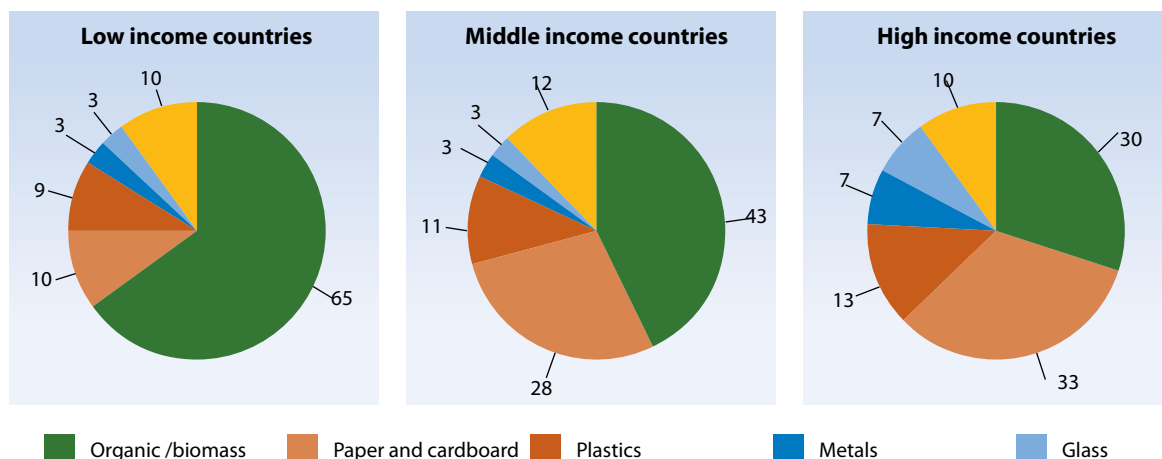
tonnes, or 46 per cent of the total waste generated) with 0.77 billion tonnes of this being produced by 25 Organisation for Economic Cooperation and Development (OECD) countries alone (UNEP 2010).

As a country develops and becomes wealthier, the composition of its waste stream typically becomes more varied and complex. Figure 2 illustrates the high proportion of organic-rich MSW in middle and lower income countries with a gross national income per capita of less than US\$ 12,196, while the high-income countries' MSW streams contain a large proportion of paper and plastics.

Apart from MSW, other major types of waste streams are listed below:

- Construction and Demolition (C&D) waste represents 10-15 per cent of total waste generated in developed countries (Bournay 2006) and some countries have reported a much higher proportions. For example, OECD (2008a) estimated that Germany generates 178.5 million tonnes of C&D waste, which is about 55 per cent of the total waste reported. C&D waste can be classified as high-volume waste with relatively low impact compared with other types of waste.

- End-of-life Vehicles account for 8-9 million tonnes of waste in the European Union (EU) with Germany, UK, France, Spain and Italy responsible for approximately 75 per cent of EU-25 vehicles de-registrations (Eurostat 2010a). Japan



**Figure 2: Composition of MSW by national income**

Source: Chalmin and Gailllochét (2009) and averaged



Quadrant	Economic status and waste generation	Country and year of data	
Q1	GDP: More than US\$ 23,000 Waste: More than 450 kg per capita	USA: United States of America <sup>a</sup> (2006) IRL: Ireland (2004) DNK: Denmark (2005) ISL: Iceland (2004) GBR: United Kingdom (2004)	NLD: Netherlands (2004) DEU: Germany (2004) FRA: France (2004) BEL: Belgium (2002)
Q2	GDP: More than US\$ 23,000 Waste: Less than 450 kg per capita	FIN: Finland (2004) CAN: Canada (2004)	JPN: Japan <sup>e</sup> (2007)
Q3	GDP: Less than US\$ 23,000 Waste: Less than 450 kg per capita	BRA: Brazil <sup>b</sup> (2002) ARG: Argentina <sup>c</sup> (2002) CHN: China <sup>d</sup> (2004) POL: Poland (2005)	CZE: Czech Republic (2005) MEX: Mexico (2006) KOR: Republic of Korea (2002) NZL: New Zealand (1999) TUR: Turkey (2004)
Q4	GDP: Less than US\$ 23,000 Waste: More than 450 kg per capita	AUS: Australia (2002) HUN: Hungary (2004) BGR: Bulgaria <sup>f</sup> (2003)	ITA: Italy (2004) AUT: Austria (2004) ESP: Spain (2004)

Note: US\$ 23,000 represents the median point in the GDP data.

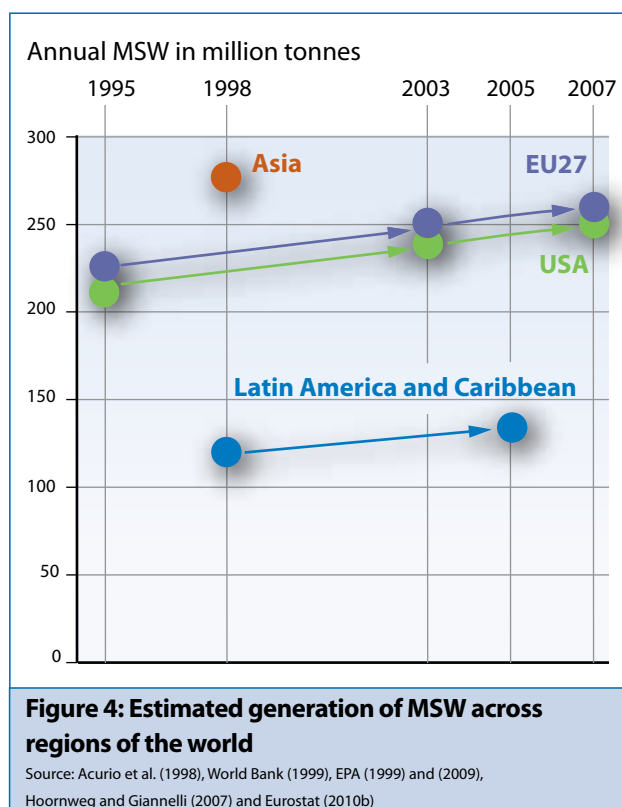
**Figure 3: GDP per capita vs. MSW per capita<sup>1</sup>**

Source: MSW data sourced from <sup>a</sup>EPA (2007), <sup>b</sup>Borzino (2002), <sup>c</sup>Methanetomarkets (2005), <sup>d</sup>World Bank (2005), OECD 2008a and <sup>e</sup>Yatsu (2010) and <sup>f</sup>GHK (2006); Population data available at <http://esa.un.org/unpp/>; GDP data sourced from World Bank.

generates about 0.7 million tonnes of Automobile Shredder Residues (ASR) every year – materials such as plastic, rubber, foam, paper, fabric, glass, etc. that remain to be recycled after the reusable parts of the automobile are removed from shredded EoLV (Kiyotaka and Itaru 2002). In the United States of America, ASR amount to 5 million tonnes annually (EPA 2010).

■ Biomass waste includes agricultural and forestry waste. It is estimated that globally 140 billion tonnes of agricultural residue is generated every year (Nakamura

1. This figure was generated by using latest available data from 27 countries including developed and developing countries from specified sources (using the GDP and population data for the year for which the latest waste data is available).



2009). Like C&D, biomass waste is a high-volume waste with a relatively low impact.

■ Health-care waste is sometimes classified as a subcategory of hazardous waste. No global estimates are available. On average, however, low-income countries generate between 0.5 kg and 3 kg of health-care waste per capita per year, which includes both hazardous and non-hazardous components. High-income countries have been reported to generate up to 6 kg of hazardous waste per person per year from health-care activities (WHO 2010).

■ Electronic waste (e-waste) continues to increase dramatically amid growing global demand for electronic

and electrical goods. It is estimated that in 2004 alone, 315 million personal computers (PC) became obsolete globally and 130 million mobile phones were estimated to have reached their end of life in 2005 (UNEP 2005). The USA produces most electronic scrap, reportedly 3.16 million tonnes in 2008 (EPA 2009). The total e-waste generated worldwide rose from 6 million tonnes in 1998 to 20-50 million tonnes in 2005 (UNEP 2005). Jinglei Yu et al. (2010) predict that obsolete PCs in developing regions will exceed those of developed regions by 2016-2018 and that by 2030 they could amount to 400-700 million units (compared with 200-300 million units in developed countries).

■ Hazardous waste requires special handling and treatment even in low quantities. They may also mix up with the stream of waste generated in the municipal or agricultural sector, for e.g. used batteries, spent paints and residual chemical pesticides as well as Ozone Depleting Substances (ODS) such as refrigerators, air-conditioners, fire extinguishers, cleaning products, electronic equipments and agricultural fumigants. Reports submitted to the Basel Convention suggest that at least 8.5 million tonnes of hazardous waste have been crossing international boundaries every year (Baker et al. 2004).

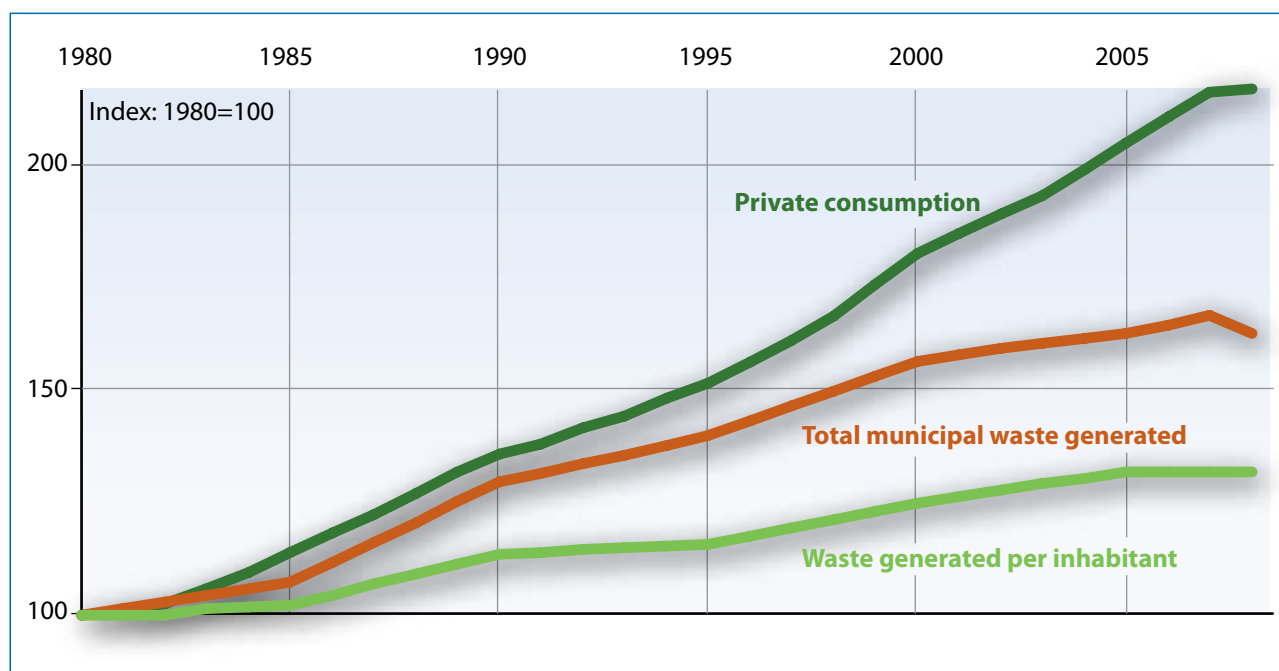
■ Packaging waste and its management has become a major issue in high-income countries. For example, EU15 recorded an increase in packaging waste from 160 kg per capita in 1997 to 179 kg per capita in 2004. According to the European Environmental Agency (EEA 2009), an increase in packaging waste has been observed in both older and newer European Union (EU) member states.

■ Marine litter consists of material discarded directly or indirectly from recreational/shoreline, ocean/waterway, smoking-related, dumping and medical and personal-hygiene-related activities and sources (UNEP 2009a). The International Coastal Cleanup (ICC) study between 1989 and 2007 counted 103,247,609 pieces of waste in the

Countries	Assessment Date	PCs	Printers	Mobile phones	TVs	Refrigerators	Total
South Africa	2007	19,400	4,300	850	23,700	11,400	59,650
Kenya	2007	2,500	500	150	2,800	1,400	7,350
Uganda	2007	1,300	250	40	1,900	900	4,390
Morocco	2007	13,500	2,700	1,700	15,100	5,200	38,200
Senegal	2007	900	180	100	1,900	650	3,730
Peru	2006	6,000	1,200	220	11,500	5,500	24,420
Colombia	2006	6,500	1,300	1,200	18,300	8,800	36,100
Mexico	2006	47,500	9,500	1,100	166,500	44,700	269,300
Brazil	2005	96,800	17,200	2,200	137,000	115,100	368,300
India	2007	56,300	4,700	1,700	275,000	101,300	439,000
China	2007	300,000	60,000	7,000	1,350,000	495,000	2,212,000

**Table 1: Estimates of e-waste generation (tonnes per year)**

Source: Adapted from UNEP and UNU (2009)



**Figure 5: Relationship between private consumption and municipal waste in OECD countries**

Note: The indicators presented here relate to amounts of municipal waste generated. They show waste generation intensities expressed per capita and per unit of private final consumption expenditure (which excludes public expenditures on education, health and similar categories) in 2006, and related changes since 1980.

Source: OECD (2008b)

world's seas. Cigarettes and cigarette filters accounted for almost a quarter of the material (25,407,457 pieces) (UNEP 2009a). Marine litter has been reported to have significant impacts on wildlife and sensitive ecosystems, human health and safety and the economies of coastal areas (Ocean Conservancy 2010).

Waste generation is linked to both population and income growth. Of the two, income level is the more powerful driver. Figure 3 shows the correlation between MSW generation and GDP. In high-income countries, an urban population of 0.3 billion generates approximately 0.24 million tonnes of MSW (0.8 kg per capita per day), while in low-income countries around the same amount (0.26 million tonnes per day) is generated by 1.3 billion people (0.2 kg per capita per day), a quarter of the level in high-income countries.

Figure 4 shows estimates of MSW generation in different parts of the world. It rose in the US and the EU by 21 per cent and 14 per cent respectively from 1995 to 2007. However, due to increased awareness and policy interventions addressing waste management (for example, EU regulations stimulating recycling of obsolete vehicles since 2000 and electrical and electronic waste since 2002), the rate of MSW generation slowed in the EU and (to a lesser extent) in the US in the period from 2003 to 2007. The linkage between affluence and waste generation remains quite strong, in spite of improvements in efficiency, and represents a significant challenge for developing countries as they become wealthier, particularly in Asia (World Bank 1999). At best, relative decoupling has begun in OECD countries, with a stabilisation of per-capita waste generation in the last decade, as shown in Figure 5.

The recent awareness on benefits of waste minimisation, but also the shifting of waste-intensive production to developing and emerging countries may have contributed to this development. Landfill remains the predominant method of disposal in these countries (OECD 2008b).

Waste volumes are not necessarily the most important challenge ahead. Mixed MSW, hazardous health-care waste, and industrial waste streams can impose serious health and ecological risks if these wastes remain uncollected or dumped in uncontrolled and unsecured landfill sites. In low-income countries, for example, collection rates are lower than 70 per cent, with more than 50 per cent of the collected waste disposed through uncontrolled landfilling and about 15 per cent processed through unsafe and informal recycling (Chalmin and Gaillochet 2009). Given the amount of valuable components in MSW, the mixing of wastes also means a lost opportunity to recover components that could be recycled and used as new resources. Box 1 gives an overview of challenges and issues to be addressed to improve recycling rates of global metal stocks.

E-waste presents a serious and growing challenge to both developed and developing countries. It is a highly heterogeneous waste stream and one of the fastest-growing segments of MSW, especially in developed and emerging economies. Table 1 gives the estimated quantity of e-waste generated in 11 countries. China generates 64 per cent of the world's e-waste, followed by India (13 per cent) and Brazil (11 per cent). Senegal, Uganda, India, China and South Africa are examples of countries where e-waste generation is expected to rise by a factor of 2 to 8, by 2020 (UNEP and the United Nations University 2009). E-waste



## Box 1: Global metal stocks and recycling rates

The rapid pace of industrialisation around the world has brought about increasing demand for metals, which are considered as core raw materials for infrastructure and manufacturing of products. The demand for metals is expected to maintain dynamic in the future: in developing countries due to economic growth, and in industrialized countries due to modern technologies with dissipative metal applications. Since metals are a finite resource, the potential challenge on metal supply could be addressed through recycling across the life-cycle.

Among the various steps of the metal life-cycle, societal or in-use metal stocks, which include all metals put into use and currently providing service, are the most relevant metal stocks to focus. On a global level, most of the world's in-use stocks reside in more developed countries. For instance, Japan and the United States possess the highest in-use stocks and exceed the value of China by 9 and 13 times. Moreover, data suggests that per capita in-use stocks in more-developed countries typically exceed those in less-developed countries by factors of 5 to 10.

One of the key strategies in meeting this increasing demand is to take advantage of anthropogenic mines, or urban stocks, which has a great potential to reduce dependency on virgin metal resources and mitigate the environmental degradation caused by mining activities. However, tremendous weak points have been found in global metal recycling. For instance, mass-scale use of specialty metals like gallium, indium, etc, in the last three decades and the lack of infrastructure for recycling in many developing countries has led to dissipative losses of such metals.

Here are the recycling rates (EOL-RR) of various kinds of metals.

■ **Ferrous metals:** predominantly iron-based, and mostly magnetic. An end-of-life recycling rate of 70-90 per cent can be estimated for iron and steel, which is one of the highest among all the industrially used metals.

■ **Non-ferrous metals:** contain no iron, and used in quantities second only to the ferrous metals. Most have high recycling rates, especially lead (EOL recycling rate > 50 per cent).

■ **Precious metals:** Most are efficiently recycled due to the scarcity. The highest EOL recycling rates include: palladium (60-70 per cent), platinum (60-70 per cent) and rhodium (50-60 per cent).

■ **Specialty metals:** the largest group with 37 kinds of metals, and are in great demand. For 32 of the 37 specialty metals, the EOL recycling rates are very close to zero (<1 per cent).

### Challenges and Way Forward to Sustainability

Thus, the recycling rates for some of the metals, especially specialty metals are relatively low.

It has been recognized that creating a circular economy is key for increasing metal needs of the future. Setting of appropriate metal recycling infrastructure and services in urban areas - that are tomorrow's metal mines - is essential and should be given high priority.

The International Resource Panel decisively states that it is important to enhance capacity building, technology transfer and international cooperation in developing countries through international recycling conferences, technological implementation programmes and specific scientific exchange programmes.

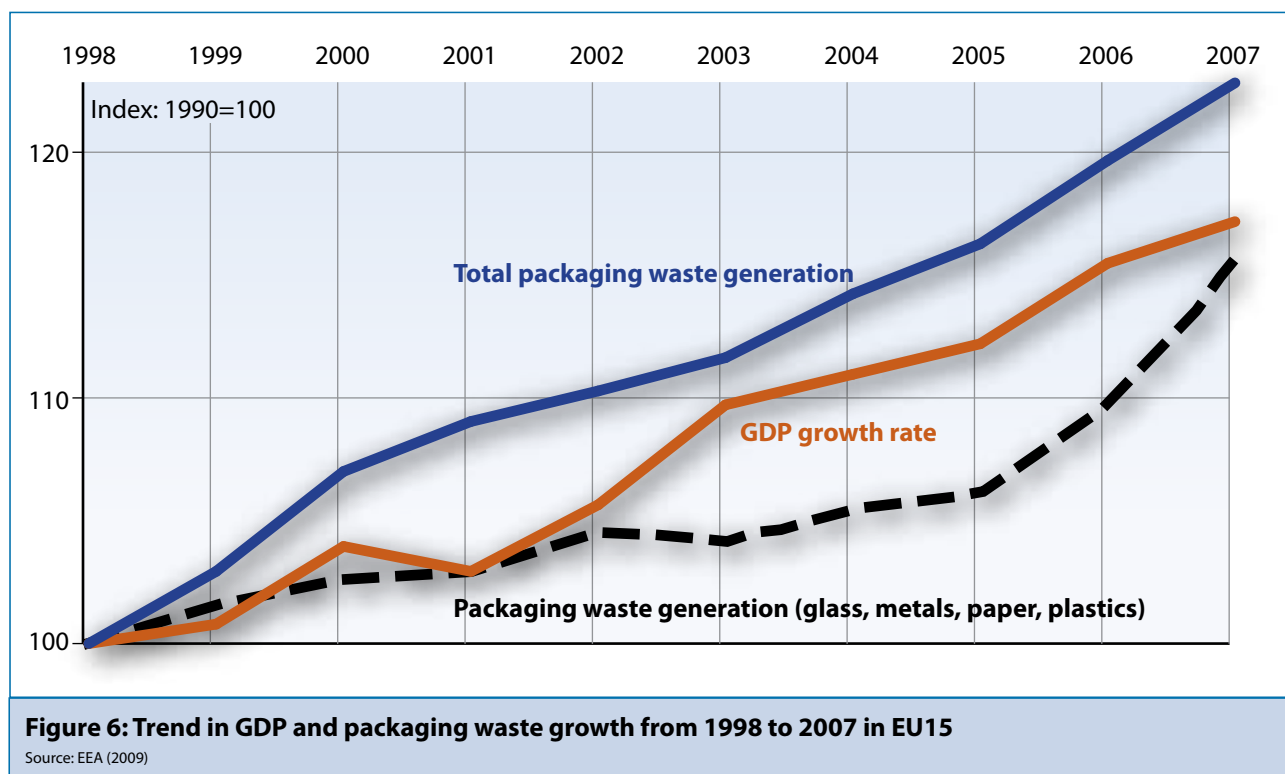
The Panel also highlights three key issues that require urgent attention:

■ **Research & development.** Data acquisition and analysis, recycling technologies research, and other research and development efforts should be a priority in the development process. Global data on a large variety of metals on equal spatial and temporal resolution is actually not available

■ **Stopping illegal waste transport.** International organisations like UNEP and OECD have to multiply their engagement in the monitoring and controlling of illegal scrap exports.

■ **Continuous improvements of legislative systems.** The more developed countries should reinforce their attempts to help the less developed countries install appropriate legislative systems and ensure their enforcement in order to take advantage of metal stocks in society.

Source: Source: UNEP (2011)



is a major source of new and complex hazardous waste additions to MSW.

Globally, UNEP and the United Nations University (UNU) estimate that 20 to 50 million tonnes of e-waste are disposed of each year, which accounts for 5 per cent of all MSW. E-waste also has a significant role to play in the recycling sector in developing countries even though it is not necessarily generated in those countries. With sales of electronic products in China and India and across Africa and Latin America predicted to rise sharply in the next ten years, the challenge is only set to grow (UNEP and UNU 2009).

Adding to the complexity of waste streams is the impact of increasing trade on waste. Lack of information on the constituents of waste products, such as valuable raw materials and toxic pollutants, makes trading of such waste challenging and risky. There have been increasing packaging requirements to minimise damage to goods in transit. Packaging requirements have also increased to meet tightened food health and safety standards. Figure 6 shows the steady increase in packaging waste coinciding with rising GDP in EU15 from 1998 to 2007. As this trend of increasing trade and packaging continues, so will the increase in the absolute generation of packaging waste and complexity of the MSW streams.

The waste problem has been accentuated by the issue of waste trafficking. Several developed countries have been illegally dumping hazardous waste and exporting significant quantities of used electrical and electronic

products to developing countries that do not have adequate infrastructure to manage them. Such illegal shipments are a matter of global concern. The Basel Convention requires its members to report the aggregated numbers, but there is ambiguity in the available data on hazardous shipments and difficulty in dealing with illegal activities. Another issue is the difficulty in classifying used electronic or electrical products as second-hand products and hazardous waste. These shortcomings heighten the threat that the hazardous waste poses to the environment and human health.<sup>2</sup>

#### Health and environment risks

The increasing volume and complexity of waste poses serious risks to human health and the environment. These risks are most obvious in situations where waste collection and treatment is insufficient or even absent but can also occur in situations where collection and treatment methods are already established. In industrialised countries, despite progress on sanitary landfill technology and incineration, and the control of direct human exposure to the waste at the related facilities, there are concerns over waste-disposal-related syndromes. While few studies exist, many health indicators have been considered in epidemiological research for health impacts from landfill sites and older incinerators, including cancer incidence, mortality, birth defects and low birth weight (WHO 2007). Protests over waste facilities in developed countries are now more than a simple Not In My Back Yard (NIMBY) reaction. Local residents often reject landfills and incinerators because of fears over health and safety and mistrust of the authorities to ensure that minimum safety or environmental protection standards are enforced. A related problem is the falling property values or the loss of livelihoods (e.g. related to agriculture, tourism) around landfill areas.

2. It may, however, be noted that the export of used electronic products is legal if the importing country has a sufficient recycling infrastructure to deal with these wastes.

In developing countries, owing to low or inappropriate collection, deficient waste treatment and disposal infrastructure, limited financial resources, and weak enforcement of laws, open, uncontrolled, and unsecured dumps are the most commonly-used method of managing waste. At these sites, dumping of mixed waste occurs alongside open burning, grazing of stray animals and leakage of hazardous substances such as leachate and gas. Uncontrolled dumping can also block drainage systems and contribute to floods, which cause additional health and environment problems such as disease outbreaks and water pollution.

Uncontrolled dumpsites have been linked to many harmful health effects such as skin and eye infections, respiratory problems, vector-borne diseases like diarrhoea, dysentery, typhoid, hepatitis, cholera, malaria and yellow fever. Rodents and other stray animals have also been known to spread a variety of diseases including plague and flea-borne fever. There are, however, no global estimates of waste-related health costs or economic costs of waste and only a limited number of country studies exist. In the Republic of Palau (an island nation in the Pacific Ocean), for example, the cost of waste-related health damage amounts to US\$ 697,000 per year (about US\$ 32 per capita) (Hajkowicz et al. 2005). In Tonga, total economic cost of waste was estimated to be at least TOP 5.6 million a year (about US\$ 2.8 million) of which US\$ 0.45 million was related to the health cost to private individuals (Lal and Takau 2006).

A lack of alternative livelihoods and the value of recovered materials entice many poor men, women, and even children to engage in dumpsite scavenging in low- and middle-income countries. Waste pickers are vulnerable to intestinal, parasitic and skin diseases. A UNEP (2007) study carried out at a 30-acre Kenyan dumpsite called Dandora found that about 50 per cent of the examined children and adolescents living close to the dumpsites (from a total of 328) had respiratory ailments and blood lead levels exceeding international threshold (10 micrograms per decilitre of blood). Further 30 per cent were confirmed to have high exposure to heavy metal poisoning detected by red blood cell abnormalities. Other severe effects observed in waste-picker children in India include worm infestation, scabies, xerophthalmia and lymph-node enlargement (Hunt 1996).

The volume of waste generation is one challenge for controlling the impact on human health and ecosystems, but it is the growing hazardous component of all waste streams that is most alarming. Unless action is taken to properly collect and segregate waste materials, many developing countries face the challenge of mixed and growing waste streams beyond what the current waste-management infrastructure can cope with. Investment in institutions and physical infrastructure to properly collect and segregate waste materials needs to happen to avoid imminent and serious consequences to environmental quality and public health in these countries with potentially long-term economic impacts.

## GHG emissions

The organic fraction of the municipal waste sector contributes to about 5 per cent of the total GHG emissions known to be responsible for climate change. According to the Intergovernmental Panel on Climate Change (IPPC) (Bogner et al. 2007), post-consumer waste-generated GHG emissions were equivalent to approximately 1,300 MtCO<sub>2</sub>-eq in 2005. In the waste sector, landfill methane is the largest source of GHG emissions, caused by the anaerobic degradation of organic material in landfills and unmonitored dumpsites. In the EU, emissions from waste (including disposal, landfill sites and water treatment) amount to 2.8 per cent of total EU27 GHG emissions (Eurostat 2010c). Emissions from landfills depend on waste characteristics (composition, density, particle size) and conditions in landfills (moisture, nutrients, microbes, temperature and pH). Landfill gas (LFG) is about 50-60 per cent methane with the remainder CO<sub>2</sub> and traces of non-methane volatile organics, halogenated organics and other compounds. Further, ozone depleting substances (ODS) released from discarded appliances (e.g. air conditioners, refrigerators) and building materials (foams), as well as industrial waste practices, contribute to ozone-layer depletion. Many of those ODS are also potent GHGs that contribute to climate change.

## 2.2 Opportunities

The opportunities for greening the waste sector come from three inter-related sources: 1) growth of the waste market, driven by demand for waste services and recycled products; 2) increased scarcity of natural resources and the consequent rise in commodity prices, which influence the demand for recycled products and WtE; and 3) emergence of new waste-management technologies. These developments have opened up significant opportunities for greening the waste sector.

### Growth of the waste market

Despite data limitations, there is a clear indication that the market for waste management is growing. The world market for municipal waste, from collection to recycling, is worth an estimated US\$ 410 billion a year (Chalmin and Gaillochet 2009). This estimate can only be indicative since assessing the exact market size is difficult given the paucity of reliable data, particularly in developing countries, and existing data being limited to the formal component of the waste-management sector.

Four factors are driving this growth: 1) the overall increase in the volume and variety of the waste generated; 2) rising political awareness of the need to better manage waste in the context of avoiding ecological and health risks and climate change; 3) urbanisation in emerging economies, which is typically accompanied with a growing interest in a better living environment including better waste

## Box 2: Companies resorting to eco-friendly packaging due to increased consumer pressure

Increased consumer demand for recycled products has compelled many companies to refurbish their product packaging to reduce the impact on the environment. Examples in North America include Hewlett Packard (HP), EnviroPAK (St. Louis) and Oxobioplast Inc. (Toronto). Hewlett Packard insists that all its packaging be recycled and labelled as such. EnviroPAK has shown great interest recently in using complex recycled paper pulp for packing electronic, small household appliances,

medical products, consumer goods, CDs and DVDs, automotive parts and food and bottled goods. By opting for paper pulp in the place of expanded polystyrene, the company has claimed to save 70 per cent in packaging and shipping costs. Oxobioplast Inc. uses an additive called "Revert" to render its plastic products biodegradable by breaking apart their polymer chains after a permitted period of use.

Source: Adapted from MachineDesign (2008)

management; and 4) development of formal and informal trade in secondary raw materials recovered from waste.

Change in the consumer demand is a major determinant underlining the potential greening of the waste sector. With increased environmental awareness, more and more consumers have started demanding recycled products and waste-derived compost. Box 2 gives examples of companies switching to eco-friendly packaging in response to consumer demand. In order to accrue benefits from recovered resources, there has been increased interest in investing in technologies such as biomethanation and WtE.

Of course, the waste market as it stands today is not necessarily green and the ways in which waste is collected and recycled may not fully comply with environmental standards and regulations. Very little data exist at present with which to estimate the magnitude of the green waste market, beyond estimates of rates of recycling. Indeed, with recycling rates

of the informal sector reaching 20-50 per cent and existing solid-waste management activities being of poor standard in developing countries, it may not be prudent to use the existing data without prior validation (Wilson et al. 2009). Furthermore, where waste collection and recycling involves child labour or indecent and unsafe working conditions, the waste market should not be considered green.

The growth of the waste market, however, does provide an opportunity for greening the sector. As the market evolves and becomes mature, consumers are likely to demand stringent standards in order to avoid any health and environmental risks. In the waste sector, existing standards focus mostly on the protection of environmental and human health, but working conditions and standards for recycled products are increasingly receiving attention. Market development in this direction thus provides a platform on which to systematically introduce green standards into waste management systems.

## Box 3: Recession and the paper-recycling rate in the UK

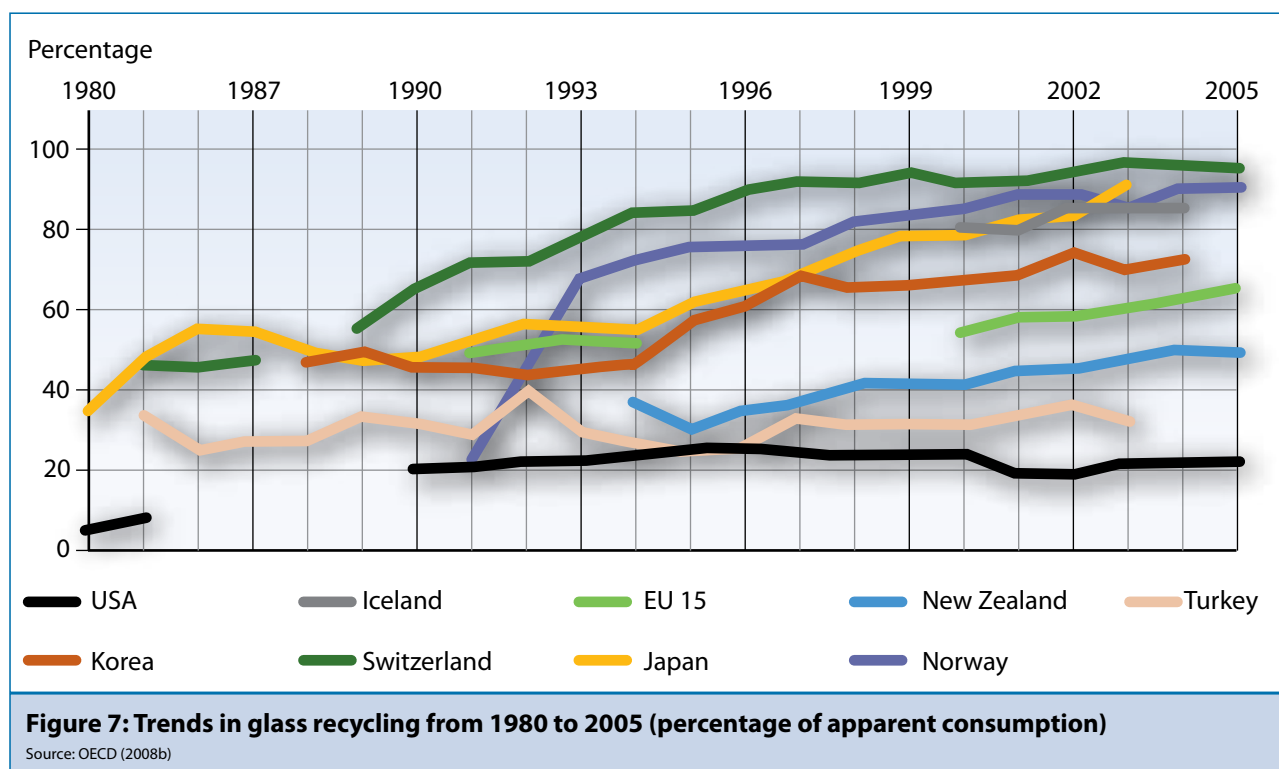
The UK paper industry produced 4.3 million tonnes of paper and cardboard in 2009, which was 14 per cent less than the previous year. Consumption declined by 10 per cent and exports dropped by 8 per cent compared with 2008, owing to the recession. The paper-recycling rate rose, however, to an all-time high of 90 per cent in 2009 and the collection rate increased by 2 per cent year on year. The UK's paper-recycling rate is expected to rise to 100 per cent with the advent of new private enterprises investing in facilities for the sector.

Source: Adapted from Packagingeurope (2010)

### Scarcity of resources

Rapid population growth and economic expansion have led to escalating demand for energy, basic industrial commodities and consumer goods. Energy consumption, for example, is expected to rise steeply as the world's population is estimated to grow by 2.3 billion over the next 40 years. This is expected to be almost entirely concentrated in the urban centres of Asia, Latin America and Africa (Pareto and Pareto 2008). According to Leggett (2005), however, the world's oil reserves are not adequate to cope with the combined forces of depletion and demand between 2008 and 2012. According to Energy Watch Group (2007) the fastest coal reserve depletion is happening in China and USA is already beyond peak production of coal. Global coal production is expected to peak around 2025 at 30 per cent above present production in the best case. Reduced energy supply has an immediate impact on energy-intensive manufacturing sectors such as mining and metal industries, reducing the production of materials and pushing up the cost of manufacturing.





Apart from oil and other commodities, metals are of vital importance to the global economy, whether in the manufacturing of buildings or cars or in the rapidly expanding production of mobile phones, air conditioners, refrigerators and other electronic consumer goods. If the total world population were to enjoy the same level of metals-use as in industrialised countries, the demand for metal stocks would be 3 to 9 times present levels.

Amid this rapid consumption of the earth's resources there appears to be great potential to create new markets by recycling and reusing existing metals, minerals, plastic, wood and other materials. Currently, however, only a quarter of the 4 billion tonnes of municipal waste produced each year is recovered or recycled (Chalmin and Gaillochet 2009). For example, scrap metals, paper and cardboard, compost, plastics are all valuable, relatively easy to recover from waste streams and can displace raw materials that are likely to become less readily available. One tonne of electronic scrap from PCs, for example, contains more gold than that recovered from 17 tonnes of gold ore and 40 times more concentrated copper than that found in copper ore (USGS 2001).

The increasing scarcity of resources and the rising cost of extracting raw materials, which feeds into higher commodity prices, are turning waste into a new source of resources to be mined. Examples include the reprocessing of metal waste, composting, waste to energy, recycling of e-waste and C&D waste. Figure 7 shows the rising trend in glass recycling in several OECD countries. Demand for recycled products can also increase at times of economic difficulty, such as has been experienced in many countries

in 2009 and 2010. Box 3 shows how recession had a positive impact on the paper-recycling rate in the UK. The same, however, cannot be said of countries such as China and India, where the average value of municipal scrap dropped by up to 45 per cent during the economic slowdown, probably because of the shrinkage of aggregate demand. Similarly, the prices for used paper dropped dramatically in Germany when demand in China and India declined.

### New technologies

The greening of the waste sector is also facilitated by significant breakthroughs in technologies required for collection, reprocessing and recycling waste, extracting energy from organic waste and efficient gas capture from landfills. Compactor trucks, fore-and-aft tippers, container hoists and open-or-closed top trailers are now available for the collection and transportation of waste. Recovering energy and other useful products from waste has been enabled by considerable technological breakthroughs. WtE technologies have replaced incineration in many OECD countries. Mechanical and biological treatment (MBT) and biomethanation have, for example, been recognised as suitable for processing organic wet waste in developing countries. However, incomplete segregation of dry and wet organic waste has been a major barrier to the widespread successful adoption of these technologies in these countries. Techniques such as vermin-composting and rapid composting have led to conversion of organic waste into useful agricultural manure at a pace faster than natural decomposition. With the aid of advanced technologies, energy-rich components of waste can be converted into useful products – a classical case of this concept is Refuse Derived Fuel (RDF), a popular product derived from high-calorific-value waste.



### 3 Making an economic case for investing in greening the waste sector

A case for investing in greening the waste sector may be made on various grounds. In the past, cases have been made largely on environmental and health-related grounds, based on costs that can be avoided by proper collection and disposal. These arguments, particularly health-related ones, continue to be important for motivating policy actions.

In order to scale up the greening of the sector, however, environmental and health-related arguments alone are inadequate or may be seen as competing with economic imperatives. For policy-makers to channel significant resources towards the greening of the sector, they need to appreciate how such actions are likely to contribute to economic performance and job creation relative to BAU scenarios. Adequate economic arguments are, therefore, needed to motivate fundamental changes in the management of the sector.

To make a primarily economic case for investing in greening the waste sector, three steps are needed, which are elaborated on in this section. First, we need to have an idea of the extent to which the sector could be greened. Second, we need to have some ideas about the financing gaps for priority areas. Third, given the priorities of greening the sector, we need to show the potential gains if green investment is made in those areas.

#### 3.1 The goals and indicators for greening the waste sector

There are no established international targets for greening the waste sector, apart from the control of specific hazardous substances as governed by international conventions. Most goals are national or even local. For example, in northern Europe, the Republic of Korea and Singapore, over 50 per cent of waste is subjected to material-recovery processes (Chalmin and Gaillochet 2009). Japan has set material-flow indicators that fall under three categories: input, cycle and output, to compare developments in recycling rates with those of previous years. The indicators include resource productivity in Yen per tonne (increased from 210,000 in 1990 to 390,000 in 2010), recycle-use rate (increased from 8 per cent in 1990 to 14 per cent in 2010), and final-disposal amount (decreased from 110 million tonnes in 1990 to

28 million tonnes in 2010 (Ministry of Environment, the Government of Japan 2008).

China has adopted the Circular Economy (CE) approach in a move towards achieving a more balanced growth as part of its 11th five-year plan. Pintér (2006) has shortlisted two input indicators (direct material input and total material requirement), one output indicator (domestic processed output), two consumption indicators (domestic material consumption and total material consumption) and two balance indicators (physical trade balance and net addition to stock) that could give credible information on the status of implementation towards achieving the CE goal.

The Republic of Korea planned to increase its waste-recycling rate of MSW from 56.3 per cent in 2007 to 61 per cent in 2012 (Ministry of Environment, Republic of Korea, 2008). Under the directive on packaging and packaging waste, the EU increased the target for overall recycling from 25 per cent (min.) and 45 per cent (max.) in 1994 to 55 per cent (min.) and 80 per cent (max.) in 2004 (EC 2009). As an example of city-level 3R policies, London's draft 2011 waste-management plan sets a goal of 45 per cent municipal waste recycling/composting by 2015, 70 per cent commercial/industrial waste recycling/composting by 2020 and 95 per cent re-use and recycling of C&D waste by 2020 (Mayor of London 2010). Table 2 gives further examples of goals and targets that can be used to measure progress in greening the waste sector.

In its Draft National Waste Management Strategy (NWMS), the Department of Environmental Affairs (2010) of South Africa has set out a minimum set of target parameters for use by municipalities in the provision of waste services. The target parameters include, number of households receiving a waste service (per cent over time), budget allocations to ensure financial support (percentage increase in budget over time), equipment and infrastructure provision, number of staff trained or capacitated to improve service, proportion of community that is aware of the waste-management services, reduction of waste to landfill and improvement of cost recovery measures. Individual municipalities are required to set out relevant target figures under these parameters.

It is, therefore, difficult to have one-size-fits-all goals for the greening of the waste sector. Generally speaking, however,

Targets	Examples
Resource efficiency or productivity	<p><b>1. Japan's Sound Material Cycle Society Target</b> Resource productivity (yen/ tonnes) calculated as GDP divided by amount of natural resources, etc. invested, to be increased from 210,000 in 1990 to 390,000 in 2010.</p> <p><b>2. London Waste Targets from London Plan Draft, Mayor of London</b> 85% regional self-sufficiency by 2020 (meaning dependency on only local and recycled resources).</p>
Waste recycling rate	<p><b>1. Republic of Korea's Green Growth Target for Waste</b> Increase in percentage of MSW recycling from 56.3 % in 2007 to 61 % in 2012.</p> <p><b>2. Japan's Sound Material Cycle Society Target</b> Cycle use rate (Cyclical use amount ÷ [cyclical use amount + amount of natural resource input]), to increase from 8% in 1990 to 14% in 2010. The status as of 2000 was 10%.</p> <p><b>3. London Waste Targets from London Plan Draft, Mayor of London</b> 45% municipal waste recycling/composting by 2015 70% commercial/industrial waste recycling/composting by 2020 95% re-use and recycling of C&amp;D waste by 2020.</p>
Waste landfilled	<p><b>1. The EC Landfill Directive Council Directive 1999/31/EC</b> not later than 16 July 2016, biodegradable municipal waste going to landfill must be reduced to 35 % of the total amount by weight of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available.</p> <p><b>2. Japan's Sound Material Cycle Society Target</b> Amount of waste landfilled to be reduced from 110 million tonnes in 1990 to 28 million tonnes in 2010. The status in 2000 was 56 million tonnes.</p> <p><b>3. Flemish Waste Management Policy, Belgium</b> Residents should not generate more than 150 kg of residual waste (waste to be landfilled or incinerated) per inhabitant per year.</p>

**Table 2: Indicators to measure the greening of the waste sector**

Sources: EC (1999), Ministry of the Environment, Government of Japan (2008), Ministry of Environment, Republic of Korea (2008), EEA (2010), Lee (2010), Mayor of London (2010)

in greening the waste sector, all countries should seek to: 1) avoid waste in the first place through sustainable community practices, 2) minimise the generation of waste; 3) recover materials and energy from waste and re-manufacture and recycle waste into usable products, where waste is inevitable; and 4) treat any remaining unusable waste in an environmentally friendly or in the least damaging way. For developing countries, one of the goals should be the formalisation of the waste sector, following environmental guidance and labour-protection measures.

The goals of greening the waste sector cannot be achieved without increased investment. Minimising waste generation requires changes to product design and production processes upstream (some of the related issues are addressed in the Industry chapter). Downstream recovering, remanufacturing, recycling, and final treatment require new facilities or upgrading of existing facilities. Investment is also needed to train the labour force in the sector as well as to formalise the informal sector.

### 3.2 Spending in the waste sector

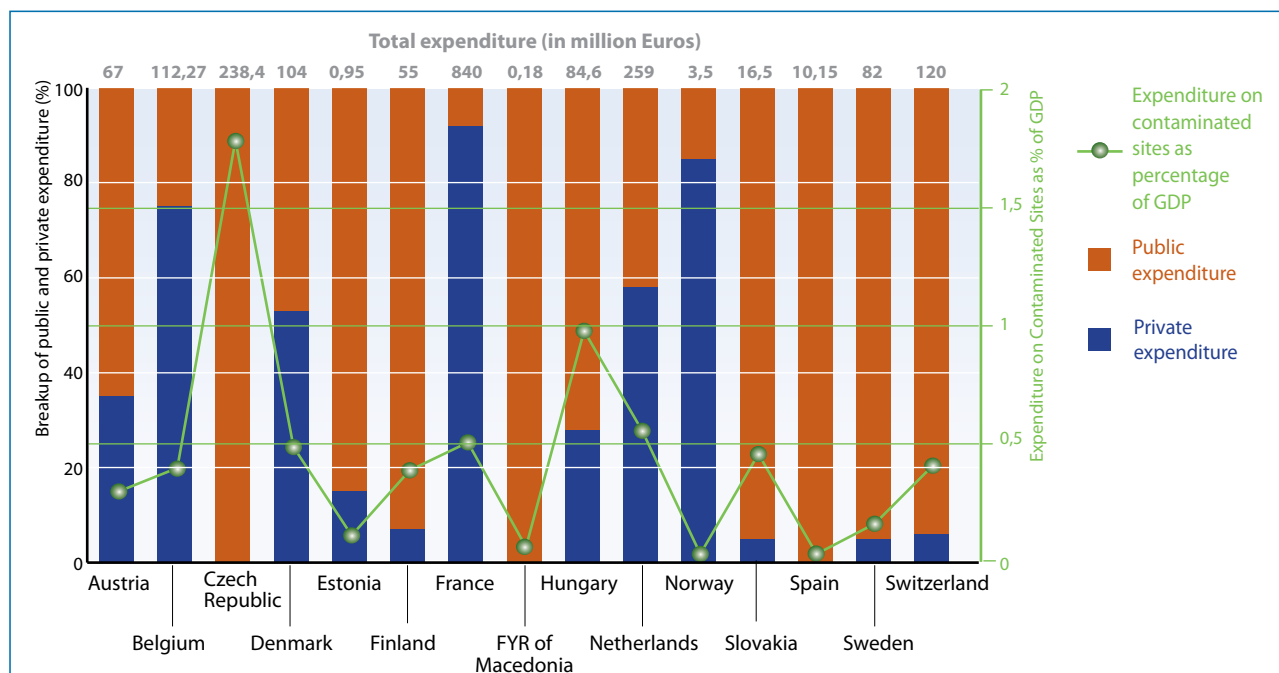
There is a substantial variation across countries in the magnitude of government spending on the waste sector. Waste management is a municipal service that is mostly financed through municipal funds, although private involvement has been observed in recent times. Section 5.1 describes the various financing options available for the

sector. The percentage of the waste spending relative to GDP may be similar for developing and developed countries (looking at specific cases), but there is a significant difference in the amount spent on waste management expressed in per capita terms. Dhaka city, for example, spends US\$ 0.9 per capita per year (0.2 per cent of GDP) on MSW management whereas Vienna spends US\$ 137 per capita per year (0.4 per cent of GDP) (Fellner 2007).

Another major phenomena to note is that developing countries typically spend more than half of their waste budget in collection alone (mainly on labour and fuel), although the collection rate remains low and the transport of waste inefficient. Spending on other segments of the waste management chain, such as technologies and facilities for treatment, recovery and disposal, is generally rather low.

In these countries, increased investment in basic collection services, the transport of waste and cleaning up dumpsites is a starting point for greening the sector. Investment can be targeted, for example, at techniques such as route optimisation and transfer stations, which can bring down the capital and operational costs of providing waste services.

In emerging economies with rapid growth and urbanisation, the need for increased investment in greening the waste sector is particularly strong. The World Bank, for example, has estimated that China has to increase its national waste management budget by at least eight-fold from 1999 levels by 2020, which requires the allocation of 230 billion



**Figure 8: Total public and private expenditure on reclamation of contaminated sites in Europe**

Source: Adapted from EEA (2007)

RMB (US\$ 126 billion) to provide and construct MSW management infrastructure (World Bank 2005).

European countries spend a significant amount on reclaiming contaminated sites, which can become valuable assets for industrial estates and commercial areas (see Figure 8). Expenditure ranges from 0.4 to 0.5 per cent of GDP in countries including Belgium, France, the Netherlands and Switzerland, to 1 per cent in Hungary and 1.8 per cent in the Czech Republic. In most of these countries, the private sector participates in funding the reclamation. In the Czech Republic, the Former Yugoslav Republic (FYR) of Macedonia, and Spain, however, the spending comes entirely from the public sector.

The appropriateness of different waste treatment methods can be influenced by factors such as urban population density, availability of space and policy enforcement capacity. In places of higher population density and limited space such as in the cities of Japan and northern Europe, most waste is incinerated. In places of lower population density and greater availability of space such as Australia, controlled sanitary landfilling is more common. State-of-the art sanitary landfilling is also used in the UK, Ireland, the USA, Greece, Spain and Italy. In some developing countries, emerging economies and even regions of developed countries where policy-enforcement capacity is weak, open landfills and incineration without energy recovery remains common practice.

Fundamentally, however, the choice of treatment options is based on a cost-benefit analysis. For example, if we only focus on the cost of technologies, landfilling appears to be as attractive as composting. Porter's data of 2002, however, shows that landfilling will incur an additional environmental

and social cost of between US\$ 45 and US\$ 75 per tonne. In this context, composting becomes a more attractive option than landfilling. Thus, a total cost-benefit analysis that addresses economic, environmental and social perspectives becomes necessary in making the right choice of technology.

Recognising the negative impacts of the least-preferred waste management options, many national and regional authorities have established command-and-control targets for better management of landfill sites and incinerators, and diversion of waste away from these facilities. For example, the U.S. Resource Conservation and Recovery Act (RCRA) (1976) was amended (Federal Hazardous and Solid Waste Amendments (HSWA)) in 1984 to include the phasing out of land disposal of hazardous solid waste. The Landfill Disposal Programme Flexibility Act (1996) also stipulates environmental management standards for land disposal. In Europe, the European Union Landfill Council Directive 99/31/EC of 26 April 1999 aims to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements. The Landfill Directive also obliges Member States to reduce the amount of biodegradable waste going to landfill to 35 per cent of 1995 levels by 2016. The Directive on the Incineration of Waste (2000/76/EC) produces similar regulation for thermal treatment facilities. Japan's Sound Material Cycle target was to reduce the amount of waste landfilled from 110 million tonnes in 1990 to 28 million tonnes in 2010. These Command and Control (CAC) approaches have been effective, particularly because economies of scale could be achieved by the legislative measure and the supply of waste materials could subsequently be ensured. However, CAC approaches are costly and require substantial enforcement capacity to produce results.

Particulars	Low-income countries	Middle-income countries	High-income countries
GDP in \$/capita/year	< \$5,000	\$5,000 – \$15,000	\$5,000 – \$15,000
Average consumption of paper and cardboard by kg/capita/year	20	20 – 70	130 – 300
Municipal waste (kg/capita/year)	150 – 250	250 – 550	350 – 750
Formal collection rate of municipal waste	< 70%	70% – 95%	> 95%
Statutory waste management framework	No or weak* national environmental strategy, little application of the statutory framework, absence of statistics	National environmental strategy, Ministry of the Environment, statutory framework but insufficient application, few statistics	National environmental strategy, Ministry of the Environment, statutory framework set up and applied, sufficient statistics
Informal collection	Highly developed, substantial volume capture, tendency to organise in cooperatives or associations	Developed and in process of institutionalisation	Quasi non-existent
Municipal waste composition (% weight basis)			
Organic/fermentable	50 – 80	20 – 65	20 – 40
Paper and cardboard	4 – 15	15 – 40	15 – 50
Plastics	5 – 12	7 – 15	10 – 15
Metals	1 – 5	1 – 5	5 – 8
Glass	1 – 5	1 – 5	5 – 8
Moisture content	50% – 80%	40% – 60%	20% – 30%
Calorific value (in kcal/kg dry basis)	800 – 1,100	1,100 – 1,300	1,500 – 2,700
Waste treatment	Uncontrolled landfills > 50% Informal recycling 15%	Landfill sites > 90%, start of selective collection, organised recycling 5%, coexistent informal recycling	Selective collection, incineration, recycling > 20%
Informal recycling	Highly developed, substantial volume capture, tendency to organise in cooperatives or associations	Developed and in process of institutionalisation	Quasi non-existent

\* In some countries, environmental strategies are weak and not comprehensive.

**Table 3: Waste collection typologies by GDP per capita**  
Source: Adapted from Chalmin and Gaillochet (2009)

In low-income countries, recycling is mostly controlled by an informal sector that is usually unrecognised by governments and primarily driven by the cost of raw materials and cheap labour. But the poor collection-to-generation ratio and exploitation of the available recyclable component by the informal sector makes it difficult to calculate overall recycling levels in developing countries. Table 3 gives the waste collection typologies by GDP per capita, which shows the informal sector being a dominant force in the waste management system.

Global data, however, do not exist to show the investment gaps between the current state of the waste sector and the desired green state. This poses a challenge for estimating how much investment is required, globally, to green the waste sector.

### 3.3 Benefits from investment in greening the waste sector

Greening the waste sector is expected to generate substantial economic, environmental and social benefits. They include: 1) natural resource and energy saving; 2) creation of new businesses and jobs; 3) compost

production supporting organic agriculture; 4) energy production from waste; 5) reduced GHG emissions; and 6) contributions to equity and poverty eradication. Improved health, avoided health costs, avoided water contamination and the consequent cost of alternative water supply are also important streams of benefits. In addition, greening the waste sector in the entire supply chain is expected to generate a whole range of benefits not fully identified in the above list. Given the limited availability of quantitative information, however, this section is not able to substantiate these benefits. Further research is needed in these areas.

#### Resource and energy conservation

Practicing 3R reduces the demand for raw materials. This is called the resource conservation effect (Ferrer and Ayres 2000). The United States Energy Information Administration (EIA) suggests, for example, that recycling paper will save up to 17 trees and reduce water-use by 50 per cent. Also related to this resource conservation effect is the embedded market value of the waste recyclables. In the State of Washington, USA, for example, such value (which was not captured) from solid waste recyclables disposed – including paper, cardboard, metals, plastics, glass, and electronics – grew from US\$ 182.4 million in 2003 to US\$ 320 million in 2008 (State of Washington 2010). A

positive example, however, is found in Viridor, a leading UK waste management company whose turnover in 2008/09 reached £ 528 million and whose profit had grown at 22 per cent since 2000/01, 40 per cent of which resulted from value recovered from waste (Drummond 2010).

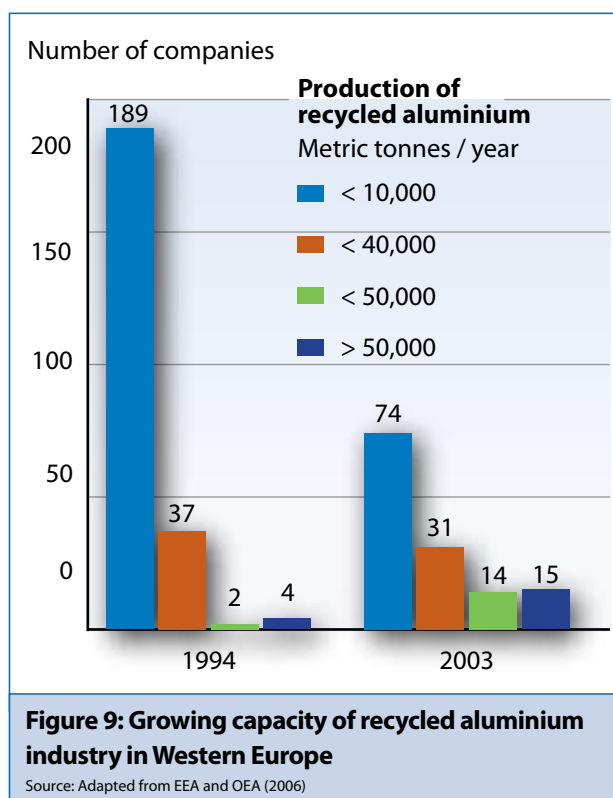
Aluminium is a major recyclable resource. According to the European Aluminium Association and Organization of European Aluminium Refiners and Remelters, the global aluminium recycling rates are about 90 per cent for transport and construction appliances and 60 per cent for beverage cans. The lower cost of recycled aluminium results from drastically lower energy consumption than is required to smelt it from the raw material, bauxite. Recycled aluminium can be used in all its applications, from castings for automotive and engineering components to extrusion billets, rolling slabs to a deoxidising agent in the steel industry.

Figure 9 shows the growing capacity of the aluminium industry in Western Europe, which almost tripled its output from about 1.2 million tonnes in 1980 to 3.7 million tonnes in 2003, primarily because the recycling activity of smelters increased by 94 per cent in this period. By doing so, Europe conserved approximately 16.4 million tonnes of bauxite and 200,000 tonnes of alloying elements such as silicon, copper, iron, magnesium, manganese, zinc and other elements used for strengthening and other purposes. Europe also saved 1.5 million m<sup>3</sup> of landfill space in the process.

European Environment Agency (EEA) demonstrates that by recycling 1 tonne of aluminium, the following resource savings could be accrued: 1.3 tonnes of bauxite residues; 15 m<sup>3</sup> of cooling water and 0.86 m<sup>3</sup> of process water. Furthermore, 2 tonnes of CO<sub>2</sub> and 11 kg of SO<sub>2</sub> can be avoided.

Aside from resource conservation, there also exists an energy-saving benefit from substituting virgin materials with resources recovered from waste streams. According to the Natural Resource Defence Council (NRDC), recycling is the most energy conserving of all waste management strategies. The Natural Resource Defense Council (1997) stresses that materials sent to an incinerator release energy only once, whereas recycling can provide energy savings through several production cycles. Recycling a tonne of aluminium and steel, for example, saves the equivalent of 37 and 2.7 barrels of oil, respectively. On the contrary, when incinerated, these materials absorb heat and reduce the amount of net energy produced.

Energy savings in turn bring reductions in GHG emissions. For example, using recycled blast furnace slag to make cement is believed to save up to 59 per cent of the embodied CO<sub>2</sub> emissions and 42 per cent of the embodied energy required to manufacture concrete and its constituent materials



(World Steel Association 2010). Recycling in the UK, in general, is already saving around 10-15 million tonnes of CO<sub>2</sub> equivalent per year (WRAP 2006). Table 4 provides estimates on energy savings from waste recycling and the net GHG flux savings (which refers to the net amount of GHG saved in an activity factoring the related emissions, absorptions, and offsets) from avoided landfilling.

A potential trade-off from making the transition to a resource recovery-based economy, however, may include

Type of material	Energy savings <sup>1,2</sup> (%)	GHG flux saving from recycling <sup>3</sup> (kg CO <sub>2</sub> eq. per tonne of recycled material)	Savings on carbon price in US\$ per 1000 tonnes of recycled material (US\$ 13.4 per tonne of CO <sub>2</sub> eq.)
Aluminium	90-95	95	1,273
Ferrous	74	63	844
Textiles	NA	60	804
Steel	62 - 74	1,512	20,260
Copper	35 - 85	NA	-
Lead	60 - 65	NA	-
Paper	40	177	2,372
Zinc	60	NA	-
Plastic	80 - 90	41 (HDPE)	549
Glass	20	30	402

NA: Data not available

**Table 4: Energy savings and GHG flux savings due to waste recycling**

Source: BIR (2008), BMRA (2010), Glass Packaging Institute (2010), World Steel Association (2011) and European Communities (2001)



## Box 4: Cost savings and resource recovery from recycling

■ The Prostheses Foundation in Chiang Mai, Thailand conducts a sensational programme using recycled materials. The foundation produces artificial limbs from aluminium ring-pulls collected from beverage canisters. The ring-pulls contain titanium, a light, strong, lustrous, corrosion-resistant and valuable metal. They are collected from sources all over the country including several large companies. Some 35,000 ring-pulls produce 1 kg of useable metal, from which two artificial limbs can be fashioned. The foundation has recycled nearly 5,000 tonnes of ring-pulls and has created a positive net socio-economic impact. Prosthetics made of recycled aluminium are much cheaper (typically Thai Baht 5,500 (US\$ 160) a piece) than similar imported ones (THB 90,000 (US\$ 2,650)). Furthermore, an artificial leg made from

recycled ring-pulls weighs just 6 kg, while many similar imported products weigh about 11 kg.

Source: Prosthetic Foundation (2007)

■ A recycling campaign to collect used mobile phones in Japan was launched in November 2009 and involved 1,886 stores and supermarkets. Those who returned used mobile phones in exchange for purchasing a new device were invited to enter a lottery to win coupons worth 1,000-50,000 Yen (equivalent to US\$ 12 to US\$ 600) depending on the price of the mobile phone they bought. The initiative collected 569,464 mobile phones containing precious metals amounting to 22 kg of gold, 140 mg of silver, 10 g of copper and 4 mg of palladium in just four months.

Source: Mohanty (2010)

an initial loss in economies of scale already established in extraction, which could have implications for the manufacturing industries, perhaps in terms of increased cost of goods in the short to medium term. This has yet to be quantitatively studied. In any event, it is expected that – as the systems of 3R get mainstreamed in business processes and as the markets mature – the costs of goods will stabilise and could even go down. Box 4 provides examples of recycling leading to cost savings and the recovery of precious metals.

### Job creation

The labour force that underpins the recycling sector contributes significantly to solving one or more global environmental issues (e.g. climate mitigation or preventing pollution). These workers, whether they are formally employed or are self-employed, should be considered a category of the agents of change that environmental and economic policies rely upon. The high value of their contribution to climate policies and social value-added should therefore be widely and more clearly recognised.

Recycling is one of the most important sectors in terms of employment creation. However, many recycling or waste-management-related jobs can not be considered green as they do not match the basic requirements of decent work. Priority indicators of decent work include: child labour, occupational health and safety, social protection and freedom of association (various forms of organisation of workers such as unions, local associations and cooperatives). On the other hand, because jobs in the recycling chain represent a source of income for workers who usually have low levels of education or poor backgrounds, these jobs are an important element

of poverty alleviation. A detailed discussion of the social dimension is presented in Box 5.

A recent estimate suggests that up to 15 million people are engaged in waste collection for their livelihood in developing countries (Medina 2008). The US recycling industry is estimated to have earned US\$ 236 billion in revenue in 2007, employing over a million people and accounting for about 2 per cent of the country's GDP (EPN 2009). Over half a million waste pickers have been reported in Brazil and the country has close to 2,400 companies and cooperatives involved in recycling and scrap trading (UNEP 2008).

In Buenos Aires, an estimated 40,000 waste scavengers are estimated to have an economic impact of US\$ 1.78 million per year, close to 0.05 per cent of the city's GDP (Medina 2008). Other estimates put the number of waste scavengers in India at least at a million, while in China up to 10 million workers are reportedly involved in recycling activities (UNEP 2008). Scheinberg et al. (2010) studied informal recyclers in six cities: Cairo, Egypt; Cluj-Napoca, Romania; Lima, Peru; Lusaka, Zambia; Pune, India; and Quezon City (part of Metro Manila), the Philippines. They found that more than 75,000 individuals and their families are engaged in recycling about 3 million tonnes of waste per year with an economic value of more than US\$ 120 million.

In developing countries the recycling segment of the waste industry is predominantly controlled by the informal sector, and it is often hazardous, unsafe work. Typically, 1 per cent of the urban population in developing countries is involved in informal scavenging, most of whom are women and children. Hence, efforts are needed to provide recognition,

## Box 5: The social dimension of waste management and recycling jobs – implications for decent work and poverty reduction<sup>3</sup>

In recent years, motivated by the need to simultaneously address the environmental degradation and boost income generation at the local and community level, a number of projects for recycling materials have been implemented in developing countries. Given that jobs involving the collection, processing and distribution of recyclables are usually performed by workers who have few options elsewhere in the economy, jobs in the recycling chain bear a significant pro-poor component.

In Ouagadougou, Burkina Faso, a project for collecting and recycling plastic waste has helped improve the environmental situation and has created jobs and generated income for locals. The project gave rise to the first recycling centre in the country, which is managed by 30 women and two technicians, all locals working eight hours a day, five days a week, and earning the equivalent of US\$ 50 per month, a relatively good salary compared with other occupations in the local economy. The 2,000 or so waste collectors earn up to US\$ 0.8 per day. Since implementation, the city and its suburbs are cleaner. Furthermore, many people have managed to secure an income, either by collecting the plastic waste or by working as full-time employees at the recycling centre. Many of them used to be among the poorest of Ouagadougou's suburban population (ILO 2007).

In Dhaka, Bangladesh, a project generating compost from organic waste helped create 400 new jobs in collection activities and 800 new jobs in the process of composting. Workers collect 700 tonnes of organic waste per day, which produces 50,000 tonnes of compost per year. These jobs provide workers with health insurance, access to a daycare center and a free meal. Other benefits include cheaper compost, a reduced need for irrigation and improved soil quality (Sinha and Enayetullah 2010).

From an employment/social perspective, it is critical to address the need for the progressive formalisation of the waste sector at the same time that environmental and economic objectives are being pursued. This can be tackled by creating new types of jobs and reorganising the economic

segments. Typical examples include door-to-door collection of MSW, up-stream sorting of municipal and industrial waste, industry-to-industry waste exchanges, segmentation of waste collection and waste recovery services (e.g. used lead acid batteries and oily waste), the emergence of contracting services, collective organisations, skills-development programmes to come to terms with the type of material that is handled by workers and enterprises and the use of environmentally-sound technologies for waste management and the introduction of targeted Occupational Health and Safety (OHS) programmes.

The application of national labour laws and OHS legislation to the informal economy is one of the most important challenges facing many countries. At the same time, OHS provides possibly the easiest entry point for the extension of basic labour protection including basic OHS measures. The work of the ILO and its recommendations regarding the informal economy should be considered in the context of the formalisation of the waste-management sector (workers, skills, OHS, co-operatives, etc) (ILO 2010).

Social innovations have proven critical in achieving sustainable outcomes by favouring a stakeholders approach. In this regard, utilising social and environmental entrepreneurs and/or trade unions to help informal waste workers to improve their working and living conditions are key options to consider. For example, the Best of 2 Worlds project, a result of joint work by Solving the e-waste Problem (StEP) and Umicore a precious metal refining group, investigates the eco-efficiency of the manual dismantling of e-waste in China with control over environmental factors.

From a green-economy perspective, enhancing decent work and labour standards are also an equally important priority for the creation of productive jobs alongside the need to exploit the economic opportunities that the waste sector can yield. This can be partly achieved through technical and technological improvements. However, the sector is also replete with attempts to introduce technologies that are not adapted to local contexts, leading to major setbacks.

3. Box developed based on contributions received from ILO to this chapter.

## Box 6: Turning urban manure into organic fertiliser

The Kunming Dongran Technology Company in China is a business that specialises in treating human waste through anaerobic digestion and turning the bio-slurry into an organic fertiliser. Dongran Technology was founded in 2003 with a capital investment of 10 million RMB (1.5 million US\$). With the advancement of its scientific capabilities, the Yunnan National Reform and Development Commission approved Dongran as a Build-Operate-Transfer project for Kunming City's Wu Hua District. This allows the enterprise to receive government funding to finance, design, construct and operate a facility, and to recover its investment, operation and maintenance expense. In most urban areas, human waste is treated with wastewater, but Dongran specifically treats human waste as a separate entity and therefore reduces the

likelihood of disease transmission. Additionally, through Dongran's separation of manure from the wastewater treatment process, the Environmental Protection and Sanitation Bureau's waste management burden is reduced. While Dongran receives money from Kunming's Wu Hua District to treat the waste, Dongran's main source of income is from producing organic manure through the fermentation of human waste, which turns the waste into a marketable product. The solid organic manure is used on tobacco farms, a major industry and source of income for Yunnan Province, and also on vegetables, flowers, fruits and tea, and the liquid organic manure is often used as a nutrient for seeds.

Source: Greening China. Available at: <http://greeningchina.wordpress.com/2010/08/25/turning-urban-manure-into-organic-fertilizer/>

respect and appropriate protection to ensure that issues related to health and safety are adequately addressed.

According to the Institute of Local Self Reliance (ILSR), sorting and processing recyclables alone sustains ten times more jobs than landfilling or incineration on a per-tonne basis. The recycling industries in the USA experienced remarkable growth from 8,000 companies employing 79,000 people and generating US\$ 4.6 billion in sales in 1967 to more than 56,000 public- and private-sector facilities that sustained 1.1 million jobs generating US\$ 236 billion in gross annual sales in 2000 (ILSR 2002). Recovery and recycling of used electrical and electronic appliances creates servicing or technician jobs. Such working skills should be developed through training and national certification programmes focusing on repairing and servicing requirements for used appliances.

As the waste business becomes more sophisticated, new avenues for employment are opening up. These include the application of information technology (e.g. for waste-tracking and mapping using Geographic Information Systems (GIS) and/or Geographic Positioning Systems (GPS), accounting software for waste-charging using Management Information System (MIS); mass communication for awareness and training for skill development. Data on these new developments are, however, not readily available.

Although waste collection, segregation, and reprocessing are labour-intensive activities, the overall effect on net employment cannot be generalised. Reduction in employment could result from centralisation of energy recovery and treatment operations such as composting and landfilling. Porter (2002) cautions that jobs created by recycling replace jobs elsewhere in the economy and are often low-wage positions. In the process of greening,

job losses in industries involved in the extraction of virgin materials and associated utilities could be of concern, as the increased use of recycled material implies reduced resource extraction, despite broader gains to the economy. However, the overall net employment effect appears to be positive. For example, studies have found that for every 100 jobs created in recycling, 13 jobs are lost in solid waste and virgin material extraction in North Carolina, USA (CEQ 1997).

The concept of creative re-use has also arisen, generating new jobs and value-added products that could be sold for profit. United Nations Conference on Trade and Development (UNCTAD) observes that international trade in creative goods and services grew at an unprecedented average rate of 8.7 per cent a year from 2000-05, with China being the leading exporter (UNCTAD 2008). Organisations such as the School and Community Reuse Action Project (SCRAP) in the USA and the Scrap Arts Project Limited in the UK promote the creative reuse of waste by offering training through workshops. China has a thriving business in the manufacture of recycled products that are mostly made from waste or semi-finished recycled products available in Africa (see Box 5 for an example of waste recycling generating decent jobs and helping to reduce poverty).

### Compost production

The use of composted organic waste as a fertiliser and soil conditioner brings economic benefits to small-scale farmers and reduces nutrient run-off and nitrogen leaching (Nyamangara et al. 2003). It could also increase carbon management properties of the soil and enhance the crop yields. An estimate of the economic value of these benefits, however, is not readily available. Box 6 provides an example on how organic waste can be turned in to a marketable product with wider benefits for the municipality. The

## Box 7: Rural energy supply from waste

■ Agri-business ventures promoting conversion of organically-rich biomass waste into biogas have great potential to supply power to rural regions. The Asian Development Bank (ADB) has supported the installation of over 7,500 biogas digesters in more than 140 rural villages in China and has suggested potential models for agri-business ventures such as community-based, small-scale industries, small- and medium- scale industries and large-scale industries for the Greater Mekong sub-region (GMS).

Source: Owens 2009

■ Anaerobic digestion of organic solid waste to generate fuel for cooking has been shown to be a promising option for villages and small towns in tropical countries such as India. More than 2,000 small-

scale plants running on kitchen and market waste and a few anaerobic medium-scale plants in India and Sri Lanka are reportedly working successfully.

Source: EAWAG (2007)

■ About 500 rural households in the Indian state of Bihar have been benefiting from off-grid power generated from rice husk since 2008. Three quintals (300 kg) of rice husk are used per day in a power plant to generate 32 kilowatts of power. The rice husk costs Rs 60 (US\$ 1.3) per quintal. The production cost per plant per month is about Rs 20,000 (US\$ 426). There is sufficient electricity for a household to light up two rooms and charge a mobile phone for about US\$ 2 per month.

Source: IFC (2010)

chapter on agriculture expands on the business case for using waste to enhance crop production.

An indirect estimate is in terms of the avoided loss of trade owing to the excessive use of chemical fertilisers. The Food and Fertilizer Technology Center (FFTC) for the Asia and Pacific region, for example, have attributed the reduction in export volume and foreign demand of some agricultural produce in the region to high fertiliser residue levels. Such economic losses could be avoided by using organic compost for agricultural production.

### Energy production from waste

Recovering energy and other useful by-products from waste has been made possible by considerable technological breakthroughs, which have led to the implementation of WtE projects. The WtE market was estimated at US\$ 19.9 billion in 2008 and according to forecasts, the market would grow by 30 per cent by 2014 (Argus Research Company, Independent International Investment Research Plc and Pipal Research Group 2010). The Republic of Korea, for example, has set a target for proportion of energy to be sourced from waste and biomass at 3.17 per cent in 2013 and 4.16 per cent in 2020 (Ministry of Environment, Republic of Korea, 2009). This is expected to result in a reduction of GHG emissions of 9.1 million tonnes in 2013 and 44.82 million tonnes in 2020. The nation has planned to convert all of its waste facilities to energy-recovery by 2020 by building at least 74 RDF and biogas plants, 24 energy-generating incinerators and 25 landfill-gas recovery plants (Ministry of Environment, Republic of Korea, 2009).

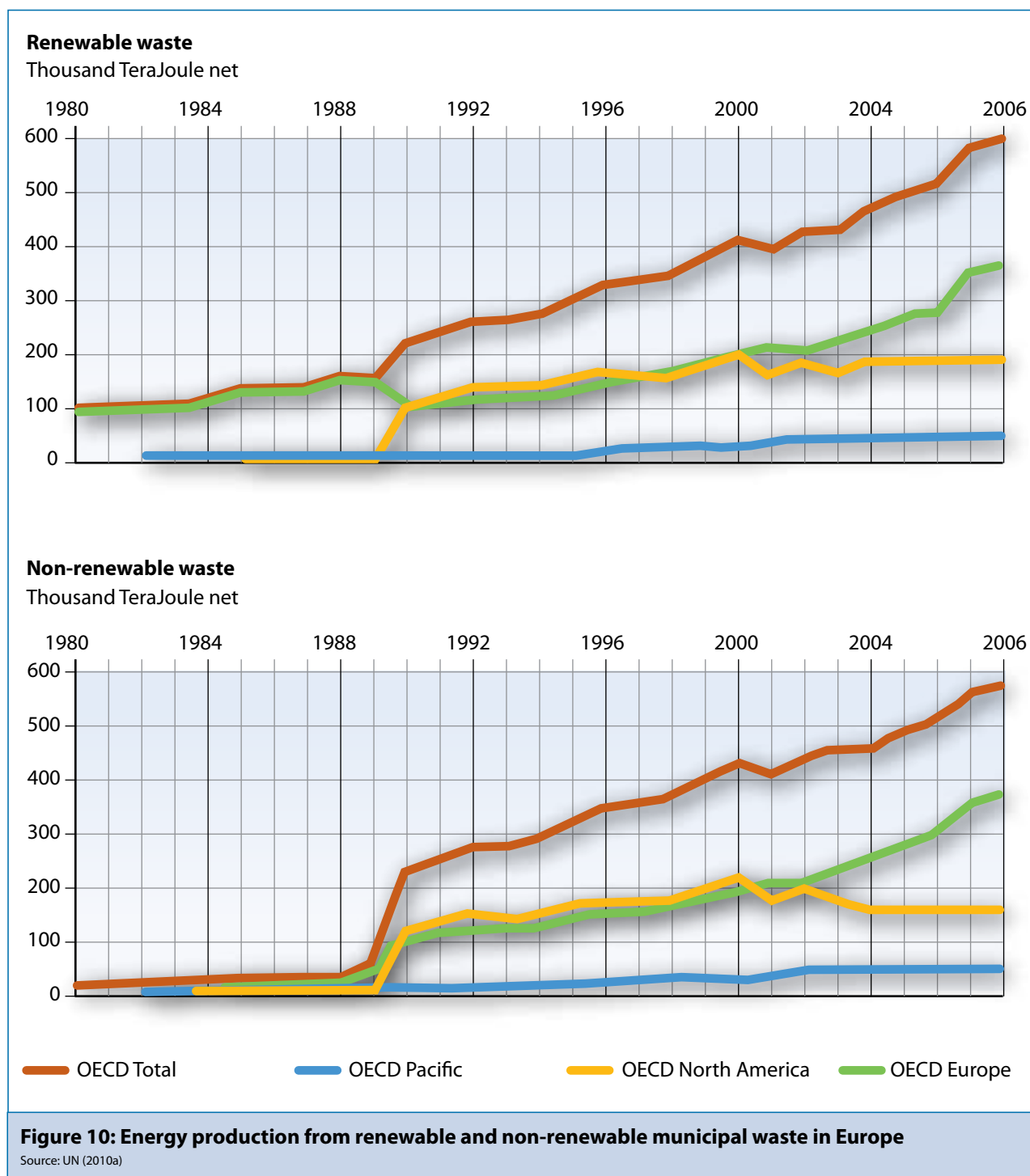
In most cases, energy-recovery projects provide opportunities for generation and distribution of power on

a decentralised basis where the electricity grid may not be available. For example, agricultural residue generated primarily in rural areas amounting to 140 billion tonnes globally has been reported to have an energy potential equivalent to 50 billion tonnes of oil (UNEP 2009c). Box 7 provides examples of the role of waste in meeting the demand for rural energy in Asia and successful entrepreneurial endeavours.

Energy-recovery projects have also been the recent focus of government investments in developed countries. In particular, there has been much interest in the EU owing to the binding targets under the EU Renewable Energy Directive (OECD 2009). Figure 10 shows the rising trend for energy production from renewable (biomass residues) and non-renewable (pellet-based waste to energy) municipal waste in the EU.

While biomethanation has been successful in Europe owing to excellent source-segregated waste upstream, the technology has not been so successful in many Asian cities where segregation of waste at source is low or almost absent. Large-scale biogas plants have proved to be economically viable with return on investments (RoI) reported to be in the order of 7 per cent to 15 per cent (Singh 2006). Smaller decentralised biogas plants benefit from a lower pay-back period owing to the avoided cost of disposal, resulting in a pay-back of two to four years.

With advanced technologies, waste itself can be converted into useful energy products. The EU alone has been estimated to produce three million tonnes of RDF in 2003 (EC 2003). Thermal technologies have been reported to contribute to a major share of the market, namely to



about 93 per cent (US\$ 18.5 billion). The rest of the market share, about 7 per cent (US\$ 1.4 billion), was attributed to biological technologies. Japan, Canada and the UK are also experimenting with advanced thermal technologies such as Plasma Arc Gasification.

### Reduced GHG emissions

The greening of the waste sector offers promising opportunities to mitigate climate change. According to recent national estimates by the UNFCCC, the waste sector, including waste water, produces on average 2.8 per cent of national GHG emissions (IPCC 2007a). The Montreal Protocol's Technology and Economic Assessment Panel (TEAP) estimated that worldwide ODS banks are available

at approximately 3.78 million ODP-weighted tonnes in 2002 (55 times the global consumption of ODS in 2007) and have the potential to release over 20 billion tCO<sub>2</sub>-eq of GHGs (UNEP 2009b).

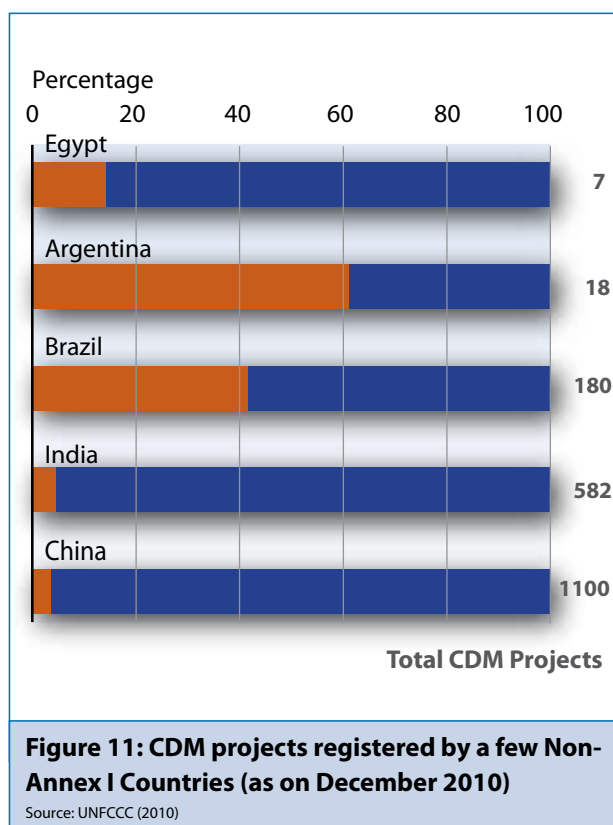
Incineration and industrial co-combustion for WtE are believed to be able to provide important climate-related benefits in two areas.

First, these technologies help reduce GHG emissions. According to IPCC (2007b), the total global mitigation potential for reducing landfill methane emissions in 2030 is estimated to be more than 1000 MtCO<sub>2</sub>-eq (or 70 per cent of estimated emissions) at costs below US\$ 100/tCO<sub>2</sub>-eq/



yr. Between 20 and 30 per cent of projected emissions for 2030 can be reduced at negative cost and 30-50 per cent at costs of less than US\$ 20/tCO<sub>2</sub>-eq/yr. More significant emission reductions are achievable at a higher cost, by additionally exploiting the mitigation potential in thermal processes for WtE.

Second, they can earn carbon credits. The CDM introduced under the Kyoto Protocol awards credit to avoided emissions from waste and hence can be applicable for all waste to energy, landfill gas recovery for power generation and composting projects. Figure 11 depicts the total number of CDM projects registered by a few non-annex I countries and the fraction of projects registered in the waste sector as on February 2010. The World Bank has estimated the potential annual carbon finance revenues per million residents at US\$ 2,580,000 for landfill gas recovery, US\$ 1,327,000 for composting, up to US\$ 3,500,000 for recycling and US\$ 115,000 (plus the fuel savings) for transfer stations (Hoorweg and Giannelli 2007). Landfill gas recovery from 1 million tonnes of waste leads to a reduction of 31,500 tonnes of CO<sub>2</sub> equivalent to a potential yielding revenue of US\$140,000 per year (carbon price at US\$ 4.5 per tonne), when registered as a CDM project (Greiner 2005).



## Box 8: Waste-based carbon credits

### ■ Fly ash re-utilisation earns carbon credits

In India, about 26,000 hectares of land is covered by ash ponds. This land contains nearly 90 million tonnes of flyash that is generated annually in the country. It is estimated that every tonne of flyash reused to make concrete reduces 1 tonne of CO<sub>2</sub> equivalent GHG emissions. Lafarge India Pvt. Ltd. has implemented a CDM project activity through fly ash reuse to replace clinker in Arasmat Cement Plant in Chattisgarh, India. By increasing the fraction of flyash (to replace clinker) added to blended cement procured from a thermal power station, the project activity has been successful in reducing approximately 69,359 tonnes of CO<sub>2</sub>e per year, with a potential to earn CERs worth US\$ 0.9 million.

Source: UNFCCC (2006)

### ■ Material recycling from solid waste earns carbon credits

A new small-scale methodology called "AMS-III AJ Recovery and Recycling of Materials from Solid Wastes" valid from 26 March 2010 was approved by the CDM Executive Body (EB). This enables the recovery and recycling of High Density Poly Ethylene (HDPE) and Low Density Poly Ethylene (LDPE) plastics in MSW to

process them into intermediate or finished products such as plastic resin. It negates the need to produce virgin HDPE and LDPE materials in dedicated facilities and results in energy savings and reduced emissions and is eligible to earn carbon credits. However, the wastes must be procured locally, from sources located within 200 km of the recycling facilities; plastics already segregated from the rest of the waste and transported more than 200 km distance are not eligible.

Source: CDM EB (2010)

### ■ CDM projects in Dhaka, Bangladesh

Waste Concern, a non-profit organisation in Bangladesh, has registered two waste-related CDM projects in Dhaka. One of the projects involves composting 700 tonnes of organic waste a day in the city and generating some 624,000 tCO<sub>2</sub> equivalents over the first crediting period of 2006-2012. The project will reduce GHG emissions by diverting high organic waste from a landfill to an aerobic composting process. Another project on landfill-gas extraction and utilisation at Matuail landfill site, Dhaka, has been registered to realise 566,000 tCO<sub>2</sub> equivalents over the same period.

Source: UNFCCC (2005)

Most of the landfill sites in China and India have been small and non-sanitary, and many larger sites have only been built over the last ten years. This has resulted in the low number of CDM projects in the waste sector (9 per cent of all registered CDM projects). This situation is expected to change over the next ten years.

Brazil is the leading developing country that has exploited the CDM option for the waste sector with 72 registered projects and over 10 million Certified Emissions Reductions (CER). The CER potential of proposed Landfill Gas to Energy (LFGTE) projects in 11 landfills from four countries: Brazil (3), Colombia (6), Peru (1) and Uruguay (1), has been estimated at 16.98 million tCO<sub>2</sub>eq by the World Bank. The CER benefits from waste recycling are illustrated in Box 8.

### **Supporting equity and poverty reduction**

Waste is the sector in which the issue of equity and poverty is probably most acute. The pollution from many below-standard waste treatment and disposal facilities directly impact populations living close to these facilities. It has been

observed that hazardous waste dumps and incinerators are mostly located in the poorest neighbourhoods, both in developed and developing countries (Wapner 2002). Much of the literature citing waste facilities in the USA discusses race and poverty elements (Jenkins et al. 2002). Furthermore, the lack of alternative livelihood options and the value of recovered materials entice many poor men, women and even children to engage in scavenging activities in the low and middle income countries without any health protection.

Greening the waste sector includes considerations of these equity and poverty issues. Investing in greening the sector is not only about building facilities; it also includes the formalisation of the sector so that workers receive training, health protection and benefits, and a fair compensation for their labour. In addition, greening the waste sector favours decentralised, localised and labour-intensive waste treatment systems as opposed to centralised, large-scale, capital intensive waste facilities so as to generate job opportunities for local communities.

## 4 Effects of increased investment in the waste sector

A systems-dynamics model was used to identify the likely effects of increased investments in the waste sector at the global level (working with global averages), with particular emphasis on waste management and recycling. In an ideal case, the analysis of investments in improved solid waste management would cover both the generation of waste and the entire waste management chain, including collection, segregation, transportation, recycling and recovery, treatment and disposal, but lack of data has limited the inclusion of all this. The estimates presented below should therefore be interpreted as illustrating the nature and scale of waste generation and highlighting possibilities to invest in waste collection and treatment. There are also considerable differences between countries, which are not reflected in the global figures, including both generation and costs.

The economy-wide model assumes 2 per cent of the global GDP to be allocated on a yearly basis as additional investment in 10 green sectors (G2) over the period 2011-2050. The results of this investment are then compared with those of a BAU scenario without additional investment, and a BAU2 scenario, in which the same additional amount is invested following the projected trends of BAU.

Within this multi-sector model, the waste sector is allocated 0.16 per cent of the global GDP or US\$ 108 billion in 2011, which rises with GDP to US\$ 310 in 2050, corresponding to an average annual investment US\$ 198 billion over the period 2011-2050. The purpose of the exercise is to illustrate what would happen if a given amount of additional investment is made available to green the waste sector (alongside the greening of the other sectors). The approach, however, does not lead to results as to how much investment is needed to reach a specific target in greening the sector. Due to data limitations, the model is also not able to estimate effects in terms of the market values of, for example, recycled materials and products, recovered energy and composted fertilisers. The modelling of the overall green economy investment scenarios across sectors is presented in detail in a separate chapter.

In the model, waste generation (i.e. before recycling and recovery) is driven primarily by population and GDP. In 2010, an estimated 11.2 billion tonnes of solid waste were collected globally.<sup>4</sup> Of this, 8.4 billion tonnes were agricultural and forestry organic waste and 1.8 billion tonnes were MSW, and the rest consisted of industrial waste, e-waste and waste from construction and

demolition (C&D waste).<sup>5</sup> Under a BAU Scenario (with no additional investments) the amount of solid waste generated each year is projected to rise 17 per cent to 13.1 billion tonnes in 2050.

The total waste collected is treated, in general, using six different approaches, including landfill, energy recovery, material recovery, incineration, composting and recycling, which all are likely to expand in the future. For example, the total power generation from waste in 2010 was estimated at about 71,600 GWh incinerating 192 million tonnes of municipal waste, with a capacity of 54 GW primarily from waste combustion plants. Under BAU (without additional investments), this generation capacity is expected to grow modestly to just over 200 GW by 2050, corresponding to 0.5 billion tonnes of waste incinerated per year. The size of landfills is also expected to expand, especially if no additional efforts are made to build WtE plants. In the BAU scenario, total accumulated waste in landfills will increase by 50 per cent from the currently almost 8 billion tonnes to 12 billion tonnes. The modern municipal waste landfills that enable production of biogas, only account for a small share, but further improvement in terms of technology and economic performance are expected in the future. Regarding material recovery from wastes, under the BAU scenario, the total amount of recyclables in MSW is projected to increase from 0.18 billion tonnes in 2010 to 0.28 billion tonnes in 2050.

The green investment scenario then allocates 0.16 per cent of the global GDP to three areas of waste management: waste recycling, composting of agricultural and forestry organic waste and waste collection. Investments for waste recycling and composting (including energy recovery) are prioritised (to support material recovery and agricultural activities) and the residual investment is spent on increasing waste collection. An average of about US\$ 46 billion per year is allocated to waste recycling and composting over the entire period, under G2, based on a global average estimated cost of recycling of US\$ 100 per tonne of waste. The average annual investment for waste collection is US\$ 152 billion for G2. The allocation for waste collection under G2 reflects the need to handle the net increase in waste generation in the coming decades.

4. The model refers to collected and not generated as typically only the waste that is collected appears in statistical data.

5. Note that these two categories overlap: The MSW can also include parts of organic waste. Please note that Chalmin and Gaillochet (2009) have reported that 3.4 to 4 billion tonnes of municipal and hazardous waste are produced every year.

In the G2 scenario, the investment leads to an increase in the percentage of MSW, industrial waste and e-waste recycled from 9.9 per cent in 2010 to 33.4 per cent 2050, which is 6.6 per cent higher than in the BAU.

These improvements can be broken down into: 1) a doubling of the recycling rate of industrial waste, (increase from 7 to 15 per cent), and 2) near full recycling of e-waste (from a current estimated level of 15 per cent)<sup>6</sup>, and 3) an increase of about 3.5 times over the current recycling rate of MSW – the principal source of recycled materials, from 10 to 34 per cent.

Further, by 2050, all organic waste would be composted or recovered for energy in the simulations, compared with 70 per cent under both BAU scenarios. The increase in composting would increase the supply of organic fertiliser with positive impacts on soil quality and yield in the agriculture sector.<sup>7</sup>

Under the BAU scenario the proportion of total waste collected that ends up in landfills is projected to increase from 22 per cent to 28 per cent by 2050. With the additional investment assumed under G2, this proportion would

be reduced to less than 5 per cent. The primary reason for the reduction is a decrease in the proportion of MSW reaching landfill declining from 60 to 20 per cent. Further, the reduction can be attributed to the increased recycling of organic waste, C&D and e-waste. The total amount of landfill waste would stabilise at 8 billion tonnes in the G2 case in 2014, and decline sharply to return to a 1970 level of 3.5 billion tonnes in 2048.

Based on relatively simple assumptions of the labour intensity of waste recycling, composting and collection activities, the assumed green investments in the waste-management sector are also expected to contribute to job creation. Almost 10 per cent additional jobs globally are expected to be created by 2050, compared to BAU2 at 23-24 million, only in waste collection activities.<sup>8</sup> These global averages, however, do not reveal regional differences. It is reasonable to expect, for example, that higher job increases could be achievable in faster growing, emerging economies where current rates of collection and recycling are low. It is also important to recall that these simulations do not include investments in reducing waste generation, which could reduce the stream of waste generated and thus cost the corresponding downstream jobs.

In summary, the simulations, though limited in scope and detail illustrate the potential for considerably reducing the proportion of solid waste going to landfill – by four-fifths – by investing in collection, recycling, including composting, as well as generating energy from organic waste.

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6. Given the time period for the projection of 40 years, a significant increase for the amount of e-waste being recycled is possible, while, however, acknowledging that a rate of 100 per cent may not be realistic.

7. As discussed in the chapter on agriculture.

8. This is based on a labour intensity of 1,760 persons/million tonnes of waste collected.

## 5 Enabling Conditions

Mobilising increased investment in greening the waste sector on a large scale will not take place automatically. There are a number of essential conditions required to enable countries to move towards that direction. This section describes four of them: 1) financing; 2) incentives; 3) policy and regulatory measures; and 4) institutional arrangements.

### 5.1 Financing

Investing in greening the waste sector requires substantial financial resources for both capital expenditures and operation. Such resources may be found from: 1) private investments; 2) international funding; 3) cost recovery from users; and 4) other innovative financing mechanisms. For financing from the general banking system and capital markets, further information is provided in the Finance Chapter.

#### Private investment

Private-sector involvement, often in the form of Public-Private Partnerships (PPPs) can, if certain conditions are met, be efficient and reduce the fiscal pressure on government budgets. Private-sector involvement has, for example, reduced the waste service cost by at least 25 per cent in countries including the UK, USA and Canada and by 23 per cent in Malaysia (Bartone 1999). Privatisation of transport services for waste management has resulted in a cost saving of 23 per cent for the city of Rajkot in India (USAID 1999).

Studies in the Republic of Ireland have also found that tendering can substantially reduce the costs incurred by local authorities in providing refuse collection services. Crude comparisons of costs before and after tendering and the costs of local authorities versus private contractors indicate that tendering can yield savings of between 34 and 45 per cent. The bulk of these cost savings are attributed to real efficiency gains as a result of contracting out (Reeves and Barrow 2000).

Public-Private Partnership arrangements can be of many types. In the case of service contracts, the private partner has to provide a clearly defined service to the public partner. In the case of a management contract, the private partner is responsible for core activities like operation and maintenance. Some types of private participation arrangements are leased, where the private partner is fully responsible for operation and maintenance and the public partner is responsible for new investments. Single or multiple private players may be involved depending on the type of waste management solution.

Developing countries are beginning to see the benefits of PPPs (Ahmed and Ali 2004). In many Columbian cities and a few large cities in India and China, municipalities provide infrastructure and equipment while private waste collectors provide the labour. In New Delhi, India, an aerobic windrow composting plant is run through a concession agreement for 25 years and a waste management project leased for ten years on the basis of Develop, Build, Operate and Transfer (DBOT) (Babu 2010).

In the Philippines, a privately-built high-temperature incinerator for high-risk health-care waste is being used by more than 200 medical centres and hospitals with a monitoring system. Dakar, Senegal, experienced a public-private joint venture that was initially a monopoly but later took to more competitive privatisation arrangement with multiple service contracts. These are some examples of innovative financing through PPPs to deliver improved services and enhanced cost efficiency.

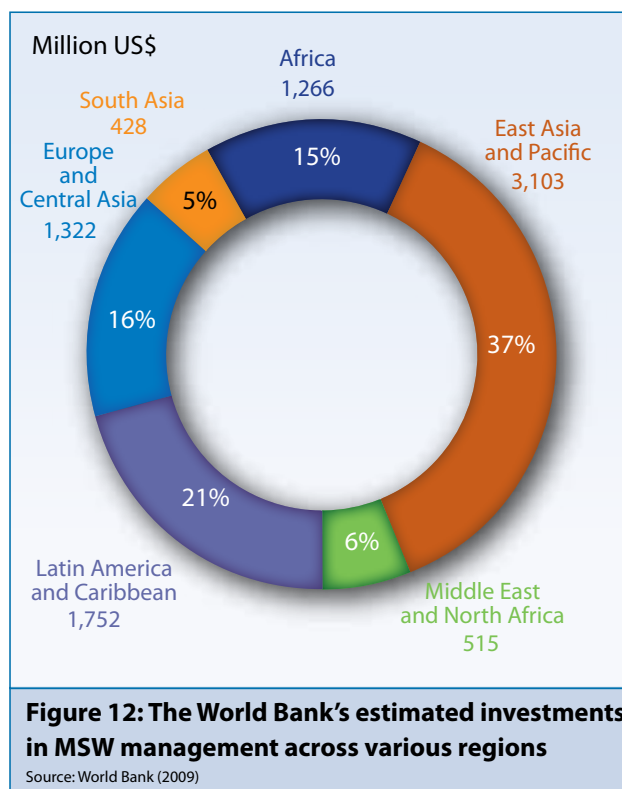
#### International funding

Certified Emission Reductions (CERs) can be a potential source of inter-governmental funding. However, at the moment, the CERs issued to waste-sector projects are much lower than the CERs claimed by the project proponents in the documents submitted to UNFCCC. Modelling for methane generation and avoidance estimations has been unclear, leading to over-estimation of CERs, which in turn result in project rejections in some cases. A few technical issues such as high leachate levels inhibiting gas extraction and other problems in monitoring and verification have been major barriers in developing countries. Addressing such barriers will enable developing countries to utilise CDM revenues for greening the waste sector.

Apart from CERs, another major international source of funding for greening the waste sector is multilateral development banks. For example, about 199 waste-related projects worth US\$ 15.7 billion were supported by the World Bank in various regions in 2009. Of all the regions, East Asia and Pacific has been receiving a major portion (37 per cent) of the support, with commitments of up to US\$ 3.1 billion in 2009, as depicted in Figure 12.

Multilateral Environmental Agreements (MEAs) lead to the creation of specific funds that can support initiatives that lead to greening of the waste sector. For example, the Multi Lateral Fund (MLF) for the Implementation of the Montreal Protocol, the Global Environment Facility and bi-lateral donors have offered their financial assistance to the United Nations Development Programme (UNDP) to enable developing countries and Countries with Economies In





Transition (CEIT) in complying with the Montreal Protocol's control measures pertaining to the phase-out of ODS. In this process, aspects of product discards and waste management get addressed. ICF (2008) suggests that while non-Article 5 countries use ODS levies (e.g., tax per kg of refrigerant imports/production), municipal taxes, and taxes on new equipment, A5 countries could use direct assistance from the MLFs, and/or through appropriate carbon trading platforms such as CDM for implementing an approved ODS destruction methodology. MLFs could consider co-funding incremental costs associated with the removal and destruction and/or recovery and recycling of ODS refrigerant and foam from appliances, or finance the disposal of older appliances.

### Cost recovery from users

Waste services are provided as public services in many countries. Payments for waste collection and transport services by households, enterprises, and large-scale industrial installations, for example, can help recover the capital cost and defray the operational costs.

Indeed, cost recovery is a strategy to generate funding for investing in greening the waste sector. It has the potential to shift the costs of environmental and public health management – including administrative, capital, and operational costs – to households, allowing for more appropriate sharing of costs following the polluter pays principle. Cost-recovery measures can include administrative charges and fees covering the establishment and maintenance of registration, authorisation or permitting systems, and user charges and fees for publicly

provided waste collection, treatment and disposal services. Environmental liability measures or environmental fines can also be designed in a way that helps ensure the cost of remediation and clean-up as well as environmental health cost is covered by the negligent parties, i.e. responsible polluters rather than drawing resources from public budgets.

### Other innovative financing mechanisms

Micro-financing and hybrid financing are particularly useful innovative financing mechanisms for supporting small-scale efforts. The Participatory Sustainable Waste Management Project established in Brazil in 2006, for example, created micro-credit funds from donations (Hogarth 2009). These funds are used as working capital for financing waste transportation and waste-related emergency responses. The funds are also used to extend loans to waste-pickers who will repay their loans after receiving payment from recycling depots.

Another example is that of micro-financing for micro-enterprises managing a 40-year-old, 2 million tonnes garbage heap called Smokey Mountain in Metro Manila, Philippines. The micro-enterprises are involved in collection, sorting, and sales of waste through a Material Recycling Facility. Micro-financing enabled these enterprises to borrow loans and increase their capacity to generate revenue. Through a donated bioreactor, the enterprise is processing up to 1 tonne of waste daily, supported by awareness programmes on segregation of organic waste in 21 buildings in the neighbourhood (UN 2010b).

Hybrid financing models (combining debt and equity) are being increasingly explored to support economically challenged waste management projects. Examples exist from the early 2000s in the UK, when the British government introduced prudential borrowing which gave municipal councils more freedom to borrow, removing any restriction on how much debt they could run up (UN 2010b).<sup>9</sup>

Another innovative financing model includes joint financing by two or more municipalities to optimise investments and attract modern technologies (such as WtE projects), which are not competitive on smaller scales (OECD 2007).

## 5.2 Economic incentives and disincentives

Economic incentives and disincentives serve to motivate consumers and businesses to reduce waste generation

9. Local authorities could decide for themselves whether and at what levels they borrow money for financing any purpose relevant to their functions provided that they meet requirements for prudent management of their financial affairs (Asanova et al. 2007). The Department of Environment, Food and Rural Affairs of the UK government advised prudential borrowing for low-risk investments. For example, about 60 per cent of an MBT process was funded through prudential borrowing in West Sussex Council.

and dispose of waste responsibly, thereby contributing to increased demand for greening the waste sector. The incentives commonly prevalent in the waste sector include: 1) taxes and fees; 2) recycling credit and other forms of subsidies; 3) deposit-refund; and 4) standards and performance bond or environmental guarantee fund.

Volumetric landfill taxes can encourage the reduction of waste and are easy to implement. Their effectiveness, however, depends on the tax rate per tonne of waste and on the existence of adequate monitoring and enforcement measures. It is also important to ensure that the tax does not result in increased illegal dumping rather than encouraging 3R.

Pay-as-you-throw (PAYT) is another way of discouraging waste generation. Precaution against illegal waste dumping or misuse of recycling facilities, should be taken, however. Full financing of the waste-management infrastructure has to be assured and sufficient awareness-raising is necessary. PAYT has a positive impact on recycling. For example, PAYT increased the recycling rate from 7 per cent to 35 per cent in Portland, Oregon and from 21 per cent to 50 per cent in Falmouth, Maine in just one year of implementation (Shawnee Kansas 2009).

Waste avoidance can also be achieved by assigning a disincentive for items such as plastic bags. For example, Nagoya city in Japan, after extensive consultation with retailing companies and two years of piloting, assigned a charge for plastic shopping bags in April 2009. The scheme was adopted by 90 per cent of the shopping market. The initiative reduced plastic-bag usage during shopping by 90 per cent as of December 2009. About 320 million bags weighing 2,233 tonnes were estimated to have been saved between October 2007 and October 2009 (Environmental Affairs Bureau 2010).

It is important to formalise the informal sector enterprises and support them through incentives in order to develop local markets and small and medium formal recycling enterprises. Recycling credit schemes can be a way to incentivise municipal or private recycling by raising its profitability, but they have had limited applications so far. Another form of positive incentive is subsidies to offset the costs of clean-up. Box 9 gives an example in New York City.

At the household-level waste-collection fees based on weight or volume for brown waste – to be either incinerated or landfilled – in tandem with free collection for recyclables, including organic matter, are widely used to incentivise 3R activities. This type of policy usually co-exists with investments in either kerbside collection or community deposit sites for recyclables. For example, in the Republic of Korea, a Volume Based Waste Fee (VBWF) system was introduced in 1995 to replace a fixed-fee system. Volume Based Waste Fee is a pay-per-sack scheme where households place residual waste in pre-paid sacks and recyclables are collected free of charge. The VBWF system led to a reduction of MSW generation of 21.5 per cent from 1994 to 2009 and an increase in the recycling rate from 15.4 per cent in 1994 to 61.1 per cent in 2009 (Ministry of Environment, Republic of Korea, 2010).

### 5.3 Policy and regulatory measures

The most common types of policy and regulatory measures include:

- regulated targets for minimisation, reuse, recycling; and required targets for virgin materials displacement in production inputs;

#### Box 9: Incentives for private investment in brownfield clean-up and remediation

In August 2010, the Mayor of New York City and the Commissioner of the New York State Department of Environmental Conservation announced an agreement that paved the way for the city to start cleaning up brownfields, or light-to-moderately contaminated areas that are not toxic enough to qualify for federal or state Superfund clean-up programmes. About 7,000 vacant or underused acres around the city could be readied for new development under the programme.

In 2008, the city created an Office of Environmental Remediation to run the programme, which began

with a small site in the Bronx. One of an estimated 1,500 to 2,000 brownfields around the city, it was chosen as the site of Pelham Parkway Towers, an affordable housing complex.

The brownfields programme, which offers financial incentives to developers to offset some of the costs of cleaning up properties, is expected to expedite the cleaning process and put an end to self-directed clean-ups managed by developers without government oversight.

Source: New York Times (2010)

- regulation relevant to the waste management market, i.e. permitting/licensing requirements for waste handling, storage, treatment and final disposal; and recycled materials standards; facilities standards, including pollution control technologies; and
- land-use policies and planning.

In most cases, a particular piece of policy or legislation may encompass these different types of regulations. The discussions below will, therefore, not differentiate these different types.

Regulatory pressure in waste management started off in the mid-1970s with the tightening of waste disposal laws in developed countries. The EU directive (1975) on the disposal of waste oil and the US RCRA (1976) governing disposal of solid and hazardous waste have been the foremost regulatory measures that identified waste management as a municipal issue for government policy.<sup>10</sup> Box 10 gives an example of how an EU directive has influenced the UK to cut down on the amount of biodegradable waste going to landfill.

The Basel Convention on Transboundary Movement of Hazardous Wastes and their Disposal was adopted in 1989 and entered into force in 1992. The Convention provides for a strict notification scheme and addresses issues such as minimising the generation of hazardous wastes in terms of quantity and hazardousness, disposing them of as close to the source of generation as possible, reducing the movement of hazardous wastes, maximising environmentally sound waste reuse and recycling, promoting environmentally sound waste disposal and treatment and extending waste service coverage.

Since the early 1990s, the EU has been actively developing waste-related policy measures. The following EU Directives and Strategies have been instrumental in greening the region's waste management industry: Packaging (1994), Waste Communication Strategy (1996), Landfill (1999), End of Life Vehicles (EoLV 2000), Waste Electrical and Electronic Equipment (WEEE 2002), the Thematic Strategy on Waste Prevention and Recycling of Waste and Sustainable Use of Natural Resources (2005), the EU's revised Waste Framework Directive (2008) and the Raw Material Initiative (2008). Meeting the 85 per cent EoLV target by 2006 had the potential to reduce the landfilling cost for the EU by € 80 million per year, which is a cost saving of 40 per cent, compared to the cost that prevailed prior to the directive. Meeting the 95 per cent target by 2015 will reduce the cost further by 80 per cent (GHK and Bio Intelligence

Service 2006). The WEEE directive has compelled electrical and electronic firms across the world to adopt effective product life-cycle policies such as take-back and recovery policies. Overall, green initiatives such as the one taken to meet EoLV and WEEE requirements have been beneficial to the companies and overall save the company 40-65 per cent in manufacturing costs through the reuse of parts and materials (Ali and Chan 2008).

Individual countries have also moved forward with waste related regulations and their enforcement. The German Packaging Ordinance introduced in 1991 helped encourage recycling of packaging waste which is collected through a third party organisation. British Columbia Recycling Regulation of 2004 brought about a considerable increase in the proportion of recycled waste in Canada.

Developing-country examples include the Law of the People's Republic of China on the Prevention and Control of Solid Waste Pollution adopted in 1995, South Africa's National Waste Management Strategy in 1999, India's Municipal Waste Management and Handling Rules in 2000, the Philippines's Ecological Solid Waste Management Act in 2000, Malaysia's Solid Waste and Public Cleansing Management Act in 2007 and Indonesia's Act regarding Waste Management in 2008. Although the real effects of such measures will come from implementation, the existence of these instruments provides a signal of political commitments to greening the waste sector.

Apart from broad national policies and legislations, there are also specific regulations. Extended Producer

## Box 10: Landfill diversion in the UK

The EU landfill directive has been a key driver in pushing the UK to look for private investors to manage its waste. The directive requires member states to cut down on the amount of biodegradable waste going to landfill to less than 35 per cent of 1995 levels by 2020. Rising generation of waste is making it even more difficult for member states such as the UK to meet the landfill targets. Therefore, the Department for Environment, Food and Rural Affairs is promoting a pipeline of projects costing up to US\$ 12.8 billion in investment that will require funding under the government's Private Finance Initiative (PFI). More incinerators are also being planned by private contractors.

Source: Adapted from Reuters (2010).

10. RCRA was the Principal Federal law enacted in the USA governing the disposal of MSW and hazardous waste and covers many regulatory functions of hazardous and non-hazardous waste. Its most prominent provisions is said to be the Subtitle C programme which tracks the progress of hazardous wastes from their point of generation, their transport, and their treatment and/or disposal. Superfund Sites refer to the abandoned waste management facilities that are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Location	Description of community cooperation
Dhaka, Bangladesh	In Dhaka, decentralised composting has been effectively implemented through community involvement. Waste Concern in Dhaka has established a business model to this effect. Community contributions in the form of a user-charge account for 30 per cent of the project revenue and made this practice financially viable. The programme created new employments for the communities and improved livelihoods in the region. <small>Source: Zurbrugg et al. (2005)</small>
Nagpur, India	Door-to-door (D2D) collection of waste with community cooperation has achieved a concrete savings of the order of Rs 50 million (equivalent to US\$ 1 million) in the municipality's solid waste services. An NGO was involved to boost the involvement of the community. The initiative provided livelihoods for 1,600 people from the most deprived segment of society. The effort also boosted the financial credibility of the NGO involved, raising the budget level at least thirty-fold. <small>Source: Agarwal (2005)</small>
Cairo, Egypt	The Zabbaleen minority community has been engaged in informal waste picking in Cairo, Egypt, since the 1930s. About 20,000 Zabbaleen were involved in waste-picking (30-40 per cent of an estimated 9,000 tonnes per day), recycling up to 80 per cent of the waste collected. Since the establishment of associations in 1970s, and launching a Zabbaleen Environment and Development Programme in 1981 with support from the Ford Foundation, the World Bank, Oxfam and others, working conditions and the basic infrastructure for waste collection and sorting has improved considerably. During the 1990s, the Zabbaleen continued to work under a franchise system by paying a license fee to the Cairo and Giza Cleansing and Beautification Authorities for the exclusive right to service a specific number of apartment blocks. They collected fees directly from households (on average US\$ 0.3 to 0.6). A primary school, a paper recycling project, a weaving school, a health centre and a project to support small industries have all been established to support the waste pickers. The use of donkey carts for waste collection was banned. <small>Source: Aziz (2004) and Wilson et al. (2006)</small>

**Table 5: Community cooperation in waste management**

Responsibility (EPR) or Producer Take-Back Responsibility programmes such as the Green Dot Programme in Europe have motivated European-based manufacturers to simplify packaging. Such programmes have triggered innovative design concepts such as Design for Environment (DfE) and Design for Disassembly (DfD). Enforcing concepts such as cleaner production and continual quality improvement in manufacturing processes could lead to generation of better quality waste for reuse and recycling. These concepts can help heightened green awareness in the supply chain and consumer behaviour. In the Republic of Korea, for example, EPR was enforced on packaging (paper, glass, iron, aluminium and plastic) and specific products (batteries, tyres, lubricating oil and fluorescent lamps) since 2003. According to the Ministry of Environment of the Republic of Korea, the initiative resulted in the recycling of 7.7 million tonnes of waste between 2003 and 2008, representing an increase in the recycling rate by 13.5 per cent, compared with the rate before EPR implementation. This resulted in an economic benefit of 1.7 trillion Won, equivalent to US\$ 1.6 billion (Ministry of Environment, Republic of Korea, 2010).

Industries can have voluntary, self-regulatory measures. For example, Hitachi has designed washing machines that can be easily disassembled, saving 33 per cent of the manufacturing time, and machines that need less service, winning consumer confidence and reducing disposal cost. Similarly, Fuji Xerox collects used photocopy machines, printers and cartridges from nine countries in the Asia Pacific region, disassembles and classifies the parts into 64 categories for reuse in new machines. Philips has launched a range of green flagship products such as Ultra High Performance lamps with 52 per cent less packaging, 25 watt T8 lights with 40 per cent less mercury, flat-screen TVs with 17 per cent less packaging, DVD players weighing 26 per cent less and defibrillators weighing 28 per cent less than their predecessors, among others.

In order for new opportunities and application to open up for reuse of waste materials and also the term “waste” not to be a misnomer, further policy developments into definitions of waste stressing its resource value is required. In addition, policy measures towards promoting awareness, education, research, training and capacity development will be essential to nurture skills and expertise required for waste management and also to bring about behavioural changes.

## 5.4 Institutional arrangements between formal and informal sectors

In many developing countries, command and control policies may not be as effective as economic instruments due to institutional capacity. Additionally, investments in the waste technologies have sometimes failed to reap benefits because of weak institutions. Investments are often deterred because of flawed institutions or missing markets.<sup>10</sup> Furthermore, institutional capacities to control imports of used goods/waste into developing countries are either non-existent or non-functional.

One of the major institutional issues in the waste sector is the relationship between the formal and informal segments of the sector. A major cause for a thriving informal sector in developing countries is the difficulty to achieve economies of scale in formalising the existing informal recycling units. Porter (2002) identifies five types of market failures in formal recycling: 1) Failure to provide households with correct market signals on recycling; 2) Failure to recycle the correct amount and choose the appropriate method of recycling by municipally owned or controlled recycling facilities (as they are bound by constraint on profit making); 3) Failure to increase stability in the recycling market, which is by nature unstable; 4) Failure to make optimal policy on taxing and subsidising substitutes for virgin products; and 5) Failure

to provide manufactures with correct market signals on disposal and recycling of their products and packaging.

Yet, the informal sector plays a significant role in waste management, especially through informal waste collection and recycling. Incentivising formal recycling activities, providing micro-finance and access to the markets could help in shifting the informal sector to a formal regime. In addition, raising awareness on the social and health related benefits of formalisation may help in understanding the importance of intangible benefits.

The operations of the informal waste businesses are subject to risks to human health and often imply working conditions that are not decent. It is important to address the health and safety risks from use of recycled and recovered products and to devise appropriate policies, regulations, and standards. Developing countries will need to adapt some of these frameworks to ensure that the workers in the informal sector and customers of the recycled products are well protected.

Suchada et al. (2003) highlight that when there was a close operating relationship between the formal and informal sectors of the waste recycling industry, the sector was observed to function efficiently, achieving a recycling rate

of 38 per cent of the total waste stream. Often, however, cooperation between government authorities and workers in the informal waste sector is weak owing to distrust.

The formalisation of waste-pickers, where desirable, often requires political support and policy reforms. But formalisation is not the only way to secure greater cooperation between the public, formal private and informal private sectors. Community based organisations (CBO) and Non-Governmental Organisations (NGO) have contributed to empowering the informal waste workers by extending micro-credits and arranging for external funding.

In community-based waste management programmes, a community leader identifies a service provider and/or plans and manages the services. Micro and small enterprises are also taking shape in developing countries such as Brazil, which unlike CBOs and NGOs, engage in waste picking activities for-profit (Ahmed and Ali 2004). Community cooperation has helped achieve considerable success in many developing countries. Waste collection through community organisation into cooperatives and micro-enterprises has been useful to manage municipal waste. Table 5 describes a few examples across the world where community cooperation has helped set up businesses in waste management.



## 6 Conclusions

The increasing volume and complexity of waste is posing threats to ecosystems and human health, but opportunities do exist to green the waste sector. These opportunities come from the growing demand for improved waste management and for resource and energy recovery from waste. This change in demand is driven by cost savings, increased environmental awareness and increasing scarcity of natural resources. The development of new waste-related technologies on 3Rs and technologies such as MBT and advanced biometanation has facilitated the greening of the sector. The growth of the waste market is a reflection of the underlying demand for greening the sector – especially the new paradigm of linking waste to resource use across the life-cycle of products.

Different countries face different waste related challenges, but the path to greening the waste sector shares common milestones. Prevention and reduction of waste at source is essential for all countries, although this is particularly important in developing countries given their higher level of population growth and increasing material and resource consumption. The absolute growth of population and income implies that the absolute volume of waste is unlikely to decline. Greening the sector is therefore the only way to decouple. It is important to reduce conversion of used materials into municipal waste. Proper collection, segregation, transport, and recycling of waste as well as the construction of basic facilities are essential steps in many developing countries. In most cases, in these countries, an additional intervention is the cleanup of existing dumpsites, which are harming the environment and the health of waste pickers most of whom are poor men, women and even children. Therefore, it is crucial to ensure that stringent regulations are in place and comprehensive environmental policies addressing the necessity of recycling and reducing landfills are developed.

The waste recovery and recycling part of the waste treatment chain probably holds the greatest potential in terms of contributions to a green economy. As natural resources become scarcer and with the prospect of peak oil, the commercial value of materials and energy recovered from waste could be substantial. The current recycling rate of all types of waste is likely to improve. Some developed countries and emerging economies have set high standards for themselves in this area and are likely to acquire

comparative advantages in remanufactured and recycled products. Developing countries, when planning their treatment facilities, may want to take into consideration the potential growth of resource and energy recovery as an increasingly significant industry. The choice of waste treatment options ought to include a full range of benefits including avoided environmental and social costs and should not be based only on technology costs.

Indeed, there are multiple benefits from greening the waste sector, although quantitative data are hard to come by. These benefits include resources recovered from waste helping to avoid extraction of raw materials, new products such as compost and energy derived from waste, lower cost of reducing GHG emissions, carbon credits, avoided health costs, and job creation. Greening of the sector will involve formalisation of the informal sector in many developing countries, including the provision of proper training, health protection, and decent level of compensation for waste workers, and thereby contribute to improving equity and poverty alleviation. Additional efforts are needed to collect data and conduct quantitative analysis at country level – taking a total cost perspective – to enable policy makers to design their strategy for greening the waste sector on a more informed basis.

Mobilising investment to green the waste sector requires a number of enabling conditions. Governments should increase their budgetary allocations to the sector. Further, entering into partnerships with the private sector has the potential for reducing fiscal pressure while enhancing the efficiency of service delivery. In many developing countries, the success of such arrangements is to a large extent dependant on a reasonably sound institutional framework and sufficient capacity to ensure transparency in awarding contracts to private service providers. Micro-financing, international development assistance and other financing mechanisms can also be explored to support localised waste treatment systems that provide employment opportunities to local communities while reducing the need for distant transport of waste. Another important component in greening the waste sector in many developing countries is building trust between the public sector and the informal waste sector. Special care should be taken to include poor waste-pickers in the formalisation process.

# References

- Acurio G., Rossin A., Teixeira P.F. and Zepeda F. (1998). "Diagnosis of Municipal Solid Waste Management in Latin America and the Caribbean, Joint publication of the Inter-American Development Bank and the Pan American Health Organization," Available at: <http://www.bvsde.paho.org/acrobat/diagnos.pdf>.
- Agarwal, V.S., (2005). "Sustainable Waste Management; Case study of Nagpur India: Asian Development Bank," Papers on Sanitation and Solid Waste Management.
- Ahmed SA. and Ali M. (2004). "Partnerships for solid waste management in developing countries: linking theories to realities," *Habitat International* Vol 28, pp. 467-479, Available at: <http://www.bvsde.paho.org/bvsacd/cd43/ali.pdf>.
- Ali L. and Chan Y.C. (2008). "Impact of RoHS/WEEE- On Effective Recycling-Electronics System Integration." IEEE, 2nd Electronics System Integration Technology Conference 521 Greenwich, UK. Available at: <http://www.ee.cityu.edu.hk/~epa/publications-ycchan/ConferencePublications/ConferencePublications-81.pdf>.
- Asenova D., Hood J., Fraser I. and Bailey S.J. (2007). "From the private finance initiative to the new prudential borrowing framework: A critical accounting perspective," Available at: <http://www.st-andrews.ac.uk/business/ecas/7/papers/ECAS-Asenova.pdf>.
- Ayres R.U. and Simonis U. (1994). *Industrial Metabolism: Restructuring for Sustainable Development*. United Nations University Press, Tokyo.
- Aziz H. (2004). "Improving the livelihood of child waste pickers: experiences with 'Zabbaleen' in Cairo, Egypt." Waste, The Netherlands.
- Babu M. (2010). "PPP in waste management in India: Opportunities, barriers and way ahead." IL&FS Waste Management and Urban Services Ltd., IWMUSL, Available at: [http://www.un.org/esa/dsd/susdevtopics/sdt\\_pdfs/meetings2010/icm0310/2g\\_Manesh\\_Babu.pdf](http://www.un.org/esa/dsd/susdevtopics/sdt_pdfs/meetings2010/icm0310/2g_Manesh_Babu.pdf)
- Baker E., Bournay E., Harayama A. and Rekacewicz P. (2004). "Vital Waste Graphics," Basel Convention, GRID Arendal, UNEP, DEWA Europe, Available at: [http://www.grida.no/\\_res/site/file/publications/vital-waste/wastereport-full.pdf](http://www.grida.no/_res/site/file/publications/vital-waste/wastereport-full.pdf).
- BIR (2008). "Report on environmental benefits of recycling." October 2008, Available at: [http://www.bir.org/assets/Documents/publications/brochures/BIR\\_CO2\\_report.pdf](http://www.bir.org/assets/Documents/publications/brochures/BIR_CO2_report.pdf).
- Bleischwitz R., Giljum S., Kuhndt M. and Schmidt-Bleek F. (2009). *Eco-innovation – putting the EU on the path to a resource and energy efficient economy*. Wuppertal Institute, Sustainable Europe Research Institute, CSCP and Factor Ten Institute. Available at: [http://www.wupperinst.org/uploads/tx\\_wibeitrag/ws38.pdf](http://www.wupperinst.org/uploads/tx_wibeitrag/ws38.pdf).
- BMRA (2010). "About Metal Recycling." Available at: [http://www.recyclemetals.org/about\\_metal\\_recycling](http://www.recyclemetals.org/about_metal_recycling).
- Bogner, J., Abdelrafie Ahmed M., Diaz C., Faaj A., Gao Q., Hashimoto S., Mareckova K., Pipatti R. and Zhang T., "Waste Management." in *Climate Change Mitigation*. (2007), Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Metz B., Davidson O.R., Bosch P.R., Dave R., Meyer L.A. (eds)], Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press, Cambridge and New York.
- Borzino M.A. (2002). "Promotion of 3Rs." at the Promotion National Level Working Group 1, Senior Officials Meeting on the 3R Initiative, Ministry of the Environment, Brazil. Available at: <http://www.env.go.jp> and follow the document links.
- Bournay E. (2006). *Vital waste graphic 2*, Volume 2, Basel Convention, UNEP and GRID-Arendal, Edition 2. Available at: [http://www.grida.no/\\_res/site/file/publications/vital-waste2/WG2\\_p32and33.pdf](http://www.grida.no/_res/site/file/publications/vital-waste2/WG2_p32and33.pdf).
- Brunner P.H. and Fellner J. (2007). "Setting priorities for waste management strategies in developing countries." *Waste Management and Research* 25(3), 234-240.
- Calcott P. and Walls M. (2005). "Waste, recycling and design for environment: Roles for markets and policy instruments." *Resource and Energy Economics*, Vol 27, Issue 4, pp. 287-305.
- Campbell C. J. (2005). *The coming oil crisis*. Multiscience publishing company and Petroconsultants SA.
- CEQ (Council on Environmental Quality). (1997). *Environmental Quality: 25th Anniversary Report*. US Government Printing Office, Washington, D.C.
- CDM EB. (2010). "Recovery and recycling of materials from solid wastes, AMS III AJ./Version 01, Sectoral Scope: 13, EB 53, Available at: <http://cdm.unfccc.int>, 26 March 2010.
- Chalmin P. and Gaillochet C. (2009). "From waste to resource, An abstract of world waste survey." Cyclope, Veolia Environmental Services, Edition Economica, France.
- Chinese Government's Official Web Portal. Available at: [www.gov.cn](http://www.gov.cn)
- Cohen N., Hertz M. and Ruston J. (1988). *Coming Full Circle*, Environmental Defence Fund, New York.
- Cointreau-Levine, S. (1994). *Private Sector Participation in Municipal Solid Waste Services in Developing Countries. Vol. 1: The Formal Sector*. Urban Management Programme Discussion Paper No. 13. UNDP/UNCHS/World Bank, Urban Management Programme.
- Department of Environmental Affairs. (2010). "National Waste Management Strategy." First draft for public comment, March 2010. Available at: [www.wastepolicy.co.za/nwms/sites/default/files/NWMS%20first%20draft.pdf](http://www.wastepolicy.co.za/nwms/sites/default/files/NWMS%20first%20draft.pdf).
- Drummond, Colon (2010), "Presentation at Bank of America Merrill Lynch Utilities & Renewables Conference." 14-15 April 2010. Available at: [www.pennon-group.co.uk/.../BankofAmericaMerrillLynchUtilities&RenewablesConference14-04-10.pdf](http://www.pennon-group.co.uk/.../BankofAmericaMerrillLynchUtilities&RenewablesConference14-04-10.pdf) (accessed 29 December 2010).
- Duan H., Huang Q., Wang Q., Zhou B. and Li J. (2008). "Hazardous waste generation and management in China: a review." *Journal of Hazardous Materials*, October 30, Vol. 158 (2-3), 221-227.
- EAWAG (2007). "Anaerobic Digestion of Biodegradable Solid Waste in Low- and Middle Income Countries." Christian Muller, May 2007. Available at: [http://www.eawag.ch/forschung/sandec/publikationen/swm/dl/Anaerobic\\_Digestion\\_high\\_resolution.pdf](http://www.eawag.ch/forschung/sandec/publikationen/swm/dl/Anaerobic_Digestion_high_resolution.pdf)
- EC (1999). "Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste." Available at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:182:0001:0019:EN:PDF>.
- EC. (2003). "Refuse derived fuel, Current practice and perspectives." (B4-3040/2000/306517/MAR/E3), Final Report, WRc Ref: CO5087-4, July 2003. Available at: <http://ec.europa.eu/environment/waste/studies/pdf/rdf.pdf>
- EC (2009). "European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste." Available at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1994L0062:20090420:EN:PDF>
- EEA and OEA (2006). "Aluminium recycling in Europe – The road to high quality products." Available at: <http://www.world-aluminium.org/cache/fl0000217.pdf>.
- EEA (2007). "Progress in management of contaminated sites – Assessment" Aug 2007, Available at: <http://themes.eea.europa.eu>.
- EEA (2009). "Generation of packaging waste and GDP in the EU-15." 18 Dec 2009. Available at: <http://www.eea.europa.eu>.
- EEA (2010). "Why Belgium cares about waste." Available at: [http://www.eea.europa.eu/soer/countries/be/soertopic\\_view?topic=waste](http://www.eea.europa.eu/soer/countries/be/soertopic_view?topic=waste).
- Energy Watch Group (2007). "Coal: Resources and future production." Final version 28032007, EWG-paper no. 1/07, Available at: [http://www.energywatchgroup.org/fileadmin/global/pdf/EWG\\_Report\\_Coal\\_10-07-2007ms.pdf](http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Coal_10-07-2007ms.pdf).
- Environmental Affairs Bureau (2010). "Waste reduction efforts in Nagoya, Challenge towards a circular society." Available at: <http://www.hls-esc.org/Documents/Session%20A%20PDF/AP2.pdf>.
- EPA (1999). "Characterization of municipal solid wastes in the United States: 1998 update." prepared for U.S. EPA Municipal and Industrial Solid Waste Division, Office of Solid Waste Report No. EPA 530- by Franklin Associates, July 1999. Available at: <http://www.epa.gov/osw/nonhaz/municipal/pubs/99tables.pdf>.
- EPA (2007). "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2006." United States Environment Protection Agency, Available at: <http://www.epa.gov/osw/nonhaz/municipal/pubs/msw06.pdf>.
- EPA (2009). "Municipal Solid Waste Generation, Recycling, and Disposal in the United States, Detailed Tables and Figures for 2008." USEPA Office for Resource Conservation and Recovery, November 2009. Available at: <http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2008data.pdf>.

- EPA (2010). "Materials Characterization Paper, In Support of the Proposed Rulemaking: Identification of Nonhazardous Secondary Materials That Are Solid Waste Auto Shredder Residue." Available at: <http://www.epa.gov/wastes/nonhaz/define/pdfs/auto-shred.pdf>.
- EPN (Environment Paper Network). (2009). "Opportunities for Economic Growth and Carbon Emissions Reduction in the U.S. Pulp and Paper Industry." Available at: <http://www.environmentalpaper.org/documents/Green%20Economy%20and%20Paper%20Industry%20%281%29%282%29.pdf>.
- Eurostat (2010a). "End-of-life vehicles (ELVs), Reuse and Recovery rate." last updated on 16.04.2010. Available at: <http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/elvs>.
- Eurostat (2010b). "Municipal waste generated, 1000 tonnes, 1995-2008." (update 11/03/2010). <http://www.environmentalpaper.org/repaper-docs/green-economy-and-paper-industry-1.pdf>
- Eurostat (2010c). *Europe in figures – Eurostat yearbook 2010*. Available at: [http://epp.eurostat.ec.europa.eu/cache/ITY\\_OFFPUB/CH\\_11\\_2010/EN/CH\\_11\\_2010-EN.PDF](http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/CH_11_2010/EN/CH_11_2010-EN.PDF).
- European Communities (2001). Waste management options and climate change, Final Report to European Commission. DG Environment, AEA Technology.
- Fellner (2007). "Responsible material flow management, The case of waste management in developing countries." Available at: <http://www.ianus.tu-darmstadt.de/Termine/Fellner.pdf>.
- Ferrer G. and Ayres R.U. (2000). "The impact of remanufacturing in the economy." *Ecological Economics*, Vol 32, No. 3, March 2000, pp. 413-429.
- Fuji Xerox (2009). "Corporate Profile, Japan." Available at: [http://www.fujixerox.com/eng/company/company\\_profile/pdf/t01\\_eall.pdf](http://www.fujixerox.com/eng/company/company_profile/pdf/t01_eall.pdf).
- GHG and Bio Intelligence Service (2006). "In the framework of the contract to provide economic analysis in the context of environmental policies and of sustainable development, Final Report to DG Environment." Available at: [http://ec.europa.eu/environment/waste/study/final\\_report.pdf](http://ec.europa.eu/environment/waste/study/final_report.pdf).
- GHK (2006). "Strategic Evaluation on Environment and Risk Prevention under Structural and Cohesion Funds for the Period 2007-2013 – National Evaluation Report for Bulgaria." Available at: [http://ec.europa.eu/regional\\_policy/sources/docgener/evaluation/pdf/evalstrat\\_env/bu\\_main.pdf](http://ec.europa.eu/regional_policy/sources/docgener/evaluation/pdf/evalstrat_env/bu_main.pdf).
- Glass Packaging Institute (2010). "Recycling and the Environment, Environmental Facts." Available at: <http://www.gpi.org/recycle-glass/environment/environmental-facts-1.html>.
- "Greening China." Available at: <http://greeningchina.wordpress.com/2010/08/25/turning-urban-manure-into-organic-fertilizer/>.
- Greiner S. (2005). "Municipal solid waste and carbon finance." Urban Week, 07 March 2005. Available at: <http://siteresources.worldbank.org>.
- Hajkowicz SA, Tellames K, Aitao J. (2005). "Economic cost scenarios for solid waste-related pollution in Palau, IWP-Pacific Technical Report." International Waters Project, No. 28. Available at: [http://www.sprep.org/att/publication/000519\\_IWP\\_PTR28.pdf](http://www.sprep.org/att/publication/000519_IWP_PTR28.pdf).
- Hogarth, R. (2009). "Microcapital story: Participatory Sustainable Waste Management Project Extends Microfinance to Informal Recyclers in Brazil." Available at: [www.microcapital.org](http://www.microcapital.org).
- Hoornweg D. and Giannelli N. (2007). "Managing municipal solid waste in Latin America and the Caribbean Integrating the private sector, harnessing incentives", Note No. 28, October 2007, GRIDlines, Public private Infrastructure Advisory Facility, World Bank, Washington. Available at: [www.ppiaf.org/documents/gridlines/28lacs.pdf](http://www.ppiaf.org/documents/gridlines/28lacs.pdf).
- Hunt C. (1996). "Child waste pickers in India: the occupation and its health risks", *Environment and Urbanization*, Vol. 8, No. 2, October 1996.
- ICF (2008). "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries", Available at: [http://ozone.unep.org/Meeting\\_Documents/mop/20mop/E-ICF%20Study%20on%20Unwanted%20ODS.pdf](http://ozone.unep.org/Meeting_Documents/mop/20mop/E-ICF%20Study%20on%20Unwanted%20ODS.pdf).
- IFC (2010). "IFC Helps Light Remote Indian Villages with Rice Husk Waste", 15 September 2010, Available at: <http://www.ifc.org/ifcext/southasia.nsf/Content/huskfeature>.
- ILO (2007). "Green jobs initiative in Burkina Faso: From waste to wages", Available at: [http://www.ilo.org/global/about-the-ilo/press-and-mediacentre/insight/WCMS\\_084547/lang-en/index.htm](http://www.ilo.org/global/about-the-ilo/press-and-mediacentre/insight/WCMS_084547/lang-en/index.htm).
- ILO (2010). "Ouagadougou Process and the ILO Jobs Pact: A Roadmap for Africa", Available at: [http://www.ilo.org/jobspect/news/lang-en/WCMS\\_123196/index.htm](http://www.ilo.org/jobspect/news/lang-en/WCMS_123196/index.htm).
- ILSR (2002). "Recycling means big money in the Big Apple." Seldman N., and Lease, K. Washington, D.C. Available at: [http://www.ilsr.org/recycling/wrrs/Big\\$BigApple.pdf](http://www.ilsr.org/recycling/wrrs/Big$BigApple.pdf).
- Indian Environmental Portal. (2000). "Surat: Banking on money." *Down to Earth* Vol: 8 Issue: 20000131, Available at: <http://www.indiaenvironmentportal.org.in/node/25936>.
- IPCC (2007a). Fourth Assessment Report: Climate Change 2007 AR4, Available at: [http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf).
- IPCC (2007b). "Climate Change 2007: Mitigation of Climate Change AR4." Chapter 10 *Waste Management*. Available at: <http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter10.pdf>.
- Jenkins R.R., Maguire K.B. and Morgan C. (2002). "Host Community Compensation and Municipal Solid Waste Landfills" National Centre for Environmental Economics. Available at: [http://yosemite.epa.gov/ee/epa/eed.nsf/WPNumber/2002-04/\\$File/2002-04.PDF](http://yosemite.epa.gov/ee/epa/eed.nsf/WPNumber/2002-04/$File/2002-04.PDF).
- Jinglei Yu, Eric, Williams, Meiting Ju and Yan Yang (2010). "Forecasting Global Generation of Obsolete Personal Computers." *Environmental Science & Technology*. Available at: <http://pubs.acs.org/stoken/presspac/presspac/full/10.1021/es903350q>.
- Kiyotaka K. and Itaru N. (2002). "Present state of end of life vehicle recycling rates and recycling of automobile shredder residue." *Proceedings of Japan Society of Automotive Engineers (JSAE) Annual Congress*, Vol 53-02, pp. 5-8.
- Krausmann F, Gingrich S, Eisenmenger N, Erb K-H, Haberl H, and Fischer-Kowalski M. (2009). "Growth in global materials use, GDP and population during the 20th century." *Ecological Economics*, 68 (10), pp. 2696-2705.
- Lacoste E. and Chalmin P. (2007). "From Waste to Resource: 2006 World Waste Survey." *Economica*, April 2007.
- Lee J.S.(2010). "Green growth strategy and energy policy in Korea." March 29, 2010, UN Governance, Available at: <http://www.greengrowth.org/download/2010/korea/Green.Strategies.and.Korea%27s.Energy.PoliciesJaeseung.Lee.pdf>.
- Leggett J. (2005). *Half Gone: Oil, Gas, Hot Air and the Global Energy Crisis*. London: Portobello Books.
- MachineDesign dated 25 October 2008, Available at: <http://machinedesign.com/article/packaging-goes-back-to-nature-1023>
- Mayor of London (2010). "The Mayor's vision for London's waste." January 2010. Available at: <http://legacy.london.gov.uk/mayor/environment/waste/docs/vision-jan2010.pdf>.
- Medina M. 9 (2008). "The informal recycling sector in developing countries Organizing waste pickers to enhance their impact." Note No. 44. October 2008, GRIDlines.
- Methanetomarkets (2005). "Methane to Markets Partnership Landfill Subcommittee, Country Profile for Argentina." Available at: [http://www.globalmethane.org/documents/landfills\\_cap\\_argentina.pdf](http://www.globalmethane.org/documents/landfills_cap_argentina.pdf).
- Ministry of the Environment, Government of Japan (2008). "The world in transition, and Japan's efforts to establish a sound material-cycle society." Available at: [http://www.env.go.jp/en/recycle/smcs/a-rep/2008gs\\_full.pdf](http://www.env.go.jp/en/recycle/smcs/a-rep/2008gs_full.pdf).
- Ministry of Environment, Republic of Korea, (2008), "4th Framework Plan for Resource Recycling."
- Ministry of Environment, Republic of Korea. (2009), "Comprehensive Masterplan for Waste-to-Energy." Available at: [http://eng.me.go.kr/board.do?met hod=view&docSeq=194&bbsCode=res\\_mat\\_policy](http://eng.me.go.kr/board.do?met hod=view&docSeq=194&bbsCode=res_mat_policy).
- Ministry of Environment, Republic of Korea. (2009). "Low-carbon green growth of Republic of Korea, Progress in 2008-2009." December 2009. Available at: [http://www.greengrowth.go.kr/english/en\\_infor mation/en\\_repor t/ userBbs/bbsView.do](http://www.greengrowth.go.kr/english/en_infor mation/en_repor t/ userBbs/bbsView.do).
- Ministry of Environment, Republic of Korea, (2010), *Annual Report of Volume Based Waste Fee*.
- Mohanty CRC. (2010). "Mainstreaming the 3Rs: Global, Regional and National Perspectives." United Nations Centre for Regional Development (UNCRD), Available at: [http://www.iges.or.jp/en/wmr/pdf/activity100728/1\\_Mohanty\\_Day1\\_Session1.pdf](http://www.iges.or.jp/en/wmr/pdf/activity100728/1_Mohanty_Day1_Session1.pdf).
- Mountford H. (2010). "Green Growth: OECD Work, IMG on a Green Economy." 23-24 March, 2010, OECD, Available at: <http://www.unemg.org/LinkClick.aspx?fileticket=GBiXQWB8NkM%3D&tabid=3563&lang ua ge=en-US>.
- Nakamura T. (2009). "Waste Agriculture Biomass Convention." The 6th Biomass Asia Workshop in Hiroshima, 18-20 November 2009, IETC Osaka, Available at: [http://www.biomass-asia-workshop.jp/biomassws/06workshop/presentation/25\\_Nakamura.pdf](http://www.biomass-asia-workshop.jp/biomassws/06workshop/presentation/25_Nakamura.pdf).



- New York Times (2010). "New York Tackles 'Brownfields' Cleanup," 'Green: A Blog about Energy and the Environment', 5 August 2010. Available at: <http://green.blogs.nytimes.com/2010/08/05/new-york-tackles-brownfields-cleanup/> (accessed 6 August 2010).
- NRDC (1997). "Too good to throw away, Recycling's proven record." Available at: <http://www.nrdc.org/cities/recycling/recyc/recyinx.asp>.
- Nyamangara J., Bergstrom L.F., Piha M.I., and Giller K.E. (2003). "Fertilizer use efficiency and Nitrate Leaching in a Tropical Sandy Soil." *Journal of Environmental Quality*, 32, 599-606.
- Ocean Conservancy (2010). *Trash Travels, From our hands to the sea, around the globe, and through the time, 2010 Report*. International Coastal Cleanup. Available at: [http://www.oceanconservancy.org/images/2010ICCRReportRelease\\_pressPhotos/2010\\_ICC\\_Report.pdf](http://www.oceanconservancy.org/images/2010ICCRReportRelease_pressPhotos/2010_ICC_Report.pdf).
- OECD (2004). *Addressing the economics of waste*. Organization for Economic Cooperation and Development, Paris.
- OECD (2007). "Lessons learnt from financing strategies for the municipal waste management sector in selected eecca countries." Environmental Finance, EAP Task Force. Available at: <http://www.oecd.org/dataoecd/54/62/39177573.pdf>.
- OECD (2008a). Environmental Data Compendium 2006-2008, Available at: <http://www.oecd.org/dataoecd/22/58/41878186.pdf>.
- OECD (2008b). "Key environmental indicators." OECD Environmental Directorate, Paris, France. Available at: <http://www.oecd.org/dataoecd/20/40/37551205.pdf>.
- OECD (2009). *Sustainable Manufacturing and Eco-innovation: Framework, Practices and Measurement Synthesis Report*. Directorate for Science, Technology and Industry, Organisation for Economic Cooperation and Development, Paris.
- The official magazine of the classic and historic automobile club of Australia*, (2007). Volume 41, No. 12, June. Available at: <http://www.chaca.com.au/Journals/web%20june2007.pdf>.
- Owens G.M. (2009). "Analyzing impacts of bioenergy expansion in China using strategic environmental assessment." *Management of Environmental Quality: An International Journal*, Vol. 18, Issue 4, 396-412.
- Packaging Europe, dated 25January 2010, Available at: <http://www.packagingeurope.com/NewsDetails.aspx?nNewsID=34203>.
- Lal P. and Takau L. (2006). "Economic costs of waste in Tonga, Apia." Samoa : SPREP, 2006. Available at: [http://www.sprep.org/att/publication/000521\\_IWP\\_PTR33.pdf](http://www.sprep.org/att/publication/000521_IWP_PTR33.pdf) (accessed 29 December 2010).
- Pareto V.E. and Pareto M.P. (2008). "The Urban Component of the Energy Crisis." Social Science Research Network.
- Pintér L. (2006). *International Experience in Establishing Indicators for the Circular Economy and Considerations for China*. Report for the Environment and Social Development Sector Unit, East Asia and Pacific Region, The World Bank.
- Porter R.C. (2002). *The economics of waste. Resources for the Future, Washington, D.C.*. ISBN 1-891853-43-0, pp. 72-74.
- Prosthetic Foundation (2007). Available at: [www.prosthesesfoundation.org.th/RecyclingInternational](http://www.prosthesesfoundation.org.th/RecyclingInternational) (2010). Available at: <http://www.recyclingbizz.com/glass/LA945887.html>.
- Reeves E. and Barrow M. (2000). "The impact of contracting out on the costs of refuse collection services: The case of Ireland." *The Economic and Social Review*. Vol. 31(2), 129-150.
- Reuters (2010). 13 August 2010. Available at: <http://www.reuters.com/article/idUSTRE67B0BT20100812>
- Reuters (2010). 16 April 2010 Available at: <http://www.reuters.com/article/idUKTR63F25D20100416?type=companyNews>, (accessed 13 August 2010).
- SAAEA (2010). "Waste to Energy - The crises South Africa faces." Available at: <http://saaea.blogspot.com/2010/03/waste-to-energythe-crises-south-africa.html>.
- Scheinberg A., Simpson M.H., Gupta Y., Anschutz J., Haenen I., Tasheva E., Hecke J., Soos R., Chaturvedi B., Garcia-Cortes S. and Gunsilius E. (2010). *Economic Aspects of the Informal Sector in Solid Waste Management Main Report*. 29 October 2010, Volume 1, Research Report, 2010, prepared under contract to GTZ and the CWG, WASTE, advisers on urban environment and development, Gouda, the Netherlands, and Skat, Swiss Resource Centre and Consultancies for Development, St. Gallen, Switzerland. Available at: <http://www.gtz.de/de/dokumente/gtz2010-en-economic-aspects-waste.pdf>.
- Schwarzer S., De Bono A., Giuliani G., Kluser S. and Peduzzi P. (2005). *E-waste, the hidden side of IT equipment's manufacturing and use*. UNEP GRID Europe. Available at: [http://www.grid.unep.ch/product/publication/download/ew\\_ewaste.en.pdf](http://www.grid.unep.ch/product/publication/download/ew_ewaste.en.pdf).
- Shawnee K. (2009). *Solid waste report*. September 2, 2009. Available at: [http://gsh.cit.yof.shawnee.or.g/pdf/cityclerk/solid\\_waste\\_report09082009.pdf](http://gsh.cit.yof.shawnee.or.g/pdf/cityclerk/solid_waste_report09082009.pdf).
- Singh, M.P. (2006). "Application of CDM to waste management projects in Punjab." Presentation made to the CM Punjab on 29 June 2006. Available at: <http://www.earthizen.org/papers/cdm-waste-management-punjab.pdf>.
- Sinha A.H. and Enayetullah I. (2010). "Innovative ways to promote decentralized composting by Waste Concern in Bangladesh, A toolbox for building sustainable solid waste system." C40 Cities Climate Leadership Group Waste Workshop, March 22-24, 2010, London, UK. Available at: [http://www.c40cities.org/londonwasteworkshop/downloads/after-the-event/Session%2005%20-%20Technologies/01%20-%20C40%20Presentation\\_UK\\_WC.pdf](http://www.c40cities.org/londonwasteworkshop/downloads/after-the-event/Session%2005%20-%20Technologies/01%20-%20C40%20Presentation_UK_WC.pdf).
- State of Washington, Department of Ecology. (2010). "Economic Value of Solid Waste Recyclables." Available at: [http://198.239.150.195/beyondwaste/bwpr/og\\_economic\\_value\\_recyclables.html](http://198.239.150.195/beyondwaste/bwpr/og_economic_value_recyclables.html) (accessed 29 December 2010).
- Suchada, P., Trankler, J., Cholada, K. and Scholl, W. (2003). "The role of formal and informal sectors in solid waste management of developing countries." Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy. 6-10 October 2003, CISA, Environmental Sanitary Engineering Centre, Italy.
- UNCTAD (2008). "Creative industries emerge as key driver of economic growth with trade nearly doubling in decade." Press release, UNCTAD/PRESS/PR/2008/003. Available at: <http://www.unctad.org/templates/Webflyer.asp?docID=9467&intItemID=1634&lang=1>.
- UNEP (2005). "E-waste, the hidden side of IT equipment's manufacturing and use." *Environmental Alert Bulletin*. Available at: [http://www.grid.unep.ch/product/publication/download/ew\\_ewaste.en.pdf](http://www.grid.unep.ch/product/publication/download/ew_ewaste.en.pdf).
- UNEP (2009a). "Marine litter: A global challenge, Ocean Conservancy, Regional Seas." GPA. Available at: [http://www.unep.org/pdf/unep\\_marine\\_litter-a\\_global\\_challenge.pdf](http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf).
- UNEP (2009b). "Report by the Secretariat on funding opportunities for the management and destruction of banks of ozone-depleting substances." Workshop on management and destruction of ozone-depleting substance banks and implications for climate change. UNEP/OzL.Pro/Workshop.3/2/Add.1. July 13, 2009. Available at: [http://ozone.unep.org/Monitoring\\_Documentation/Workshop\\_on\\_ODS\\_banks/WORKSHOP-3-2-Add1E.pdf](http://ozone.unep.org/Monitoring_Documentation/Workshop_on_ODS_banks/WORKSHOP-3-2-Add1E.pdf).
- UNEP (2009c). "Converting waste agricultural biomass into a resource, Compendium of technologies." Available at: [http://www.unep.org/jp/letc/Publications/spc/WasteAgriculturalBiomassEST\\_Compendium.pdf](http://www.unep.org/jp/letc/Publications/spc/WasteAgriculturalBiomassEST_Compendium.pdf).
- UNEP (2010). "Framework of global partnership on waste management." Note by Secretariat. Available at: [http://www.unep.org/jp/letc/SPC/news-nov10/3\\_FrameworkOfGPWM.pdf](http://www.unep.org/jp/letc/SPC/news-nov10/3_FrameworkOfGPWM.pdf).
- UNEP and UNU (2009). "Recycling- from e-waste to resources, Sustainable innovation and technology transfer industrial sector studies." July 2009.
- UNEP (2011). Assessing Mineral Resources in Society: Metal Stocks & Recycling Rates. International Resource Panel. UNEP, Nairobi.
- UNEP (2007). "Environmental Pollution and impacts on public health: Implications of the Dandora Municipal dumping site in Nairobi, Kenya, Report Summary." Available at: [http://www.unep.org/urban\\_environment/pdfs/dandorawastedump-reportsummary.pdf](http://www.unep.org/urban_environment/pdfs/dandorawastedump-reportsummary.pdf)
- UNEP (2008). Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World, UNEP, Nairobi.
- UNESCAP (2009). "Review of progress, constraints and policy challenges with regard to the implementation of international, regional and national commitments: waste management (hazardous and solid wastes), Regional Implementation Meeting for Asia and the Pacific ahead of the eighteenth session of the Commission on Sustainable Development" 30 November-1December 2009, Bangkok. Available at: <http://www.unescap.org/esd/rim/18/documents/new/WASTE%20MANAGEMENT.pdf>.
- UNFCCC (2005). "Project 0169, Composting of Organic Waste in Dhaka." Version 17\_00, 9 December 2005, Project Design Document. Available at: [www.cd.unfccc.int](http://www.cd.unfccc.int).
- UNFCCC (2006). "Substitution of clinker with fly ash in Portland Pozzolana Cement (Blended Cement) at Lafarge India Pvt. Ltd. - Arasmeta Cement Plant." Project Design Document - Version 02, Project 0746, 19th September 2006. Available at: [www.cdm.unfccc.in](http://www.cdm.unfccc.in) (2010a). *Trends in sustainable*

development – Chemicals, mining, transport and waste management. Department of Economic and Social Affairs, Division of Sustainable Development. Available at: [http://huwu.org/esa/dsd/resources/res\\_pdfs/publications/trends/trends\\_Chemicals\\_mining\\_transport\\_waste\\_management.pdf](http://huwu.org/esa/dsd/resources/res_pdfs/publications/trends/trends_Chemicals_mining_transport_waste_management.pdf).

UN (2010b). "Policy options and actions for expediting progress in implementation: Waste Management." Report of the Secretary-General, Economic and Social Council, 20 December 2010. Available at: [http://www.pfcmc.com/esa/dsd/csd/csd\\_pdfs/csd-19/sg-reports/CSD-19-SG-report-waste-management-final-single-spaced.pdf](http://www.pfcmc.com/esa/dsd/csd/csd_pdfs/csd-19/sg-reports/CSD-19-SG-report-waste-management-final-single-spaced.pdf).

UNFCCC (2010). Project Search. Available at: <http://cdm.unfccc.int/Projects/projsearch.html>.

UN-Habitat (2010). "Women in Informal Employment Globalizing and Organizing (WIEGO)." Available at: [www.wiego.org/publications/Refusing%20to%20be%20Casted%20Aside-Wastepickers-Wiego%20publication-App.pdf](http://www.wiego.org/publications/Refusing%20to%20be%20Casted%20Aside-Wastepickers-Wiego%20publication-App.pdf).

USAID (1999). "Innovative Approaches to Solid Waste Management in India, Focus on Private Sector Participation." Note No. 15, February 1999, Indo-US Financial Institutions Reformed Expansion Project – Debt Market Component FIRE (D). Available at: <http://www.niua.org/indiaurbaninfo/fire-D/ProjectNo.15.pdf>.

USGS (2001). "Fact Sheet, FS-060-01." July 2001. Available at: <http://pubs.usgs.gov/fs/fs060-01/fs060-01.pdf>.

Van der Zee D.J., Achterkamp M.C. and de Visser B.J. (2004). "Assessing the market opportunities of landfill mining." *Waste Management*, Vol. 24, 795-804.

Wapner P. (2002). "Ecological Displacement and Transnational Environmental Justice." *Global Dialogue*, Vol 4, No. 1, Winter 2002, The Fragile Biosphere. Available at: <http://www.worlddialogue.org/content.php?id=178>.

WHO. (2007). "Population health and waste management, Scientific data and policy options." Report of WHO workshop, Rome, Italy, 29-30 March 2007. Available at: [http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0012/91101/E91021.pdf](http://www.euro.who.int/__data/assets/pdf_file/0012/91101/E91021.pdf).

WHO (2010). "Wastes from health-care activities, Fact sheet N°253." Reviewed November 2007. Available at: <http://www.who.int/mediacentre/factsheets/fs253/en/>.

Wilson D., Velis, C., and Cheeseman C. (2006). "Role of informal sector recycling in waste management in developing countries," *Habitat International*, 30, 797-808.

Wilson D.C., Araba A.O., Chinwah K. and Cheeseman C.R. (2009). "Building recycling rates through the informal sector." *Waste Management*, Vol. 29, Issue 2, 629-635.

World Bank (1999). "What a Waste: Solid Waste Management in Asia." Urban Development Sector Unit, East Asia and Pacific Region. Available at: [www.worldbank.org/urban/solid\\_wm/erm/CWG%20folder.uwp1.pdf](http://www.worldbank.org/urban/solid_wm/erm/CWG%20folder.uwp1.pdf).

World Bank (2005). "East Asia infrastructure department. Waste management in China: issues and recommendations." Urban development working Paper No. 9. Available at: <http://resources.worldbank.org/INT/EA/PREGTOP/URBDEV/Resources/China-Waste-Management1.pdf>.

World Steel Association (2010). "Factsheet, Steel industry by-products, Achieving the goal of zero waste." Available at: [http://www.worldsteel.org/pictures/programfiles/Fact%20sheet\\_By-products.pdf](http://www.worldsteel.org/pictures/programfiles/Fact%20sheet_By-products.pdf).

World Steel Association (2011). "LCI Data for Steel Products", Data provided by Clare Broadbent, 9 June 2011.

WRAP. (2006). "Environmental benefits of recycling: An international review of life cycle comparisons for key materials in the UK recycling sector." Waste & Resources Action Programme, Available at: [http://www.wrap.org.uk/downloads/LCA\\_report\\_Executive\\_Summary\\_May\\_2006.598516be.pdf](http://www.wrap.org.uk/downloads/LCA_report_Executive_Summary_May_2006.598516be.pdf)

WWF International. (2008). *Living Planet Report*. Switzerland. Available at: [www.footprintnetwork.org/download.php?id=505](http://www.footprintnetwork.org/download.php?id=505).

Yatsu R. (2010). "Comprehensive Policies and Programs towards a Sound Material Cycle Society, International Consultative Meeting on Expanding Waste Management Services in Developing Countries," 18 March 2010, Tokyo.

Zurbrugg C., Drescher S., Rytz I., Sinha AHM, Enayetullah I. (2005). "Decentralized composting in Bangladesh, a win-win situation for all stakeholders." *Resources, Conservation and Recycling*, Vol. 43, pp. 281-292.









# Buildings

Investing in energy and resource efficiency



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## List of acronyms

ADB	Asian Development Bank	IPCC	Intergovernmental Panel on Climate Change
ADEME	French Environment and Energy Management Agency	ITUC	International Trade Union Confederation
BAU	Business-as-usual	KfW	German Development Bank
BCA	Building and Construction Authority (Singapore)	LCA	Life-cycle assessment
CDM	Clean Development Mechanism	LED	Light emitting diode
CEDEFOP	European Centre for the Development of Vocational Training	LEED	Leadership in Energy and Environmental Design
CEU	Central European University	LPG	Liquefied petroleum gas
CFL	Compact fluorescent lamp	LTCR	Lost time case rates
CHP	Combined heat and power	MEPS	Minimum efficiency performance standards
CO <sub>2</sub>	Carbon dioxide	MURE	Mesures d'Utilisation Rationnelle de l'Energie
CRC	Carbon Reduction Commitment	NPV	Net Present Value
CSIR	Council of Scientific and Industrial Research	O&M	Operation and management
DVD	Digital versatile disc	OECD	Organisation for Economic Co-operation and Development
EC	European Commission	OSHA	Occupational Safety and Health Administration (USA)
EEFS	Energy Efficiency Co-Financing Scheme	PV	Photovoltaic
EPBD	Energy Performance of Buildings Directive (EU)	PwC	PricewaterhouseCoopers
EPC	Energy performance contracting	RIRs	Recordable incident rates
ESCO	Energy service company	SB	Sustainable Buildings
EU	European Union	SEEP	Serbian Energy Efficiency Programme
FIDE	Fund for Electric Energy Savings (Mexico)	TBL	Triple bottom line
G2	Green Scenario 2	TCO	Total cost of ownership
GBC	Green Building Council	UN DESA	United Nations Department of Economic and Social Affairs
GDP	Gross Domestic Product	UN Habitat	United Nations Human Settlements Programme
GER	Green Economy Report	UNEP	United Nations Environment Programme
GHG	Greenhouse gas	UNEP SBCI	United Nations Environment Programme Sustainable Buildings and Climate Initiative
GRIHA	Green Rating for Integrated Habitat Assessment	UNFCCC	United Nations Framework Convention on Climate Change
HVAC	Heating ventilation and air conditioning	WBCSD	World Business Council for Sustainable Development
ICT	Information & Communication Technology	WHO	World Health Organization
IEA	International Energy Agency		
ILO	International Labour Organization		
INFONAVIT	National Workers' Housing Fund Institute (Mexico)		
IOE	International Organisation of Employers		

# Key messages

**1. The Buildings sector of today has an oversized ecological footprint.** The buildings sector is the single largest contributor to global greenhouse gas emissions (GHG), with approximately one-third of global energy end use taking place within buildings. Furthermore, the construction sector is responsible for more than a third of global resource consumption, including 12 per cent of all fresh water use and significantly contributes to the generation of solid waste, estimated at 40 per cent of the total volume. Therefore, the building sector is central to any attempt to use resources more efficiently.

**2. Constructing new green buildings and retrofitting existing energy- and resource intensive buildings stock can achieve significant savings.** There are significant opportunities to improve energy-efficiency in buildings, and the sector has the greatest potential, out of those covered in this report, to reduce global GHG emissions. Various projections indicate that investments, ranging from US\$ 300 billion to US\$ 1 trillion (depending on assumptions used) per year to 2050, can achieve savings of about one-third in energy consumption in buildings worldwide. In addition, these investments can significantly contribute to the reduction in CO<sub>2</sub> emissions needed to attain the benchmark 450 ppm concentration of GHGs. Emission reductions through increased energy efficiency in buildings can be achieved at an average abatement cost of US\$ 35 per tonne, reflecting energy cost savings, compared to US\$ 10 per tonne costs in the transport sector or positive abatement costs on the power sector of US\$ 20 per tonne.

**3. Greening buildings also brings significant health and productivity benefits.** Greening buildings can also contribute significantly to health, liveability and productivity improvements. The increased productivity of workers in green buildings can yield savings higher than those achieved from energy-efficiency. In residential buildings in many developing countries, indoor pollution from poorly-combusted solid fuels (e.g. coal or biomass), combined with poor ventilation, are a major cause of serious illness and premature death. Lower respiratory infections such as pneumonia and tuberculosis linked to indoor pollution are estimated to cause about 11 per cent of human deaths globally each year. Women and children tend to be most at risk due to their daily exposure. Improved access to water and basic sanitation are other significant benefits that come with green building programmes.

**4. Greening the building sector can lead to an increase in jobs.** Investments in improved energy-efficiency in buildings could generate additional employment in developed countries where there is little growth in building stock. It is estimated that every US\$ 1 million invested in building efficiency

retrofits creates 10 to 14 direct jobs and 3 to 4 indirect jobs. If the demand for new buildings that exists in developing countries is considered, the potential to increase the number of green jobs in the sector is still higher. Various studies point to job creation through different types of activities, such as new construction and retrofitting, production of resource-efficient materials and appliances, the expansion of renewable energy sources and services such as recycling and waste management. Greening the building industry also provides an opportunity to engage the informal sector and improve working conditions across the industry, by implementing training programmes targeting new skill requirements and improving inspection approaches.

**5. Developing countries have the opportunity to lay the foundation of energy-efficient building stocks for decades to come.** Significant new construction is expected in the developing world in order to provide adequate housing for over 500 million people, while providing access to electricity for some 1.5 billion people. Urbanisation and economic growth in emerging economies also point to the rapid growth of new building stock. In developing countries, taking into account sustainable building considerations at the time of design and construction makes good economic sense. Green retrofitting at a later stage invariably carries higher costs, both financially and environmentally, than integrating sustainability considerations already at the early stages of design and construction. For developed countries, which account for the majority of the existing building stock, the priority is to put in place measures and incentives that will enable large-scale investments in retrofitting programmes.

**6. The role of public policy and leadership by example is vital in triggering the greening of the building sector.** A life-cycle approach is required covering the building design, the manufacturing of material supplies, the construction process, buildings operation and maintenance as well as the disposal, recycling and reuse of building, construction and demolition waste. Considering, in particular, the hidden costs and market failures that characterise the building industry, regulatory and control measures are likely to be the most effective and cost-efficient in bringing about a green transformation of the sector. These need to be combined with other pricing instruments for greater impact, given realities such as the level of development of the local market and household income-levels. Additionally, government-owned buildings such as public schools, hospitals and social housing units are ideal locations to begin implementing greener building policies, including green public procurement. At the same time, the role of progressive private sector actors organised, for example, through Green Building Councils can drive the transition to lower carbon and more resource-efficient buildings.



# 1 Introduction

## 1.1 The aim of this chapter

This chapter makes a case – focusing on economic arguments – for greening the building sector. It also provides guidance on policies and instruments that can bring about this transformation. The broader goal is to enable public- and private-sector actors to seize environmental and economic opportunities, such as the efficient use of energy, water and other resources, to improve health, boost productivity and create jobs that reflect decent work and reduce poverty.

## 1.2 Scope and definition

This chapter encompasses both new construction and the retrofitting of existing buildings, with the focus on urban areas, which are expanding and now home to more than half the world's population. The chapter covers an environmental and socio-economic agenda, with special consideration given to climate, health and employment. The analysis of resource use focuses mainly on energy, given its importance to the building sector and the relative abundance of data at the global scale. While efficiency in the use of water and land as well as recycling and waste is considered, covering a comprehensive environmental agenda of all life-cycle impacts is beyond the scope of this analysis.

According to the International Energy Agency (Laustsen 2008), green buildings are characterised by increased energy efficiency, reduced water and material consumption, and improved health and environment. The International Organization for Standardization's definition of sustainable buildings combines a minimum

adverse environmental impact with economic and social aspects across various geographic scales. In this chapter, the concept of green buildings is similarly broad, including not only the environmental dimensions, but also economic dimensions (such as energy savings, the cost of greening, payback periods, productivity and job creation) and social dimensions (such as indoor pollution and health).

## 1.3 Structure of the chapter

This chapter has three main parts. Firstly, it introduces the sector and highlights key challenges and opportunities it faces today. Developmental, energy and environmental challenges are highlighted. The section notes trends in population growth and urbanisation, drivers for growth in the industry, and its resource use and environmental impact. Secondly, the next section sets out the case for investment in green buildings. This starts with a description of investment needs, cost benefit analysis and efficiencies to be gained. An overview of benefits covers energy and water, waste and materials, productivity and health, as well as job creation. Special consideration is given to the policy target of reducing GHG emissions from the building sector, based on 450 parts per million (ppm) as climate benchmark used by the International Energy Agency (IEA) in its climate change mitigation scenarios. Modelling by the Millennium Institute provides a green investment scenario for the sector, quantifying the implications of going beyond business-as-usual (BAU). Thirdly, the chapter gives an overview of policy instruments and tools that can be used by Government or regulatory institutions at different levels to advance green building.

## 2 Challenges and opportunities

### 2.1 Challenges

The last 40 years have seen much experimentation and significant progress with low-energy building design strategies and technologies. However, in most countries, green buildings are still at a nascent phase of development. Yet they are expected to become the norm in future. Experimentation with net-zero-carbon buildings, passive houses and energy-plus buildings are emerging worldwide. The main challenges facing green buildings are discussed with special reference to the sector's significant use of resources and emissions of CO<sub>2</sub>. This covers both existing building stock and the projected growth of new construction. A key component of green buildings is related to their location and how they interact with other components of urban and regional systems, which is covered in the Cities chapter.

#### Sizing the building sector

Driven by population growth and urbanisation, the building sector itself is a significant contributor to economic growth, both globally and at the national level. Globally, it is estimated to be worth US\$ 7.5 trillion per year or approximately 10 per cent of global GDP (Betts and Farrell 2009) and the construction sector employs more than 111 million people (ILO 2001). At the national level, the sector generates 5-10 per cent of employment (UNEP SBCI 2007a).

There are important differences between developed and developing countries in both the current building stock and projected building-sector growth. Developed country populations are broadly more urbanised and more economically reliant on the service sector than on industry or agriculture. They also have higher household incomes than developing country populations. Developed countries currently account for the majority of the world's existing building-related energy demand and CO<sub>2</sub> emissions.

This picture is changing rapidly. Projected economic growth is modest and projected population growth flat or even negative in Western Europe, Russia and Japan. Thus building-related energy demand and CO<sub>2</sub> emissions in these countries will see little growth in the coming decades. There are some exceptions among richer countries such as the United States of America, where higher fertility and immigration rates are expected. In contrast, developing countries are fast-growing, rapidly

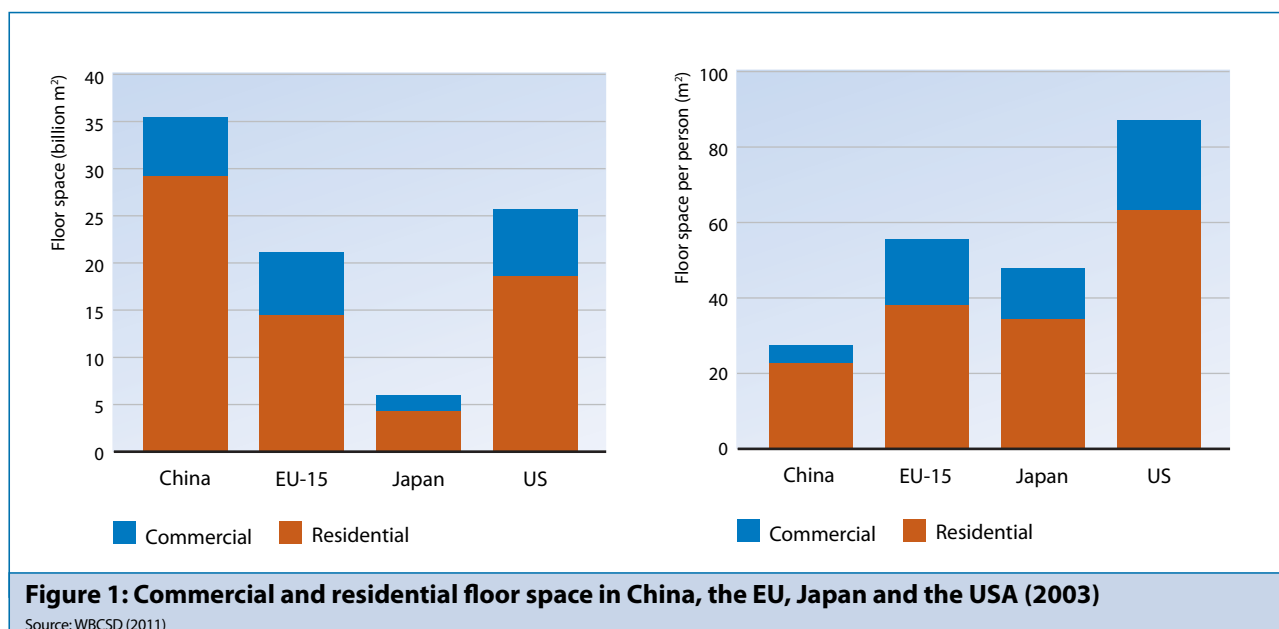
urbanising and are projected to add 2.3 billion to global population over the coming four decades (UN DESA 2009). Of the 9 billion people predicted to live on Earth in 2050, 70 per cent are expected to live in urban areas (UN-HABITAT 2010).

India is short of 24.7 million homes (NHHP 2007; Roy et al. 2007) and the country will need millions of homes to be built over several decades to accommodate projected income growth and urbanisation. New construction growth for commercial and residential buildings currently averages 7 per cent per year in China and 5 per cent per year in India and South-east Asia, compared with only 2 per cent in developed countries (Baumert et al. 2005). As estimates of the global building stock are not available, Figure 1 provides an overview of the scale of residential and commercial floor space in China, the EU, Japan and the USA.

China is expected to add twice the amount of current US office space between 2000 and 2020 (WBCSD 2009). Another study indicates the stock of office space in China as 3.5 billion m<sup>2</sup> and predicts it will grow by over 70 per cent by 2020 (Zhou et al. 2007). In 2007 alone, 0.8 billion m<sup>2</sup> of new buildings were constructed in China and it is projected that in each year to 2020, an additional one billion m<sup>2</sup> of new buildings will be constructed (Cheng 2010). Global cement production is set to double by 2050, with China and India accounting for nearly half of all production (WBCSD 2007b).

Historical trends demonstrate that increasing wealth leads to higher space standards and an increase in household appliances, with implications for energy consumption. Another critical factor in developed countries is demographic and societal change, with a significant increase in one-person households. For example, in Germany, the energy consumption for space heating increased by 11 per cent from 1995 to 2000 before decreasing by 7 per cent from 2000 to 2005 – mainly because of higher energy costs – resulting in an overall rise of 2.8 per cent from 1995 to 2005. Domestic hot-water consumption decreased slightly (by 1.4 per cent) in the period but home appliances still contributed 17 per cent to total energy consumption despite substantial improvements in their energy efficiency. While great improvements in energy efficiency have been achieved in certain sectors, the overall energy consumption of private households in Germany rose by 3.5 per cent between 1995 and 2005 (UBA 2006).





### Developmental challenges

Developing countries are urbanising at a rate two to three times faster than developed countries, resulting in massive informal settlements and slums (UNEP, ILO, IOE, ITUC 2008). In the majority of the developing world, the scale of informal and low-cost housing is vast. In some cities, the informal city is bigger than the formal city. In Indonesia, an estimated 70-80 per cent of housing construction is informal (Malhotra 2003). In Brazil, more than half of all low-cost homes are built by the informal sector (UNEP SBCI 2010b).

In this context, providing affordable green housing for the poor is a considerable challenge when so many already face major economic barriers to afford conventional housing. Analysis of social housing, however, does not lead to clear results as to whether green social housing is more expensive at the point of construction; environmental design features may be but do not have to be, more expensive than the conventional features. For example, a detached social housing project Casa Alvorada (48.50 m<sup>2</sup>) in the city of Porto Alegre, Rio Grande do Sul, in Brazil, was 12 per cent more expensive per square metre than the typical housing solution of similar size implemented by the municipality, but still 18 per cent cheaper per square metre compared to another municipal typical model of about half of the floor area per unit (23 m<sup>2</sup>) (Sattler 2007). Further, if the environmental features are more expensive at the point of construction, they may yield benefits in terms of savings on water and energy during the occupation of the building.

Poverty and housing raises other unique challenges for sustainable building and construction in developing societies. Slums, be they informal settlements or run-down and overcrowded housing estates, are associated with social and environmental challenges including

lack of access to electricity, fresh water, health-care and effective waste management. Marginal locations poorly connected to public transport services are an additional obstacle in that they constrain access to employment opportunities (see Cities chapter).

Greening of buildings can be one of a series of strategies that improve access to basic services and reduce vulnerability and, more broadly, contribute to better living conditions of the poor. Facing this challenge, India, for example, is experimenting with three approaches, namely vernacular building (which focuses on local solutions and traditional knowledge), green building (supported by the internationally recognised Indian GRIHA rating systems, developed by TERI) and; energy-efficient building (focused on energy-use in commercial buildings) (UNEP SBCI 2010a). New approaches can contribute to providing electricity to the 1.5 billion people in the developing world currently living without it (IEA 2010a), and to lifting 100 million people from slum conditions and providing them with safe water and sanitation – a distinct Millennium Development Goal.

Cleaner and more efficient energy use will be critical to avoid any possible lock-in effect for poorer segments of society. Savings on energy costs can also free resources for investment in other basic needs. A recent study by the CSIR for the ILO (Van Wyk et al. 2009) provides several examples of energy-related projects in Africa: the installation of solar PV systems on schools, clinics and community centres in Zambia, the introduction of solar lighting and electricity into homes by local solar entrepreneurs in Malawi, the electrification of 60 health centres using solar energy in Mozambique, and the construction of windmills and solar-powered water systems as well as 10,000 improved cooking stoves for more than 250,000 people in Somalia.

Some aspects of improved well-being (e.g. health, water, sanitation and energy access) can be linked to building design and technology. Yet developmental challenges have to be seen in a broader context and go beyond the construction of housing to consider social and economic inclusion and the link to other urban activities (see Cities chapter). The poverty relevance of green buildings in this context is closely linked to the impacts of electrification programmes (see discussion in the Energy chapter) as well as the impacts of city structure and transport systems on poverty (see Transport and Cities chapters).

### Energy and environmental challenges

Whether existing building stock or projected growth of building stock, this sector is already the single-largest contributor to global greenhouse gas emissions. Approximately one-third of global energy end-use takes place within buildings (IEA 2010a). Nearly 60 per cent of the world's electricity is consumed in residential and commercial buildings, although this usage varies widely according to geographical location, climate and consumption patterns (IEA 2009b). For developed countries located in cooler regions of the world, space heating, on average, represents 60 per cent of residential energy consumption, followed by water heating at 18 per cent (UNEP SBCI 2007a).

Projections for 2030 based on IPCC scenarios suggest CO<sub>2</sub> emissions from buildings will continue to account for around one-third of total CO<sub>2</sub> emissions. Table 1 summarises these projections for CO<sub>2</sub> emissions under two scenarios (IPCC 2007). In the high-growth scenario, the largest contribution is from developing countries while in the low-growth scenario the largest share is from North America and developing Asia, which includes China and India. If per-capita CO<sub>2</sub> emissions are considered, both scenarios suggest that by 2030 the greater share of emissions will still be from OECD countries.

GHG emissions are the single most important negative externality from excessive fossil fuel consumption but the burning of fossil fuels also causes other externalities such as air pollution and health problems. Approximately 3 billion people worldwide rely on biomass and coal to meet cooking and other energy needs (IPCC 2007). Indoor air pollution in residential buildings in developing

countries from poorly combusted solid fuels combined with poor ventilation is a major cause of serious illness and premature death. Lung infections such as pneumonia and tuberculosis linked to indoor pollution are estimated to cause about 11 per cent of all human deaths globally each year (UNEP SBCI 2010b). The WHO (2009) estimates that every year about 1.3 million people (mostly women and children) die prematurely owing to indoor air pollution from biomass. Estimates by the WHO (2009) further attribute 76 per cent of all lung cancer deaths to the indoor use of solid fuels.

Apart from energy use and emissions, the building sector is responsible for more than a third of global resource consumption annually, including 12 per cent of all fresh water use. The manufacture of building materials consumes about 10 per cent of the global energy supply. Building construction and demolition waste contributes about 40 per cent of solid waste streams in developed countries, with most waste associated with the demolition phase (UNEP SBCI 2010b).

### Data challenges

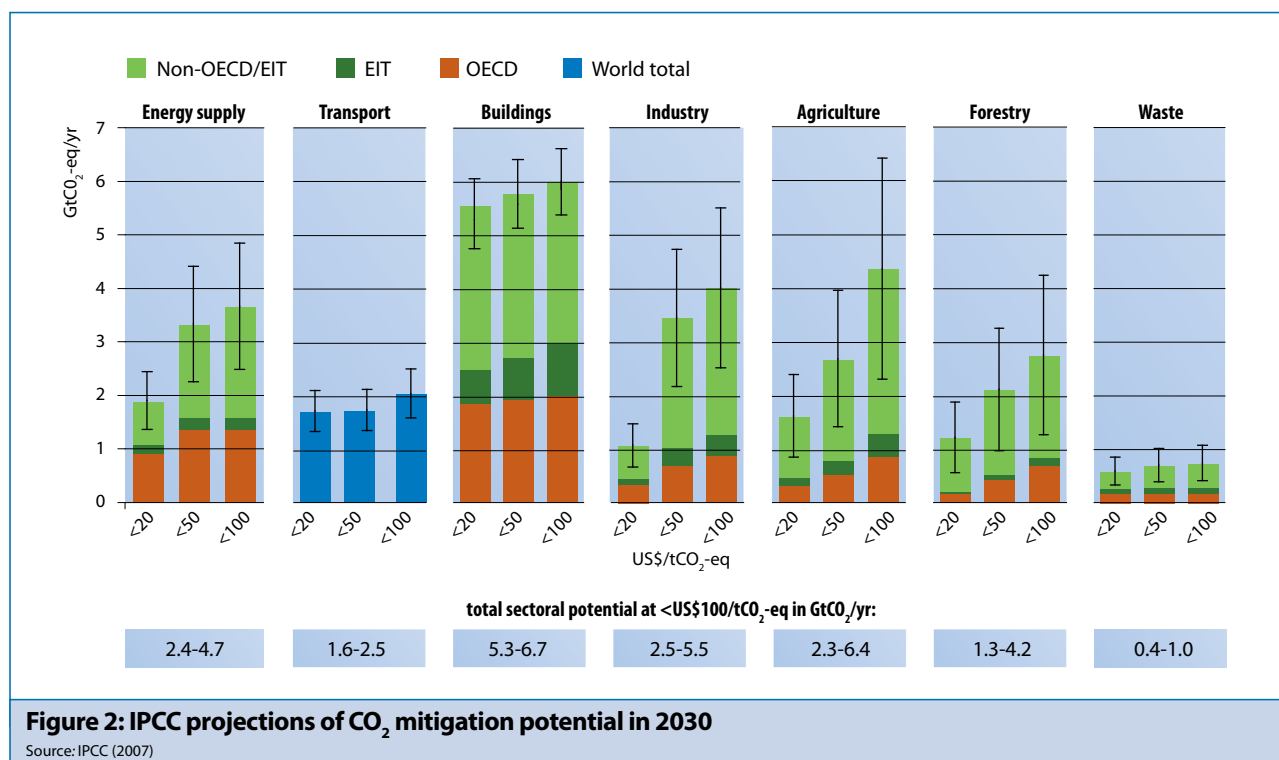
When considering the environmental credentials of buildings, the true measure of their performance only becomes evident with occupation, given the impact of factors such as behaviour (cultural habits, environmental expectations and life-style), climatic changes and particularities of the control of technical systems in buildings. The only realistic way to rate the energy efficiency of a building is by measuring how much energy has been consumed during a period of occupation, ideally, a minimum of two years. A dearth of accurate data is hampering our understanding of impacts such as occupation, design and technological components.

## 2.2 Opportunities

The major opportunities for greening the building sector are the relatively low cost of the process, be it retrofitting or new construction, the availability of technologies, and the green evolution of energy supply and demand. These trends are encouraging the effort to transform the building sector.

	High-growth scenario (A1)	Low-growth scenario (B2)
CO <sub>2</sub> emissions (in GtCO <sub>2</sub> )	8.6 → 15.6 (2004) (2030)	8.6 → 11.4 (2004) (2030)
Largest share from	Developing Asia, Middle East/North Africa, Latin America, sub-Saharan Africa	North America and developing Asia
Average annual CO <sub>2</sub> emissions growth rate (2004-2030)	2.4%	1.5%

**Table 1: Projected CO<sub>2</sub> emissions from buildings to 2030**  
Source: IPCC (2007)



**Figure 2: IPCC projections of CO<sub>2</sub> mitigation potential in 2030**

Source: IPCC (2007)

### Low net cost

Although the building sector is the largest contributor to human-related GHG emissions, it also holds the greatest potential to reduce these emissions (IPCC 2007). Based on 80 studies spanning 36 countries, the IPCC report suggests that a 29 per cent reduction in projected baseline emissions by 2020 is achievable at zero cost (below 0 US\$/tCO<sub>2</sub>-eq), while further improvements could be made with relatively low levels of investment.

Figure 2 shows sectoral estimates of the economic mitigation potential of using technologies and practices expected to be available by 2030, at various costs in US dollars per tonne of CO<sub>2</sub>-equivalent (tCO<sub>2</sub>-eq). The mitigation potential is expressed in GtCO<sub>2</sub>-eq/yr and the marginal cost in US dollars per tCO<sub>2</sub>-eq. For each sector, the mitigation potential is represented as three ascending bars, according to the amount that can be achieved at less than US\$ 20, less than US\$ 50 and less than US\$ 100 per tCO<sub>2</sub>-eq.<sup>1</sup> In the building sector, assuming a cost per tCO<sub>2</sub>-eq of no more than US\$ 100, the global economic mitigation potential ranges between 5.3 and 6.7 GtCO<sub>2</sub>-eq/yr by 2030. Most importantly, about 90 per cent of this potential could be achieved at less than US\$ 20 per tCO<sub>2</sub>-eq, far more than could be achieved in any of the other sectors depicted. This range is represented by the segment within the third bar for buildings (<100). The bulk of this mitigation potential can be attributed to non-OECD/EIT (Economies in Transition) countries, followed by OECD countries and to a lesser extent EIT countries.

1. Note that potential that can be achieved for less than US\$ 50 per tCO<sub>2</sub>-eq includes the potential that can be achieved at less than US\$ 20 per tCO<sub>2</sub>-eq, and similarly for US\$ 100 per tCO<sub>2</sub>-eq. Hence the bars grow in size from left to right.

### Adapting behaviour patterns

Before addressing the technical, financial and regulatory potential of green buildings and their impacts on the green economy, it is important to recognise that profound changes in attitudes and behaviour will be required amongst policy-makers, investors, consumers and occupants in order to implement real change. People spend most of their lives in their homes, places of work and other buildings; North Americans, on average, spend 90 per cent of their time indoors (United States General Services Administration 2008) and there are deeply-rooted attitudes and practices relating to how people establish patterns of comfort and efficiency. For this reason, understanding the economic and psychological rationale of decisions made by individuals and institutions is increasingly recognised as fundamental to achieving energy-efficiency improvements in buildings. For example, a recent report on energy efficiency in the USA highlighted various behavioural biases affecting consumers' energy consumption decisions (Swim et al. 2009; Granade et al. 2009).

The core concept of "thermal comfort" is more of a state of mind (reflecting different cultural, class and geographical conditions) than a technical certainty (ASHRAE 2005). Assessing the right level of thermal comfort is critical to setting performance standards for buildings (Cena and Clark 1981) but requires not just an understanding of what a human body can bear, but also to what extent people are ready to make behavioural changes in the way they experience comfort in their environment. This affects the way building occupiers interact with their environment in very precise ways – from choosing to pull down external blinds to limit sun

penetration at certain times of day (rather than switching on the air conditioning) to putting on a sweater when the external temperature drops (rather than turning up the thermostat). On balance, green buildings require a more proactive engagement between occupier and the environment, which reflects the degree of “active” or “passive” environmental design techniques available in individual buildings, to which the report now turns.

### Design and technology

The greatest opportunities to achieve a higher environmental performance for buildings can be found in the early stages of their design. An integrated design methodology of green buildings combines environmental principles and technological inputs at various design stages. It requires a multidisciplinary approach and broadens conventional building design by including rigorous assessment procedures to comply with performance targets (Baker and Steemers 1999). Designing buildings based on environmental considerations implies continuous feedback between different design components, as decisions regarding building form, orientation, components, other architectural aspects as well as building systems are entirely integrated.

There are two basic paradigms of green building. The first is based on the concept of “passive” design where buildings respond to their local site context by using natural elements (such as air-flow and sunlight) to limit the effect of external conditions on the internal environment. Many traditional buildings with thick walls and small windows in hot climates, or with natural through-ventilation with courtyards and terraces in humid areas, belong to this category. Passive design aims to provide a comfortable environment while eliminating or reducing the need for space heating, cooling, ventilation or artificial lighting. The second paradigm is based on a more “active” approach that uses newer technology and state-of-the-art building management systems to reduce the energy load of buildings. Solar screens, lighting scoops, environmental flues, photovoltaic cells (PV), wind turbines and other devices are found in most state-of-the-art high-tech buildings. Both paradigms can be applied to new buildings as well as retrofitting existing building stock.

Many passive design techniques are finding their way into a new generation of building designs across the developed world, while new forms of green energy generation are being integrated in building projects in the developing world (Baker and Steemers 1999; Hawkes 1996; Herzog 1996). The field is littered with examples of how both passive design and technology have successfully reduced the energy footprint of buildings. A recent study of 5,375 commercial buildings in the USA showed that in new buildings the use of energy-efficient

lighting, heating, ventilation, air conditioning and shading can achieve a 64 per cent reduction in energy use (Griffith et al. 2006). In the UK, energy consumption guidelines indicate that the introduction of natural ventilation can achieve 55-60 per cent reduction in energy consumption in office buildings, compared with fully air-conditioned and fully glazed office buildings (CIBSE 2004).

Greater attention is now given to the impact of sustainable environmental design solutions on the running costs of buildings and how much energy is embodied in construction materials and processes. Increasingly, life-cycle assessments (LCA)<sup>2</sup> are being applied, which include not only operation and maintenance, but also the manufacture of construction materials (McDonough and Braungart 2002). In addition, a new generation of building guidance is focussing on the total energy costs of buildings, from the design stage through to completion, including considerations about their recyclability (Anderson et al. 2009; Hammond and Jones 2008).

Beyond the fabric and construction of the building, a more holistic approach to the design of buildings and their use also requires consideration of all energy-related components, including appliances and equipment used in buildings. Their relative energy use varies from country to country, based on climatic and cultural differences. The following listing of appliances and equipment by residential and public or commercial categories demonstrates the range of supplier industries involved.

Residential building sector	Office and commercial building sector
<ul style="list-style-type: none"> <li>• Space heating and cooling</li> <li>• Mechanical ventilation</li> <li>• Hot water systems</li> <li>• Appliances (incl. cooking, washing, refrigeration, entertainment and cleaning)</li> <li>• Indoor lighting</li> </ul>	<ul style="list-style-type: none"> <li>• Space heating, cooling and ventilation, air conditioning (HVAC)</li> <li>• Indoor lighting</li> <li>• Outdoor lighting</li> <li>• Office equipment</li> <li>• Servers and data centres</li> </ul>

In commercial buildings, office equipment comprises the fastest-growing area of energy consumption. In residential buildings world-wide, a growing proportion of energy consumption is associated with household appliances, including televisions, DVD players and home computers. Implementing the best available technologies can reduce their energy consumption by

2. Life-Cycle Assessment (LCA) is a tool devised for evaluating the environmental impact of a product, process or a service across its life cycle, also referred to as the “environmental footprint”. All inputs and outputs of material, energy, water and waste over the entire product life cycle and their relative impacts are accounted for, including the extraction of raw materials, processing, manufacturing, transport, use and disposal. The main objective of a LCA is to compare the impacts of several alternative processes in order to choose the least damaging one.

more than 50 per cent. The household-appliance share of energy consumption in residential homes vary from 21 per cent in China in 2000, to 25 per cent in the EU in 2004 and 27 per cent in the USA in 2005 (von Weizsäcker et al. 2009).

### Managing energy supply and demand

Energy use and emission patterns are affected by a building's environmental performance and its energy load (on the demand side) or by the extent of its use of green sources of energy (on the supply side). Recent developments in design and technology offer significant potential to change the way energy demand and supply is managed in buildings.

On the demand side, there is growing evidence that energy consumption can be reduced by modifying the specification of technologies, appliances and fittings within buildings – in addition to designing the built form in a more sustainable way. Leading Information & Communication Technology (ICT) Infrastructure firms produce software for command centres, which can actively help to reduce a building's carbon footprint by monitoring and controlling all components of a building's energy use, from heating/cooling demand, to lighting and printing.

But the pattern of energy use in buildings varies considerably among regions and countries according to geographical location, climate, consumption patterns and state of development and urbanisation (IPCC 2007). Space heating is a dominant component of energy use in Europe and northern China, while water heating is of great significance in Japan (WBCSD 2009). In these areas, effective means of controlling energy demand and emissions include the improvement of heat-recovery systems, optimising daylight penetration with shallower buildings, substituting incandescent lighting with more energy-efficient systems such as CFL and LED lamps and introducing solar shading to reduce overheating.<sup>3</sup> In addition to these design solutions, smart metering, which provides utility customers with information in real-time about their domestic energy consumption, has also proved effective at reducing overall household electricity consumption, with a 5-10 per cent drop recorded in private households in Germany and the UK (Luhmann 2007). In contrast, buildings located in warmer regions do not usually require space heating and require less hot water. Energy needs in low-income rural communities are largely determined by cooking (70 per cent) and other household activities (15 per cent) (Nekhaev 2004). In these locations, the impact of energy use will be more radically affected by introducing greener and cleaner fuel sources and

more efficient domestic appliances than by introducing green building technologies.

On the supply side, there has been a significant shift in some countries in favour of renewable energies with bio-fuel and solar heating technologies becoming competitive with conventional sources (European Renewable Energy Council 2008). Photovoltaic (PV) technology is still relatively expensive but with the increasing volume of installed capacity and improvements in production, prices are lowering steadily.<sup>4</sup> District heating and cooling systems<sup>5</sup> that link buildings are also proving effective at reducing energy costs, notably in Iceland, where 94 per cent of heat demand is now provided by these technologies (Euro Heat & Power 2009).

### Retrofitting and new construction

In developed countries, opportunities for greening the building sector are found mainly in retrofitting existing buildings to render them more environmentally efficient by reducing energy demand and using renewable energy sources. The urbanised regions of northern Europe and North America are no longer increasing their building stock rapidly. In the UK, for example, 75 per cent of the existing building stock is expected to be in use in 2050. In such circumstances, retrofitting existing buildings becomes a critical area of intervention to reduce energy demands and thus GHG emissions (Ravetz 2008).

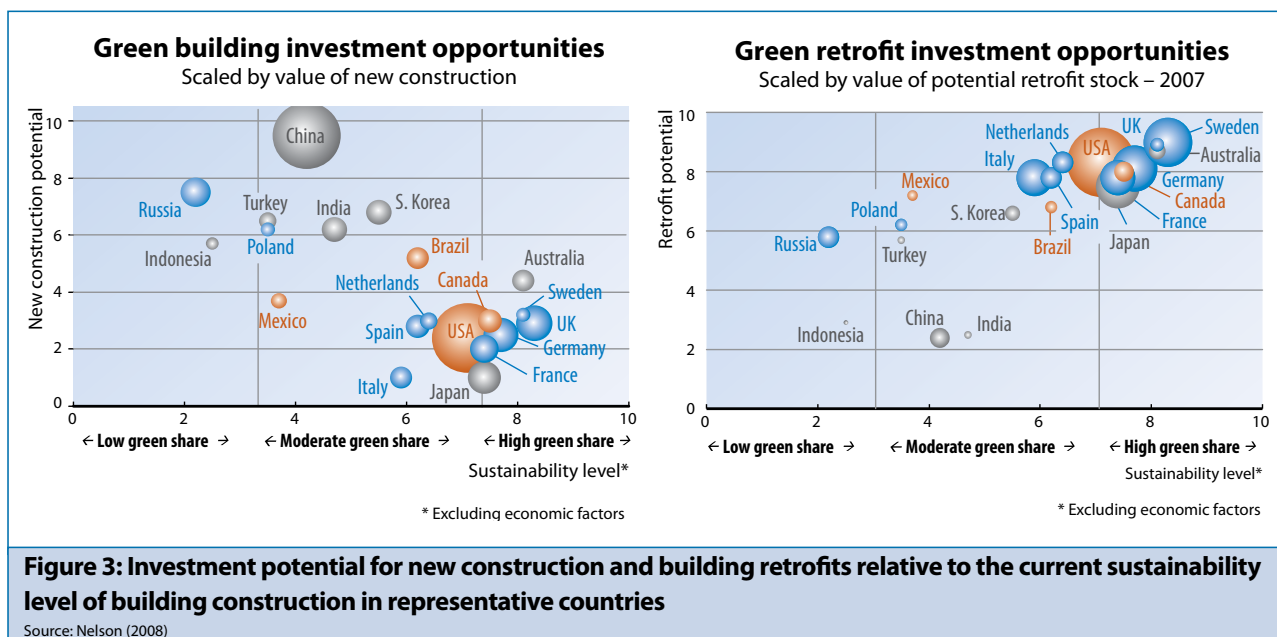
For the majority of non-OECD countries, which have a significant housing deficit, the greatest potential to reduce energy demand will come from new generations of buildings with more efficient design performance standards (WBCSD 2007a). It follows that the major environmental and business case for the OECD residential and commercial sector will depend on retrofitting existing buildings, while non-OECD countries will have to invest heavily in new forms of sustainable design that goes beyond the performance of individual buildings (as discussed in the Cities chapter). Nonetheless, there are significant opportunities for retrofitting buildings in some of the bigger cities of the developing world by adopting energy efficiency design measures such as solar technology, clean water

3. For example, as part of the Serbian Energy Efficiency Programme (SEEP 1) (IDA Credit and IRBD loan), 28 schools and hospitals were refurbished in Belgrade in 2005-09 with average energy savings of 39 per cent.

4. Grid parity, where the electricity produced by PV panels is available at the same cost level as electricity provision from the grid, is predicted to be achievable by 2013-14 based on data from Germany (Bhandari and Stadler 2009).

5. District heating and cooling describes systems distributing heat and/or cold generated in a centralised location for heating and combined heat and power respectively. District heating serves both, space and domestic water heating. Moreover, commercial and industrial as well as public buildings can be supplied with process heat. The heat often comes from combined heat and power plants (CHP) and therefore has the ability to achieve higher efficiencies and lower emissions than a separate heat and power production. Historically, district heating stations are dependent on fossil fuels but in the last years renewable sources were introduced.





**Figure 3: Investment potential for new construction and building retrofits relative to the current sustainability level of building construction in representative countries**

supplies and reducing dependency on air-conditioning through technical improvements.<sup>6</sup> In India, for example, potential energy savings of 25 per cent have been estimated through cost-effective retrofitting of existing commercial buildings (UNEP SBCI 2010a).

The pros and cons of constructing a new building or retrofitting an existing structure have to be individually examined and compared. In some cases, retrofitting allows a further reduction of the energy load by preserving building materials, which can contain high levels of embodied energy,<sup>7</sup> expended in the extraction of resources, the manufacture of materials and their transportation. Both new building construction and

retrofitting are fundamental for catalysing a green building transformation. Retrofitting in developed countries can yield significant energy savings as the design, construction and technology of older buildings is often significantly less efficient than current best practices. In addition, retrofits that address daylight or on-demand ventilation to improve air quality can bring benefits through lower health care costs and higher productivity levels.

While less significant in terms of volume compared with new construction, retrofits can play an important role in addressing energy poverty in developing countries. At least 20 per cent of the world's population lack access to electricity and it is expected that 1.2 billion people will still be without electricity in 2030; 87 per cent of them living in rural areas (IEA 2010a). Equipping households with electrical appliances, heating and cooling systems and either on-site renewable energy generation (such as rooftop solar panels) or a connection to the power grid may increase overall energy demand. Yet it will come in a far cleaner form than the coal, dung or wood many

6. In Brazil, for example, refrigerators are responsible for 33 per cent of all electricity use in residential buildings over the year, with electric showers, lighting and air conditioning accounting for 20, 11 and 10 per cent respectively (Ghisi, Gosch and Lamberts 2007).

7. Embodied energy is energy needed for the production and processing of materials, transport and demolition as well as for manufacturing of furniture, appliances and the provision of infrastructure services such as water and sanitation. Embodied energy is highly dependent on the design and construction technique of buildings.

	Building retrofits	New construction
Developed Countries	<p>(Key focus)</p> <ul style="list-style-type: none"> <li>Single homes that lack efficiency norms (e.g. EU)</li> <li>Homes to increase lifespan (e.g. Japan)</li> <li>Appliances in large, relatively new homes (e.g. USA)</li> <li>Older multi-family buildings (e.g. Europe)</li> </ul>	<p>(Secondary focus)</p> <ul style="list-style-type: none"> <li>High rate of new construction expected in USA and Japan. High potential to meet green standards, e.g. zero-carbon, zero-waste and 3R (Japan).</li> </ul>
Emerging Economies	<p>(Secondary focus)</p> <ul style="list-style-type: none"> <li>Single homes built by the informal sector to meet basic efficiency standards (e.g. Brazil)</li> <li>Multi-family homes (e.g. China, Brazil and Russia)</li> <li>Predominance of single homes in countries such as India – needs retrofits to sustenance levels (basic electricity, better cooking fuels, durable)</li> </ul>	<p>(Key focus)</p> <ul style="list-style-type: none"> <li>Huge housing shortage – opportunity for greening through publicly subsidized and privately financed housing (e.g. India, China, Brazil, Russia and other emerging economies)</li> <li>Huge demand for office space. Potential for greening through corporate demand.</li> </ul>

**Table 2: Summary of the major opportunities for green buildings in different sectors**

Source: Based on WBCSD analysis (2007a)

households currently use for lighting, heating and cooking. Replacing these traditional fuel sources will produce significant environmental and public-health benefits.

Table 2 summarises elements that describe the retrofitting and new construction potential in greening the building sector in developed countries and emerging economies. It is clear that there is a strong case for retrofitting buildings in developed countries. In emerging economies, retrofitting and new construction both have compelling cases although the potential for new construction is much greater than retrofitting. Figure 3 correlates the expected value of new construction and retrofitting potential with its level of sustainability (from low to high share of green construction). It can be seen that emerging economies such as China and India have a great potential for new

construction, but it is not expected to be particularly green. Developed countries have a high potential for retrofitting, with a high level of sustainability. The new construction potential in these countries is very low.

A conscious effort is needed to turn new construction green in developing countries and emerging economies, given that buildings generally last for decades and often centuries, whereas a country's car fleet may be turned over in as little as 12 years. If a building is constructed to low standards of efficiency, retrofitting it later is an unnecessary complication compared with getting it right the first time. Retrofitting existing buildings, however, reduces energy demand compared with new-builds through a lower demand for building materials such as steel, glass and cement, which themselves require considerable amounts of energy to produce.

# 3 The case for investment in green buildings

## 3.1 Investment needs

The analysis in this chapter is predicated on climate change and GHG emissions being an overriding concern for the building sector. Related to this are key environmental challenges such as water scarcity, land use, waste and sanitation. Climate change both impacts and is impacted by these. The social and economic dimensions are addressed in terms of how a more efficient use of resources in the building sector and a reduction of its GHG emissions can contribute to energy savings, health and productivity gains, as well as job creation. Overall, green building investment needs are primarily driven by climate and resource scarcity or efficiency imperatives.

Buildings currently account for 40 per cent of energy use in most countries (IEA 2010b), with projections that demand in this sector will increase by 60 per cent by 2050 (IEA and OECD 2010). This is larger than either the transportation or industrial sector. The IEA and OECD (2010) estimate that building sector carbon emissions will need to be reduced from the 15.2 Gt per year currently projected for 2050 to approximately 2.6 Gt per year as part of a strategy to successfully address climate change.<sup>8</sup>

Greening the global building stock will require considerable investment in new technologies and sustainable building materials as well as in design and engineering expertise. This will increase the upfront cost of building construction relative to continuing with business-as-usual. The IEA and OECD (2010) estimate that a 12.6 Gt reduction by 2050 could be achieved with an average investment of US\$ 308 billion per year between 2010 and 2050.<sup>9</sup> A higher estimate of US\$ 1 trillion per year on average between 2010 and 2050 was obtained in a separate study by the Peterson Institute for International Economics (Houser

8. This reduction of 12.6 Gt CO<sub>2</sub> emissions by 2050, published in the Energy Technology Perspectives 2010 (IEA and OECD 2010) revises earlier estimates that CO<sub>2</sub> emissions from buildings would need to be reduced by 8.2 Gt from a projected 20.1 Gt in 2050 to 11.9 Gt (IEA 2008). The earlier estimates formed a reference point for other analysis, including by the Peterson Institute for International Economics (Houser 2009). The 2010 estimates also include reductions achieved by fuel-switching and electricity de-carbonisation, whereas the earlier estimates were limited to efficiency measures.

9. The IEA and OECD (2010) modelled a scenario that estimates a total investment of US\$ 12.3 trillion required over this 40-year period, consisting of US\$ 7.9 trillion in the residential sector, and US\$ 4.4 trillion in the services sector. IEA's estimates are all in US\$ 2007.

10. Net present value is calculated by subtracting the additional up-front operation and maintenance cost required for the more-efficient investment from the expected energy cost saving over the lifetime of the more-efficient investment. Energy cost savings are discounted by 6 per cent annually. NPV is then divided by the cumulative change in emissions resulting from the investment over the course of its life-time. This is known as abatement cost and expressed in US dollars per tonne of CO<sub>2</sub> (Houser 2009).

Country/region	Additional investment, 2005-50 (US\$ billion /year)	NPV 2005-50 <sup>10</sup>	CO <sub>2</sub> reduction* (million tonnes 2050)	Ave. abatement cost, 2005-50 (US\$/ tonne)
<b>OECD N. America</b>	<b>244</b>	<b>-46</b>	<b>1,699</b>	<b>30</b>
USA	209	-40	1,555	28
<b>OECD Europe</b>	<b>170</b>	<b>-26</b>	<b>915</b>	<b>30</b>
<b>OECD Pacific</b>	<b>67</b>	<b>-17</b>	<b>353</b>	<b>48</b>
Japan	37	-9	168	52
<b>Transition Economies</b>	<b>78</b>	<b>-12</b>	<b>548</b>	<b>24</b>
<b>Developing Asia</b>	<b>188</b>	<b>-26</b>	<b>2,343</b>	<b>14</b>
China	114	-15	1,427	14
India	19	-2	221	12
<b>Latin America</b>	<b>31</b>	<b>-5</b>	<b>148</b>	<b>39</b>
<b>Middle East</b>	<b>80</b>	<b>-17</b>	<b>663</b>	<b>32</b>
<b>Africa</b>	<b>29</b>	<b>-3</b>	<b>298</b>	<b>10</b>
<b>WORLD</b>	<b>1,042</b>	<b>-180</b>	<b>8,200</b>	<b>25</b>

\*Relative to business-as-usual

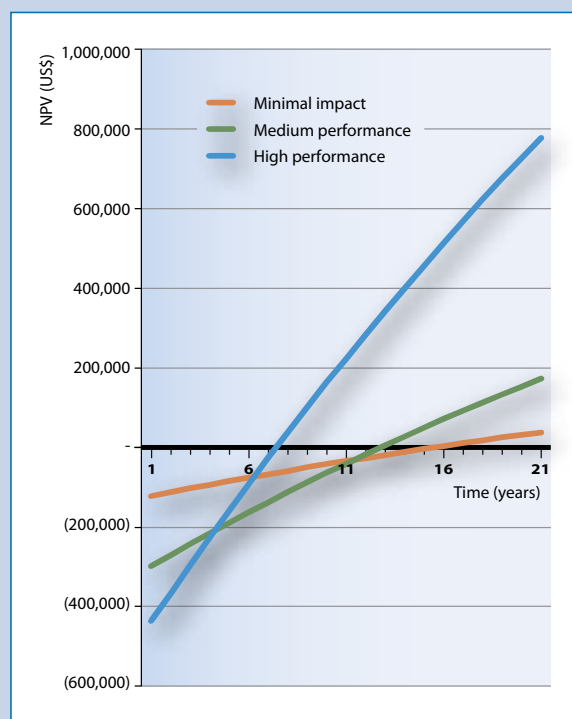
**Table 3: The economics of global building transformation**

Source: Adapted from Houser (2009)

## Box 1: Life cycle cost for a commercial office in a tropical climate<sup>12</sup>

In the example, a 100,000 m<sup>2</sup> commercial building is being designed for the tropics. Based on the building programme typically employed by the owner, there are several green technologies that can be added to the baseline cost to improve overall building performance. The new technology either costs more than the baseline technology it replaces, or it adds a new technology and additional cost. The technology investment is being considered because it produces higher performance and yields savings over the baseline technology. By expressing the savings as positive cash flow, and showing the total accumulated savings (net present value, NPV) over the life of the technology, it can be shown that the overall investment (added cost plus accumulated savings) pays off over time.

In this example, the building is a centre of commerce and the occupants will be wearing Western business attire, so air conditioning was considered necessary. Given this high cooling load, technologies that could mitigate solar gain and meet the load more efficiently were considered. These include window film, exterior shading, a wider comfort band on the thermostats, demand control for ventilation and wall insulation. Three envelope packages are compared to a building built to the local standard practice construction methods. The costs of the features were estimated using standard construction pricing techniques. Energy savings were estimated using energy simulation software. The blue line shows the Minimal Impact package (window film and optimised wall insulation), which is the cheapest technology to implement. The dark window film in this package, however, offsets potential daylight savings and does not provide much benefit over its useful life (as shown by the flat slope of the blue line). The Medium and High Performance scenarios have higher first costs, which are offset by higher



energy savings over the life of the building. The steep purple slope of the High Performance package (including exterior window shading and demand control ventilation) means that the owner will see a large reduction in the total cost of ownership over the life of the building – almost US\$ 800k for the period of the analysis shown.

Similar studies analysing the trade-offs between building components have shown that there can even be a net initial cost saving for green measures. An assessment of the TCO for a Passive House concluded that the integrated design could immediately provide net initial cost savings because the incorporation of higher insulation levels eliminates the need for a traditional heating system (Laustsen 2008).

2009) in order to reduce emissions in the building sector by 8.2 Gt per year by 2050 (see Table 3).<sup>11</sup>

Retrofits in developed countries will account for a meaningful share of this additional investment, particularly in the early years of greening the buildings.

11. The analysis by Houser (2009) uses a different approach to estimating the costs of achieving the emissions reduction of 8.2 Gt/year, which corresponds to the earlier estimated necessary reduction from IEA (2008) – see footnote 8 above. Houser's estimates use data and an investment cost model developed by WBCSD (2009) and notes various explanations for the higher cost estimates, including the assumptions on the cost of solar photovoltaic technology, as well as future projections of energy prices.

But the bulk of the incremental investment will occur through greening new buildings, an opportunity firms and households are already starting to take advantage of.

For the USA, a recent study predicts that the green retrofits of non-residential buildings will grow to a US\$ 6.6 billion market by 2013, targeting the third of the US commercial building stock that could benefit from such a retrofit – a US\$ 400 billion market (Pike Research 2009). For new commercial construction and new residential

12. Simulations and text contributed to this chapter by Tom Paladino.

construction, an estimated 10-12 per cent and 6-10 per cent is green, representing a US\$ 24-29 billion and US\$ 12-20 billion market, respectively. By 2013, the green commercial construction market is expected to grow to US\$ 56-70 billion annually and the green residential market is expected to grow to US\$ 40-70 billion (McGraw Hill 2009).

Although impressive, this market-driven change is not sufficient to meet the US\$ 209 billion average annual investment required in the USA alone to reduce the building sector's carbon footprint in line with the IEA's projected low-carbon pathway (Houser 2009). Increasing investment in green buildings will require policies, and smart policy design requires an accurate appraisal of the costs and benefits of green building investments.

### 3.2 Measuring the costs and benefits

A correct evaluation of green building economics requires a Total Cost of Ownership (TCO) approach, where the differences in upfront investment costs (known as first costs) are considered alongside long-term costs and benefits. While certain green buildings may cost more to construct than a conventional alternative, the first cost premium may be recouped through lower energy bills, avoided climate change impacts, improved public health or increases in worker productivity. Box 1 describes the economic benefits of green buildings technologies and how these can offset their investment costs over time.

Looking only at the cost differential between constructing green and conventional buildings, a recent study by Greg Kats (2010) suggests that cost premiums are considerably lower than generally perceived. Data from 170 green buildings in the USA showed that they cost on average only 1.5 per cent more than conventional buildings, while public perception of the average additional costs of going green were 17 per cent. Per square metre the green premium ranged from US\$ 0/m<sup>2</sup> to US\$ 764.2/m<sup>2</sup> with a median of US\$ 36.6/m<sup>2</sup>.<sup>13</sup> While Kats found the premium to be often greater for buildings achieving higher green standards, these same high standards were in many cases achieved with minimal or zero additional cost. This suggests that the green-cost premium depends to a great extent on the skill of the designers and builders, rather than on the level of greenness *per se*. The study also indicated that green retrofits have a slightly higher average green premium than new construction.

13. Original text indicates per square foot a green premium ranging from US\$ 0/sf to US\$ 71/sf with a median of US\$ 3.40/sf.

### Comparative efficiency by sector and region

The economic benefit of green building investment is backed up by low or even negative costs of greening the building sector. One study estimates that 3.5 gigatons of CO<sub>2</sub> emissions could be reduced through investment in green buildings by 2030 at an average abatement cost of US\$ 35 per tonne.<sup>14</sup> This compares with US\$ 10 per tonne in transportation, US\$ 17 per tonne in steel production or US\$ 20 per tonne in the power sector (McKinsey 2009). Going beyond 2030, the Peterson Institute study Houser (2009) found that achieving the 8.2 Gt (i.e. aiming at 450 ppm) of emission reductions from the building sector by 2050 would cost US\$ 25 per tonne, but it would still be among the cheapest sources of abatement. Failure to transform the building sector and reliance on more costly emission reductions from the transport, power and industrial sectors would increase the economic cost of combating climate change by at least US\$ 500 billion per year globally between 2010 and 2050.

Boxes 2 (China) and 3 (US) show the challenge of weighing short- and longer-term costs and benefits, as well as the tendency for growing energy consumption to undermine efficiency gains in commercial and residential buildings. Box 2 presents a case study of residential construction in China and illustrates the energy savings from design and management interventions. From this and other studies, it is clear that green buildings have a significant economic return on investment, and should occupy centre stage for long-term policies that aim to change patterns of production and consumption behaviour.

Although a wealth of energy efficiency measures and their attendant carbon emission reductions come at zero or even negative cost, policy intervention is needed to transform the global building stock in line with what the IEA sees as necessary to put the world on a low-carbon pathway. They also show the need for approaches that are regionally specific to reflect local building industry and local economic realities, mindful that the urban challenge in green building shows many similarities across regions.

An example of new policy and regulatory intervention comes from the EU's Energy Performance of Buildings Directive<sup>15</sup> (EPBD), which has generated debate about time frames for meeting requirements, the level of harmonisation across countries and the possible administrative burden imposed (e.g. compulsory

14. The reduction of 3.5 Gt of CO<sub>2</sub> emissions from buildings through increased energy efficiency is part of a larger emission reduction of 38 Gt in 11 sectors, which aims to bring CO<sub>2</sub> emissions close to the 450 ppm target by 2030.

15. The EPBD directive combines regulatory (energy performance requirements) and information-based (certification and inspection) measures and provides a holistic approach to emissions reduction, which encompasses the energy needs for space and water heating, cooling, ventilation and lighting.



## Box 2: Residential construction in China

### Multi-family new building construction in China

	Base case	Green development	Difference savings (or costs)
Growth in energy use 2005-2050	~ 530 billion kWh/yr	~ 305 billion kWh/yr	~ 225 billion kWh/yr
Incremental cost per year	NA	~ US\$ 12 billion	(~ US\$ 12 billion)
Space heat energy savings	NA	76%	76%
Value of energy savings per year	NA	About equal to costs on annual basis	~ US\$ 12 billion

In China, the demand for multi-family dwellings will continue to grow rapidly owing to rural-urban migration and rising incomes. Between 2010 and 2050, the World Business Council on Sustainable Development (WBCSD) estimates electricity demand in multi-family buildings will increase by 200 per cent for lighting and 325 per cent for appliances. Current building practices are characterised by poorly designed and insulated building envelopes and inefficient heating systems, while energy for heating is priced at a fixed rate irrespective of consumption. Analysis by WBCSD (2009) looks at the impact of improving the efficiency of typical blocks of multi-family buildings in China (a six-story building containing 36 apartments) over a 45-year period spanning 2005-2050.

The table shows the impact of a 76 per cent improvement in building energy efficiency through a series of design and management interventions, including a better-designed and insulated building envelope, apartment-level temperature controls and electricity sub-metering. If replicated at a national level across China, these steps could lead to a total saving of about 225 billion kWh per year, or US\$ 12 billion per year at current electricity prices. However, although substantial building energy savings are achieved, the growth in national building stock in China will outpace the efficiency improvements, resulting in a net increase of 305 billion kWh per year in energy demand over the given time period.

Source: WBCSD (2009)

inspections by accredited experts). An impact assessment was recently conducted of the directive, which came into force in 2002 (Haydock and Arbon 2009). The study concluded that a reduction of 5-6 per cent of the EU's final energy demand, with 60-80 Mt of energy savings per year, was possible. This accounts for 4-5 per cent of the EU's CO<sub>2</sub> emissions. It showed that savings of 160-210 Mt CO<sub>2</sub>/year can be achieved by 2020, along with the creation of 280,000-450,000 new jobs. This confirms that greening costs are low compared with the mid- to long-term benefits. Moreover, abolishing the EPBD's current 1,000 m<sup>2</sup> compliance threshold could yield an additional € 25 billion energy cost savings per year by 2020 at an additional capital investment cost of € 8 billion per year – an overall negative CO<sub>2</sub> abatement cost (EC 2008).

### 3.3 Economic, environmental and social impacts

#### Energy benefits

The primary benefit of green buildings is the reduction in tenant energy costs through improved energy

efficiency. McKinsey estimates that in the USA, US\$ 229 billion of investment in residential energy efficiency between 2009 and 2020 would yield US\$ 395 billion in energy cost savings and reduce overall residential energy demand by 28 per cent. In commercial buildings, US\$ 125 billion in investment would reduce energy demand by 29 per cent and yield energy cost savings of US\$ 290 billion (Granade et al. 2009). In developing countries, the firm estimates that US\$ 90 billion in energy efficiency investment would reduce energy expenditure by US\$ 600 billion (McKinsey 2010).

In its 2009 World Energy Outlook, the IEA estimated that US\$ 2.5 trillion additional investment in green buildings globally between 2010 and 2030 would yield US\$ 5 trillion (undiscounted) in energy savings over the life of the investment. A study by the WBCSD found the potential for US\$ 150 billion a year of green building investment in the USA, EU, Brazil, China, India and Japan where energy cost savings would pay back the additional upfront investment in less than 5 years. An additional US\$ 150 billion a year of investment would pay back within 5-10 years (WBCSD 2009). The

### Box 3: Retrofitting existing office buildings in the USA<sup>17</sup>

US commercial buildings	10% energy savings	40% energy savings
Existing commercial building area (EIA 2003)	72 billion sq.ft.	72 billion sq.ft.
Existing office-building area (EIA 2003)	12.2 billion sq.ft.	12.2 billion sq.ft.
Number of office buildings (EIA 2003)	824,000	824,000
Office energy use/sq.ft. (EIA 1998)	97.2 kBtu/sq.ft./yr	97.2 kBtu/sq.ft./yr
Assumed office-space retrofit per year	100 million	100 million
Assumed energy savings (%)	10%	40%
Assumed energy savings (converted to kWhr)	2.85 kWhr/sq.ft./yr	11.4 kWhr/sq.ft./yr
Total value of energy savings (at US\$ 0.105/kWhr)	US\$ 29,925,000	US\$ 119,700,000
Assumed cost of retrofit (Pike Research 2009)	US\$ 1/sq.ft.	US\$ 25/sq.ft.
Total cost of retrofit	US\$ 100 million	US\$ 2.5 billion
Assumed productivity increase 1%	US\$ 2.5/sqft/yr	US\$ 2.5/sqft/yr
Total value of productivity	US\$ 250 million	US\$ 250 million
Assumed discount rate	5%	5%
Assumed life of retrofit measures	15 years	15 years
<b>Net present value (direct energy benefits)</b>	<b>US\$ 210 million</b>	<b>US\$ 1.26 billion</b>
<b>Net present value (direct energy + indirect productivity benefits)</b>	<b>US\$ 2.81 billion</b>	<b>US\$ 1.34 billion</b>

The market size of existing office retrofit building stock in the USA is about 12.2 billion square feet (EIA 2003) while the median age of US office buildings in 1995 was 23.5 years. Office buildings consume the most energy of all building types, with an energy-use intensity of 97,200 Btu per square foot (EIA 1998). Over the next 4 years alone, the US retrofit market for non-residential buildings is projected to grow from US\$ 2.1-3.7 billion in 2010 to US\$ 10.1-15.1 billion by 2014 (McGraw Hill 2009). Energy savings of 10 per cent can be achieved with an investment of less than US\$ 1 per square foot. To achieve a more aggressive target of 40 per cent, an investment of US\$ 10- 30 per square foot is required (Pike Research 2009).

The table shows it is easy to justify the investment because the 10 per cent energy savings alone show a positive NPV of US\$ 210 million after a 15-year life of the retrofit measures. This increases to US\$ 2.81 billion savings if a 1 per cent productivity increase is assumed. However, for the more aggressive scenario of 40 per cent energy savings, the NPV is negative after 15 years unless productivity increases are taken into account. While this case study confirms the benefits of investing in green building retrofits, it also sets out the complexities associated with significant capital outlays, which cannot be easily translated into short-term gains.

Source: WBCSD (2009)

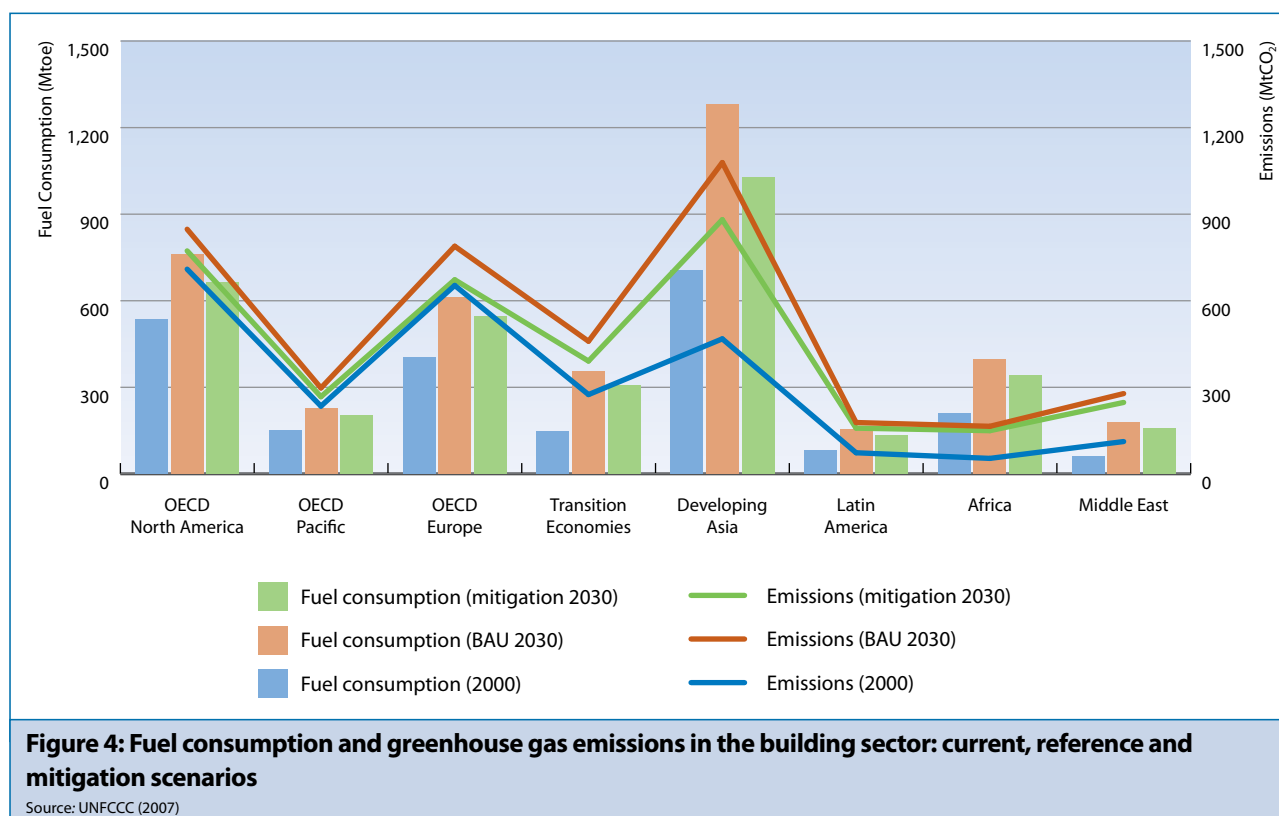
average payback time from energy savings for the green buildings analysed by Kats was 6 years, while over 20 years financial gains from reduced energy costs exceed the green premium by a factor of four to six – US\$ 43.1 to US\$ 172.2 per square metre (Kats 2010).<sup>16</sup>

But the opportunity for energy saving in buildings is not equally distributed at the global level. A recent UNFCCC study, illustrated in Figure 4, shows that in Asia (including China and India) there is a significant difference between current emissions and projected mitigated

emissions, reflecting the accelerated economic growth of these nations and their subsequent need for energy. In contrast, the study shows that OECD countries can mitigate emissions by 2030 to levels as low as those seen in 2000, confirming that advanced economies have the potential to make major strides in reducing energy demand in critical sectors such as the building industry.

16. Original text indicates green premium of US\$ 4 to US\$ 16 per square foot.

17. This example from the USA is referring to square foot. In the table the existing commercial building area corresponds to an area of 6.7 billion sq.m, with an office energy use of 1.1 million Btu/sq.m./yr, assumed energy savings of 30.7 kWhr/sq.m./yr (10%) and 122.7 kWhr/sq.m./yr (40%), assumed cost of retrofit of US\$ 10.8/sq.m. (10%) and US\$ 269.1/sq.m (40%), and assumed gains from a productivity increase of 1 per cent of US\$ 26.9/sq.m/yr.



### Water benefits

The water efficiency of green buildings translates into cost savings for the supply of potable water. A variety of water-efficiency strategies is being pursued particularly by countries facing water stress and water scarcity. In India, innovation in indigenous and green building approaches include rainwater harvesting with segregation of surface and roof-top run-off, the use of pervious paving to maximise groundwater recharge, as well as the introduction of waterless urinals (UNEP SBCI 2010a). In Mexico, a Green Mortgages programme of the public fund, INFONAVIT, provides credit for water and energy-conservation measures, including the introduction of solar water heating and low-flow showers (UNEP SBCI 2009b). In New South Wales, Australia, the government-owned land and property developer, Landcom, has defined principles such as water sensitive design, which have to be met by suppliers. It has promoted building-sustainability indicators, introduced by state regulation and requiring 40 per cent improvement in GHG emissions and water management in all new housing (Martinez-Fernandez et al. 2010). In Melbourne, City Council House II has achieved a 72 per cent reduction in mains water usage through a combination of water efficiency, rainwater harvesting, water recycling and sewer mining (von Weizsäcker et al. 2009).

Further, demand-side management of household water-use covers appliances used for toilets, urinals, showerheads, taps, washing machines and dishwashers. Using water efficient appliances in the home can result

in significant water savings. For example, modern water efficient dishwashers and toilets can use as much as a 50 per cent less water than less efficient older models or even 100 per cent less in the case of waterless toilets and urinals (Waterwise 2011a and 2011b).

According to Kats (2010), the net present value of 20 years of water savings in a typical green building in the USA range from US\$ 5.4 to US\$ 21.5 per square metre.<sup>18</sup> He further suggests that these direct savings in green buildings outweigh the initial costs of water-efficiency strategies such as rainwater harvesting, waterless urinals and the use of grey water for all building types. A specific example is provided in Box 4. Reducing hot-water usage also brings benefits by reducing water and energy costs for households, businesses, institutions and water utilities.

### Waste and material benefits

The building sector can be called the industry of “thirds”: over a third of all CO<sub>2</sub> emissions come from building construction and operations, over a third of all energy and material resources is used to build and operate buildings, and over a third of total waste results from construction and demolition activities. Considering efficiency in use of land and materials, green building presents an opportunity to address growing scarcity issues that many societies face owing to the unsustainable use of ecosystem services. It also presents an opportunity to address other environmental and health problems such

18. Original text indicates a range from US\$ 0.50 to US\$ 2 per square foot.

as noise pollution, chemical pollution and hazardous waste issues such as asbestos and lead content in paint (UNEP SBCI 2010b).

Avoiding waste, in addition to minimising energy and water consumption over a building's life-cycle, is crucial to the sustainable performance of buildings. Life-cycle management brings a cradle-to-cradle perspective, covering a building value chain that includes the manufacturing of material supplies, the construction process, building operation and maintenance as well as the disposal, recycling, or reuse of building, operations, construction, and demolition waste.

Buildings consume great quantities of materials, energy and other resources, the root of which start with planning and design and reach all the way to eventual demolition. The consumption of these resources can have significant environmental impacts at global and local levels. Ensuring that undesirable impacts are minimised, architects and design professionals play a major role in energy conservation and responsible resource usage. Research into the energy consumption of buildings today is directed towards analysis of operational energy (during use phase) as well as the energy embodied within the fabric of the building, energy needed to extract and process raw material into finished building components, as well as energy used in the construction of the building. As operational energy consumption is improved, embodied energy becomes proportionally more significant. The embodied energy of a building's materials is one measure of its ecological impact and use of ecosystem services, which raises questions about the acquisition of raw and processed materials.

Measuring the embodied energy of building material components, or the building as a whole, presents an enormous challenge unless information is systematically collected from the design stage to the completing of construction and is made available by all manufacturers involved.

In order to reduce the building impact and fulfill a complete life-cycle of building and material construction analysis, it is necessary to establish low-impact criteria during the design process; construction, operation/maintenance and disposal/recycling. The following criteria can be considered: raw material availability; land and water availability; minimal environmental impact; embodied energy efficiency (production and process energy requirements); transportation; product lifespan; ease of maintenance; potential for product re-use; and material durability and recyclability. In order to analyze the environmental impact of the materials according to their entire life-cycle, building materials are divided in three groups: organic, ceramic and metallic. Organic building materials include

timber. Ceramic building materials are the inorganic, non-metallic ones, primarily consisting of concrete and masonry products as well as glass. The metallic building materials include steel, aluminum, copper and lead. These are all natural resources. Issues also arise from the increasing use of synthetic materials such as plastics, which tend to be complex materials that pose difficult problems for recycling and reuse. Reducing the number of material components in products as well as separating natural from synthetic material allows higher rates of recyclability and reuse (McDonough and Braungart 2002).

Comparative analysis of materials using the above-listed criteria (Lawson 1996) shows that, by example, sustainably-sourced wood is one of the best options for ensuring low embodied energy and a minimal environmental impact. While metallic materials have the highest embodied energy, they also perform well in terms of their lifespan, maintenance, reuse and recyclability. Lawson's study, carried out in Australia, reported that 95 per cent of embodied energy that would otherwise go to waste can be saved by the reuse of building materials. Savings range from 95 per cent for aluminium to only 20 per cent for glass.

The recycling of building materials is a relatively new concept and has only been assessed in a few studies. In a study carried out in Sweden, two cases were compared: (a) a building with a large proportion of re-used materials and components, and (b) the same

#### Box 4: Water savings in a 4-person single house

Water use in a standard 4-person single-family detached house can be reduced by 57 per cent (from 500 litres to 218 litres per day) by installing more efficient devices in place of conventional toilets, showerheads, taps, dishwashers, washing machines etc. (van Wyk 2009). Water-efficient appliances such as rainwater harvesting systems and systems for re-using grey water require additional investment costs, but most cost-saving effects relate to saved potable water. These are determined by the average cost of potable water. In the case of a 4-person single-family household, setting a high price for water (US\$ 1.91 per m<sup>3</sup>, as in Germany) will result in a saving of about US\$ 202 per year, whereas with a lower price of US\$ 0.40 per m<sup>3</sup> (as in Canada) the saving will be about US\$ 42 per year.

UNESCO (2001)

building for which new materials and components were used. The results showed that the environmental impacts caused by reused materials are at 55 per cent of the impact caused if all materials had been new (Thormark 2000 and 2006). Other studies show that by using recycled materials between 12 per cent and 40 per cent of the energy used for material production could be saved. Reasons for the mixed results between studies include differences in recycling rates and the material composition in buildings.

Although recycling building materials requires energy consumption, studies show that recycling materials still delivers net emissions savings. Following a life-cycle approach (Sára 2001), compared CO<sub>2</sub> emissions from produced recycled clay/gravel with and without selective dismantling and classification. The research indicates that CO<sub>2</sub> emissions were reduced from 107.7 kg to 6 kg per tonne of recycled clay/gravel produced. Recycling rates of specific materials that are significant in construction and demolition waste streams can be significant indicators of sustainability. In developing societies, recycled building components are often cheaper and of higher quality than conventional materials, providing benefits to the urban poor (UNEP SBCI 2010a).

### Productivity and health benefits

Green buildings provide benefits beyond environmental advantages at a low or negative cost. These include improved worker productivity and work quality resulting from a more comfortable office environment as well as improved public health resulting from reduced indoor air pollution (after replacing biomass with electricity or clean burn biomass in developing countries), reduced noise pollution and reduced overall air pollution (owing to reduced use of fossil fuels in developed countries and emerging markets).

These benefits can rival, if not supersede, the energy cost and climate benefits outlined above. For example, a recent study for the US Green Building Council estimated that greening an average US commercial office building saves US\$ 5.6 per square metre per year in energy costs (Booz Allen Hamilton 2009).<sup>19</sup> While significant in absolute terms, energy costs for most businesses pale in comparison to labour costs, particularly in developed countries. Even a 1 per cent increase in productivity resulting from investment in green buildings yields a labour-cost saving several times higher than the energy-cost savings noted above. Results from a series of research studies on the effects of environmental conditions within workplaces show that productivity savings can be significantly greater than 1 per cent:

■ *Indoor air quality*: 6-9 per cent productivity gain (Wyon 2004);

■ *Natural ventilation*: 3-18 per cent productivity gain (NSF/IUCRC 2004);

■ *Local thermal control*: 3.5-37 per cent productivity gain (Loftness et al. 2003);

■ *Daylighting*: 3-40 per cent productivity and sales gain (Loftness et al. 2003); and

■ *Rent premium*: up to a 36 per cent increase (Baker et al. 2008).

Increased day lighting, views and contact with nature have also been linked to positive health and productivity impacts beyond commercial workplaces, for example, in hospitals and schools. Enhanced environments within school buildings are linked to improved student performance (Aumann et al. 2004) and those in hospitals have been associated with faster patient recovery (Ulrich 1984). Of 13 studies linking improved access to the natural environment with gains in individual and organisational productivity, seven identified 3-18 per cent increases in individual productivity (including student test results) and 40 per cent increases in sales (an organisational productivity measure) as a result of the introduction of daylight to workplaces (Loftness et al. 2003).

One of the earliest and most widely-cited studies on economies from green buildings documented 33 commercial buildings with green certification in California (Kats 2003). The report found an average green-building cost premium of US\$ 32.3-53.8 per square metre.<sup>20</sup> The total benefits of the investment are highlighted in Table 4, which measured net-present value (NPV) over a 20-year period, showing net benefits of between US\$ 516.7-721.2 per square metre, depending on level of certification.<sup>21</sup>

In developing countries, the health benefits of investment in the green buildings, specifically in technologies and appliances for heating and cooking, are directly contributing to improved human well-being. Indoor pollution is a major cause of serious illness and premature death in developing countries. Greening the building sector, in this context, is expected to derive its main benefits from reducing indoor pollution and improving the health of the poor, particularly women and children. Studies conducted by Ezzati and Kammen (2002) showed that the cost-effectiveness of measures

19. Original text indicates saving of US\$ 0.52 per square foot per year in energy costs.

20. Original text indicates an average green-building cost premium of US\$ 3-5 per square foot.

21. Original text indicates net benefits of between US\$ 48-67 per square foot.



such as distributing cooking stoves was superior to many public-health programmes around the world.

Analysis of low- and middle-income countries for the WHO has shown that by 2015, the availability of improved stoves to half of those who in 2005 were still burning biomass fuels and coal on traditional stoves “would result in a negative intervention cost of US\$ 34 billion a year and generate a return of US\$ 105 billion per year” (Hutton et al. 2006). The study concludes that “economic benefits include reduced health-related expenditure as a result of less illness, the value of assumed productivity gains resulting from less illness and fewer deaths and time savings due to the shorter time spent on fuel collection and cooking.” A potential global demand for 0.61 billion LPG stoves or electrical hot plates by 2030 to replace open-fire biomass fuel for cooking augurs well for job opportunities in areas such as sales, transport, maintenance and manufacturing (Keivani et al. 2010).

### Benefits in employment

The construction sector (including buildings) accounts for 5-10 per cent of employment at the national level, amounting to over 111 million people directly employed worldwide (UNEP SBCI 2007a; ILO 2001). Three-quarters of construction jobs are in developing countries and 90 per cent in firms of less than 10 employees or micro firms (Keivani et al. 2010). The real figure is likely to be much higher, as many construction workers are informally employed and therefore not accounted for in official statistics.

Greening the global building stock will impact global employment through job creation, job substitution, job elimination and job transformation. There are many channels through which green buildings generate employment including: the new construction and retrofitting of buildings, increased production of green materials, products, appliances and components, employment through energy-efficient operations and maintenance, the expansion of renewable energy sources and generation mix, and tangential activities such as recycling and waste management.

Several studies estimate the number of jobs created as a result of different types of green building investment. Before reporting the evidence, it is important to mention two key aspects of these studies. Firstly, new jobs created as a result of green investments are not necessarily green jobs. According to ILO definitions, to be considered green, jobs must meet as well the criteria of decent work. Some indicators in the building sector point to serious shortfalls in decent work. Box 5 discusses this issue in more detail.

Secondly, case studies often report the gross impact of investment on the labour market. Yet an accurate labour-

Category	20-year NPV
Energy value	\$ 62.3
Emissions value	\$ 12.7
Water value	\$ 5.5
Waste value (construction only) – 1 year	\$ 0.3
Commissioning O&M value	\$ 91.2
Productivity and health value (certified and silver)	\$ 397.1
Productivity and health value (gold and platinum)	\$ 595.6
Less green cost premium	(\$ 43.1)
<b>Total 20-year NPV (certified and silver)</b>	<b>\$ 526</b>
<b>Total 20-year NPV (gold and platinum)</b>	<b>\$ 724.5</b>

**Table 4: Financial benefits of green buildings (US\$ per sq.m)<sup>22</sup>**  
Source: Kats (2003)

market assessment also requires evaluating the net effects. A number of jobs will be lost when investment is redirected to green buildings, when green materials replace brown materials, and so on. In practice, substitution, budget and external effects are not easily quantifiable.

Considering research on new construction, Booz Allen and Hamilton (2009) estimated that in the US green-building construction supported over 2.4 million jobs between 2000 and 2008 and these are projected to grow to up to 7.9 million between 2009 and 2013. Another study on the green building industry in Brazil shows that jobs related to greening the construction, commercialisation, maintenance and use of buildings grew from 6.3 per cent of the total number of formal jobs in 2006 to 7.3 per cent in 2008 (ILO 2009).

In terms of retrofitting activities, it is generally accepted that every US\$ 1 million invested in building-efficiency retrofits would create 10-14 direct jobs and 3-4 indirect jobs. Using a value of 12.5 jobs per US\$ million invested, a recent report (Hendricks et al. 2009) calculated the jobs that could be created if 40 per cent of US building stock – 50 million buildings – is renovated by 2020 with an average investment of US\$ 10,000 per retrofit. This would result in a US\$ 500 billion market, which would lead to 6,250,000 jobs over ten years. Table 5 further illustrates how the economy might benefit from a US\$ 1 million investment in green buildings and how this would generate a net gain of 16.4 job-years over 20 years.

Important additional employment opportunities are also generated from the design of environmentally-

22. Original text presents the figures in US\$ per sq.ft: \$ 5.79 of energy value; \$ 1.18 of emissions value; \$ 0.51 of water value; \$ 0.03 of water value (construction only) for a year; \$ 8.47 of commissioning O&M value; \$ 36.89 of productivity and health value (certified and silver); \$ 55.33 of productivity and health value (gold and platinum); \$ 4.00 of less green cost premium; \$ 48.87 of total 20-year NPV (certified and silver); \$ 67.31 of total 20-year NPV (gold and platinum).

## Box 5: The social dimension of green buildings: implications for decent work and poverty reduction<sup>23</sup>

The building sector has high potential for pro-poor economic growth through its high labour absorption capacity in developing countries. The sector employs a wide range of workers with different levels of education and has the ability to absorb the excluded (de Souza 2000). This has strong implications for income generation and poverty reduction. Take the example of the Johannesburg Housing Company project in South Africa (Keivani et al. 2010). This project involves the introduction of energy-efficient light bulbs and day-night sensors, solar energy systems for heating water and the insulation of boilers. It provides jobs for over 1,000 contractors in maintenance, cleaning and security services and even more in specialised functions such as plumbing and electrical services. The Wateryg Soweto project for the rehabilitation of plumbing fixtures has provided 1,500 temporary jobs.

Despite this potential, workers of the construction industry are often subject to poor working conditions. High informality, low wages, instability, gender discrimination, frequent accidents and occupational diseases characterise the working conditions of a large share of workers in the building sector around the world, especially in developing economies where construction work is more precarious and less formalised.

Where the employment relationship of contractors, subcontractors and workers is casual or informal, workers' rights are often unclear and they enjoy less protection from the law than those directly employed. In recent years it has become the norm for workers to be employed on a short-term basis, and instability of work is one of the major problems facing the building industry.

Construction is also one of the most dangerous occupations. Workers in this sector are 3-4 times more likely than other workers to die from accidents at work. Many others suffer and die from diseases arising from exposure to dangerous substances at the workplace, such as asbestos. In regard to social

protection, there is evidence that many employers do not pay into social security funds for workers who are on temporary contracts, depriving them from health care, holiday pay, and compensation owing to unemployment, ill health, accidents or old age.

For a long time the ongoing dialogue with employers as well as the government has been a successful approach for workers to collectively negotiate better wages and working conditions. However, nowadays a large workforce of temporary, casual, informal and unemployed workers find it very difficult to organise themselves to engage in such dialogue. The greening of buildings may provide a new opportunity for social dialogue. Many employers and government authorities have shown enthusiasm for green construction. This may open a new door to dialogue with workers on labour issues in the context of greening of the industry, involving workers in green management, resource efficiency and safety improvements.

In the area of working conditions, greening the building sector will have an impact on health and safety. Green construction is however not safer per se, as is shown in research by the American Society of Civil Engineers. With data collected through a structured questionnaire survey, the study tested the presence of a difference in Occupational Safety and Health Administration (OSHA) recordable incident rates (RIRs) and lost time case rates (LTCRs) between green and non-green projects. There was suggestive, but inconclusive evidence of a statistically significant difference in the RIRs of the green and non-green building projects that were examined. Also, no statistically significant difference was found between the respective LTCRs.

These considerations provide further cause to turn the role of labour inspectors to one of education and prevention, as opposed to mere inspection and prosecution. The greening of the industry brings the opportunity to create synergies between inspection about the environmental and the health & safety components of construction.

sound materials, products and renewable energy. A study conducted by ADEME (2008) in France displays the number of jobs directly involved in carrying out

insulation work of opaque walls, which involve interior insulation of the walls, ceilings and floors and the use of associated materials. In 2006 the industry accounted for 9,700 jobs related to these activities and 7,150 jobs related to the production and application of related

23. This Box was prepared based on contributions from ILO to this chapter.

Spending category	Impact	Amount (millions)	Job multiplier	Job impact (job years)
Construction	Green premium increases construction spending	\$ 1.0	12	12.00
Consumer Spending	Because of the green premium, consumers spend less in the short term	\$ -0.6	11	-6.60
Consumer savings	Because of the energy savings, consumers spend more in the long term	\$ 1.0	11	11.00
Lost utility revenues	Utility revenues decrease because of energy savings	\$ -0.8	3	-2.40
Loan interest	Interest paid to banks on construction loans	\$ 0.3	8	2.40
Net-job years: 20 year total				16.40

**Table 5: Twenty-year net economic impact of a US\$ 1 million investment in green building improvements – Illustrative examples**

Source: Kats (2010)

materials. The figures are projected to grow to 21,000 and 15,000 respectively by 2012. The same study concludes that roof insulation activities accounted for 3,050 direct jobs in 2006, expected to double by 2012.

The use of green appliances and components has high job creation potential as well. Research by the U.S. Department of Energy estimates that adopting standards for washing machines, water heaters, and fluorescent lamps alone would create 120,000 jobs in the USA by 2020. In India the introduction of a single appliance, fuel-efficient bio-mass cooking stove to replace the traditional stoves in 9 million households could produce 150,000 jobs in addition to the health benefits (UNEP, ILO, IOE, ITUC 2008).

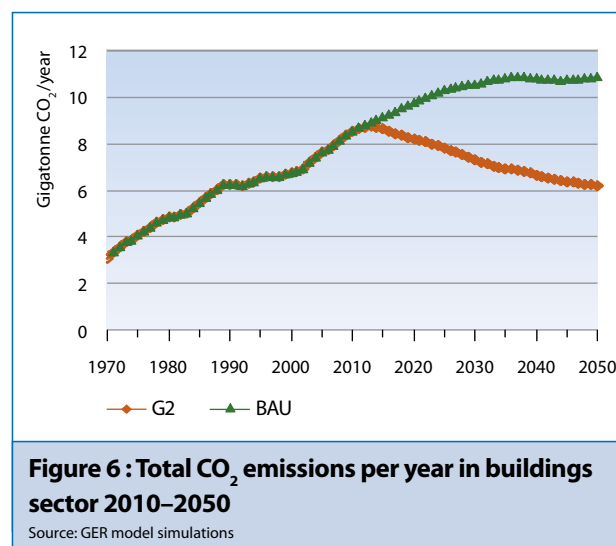
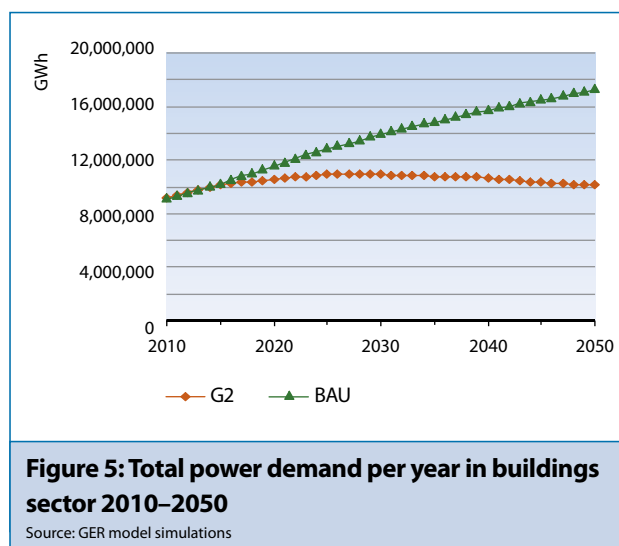
Green investment associated with recent government stimulus packages has boosted investment in green buildings. An estimated 13 per cent of Germany's overall stimulus package (around US\$ 105 billion) is expected to create 25,000 jobs in manufacturing and construction for retrofitting buildings (UNEP 2009a). Opportunities for training in retrofitting are also increasing as the lack of skilled and certified professionals is proving to be a significant barrier in the adoption of green buildings, especially in developing countries.

Focusing on existing residential and public-sector buildings, a recent study by Ürge-Vorsatz et al. (2010) investigated the net employment impacts of a large-scale energy-efficiency renovation programme in Hungary. The study simulates five scenarios that are characterized by two factors: the type or depth of retrofits included in the programme and the speed of renovation assumed. The BAU scenario assumes no intervention and a renovation rate of 1.3 per cent of the total floor area per year. Conversely, the "Deep Retrofit, fast implementation rate" scenario assumes that 5.7 per cent of the total floor area will be renovated per year. This research demonstrates that a renovation programme of this scale could generate up to 131,000 net new jobs in the country, whereas a less ambitious scenario would see the creation of only about 43,000 new jobs.

Under the "deep renovation" scenario, job creation is calculated to peak in 2015 with a massive new 184,000 jobs, notwithstanding employment losses in the energy-supply sector. It is important to highlight that close to 38 per cent of these employment gains result from indirect effects on sectors supplying the construction sector, as well as from the higher spending power resulting from the previous rise in employment.

A number of studies have demonstrated that investments in green buildings produce more jobs than they replace in the energy-supply industry. A study by Wei, Patadia and Kammen (2010) found that solar panels (often used in green buildings) create 0.87 job-years per gigawatt-hour (GWh) produced and energy-efficiency investments create 0.38 job-years per GWh saved. That is considerably higher than coal (0.11 job-years per GWh), natural gas (0.11 job-years per GWh), or nuclear power (0.11 job-years per GWh) create. A study by David Roland-Holst (2008) found that between 1976 and 2006, energy-efficiency improvements in California created 1.5 million jobs, net of the jobs lost in energy-producing industries. Nevertheless, the ILO (CEDEFOP 2010) has reported job losses in the cement industry associated with employment shifts to other industries, which underline the need for retraining and upgrading skills.

The studies referenced here confirm the potential for job creation in the building construction sector. If the huge demand for new buildings (social housing, hospitals, schools, etc.) that exists in developing countries is to be considered, the potential is much higher. Further, programmes for greening the sector will provide an opportunity to address informal production and ensure creating green and decent jobs, engaging and updating the skills of both the formal and informal sector workforce. On the other hand, most of the studies do not net out the jobs lost from redirecting investment into green buildings that would have otherwise been invested elsewhere in the economy. Also there is a range of barriers, which hamper the employment-generating potential of construction investment being fully realised.



Removing these barriers, for example through the application of appropriate policy instruments, will increase overall economic output and net employment by increasing average returns to capital economy-wide. Policy interventions (more below) also need to address constraints in the planning and procurement of construction projects, and the lack of capacity in the local industry.

### 3.4 Investment scenarios for increased energy efficiency in buildings

A comprehensive analysis of investment in greening the building sector would investigate the effects from implementing the range of measures discussed above including new building and construction methods and design as well as retrofitting existing buildings. Conducting such analysis is, however, limited by a lack of global data particularly on the building stock and its evolution in recent years.

The modelling of green investment scenarios in this report includes an analysis of the effect from increased energy efficiency in buildings.<sup>24</sup> This analysis is feasible using existing data on energy supplied to the building sector. Although investment in energy efficiency is only part of a range of investment needed to shift to green buildings, it is a major component.

The economy-wide model assumes 2 per cent of the global GDP to be allocated on a yearly basis as additional investment in 10 green sectors (G2) over the period 2011–2050. The results of this investment are then compared with those of a BAU scenario without additional investment, and a BAU2 scenario, in which the same additional amount is invested following the projected trends of BAU.<sup>25</sup> Within this multi-sector model, the building sector is allocated 0.2 per cent of the global GDP to increase energy efficiency. Since model projections result in GDP growth (under all scenarios), this annual investment under G2 continues to rise: from US\$ 134 billion in 2011 to US\$ 389 billion in 2050 (with a yearly average of US\$ 248 billion).<sup>26</sup> These amounts are somewhat lower than but generally comparable in scale to the latest estimates from IEA and OECD (2010).<sup>27</sup>

The effectiveness of these investments in energy efficiency is simulated in the model by using the average emission-abatement costs estimated by IEA (2009a) for introducing the measures in the building sector. These rise from about US\$ 18/unit/t CO<sub>2</sub> in 2015 to US\$ 58/unit/t in 2030 and US\$ 166/unit/t in 2050, reflecting the expectation that measures to reach further efficiency improvements will become more costly over time.

Under a BAU scenario, power demand from the building sector almost doubles from 9.4 million Gwh in 2010 to 17 million Gwh in 2050 (Figure 5). The G2 results, in contrast, suggest the possibility of decoupling buildings' power demand from economic growth. In the simulation, power consumption peaks at 10.9 million Gwh in the period 2025–2030, then drops slightly to 10.1 million Gwh by 2050 while GDP continues to grow in that period.

In terms of reduction in the intensity of buildings' power demand per unit of GDP, the results of the simulation show that under G2, by 2020, the intensity will decline by 17 per cent over the baseline in 2010, compared with a reduction of 5 per cent under BAU. By 2030, the

24. The modelling of green economy investment scenarios is presented in detail in a separate chapter.

25. In order to be conservative about projected reductions in emissions in the buildings sector, G2 results are compared here with BAU only. When G2 results are compared with BAU2 results, the extent of emission reductions would be more significant because BAU2 projects higher growth in emissions than BAU.

26. All monetary figures are in constant US\$ with base year 2010.

27. As seen below, the somewhat lower investment amounts modelled here also lead to lower emissions reductions than in IEA (2010), although as explained, part of the emissions reduction in the G2 scenario owes to investment in renewable energy, which is not included in the costs presented for investment in energy efficiency.

Scenarios	Emission intensity – CO <sub>2</sub> emissions per US\$ GDP		Carbon intensity – CO <sub>2</sub> emissions per unit of energy consumption	
	Reduction between 2005 and 2050	Reduction relative to BAU in 2050	Reduction between 2005 and 2050	Reduction relative to BAU in 2050
BAU	-45%	-	-3.2%	-
G2	-76%	-57.0%	-45.0%	-42.8%

**Table 6: Emissions intensity in the GER model simulations**

reduction in this intensity under G2 will be 36 per cent compared with 9 per cent in the BAU. In 2050, the G2 scenario would deliver a 64 per cent reduction in the intensity of power demand relative to BAU.

Power demand, however, only accounts for approximately 30 per cent of energy use by all buildings in 2010 (21 per cent for residential buildings and 51 per cent for commercial buildings). Efficiency improvements in the use of other energy sources in buildings were not simulated, due to lack of data. In these partial results of the simulation, therefore, total energy use in the building sector, which is influenced in the model primarily by economic growth, continues to rise. It turns out that the increased energy use from non-power sources, such as fuel for heating, driven by additional economic growth in the green investment scenarios, approximately offsets the savings in power demand. Thus, total energy-use rises similarly under all scenarios. This is, in part, an example of the rebound effect (see Box 6). It should be emphasised, however, that improvements in the efficiency of energy use from non-power sources, which are not captured by the model and its simulations, should entail lower energy use under any potential green investment scenario.

As mentioned, the green investment scenario modelled includes an integrated package of investments in multiple sectors, which affect each other, sometimes indirectly, through inter-sectoral linkages and economy-wide effects. For this reason, the results in one sector, such as the buildings, need to be seen as a result of both direct effects from the specific investments in the sector, in this case energy-efficiency, as well as indirect effects, such as those that affect GDP growth.

The multi-sector G2 scenario also entails substantial investment in the supply of energy from renewable sources. In the G2 scenario, 0.5 per cent of GDP is committed to renewables with the aim of reaching the targets set in IEA's Blue Map scenario (IEA 2008). Although total energy use in buildings may still continue to rise under any scenario due to continued economic growth, the level of emissions would be much lower due to the increased share of renewables.

The simulations (see Figure 6) reveal that by 2050 the green scenario leads to levels of emissions that are 4.7 GtCO<sub>2</sub> below the BAU and approximately 27 per cent lower than current emissions. In G2, the absolute level of CO<sub>2</sub> emissions increases slightly during the first years

## Box 6: The rebound effect

The phenomenon known as the "rebound effect" describes the limits to energy savings achievable by increasing the energy efficiency of a given technology. Financial savings incurred owing to greater efficiency may lead to increased use of the same product or to the consumption of other energy-consuming goods and services. This highlights the Jevons paradox, where efficiency gains from a new technology are undermined by increase in consumption of the resource involved. Examples are leaving lights on because they are energy-saving bulbs and driving a more efficient car further or using the money saved on petrol to buy another car. It highlights the importance of accompanying new technologies with appropriate behavioural and institutional change. This rebound effect is widely

recognised, but its estimated magnitude varies by activity, as shown by the following estimates (WBCSD 2007a):

- Space heating: 10-30 per cent
- Space cooling: 0-50 per cent
- Lighting: 5-20 per cent
- Water heating: 10-40 per cent
- Automobile: 10-30 per cent.

The rebound effect has to be viewed differently in low-income countries, where consumption increases from a low status quo. Here energy efficiency can contribute to development as reduced expenditure on energy enables poor families to invest in other necessities of daily life.



of the projection. In 2015, it drops back to the 2010 level, which represents a 5.5 per cent reduction compared with BAU. In 2050, worldwide CO<sub>2</sub> emissions in the building sector are slightly below the level of 1990 and 43 per cent lower than BAU.

The most important result of these projections is that the green investment scenario for the building sector reaches substantial emission reductions compared with BAU, although the additional investment in the building sector and across the economy leads to an increase in GDP and energy demand. This shows the potential of the integrated investment package to reduce carbon intensity by decoupling economic growth from CO<sub>2</sub> emissions.

Table 6 illustrates the general trend for emissions intensity relative to GDP in the building sector and the significant projected reduction of carbon intensity per unit of energy consumption resulting from the additional investment in greening the sector. The investments modelled in G2 result in a reduction of 45 per cent of carbon intensity compared with 2005, reflecting the stabilisation of energy demand through enhanced energy efficiency.

When considering the enactment of a cap and trade mechanism with carbon prices aligned with the 2009 US domestic proposal (reaching US\$ 77 per tonne of CO<sub>2</sub> by 2030 and US\$ 221 by 2050, in constant US\$ 2010), the

reduction in emissions in the building sector as a result of the green investment scenario would translate to about US\$ 330 billion per year on average between 2012 and 2050.

Finally, energy efficiency will have an impact on job creation and employment. Energy-efficiency investments are estimated to create 0.38 job-years per GWh saved (Wei et al. 2010). The GER model simulations thus estimate that these investments would generate more than 1.2 million jobs by 2030, and a total of 2.6 million jobs by 2050 in the G2 scenario. Additional investments in greening the buildings and construction sector in other ways, such as more sustainable building materials, also have the potential to generate employment. It was not possible to include these in the model simulations, but it is important to note that such a shift will likely also require investments in workers' education and training in addition to other transitional measures.

In summary, the green investment scenarios are limited in terms of specific investments in the building sector to energy efficiency, and have not been able to capture a wider range of possible measures. However, the results of even these limited simulations reveal the potential savings in buildings' power demand. When the effects of rising renewable energy use are included, substantial reductions in GHG emissions are projected.

## 4 Enabling conditions and policy instruments

The climate and resource-use challenges in the building sector are clear. Technological solutions exist to green the sector at low or even negative average cost. The socio-economic case for greening the sector is strong. But the greening of buildings has not taken place on a large scale in either developed or developing countries.

Besides more general constraints in advancing green building policy and regulation such as those related to governance and capacity, two key barriers relate to (a) financial constraints and (b) market and industry structures. These are discussed below, following which an overview of available instruments and tools is given. The latter will build on research done by the Central European University (CEU) for the UNEP Sustainable Buildings and Construction Initiative (UNEP SBCI 2007b), considering evaluation studies or reviews of policy instruments implemented in countries all over the world. Of key consideration is the relative effectiveness of instruments and tools in achieving high energy savings and GHG reductions, and their cost effectiveness.

### 4.1 Barriers to green buildings

Barriers to environmental and energy-efficiency improvements in buildings can be economic or financial, resulting from hidden costs and benefits, market failures or a specific market and industry structure. They can also be political or structural, associated with behavioural or organisational constraints, or linked to information and capacity limitations (UNEP SCBI 2007b). Recognising the latter two barriers is of particular importance in a developing-world context. Hidden costs include transaction costs associated with securing energy-efficient solutions and risks associated with replacement technologies (Westling 2003; Vine 2005). Transaction costs are often high owing to the fragmented structure of the building sector with many small owners and agents. Market failures can take the form of misplaced incentives, such as when building tenants (as bill-payers) have an interest in environmental improvements that are not shared by the building owners. While low energy prices may give little incentive for affluent households and businesses in developed countries to change their behaviour, subsidies often keep energy prices in developing countries artificially low and again take away any incentive to change.

#### Financial constraints

Key financial constraints relate to upfront costs and payback periods, misalignment between investors and beneficiaries, the ability of households to pay, and investors' policies on what to include in their investment portfolios.

*Upfront investment cost and payback period:* Although buildings can be greened at low or zero net cost over the lifetime of the investment, the initial additional capital outlay, the so-called "first cost", could be a deterrent for those who demand finance for greening buildings (home owners, construction firms, and small businesses). In developing countries with acute housing shortages, actual or perceived high upfront costs are often a key barrier. Furthermore, energy-efficient multi-family housing is still widely perceived to be much more expensive to build than is actually the case (in new construction, 20 per cent improvements in energy consumption are achievable with modest financial costs (Brown and Wolfe 2007)).

Moreover, although investments in greening buildings tend to have relatively short payback period (say 5-10 years), many private investors may not proceed unless the net benefit stream starts flowing in within a couple of years. For large-scale green-building programmes, governments usually need to raise significant funds.

*Split incentives:* A related barrier is that the benefits of energy savings may not go directly to the person making the investment. For example, the owner of a building is likely to be responsible for making energy-efficiency investments, but the occupier may receive the benefit of lower energy bills (although landlords could benefit from higher rents if regulations so allow). On the other hand, if the landlord is responsible for the energy bills, the tenant has no direct incentive to invest in saving energy.

*Household ability to pay:* Financial capacity is an impediment particularly in multi-family housing where residents often have low incomes. While this group stands to save the highest percentage of income, they are likely to have the greatest difficulty in paying for effective investments, especially as the best results are achieved through a comprehensive retrofitting approach, which encompasses the modernisation

of the building envelope (insulation and windows), together with the replacement of heating and air-conditioning systems. The benefits of such an approach are clear, with efficiency improvements of 50-75 per cent documented, and savings of 30 per cent routinely achieved.

*Institutional investor offering:* For financial institutions, energy-efficiency projects in buildings are often associated with the following major hurdles: low financial returns, credit risks, uncertainty, and difficulty in evaluating the added financial value of green buildings. If the projects are small-scale, they do not fit into the traditional financial toolbox. But this situation is also changing. After the recent financial crisis, some long-term institutional investors such as pension funds have started searching for new asset classes to rebalance their portfolios. Green buildings – retrofitted or newly constructed, as well as the manufacturing of related materials and equipment – may become an asset class that can help diversify portfolios and generate steady growth of earnings. Additional discussion on this can be found in the Finance chapter of this report, which includes the case study: “The emergence of responsible property as an asset class”.

### Market and industry structure

The building market is highly fragmented with many small landlords, corporate property owners managing multiple buildings, usually in local or regional markets, and public housing authorities, which are also mostly local. Coordination between all these stakeholders in the building and construction value chain is uncommon. By example, decisions taken during the feasibility assessment and design phases will have a major impact on the level of emissions during the building use or operational phase, but feasibility assessments tend not to account for the life-time running costs of the building since these are not paid for by the property developer (UNEP SBCI 2009b).

Owing to the fragmentation of the building market, it is difficult to make use of the Clean Development Mechanism (CDM) as building projects often do not provide sufficient carbon emission reduction pay-off and stakeholder commitment. In addition, the fragmentation also makes it difficult to comply with baselines and additionality requirements. Other obstacles include the CDM methodologies and procedures (see below).

Another aspect of the fragmentation is reflected in the differing interests of individual households and utilities. While householders may be intrigued by the prospect of greening their homes and reaping energy savings and health benefits, utilities face a potential reduction in their sales revenue and therefore may have little interest in supporting investment in green buildings.

## 4.2 Policy instruments and tools

Following the analysis of UNEP SBCI (2007b), policy instruments and tools for greening buildings can be classified as follows:

- Regulatory and control mechanisms, which cover
  - Regulatory-normative mechanisms such as standards and
  - Regulatory-informative mechanisms when the end-user is informed but not obliged to follow the advice (e.g. labelling);
- Economic or market-based instruments;
- Fiscal instruments and incentives; and
- Information and voluntary action.

These categories of instruments and tools are analysed below in terms of their use, efficiency and likely effectiveness in different contexts.

### Regulatory and control mechanisms

Regulatory and control mechanisms have to be monitored, evaluated and updated regularly to remain in touch with technological developments and market trends. They are easier to enforce with respect to new rather than existing buildings. Examples of such measures are appliance standards, building codes, procurement regulations, energy-efficiency obligations or quotas, mandatory audit programmes and utility demand-side management programmes. Examples of their cost-effectiveness expressed in US\$/tCO<sub>2</sub> for most of the cases are the following (UNEP SBCI 2007b):

- Appliance standards: – US\$ 65/tCO<sub>2</sub> in 2020 (USA), – US\$ 194/tCO<sub>2</sub> in 2020 (EU);
- Building codes: from – US\$ 189/tCO<sub>2</sub> to – US\$ 5/tCO<sub>2</sub> for end-users (Netherlands);
- Procurement regulations: US\$ 1 million in purchases saves US\$ 726,000 per year (Mexico);
- Energy Efficiency Obligations: – US\$ 139/tCO<sub>2</sub> (UK);
- Mandatory certification and labelling: – US\$ 30/tCO<sub>2</sub> (Australia); and
- Utility Demand-side Management Programmes: – US\$ 35/tCO<sub>2</sub> (USA), – US\$ 255/tCO<sub>2</sub> (EU).

Complications in the use of these regulatory instruments relate mainly to lack of enforcement and the rebound effect, where the end-user buys more of or uses the more efficient technology more extensively than before and

## Box 7: Reliable measurement and accounting

To ensure that information is accurate, there is a need to collect robust data on the performance of green buildings and their subsequent costs. Current methods of accounting mainly include energy audits and labelling, Triple Bottom Line<sup>28</sup> indicators and sustainability certificates. These tools can be effective, but must be tailored to target group needs. Energy audits and labelling identify opportunities to upgrade built environments and track the progress of existing energy efficiency investments. Recent evidence on the performance gap in one of the certification systems (LEED) has highlighted the importance of such measures (Murphy 2009), triggering renewed discussion on their efficiency. Building certification systems can

be static, i.e. based on engineering design estimates and assumptions, or dynamic, being updated as building-use patterns change. A wide range of audit systems are available, many of which are voluntary, although governments are increasingly favouring mandatory audits as opportunities to collect data and enable interventions. An important challenge posed by energy audits is the significant administrative cost posed by their implementation, including energy consultants, monitoring, and time and resource burdens on the owner. Energy benchmarking, as opposed to auditing, can serve as a lower burden alternative to identify energy-saving potential. In the benchmarking process, energy use is measured and compared with related values.

causes emission reductions to be offset by increased consumption. The latter provides an example of where the instrument needs to be combined with other instruments to guide users to more efficient use of technologies.

Improved enforcement requires adequate education and training, for example, of building-inspection and procurement officers. This is confirmed by recent examples of energy-efficiency improvement measures introduced in the public sector in Mexico, China, Thailand, South Africa, Kenya and Ghana. The case of Mexico has shown how introducing *public procurement regulation* at the city level may be a more effective point of departure before launching a programme nationally.

In the case of building codes applied to new buildings in developing countries, the basis for improved enforcement can be laid through starting with voluntary schemes, the use of incentives and improved inspection. China is showing how building regulations, together with voluntary and self-regulating market systems for green buildings can become key drivers in ensuring a higher level of energy-efficient construction and the deployment of environmentally-responsive technologies. Anderson, Iyer and Huang (2004) propose with regards to developing countries a structured implementation phase, including the necessary provisions for building code administration and enforcement structures, the development of and conduction of training programmes and the construction of multiple demonstration buildings.

Control and regulatory mechanisms, especially codes and standards, can be a rapid way to implement effective technology and best practices and lure risk-averse investors (Granade et al. 2009). In the general assessment of energy efficiency in building codes two mayor types of energy codes can be identified: “prescriptive” and “performance-based” (Hitchin 2008; Laustsen 2008). Although performance-based codes are more complex in their application, they yield a number of benefits. These, according to Hitchin (2008), consist in the flexibility for policy makers to weight different aspects of the building’s energy balance, even after the first implementation of the legislation; and also in the possibility of using the calculation procedure to integrate an energy performance labelling scheme or energy audits.

Mandatory *energy audits* are an extension of building codes and commissioning processes (UNEP SBCI 2009b) and underline the importance of reliable measurement and accounting (Box 7). In many European countries, governments have made energy audits mandatory for their public buildings as well as other major energy consuming sectors. The EU’s Energy Performance in Buildings Directive (EPBD) requires mandatory energy performance certificates to be presented to the customer during any sale or lease transaction of a building. It also requires public buildings of a certain size to publicly display their energy certificates, although critics point out that it does not account for the energy used by buildings’ occupants, which constitutes a large part of overall performance (Ries et al. 2009).

### Economic and market-based instruments

These instruments include energy performance contracting, cooperative procurement, efficiency

28. The concept of the Triple Bottom Line (TBL), also known as “people, planet, profit” or “the three pillars” represents a comprehensive set of criteria for evaluating the development of organisations and societies – economically, ecologically and socially.

certificate schemes and credit schemes such as flexible mechanisms<sup>29</sup> introduced under the UNFCCC and most recently, cap-and-trade schemes. Examples of their cost-effectiveness are the following (UNEP SBCI 2007b):

- Cooperative procurement: – US\$ 118/tCO<sub>2</sub> saved (USA);
- Energy efficiency/white certificate schemes: US\$ 0.013/kWh expected (France); and
- Kyoto flexibility mechanisms: – US\$ 10/tCO<sub>2</sub> (Latvia).

*Energy performance contracting* involves an energy service company (ESCO) as an implementing agent, guaranteeing certain energy savings over a period of time, implementing improvements and getting paid out of the energy savings. They are already used in the USA, Germany, China and Brazil. They do require supportive legal, financial and business environments and the absences of subsidies that send the wrong energy-price signals. Analysis of the experience in the Netherlands (Keivani et al. 2010) has shown the importance of institutional support for ESCOs that can facilitate measures that reduce energy consumption costs for all stakeholders, particularly households.

Advanced institutional structures are also required for the running of efficiency certificate schemes. The Fund for Electric Energy Savings (FIDE) in Mexico offers a “seal of quality” to certify energy efficient equipment, materials and technologies. FIDE is a joint initiative of the state-owned electric power utility, the Mexican electric workers union and members of the business community (Martinez-Fernandez et al. 2010).

The UK Carbon Reduction Commitment (CRC) programme, a cap-and-trade scheme, aims to reduce greenhouse gases by 2050 by at least 80 per cent compared with the 1990 baseline (DECC 2010). Now called the CRC Energy Efficiency Scheme, it applies to organisations that have an electricity consumption measured through half-hourly metering greater than 6,000 MWh per year (equivalent to an annual electricity bill of about £ 400,000–£ 500,000). This covers organisations that fall below the threshold for the European Union Emissions Trading Scheme, yet account for some 10 per cent of the carbon emissions in the UK. These tend to be organisations such as hotels, supermarkets, banks, national and local public authorities. Organisations will purchase their first allowances in 2011, and the more each consumes over 6,000 MWh per year, the more each organisation will have to pay. Participant organisations will report progress annually and pay penalties for non-compliance.

*Carbon credit trading schemes* crucially require reliable measurement and baselines. One of the reasons that the CDM under the Kyoto Protocol attracted so few building energy-efficiency projects was the fragmentation of the building market with few baselines and reference cases that could be used to determine additionality. High transaction costs and the absence of a sector-specific methodology was another reason for so few CDM projects in developing countries involving the building sector. The accumulative impact of change at the level of many small units has been a further complication. Energy-efficiency projects for buildings are often small in scale and use a variety of measure to decrease overall consumption. The necessity to validate, audit, monitor and verify each measure generates tremendous effort and extra costs that strongly impact the viability of the projects. Other limitations include the methodology to assess the impact of soft or non-technological measures (building design, occupants’ behavior). Finally, CDM has its limitation for the low-income housing sector where energy poverty induces low-energy consumption and carbon emission (Cheng et al. 2008; Schneider 2007; Ellis and Kamel 2007).

Considering ways of improving the use of an international credit scheme for the building sector, industry partners of the UNEP SBCI (2007a) made six recommendations for a post-Kyoto agreement. These underlined the need for using performance-based indicators (eg energy consumption per square metre) along with technology-based indicators, as well as the need for common baselines and national building energy-efficiency standards. In addition, it called for special recognition of energy-efficient housing for low-income groups, providing the poor with access to energy in an efficient manner even while absolute levels of energy consumption may be increasing (Ellis and Kamel 2007).

In April 2010 the Tokyo Metropolitan Government introduced the world’s first cap-and-trade scheme for urban buildings, covering 1,400 buildings, including commercial office buildings and industrial facilities (World Bank and Padeco Co. LTD. 2010)<sup>30</sup>. At the same time, the Seoul Metropolitan Government started a three-year trial of a carbon-trading system among 47 state-run public agencies, with a goal to achieve a 10 per cent reduction in GHG emissions (Hee-sung 2010).

Common carbon metrics are a recent international initiative to promote sustainability in the building sector. It is being developed by UNEP SBCI, the World Green Building Council (World GBC<sup>31</sup>) and the Sustainable Building Alliance (SB Alliance<sup>32</sup>). The focus has been on energy GHG emissions, but the metrics will address waste,

29. Among the flexible mechanisms (sometimes referred to as flexibility or Kyoto mechanisms) introduced under the Kyoto Protocol: Emissions trading, Joint Implementation and Clean Development Mechanism only the latter two are considered in the building sector.

30. It sets a 2020 target of reducing carbon emissions by 25 per cent (below 2000 levels), with a cap set at a level of 6 per cent below base emissions for the first compliance period (2010–14), and then approximately 17 per cent below base emissions from 2014 to 2020.



water, indoor air quality and financial performance (UNEP SBCI and WRI 2009; UNEP SBCI 2009a).

### Fiscal instruments and incentives

These instruments include energy or carbon taxes, tax exemptions and reductions, public benefits charges, and capital subsidies, grants, subsidised loans and rebates. Further details as well as examples are provided in Box 8. They target energy consumption and/or upfront investment costs. Examples of their cost-effectiveness include (UNEP SBCI 2007b):

■ Tax exemptions: Benefit/Cost Ratio 1:6 for new houses (USA);

■ Public benefits charges: - US\$ 53/tCO<sub>2</sub> to - US\$ 17/tCO<sub>2</sub> (USA); and

■ Subsidies: Benefit/Cost Ratio 12:1 (Brazil), - US\$ 20/tCO<sub>2</sub> (Denmark).

Taxes can reinforce the impact of other instruments such as standards and subsidies, affecting the whole building life cycle and making energy efficiency investments more profitable. They offer governments the possibility of investing tax revenues into green-building improvements. A challenge in their implementation remains low price-elasticity of demand, depending on how households spend their disposable income and the availability of substitute technologies.

Grants and subsidies are well suited to low-income households, which tend not to make investments in energy efficiency even if they have access to capital. By providing unconditional grants and subsidies, governments can provide direct capital rather than access to capital (UNEP 2009b). Grants are also best suited to encourage innovators and small businesses who would like to invest in R&D but find it difficult to access capital from the market. For example, the Danish energy authority made an agreement with the glass industry to develop highly-efficient double-glazed windows (de T'Serclaes 2007). Under the Energy Premium Scheme, the Dutch energy agency provided grants to evaluated buildings for introducing energy-saving measures (Keivani et al. 2010).

For middle- and upper-income households, preferential loans may be more appropriate for those wishing to carry out energy-efficiency improvements. These can be granted through public-private partnerships in which governments give some fiscal incentives to banks, which

in turn establish low interest rates for their customers. For example, KfW, a German development bank, launched preferential loans using a double-edged mechanism to finance them through public tax exemption for investments in efficiency projects coupled with direct public subvention (de T'Serclaes 2007).

For larger-scale, commercial greening efforts, the introduction of reduced fees and waivers can significantly aid the uptake of green building measures. Ordinarily, building and permit fees are significant barriers to new development projects – green or otherwise – as they are non-trivial and have to be paid upfront. Reducing or waiving these fees if a building meets certain green criteria helps stimulate green building development.

Another effective measure for developers is a reduction or temporary freeze in property taxes tied to the energy performance of buildings. These rewards can be used to cover any additional costs that green-building measures incur, meaning that building green need not cost any more than conventional construction. For example, the Oregon Department of Energy offers energy tax credits to businesses that invest in energy conservation, recycling, renewable energy resources and reductions in transportation related energy use on both retrofit and new construction projects. The Business Energy Tax Credit is 35 per cent of eligible project costs, the increased project cost above industry standard. Since the scheme has been introduced more than 7,400 energy tax credits have been awarded (Oregon Department of Energy 2010). Tax exemptions and reductions are efficient in stimulating initial sales of alternative technologies. Important is that the tax credits are sufficiently high to create a real incentive.

Public benefits charges are a special form of energy tax, whose revenues are invested in efficiency improvements. In Brazil for example, all distribution utilities are required to spend at least 1 per cent of their revenue on energy-efficiency improvements. Governments can also require utilities to adopt a business model based on the delivery of energy service (including efficiency improvements) rather than the delivery of energy per se.

Finally, and across several of the categories above, public-sector financial institutions have an important role to play in addressing credit barriers. Backed by governments they also help local financial institutions to share the risk related to energy-efficiency projects. For example, the Asian Development Bank (ADB) has supported green buildings and other energy efficiency programmes through partial credit-guarantee schemes (UNEP 2009b). The total investments towards new energy-efficient green buildings and building retrofits supported by guaranteed loans is expected to exceed US\$ 150 million by 2012 (ADB 2009).

31. World GBC is a worldwide union of national Green Building Councils: Available at <http://www.worldgbc.org/>

32. SB Alliance is an international organisation that regroups key actors from the property and construction industries, standard-setting organisms and national building research centres: Available at <http://www.sballiance.org/>

## Box 8: Tools to promote the greening of buildings

Carbon credit	As of 2005, large-scale renewable energy projects accounted for 60% of total CDM projects. While the building sector offers theoretically great potentials only around 1% of the certificates have been generated through demand-side energy-efficiency measures (Fenhann and Staun 2010) <sup>1</sup> . Therefore, the potential for green buildings to be eligible for carbon credits needs to be explored further.
White certificates	Used in Australia, France and Italy, these certificates can enable building owners and even residential landlords to trade their emissions allowances (Ries et al. 2009). In principle, the various trading schemes will promote the desired effect, such as the reduction of GHG emissions, at a minimal cost (Bürger and Wiegmann 2007).
Third-party financing arrangements	Energy Service Companies (ESCOs), by engaging in Energy Performance Contracting – sometimes referred to as Energy Savings Performance Contracting – with building owners, develop, install and monitor projects designed to improve energy efficiency. Compensation for an ESCO service and often the initial investment needed are directly linked to the energy savings associated with the project. Hence, the major barrier of upfront cost is addressed by allowing future energy savings to pay for the investment (Bleyle-Androschin and Schinnerl 2008).
Rebates	These can be built into the tax system to give credits to homeowners for adopting specific energy saving measures rather than whole building performance. The Power Saver Program in Austin, Texas currently supports more than 1,000 privately-owned solar power systems as well as around 70 commercial and several dozen municipality-run systems, which in all provide more than 4 megawatts of generation capacity (Austin Energy 2010).
Feebates	This new form of credit incentive is currently being tested and is based on a carbon tax or a tax on the carbon footprint of a building or sale certification fees. The feebate rewards homeowners who maintain energy efficient homes or carry out upgrades prior to sale. They pay less or their fees get waived, rebated or tax credited. In this system, tax revenue is not lost because the feebates pay for themselves as higher fees offset lower fees. The level of feebates can also adjust to higher standards of efficiency and can gear up as more building owners go above minimum requirements.
Green mortgages	Credits based on a home's energy efficiency are factored into the mortgage, allowing individuals to finance energy-efficient improvements in their property (Hendricks et al. 2009).
Equity finance or external capital	This is used for funding high-risk projects whereby project developers sell a majority of their ownership in the project to entities that have sufficient resources to finance the project. The disadvantage is giving up part of the control over the project.
Revolving Funds	Loans can be repaid with the cash-flow arising from energy savings. The repaid loans then finance new energy efficiency projects. For example, in Hungary, the PHARE Energy Efficiency Co-Financing Scheme (EEFS) provides interest-free credit from a Revolving Fund with a total budget of € 5 million for energy-efficiency purposes (EuroACE 2005).

### Capacity support, information and voluntary action

This category of instruments includes voluntary certification and labelling programmes, voluntary and negotiated agreements, public-leadership initiatives, awareness raising and education, as well as detailed billing and disclosure programmes. Examples of their cost-effectiveness are the following (UNEP SBCI 2007b):

■ Voluntary labelling: US\$ 0.01-0.06/kWh (USA);

■ Leadership programmes: US\$ 13.5 billion savings by 2020 (EU) – US\$ 125/tCO<sub>2</sub> (Brazil); and

■ Info and awareness raising initiatives: US\$ 8/tCO<sub>2</sub> for Energy Trust programmes (UK).

International building *labels* are a source of inspiration. Passivhaus and Minergie have succeeded in promoting different combination of measures to achieve national targets and policy objectives for green buildings within the developed world. When applying labels in developing countries, however, they clearly need to adapt to local geographic and cultural conditions.

Appliance efficiency *standards* and labels are also important in greening the building sector (Meyers,

McMahon and Atkinson 2008). Among the oldest and most comprehensive are the US Federal Minimum Efficiency Performance Standards (MEPS) programme, the comparative labelling programme implemented by the European Union (European Parliament and Council Directive 2010/30/EU and the US Energy Star endorsement label programme. An example of voluntary labelling programmes in developing countries is the energy efficiency standards for air conditioning and refrigerators introduced in Thailand.

The public sector, which can include both housing and institutional buildings, is unique in that it can act as an exemplar for environmental targets. *Public leadership programmes* can reduce costs in the public sector and provide demonstration of new technologies that can be followed by the private sector. In Germany, 25 per cent of energy was saved in the public sector over 15 years. In Brazil, where the government agency PROCEL provides funding for retrofits in Government buildings, 140 GWh are saved yearly (UNEP SBCI 2007b).

A number of developed countries are leading the way for green public procurement to drive the green transformation in the building sector. A recent PwC survey of seven European countries concluded that

energy reduction targets had been put in place by at least two-thirds of all those procurement agencies surveyed in each country, with the UK and Germany reaching 100 per cent. The most common requirements were double-glazing and insulation standards. The study further suggests that where green procurement is applied, a 70 per cent reduction in CO<sub>2</sub> emissions per functional unit is achieved while life-cycle costs are reduced by 10 per cent (PricewaterhouseCoopers, Significant and Ecofys 2009).

An example of *billing and disclosure programmes* is the smartcard meter for prepayment of electricity. Similar to information instruments, these can be particularly effective in targeting households. The use of smartcard meters in households have proven their value recently in South Africa, when electricity supply-shortages have caused the government and the power utility to pay closer attention to demand-side management. Moreover, smart metering providing customers with information on a real-time basis may help reducing energy demand by 5-10 per cent.

With respect to *education and training*, it is evident that the green transformation the building sector necessitates large numbers of skilled professionals. While in developed countries, there is already a critical mass of such professionals, many developing countries still lack the necessary expertise in the development and implementation of building codes and standards, standards for appliances, green building design, energy auditing, labelling and certification, and energy efficient operation & management (O&M). CEDEFOP (2010) listed the following new skills required for the building industry:

- Knowledge of new materials, technologies and energy efficiency-adapted technical solutions;
- Cross-cutting knowledge of energy issues;
- Understanding other occupations related to building renovation; and
- Client counselling/advice to meet new market demands.

A Green Skills Checklist prepared for the UK Government (DEFRA, UK and Pro Enviro Ltd 2009) noted the following areas of need for the building sector: building energy management, integration of renewable energy, energy-efficient construction, facilities management (including water and waste management), as well as building energy auditing and carbon rating. Based on its Strategy for Reduction of Energy Consumption in Buildings Denmark is developing a strategic skills development response for the building and construction value chain (CEDEFOP 2010). In Thailand, the Ministry of Energy has launched an initiative to train technicians in energy management, technology and end-use systems in buildings and companies. The Brussels Capital Region has created a Construction

Reference Centre, anticipating possible skills shortages and initiating training programmes to increase the supply of trained labour in the eco-construction industry (Martinez-Fernandez et al. 2010). Courses are offered in, for example, isolation and water proofing, energy efficiency and handling of materials. As part of its Second Green Building Masterplan the Singapore Building and Construction Authority (Singapore BCA 2009) announced a comprehensive training framework aimed at educating around 18,000 green building-design, construction and maintenance professionals over the next 10 years.<sup>33</sup>

### Evaluation of policy instruments

The analysis in UNEP SBCI (2007b) of 80 case studies world-wide conclude that regulatory and control measures are probably the most effective as well as the most cost-effective category, at least in developed countries. Grants and rebates are especially needed in developing countries because the first cost-barrier often completely prevents energy efficiency improvements there. Tax exemptions appeared to be the most effective tool in the category of fiscal instruments. Subsidies, grants and rebates can also achieve high savings, but can be costly to society. It was concluded that financial instruments are typically most effective if they are applied in a package with other instruments, such as labelling combined with a tax exemption.

The results of the UNEP SBCI study as well as of the MURE database<sup>34</sup> appear to contradict general expectations, especially the high effectiveness and cost effectiveness of regulatory instruments compared with economic ones. These findings are probably specific to the building sector, considering which barriers specific policy instruments address. Regulatory and control instruments are particularly effective in addressing two key barriers in the building sector, namely hidden costs (transaction costs) and market failures.

Governments would be well-advised to consider combinations of policy instruments, an approach likely to result in synergistic impacts and higher savings. Appliance standard are, for example, often combined with labelling and rebates to give incentives for investments beyond the minimum level required by the energy-efficiency standard. Also, labelling of energy-efficient products can be critical in enabling financial incentives such as loans, subsidies and tax credits to be more effective. In the USA, mandatory energy-efficiency

33. For further information and case studies please see Second Green Building Masterplan and Inter-Ministerial Committee on Sustainable Development (2009); A lively and liveable Singapore: Strategies for sustainable growth. Ministry of the Environment and Water Resources (MEWR) and Ministry of National Development (MND), Singapore.

34. The MURE (Mesure d'Utilisation Rationnelle de l'Energy) database, developed by European experts, provides online a description and brief assessment of policy measures for energy efficiency in EU member states. Available at <http://www.isisrome.com/mure/>

regulations are coupled with voluntary labels and tax credits for both manufacturers and consumers. This combination eliminates the least efficient products while compensating manufacturers for some of the increased production costs through tax credits and premiums charged for Energy Star designs.

Barriers that are particularly prominent in developing countries are “subsidised, not cost-reflective energy prices, lack of awareness on the importance and the potential of energy efficiency improvements, lack of financing, lack of qualified personnel and insufficient energy service levels” (UNEP SBCI 2007b). Several developing countries have enacted legislation on energy efficiency in buildings. Special enabling factors to support measures for green buildings in developing countries are the need for:

- Getting the energy price right, so that more efficiency investments become profitable;
- Technical assistance and training;
- Demonstration projects and information to build trust;
- Financial assistance or funding mechanisms;
- Regulatory measures, such as mandatory audits, combined with incentives such as subsidies or awards;
- Monitoring and evaluation (requiring baseline data);
- Institutionalisation (e.g. establishing energy agencies independent of utilities); and
- Adaptation to local circumstances, including climate and culture.

Clearly, adjusting the priorities of enabling instruments to their context is critical. In developing countries the first step might introduce non-mandatory standards that act as educational platforms. The next move could include mandatory standards, which exclude less efficient products from the market. Subsidies or rebates that provide an incentive to replace old equipment with new, more efficient products are yet a further possible step. At the same time, public leadership and energy-performance contracting can play a key role in public housing projects. In developed countries mandatory standards and regulatory actions are the way to start, followed by rebates for retrofitting and green mortgages.

An integrated policy framework that combines regulatory instruments, such as standards or mandatory audits in certain buildings, capacity-building, training and information campaigns as well as demonstration projects coupled with (fiscal or other) incentives is most likely to effectively reduce GHG emissions in developing countries. The following policy instruments, for example, can be effectively combined (UNEP SBCI 2007b):

- Standards, labelling and financial incentives;
- Regulatory instruments and information programmes; and
- Public leadership programmes and energy performance contracting (EPC) in the public sector.

In assessing the impact of instruments in developing countries, it is important to note that initiatives to address restricted energy services aim not to reduce energy consumption, but rather to ensure more energy services can be accessed and afforded with the available resources.

## 5 Conclusions

The building sector should be central to any attempt to use resources more efficiently. Buildings consume a large proportion of the global energy supply but opportunities to improve efficiency are huge and the sector has the greatest potential – more than any other covered in this report – to reduce global GHG emissions. Great gains can also be achieved from a broader, more holistic approach to buildings; a life-cycle perspective that covers each stage from the building design and the extraction of resources to construction and usage and through to disuse and eventual demolition and the recycling or disposal of the building materials. The most significant environmental impact of buildings lies in their energy demand over decades or even centuries of use. As a result, the design and use of energy efficient buildings has a key part to play in mitigating climate change and the transformation to a global green economy.

*Whether construction of new or retrofitting existing buildings, they both offer a high GHG reduction potential and environmental benefits at low cost.*

Patterns of energy consumption and emissions, as well as the predicted future trends, vary widely across the developed and developing world. Major regions of the world need to pursue green building strategies that are appropriate to their respective circumstances. For developed countries, which account for most of the existing building stock, the priority is to put in place measures and incentives that will enable large-scale investments in retrofitting programmes. Those will come not only with the benefits of energy savings but also a high potential of net job creation. For developing countries, particularly fast-growing economies that are experiencing a construction boom, the priority is to ensure that new buildings will be green by investing in the most appropriate available technology, whether traditional or high-tech, and design options and avoiding any possible lock-in to an inefficient building stock with long-term consequences.

In both cases, retrofitting and new construction, pay-back periods of investments in energy efficiency are reasonably short and they offer a significant return on investment in the medium- and long-term. On a global scale, aggregated investments in energy efficiency in buildings pay back two fold in energy savings over 20 years. These savings are, in most cases, sufficient to justify investments in greening, beyond the positive externalities associated with mitigating climate change. Greening also brings the opportunity to improve efficiency in use of water, materials and land, and avoid

risks associated with climate change and hazardous substances.

*The process of greening buildings and their subsequent use provides a wide range of direct social benefits, including the improved health, productivity and wellbeing of those who live and work in them and the creation of jobs in construction, maintenance and the supply of energy, water and sanitation.*

The increase in the productivity of employees working in green buildings can yield labour-cost savings that may be higher than energy-cost savings, which are themselves substantial. The construction of new, green buildings, retrofitting and accompanied use of resource-efficient construction materials, products and energy supply and maintenance can provide net jobs gains and decent work. While the construction industry in many countries has a poor image with respect to meeting workers' rights, green building offers an opportunity to use improved training, skills management and inspection to improve the quality of employment.

Improved health and quality-of-life benefits of green buildings are equally significant. In developing communities, where most household energy is used for cooking, more efficient appliances (cleaner stoves) can bring extensive economic benefits in the form of reduced health-related expenditure as a result of less illness, associated productivity gains and time-savings. The benefits of simple measures, such as replacing solid fuels with electricity in informal and low-cost housing, are particularly striking when considering the devastating health impacts of indoor air pollution on women and children.

*Improved regulation and control, adjusting energy prices to internalise external costs and other policy instruments such as tax exemptions and grants are required to overcome persistent barriers such as market failure and non-cost reflective energy prices in particular:*

Despite these opportunities, investment in green buildings is held back owing to assumed cost premiums that are exaggerated and a range of barriers that range from financial constraints to the fragmented structure of the industry. While some barriers relate to hidden costs or benefits and market failure, others relate to behavioral culture, lack of awareness and capacity.

Seeking to address these and create an enabling environment, governments need to take stock and



determine the most appropriate mix of policy instruments, considering regulatory and control mechanisms, economic or market-based instruments, fiscal instruments and incentives, as well as information and voluntary action. Considering in particular the hidden costs and market-failure barriers the building industry faces, analysis of cases world-wide suggests that regulatory and control measures are likely to be most effective and cost-efficient when adequately implemented. This is particularly the case in developed countries.

Regulatory and control instruments can be combined with other instruments for greater impact, considering local realities such as the level of development of the local market and income-level of households involved. Among fiscal instruments, tax exemptions appear to be the most effective, while subsidies, grants and rebates can achieve high energy savings in developing countries by helping organisations or families overcome upfront investment or first-cost barriers. Examples from Brazil and Thailand have shown high cost-benefit ratios in the use of subsidies and grants to support energy efficiency improvements, combined with mandatory audits, awareness raising, training and demonstration to build capacity and trust in the use of new technologies.

A particular challenge in developing countries, at the same time, is doing away with subsidised, non-cost-reflective energy prices.

*Facing global demand for more and better housing and facilities, governments at all levels can lead by example through public procurement and green housing schemes:*

Finally, governments can set a leadership example by using public procurement in the construction and management of their facilities to drive the greening of the building sector. Experience from Mexico and China has shown how energy-efficiency improvement programmes in the public sector can also be boosted by the immediate pressure of high energy prices and energy shortages. Public assets, be they in the form of government buildings, hospitals or schools, hold wide-ranging opportunities of greening measures that result in a more efficient use of resources, reduced GHG emissions, improved productivity and avoided illness resulting from indoor air pollution. In addition, government-supported social housing schemes provide an opportunity to combine socio-economic and environmental gains in designing and building single or multi-family homes.

# References

- ADB. (2009). *Investing in sustainable infrastructure: Improving lives in Asia and the Pacific*. Asian Development Bank, Manila. Available at: <http://www.adb.org/Documents/Reports/Sustainable-Infrastructure/pdf>.
- ADEME. (2008). "Activities related to renewable energy and energy efficiency. Markets, employment and energy stakes 2006-2007. Projections 2012."
- Anderson, J., Iyer, M. and Huang, Y.J. (2004). "Transferred just on paper? Why doesn't the reality of transferring/adapting energy efficiency codes and standards come close to the potential?" *Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings*. USA.
- Anderson, J., Shiers, D. and Steele, K. (2009). *The green guide to specification: an environmental profiling system for building materials and components*. IHS BRE Press; Wiley-Blackwell, UK; USA.
- ASHRAE. (2005). *Handbook of fundamentals*. American Society of Heating Refrigerating and Air-Conditioning Engineers, Atlanta.
- Aumann, D., Hescong, L., Wright, R. and Peet, R. (2004). "Windows and classrooms: Student performance and the indoor environment" *Proceedings of the 2004 ACEEE Summer Study*. 7-1.
- Austin Energy. (2010). "Energy Efficiency." [Online] Available at: <http://www.austinenenergy.com/Energypercent20Efficiency/index.htm>. (Accessed 9 January 2011).
- Baker, N., Spivey, J., and Florance, A. (2008). "Does green pay off?" *Journal of Real Estate Portfolio Management*, 14, 4, 385-400.
- Baker, N. and Steemers, K. (1999). *Energy and environment in architecture: A technical design guide*. E&FN Spon, New York.
- Ball, M. and Wood, A. (1995). "How many jobs does construction expenditure generate?" *Construction Management and Economics*, 13, 4, 307-318.
- Baumert, K., Herzog, T., and Pershing, J. (2005). "Navigating the numbers: Greenhouse gas data and international climate policy." World Resources Institute, Washington, D.C.
- Betts, M. and Farrell, S. (2009). "Global construction 2020: A global forecast for the construction industry over the next decade." *Global Construction Perspectives* and Oxford Economics, London.
- Bhandari, R. and Stadler, I. (2009). "Grid parity analysis of solar photovoltaic systems in Germany using experience curves." *Solar Energy*, 83, 9, 1634-1644.
- Bleil-Androschin, J.W. and Schinnerl, D. (2008). *Comprehensive refurbishment of buildings through energy performance contracting: A guide for building owners and ESCos*. Grazer Energieagentur, Graz.
- Booz Allen Hamilton (2009). "Green jobs study." U.S. Green Building Council, Washington, D.C. Available at: <http://www.usgbc.org/ShowFile.aspx?DocumentID=6435>. [Accessed 10 January 2011].
- Brown, M. and Wolfe, M. (2007). "Energy efficiency in multi-family housing: A profile and analysis." *Energy Programs Consortium*, Washington, D.C.
- Bürger, V. and Wiegmann, K. (2007). "Energieeinsparquote und Weiße Zertifikate. Potenziale und Grenzen einer Quotenregelung als marktorientiertes und budgetunabhängiges Lenkungsinstrument zur verstärkten Durchdringung von nach-frageseitigen." *Energieeinsparmaßnahmen*. Öko Institut, Freiburg/Darmstadt.
- CEDEFOP. (2010). "Skills for green jobs: European synthesis report". European Centre for the Development of Vocational Training. Publications Office of the European Union, Luxembourg.
- Cena, K. and Clark, J.A. (1981). *Bioengineering, thermal physiology and comfort*. Elsevier, Amsterdam; New York.
- Cheng, C. (2010). "A new NAMA framework for dispersed energy end-use sectors." *Energy Policy*, 38, 10, 5614-5624.
- Cheng, C., Pouffary, S., Svenningsen, N. and Callaway, M. (2008). "The Kyoto protocol, the clean development mechanism, and the building and construction sector." A report for the UNEP Sustainable Buildings and Construction Initiative. United Nations Environment Programme, Paris.
- CIBSE. (2004). *Energy efficiency in buildings*. 2nd Edn. Chartered Institution of Building Services Engineers, London.
- DECC. (2010). The Carbon Reduction Commitment Order 2010: Summary of main points. Available at: [http://www.decc.gov.uk/publications/basket.aspx?FilePath=188\\_20090312092018\\_e\\_per cent40per cent40\\_crcdraftordersummary.pdf&filetype=4](http://www.decc.gov.uk/publications/basket.aspx?FilePath=188_20090312092018_e_per cent40per cent40_crcdraftordersummary.pdf&filetype=4).
- DEFRA, UK and Pro Enviro Ltd. (2009). "Skills for a low carbon and resource efficient economy." Available at: <http://skills4lowcarboneconomy.co.uk/Skills-Checklist.aspx>.
- EC. (2008). "Summary of the impact assessment." Accompanying document to the proposal for a recast of the energy performance of buildings directive (2002/091/EC). Commission staff working document, Commission of the European Communities. Available at: <http://eur-lex.europa.eu/SECMonth.do?year=2008&month=11>.
- EIA. (1998). *A look at commercial buildings in 1995: characteristics, energy consumption, and energy expenditures*. Energy Information Administration, Office of Energy Markets and End Use, U.S. Dept. of Energy, Washington, D.C.
- EIA. (2003). "Households, Buildings, Industry & Vehicles end-use energy consumption data & analyses." [Online]. U.S. Energy Information Administration, Independent Statistics and Analysis, U.S. Dept. of Energy, Washington, D.C. Available at: <http://www.eia.doe.gov/emeu/consumption/index.html>. [Accessed 11 January 2011].
- EIA. (2010). "International Energy Outlook - Highlights". U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Dept. of Energy, Washington, D.C. Available at: <http://www.eia.doe.gov/oiaf/ieo/highlights.html>
- Ellis, J. and Kamel, S. (2007). "Overcoming Barriers to Clean Development Mechanism Projects." Organisation for Economic Cooperation and Development and the International Energy Agency, Paris.
- EuroACE. (2005). "Investing in building energy efficiency in the enlarged European Union." Klinckenberg Consultants for European Alliance of Companies for Energy Efficiency in Buildings. Available at: <http://www.euroace.org/MediaPublications/News/tabid/69/currentpage/10/Default.aspx>.
- Euro Heat & Power. (2009). "District heating and cooling. Country by country 2009 survey." Euro Heat & Power, Brussels.
- European Renewable Energy Council (2008). *Renewable energy technology roadmap: 20 per cent by 2020*. Available at: [http://www.erec.org/fileadmin/erec\\_docs/Documents/Publications/Renewable\\_Energy\\_Technology\\_Roadmap.pdf](http://www.erec.org/fileadmin/erec_docs/Documents/Publications/Renewable_Energy_Technology_Roadmap.pdf).
- Ezzati, M. and Kammen, D.M. (2002). "Evaluating the health benefits of transitions in household energy technologies in Kenya." *Energy Policy*, 30, 10, 815-826.
- Fenhann, J. and Staun, F. (2010). "An analysis of key issues in the Clean Development Mechanism based on the UNEP Risoe Clean Development Mechanism pipeline." *Carbon Management*, 1, 1, 65-77.
- Ghisi, E., Gosch, S. and Lamberts, R. (2007). "Electricity end-uses in the residential sector of Brazil." *Energy Policy*, 35, 8, 4107-4120.
- Granade, H.C., Creyts, J., Derkach, A., Farese, P., Nyquist, S., and Ostrowski, K. (2009). "Unlocking energy efficiency in the U.S. economy". McKinsey. Available at: <http://www.mckinsey.com/mgi/publications/>.
- Griffith B., Torcellini P., Long N., Crawley D., and Ryan J. (2006). "Assessment of the technical potential for achieving zero-energy commercial buildings." National Renewable Energy Laboratory. Conference Paper NREL/CP-550-39830, June 2006 Available at: <http://www.nrel.gov/docs/fy06osti/39830.pdf>.
- Hammond, G.P. and Jones, C.I. (2008). "Embodied energy and carbon in construction materials." *Proceedings of the Institution of Civil Engineers-Energy*, 161, 2, 87-98.
- Hawkes, D. (1996). *Environmental tradition: Studies in the architecture of environment*. 1st Edn. E & FN Spon, London; New York.
- Haydock, H. and Arbon, J. (2009). "Study on energy performance of buildings." European Parliament, Policy Department: Economic and Scientific Policy, Brussels.

- Hee-sung, K. (2010). "Seoul hosts carbon emission trade." Korea.net. [Online]. Available at: <http://www.korea.net/detail.do?guid=50220>. (Accessed 9 January 2011).
- Hendricks, B., Goldstein, B., Detchon, R. and Shickman, K. (2009). "Rebuilding America: A national policy framework for investment in energy efficiency retrofits." Center for American Progress and Energy Future Coalition, USA.
- Herzog, T. (1996). *Solar energy in architecture and urban planning*. Prestel, Munich; New York.
- Hitchin, R. (2008). *Can building codes deliver energy efficiency? Defining a best practice approach*. A report for the Royal Institution of Chartered Surveyors by the Building Research Establishment, UK.
- Houser, T. (2009). "The economics of energy efficiency in buildings." Peterson Institute for International Economics, Washington, D.C. Available at: <http://www.piie.com/publications/pb/pb09-17.pdf>.
- Hutton, G., Rehfuess, E., Tediosi, F. and Weiss, S. (2006). "Evaluation of the costs and benefits of household energy and health interventions at global and regional levels." World Health Organization, Geneva.
- IEA. (2001). *Dealing with climate change: Policies and measures in IEA member countries*. International Energy Agency, Paris.
- IEA. (2008). *Energy technology perspectives 2008: Scenarios and strategies to 2050*. International Energy Agency, Paris.
- IEA. (2009a). *World energy outlook 2009*. International Energy Agency, Paris.
- IEA. (2009b). *Key World Energy Statistics*. International Energy Agency, Paris.
- IEA. (2010a). *World energy outlook 2010*. International Energy Agency, Paris.
- IEA. (2010b). *Policy pathways: Energy performance certification of buildings*. International Energy Agency, Paris. Available at: [http://www.iea.org/publications/free\\_new\\_Desc.asp?PUBS\\_ID=2295](http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2295).
- IEA and OECD. (2010). *Energy technology perspectives 2010: scenarios and strategies to 2050*. International Energy Agency and the Organisation for Economic Co-operation and Development, Paris.
- ILO. (2001). "The construction industry in the twenty-first century: Its image, employment prospects and skill requirements." TMIC, ILO, Geneva.
- ILO. (2009). "Empregos Verdes no Brasil: Quantos são, onde estão e como evoluirão nos próximos anos." Organização Internacional do Trabalho, Escritório no Brasil.
- IPCC. (2007). "Climate change 2007: Mitigation of climate change." Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; New York.
- Jones Lang Lasalle and CoreNet (2009). "Results of the 2009 CoreNet Global and Jones Lang LaSalle global survey on corporate real estate and sustainability." Available at: [http://www.joneslanglasalle.com/ResearchLevel1/JLL\\_Perspectives\\_on\\_Sustainability\\_CRE\\_2009\\_Final.pdf](http://www.joneslanglasalle.com/ResearchLevel1/JLL_Perspectives_on_Sustainability_CRE_2009_Final.pdf).
- Kats, G.H. (2003). "Green building costs and financial benefits." Massachusetts Technology Collaborative, USA. Available at: <http://www.nhphps.org/docs/documents/GreenBuildingspaper.pdf>.
- Kats, G. (2010). *Greening our built world: Costs, benefits, and strategies*. Island Press, Washington, D.C. Available at: [http://www.cap-e.com/Capital-E/Resources\\_per cent26\\_Publications.html](http://www.cap-e.com/Capital-E/Resources_per cent26_Publications.html).
- Keivani, R., Tah, J.H.M., Kurul, E., and Abanda, F.H. (2010). "Green jobs creation through sustainable refurbishment in the developing countries. A literature review and analysis conducted for the International Labour Organization (ILO)." International Labour Office, Geneva. Available at: <http://www.ilo.org/public/english/dialogue/sector/papers/construction/wp275.pdf>.
- Laustsen, J. (2008). *Energy efficiency requirements in building codes, energy efficiency policies for new buildings*. International Energy Agency, Paris. Available at: [http://www.iea.org/g8/2008/Building\\_Codes.pdf](http://www.iea.org/g8/2008/Building_Codes.pdf).
- Lawson, B. (1996). "Building materials energy and the environment: Towards ecologically sustainable development." Royal Australian Institute of Architects.
- Loftness, V., Hartkopf, V. and Gurtkein, B. (2003). "Linking energy to health and productivity in the built environment." Available at: [http://www.usgbc.org/Docs/Archive/MediaArchive/207\\_Loftness\\_PA876.pdf](http://www.usgbc.org/Docs/Archive/MediaArchive/207_Loftness_PA876.pdf).
- Luhmann, H.J. (2007). "Smart metering als neue Energieeffizienzquelle." *Energie & Management*, 6.
- Malhotra, M. (2003). "Financing her home, one wall at a time." *Environment and urbanization*, 15, 2, 217.
- Martinez-Fernandez, C., Hinojosa, C. and Miranda, G. (2010). *Greening jobs and skills labour market implications of addressing climate change*. OECD Publishing, Paris.
- McDonough, W. and Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. 1st Ed. North Point Press, New York.
- McGraw Hill (2009). "Green building retrofit and renovation: rapidly expanding market opportunities through existing building." Smart market report. McGraw Hill Construction, Bedford. Available at: [http://construction.ecnext.com/coms2/summary\\_0249-323452\\_ITM\\_analytics](http://construction.ecnext.com/coms2/summary_0249-323452_ITM_analytics).
- McKinsey (2009). "Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve." McKinsey & Company. Available at: <https://solutions.mckinsey.com/ClimateDesk/default.aspx>.
- McKinsey (2010). "Energy efficiency: A compelling global resource." McKinsey & Company. Available at: <http://www.mckinsey.com/client-service/sustainability/>.
- Meyers, S., McMahon, J. and Atkinson, B. (2008). "Realized and projected impacts of U.S. energy efficiency standards for residential and commercial appliances." Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, University of California, Berkeley. Murphy, P. (2009). *The green tragedy: LEED's lost decade*. 1st Ed. Arthur
- Morgan Institute for Community Solutions, Yellow Springs, Ohio.
- Nekhaev, E.V. (2004). "The energy access situation: The nature of the problems ahead." Presented at the World Energy Technologies Summit, Paris, February 10, 2004.
- Nelson, A.J. (2008). "Globalization and global trends in Green real estate investment." RREEF Research. [Online] Available at: <http://www.capitalmarketspartnership.com/> (accessed 5 Jan 2011).
- NHHP. (2007). "National urban housing and habitat policy 2007." Government of India Ministry of Housing & Urban Poverty Alleviation, New Delhi, India. Available at: <http://mhupa.gov.in/policies/owingpa/HousingPolicy2007.pdf>.
- NSF/IUCRC. (2004). "Guidelines for high performance buildings." Available at: <http://cbpd.arc.cmu.edu/ebids/pages/home.aspx>.
- Oregon Department of Energy. (2010). "Business energy tax credits." Oregon Department of Energy – Conservation Division. [Online] Available at: <http://www.oregon.gov/ENERGY/CONS/BUS/BETC.shtml>. (Accessed 9 January 2011).
- Pike Research. (2009). "Energy efficiency retrofits for commercial and public buildings." Pike Research, Cleantech Market Intelligence. Available at: <http://www.pikeresearch.com/research/energy-efficiency-retrofits-for-commercial-and-public-buildings>.
- PricewaterhouseCoopers, Significant and Ecofys. (2009). "Collection of statistical information on green public procurement in the EU. PwC Netherlands." Available at: [http://ec.europa.eu/environment/gpp/pdf/statistical\\_information.pdf](http://ec.europa.eu/environment/gpp/pdf/statistical_information.pdf).
- Ravetz, J. (2008). "State of the stock – What do we know about existing buildings and their future prospects?" *Energy Policy*, 36, 12, 4462-4470.
- Ries, C., Jenkins, J. and Wise, O. (2009). "Improving the energy performance of buildings: Learning from the European Union and Australia." RAND Corporation, Santa Monica CA.
- Roland-Holst, D. (2008). "Energy efficiency, innovation, and job creation in California." University of California, Berkeley.
- Roy, A.U.K., Ahadzi, M., and Saha, S. (2007). "Mass-industrialized housing to combat consistent housing shortage in developing countries: Towards an appropriate system for India." World Congress on Housing. Available at: <http://atiwb.gov.in/U4.pdf>.
- Sára, B. (2001). "Application of life-cycle assessment (LCA) methodology for valorization of building demolition materials and products." Proceedings of SPIE: Environmentally conscious manufacturing. Boston, 382-390. Available at: <http://link.aip.org/link/?PSI/4193/382/1&Agg=doi>.
- Sattler, M.A. (2007). "Habitações de baixo custo mais sustentáveis: A casa alvoreada e o centro experimental de tecnologias habitacionais sustentáveis." Coleção HABITARE / FINEP, volume 8. Associação Nacional de Tecnologia do Ambiente Construído (ANTAC), Porto Alegre.



- Schneider, L. (2007). "Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement." Prepared for the World Wildlife Fund, Berlin.
- Singapore BCA (2009). "2nd green building masterplan". Building and Construction Authority, Singapore.
- de Souza, U. (2000). "Managing workers in production: Overview of labour in the building industry." Translation of a presentation (TG-007), University of Sao Paulo.
- Swim, J., Clayton, S., Doherty, T., Gifford, L.L.C.R., Howard, G., Reser, J., Stern, P., and Weber, E. (2009). "Psychology and global climate change: Addressing a multi-faceted phenomenon and set of challenges." A report by the American Psychological Association's Task Force on the interface between psychology and global climate change. Available at: <http://www.apa.org/science/about/publications/climate-change.pdf>.
- de T'Serclaes, P. (2007). "Financing energy efficient homes: Existing policy responses to financial barriers." International Energy Agency, Paris.
- Thormark, C. (2000). "Environmental analysis of a building with reused building materials." *International Journal of Low Energy and Sustainable Buildings*, 1.
- Thormark, C. (2006). "The effect of material choice on the total energy need and recycling potential of a building." *Building and Environment*, 41, 8, 1019-1026.
- UBA. (2006). "Wie private Haushalte die Umwelt nutzen – höherer Energieeffizienz trotz Effizienzsteigerung." Umweltbundesamt, Germany. Available at: <http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Presse/pk/2006/UGR/UBA-Hintergrundpapier,property=file.pdf>.
- Ulrich, R.S. (1984). "View through a window may influence recovery from surgery." *Science*, 224, 4647, 420.
- UN DESA. (2009). "World Population Prospects: The 2008 revision." United Nations, Department of Economic and Social Affairs, Population Division, New York. Available at: [http://www.un.org/esa/population/publications/wpp2008/wpp2008\\_highlights.pdf](http://www.un.org/esa/population/publications/wpp2008/wpp2008_highlights.pdf).
- UNEP. (2009a). "Global green new deal: An update for the G20 Pittsburgh Summit." United Nations Environment Programme, Pittsburgh. Available at: <http://www.unep.org/greeneconomy/LinkClick.aspx?fileticket=ciH9RD7XHwpercent3d&tabid=1394&language=en-US>.
- UNEP (2009b). "Energy Efficiency in the Finance Sector: A survey on lending activities and policy issues." United Nations Environment Programme, Finance Initiative, Geneva. Available at: [www.unepfi.org/fileadmin/documents/Energy\\_Efficiency.pdf](http://www.unepfi.org/fileadmin/documents/Energy_Efficiency.pdf).
- UNEP, ILO, IOE, ITUC. (2008). "Green Jobs: Towards decent work in a sustainable, low carbon world." United Nations Office at Nairobi (UNON), Nairobi.
- UNEP SBCI. (2007a). *Buildings and climate change: Status, challenges, and opportunities*. United Nations Environment Programme, Sustainable Buildings and Construction Initiative, Paris.
- UNEP SBCI. (2007b). "Assessment of policy instruments for reducing greenhouse gas emissions from buildings." United Nations Environment Programme, Sustainable Buildings and Construction Initiative and the Central European University, Budapest. Available at: [http://www.unep-sbci.org/SBCIResources/Brochures/documents/Assessment\\_of\\_Policy\\_Instruments\\_for\\_Reducing\\_Greenhouse\\_Gas\\_Emissions\\_from\\_Buildings/SBCI\\_CEU\\_Policy\\_Tool\\_Report.pdf](http://www.unep-sbci.org/SBCIResources/Brochures/documents/Assessment_of_Policy_Instruments_for_Reducing_Greenhouse_Gas_Emissions_from_Buildings/SBCI_CEU_Policy_Tool_Report.pdf).
- UNEP SBCI. (2009a). "Common carbon metric for measuring energy use and reporting greenhouse gas emissions from building operations." United Nations Environment Programme, Sustainable Buildings and Climate Initiative, Paris. Available at: <http://www.unep.org/sbci/pdfs/UNEP-SBCI-CarbonMetric.pdf>.
- UNEP SBCI. (2009b). "Greenhouse gas emission baselines and reduction potentials from buildings in Mexico. A discussion document." United Nations Environment Programme Sustainable Buildings and Climate Initiative, Paris. Available at: <http://www.unep.org/sbci/pdfs/SBCI-Mexicoreport.pdf>.
- UNEP SBCI. (2010a). "The 'State of Play' of sustainable buildings in India." United Nations Environment Programme, Sustainable Buildings and Climate Initiative, Paris. Available at: [http://www.unep.org/sbci/pdfs/State\\_of\\_play\\_India.pdf](http://www.unep.org/sbci/pdfs/State_of_play_India.pdf).
- UNEP SBCI. (2010b). "Draft briefing on the sustainable building index." United Nations Environment Programme, Sustainable Buildings and Climate Initiative, Paris. Available at: [http://www.unep.org/sbci/pdfs/SYM2010-UNEP-SBCI\\_SB\\_Index\\_Briefing.pdf](http://www.unep.org/sbci/pdfs/SYM2010-UNEP-SBCI_SB_Index_Briefing.pdf).
- UNEP SBCI and WRI. (2009). "Common carbon metric: Protocol for measuring energy use and reporting greenhouse gas emissions from building operations." United Nations Environment Programme, Sustainable Buildings and Climate Initiative and the World Resources Institute, Paris. Available at: <http://www.unep.org/sbci/pdfs/Common-Carbon-Metric-for-Pilot-Testing-220410.pdf>.
- UNESCO. (2001). Prices of water in various countries 2001. Go to <http://www.unesco.org/water/> and follow the document links.
- UNFCCC. (2007). "Investment and financial flows to address climate change." United Nations Framework Convention on Climate Change, Germany. Available at: [www.unfccc.int](http://www.unfccc.int).
- UN-HABITAT. (2010). *State of the world's cities 2010/2011: Bridging the urban divide*. Earthscan, London and Washington DC. Available at: <http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2917>.
- Ürge-Vorsatz, D., Arena, D., Herrero, S.T., and Butcher, A. (2010). "Employment impacts of a large-scale deep building energy retrofit programme in Hungary." Central European University and the European Climate Foundation, Hungary. Available at: <https://www.ceu.hu/node/6234>.
- Van Wyk, L., Kolev, M., Osburn, L., de Villiers, A., and Kimmie, Z. (2009). "Employment aspects of energy-related improvements in construction in South Africa." Council for Scientific and Industrial Research for the ILO. Joint SECTOR-ENTERPRISE publication. Van Wyk (ed.) (2009). *The green building handbook South Africa. Volume 1*. Green Building Media, South Africa.
- Vine, E. (2005). "An international survey of the energy service company (ESCO) industry." *Energy Policy*, 33, 5, 691-704.
- Waterwise. (2011a). "Toilet flushing (at home)." [online] (Updated 4 Feb 2011) Available at: [http://www.waterwise.org.uk/reducing\\_water\\_wastage\\_in\\_the\\_uk/house\\_and\\_garden/toilet\\_flushing\\_at\\_home.html](http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/house_and_garden/toilet_flushing_at_home.html) (Accessed 4 February 2011).
- Waterwise. (2011b). "Choosing a dishwasher." [online] (Updated 4 Feb 2011) Available at: [http://www.waterwise.org.uk/reducing\\_water\\_wastage\\_in\\_the\\_uk/house\\_and\\_garden/choosing\\_a\\_dishwasher.html](http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/house_and_garden/choosing_a_dishwasher.html) (Accessed 4 February 2011).
- WBCSD. (2007a). "Energy efficiency in buildings: Business realities and opportunities. Summary report." World Business Council for Sustainable Development, Geneva. Available at: <http://www.wbcsd.org/DocRoot/1QaHhV1bw56la9U0Bgrr/EEB-Facts-and-trends.pdf>.
- WBCSD. (2007b). "The cement sustainability initiative." World Business Council for Sustainable Development, Switzerland.
- WBCSD. (2009). "Energy efficiency in buildings: Transforming the market." World Business Council for Sustainable Development, Geneva. Available at: <http://www.wbcsd.org/Plugins/DocSearch/details.asp?DocType=25&ObjectId=MzQyMDQ>.
- WBCSD. (2011). "Energy efficiency in buildings. Business Realities and Opportunities." World Business Council for Sustainable Development, Geneva. Available at: [http://www.wbcsd.org/DocRoot/JNHhGvCWoRIP4p2NaKl/WBCSD\\_EEB\\_final.pdf](http://www.wbcsd.org/DocRoot/JNHhGvCWoRIP4p2NaKl/WBCSD_EEB_final.pdf).
- Wei, M., Patadia, S., and Kammen, D.M. (2010). "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy*, 38, 2, 919-931.
- von Weizsäcker, E., Hargroves, K.C., Smith, M.H., Desha, C., and Stasinopoulos, P. (2009). *Factor five: Transforming the global economy through 80 per cent improvements in resource productivity*. A report to the Club of Rome. Earthscan/James & James, UK; USA.
- Westling, H. (2003). "Performance contracting. Summary report from the IEA DSM Task X within the IEA DSM implementing agreement." International Energy Agency, Paris.
- WHO. (2009). *Global health risks: Mortality and burden of disease attributable to selected major risks*. World Health Organization, Geneva.
- World Bank and Padeco Co. LTD. (2010). "Cities and climate change mitigation: Case study on Tokyo's emissions trading system." World Bank Urban Development Unit. Available at: [http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1226422021646/Tokyo\\_ETS\\_Padeco.pdf](http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1226422021646/Tokyo_ETS_Padeco.pdf).
- Wyon, D.P. (2004). "The effects of indoor air quality on performance and productivity." *Indoor Air*, 14, 7, 92-101.
- Zhou, N., McNeil, M.A., Fridley, D., Lin, J., Price, L., de la Rue du Can, S., Sathaye, J., and Levine, M. (2007). "Energy use in China: Sectoral trends and future outlook." Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division. Available at: <http://china.lbl.gov/publications/energy-use-china-sectoral-trends-and-future-outlook>.







# Transport

Investing in energy and resource efficiency



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## List of acronyms

BAU	Business-as-usual	NAMA	Nationally Appropriate Mitigation Action
BRT	Bus Rapid Transit	NAFTA	North American Free Trade Agreement
CAFE	Corporate Average Fuel Economy	NMT	Non-Motorised Transport
CBD	Central Business District	NO <sub>x</sub>	Nitrogen oxide
CDM	Clean Development Mechanism	ODA	Official Development Assistance
CIF	Climate Investment Fund	OECD	Organisation for Economic Co-operation and Development
CO <sub>2</sub>	Carbon dioxide	PKM	Passenger per kilometres
CTF	Clean Technology Fund	PPP	Public-private partnership
ECMT	European Conference of Ministers of Transport	PT	Public transport
ETS	Emissions Trading Scheme	R&D	Research and development
FIA	Fédération Internationale de l'Automobile	SLoCaT	Partnership on Sustainable Low Carbon Transport
G2	Green Scenario 2	SOX	Sulphur oxide
GEF	Global Environment Facility	SSA	Sub-Saharan Africa
GDP	Gross Domestic Product	T21	Threshold 21 model
GFEI	Global Fuel Economy Initiative	TDM	Transport Development Management
GHG	Greenhouse gas	TKM	Tonnes per kilometre
HC	Hydro Carbon	TNA	Technology Needs Assessment
ICC	International Chamber of Commerce	TPK	Tonnes per kilometre
IEA	International Energy Agency	TRL	Transport Research Laboratory (UK)
IET	International Emissions Trading	UNEP	United Nations Environment Programme
IMO	International Maritime Organization	VKM	Vehicle kilometres
IQ	Intelligence quotient	VOC	Volatile Organic Compounds
ITF	International Transport Forum	VTPI	Victoria Transport Planning Institute
JI	Joint Implementation	WHO	World Health Organization
LDVs	Light-duty vehicles		
Mtoe	Million tonnes of oil equivalent		



# Key messages

**1. Present patterns of transportation – based mainly on petrol and diesel-fuelled motor vehicles – generate serious social, environmental and economic damage and are highly unsustainable.**

At present, transportation consumes more than half of global liquid fossil fuels; emits nearly a quarter of the world's energy-related CO<sub>2</sub>; generates more than 80 per cent of the air pollution in cities in developing countries; results in more than 1.27 million fatal traffic accidents per year; and produces chronic traffic congestion in many of the world's urban areas. These costs to society, which can add up to more than 10 per cent of a country's Gross Domestic Product (GDP), are likely to grow, primarily because of the expected growth of the global vehicle fleet.

**2. Business-as-usual (BAU) will significantly enlarge vehicle fleets and exacerbate their costs to society.**

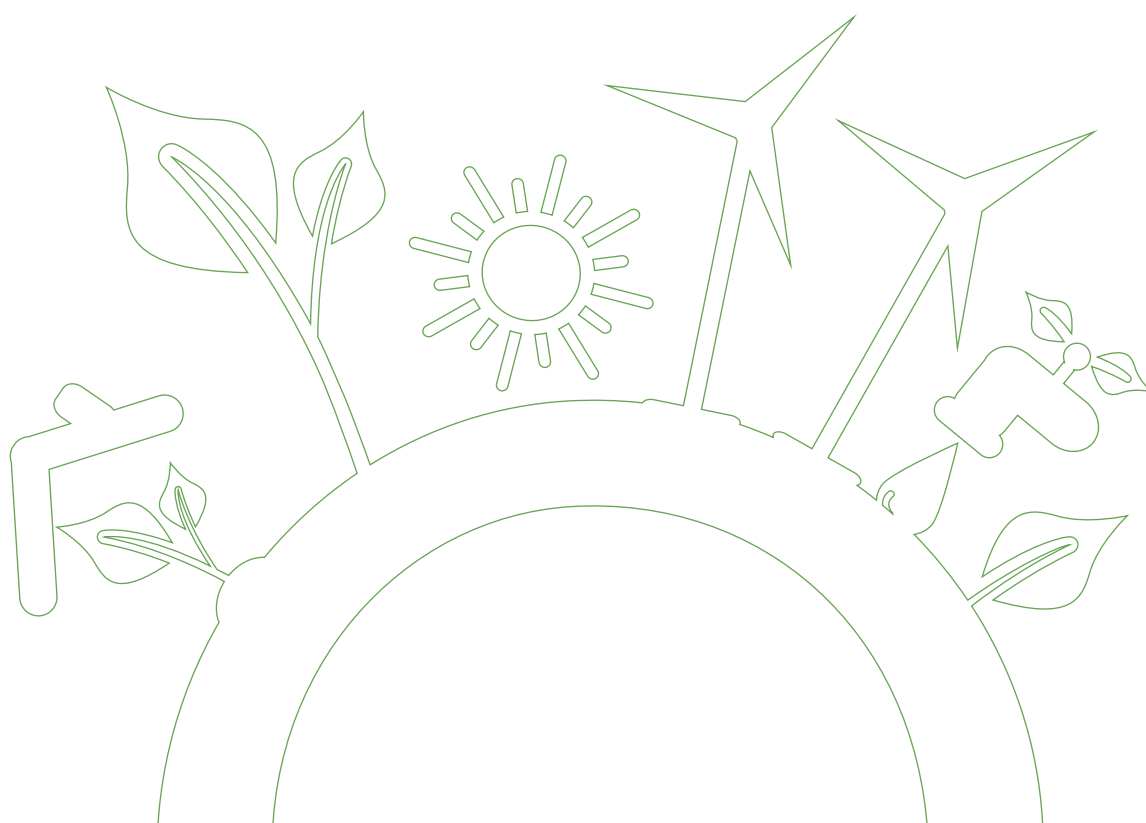
If we continue on a BAU path, the global vehicle fleet is set to increase from around 800 million to between 2 and 3 billion by 2050. Most of this growth will take place in developing countries. Aviation growth is expected to increase exponentially in the coming decades, fuelled largely by income growth in developing countries. Carbon emissions from shipping could also grow by up to 250 per cent.

**3. A three-pronged investment strategy is needed to transform this sector: promote access instead of mobility; shift to less harmful modes of transportation; and improve vehicles towards lower carbon intensity and pollution.**

A fundamental shift in investment patterns is needed, based on the principles of *avoiding* or reducing trips through integrating land use and transport planning and enabling more localised production and consumption. *Shifting* to more environmentally efficient modes such as public and non-motorised transport (for passenger transport) and to rail and water transport (for freight) is recommended. Investment in public transport and infrastructure that promotes walking and cycling generates jobs, improves well-being and can add considerable value to regional and national economies. *Improving* vehicles and fuels is a priority in order to reduce urban air pollution and greenhouse gas emissions (GHG). Green transport policies will also reduce road accidents and alleviate poverty by improving access to markets and other essential facilities.

**4. Investment in public transportation and vehicle efficiency improvements generates exceptional economic returns.** Several scenarios show that a green, low carbon, transport sector can reduce greenhouse gas emissions by 70 per cent without major additional investment. A reallocation of just 0.34 per cent of global GDP in support of public transport infrastructure and efficiency improvements to road vehicles would reduce the expected increase in travel volume of road vehicles by around one-third by 2050. It would diminish the use of oil-based fuel by up to one-third and promote strong and sustainable employment in the sector.

**5. Enabling conditions for green transportation have to be wide-ranging in order to be effective.** Such investments, among other measures, should be enabled via policies, including land use planning to promote compact or mass-transit corridor-based cities; regulation of fuel and vehicles; and the provision of information to aid decisions by consumers and industry. In addition, shifting financing priorities towards public transport and non-motorised transport, coupled with strong economic incentives such as taxes, charges and subsidy reform will also send a strong signal. Finally, developing and widely applying green transport technology; as well as setting up and building the capacity of institutions to foster greener transport will help ensure close cooperation with other key sectors.



# 1 Introduction

Transport is central to the lives of citizens across the world, yet the current patterns of transport, dictated mainly by fossil-fuel driven motor vehicles, generate a range of environmental, social and economic costs. It is estimated, for example, that transport is responsible for nearly a quarter of global energy-related carbon dioxide (CO<sub>2</sub>).

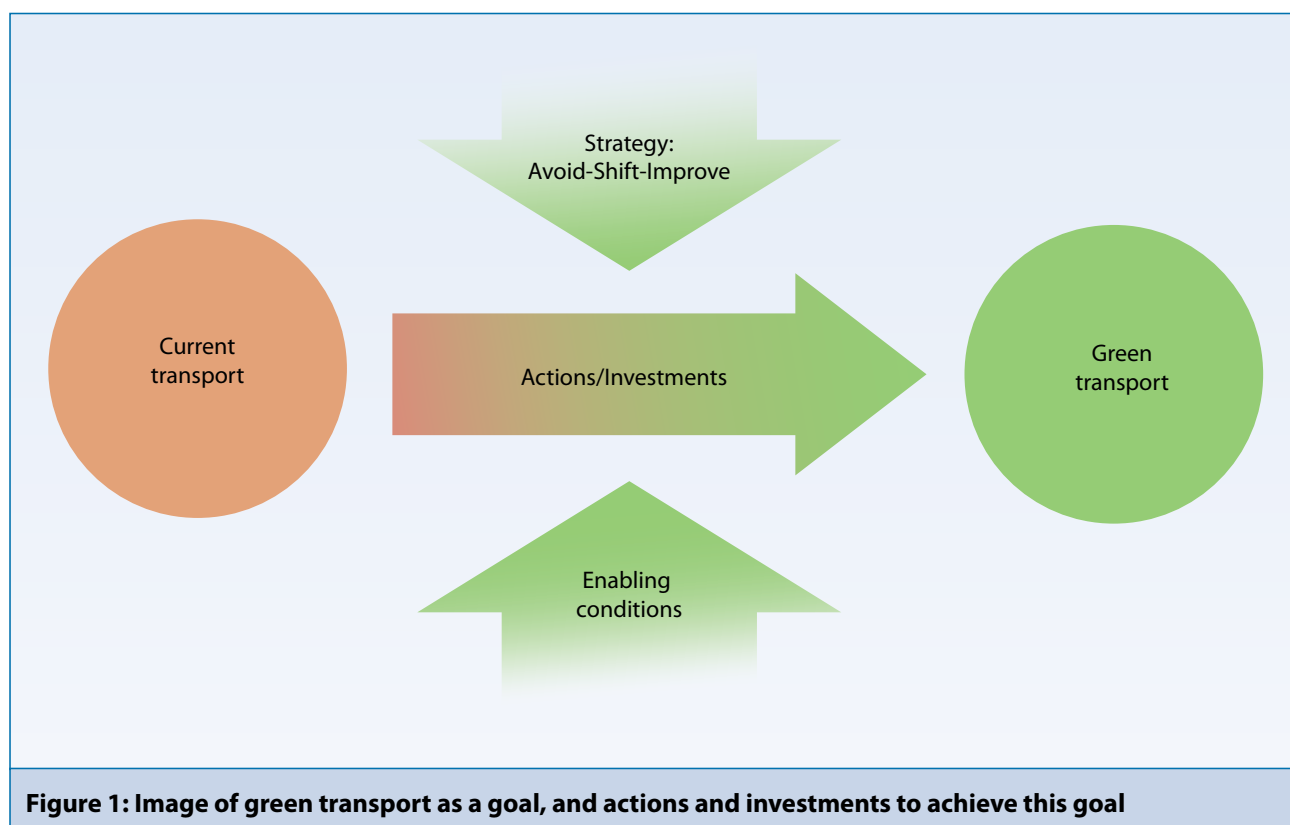
There is a growing consensus on the need for more sustainable patterns of transport activity but investment patterns are still heavily skewed towards supporting the “motorisation” model of development. The recent economic recession has led to various stimulus packages that focus (with notable exceptions) on preserving current industries and forms of transport such as car manufacturing and road building.

This chapter examines the role of transport in a green economy and makes a case for ensuring future investment in the sector is increasingly green. It highlights a strategy of *avoiding* or reducing trips, *shifting* to more environmentally-friendly modes of transport and *improving* the efficiency of all modes of transport. It explores the challenges and opportunities posed by shifting to a greener transport system and examines the various options for conditions that can enable actions and investments for the development

of sustainable transport.<sup>1</sup> The analysis encompasses all modes of freight and passenger transport, with an emphasis on land transport, and it takes into account the varying circumstances of developed and developing countries, regional differences and rural-urban disparities.

Given the pivotal role of transport in the global economy, much of the analysis of the potential for greening the sector is interwoven with other chapters, notably cities, energy, manufacturing and tourism. The chapter was compiled through extensive collaboration with experts from around the world, whose background papers are available in the accompanying Full Technical Report.

1. Green transport is hereby defined as one that supports **environmental** sustainability through e.g. the protection of the global climate, ecosystems, public health and natural resources. It also supports the other pillars of sustainable development, namely **economic** (affordable, fair and efficient transport that supports a sustainable competitive economy as well as balanced regional development and the creation of decent jobs) and **social** (e.g. allowing the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promoting poverty reduction and equity within and between successive generations). This definition was developed through extensive discussions with transport experts including those at UN agencies and was based on a review of existing and well-acknowledged definitions such as European Conference of Ministers of Transport (2004).



**Figure 1: Image of green transport as a goal, and actions and investments to achieve this goal**

## 2 Challenges and opportunities in the transport sector

### 2.1 Challenges

#### Unsustainable trends

The challenges for the transport sector in becoming green are made obvious by observing current trends, whereby:

- Overall demand for transport activity (for both passenger and freight) is growing rapidly, and it is predicted to roughly double between 2005 and 2050 (IEA 2009b);

- Transport activity is increasingly motorised (private cars for passenger transport and lorries for freight, almost all of which are propelled by internal combustion engines);

- The global vehicle fleet is set to multiply three or four-fold in the next few decades, with most of this growth set to occur in developing countries. In 2050, two-thirds of the global vehicle fleet is expected to be in non-OECD countries; and

- Technological improvements such as fuel-efficient vehicles and alternative power sources have not been rapid enough to offset the impacts of this growth.

These trends translate directly into various costs for the environment, society and economy including:

- Energy consumption and greenhouse gas emissions (GHG);

- Congestion (and associated losses in productivity of urban areas);

- Resource depletion and land grab;

- Degradation of human health (through air pollution, noise, vibration, etc);

- Reduction in human security (through traffic accidents);

- Reduction of accessibility and severance of communities; and

- Loss of biodiversity.

It should be acknowledged that such costs vary significantly between regions, and that priorities may differ between regions and by urban and/or non-urban area.

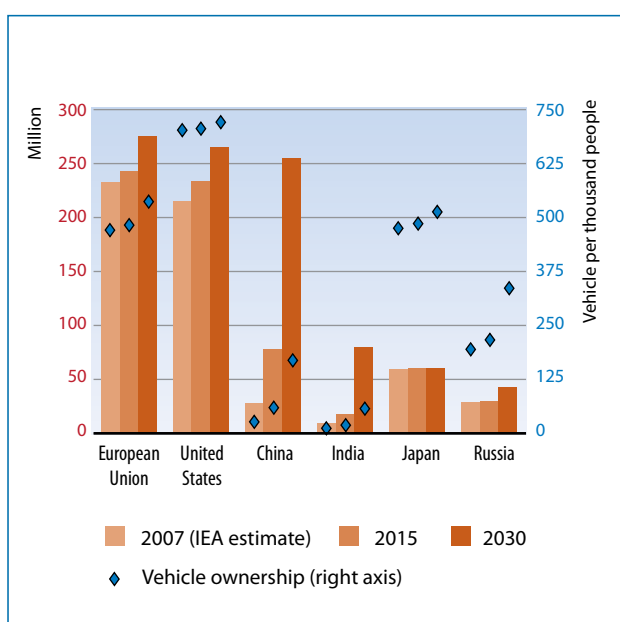
#### Fuel and natural resources

The transport sector's impact on natural resources is wide-ranging, including through manufacturing of vehicles and/or rolling stock (e.g. metals and plastic) and the construction of infrastructure<sup>2</sup> (e.g. concrete and steel). Fossil fuels, engine oil, rubber and other consumable material (including biofuels, which in certain circumstances may deplete farmland for food production) are consumed through the operation and maintenance of vehicles.

Transport consumes more than half of global liquid fossil fuels (IEA 2008) and it is expected to account for 97 per cent of the increase in the world's primary oil use between 2007 and 2030.

#### Greenhouse gases

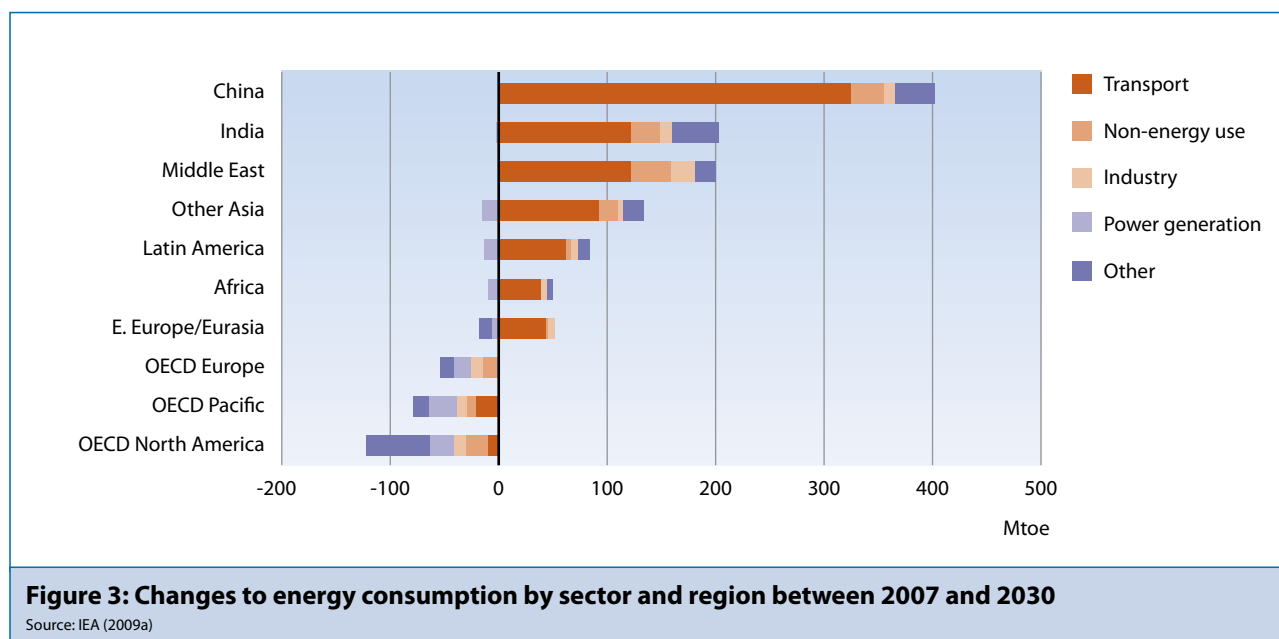
The transport sector's consumption of fossil fuels translates into around a quarter of global energy-related



**Figure 2: Passenger light-duty vehicle fleet and ownership rates in key regions**

Source: IEA (2009a)

2. Infrastructure is not limited to roads, bridges and railways, but also includes supporting infrastructure such as parking facilities, fuelling stations, etc.



CO<sub>2</sub> emissions<sup>3</sup>, which is projected to increase by 1.7 per cent a year from 2004 to 2030.<sup>4</sup> Land transport accounts for roughly 73 per cent of the sector's total CO<sub>2</sub> emissions, followed by aviation (11 per cent) and shipping (9 per cent). Passenger transport accounts for the lion's share of overall emissions, with freight transport – predominantly road-based trucks – comprising 27 per cent of all transport energy use (and therefore emissions). More

than 80 per cent of the predicted growth in transport emissions is expected to come from road transport in developing countries (IEA 2009b).

Moreover, it is estimated that around 15 per cent of the total CO<sub>2</sub> emissions generated from the car are a result of manufacturing and disposal, when a full life-cycle analysis is conducted (King 2007).

3. OECD (2005) CO<sub>2</sub> Emissions from Combustion 1971–2003.

4. IEA (2006) World Energy Outlook 2006, Available at <http://www.worldenergyoutlook.org/2006.asp>

## Box 1: Externalities

Economic efficiency requires prices of goods or activities to match their social marginal cost including all external costs. Prices for transport services need to include costs imposed on society through congestion, accidents, infrastructure wear and tear, air pollution, noise and climate change so that choices made by the users of transport will take into account these costs (World Bank 2001; Button 1993).

Congestion, accident and pollution externalities make up a significant and increasing cost to the economy, amounting in some cases to over 10 per cent of national or regional Gross Domestic Product (GDP). A recent study by Creutzig and He (2009) estimates that in Beijing, China, the social costs induced by motorised transportation are equivalent to between 7.5 per cent and 15 per cent of the city's GDP.

## Pollution and health

Transport-related pollution, noise and vibration can pose serious threats to human health and wellbeing.<sup>5</sup> Local air pollution is caused by exhaust emissions produced by traffic, mostly in the form of Sulphur Oxides (SO<sub>x</sub>), Nitrogen Oxides (NO<sub>x</sub>), Carbon Monoxide (CO), Hydro Carbon (HC), Volatile Organic Compounds (VOC), Toxic Metals (TM), Lead Particles<sup>6</sup> and Particulate Matter (PM) – including Black Carbon.<sup>7</sup> These emissions represent a large proportion of pollutants, especially in developing cities.

Such air pollutants are a cause of cardiovascular/pulmonary and respiratory disease. For example, exposure to lead can cause increased blood pressure,

5. The UNECE's Transport, Health and Environment Pan-European Programme (PEP) has published guidelines for improved cooperation on sustainable transport among various sectors (see UNECE 2009). A system of monitoring and reporting is being instituted to assess the extent to which Member States are effectively implementing the mechanisms agreed, and to measure progress against the priority goals of the Amsterdam Declaration, in particular Amsterdam Goal 1: "To contribute to sustainable economic development and stimulate job creation through investment in environment and health-friendly transport."

6. Although almost all countries have now banned leaded gasoline, there are still seven countries in which action is still needed.

7. Black carbon is "the solid fraction of PM<sub>2.5</sub> that strongly absorbs light and converts that energy to heat" (ICCT 2009). Black carbon not only affects public health, but also contributes to climate change. Actions are needed to both reduce CO<sub>2</sub> and black carbon. Available at: [http://www.theicct.org/pubs/BCsummary\\_dec09.pdf](http://www.theicct.org/pubs/BCsummary_dec09.pdf).



Region*	GNP, 1997 (US\$ billion)	Estimated annual crash costs	
		As percentage of GNP	Costs (US\$ billion)
Africa	370	1	3.7
Asia	2,454	1	24.5
Latin America and Caribbean	1,890	1	18.9
Middle East	495	1.5	7.4
Central and Eastern Europe	659	1.5	9.9
Subtotal	5,615		64.5
Highly motorised countries	22,665	2	453.3
Total			517.8

GNP: Gross National Product

\* Data are displayed according to regional classification of the Transport Research Laboratory Ltd, United Kingdom

**Table 1: Accident costs from various world regions**

Source: Jacobs et al. (2000)

liver and kidney damage, impaired fertility, comas, convulsions, and even death. Children are particularly vulnerable; they can suffer from reductions in IQ and attention span, learning disabilities, hyperactivity, impaired growth and hearing loss (Rapuano et al. 1997). Hatfield et al. (2010) estimate that the removal of lead from vehicle fuels has resulted in more than 1 million avoided premature deaths per year with annual financial benefits over US\$ 2.4 trillion.

Sánchez-Triana et al. (2007) note that for Colombia, the health cost of urban air pollution was roughly 0.8 per cent of the nation's GDP, amounting to 1,500 billion pesos (US\$ 698 million).<sup>8</sup> Noise pollution generated by transport can be detrimental to health and well-being, particularly if it contributes to sleep disturbance, which can lead to increased blood pressure and heart attacks (WHO 2009b). Research by

Lambert (2002) and Martínez (2005) indicate that the economic cost of noise can reach nearly 0.5 per cent of GDP in the European Union.

### Human security and accidents

The latest report from the World Health Organization (WHO 2009a) confirms that road accidents remain a serious public health issue. Every year more than 1.27 million people die in road accidents, of which 91 per cent occur in low and middle income countries. About half of those who die in road accidents worldwide are pedestrians, cyclists and motorcyclists, for whom infrastructure provision is often neglected. In Europe, traffic accidents are a major cause of fatalities for young people, particularly men aged between 15 and 25 (WHO 2008).

It is estimated that the cost of traffic accidents amounts to US\$ 518 billion, and represents between 1 per cent and 1.5 per cent of GDP in low-and middle-income

8. Calculated based on 2150 Colombian Pesos to US\$ 1.

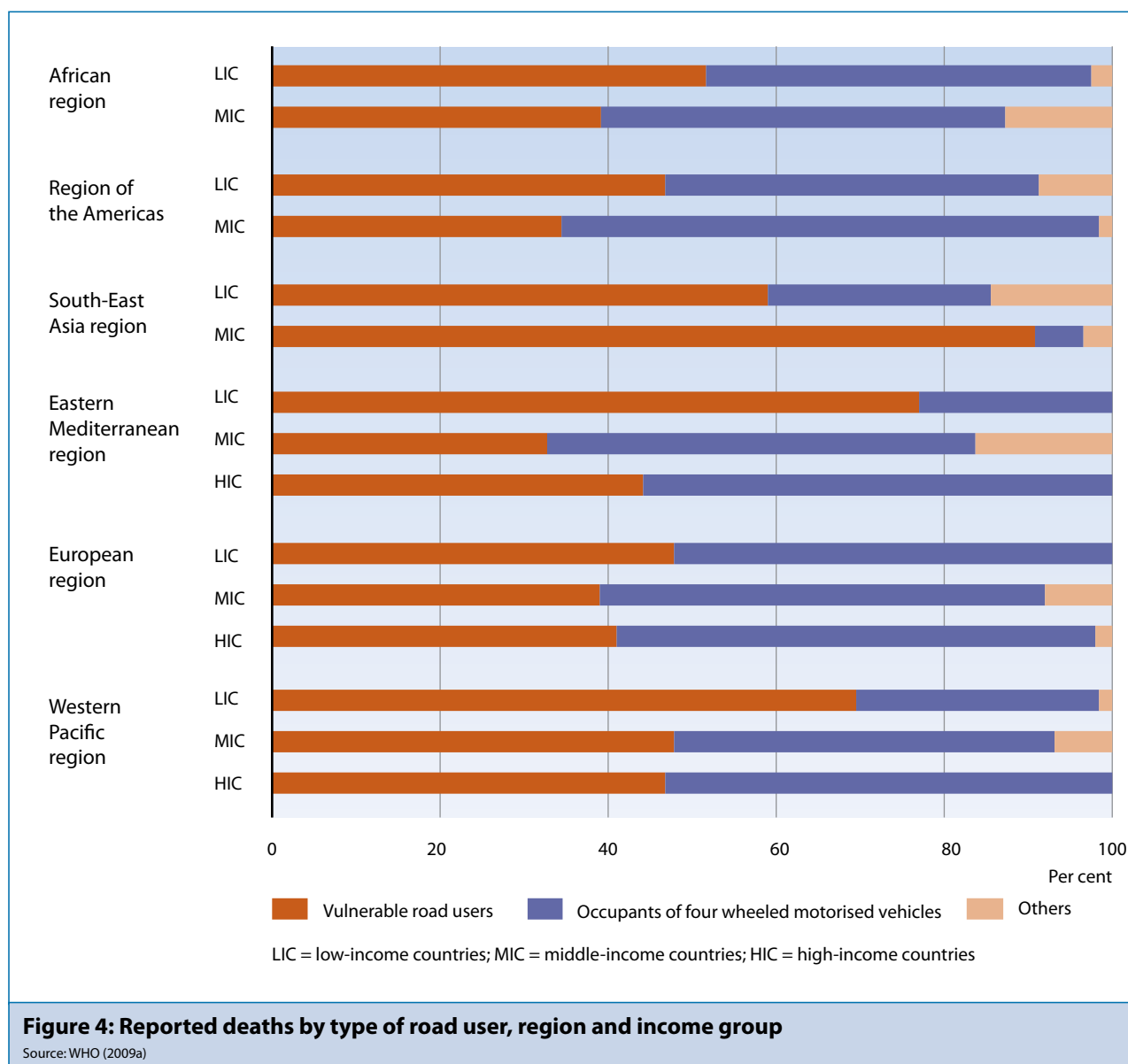
## Box 2: Maritime and aviation emissions

Road transport accounts for the majority of GHG emissions and their predicted growth, but those from maritime and aviation transport are increasing at a very rapid rate.

For maritime transport, developments in world trade are increasing while both the volume and distance of goods are being shipped at a pace that exceeds growth in world GDP. International Maritime Organization (2009) predicts that by 2050,

in the absence of additional policies, emissions from ships may grow between 150 per cent and 250 per cent (compared with 2007).

Despite a temporary slowdown in demand owing to the economic recession, the fundamental growth in the aviation sector remains strong. Aviation emissions are projected to increase exponentially in the next few decades, fuelled by income growth and reductions in the price of air travel.



### Box 3: Benefits of cleaner fuels in sub-Saharan Africa

A recent modelling study by Inner City Fund International for the World Bank and the African Refiners Association looked at the costs and benefits of investing in refineries in sub-Saharan Africa (SSA) to improve the quality of their produced fuels. It found that by reducing the sulphur content of fuels used for transport, a significant amount of health costs could be saved (US\$ 640 million per year in West SSA, US\$ 340 million per year in East SSA). These benefits were amplified by many-fold when coupled with policies to improve emission controls, particularly for motorcycles.

Source: ICF International (2009)

countries and 2 per cent of GDP in high-income countries, as shown in Table 1 (Jacobs et al. 2000). For example, reducing accidents requires a systematic approach incorporating elements of better infrastructure, vehicle inspection and education to control speed and alcohol consumption.

#### Congestion

Congestion is caused when the volume of traffic reaches the capacity of infrastructure. It is particularly common in urban areas, where it can severely limit the positive effects of agglomeration (Cities Chapter). Travel times for public transport users, as well as pedestrians and cyclists, frequently increase if dedicated infrastructure is not provided. Congestion also increases fuel consumption and the level of pollution, as fuel is still consumed whilst cars are stationary.

According to Texas Transport Institute, congestion costs are increasing. Congestion costs in 439 urban areas of the United States were estimated at US\$ 24 billion

Strategy	Developed Countries	Developing Countries
<b>Avoid</b>	Reduce vehicle kilometres (VKM) through Transport Demand Management (TDM), land use planning, localised production, and shorter supply chains.	Avoid unnecessary generation of VKM through land use and transport planning.
<b>Shift</b>	Shift from private vehicles to Non-Motorised Transport (NMT) and Public Transport (PT) and from aviation to rail/PT. Transfer freight from road to rail and water transport.	Enable conditions for the lowest-emitting modes (both freight and passenger). Prevent shift from NMT and PT to private vehicles by ensuring that attractive alternatives to private vehicles exist.
<b>Improve</b>	Improve existing vehicles. Down-scale vehicle engine size. Increase penetration of electric vehicles and carbon-neutral liquid fuels. Electrify rail (for both freight and passengers).	Ensure future vehicles/fuels are cleaner, encouraging small efficient cars. Design innovations for traditional NMT such as cycle rickshaws.

**Table 2: Avoid, Shift and Improve strategy**

Source: Dalkmann (2009)

in 1982, US\$ 85 billion in 2000, and US\$ 115 billion in 2009. Furthermore, congestion in the US cost 3.9 billion gallons of wasted fuel and 4.8 billion hours of extra time. According to Organisation for Economic Co-operation and Development (2009), congestion in Toronto, Canada costs the city around US\$ 3.3 billion Canadian dollars a year in productivity (1.2 per cent of Toronto's GDP), while in the UK the estimated cost of time lost in traffic is £ 20 billion a year, or 1.2 per cent of GDP (The Telegraph Business Club et al. 2009). In developing countries, a lack of traffic data often makes it difficult to estimate the loss of productivity. Data are available for Lima, Peru: people living within the city are estimated to lose an average of four hours in daily travel, which leads to a loss of approximately US\$ 6.2 billion, or around 10 per cent of GDP every year (UNESCAP et al. 2010). The traditional approach to tackling congestion – providing more road capacity – has often been counter-effective, as the extra capacity induces further demand for traffic activity (SACTRA 1997).

### Accessibility and severance

Traffic-filled roads can become physical and psychological barriers that can sever communities and divide entire cities (Cities Chapter). There are various ways in which accessibility and severance can be quantified and monetised. Although values are highly context-dependent and differ greatly by region, Sælensminde (2002) in VTPI (2007) notes an extra cost of US\$ 0.54-0.62 per mile of vehicle activity shifted from non-motorised transport to the car. Transport systems dominated by motor vehicles have been shown to hinder access to jobs, markets and essential facilities, particularly for the poorest and most vulnerable members of society.

### Land use and loss of biodiversity

Roads, railways, airports, harbours and other transport infrastructure can have a severe impact on the natural environment, from the removal of vegetation during construction or the subsequent fragmentation of habitats (CEU 2002; Kaczynska 2009). Fragmentation, without proper ecological infrastructure planning can severely disturb wildlife and reduce biodiversity.

## 2.2 Opportunities

### Leapfrogging towards green transport

Responding to these challenges will require a paradigm shift in the way the transport sector develops in the coming decades. Action is required in all countries, but opportunities are greatest for developing countries, where future patterns of transport can be shaped by the investment and planning decisions made today. Investing in green transport will enable such countries to leapfrog towards a sustainable path, rather than reproducing the mistakes made by industrialised countries (Dalkmann 2009).

### Avoid, Shift and Improve strategy

Making a decisive shift to green transport arguably requires a holistic strategy that combines the following three elements:<sup>9</sup>

1. *Avoiding* or reducing the number of journeys taken.

This can be achieved by integrating land use and transport planning; designing denser, more compact settlements; harnessing telecommunication technologies such as teleconferencing and localising production and consumption.<sup>10</sup> Demand for freight transport can be reduced by localising production and consumption and by optimising logistics to reduce empty runs and ensure a high load factor.

2. *Shifting* to more environmentally efficient forms of transport.

9. For further information, see Dalkmann and Brannigan in GTZ (2007), and the Common Policy Framework on Transport and Climate Change, which represents an increasing level of consensus amongst transport experts and policy makers on this approach. Available at: <http://www.sutp.org/slocat/bellagio-process/common-policy-framework-cpf-on-transport-and-climate-change-in-developing-countries/> The combination of the above three strategies will ensure transformation of both behaviour and technology.

10. Such technologies may not necessarily reduce the demand for travel activity by itself, and need to be combined with measures to reduce incentives to travel by private modes, such as road user charging, parking charges, vehicle tax and fuel tax.

This involves promoting public transport as well as walking and cycling, which usually requires substantial investment in infrastructure. For public transport to rival the private car it needs to be frequent, reliable, affordable and comfortable. Railways and waterways are generally greener methods of transporting freight, and shifting to them frees up road space.

3. *Improving* vehicle and fuel technology to reduce adverse environmental effects such as pollution and resource depletion.

Enhancing the fuel economy of conventional engines; reducing the weight of vehicles and developing alternatives such as electric and hybrid vehicles, biofuels, and hydrogen fuel technologies are all examples of this strategy.<sup>11</sup> Further efficiency gains can be achieved through an improvement in the occupancy rate of vehicles, or through better driving (eco-driving).

Given that transport systems vary greatly around the world, it is important that the above three strategies are applied in ways which fully consider the context and main problems facing each region. Many developing countries are heavily reliant upon non-motorised

transport and therefore present opportunities for creating more sustainable transport systems than those in developed nations (Table 2).

Enacting the Avoid, Shift and Improve strategy requires adequate investment in the research, development, production and operation/management of:

■ *Infrastructure* such as tracks for buses and rail, pavements and cycle routes and park-and-ride facilities;<sup>12</sup>

■ *Greener vehicles and transport modes* (including bicycles, public transport vehicles and low emission vehicles, utilising technologies listed in section 5.3);

■ *Cleaner fuels*;

■ *Telecommunication technology* to substitute conventional transport, e.g. telework/ teleconferencing; and

■ *Technologies* to enact green transport, e.g. GPS systems, Intelligent Transport Systems, green logistics, etc.

The above would need to be supported by appropriate enabling conditions, which are explored in Section 5.

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11. It is important that the generation of electricity, production of hydrogen and biofuels are all conducted in a sustainable manner.

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12. It is vital that such infrastructure promote connectivity between modes, so that journeys are made seamless.

### 3 Transport in a green economy

This section examines how a green transport sector can lead to green economic growth, create jobs and reduce poverty.

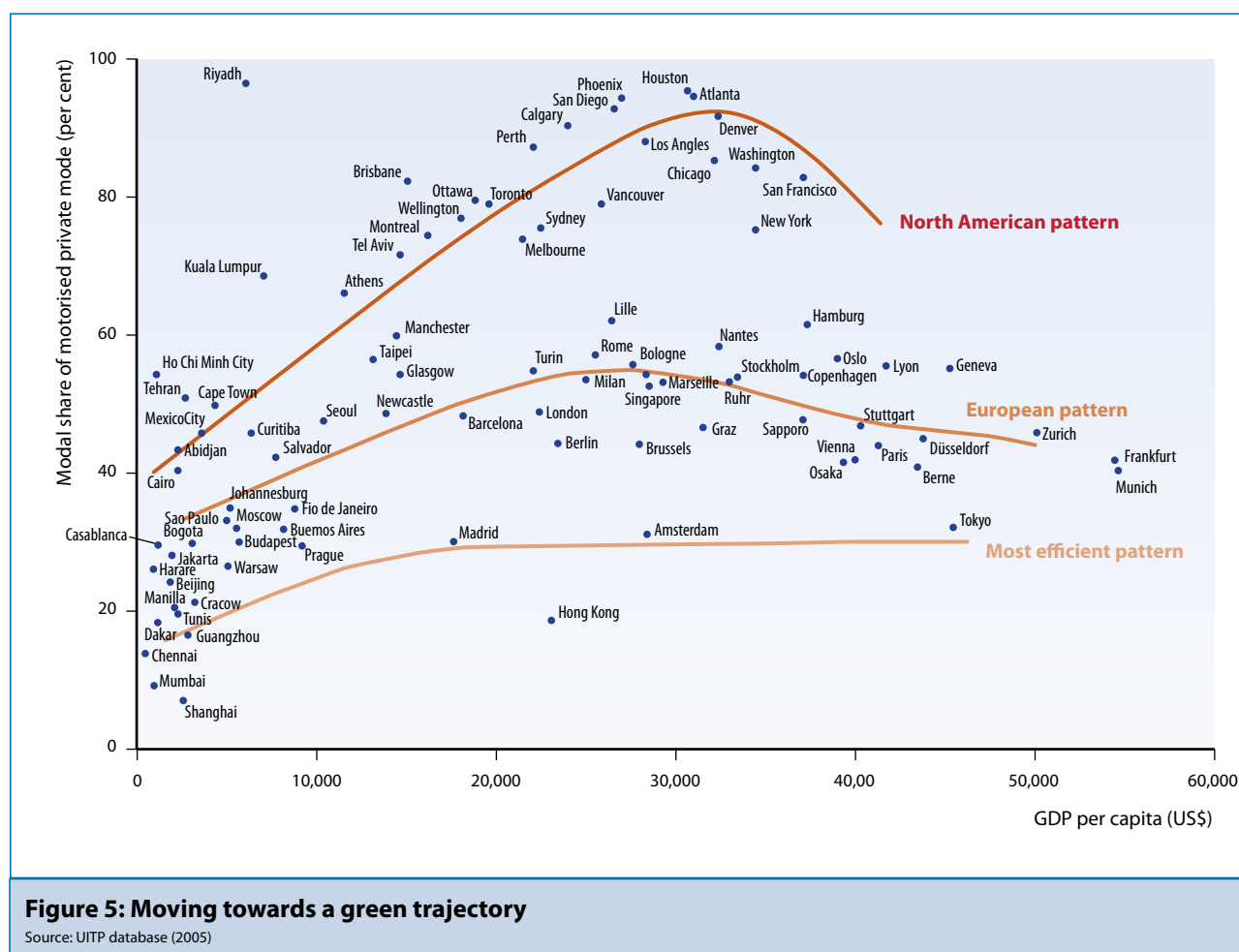
#### 3.1 Supporting green growth

Investment in transport is often justified on the grounds that the movement of goods, services and workers is the vital fuel of the economic engine. Freight transport volumes have traditionally been thought to strongly correlate with economic growth on the supply side and passenger car use to be driven by economic growth on the demand side. There is evidence, however, to suggest that high levels of GDP can be accompanied by transportation systems that rely less on the private car, as may be seen in Figure 5.

This figure shows that cities and regions can significantly decouple car use – and the associated environmental pressures – from economic growth. In a green economy, mobility needs would be reduced through better city

design and planning and impacts would be decoupled from growth through providing high quality, low carbon transport, especially through public transport, NMT infrastructure and cleaner, more efficient vehicles. For individuals, the lower levels of congestion and reduced travel time would leave more time for productive activities, especially if there is access to more frequent, reliable and affordable public transport services. By reducing fuel use and transport time, companies can be more competitive and profitable. McKinnon (2008) and UNEP (2008c) show that measures designed to improve the efficiency of freight transport reduce operational costs in addition to delivering carbon savings.

Of the various channels through which investment can flow into green transport, investment in infrastructure offers the greatest potential for economic growth by encouraging government investment and stimulating new business opportunities. Investment in green transport technology is also likely to benefit the overall economy, particularly through its potential to stimulate government investment (see Table 3).





### 3.2 Creating jobs

Transport is fundamental to the functioning of economies and it is also a key sector in its own right in terms of generating employment, from manufacturing vehicles to refining fuels, managing transport services and developing and maintaining infrastructure.<sup>13</sup>

Under a green economy, transport-sector jobs would increasingly be those that are generated through investment in green transport infrastructure and vehicles, alternative fuels and telecommunication and other technologies (see section 2.2).

Empirical studies are scarce, but several studies suggest a strong link between green jobs and the transport sector. Based on US figures, the Economic Development Research Group (2009) and the Surface Transportation Policy Project (2004) suggest that US\$ 1 billion spent on public transport generates around 36,000 jobs (averaging between operations and capital projects<sup>14</sup>), which is 9 per cent and 19 per cent higher than the job-creation potential of road maintenance or new road projects

13. Furthermore, by providing the physical link between jobs and workers, transport contributes to employment.

14. The methodology employed by the Economic Development Research Group includes direct effects (public transportation manufacturing / construction and operations jobs), indirect effects (jobs at suppliers of parts and services) and induced jobs (jobs supported by workers re-spending their wages). See [http://www.apta.com/gap/policyresearch/Documents/jobs\\_impact.pdf](http://www.apta.com/gap/policyresearch/Documents/jobs_impact.pdf)

#### Box 4: Re-examining the employment generating effects of aviation

It is often claimed that aviation is vital for the economy, because it generates jobs both directly and indirectly; the latter through the facilitation of tourism and business (OEF 2006). This is often given as a key reason to exempt aviation from fuel taxes and other levies, which not only distorts competition between modes, but leaves aviation externalities unchecked. Sewill et al. (2005) argue that the economic case for investing in aviation is often overstated, if not weak, owing to the large amounts of externalities the sector produces. He suggests that alternative forms of employment can be generated through taxing high-polluting industries such as aviation, and using the revenue to promote other sectors. As an example, the EU in its Emissions Trading Scheme should consider the use of revenue from aviation credits (EC 2011) for climate mitigation actions in developing countries, which could also create new forms of green jobs.

respectively, with the same amount of resources spent. Chmelynski (2008) suggests that in the US, each US\$ million block of consumer spending that is shifted from vehicle fuels to public transport generates 18.5 jobs.<sup>15</sup>

Furthermore, a study by Weisbrod and Reno (2009) of 13 public transport investments in Europe suggests that a unit of investment in public transport would yield between 2 and 2.5 times this value to the regional economy.

UNEP (2008a) estimates that roughly 250,000 jobs in the car industry are targeted at relatively green cars and their components.<sup>16</sup>

### 3.3 Supporting equity and poverty reduction

Current transport systems, built primarily for private motor vehicles are, by nature, inequitable and impede efforts to reduce poverty by continuing the mobility

15. Local employment potential depends heavily on the local context, for example, how much of the good/service is provided domestically (versus imported). The figures are meant to be indicative.

16. Such figures depend heavily on the definition of green jobs, as well as the assumptions regarding the penetration rate of green vehicles. Further work is required to estimate a more accurate set of figures.

Expense category	Value added 2006 dollars	Employment FTEs	Compensation 2006 dollars
Auto fuel	1,139,110	12.8	516,438
Other vehicle expenses	1,088,845	13.7	600,082
Household bundles			
<i>Including auto expenses</i>	1,278,440	17.0	625,533
<i>Redistributed auto expenses</i>	1,292,362	17.3	627,465
Public transit	1,815,823	31.3	1,591,993

**Table 3: Economic impacts per US\$ 1 million expenditures**

Source: Chmelynski (2008)

#### Box 5: Green transport as a business

There are many revenue-generating opportunities for the private sector to support or complement sustainable transportation systems and operations. These may take the form of public-private partnerships, concession contracts between a public agency and private entity, or a for-profit business providing a service or product directly to users. Table 4 lists such businesses in the context of the Avoid, Shift and Improve strategy for sustainable transport.

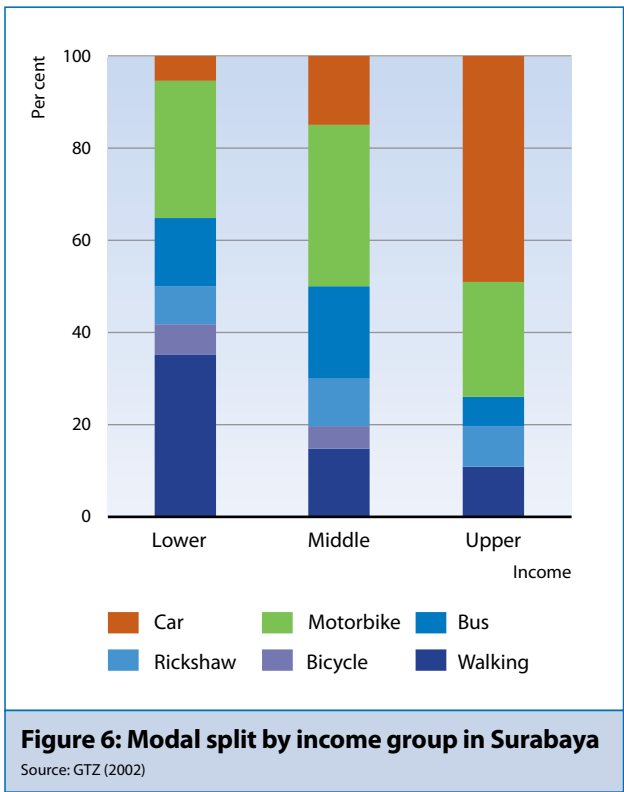
Avoid, Shift, Improve	Sustainable business	Emissions reduction potential	Examples
Avoid	<b>Telecommunication technology and services</b>	<b>Medium</b> – Provides alternatives to physical travel	Teleconferencing and teleworking by major companies in Europe, US, etc.
Avoid and Shift	<b>Parking providers</b>	<b>High</b> – by providing formal parking space and replacing informal parking	Private parking operators in Tokyo
	<b>Shared vehicle systems</b>	<b>High</b> – by encouraging less private car usage	Car-sharing integrated with rail and public transport in Switzerland; Bicycle sharing such as: JCDecaux/Cyclocity, Paris, Clear Channel/SmartBike, Barcelona
Shift	<b>Public transport operations</b> (including fare collection, depot/fleet management, station management, security)	<b>High</b> – by increasing the quality of service and making transit systems more attractive	Bus Rapid Transit systems in Bogotá, Pereira, Curitiba, Ahmedabad, Guayaquil, Mexico, Leon, Guadalajara, Guatemala; Bus systems in Santiago, Sao Paulo (and most Brazilian cities); Metro rail systems in Singapore, etc.
	<b>Taxis and paratransit operations</b>	<b>Medium</b> – by providing door-to-door alternative to private cars (depends on fuel type and operational efficiency)	Auto-rickshaws in India, Pakistan
	<b>Non-motorised transport (NMT) services</b>	<b>High</b> – particularly when coupled with land use patterns that support shorter journeys achievable by NMT.	Bicycle rickshaws in India, New York City, San Francisco; Bicycle stations in Germany; Bicycle rentals in Amsterdam; Walking tours in Boston
	<b>Intelligent Transportation Systems</b>	<b>Medium</b> – optimising transportation system performance to minimising vehicle delays and making public transport attractive	Technology providers in Santiago, Guayaquil
	<b>Commercial enterprises in public spaces, advertising and street furniture</b>	<b>Medium</b> – improves the user experience of transit/non-motorised transport oriented cities	Barcelona, Buenos Aires, Guayaquil
Improve	<b>Low carbon vehicles</b>	<b>High</b> – by allowing better energy efficiency	Small, lightweight vehicles, ultra low emission engines, hybrid vehicles, plug-in hybrids linked with sustainable generation of electricity
	<b>Alternative fuels</b>	<b>High</b> – by allowing lower CO <sub>2</sub> per unit of energy	Biofuels, conforming to stringent and comprehensive sustainability criteria
	<b>Vehicle Maintenance</b>	<b>Medium</b> – proper vehicle maintenance can reduce emissions and GHG	Annual vehicle checks in e.g. Indonesia

**Table 4: Green transport businesses in the Avoid, Shift and Improve groups**

## Box 6: The role of transport in reducing rural poverty

There is a large body of empirical evidence that shows a positive correlation between transport investment and economic outputs Liu (2005). Binswanger et al. (1993) and AITD (2003) found that rural road investment directly contributes to the growth of agricultural output, increased use of fertilisers, commercial bank expansion and overall improvements in the socio-economic conditions of rural villages in India. Khandker et al. (2009) their research for the World Bank, Khandker et al. (2009) found that rural road investments in Bangladesh reduced poverty significantly through higher agricultural production, higher wages, lower input and transportation costs and higher output prices. Rural roads were also found to lead to higher rates of school attendance for both girls and boys and to be pro-poor. However, together

with rural road infrastructure, investments also need to be made in facilities for public transport, NMT and a multi-modal transport infrastructure. For those without access to private motor vehicles, this would lead to their increased mobility. This is especially the case when connecting urban centres with rural areas. Van de Walle (2002), in her work for the World Bank, argues that failing to consider the equity objective alongside the efficiency one can bias investment against poorer areas and poor people. This is particularly true in Asian transition economies where roads are one of many constraints on development. Their economic, social and environmental benefits will be dependent on other factors such as whether or not affordable transport services follow the road investment.



divide. In many developing countries there is a vast gap between income groups in terms of access to paved roads, as well as affordable and safe transport.

Investment in green solutions such as public transport networks that are accessible, reliable and affordable can help alleviate poverty in a number of ways; providing people with the means to reach employment opportunities, education and healthcare. New jobs can be created in previously isolated areas, for example, by involving local workers and co-operatives in road maintenance.<sup>17</sup> Stimulating the local economy can also bring down costs and foreign exchange, while lower travel costs and reduced journey times can make essential goods and services cheaper. Safe and clean transport networks help protect the most vulnerable members of society from some of the adverse impacts of transport such as road traffic accidents and air pollution.

17. Such methods could be equally targeted at the construction and maintenance of infrastructure for public and non-motorised transport.

## 4 Quantifying the economic implications of green transport

To quantitatively assess the macroeconomic implications of investing in green transport at the global level, the study applied a modelling approach utilising the Millennium Institute's T21 model.<sup>18</sup> Within the multi-sector green investment scenario in which 2 per cent of the global GDP is allocated for investment in greening a large number of sectors, transport was assumed to receive 17 per cent of the total.

This section describes the differences between investing the assumed additional amount in green transport and in the business-as-usual scenario (BAU), including their macro-level implications up to the year 2050. Due to the scarcity of studies that employ the same modelling technique, the outcomes are to be interpreted as indicative of the direction of change that can be expected with green investment, and should be validated through further work. The figures should be assessed together with projections made by other models such as the IEA's Mobility Model, to which comparisons are made in this section.

### 4.1 Transport trends under business-as-usual

Under BAU without additional investment, the total number of road vehicles<sup>19</sup> increases rapidly. The stock of light-duty vehicles (LDVs) in particular would grow from the current 0.8 billion to 2.2 billion by 2050.<sup>20</sup> In line with the future growth in total vehicle stock, travel volume would increase for both passenger and freight transport. In the year 2050, passenger transport would reach 103 trillion passengers per kilometre (pkm), whereas freight transport would be approximately 38 trillion tonnes per kilometre (tkm). Compared with baseline figures from IEA, these figures are higher,

especially for freight where IEA predicts only 13 trillion tkm in the same year.

In BAU, for passenger transport LDVs would continue to dominate all transport modes with an increasing share (47 per cent in 2010 rising to 62 per cent in 2050) of the passenger travel load over the period, while the share of buses would decline from 25 per cent to 15 per cent.<sup>21</sup> A steady share of the passenger travel load (6–7 per cent) is expected to be by rail, and around 10 per cent by aviation. For freight transport, the volume carried by rail would decline from 55 per cent in 2010 to 52 per cent in 2050, contrasted with an increase in road-based transport (trucks).<sup>22</sup>

With regards to *energy use* and *carbon emissions*, both are projected to increase by nearly 50 per cent by 2030 and more than 80 per cent by 2050 in the BAU case. The modes that will contribute most to emissions in 2050 are LDVs (56 per cent), trucks (16 per cent) and aviation (18 per cent). By 2050 the CO<sub>2</sub> emissions of the transport sector would have increased to one fourth of global energy related CO<sub>2</sub> emissions.

In the BAU case, *total employment* in the transport sector, which is 67.9 million in 2009, will continue to grow by 1.3 per cent per year on average through to 2050 and reach approximately 116 million.<sup>23</sup>

### 4.2 The Avoid, Shift and Improve strategy as a basis for redirecting investments

The transport sector will see massive investments in the coming decades, mainly through city planning, infrastructural works, public transport systems and

18. The information contained within this section draws from modelling work conducted by the Millennium Institute (MI). Whilst every effort has been taken to accurately integrate the modelling results throughout the entire report, there may be certain figures which are subject to further refinement or corrections, based on the larger modelling process and changes in other sectors. Note also that the modelling process has been limited by the relative lack of standardised evidence and data, for example assumptions on employment in the transport sector, harmonised information on transport activity by city, region and country, standardised figures on transport externalities and the interrelationships between modes and sectors.

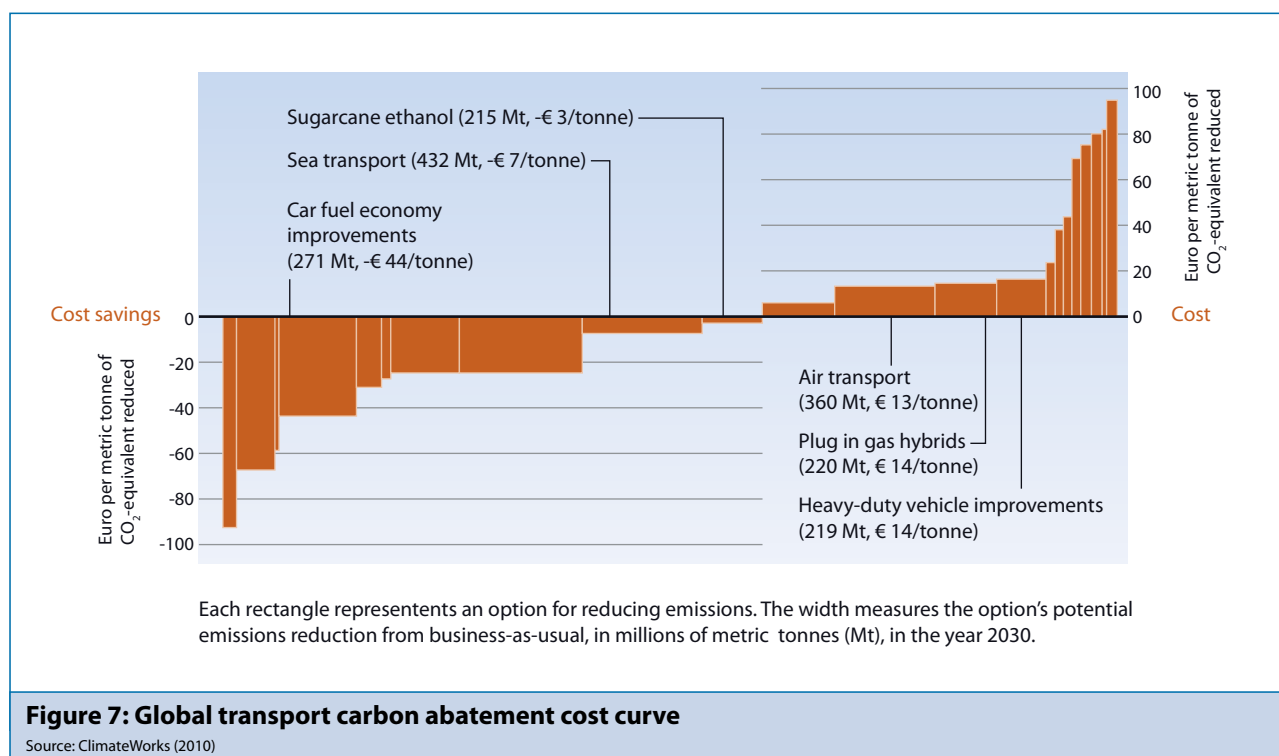
19. Includes both urban and non-urban, freight and passenger.

20. Others predict that this growth could even be higher. For example, IEA predicts the number of LDVs to reach 2.7 billion by 2050.

21. Of all passenger transport, IEA estimated, in terms of passenger-km per year (different from the measure in this model), 7 per cent to 6 per cent by rail, from 10 per cent in 2010 to 15 per cent in 2050 by air, and the remainder by road transport modes, in which 45–56 per cent of all passengers are carried by LDVs. Within road passenger transport, for which IEA reported total travel distance in km traveled by all road vehicles per year (same measure as in the model), LDVs account for 67–78 per cent of road passenger travel volume in 2010–2050.

22. The International Energy Agency (IEA) estimates the percentage of freight transport load, in terms of tonne-km per year, that is carried by road vehicles increases from 55 per cent in 2000 to 59 per cent in 2050.

23. These figures exclude the large level of informal labour in the transport sector (for example, the maintenance of vehicles, operation of micro buses in developing countries), which were not able to be estimated due to data restrictions. Such forms of employment may also benefit from the shift in investments towards a green scenario.



procurement of transport vehicles. IEA (2010) predicts that under BAU by 2050 the world will spend another US\$ 150 trillion on motor vehicles.<sup>24</sup> There will be an investment of another US\$ 100 trillion in other types of transport vehicles (trucks, ships, aircraft, etc.) and US\$ 150 trillion in fuels.

However, in a green economy these investments, if properly designed, would help limit the growth in emissions. Redirecting investment to green transport options can provide the same mobility needs but with significant reduced societal and environment impacts and in some cases even for less money. The global carbon abatement costs curve of McKinsey (2010) – presenting carbon benefits from investment in potential actions to reduce

carbon emissions – shows that investing in green transport can be among the most cost-efficient actions to reduce carbon emissions. For example, investing in improving the fuel efficiency of vehicles is claimed to be able to generate net savings of € 65 per tonne carbon abated. The global transport carbon abatement cost curve of ClimateWorks (2010), see Figure 7, shows a similar amount for initial improvements in fuel efficiency.

It is important to look not only at carbon abatement efficiency but also other impacts on the various challenges identified in the first chapter of this report. When comparing interventions and their costs and benefits it is also important to look at secondary impacts. For example, some interventions can result in major increases or decreases in tax revenue. Table 5 shows that

24. Undiscounted dollars over the next 40 years worldwide.

	INVESTMENTS		BENEFITS				
	Direct investment	Long term costs/ investment	Air quality	GHG emissions	Congestion	Transport accessibility	Road safety
Bus Rapid Transit (BRT)	++	+	++	++	++++	++++	++
Light Rail	+++	++	++	++	++++	+++	++
Rail	++++	++	+	++	+++	++	+
Cleaner & more efficient vehicles	++	+	++++	+++	+/-	+/-	+/-
NMT infrastructure	++	+	++	+	+++	+++	+++
City planning/ design	++	++	+++	++	++++	++++	+++

**Table 5: Costs and benefits of investing in green transport**

Source: Estimates by UNEP and authors. The more the pluses the bigger the investment or the benefit associated with the intervention.



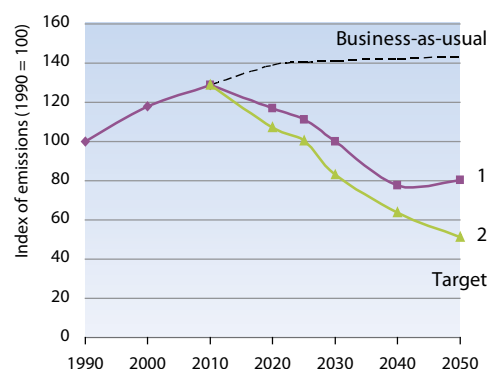
while some transport interventions are cost effective ways to reduce carbon emissions, others are more effective in increasing accessibility or decreasing congestion.

While there are differing views on the role that biofuels can play in reducing GHG emissions in the transport sector, its use has been rapidly increasing over the past years. Much of this development has been triggered by mandates for blending biofuels into vehicle fuels, enacted in at least 41 states/provinces and 24 countries at the national level. Ethanol, made primarily from corn and sugar cane, and biodiesel, produced primarily from oil seeds such as rapeseed and oil palm seeds, are currently the key biofuels for transport. Most mandates require blending 10-15 per cent ethanol with gasoline or blending 2-5 per cent biodiesel with diesel fuel. Standards comprehensively addressing environmental and social concerns raised in the context of production of biofuels should be applied to ensure sustainability.

To achieve a green transport sector and meet targets set in terms of improved urban air quality, reduced carbon emissions and reduced road accidents, a mix of strategies is needed combining Avoid, Shift and Improve interventions. Models of the International Energy Agency (IEA, 2009b) and the European Environment Agency (EEA, 2010) show that a package of measures, combining measures in the Avoid, Shift and Improve areas, are needed to achieve major emissions reductions (see Box 7). UNEP's work also arrives at a similar conclusion (see Box 8).

### Box 7: Net savings from greening the transport sector

In the context of climate-change mitigation, it is often claimed that actions in transport are costly due to the required new technologies. However, as demonstrated by several studies such as Cambridge Systematics (2009) in its "Moving Cooler" study and McKinsey's and ClimateWorks' cost abatement curves (see earlier), the cost of many transport interventions and especially a comprehensive set of policies based on the Avoid, Shift, and Improve strategy can often result in net savings to the economy as a whole. The savings in fuel costs brought about by a mixture of behavioral and technological changes far outstrip the implementation costs. A World Bank (2009) study on Mexico notes that projects targeted at improving the efficiency of bus networks, rail freight and vehicle-inspection schemes generated large net savings.



Each curve shows the additional effect of adding further instruments.

1. Improve package: improved engine and vehicle design, electric cars, low-carbon fuels and technologies encouraging behavioural change. These measures lead to a 44 per cent reduction in transport CO<sub>2</sub> emissions.

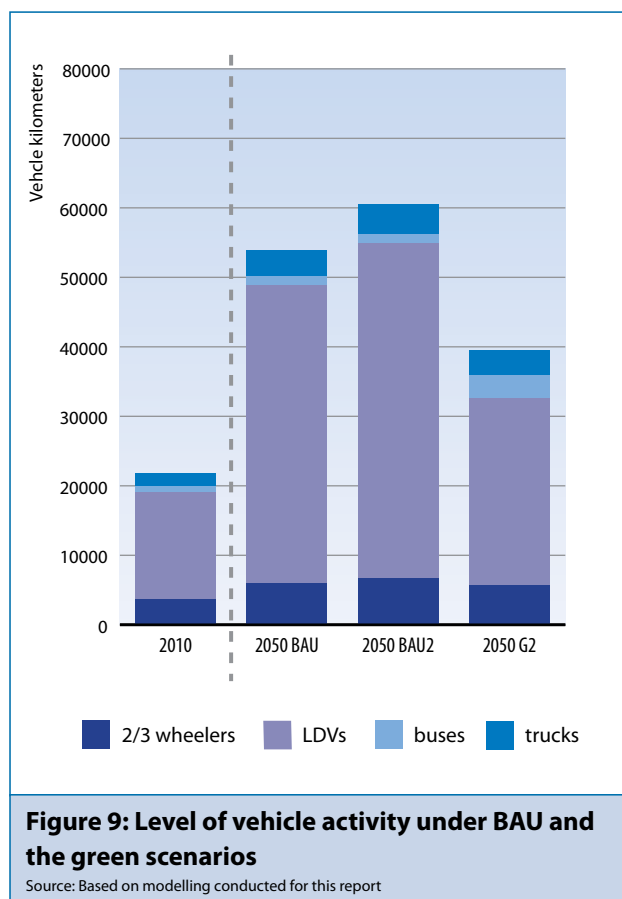
2. Avoid and shift package: road pricing, car clubs, increasing population density in cities and travel planning. These measures lead to a 20 per cent reduction in transport CO<sub>2</sub> emissions.

**Figure 8: Effect of a combination of Avoid, Shift and Improve measures to reduce CO<sub>2</sub> emissions from the transport sector in the EU**

Source: EEA (2010)

### Box 8. Effects of combining investments in measures in the Avoid, Shift and Improve areas on reducing transport emissions

UNEP has been working closely with IEA and others in promoting clean and efficient vehicles. In doing so, UNEP has found that major reductions can be achieved through the introduction of cleaner fuels and vehicles. However, UNEP also found that to achieve the emissions reductions needed investments must be made in all three areas: Avoid, Shift and Improve. Models of the IEA and European Environment Agency (EEA) show that emissions reductions of 70 per cent or more are possible with the right policies and investments – with about two-thirds coming from measures in the Improve area and one-third from measures in the Avoid and Shift areas.



### 4.3 Investing in green transport

#### Inputs and assumptions

The green investment scenario (G2) assumes US\$ 419 billion in constant US\$ 2010 invested per year over the next 40 year period into:

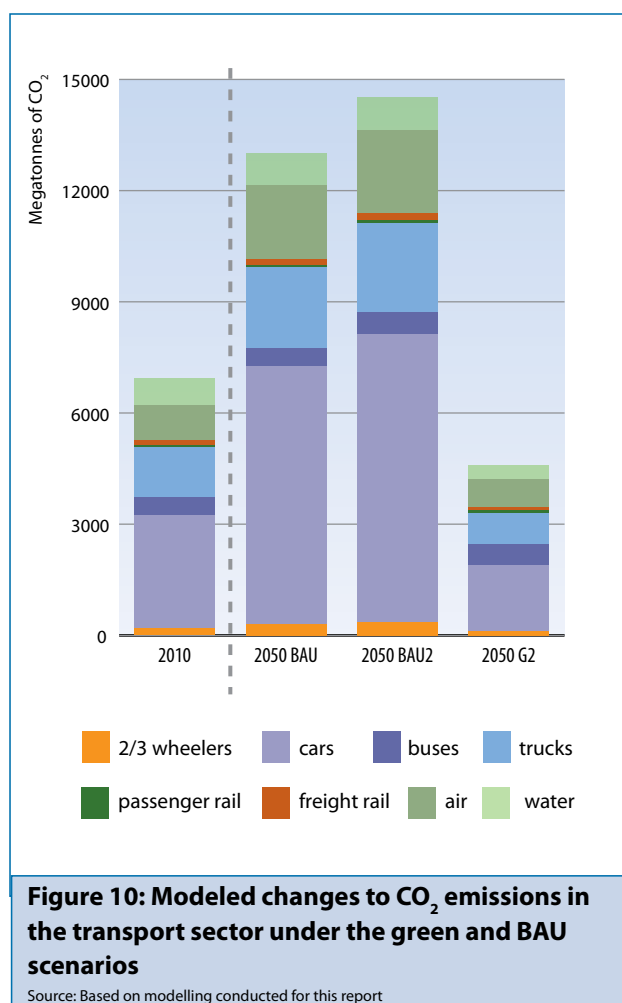
- Expanding the *public transport infrastructure* (promoting modal share to bus and rail transport); and
- Increasing the *efficiency of road vehicles*.

With respect to *public transport infrastructure*, investments are made to reduce LDV (cars) and air travel and increase bus and rail travel volume, promoting a modal shift to less carbon intensive forms of transport. An annual investment of around US\$ 24 billion is allocated to transport infrastructure over the 40 year period.

With respect to *energy efficiency improvement*, around US\$ 384 billion is assumed to be invested in more efficient vehicles on average each year between 2011 and 2050. Note that the investments assumed in the model for measures under the Avoid, Shift and Improve strategies are in line with the EEA and IEA green transport investment scenarios discussed earlier.

Furthermore, to represent future *changes in travel needs* under the green scenarios, a 25 per cent avoidance of total transport volume is initially assumed, in accordance with IEA's outlook on total travel volume.<sup>25</sup> This reduction is assumed to happen at no cost as a result of changing needs and behaviour motivated by the various enabling conditions such as better city planning, more e-working, strict regulations, etc. Note that the above assumptions on investment and behavioural changes directly mirror the Avoid, Shift and Improve paradigm set out in Section 2.2. These are shown to impact on the transport modal split, energy consumption, energy-related emissions, and employment as discussed below.

The annual green investment in the transport sector would generally encourage the shift from (or retain the modal share of) private transport to public or non-motorised transport, compared to the various BAU scenarios. The total travel volume of road vehicles will limit its increase from 21 trillion VKM in 2009 to 39 trillion VKM in 2050, 35 per cent below BAU2 (BAU with the same amount of additional investment as in G2).



25. Assumed to be primarily driven by transit oriented development, telework, shorter but more frequent trips, among others (as indicated in IEA's Transport, Energy and CO<sub>2</sub> study). On the other hand, the positive impact of the green scenarios on GDP are projected to push total travel volume higher, partially offsetting the impacts of this initial assumption.

Figure 9 shows the level of road transport activity (in vehicle kilometres) under various BAU scenarios as well as the green investment scenario.

In terms of modal split, the green investment scenario assumes a fall in the share of passenger kilometres by car in 2050 from 62 per cent (BAU2) to 33 per cent.<sup>26</sup> For freight, rail retains a relatively large share of 52 per cent of the transport volume (tkm).

The *total energy consumption* of the transport sector will be limited to 2.2 thousand million tonnes of oil equivalent (Mtoe) in 2050 in green investment scenario. About 874 Mtoe are satisfied by biofuels,<sup>27</sup> limiting oil-based fuels to 1,251 Mtoe in 2050, 81 per cent lower than BAU2. Considerable energy savings come from the switch to public transport as the increase in emissions by buses and electrified rail are much smaller than the avoided emissions from LDVs.

## Results

As a result of these investments, carbon emissions are reduced radically, by 8.4 Gt of CO<sub>2</sub>, or 68 per cent relative to BAU2 in 2050. The green investment scenario corresponds roughly to the level of emissions modelled by IEA in their low carbon (BLUE Map) scenario, which combines incremental improvements in fuel efficiency of conventional engines, a 20-fold increase in biofuels and uptake of new vehicles such as hybrids and fuel cell vehicles. In the BLUE Map scenario, IEA estimates

\$20 trillion additional investments in vehicles (for more efficient vehicles including electric vehicles) but about a similar, US\$ 20 trillion, savings in fuel costs due to increased fuel efficiency<sup>28</sup> (IEA 2009b). Therefore, a major global carbon reduction can be achieved without any cost (but would need investment policies that would promote investment in cleaner and more efficient vehicles).

Total employment in the transport sector will remain substantial, with large growth in public transport modes such as passenger rail. Overall employment in the transport sector in 2050 is modeled to be higher in the green scenario compared to BAU2, by roughly 10 per cent. Jobs related to cars (including production and maintenance) will also grow, albeit less rapidly compared with BAU2 owing to the lower levels of car ownership under the green scenario.<sup>29</sup> As a result of the large reductions in carbon emissions, together with continued strong growth in transport employment, the carbon intensity of each transport job is reduced by around 70 per cent compared with BAU2, reflecting the decoupling of transport emissions from economic growth, and the greening of jobs in this sector.<sup>30</sup>

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28. 2008 as a base year.

29. Note: Reliable job estimates on maintenance of cars could not be found and have not been included explicitly in the modelling. Concerning public transport, management and operation job numbers were calculated based on EU data (excluding France and Germany which have disproportionately high levels of employment in this subsector) to estimate employment at the world level.

30. The approach taken in this chapter to quantify the greenness of jobs may help inform existing and future definitions of green jobs – for example those from the International Labour Organization (ILO). Further refinement and coordination of approaches in this aspect would prove beneficial in better quantifying and monitoring the transition towards a green economy.

26. This Figure heavily depends on the assumptions that are used on the effectiveness of measures to avoid the need for travel, as well as to what extent the demand shifts towards public and non-motorised transport.

27. Care needs to be taken to ensure that the biofuels used comply strictly with sustainability criteria that cover the different environmental and social concerns including food prices.

## 5 Enabling conditions

Enabling conditions are background conditions in the investment and political environment that collectively allow the transition to a green economy. They will assist the implementation of the green investments identified for the transport sector, particularly if efforts are taken to ensure a harmonised and integrated approach that facilitates best available policies and technologies across the world. Below, we explore the key enabling conditions for green transport, namely:

- Designing appropriate regulation, planning and information provision;
- Setting the right financial conditions and economic incentives;
- Ensuring technology transfer and access; and
- Strengthening institutions and capacity.

Transport is a complex sector, which is shaped over a long period of time, and by various external sectors and factors (EEA 2008). Therefore, a combination of strategic approaches and policy instruments is required to green the transport sector. An inventory of policy instruments for environmentally sustainable transport and extensive discussion of their possible use in selected countries may be found in (OECD 2002).

### 5.1 Designing appropriate regulation, planning and information provision

A wide range of policies could support the Avoid, Shift and Improve strategies for green transport, namely:

- *Planning* – can reduce the need or distance to travel by bringing closer together the people and the activities that they need to access. It can enable the implementation, and increase the attractiveness of new green transport infrastructure, including for public transport, cycling and walking;
- *Regulation* – can be used to restrict the use of certain motorised vehicles but can also influence the types of vehicles used and the standards that they should adhere to (both in terms of vehicle performance and road regulations);
- *Information* – can increase peoples' awareness of alternative means of transport, leading to a modal shift. Information can also be provided to improve driver behaviour and reduce fuel consumption; and

■ *Economic Instruments* – can provide incentives to change behaviour regarding choice of: vehicle type, fuel, type and timing of travel mode, etc. (see 5.2 for details).

Examples are provided in Table 6. Combining these individual policies is imperative to increasing their effectiveness. For example, restrictions on parking (or high fees) push users away from cars, whilst planning for public transport pulls them towards green transport.

Details of how these policies can enable green transport are provided in the sections below.

#### Planning

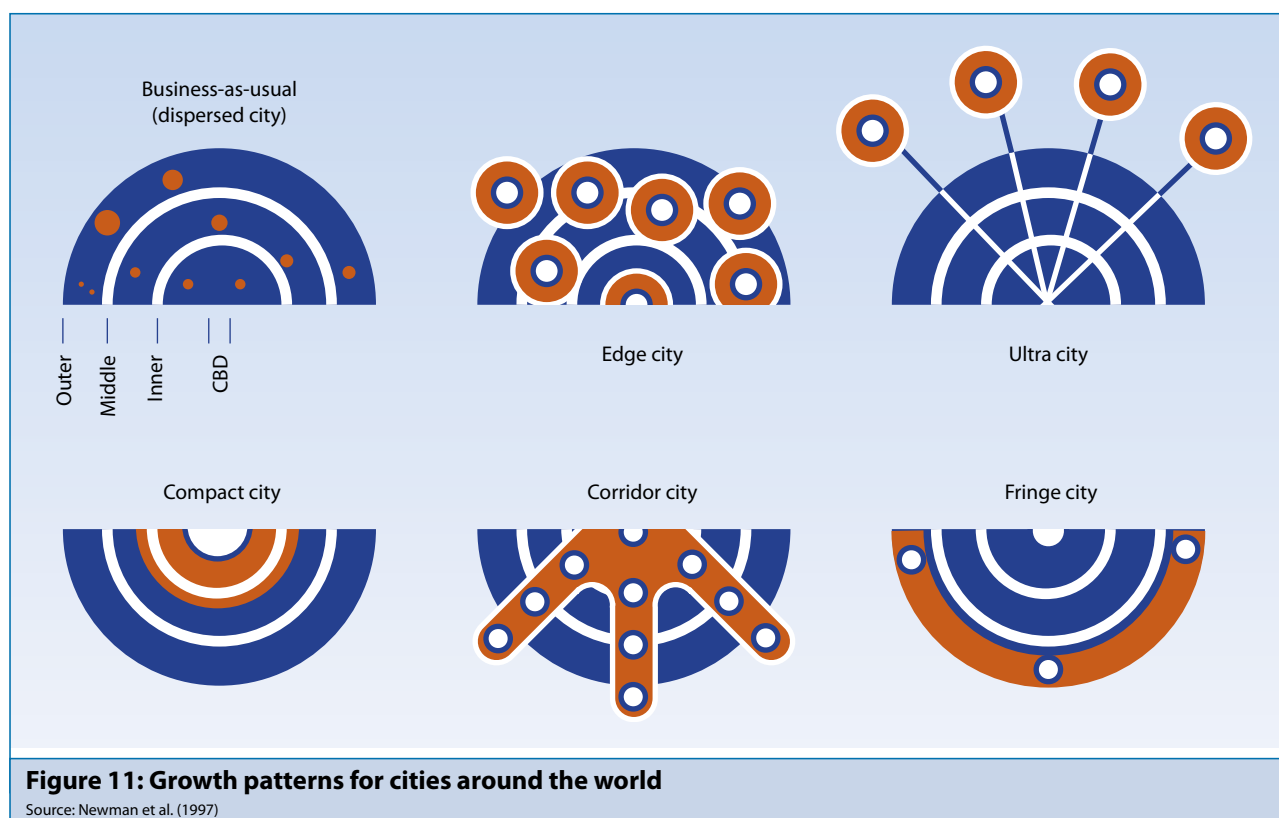
Planning is essential in realising sustainable development. Good planning on all levels (urban, regional, and national) is a prerequisite for green transport, as land use often determines patterns of transport for many years (see the Cities chapter).

Planners have investigated and postulated growth patterns for cities over the years. Six of the most common forms of city evolution or current growth patterns are outlined in Figure 11. The “compact city”, which accommodates increases in population through densification of the city centre and the “corridor city”, which is synonymous with transit-oriented development are thought to be the most sustainable spatial approaches. The mid-sized city of Freiburg, Germany is a good example of the former, whereas Tokyo, Japan is a good example of the latter. Efforts have been made in many developing countries to build cities suited to public transport and non-motorised transport,<sup>31</sup> and Aguascalientes, Mexico is a good example (Embarq, no date). On the other hand, the “fringe city” based on suburban sprawl is synonymous with a heavily private car-dependent society, a result of a traditional, sectoral-based, planning approach.

#### Regulatory instruments

Owing to the inelastic nature of transport demand, economic signals such as the price of fuel are often insufficient on their own to trigger a large shift in behaviour for both consumers and industry. Regulatory instruments therefore play a large role in creating additional incentives to enable change. Timilsina and

31. The potential for land use and urban planning to shape long-term transport patterns is higher in developing countries, where cities are still emerging and have not yet locked themselves into a car-dominated society. To incorporate the increasing population brought by the trend towards urbanisation, cities in developing countries can set clear physical boundaries to define the outer perimeter of the city, promote mixed land use, and (if needed) develop new land around public transport corridors.



Dulal (2009) note that the main regulatory measures used to reduce environmental externalities in transport are those that relate to (1) fuel economy; (2) vehicle emission levels; (3) fuel quality; (4) vehicle inspection regimes; and (5) measures to discourage vehicle use or encourage high occupancy of vehicles. At present, many countries, and especially developing countries, lack comprehensive policies to regulate these five main areas. Practical applications of these regulatory measures are provided in Table 7.

Regulation must be considered in conjunction with economic measures to ensure economic efficiency and avoid government failure. Regulation must also be feasible to enforce. Often a well-intended scheme results in unforeseen consequences. For example, in Jakarta, a policy to mandate vehicle occupancy of three persons in one vehicle in the city centre has resulted in illegal “jockeys” receiving money from drivers to ride in their cars to help evade penalty fees.

#### Information instruments

Information instruments may induce further changes in behaviour through raising awareness of alternative modes or methods of travel. Public-awareness campaigns, mobility management, labelling of new cars, and driver education are representative examples.

By monitoring, accounting for and communicating the real financial, environmental and social implications

of motorised transport, users may actively choose mobility patterns more in line with the Avoid, Shift and Improve approach. It is important to communicate the benefits of green transport in ways that directly relate to people’s lives, such as improved health,<sup>32</sup> less financial expenditure, and reduced commuting time and stress.

Driver education and training can focus on “eco-driving” techniques, which can typically save between 5 and 10 per cent of fuel (ecodrive.org 2010). Highlighting the reductions in fuel costs through eco-driving is likely to appeal particularly to operators of commercial vehicles.

## 5.2 Setting the right financial conditions and economic incentives

In order for investments in green transport to reach their full potential, a set of changes must be made to the current financing framework, coupled with the creation of market conditions that permit green transport to be economically feasible.

32. The World Health Organization has developed a methodology on evaluating the costs and benefits of human-powered mobility: Methodological guidance on the economic appraisal of health effects related to walking and cycling. Available at: [http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0007/87478/E90944sum.pdf](http://www.euro.who.int/__data/assets/pdf_file/0007/87478/E90944sum.pdf).



Type	Avoid	Shift	Improve
Planning	High density mixed land use development. Parking standards.	Integrated public transport planning. Land use planning.	Planning of smart grids. Planning of decarbonised electricity sources.
Regulatory	Traffic restrictions and travel bans (e.g. in city centres).	Parking restrictions. Road space allocations. Restrictions on the type of vehicles.	Vehicle standards (on e.g. emissions). Speed limits. Regulation of production processes.
Information	Increase awareness of the real costs of travel by various modes. Mobility management and marketing.	Increase awareness of alternatives. Mobility management and marketing. Co-operative schemes.	Eco-driving Public awareness campaigns. Labelling of the environmental performance of vehicles.
Economic	National subsidies for low carbon transport city design and planning.	Public-private partnerships for public transport systems (esp. BRT and light rail). Removal of fuel subsidies/ taxing of fuels. Allocating fixed percentage of road infrastructure for NMT.	Fiscal incentives for cleaner and more efficient vehicles. "Cash for clunkers" programmes (buy-out of old/ polluting vehicles). Fiscal incentives for cleaner fuels.

**Table 6: Overview of instruments to support Avoid, Shift and Improve strategies**

Source: Authors' estimate

### Options for financing green transport

Transport is a major attractor of public and private investment (Sakamoto, in Leather et al. 2009), characterised by:

- Strong prevalence of public-sector funding for transport infrastructure;
- Strong preference by international donors and national governments for the roads sector (particularly inter-city highways);
- High level of private and informal provision of transport services; and

- Limited recognition of, and funding for, green transport.

To enact green transport, it is clear that financing patterns must be reformed, so that:

- Adequate funding is provided for green transport in all aspects (e.g. technology, capacity-building, operation, infrastructure, etc.) so that all extra costs associated with green transport can be recovered;
- Resources shifted from supporting non-sustainable forms of transport towards green transport, and additional resources are mobilised and scaled up wherever they are lacking;

Regulatory measure	Example application	Effects	Keys to success
Measures on fuel economy (regulating fuel consumption per kilometre of travel)	Corporate Average Fuel Economy (CAFE) standards in the US.	<ul style="list-style-type: none"> <li>■ 50 per cent increase in fuel economy between 1975 and 1995. (Greene 1998)</li> <li>■ Modelled net increase in jobs (140,000 by 1985). (Dacy et al. 1980)</li> <li>■ Fuel saving of US\$ 54 billion (in 1990 dollars). (Geller et al. 1992)</li> </ul>	<ul style="list-style-type: none"> <li>■ Continuous improvement in the stringency of standards.</li> </ul>
Measures on vehicle emission levels (regulating level of tailpipe emissions)	EURO standards in Europe, with gradually increasing level of strictness for CO, HC, HC+NO <sub>x</sub> , NO <sub>x</sub> and PM.	<ul style="list-style-type: none"> <li>■ Reduction of transport-related PM (-30 per cent), acidifying substances (-34 per cent) and ozone precursors (-48 per cent) between 1990 and 2007. (EEA 2010)</li> <li>■ Adoption of identical or similar standards (with time lags) in various developing countries.</li> </ul>	<ul style="list-style-type: none"> <li>■ Combination with other measures such as fuel economy standards, fuel quality standards and fuel taxation to further improve effectiveness.</li> </ul>
Measures on fuel quality	Phasing out of lead, sulphur etc. from fuels, biofuel blending mandates in Brazil, etc.	<ul style="list-style-type: none"> <li>■ Reduction in health problems associated with lead and sulphur intake.</li> <li>■ Reduction in carbon intensity of fuels.</li> </ul>	<ul style="list-style-type: none"> <li>■ Strong political will</li> <li>■ Continuous pressure from civil society.</li> </ul>
Measures for vehicle inspection	Vehicle inspection and maintenance system in e.g. Beijing.	<ul style="list-style-type: none"> <li>■ Reduction of local emissions by 28 to 40 per cent. (Kebin and Chang 1999)</li> </ul>	<ul style="list-style-type: none"> <li>■ Proper enforcement and tackling of corruption.</li> </ul>
Measures to discourage vehicle use/encourage high occupancy of vehicles	Car-free zones in e.g. Germany, partial traffic bans in Mexico, speed restrictions.	<ul style="list-style-type: none"> <li>■ Increased quality of life and regeneration of economic activity in city centres.</li> <li>■ Reduction of traffic congestion and air pollution.</li> </ul>	<ul style="list-style-type: none"> <li>■ Prior communication of the benefits to local businesses and residents.</li> </ul>

**Table 7: Regulatory measures in practice**

Adapted from Timilsina and Dulal (2009)

Funding stream		Avoid	Shift	Improve
<b>Transport oriented funding streams</b>				
<b>Public Sector Funding</b>	Fuel tax	+++	++	+++
	Vehicle taxes	++	++	++
	Parking charges	++	++	
	Road pricing	+++	+++	+
	Fare revenue*		+	
	Public transport subsidies		+	+
	Business taxes (e.g. Versement Transport in France)		+	
	Land related taxes and charges	+++	++	
	Grants, loans, tax transfers	++	++	++
Advertising			+	
Private sector investments		+	+	+++
<b>Green funding streams</b>				
Environmental taxation and subsidies		+	++	++
Clean Development Mechanism (CDM)		P	P	P
Joint Implementation (JI)		P	P	P
International Emissions Trading (IET)		P	P	+ / P
Global Environmental Facility (GEF)		P	+	+
Multilateral/ bilateral funds		PPP	+ / PPP	+ / PP
Green Climate Fund, Fast Start Financing		PP	PP	PP
+++: High contribution; ++: Medium contribution; +: Low contribution; P: Low future potential, PP: Medium future potential, PPP: Large future potential * Fare revenue in many cases also accrues to the private sector, if the transport operator is private. ** Funding NAMAs could potentially be linked to the Avoid, Shift and Improve paradigm.				

**Table 8: Options for financing green transport**

Modified from: Sakamoto (2009)

■ Public funding at all levels (international – including Official Development Assistance and climate-related funds – national and local) is mobilised to support green transport;<sup>33</sup>

■ Private finance is leveraged, through the appropriate design of markets and the creation of consistent, long-term incentives to invest in green transport and through the application of public-private sector models to invest in and operate green transport systems (such as Bus Rapid Transit (BRT) systems); and

■ Financing flows from different sources are designed to complement each other, rather than work towards different goals.

A range of financing streams could contribute to providing support for green transport. These include not only funds and mechanisms devised specifically to

support green options, but also existing sources. Table 8 outlines these options and assesses their relative support with regards to the Avoid, Shift and Improve strategies.

Typically, public-sector funding provides a major part of the overall financing volume for transport infrastructure investments, at an average of 52.9 per cent in developing countries (UNCTAD 2008). Here, efforts are required to screen transport investments according to sustainability criteria, so that resources will flow towards green transport (Sakamoto 2009). The creation of a national green transport fund<sup>34</sup> (mirroring existing road funds found, for example, in Japan, fed by fuel and vehicle taxes) may be another option to guarantee adequate resources for green transport and help recoup any additional costs associated with green modes.

As transport investments are costly, increasingly public-private partnerships have become common. Such partnerships are also increasingly common in developing countries, for example in the operation of BRT systems.

33. Decision-making tools (e.g. project appraisal) should be reformed to ensure consistency with supporting green transport. Independent environmental analyses for transportation projects may be used to screen potential projects before they occur. They should also fully incorporate the potential synergies and trade-offs between projects for different modes/sectors. Promoting transversal programmes without a sectoral focus may also be a way of integrating land use, transport and social services spontaneously.

34. Alternatively, such a fund could be set up under a wider “national green investment fund” which mobilises resources in all green sectors including transport.

Private-sector funding can be mobilised through, for example, Build-Operate-Transfer schemes, which have successfully channelled private resources into large infrastructure projects in many developing countries.<sup>35</sup>

Furthermore, there are a number of climate-oriented financing instruments with increased levels of funding available for green transport. For example, the Global Environment Facility (GEF) has released US\$ 2.675 billion for transport projects over the last 20 years (GEF, 2009).<sup>36</sup> The Climate Investment Fund (CIF) and its Clean Technology Fund (CTF) have started to address transport as a key sector.

The financing framework (or the combination of the above options) for green transport would need to consider the following issues (Sakamoto et al. (2009):

- Its ability to generate the level of funding required to shift the emphasis towards sustainable transport;
- The ongoing stability of funding – enabling the sustainable transport strategy to be continuously implemented and long-term goals to be pursued;
- Efficiency – ensuring that resources are allocated to their best use, and reducing transaction costs throughout the system;

35. For practical guidance on utilising private finance for transport, see for example World Bank/ICA/PPIAF (2009).

36. US\$ 201.5 million of direct finance matched by US\$ 2.47 billion in co-financing as of May 2009.

## Box 9: Share the Road

UNEP's Share the Road campaign promotes non-motorised transport (NMT) by advocating increased investment by donors and governments in NMT infrastructure within road projects (e.g. at least 10 per cent of the overall budget). The emphasis is on a paradigm shift towards roads that benefit all users and thus re-thinking how space and resources are shared between pedestrians, cyclists, users of public transport and motorists. Increased investment in NMT infrastructure can substantially benefit the environment (air quality, GHG emissions), development (accessibility, affordability), and safety (protected facilities for vulnerable users), and it is a prerequisite for building resource-efficient, liveable cities. Share the Road is working with partners with a view to making safe, low carbon and accessible mobility a reality for all users (UNEP and FIA Foundation, forthcoming at [www.unep.org/transport/sharetheroad](http://www.unep.org/transport/sharetheroad)).

■ Equity – both horizontally (i.e. fair treatment of all transport users) and vertically (i.e. across income groups, ensuring support to those who are most deprived);

## Box 10: The future role of climate finance in enacting green transport

In the context of the ongoing negotiations on climate change, the design of financial instruments need to take into account the failure of existing instruments such as the Clean Development Mechanism (CDM),<sup>37</sup> to be fully applied to the transport sector. Under a Post-2012 framework, mitigation actions in transport in developing countries are likely to fall under the umbrella of Nationally Appropriate Mitigation Actions (NAMAs), which could be financed through:

- A transport window under a Mitigation Fund such as the future Green Climate Fund;
- An up-scaled, programmatic CDM;
- A transport-specific instrument (see Bridging the Gap, 2010 for a proposal for a sectoral approach in transport); and
- Other potential funds specific to capacity-building or technology.

Nationally Appropriate Mitigation Actions supported by developed countries are likely to be backed by fund-type instruments, whereas actions taken to acquire credits would be enacted through a crediting scheme such as an up-scaled CDM.<sup>38</sup>

37. Of the 2,400 registered CDM projects (as of October 2010) only three are transport projects, and only 32 out of the 5,529 CDM projects in the pipeline relate to the transport sector. Transport therefore only constitutes less than 0.1 per cent of expected CERs. Source: UNEP-Risoe Centre.

38. The framework surrounding NAMAs is continuing to evolve, with the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) agreeing at its 16th session in Cancun Mexico that developed countries shall provide support for preparation and implementation of developing country NAMAs, and that a registry will be set up to match finance, technology and capacity building support to NAMAs seeking international support. Nationally Appropriate Mitigation Actions are principally driven by the developing countries. As noted in Binsted et al. (2010), many developing countries (26 of the 43 countries that submitted NAMAs to the UNFCCC by September 2010) have proposed NAMAs in the transport sector. Available at: [http://www.transport2012.org/bridging/ressources/files/1/913,828,NAMA\\_submissions\\_Summary\\_030810.pdf](http://www.transport2012.org/bridging/ressources/files/1/913,828,NAMA_submissions_Summary_030810.pdf)

■ **Practicality** – both in terms of political acceptability and technical feasibility, taking into account local conditions and priorities; and

■ **Measurability and transparency** – to ensure that the effects of the new funding arrangements on carbon emissions can be monitored and evaluated against various criteria including cost effectiveness.

### **Pricing practices and their reform (energy costs, taxation, subsidies)**

The market for transport is currently distorted in many ways. Firstly, the various impacts of motorised transport (see Section 2) are in most cases not accounted for in transport costs. Secondly, roads, fuels and sometimes vehicles are subsidised in many countries. These subsidies can be significant, in the European Union they are estimated to amount to 4 per cent of GDP (however, total taxes related to transport are about the same size). This results in unsustainable transport patterns and is a major barrier to the introduction of green transport models. On the other hand, studies show that there is an economic case for subsidising mass transit systems. For example, a study by Parry and Small (2007) shows subsidies for public transport are warranted as they support a reduction of urban traffic congestion and various scale economies that can be exploited (e.g. less time wasted waiting at stops when trains and buses run more frequently).

To escape this deadlock, economic instruments such as charges and taxes need to be applied, which can be designed to reflect at least some of the external costs onto the users. As regards transport taxes, Hayashi and Kato

(2000) point out that such instruments can be applied at three different levels, namely *car purchase*, *car ownership* and *car use* (e.g. fuel/mileage tax, road user charging and parking charges). The distinction between car ownership and use is important. Many developed countries, especially in Europe, combine high levels of car ownership with limited vehicle use. For example, the city of Vienna has one of the highest car ownership rates among European cities, while the use of public transport is also among the highest. Taxing car use rather than ownership, together with providing high quality public and non-motorised transport alternatives, seem to be able to limit car use in many European cities.

Changes in pricing are essential in promoting green transport. Revenues from a full-cost-priced transport system<sup>39</sup> can be used to invest in green transport. Such changes do not necessarily have to result in increased tax burden; reforming existing tax structures can effectively reduce congestion and reduce emissions. London's Congestion Charge scheme, for example, directs part of its revenue towards improving the quality of the city's bus services (see Box 12). Pricing private modes of transport correctly will also ensure a level playing field for public transport.

The relationship between levels of trade and environmental sustainability is complex and their impacts should be assessed from a holistic perspective. In some cases, importing goods from other countries may actually

39. Especially in developing countries where coverage of all transport costs is difficult due to existing structures, one may begin by initially pricing for the variable (operational and maintenance costs), and/or subsidising certain elements of transport from other transport revenues in the form of cross-subsidies, for example, using fuel tax revenue to cover rail transport infrastructure.

### **Box 11: Fuel subsidies – transitional arrangements**

The implementation of policies and shifts in financing priorities will inevitably lead to some groups in society to be worse off, at least in the short term. The elimination of fuel subsidies may impact disproportionately on poorer households, with little access to alternative sources of energy. UNEP (2008b) argues that targeted subsidies towards the lower income groups may offset such impacts. Lessons can be learnt from the recent reduction of fuel subsidies in Indonesia, which has been coupled with cash compensations and increases in other types of social benefits for vulnerable groups, such as staple food prices and education (Bank of Indonesia 2008).

### **Box 12: Congestion charging**

Congestion charging, a fee charged to motorist to enter a zone prone to heavy congestion, may be an important element of more comprehensive energy price rationalisation in the longer term, particularly in developed countries. Congestion charging in London is thought to have reduced the vehicle volumes by around 15 per cent in 2003-2004 (Green Fiscal Commission 2009). The Eddington Review (2006), for example, emphasised the importance of controlling spiralling future congestion costs in the UK. This may facilitate a restructuring – and in some cases perhaps lowering – of fuel excises to focus them on the objectives they are best served to address, such as climate change mitigation.

		Level of importance/significance*		
Green Transport Goals	Technologies	2010	2020	2030
<b>■ Improvement in energy efficiency</b> <b>■ Reduction in air pollution and greenhouse gases</b> <b>■ Increased use of renewable resources</b> <b>■ Reduced use of non-renewable resources</b>	■ Improved internal combustion engines (ICEs)	+++	++	+
	■ Vehicle technology improvements (e.g. material substitution, aerodynamics)	++	+++	+++
	■ Retrofitting technologies	+++	+++	+
	■ Hybrid and Plug-in hybrid electric vehicles	+++	+++	++
	■ Battery electric vehicles	++	+++	++
	■ Solar electric vehicles	+	+	+
	■ Fuel cell vehicles	+	+	+++
	■ Flex-fuel vehicles	++	+++	+++
	■ Alternative fuel technologies – Biofuels, CNG, LNG, LPG <sup>1</sup> and hydrogen	+	+++	+++
	■ Non-motorised transport vehicles	+++	+++	+++
	■ Public transport systems	+++	+++	+++
	■ Intelligent transport systems	++	+++	+++
	■ Use of Information technologies for traffic management (smart infrastructure)	++	+++	+++
	■ e/tele-technologies for travel demand reduction	++	+++	+++
	■ Integrated ticketing	+++	+++	+++
	■ Eco-driving and speed control	++	+++	+++
■ Waste minimisation	■ Material substitution, use of composite materials	++	+++	+++
■ Reduction in land pollution	■ Recycling technologies	++	+++	+++
■ Reduced noise pollution	■ Electric vehicles, hybrids	++	+++	+++
	■ Silencers, etc.	+	++	++
■ Safety	■ Vehicle safety technologies such as tyre-pressure monitoring, Adaptive cruise control/collision mitigation, Emergency brake assist/collision mitigation, etc.	++	+++	+++
+++ : Central, ++: Highly Relevant, + : Relevant				
1 Compressed natural gas (CNG); Liquefied natural gas (LNG); Liquefied petroleum gas (LPG)				
<b>Table 9: Various technologies to support green transport goals</b> <small>Authors' assessment based on IEA (2009); Petersen et al. (2009)</small>				

be less carbon intensive – for example if organically grown imports replace food crops grown in greenhouses. In other cases, there could be a renewed case for local production and consumption of seasonal products.

A related issue is the trading of transport vehicles themselves. On the one hand, the global market may allow the rapid diffusion of the most recent technology, including green vehicles. On the other hand, Davis and Kahn (2009) point out that free-trade agreements (such as NAFTA) have enabled used cars (often not meeting environmental standards) to flow from rich countries to developing countries and adversely affect the environment. In this context, it is vital that environmental standards are harmonised to mitigate the creation of pollution havens.<sup>40</sup>

40. UNEP is currently working, with partners in the Partnership for Clean Fuels and Vehicles (PCFV) to regulate the export of used vehicles to developing countries and transitional countries. For additional information, see: [www.unep.org/PCFV](http://www.unep.org/PCFV).

### 5.3 Ensuring technology transfer and access

A wide range of technologies are relevant to green transport, as shown in Table 9. Conventional technologies involve the use of fossil fuels for vehicle propulsion, which are the main cause of air pollution and GHG emissions. Advanced transportation technologies aim at energy efficiency, switching from fossil fuels to renewable and clean technologies, improvements in public transport and non-motorised transport systems and infrastructure and travel demand management in order to reduce the negative externalities caused by conventional technologies.

In order to meet the sustainable transport development challenge for future, it is important to continue to develop new technologies. According to the International Chamber of Commerce (2007), technology developments in the transport sector should focus on:



1. Promoting use of existing efficient technologies;
2. Retiring existing inefficient technologies; and
3. Supporting R&D for advanced technology developments.

At the same time, there is a need for commercialisation and widespread dissemination of existing efficient technologies. For example, applying already existing efficiency measures at a global scale (weight saving measures, stop-and-start technology, low resistance measures and hybridisation of vehicles, etc.) can already double the fuel economy of the global vehicle fleet. This is without introduction of state-of-the-art technologies such as electric and hydrogen vehicles (see Box 13).

### Technology transfer/access needs

Technologies developed for developed nations often cannot simply be transferred to developing countries. According to UNEP (2009), effective technology transfer in the transport sector requires:

- Accelerated deployment and diffusion of technologies;
- Learning from the technology progress within countries already practicing technology transfer; and
- Supporting mechanisms through appropriate financial mechanisms, knowledge networks and capacity building.

Technological, financial, institutional, information and social barriers can prevent the effective transfer of technology. The United Nations Environment Programme (2009) highlights economic and market barriers as some of the main obstacles of technology transfer. Furthermore, technology and knowledge transfer in transport should take place between developing countries, for example, to share experiences in applying low cost transport solutions such as BRT systems.

To facilitate an increased level of technology transfer, a detailed inventory of relevant technologies should be developed at national and regional levels. This may be linked to a Technology Needs Assessment, currently undertaken by many developing countries, which could also identify key actions for support from the international community.

## 5.4 Strengthening institutions and capacity

Realising the changes to investments and enforcing/ executing the aforementioned policies, regulations and standards for green transport calls for strong institutional arrangements at both national and sub-national levels:

### Box 13: The Global Fuel Economy Initiative

Improving the efficiency of conventional engines is shown (at least in the short term) as one of the most cost-effective means to reduce environmental impacts (McKinsey and Company 2009). In this context, UNEP works with the IEA, the International Transport Forum (ITF) and the FIA Foundation in the Global Fuel Economy Initiative (GFEI)<sup>41</sup> to promote vehicle efficiency worldwide. The GFEI is promoting at least a doubling of global vehicle fuel efficiency by 2050, and through this will make a major contribution to a future climate regime and meeting of climate targets. By providing the space for discussion and consensus on automotive fuel economy, the GFEI serves as a bridge between the car industry, governments, international organisations and NGO groups worldwide, in addition to providing support for the development of national clean and efficient vehicle policies.

- National level institutions, such as Ministries of Transport (in strong coordination with Ministries of Finance, Environment, Energy, Urban Development and Health) can help direct investments towards green technology to promote sustainable low carbon transport, bring in fiscal measures such as taxes and subsidies on vehicles and fuels and introduce regulations that restrict or discourage the usage and development of energy-intensive modes/ transport systems.

- Sub-national level institutions, such as the Municipal Transport Agencies (in strong coordination with land use planning agencies and other local level agencies) can help integrate urban land use planning with transport infrastructure development, coordinate public transport systems, and introduce transport demand management measures such as congestion pricing, parking management, etc. (see section 5.1 for further details). The development of integrated urban transport agencies as seen in Singapore may help towards these aims.

Capacity building can help fine-tune the existing institutions to remove their infirmities and develop new ones to fill the vacuum, wherever it exists. To enable green transport, capacity building can in particular be targeted at:

41. See <http://www.globalfuelconomy.org/>

- Improving administrative capacity of national and sub-national institutions to frame and execute green transport policies as well as develop core financing mechanisms directed towards investment in sustainable transport;
- Methods to raise public awareness to use environment-friendly and energy efficient modes of transport;
- Methods to mobilise the private sector, including the management of Public-Private-Partnerships (PPP), and support for indigenous technological development, encompassing R&D capability; and
- Collection and maintenance of data which are essential for planning and monitoring progress towards green transport.

## 6 Conclusions

This report highlighted that the current patterns of transport activity, based primarily on private motorised vehicles, generates many social, environmental and economic costs, represented for example by:

- Consumption of more than half of global liquid fossil fuels;
- Emission of nearly a quarter of the world's energy-related CO<sub>2</sub>;
- The source of typically more than 80 per cent of developing cities' local air pollutants;
- More than 1.27 million fatal traffic accidents per year, mostly in developing countries; and
- Chronic traffic congestion amounting to time and productivity loss.

Such costs, which can add up to nearly or over 10 per cent of a region or country's GDP, were shown to grow further under the current trends of ever-increasing motorisation. This trend is unsustainable.

There is a need for a fundamental shift in investment patterns, based on the principles of:

- **Avoiding** or reducing trips through integration of land use and transportation planning, and localised production and consumption;
- **Shifting** to more environmentally efficient modes such as public transport and non-motorised transport and to rail and water transport (for freight); and
- **Improving** fuels and vehicles through introduction of cleaner more efficient fuels and vehicles.

Models and scenarios show that a global paradigm shift is possible; investing in green transport measures could reduce emissions of the global transport sector by as much as 70 per cent. However this is only achievable with integrated policies that combine measures from all three components of the Avoid, Shift and Improve strategy.

Quantitative analysis using an integrated macro-economic model suggests that a small reallocation of investments (approximately 0.16 to 0.34 per cent of

global GDP) in support of public transport infrastructure and efficiency improvement of road vehicles would (in the year 2050, and compared to BAU) avoid travel volume of road vehicles by 27 per cent and 35 per cent, shift the share of private-car transport to other modes (by nearly 30 per centage points), reduce oil-based fuel usage by between 16 per cent and 31 per cent, reduce carbon emissions by 5 to 8.1 Gigatonnes (38 to 63 per cent compared with BAU), and retain strong and growing employment. Most of the green transport measures would actually be cost-efficient – for example major carbon reductions can be achieved with little or no extra investment.

Moving towards a green transport sector as part of an overall green economy strategy would also result in:

- **Green growth**, by supporting cities with less congestion, air pollution and other costs;
- **The creation of jobs**, particularly through the development for public transport infrastructure and operations; and
- **The alleviation of poverty** by increasing affordability of transport and improving accessibility to markets and other essential facilities.

Furthermore, it was highlighted that, among others, such investment should be enabled via:

- **Policies**, including **land use planning** to promote compact or mass transit corridor-based cities and conservation-based transportation infrastructure, **regulation** of, for example, fuel and vehicle standards, and the provision of **information** and awareness raising (e.g. on the health and safety benefits of active travel such as cycling and walking) to promote behavioural change in the form of modal choice;
- A shift in **financing** priorities towards public and non-motorised transport, coupled with strong **economic incentives** (via taxes and charges) to promote sustainable consumption patterns and behaviour and to ensure green modes are commercially feasible and economically attractive; and
- Development and application of green transport **technology**.

# References

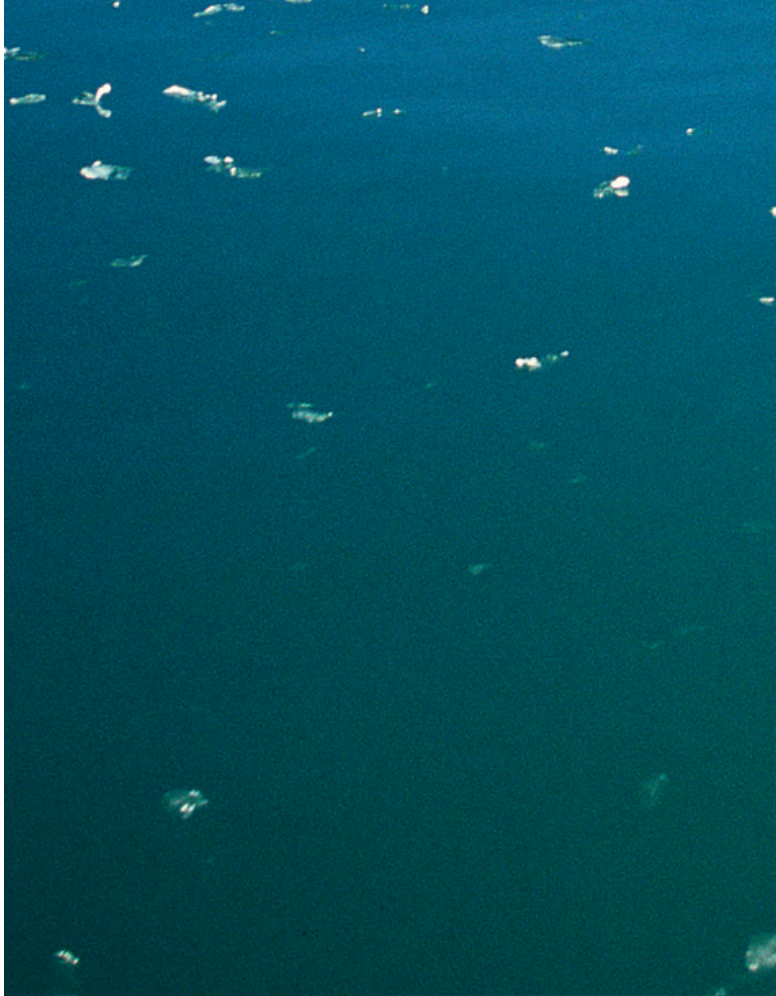
- ADB. (2009). Transport Operations, Asian Development Bank, Manila. Available at: <http://www.adb.org/Transport/operations.asp>
- AITD. (2003). Socioeconomic Impact of National Highway Four-Laning Project. Asian Institute of Transport Development.
- Bank of Indonesia. (2008). Press release – Government explanation on government of Indonesia decree regarding the reduction of fuel subsidy and other related policies. Available at: <http://www.bi.go.id/web/en/Publikasi/Investor+Relation+Unit/Government+Press+Release/Fuel+Subsidy.htm>
- Binsted, A., Bongardt, D., Dalkmann, H. and Wemaere, M. (2010). *What's next? The outcome of the climate conference in Copenhagen and its implications for the land transport sector*. Available at: [http://www.transport2012.org/bridging/ressources/files/1/611,556,Copenhagen\\_report\\_FINAL\\_Bridging.pdf](http://www.transport2012.org/bridging/ressources/files/1/611,556,Copenhagen_report_FINAL_Bridging.pdf)
- Binsted, A., Davies, A. and Dalkmann, H. (2010). *Copenhagen Accord NAMA Submissions Implications for the Transport Sector*. Available at: [http://www.transport2012.org/bridging/ressources/files/1/913,828,NAMA\\_submissions\\_Summary\\_030810.pdf](http://www.transport2012.org/bridging/ressources/files/1/913,828,NAMA_submissions_Summary_030810.pdf)
- Binswanger, H., Khandker, S. and Rosenzweig, M. (1993). "How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India." *Journal of Development Economics*, Vol. 41, pp. 337-336. Elsevier.
- Bongardt, D. and Schmid, D. (2009). *Towards Technology Transfer in the Transport Sector: An Analysis of Technology Needs Assessments*. Available at: <http://www.transport2012.org/bridging/ressources/documents/1/449,TechnoTransf.pdf>
- Bridging the Gap. (2010). *Reducing Emissions through Sustainable Transport (REST)*. Available at: [http://www.transport2012.org/bridging/ressources/files/1/817,Transport\\_sectoral\\_approach\\_18-08-20.pdf](http://www.transport2012.org/bridging/ressources/files/1/817,Transport_sectoral_approach_18-08-20.pdf)
- Button, K. (1993). *Transport Economics* 2ED. Edward Elgar, Cheltenham.
- CABE. (2007). "Paved with gold: The real value of good street design." Commission for Architecture and Built Environment. Available at: <http://www.cabe.org.uk/files/paved-with-gold.pdf>
- Cambridge Systematics. (2009). "Economic Impact of public transportation investment." Prepared for the American Public Transportation Association.
- CEU. (2002). "Environmental Impacts of Transport." Prepared by the Department of Environmental Sciences and Policy, Central European University. Available at: <http://web.ceu.hu/envsci/sun/EnvImpactsOfTransport.pdf>
- Chmelynski, H. (2008). National Economic Impacts per \$1 Million Household Expenditures (2006); Spreadsheet Based On IMPLAN Input-Output Model, Jack Faucett Associates. Available at: <http://www.jfaucett.com>.
- ClimateWorks. (2010). Global Transport Carbon Abatement Cost Curve. Available at: <http://www.climateworks.org/network/sectors/sector/?id=94067c68-ee84-8275-c566-f97a2f59b590>
- Commission of the European Communities. (2009). "Cost Estimate for S.1733 Clean Energy Jobs and American Power Act Clean Energy and Security Act." December 16, Washington, DC.
- Creutzig, F. and He, D. (2009). "Climate change mitigation and co-benefits of feasible transport demand policies in Beijing. Transportation Research Part D." *Transport and Environment*, Vol. 14, No. 2, March, pp. 120-131.
- Dacy, D.C., Kuenne, R.E. and McCoy, P. (1980). Employment impacts of achieving automobile efficiency standards in the United States. *Applied Economics* 12, 295-312.
- Dalkmann, H. (2009). "Policies for Low Carbon Transport" in Leather, J. and the Clean Air Initiative for Asian Cities Center Team. *Rethinking Transport and Climate Change – New Approaches to Mitigate CO<sub>2</sub> Emissions from Land Transport in Developing Asia*. Asian Development Bank, Manila. Available at: <http://www.adb.org/documents/papers/adb-working-paper-series/ADB-WP10-Rethinking-Transport-Climate-Change.pdf>
- Dalkmann, H., Bongardt, D., Sakamoto, K., Neuweg, I. and Avery, K. (2010). *Formulating NAMAs in the Transport Sector: Kick-starting action*. Available at: [http://www.transport2012.org/bridging/ressources/documents/1/567,Guidance\\_on\\_Transport\\_NAMA.pdf](http://www.transport2012.org/bridging/ressources/documents/1/567,Guidance_on_Transport_NAMA.pdf)
- Dalkmann, H. and Brannigan, C. in GTZ (2007). *Transport and Climate Change. Module 5e: Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*. Available at: <http://siteresources.worldbank.org/EXTAFRUSUBSAHTRA/Resources/gtz-transport-and-climate-change-2007.pdf>
- Davis, L. and Kahn, M. (2009). *International Trade in Used Vehicles: The Environmental Consequences of NAFTA*.
- Dextre, J.C. (2009). De la circulación a la movilidad. Documento de trabajo, Área de Transporte de la Pontificia Universidad Católica del Perú.
- European Commission (EC). (2011). Reducing emissions from the aviation sector. Available at: [http://ec.europa.eu/clima/policies/transport/aviation/index\\_en.htm](http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm)
- ECMT. (2004). Assessment and decision making for sustainable transport. European Conference of Ministers of Transport.
- Ecodrive.org. (2010). What is ecodriving? Available at: <http://ecodrive.org/What-is-ecodriving.228.0.html>
- The Eddington Review. (2006). "Transport's role in sustaining UK's Productivity and Competitiveness: The Case for Action". London.
- EDRG. (2009). *Job Impacts of Spending on Public Transportation: An Update*. Prepared for the American Public Transportation Association. Economic Development Research Group. Available at: [http://www.apta.com/gap/policyresearch/Documents/jobs\\_impact.pdf](http://www.apta.com/gap/policyresearch/Documents/jobs_impact.pdf)
- EEA. (2000). European Environment Agency Says Transport Sector Falling Short of Goals, by Walsh, M. P in *Car Lines, Issue 2000-3*.
- EEA. (2008). Beyond transport policy – exploring and managing the external drivers of transport demand. European Environment Agency, Copenhagen. Available at: [http://www.eea.europa.eu/publications/technical\\_report\\_2008\\_12](http://www.eea.europa.eu/publications/technical_report_2008_12)
- EEA. (2010). Towards a resource efficient transport system, TERM 2009: Indicators tracking transport and environment in the European Union. Copenhagen. Available at: <http://www.eea.europa.eu/publications/towards-a-resource-efficient-transport-system>
- Embarq. (no date). Aguascalientes – Housing. A New Urban Paradigm. Available at: <http://www.embarq.org/en/project/aguascalientes-housing>
- Embarq. (2011). Latin America – SIBRT. Available at: <http://www.embarq.org/en/project/latin-americas-sibrt>
- FHWA. (2000). Operations Story. Federal Highway Administration, Washington, DC. Available at: <http://www.ops.fhwa.dot.gov/aboutus/opstory.htm>
- FIA Foundation, UNEP, IEA and ITF. (2009). 50by50: Global Fuel Economy Initiative. Available at: <http://www.fiafoundation.org/50by50/pages/homepage.aspx>
- Foster, V. and Briceño-Garmendia, C. (2010). Africa's Infrastructure – A time for Transformation. Available at: <https://www.infrastructureafrica.org/aicd/flagship-report>
- Frazila, B. (2009). Unpublished report on transport and climate change.
- GEF. (2009). *Investing in Sustainable Urban Transport: The GEF Experience*. Global Environment Facility, Washington, DC. Available at: [http://www.thegef.org/gef/sites/thegef.org/files/publication/Investing-Urban-Transportation\\_0.pdf](http://www.thegef.org/gef/sites/thegef.org/files/publication/Investing-Urban-Transportation_0.pdf)
- Geller, H., DeCicco, J. and Laitner, S. (1992). Energy efficiency and job creation: the employment and income benefits from investing in energy conservation technologies. Report No. ED922, American Council for an Energy-Efficient Economy; Washington, DC.
- Greene, D. L. (1991). Short-run Pricing Strategies to Increase Corporate Average Fuel Economy. *Economic Inquiry*, 29, 101-114.
- Green Fiscal Commisison. (2009). The Case for Green Fiscal Reform: Final Report of the UK Green Fiscal Commission. London.

- GTZ. (2002). *Transport and Poverty in Developing Countries*. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn. Available at: <http://www.gtkp.com/uploads/20091127-182046-6236-en-urban-transport-and-poverty.pdf>
- Hatfield, T. and Tsai, P. (2010). *The Global Benefits of Phasing Out Leaded Fuel*. California State University, Northridge, California.
- Hayashi, Y. (1989). *Issues in Financing Urban Rail Transit Projects and Value Captures*. Department of Civil Engineering, Nagoya University, Nagoya.
- Hayashi, Y. and Kato, H. (2000). *A Model System for the Assessment of the Effects of Car and Fuel Green Taxes on CO<sub>2</sub> Emissions*. Department of Geotechnical and Environmental Engineering, Nagoya University, Nagoya.
- ICC. (2007). *Business perspectives on a long-term international policy approach to address global climate change*. Department of Policy and Business Practices, International Chamber of Commerce, Paris. Available at: [http://www.iccwbo.org/uploadedFiles/ICC/policy/Environment/ICC\\_Longer\\_term\\_paper\\_FINAL.pdf](http://www.iccwbo.org/uploadedFiles/ICC/policy/Environment/ICC_Longer_term_paper_FINAL.pdf)
- ICCT. (2009). *A policy-relevant summary of black carbon climate science and appropriate emission control strategies*. International Council on Clean Transportation, Washington, DC. Available at: [http://www.theicct.org/pubs/BCsummary\\_dec09.pdf](http://www.theicct.org/pubs/BCsummary_dec09.pdf)
- ICF International. (2009). *Sub-Saharan Africa Refinery Project – Final Report*. Available at: [http://www.unep.org/pcfv/PDF/Final\\_Executive\\_Summary\\_6-08-09.pdf](http://www.unep.org/pcfv/PDF/Final_Executive_Summary_6-08-09.pdf)
- IEA. (2005). *CO<sub>2</sub> Emissions from Fuel Combustion 1971-2004*. International Energy Agency, Paris.
- IEA. (2006). *World Energy Outlook 2006*. International Energy Agency, Paris. Available at: <http://www.worldenergyoutlook.org/2006.asp>
- IEA. (2008). *Energy Technology Perspectives: Scenarios and Strategies up to 2050. Part 1, Technology and the Global Energy Economy to 2050*. International Energy Agency, Paris.
- IEA. (2009a). *World Energy Outlook 2009*. International Energy Agency, Paris.
- IEA. (2009b). *Transport, Energy and CO<sub>2</sub>: Moving towards Sustainability*. International Energy Agency, Paris.
- IEA. (2010). *Energy Technology Perspectives*. International Energy Agency, Paris.
- IMO. (2009). *Prevention of Air Pollution from Ships*. Marine Environment Protection Committee: 59th session. International Maritime Organization, London.
- Jacobs, G. and Aeron-Thomas, A. (2000). *A review of global road accident fatalities*. RoSPA Road Safety Congress, Plymouth, UK, 3 - 7 March 2000.
- Jacobs, G., Aeron-Thomas, A. and Astrop, A. (2005). *Estimating global mortality and burden of disease, 2002-2030: data sources, methods and results*. World Health Organization, Geneva.
- Kaczynska, M. (2009). *Impact of transport on biodiversity and nature protection legislation*. European Investment Bank Workshop May 2009. Available at: [http://www.eib.org/attachments/general/events/brussels\\_15052009\\_impact-on-biodiversity.pdf](http://www.eib.org/attachments/general/events/brussels_15052009_impact-on-biodiversity.pdf)
- Kebin, H. and Chang, C. (1999). *Present and Future Pollution from Urban Transport in China*. China Environment Series, 3, 38-50. Available at: <http://wwics.si.edu/topics/pubs/ACF4BA.pdf>
- Khandler, S. Baakht, H. and Koolwal, G. (2009). "The poverty impact of rural roads: evidence from Bangladesh." *Economic Development and Cultural Change*, Vol. 57, Issue 4, pp. 685-722.
- King, J. (2007). *The King Review of low carbon cars. Part I: the potential for CO<sub>2</sub> reduction*. HM Treasury, Norwich. Available at: [http://www.hm-treasury.gov.uk/d/pbr\\_csr07\\_king840.pdf](http://www.hm-treasury.gov.uk/d/pbr_csr07_king840.pdf)
- Lambert, J. (2002). *International Meeting on Acoustic Pollution in Cities*. Madrid. Inrets-Lte, Cedex. Available at: <http://www.inrets.fr/ur/lte/publications/publications-pdf/Lambert-publi/Madrid-2002.pdf>
- Litman, T. (2009). *Smart Transportation Economic Stimulation: Infrastructure Investments That Support Economic Development*. VTPI. Available at: [http://www.vtpi.org/econ\\_stim.pdf](http://www.vtpi.org/econ_stim.pdf)
- Litman, T. (2010). *Win-Win Transportation Emission Reduction Strategies: Good News for Copenhagen*.
- Liu, Z. (2005). "Transport Investment, Economic Growth and Poverty Reduction." *Journal of Transport and Infrastructure, The Asian Journal*, Vol. 12, No. 1, August. Available at: <http://siteresources.worldbank.org/INTURBANTRANSPORT/Resources/340136-1152550025185/TransportGrowth&Poverty-ZL.pdf>
- Martínez Sandoval, A. (2005). *Ruido por tráfico urbano: Conceptos, medidas descriptivas y valoración económica*. (Urban traffic noise: Concepts, descriptive measures and economic value). La Revista Económica y Administración – Universidad Autónoma de Occidente, Cali, Colombia. Available at: [http://dali.uao.edu.co:7777/pls/portal/docs/PAGE/UNIAUTONOMA\\_INVESTIGACIONES/REVISTA\\_ECONOMIK/NUMEROS/ECONOMIA2/RUIDO\\_0.PDF](http://dali.uao.edu.co:7777/pls/portal/docs/PAGE/UNIAUTONOMA_INVESTIGACIONES/REVISTA_ECONOMIK/NUMEROS/ECONOMIA2/RUIDO_0.PDF)
- McKinnon, A. (2008). "The Potential of Economic Incentives to Reduce CO<sub>2</sub> Emissions from Goods Transport." Paper prepared for the 1st International Transport Forum on Transport and Energy: the Challenge of Climate Change. Leipzig, 28-30 May. Available at: <http://www.internationaltransportforum.org/Topics/Workshops/WS3McKinnon.pdf>
- McKinsey & Company. (2009). *Roads toward a low-carbon future: Reducing CO<sub>2</sub> emissions from passenger vehicles in the global road transportation system*. Available at: [http://www.mckinsey.com/clientservice/ccsi/pdf/roads\\_toward\\_low\\_carbon\\_future.pdf](http://www.mckinsey.com/clientservice/ccsi/pdf/roads_toward_low_carbon_future.pdf)
- McKinsey & Company. (2010). *Impact of the financial crisis on carbon economics*.
- Motor Trader. (2009). *Scrappage schemes boost European Car Sales by 11.2 per cent in October*. Available at: <http://www.motortrader.com/industry-news/car-dealer-news/29492-scrappage-schemes-boost-european-car-sales-rise-112-per-cent-in-october.html>
- Newman, P., Manins, P.C.L., Simpson, R., and Smith, N. (1997). *Reshaping cities for a more sustainable future: exploring the link between urban form, air quality, energy and greenhouse gas emissions*. Australian Housing and Urban Research Institute.
- North, D. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press.
- OECD. (2002). *Policy Instruments for Achieving Environmentally Sustainable Transport*. Organisation for Economic Co-operation and Development, Paris.
- OECD. (2009). *Territorial Reviews: Toronto, Canada*. Organisation for Economic Co-operation and Development, Paris. Available at: <http://www.oecd.org/gov/regional/toronto>. Retrieved 12-10-2009.
- OEF. (2006). *The Economic Contribution of the Aviation Industry in the UK*. Oxford Economic Forecasting, Oxford. Available at: [www.oef.com/Free/pdfs/Aviation2006Final.pdf](http://www.oef.com/Free/pdfs/Aviation2006Final.pdf)
- Parry, I. and Small, K. (2007). *Should Urban Transit Subsidies Be Reduced?* Available at: <http://www.rff.org/documents/RFF-DP-07-38.pdf>
- Petersen, M., Sessa, C., Enei, R., Ulied, A., Larrea, E., Obisco, O., Timms, P. and Hansen, C. (2009) *Report on Transport Scenarios with a 20 and 40 Year Horizon, Final report*. Available at: [http://ec.europa.eu/transport/strategies/studies/doc/future\\_of\\_transport/2009\\_02\\_transvisions\\_report.pdf](http://ec.europa.eu/transport/strategies/studies/doc/future_of_transport/2009_02_transvisions_report.pdf)
- Rapuan, K.W., Rochow, J., and Garcia-Costas, A. (1997). *Myths and Realities of Phasing Out Leaded Gasoline*. Alliance To End Childhood Lead Poisoning. Washington, DC. Available at: <http://www.unep.org/pcfv/PDF/Pub-AECLP-Myths.pdf>
- Reitveld, P. and Stough, R. (2004). "Institutions, regulations and sustainable transport: A cross national perspective". *Transport Review*, Vol. 24, No. 6, pp.707-719, November.
- SACTRA. (1997). *Transport and the economy: summary report*. The Standing Advisory Committee on Trunk Road Assessment. Available at: <http://www.cipra.org/alpknowhow/publications/sactra/sactra1>
- Sælensminde, K. (2002). *Walking and Cycling Track Networks in Norwegian Cities: Cost-Benefit Analysis Including Health Effects and External Costs of Road Traffic*. Institute of Transport Economics, Oslo. Available at: [www.toi.no/getfile.php/Publikasjoner/T%20D8I%20rapporter/2002/567-2002/sum-567-02.pdf](http://www.toi.no/getfile.php/Publikasjoner/T%20D8I%20rapporter/2002/567-2002/sum-567-02.pdf)



- Sakamoto, K. (2009). in Leather, J. and the Clean Air Initiative for Asian Cities Center Team. Rethinking Transport and Climate Change – New Approaches to Mitigate CO<sub>2</sub> Emissions from Land Transport in Developing Asia, Asian Development Bank, Manila. Available at: <http://www.adb.org/documents/papers/adb-working-paper-series/ADB-WP10-Rethinking-Transport-Climate-Change.pdf>
- Sanchez-Triana, E., Ahmed, K., and Awe, Y. (2007). "Environmental Priorities and Poverty Reduction – A Country Environmental Analysis for Colombia." World Bank, Washington, DC. Available at: [http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/08/13/000020953\\_20070813145440/Rendered/PDF/405210Env0prio101OFFICIAL0USE0ONLY1.pdf](http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/08/13/000020953_20070813145440/Rendered/PDF/405210Env0prio101OFFICIAL0USE0ONLY1.pdf)
- Sewill, B. (2005). *Fly now, grieve later: How to reduce the impact of air travel on climate change*. Aviation Environment Federation, London. Available at: <http://www.aef.org.uk/downloads/FlyNowFull.pdf>
- STPP. (2004). Setting the Record Straight: Transit, Fixing Roads and Bridges Offer Greatest Job Gains. Surface Transportation Policy Project. Available at: [www.transact.org/library/decoder/jobs\\_decoder.pdf](http://www.transact.org/library/decoder/jobs_decoder.pdf)
- The Telegraph Business Club and IBM. (2009). "Future Focus: Travel." *The Telegraph Business Club and IBM*, June. Available at: [https://www-304.ibm.com/businesscenter/cpe/download0/177501/IBM\\_White\\_Paper\\_3.pdf](https://www-304.ibm.com/businesscenter/cpe/download0/177501/IBM_White_Paper_3.pdf)
- Texas Transportation Institute. (2010). Urban Mobility Report 2010. Available at: [http://tti.tamu.edu/documents/mobility\\_report\\_2010.pdf](http://tti.tamu.edu/documents/mobility_report_2010.pdf)
- Timilsina, G. and Dulal, B. (2009). *A Review of Regulatory Instruments to Control Environmental Externalities from the Transport Sector*. Available at: [http://www-wds.worldbank.org/external/default/WDSContentServer/IB/2009/03/17/000158349\\_20090317095252/Rendered/PDF/WPS4867.pdf](http://www-wds.worldbank.org/external/default/WDSContentServer/IB/2009/03/17/000158349_20090317095252/Rendered/PDF/WPS4867.pdf)
- UITP (International Association of Public Transport) database (2005). A Panorama of Urban Mobility Strategies in Developing Countries, presentation at the World Bank on 5 September 2006 by Hubert Metge and Aurélie Jehanno of Systra. Available at: <http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1122908670104/1504838-1157987224249/2SYSTRA1.pdf>
- UNCTAD. (2008). *World Investment Report 2008*. United Nations Conference on Trade and Development, Geneva. Available at: [www.unctad.org/en/docs/wir2008\\_en.pdf](http://www.unctad.org/en/docs/wir2008_en.pdf)
- UNECE. (2009). *Working together for Sustainable and Healthy Transport: Guidance on Supportive Institutional Conditions for Policy Integration of Transport, Health and Environment*, United Nations Economic Commission for Europe, Geneva. Available at: <http://www.unece.org/thepep/en/publications/WorkingTogether.Guidance.en.pdf>
- UNEP. (2008a). *Green Jobs: Towards decent work in a sustainable, low-carbon world Part II – Employment Impacts: Transportation*. United Nations Environment Programme, Nairobi. Available at: [http://www.unep.org/labour\\_environment/PDFs/Greenjobs/UNEP-GreenJobs-E-Bookp148-171-Part2section3.pdf](http://www.unep.org/labour_environment/PDFs/Greenjobs/UNEP-GreenJobs-E-Bookp148-171-Part2section3.pdf)
- UNEP. (2008b). *Reforming Energy Subsidies – Opportunities to Contribute to the Climate Change Agenda*. United Nations Environment Programme, Nairobi. Available at: [http://www.unep.org/pdf/pressreleases/reforming\\_energy\\_subsidies.pdf](http://www.unep.org/pdf/pressreleases/reforming_energy_subsidies.pdf)
- UNEP. (2008c). *Toolkit for Clean Vehicles Fleet Strategy Development*, United Nations Environment Programme, Nairobi. Available at: <http://www.unep.org/tnt-unep/toolkit>
- UNEP. (2009). *Global Trends in Sustainable Energy Investment 2009*. Analysis of trends and Issues in the financing of renewable energy and energy efficiency. United Nations Environment Programme, Nairobi. Available at: <http://www.sefi.unep.org>
- UNEP. (2010). *Driving a Green Economy Through Public Finance and Fiscal Policy Reform*. United Nations Environment Programme, Nairobi. Available at <http://www.unep.org/greenconomy/Portals/30/docs/DrivingGreenEconomy.pdf>
- UNEP and FIA Foundation (Forthcoming). *Share the Road Initiative Report*. Will be available at: <http://www.unep.org/transport/sharetheroad>.
- UNEP Risoe Centre. (2010). CDM Pipeline overview. Copenhagen. Available at: <http://cdmpipeline.org/publications/CDMpipeline.xlsx>
- UNESCAP, UN-ECLAC, and Urban Design Lab. (2010). "Are We Building Competitive and Liveable Cities? Guidelines on Developing Eco-efficient and Sustainable Urban Infrastructure in Asia and Latin America." United Nations Economic and Social Commission for Asia and Pacific, United Nations Economic Commission for Latin America and Caribbean, and Urban Design Lab. Available at: [http://www.unescap.org/esd/environment/infra/documents/UN\\_Sustainable\\_Infrastructure\\_Guidelines\\_Preview.pdf](http://www.unescap.org/esd/environment/infra/documents/UN_Sustainable_Infrastructure_Guidelines_Preview.pdf)
- U.S. Department of Transportation. (2009). *Car allowance rebate system*. Washington, DC. Available at: <http://www.cars.gov/fac>
- Vanderschuren, M. (2003). *Optimising Settlement Location Planning in Cape Town*. University of Cape Town, Cape Town.
- Van de Walle, D. (2002). "Choosing Rural Road Investments to Help Reduce Poverty". *World Development*, Vol. 30, No.4, pp.575-589.
- Veolia Transport, International Association of Public Transport (UITP) and UNEP. (2009) *Strategies to bring land transport into the climate change negotiations: Discussion Paper*.
- VTPI. (2007). *Transportation Cost and Benefit Analysis II – Barrier Effect*. Victoria Transport Policy Institute, British Columbia. Available at: <http://www.vtppi.org/tca/tca0513.pdf>
- VTPI. (2010). *Economic Development Impacts: Evaluating Impacts On Productivity, Employment, Business Activity and Wealth*. TDM Encyclopaedia. 13 December. Victoria Transport Policy Institute, British Columbia. Available at: <http://www.vtppi.org/tdm/tdm54.htm>
- WBCSD. (2004). *Mobility 2030: Meeting the challenges to sustainability*. World Business Council for Sustainable Development, Geneva. Available at: <http://www.wbcd.org/web/publications/mobility/mobility-full.pdf>
- Weisbrod, G. and Reno, A. (2009). *Economic Impact of Public Transportation Investment*. Prepared for American Public Transportation Association. Available at: [http://www.apta.com/resources/reportsandpublications/Documents/economic\\_impact\\_of\\_public\\_transportation\\_investment.pdf](http://www.apta.com/resources/reportsandpublications/Documents/economic_impact_of_public_transportation_investment.pdf)
- Weisbrod, G., Vary, D. and Treyz, G. (2003). *Measuring the Economic Costs of Urban Traffic Congestion to Business*. Available at: <http://www.edrgroup.com/pdf/weisbrod-congestion-trr2003.pdf>
- WHO. (2008). *Economic valuation of transport-related health effects. Review of methods and development of practical approaches, with a special focus on children*. World Health Organization, Geneva. Available at: [http://www.euro.who.int/\\_data/assets/pdf\\_file/0008/53864/E92127.pdf](http://www.euro.who.int/_data/assets/pdf_file/0008/53864/E92127.pdf)
- WHO. (2009a). *Global status report on road safety*. World Health Organization, Geneva. Available at: [http://www.who.int/violence\\_injury\\_prevention/road\\_safety\\_status/2009/en/](http://www.who.int/violence_injury_prevention/road_safety_status/2009/en/)
- WHO. (2009b). *Night noise guidelines for Europe*. World Health Organization, Geneva. Available at: <http://www.euro.who.int/document/e92845.pdf>
- World Bank. (2001). *Cities on the move: a World Bank urban transport strategy review*. Washington, DC. Available at: [http://siteresources.worldbank.org/INTURBANTRANSPORT/Resources/cities\\_on\\_the\\_move.pdf](http://siteresources.worldbank.org/INTURBANTRANSPORT/Resources/cities_on_the_move.pdf)
- World Bank. (2007). *A decade of action in transport – an evaluation of World Bank assistance to the transport sector, 1995-2005*. Washington, DC. Available at: <http://go.worldbank.org/FQPZR5DCN0>
- World Bank. (2009). *Low-Carbon Development for Mexico*. Washington, DC. Available at: <http://siteresources.worldbank.org/INTMEXICO/Resources/MEDECExecutiveSummaryEng.pdf>
- World Bank/ICA/PPIAF. (2009). *Attracting Investors to African Public-Private Partnerships: A Project Preparation Guide*. World Bank, The Infrastructure Consortium for Africa, and Public-Private Infrastructure Advisory Facility.





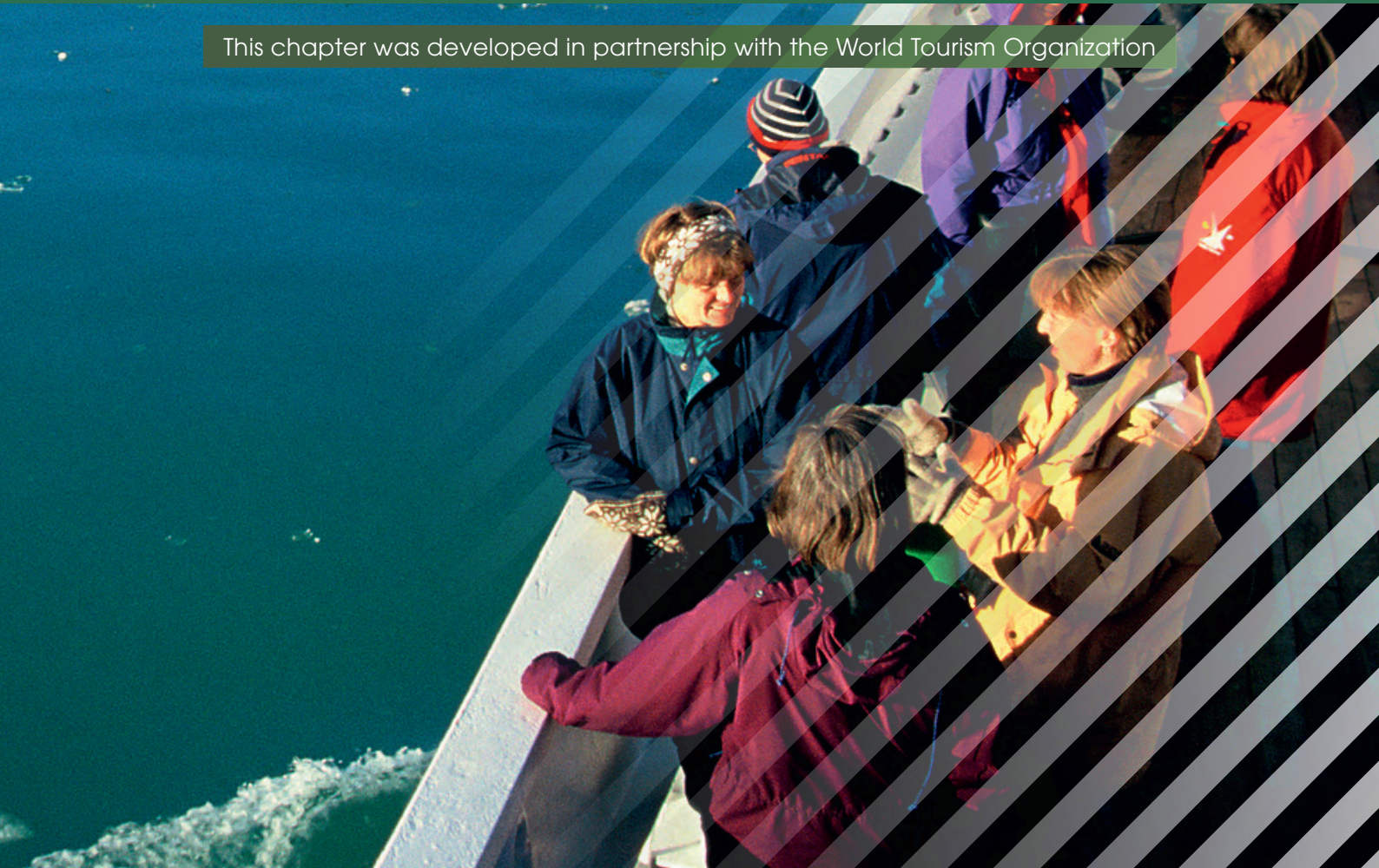




# Tourism

Investing in energy and resource efficiency

This chapter was developed in partnership with the World Tourism Organization





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## List of acronyms

ACIF	Amazon Carbon and Biodiversity Investment Fund	OECD	Organisation for Economic Co-operation and Development
BAU	Business-as-usual	PES	Payment for Ecosystem Services
CBD	Convention on Biological Diversity	PPI	Pro-poor income
ECLAC	Economic Commission for Latin America and the Caribbean	RM	Ringgit Malaysia, currency of Malaysia
CESD	Center on Ecotourism and Sustainable Development	ROI	Return on investment
CO <sub>2</sub>	Carbon dioxide	SIFT	Sustainable Investment and Finance in Tourism
CSR	Corporate Social Responsibility	SME	Small and medium-sized enterprise
DFI	Development Finance Institution	SNV	Netherlands Development Organization
DMO	Destination Management Organization	SPAN	Strengthening the Protected Area Network
ERT	Environment-related tourism	ST-EP	Sustainable Tourism for Eliminating Poverty Initiative
EU	European Union	TEEB	The Economics of Ecosystems and Biodiversity
FAO	Food and Agriculture Organization of the United Nations	TIES	The International Ecotourism Society
FDI	Foreign Direct Investment	TPRG	Tourism Planning Research Group
FONAFIFO	Costa Rica's National Forestry Financing Fund	TSA	Tourism Satellite Account
G2	Green Scenario 2	UNCCD	United Nations Convention to Combat Desertification
GDP	Gross Domestic Product	UNCTAD	United Nations Conference on Trade and Development
GEF	Global Environment Facility	UNEP	United Nations Environment Programme
GER	Green Economy Report	UNEP FI	United Nations Environment Programme Finance Initiative
GFANC	German Federal Agency for Nature Conservation	UNESCO	United Nations Educational, Scientific and Cultural Organization
GHG	Greenhouse gas	UNFCCC	United Nations Framework Convention on Climate Change
GSTC	Global Sustainable Tourism Criteria	UNWTO	World Tourism Organization
IEA	International Energy Agency	VFR	Visiting Friends and Relatives
ILO	International Labour Organization	WEF	World Economic Forum
IPA	Investment Promotion Agency	WTP	Willingness to Pay
ISO	International Organization for Standardization	WTTC	World Travel and Tourism Council
ITF-STD	International Task Force on Sustainable Tourism Development	WWF	World Wide Fund for Nature
IUCN	International Union for Conservation of Nature		
LDCs	Least Developed Countries		
Mtoe	Million Tonnes of Oil Equivalent		

# Key messages

**1. Tourism has significant potential as a driver for growth for the world economy.** The tourism economy represents 5 per cent of world Gross Domestic Product (GDP), while it contributes to about 8 per cent of total employment. International tourism ranks fourth (after fuels, chemicals and automotive products) in global exports, with an industry value of US\$1 trillion a year, accounting for 30 per cent of the world's exports of commercial services or 6 per cent of total exports. There are around four billion estimated domestic arrivals every year and in 2010, some 940 million international tourists were recorded. Tourism is one of five top export earners in over 150 countries, while in 60 countries it is the number one export. It is also the main source of foreign exchange for one-third of developing countries and one-half of least developed countries (LDC).

**2. The development of tourism is accompanied by significant challenges.** The rapid growth in both international and domestic travel, the trends to travel farther and over shorter periods of time, and the preference given to energy-intensive transportation are increasing the non-renewable energy dependency of tourism, resulting in the sector's contribution of 5 per cent to global greenhouse gas (GHG) emissions, which is expected to grow substantially under a business-as-usual (BAU) scenario. Other challenges include excessive water consumption compared with residential water use, discharge of untreated water, the generation of waste, the damage to local terrestrial and marine biodiversity and the threats to the survival of local cultures, built heritage and traditions.

**3. Green tourism has the potential to create new, green jobs.** Travel and tourism are human-resource intensive, employing directly and indirectly 8 per cent of the global workforce. It is estimated that one job in the core tourism industry creates about one and a half additional or indirect jobs in the tourism-related economy. The greening of tourism, which involves efficiency improvements in energy, water and waste systems, is expected to reinforce the employment potential of the sector with increased local hiring and sourcing and significant opportunities in tourism oriented toward local culture and the natural environment.

**4. Tourism development can be designed to support the local economy and reduce poverty.** Local economic effects of tourism are determined by the share of tourism spending in the local economy as well as the amount of the resulting indirect economic activities. Increasing the involvement of local communities, especially the poor, in the tourism value chain can, therefore, contribute to the development of the local economy and to poverty reduction. For example, in Panama, households capture 56 per cent of total local tourism income. The extent of direct benefits to communities and poverty reduction will largely depend on the percentage of tourism needs that are locally supplied, such as products, labour, tourism services, and increasingly "green services" in energy and water efficiency and waste management. There is increasing evidence that more sustainable tourism in rural areas can lead to more positive poverty-reducing effects.

**5. Investing in the greening of tourism can reduce the cost of energy, water and waste and enhance the value of biodiversity, ecosystems and cultural heritage.** Investment in energy efficiency has been found to generate significant returns within a short payback period. Improving waste management is expected to save money for tourism businesses, create jobs and enhance the attractiveness of destinations. The investment requirement in conservation and restoration is small relative to the value of forests, mangroves, wetlands, and coastal zones including coral reefs, which provide ecosystem services essential for the foundation of economic activities and for human survival; the value of ecosystems for tourists remains undervalued in many cases. Investment in cultural heritage—the largest single component of consumer demand for sustainable tourism—is among the most significant and usually profitable investments. Under a green economy investment scenario, tourism makes a larger contribution to GDP growth, while

significant environmental benefits include reductions in water consumption (18 per cent), energy use (44 per cent) and CO<sub>2</sub> emissions (52 per cent), compared with BAU.

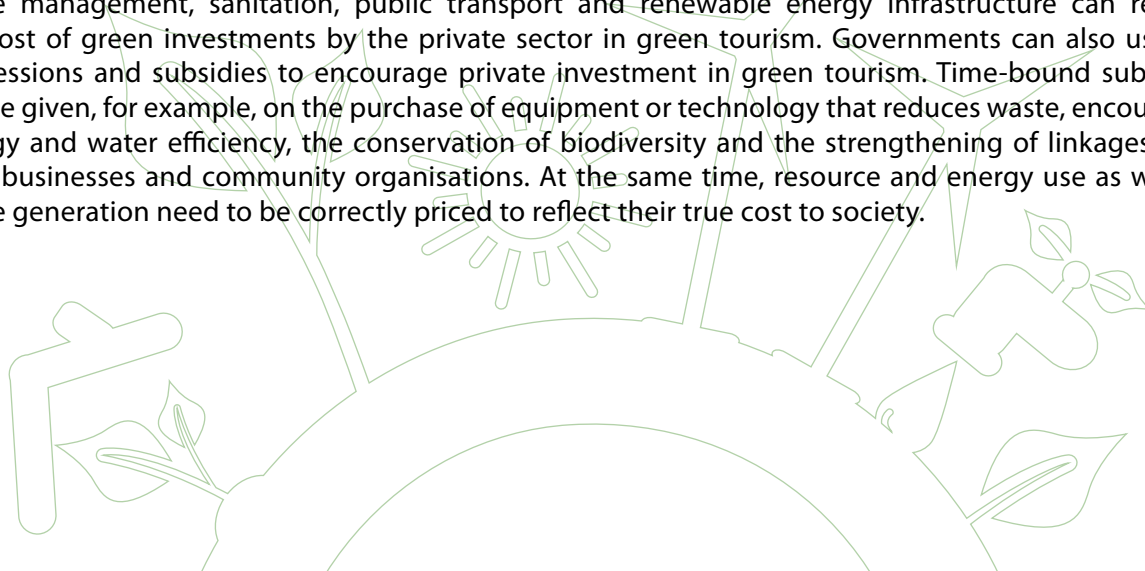
**6. Tourists are demanding the greening of tourism.** More than a third of travellers are found to favour environmentally-friendly tourism and be willing to pay between 2 and 40 per cent more for this experience. Traditional mass tourism has reached a stage of steady growth. In contrast, ecotourism, nature, heritage, cultural and “soft adventure” tourism are taking the lead and are predicted to grow rapidly over the next two decades. It is estimated that global spending on ecotourism is increasing at a higher rate than the industry-wide average growth.

**7. The private sector, especially small firms, can, and must be mobilised to support green tourism.** The tourism sector involves a diverse range of actors. The awareness of green tourism exists mainly in a selection of larger-scale firms. Smaller firms are mostly outside this sphere and diverse supplier groups may not be connected at all. Specific mechanisms and tools to educate small and medium-sized tourism-related enterprises are critical and are most effective when they are accompanied by actionable items. The promotion and widespread use of recognised standards for sustainable tourism, such as the Global Sustainable Tourism Criteria (GSTC), can help businesses improve sustainability performance, including resource efficiency, and assist in attracting additional investment and customers.

**8. Much of the economic potential for green tourism is found in small and medium-sized Enterprises (SMEs), which need better access to financing for investing in green tourism.** The majority of tourism businesses are SMEs with potential to generate greater income and opportunity from green strategies. Their single greatest limiting factor for greening, however, is lack of access to capital. Governments and international organisations can facilitate the financial flow to these important actors with an emphasis on contributions to the local economy and poverty reduction. Public-private partnerships can spread the costs and risks of large green tourism investments. Besides reducing administrative fees and offering favourable interest rates for green tourism projects, in-kind support such as technical, marketing or business administration assistance, could also help.

**9. Destination planning and development strategies are the first step towards the greening of tourism.** In developing tourism strategies, local governments, communities and businesses need to establish mechanisms for coordinating with ministries responsible for the environment, energy, labour, agriculture, transport, health, finance, security and other relevant areas. Clear requirements are needed in such areas as zoning, protected areas, environmental rules and regulations, labour rules, agricultural standards and health requirements particularly related to energy, emissions, water, waste and sanitation.

**10. Government investments and policies can leverage private sector actions on green tourism.** Government spending on public goods such as protected areas, cultural assets, water conservation, waste management, sanitation, public transport and renewable energy infrastructure can reduce the cost of green investments by the private sector in green tourism. Governments can also use tax concessions and subsidies to encourage private investment in green tourism. Time-bound subsidies can be given, for example, on the purchase of equipment or technology that reduces waste, encourages energy and water efficiency, the conservation of biodiversity and the strengthening of linkages with local businesses and community organisations. At the same time, resource and energy use as well as waste generation need to be correctly priced to reflect their true cost to society.





# 1 Introduction

This chapter seeks to make the case, primarily an economic one, for investing in the greening of tourism and it provides guidance on how to mobilise such investments. The objective is to inspire policy makers to support increased investment in greening the sector. The chapter shows how green investment in tourism can contribute to economically viable and robust growth, decent work creation, poverty alleviation, improved efficiency in resource use and reduced environmental degradation.

A growing body of evidence shows that greening tourism can lead to broad economic, social and environmental benefits for host countries and their communities (Mill and Morrison 2006, Rainforest Alliance 2010, World Economic Forum 2009a, Klytchnikova and Dorosh 2009). Tourism's potential for creating employment, supporting livelihoods and enabling sustainable development is huge, given that it is one of the main sources of foreign-exchange income—the principal source for one-third of developing countries and one-half of the world's LDCs according to the UN Conference on Trade and Development (UNCTAD 2010).

The chapter starts with an explanation of what is meant by greening tourism, followed by a discussion of the challenges and opportunities facing the sector. It then discusses the goals for greening the sector and the potential economic implications of green investment being made in the sector, including the results from a modelling exercise. Finally, the chapter presents the conditions that are important for enabling the greening of the sector.

## 1.1 Tourism in a green economy

Tourism in a green economy refers to tourism activities that can be maintained, or sustained, indefinitely in their social, economic, cultural and environmental contexts: "sustainable tourism". Sustainable tourism is not a special form of tourism; rather, all forms of tourism may strive to be more sustainable (UNEP and UNWTO 2005). A

clear distinction should be made between the concepts of ecotourism and sustainable tourism: "the term ecotourism itself refers to a segment within the tourism sector with focus on environmental sustainability, while the sustainability principles should apply to all types of tourism activities, operations, establishments and projects, including conventional and alternative forms".<sup>1</sup>

Sustainable tourism describes policies, practices and programmes that take into account not only the expectations of tourists regarding responsible natural-resource management (demand), but also the needs of communities that support or are affected by tourism projects and the environment (supply).<sup>2</sup> Thus, sustainable tourism aspires to be more energy efficient and climate sound (e.g. by using renewable energy); consume less water; minimise waste; conserve biodiversity, cultural heritage and traditional values; support intercultural understanding and tolerance; generate local income and integrate local communities with a view to improving livelihoods and reducing poverty. Making tourism businesses more sustainable benefits local communities and raises awareness and support for the sustainable use of natural resources. In this chapter, the conceptual and operational framework for sustainability in tourism is based on the Global Sustainable Tourism Criteria (GSTC), an international consensus on the minimum criteria that a tourism business should follow to approach sustainability.<sup>3</sup> A group of key variables based on the GSTC are used for the analysis of the greening of tourism in this chapter.

The movement toward more sustainable tourism promotes significant improvements in the performance of conventional tourism, as well as growth and improvements in smaller, niche areas centred on natural, cultural and community resources. The expansion of the latter, as a proportion of the industry as a whole, may have especially positive implications for biodiversity conservation and rural poverty reduction. However, the greening of conventional and mass tourism is likely to have its largest effects on resource use and management, as well as on increased economic spillovers and the inclusion of disadvantaged populations.

1. *International Year of Ecotourism 2002*, available at [http://www.unep.fr/scp/tourism/events/iye/pdf/iye\\_leaflet\\_text.pdf](http://www.unep.fr/scp/tourism/events/iye/pdf/iye_leaflet_text.pdf).

2. ILO (2010b) views sustainable tourism as "composed of three pillars: social justice, economic development, and environmental integrity. It is committed to the enhancement of local prosperity by maximizing the contribution of tourism to the destination's economic prosperity, including the amount of visitor spending that is retained locally. It should generate income and decent employment for workers without affecting the environment and culture of the tourists' destination and ensures the viability and competitiveness of destinations and enterprises to enable them to continue to prosper and deliver benefits in the long term".

3. The Global Sustainable Tourism Criteria (GSTC) were developed as part of a broad initiative managed by *The Partnership for Global Sustainable Tourism Criteria* (GSTC Partnership), a coalition of over 40 organisations working together to foster increased understanding of sustainable tourism practices and the adoption of universal sustainable tourism principles. The Partnership was initiated by the Rainforest Alliance, the United Nations Environment Programme (UNEP), the United Nations Foundation and the United Nations World Tourism Organization (UNWTO). See [www.gstccouncil.org/resource-center/gstc-criteria.htm](http://www.gstccouncil.org/resource-center/gstc-criteria.htm).

## 2 Challenges and opportunities for tourism in a green economy

### 2.1 Challenges

The tourism industry faces a multitude of significant sustainability-related challenges. Challenges that need to be resolved through the greening of the industry include (1) energy and GHG emissions; (2) water consumption; (3) waste management; (4) loss of biological diversity; and, (5) effective management of cultural heritage.

#### Energy and GHG emissions

The tourism sector's growing consumption of energy, especially in travel and accommodation, and its dependence on fossil fuels has important implications for global GHG emissions and climate change as well as for future business growth. Several elements contribute to tourism's increasing energy consumption, including growth rates in international tourist arrivals and domestic travel; trends to travel further and over shorter periods of time; as well as preference given to energy-intense transportation (e.g. aircraft and car travel over train and bus, and flying first and business class instead of economy, (Peeters et al. 2010). The sustainability and competitiveness of tourism depends in part on energy efficiency (reductions in overall energy use) and a more intensive use of renewable resources.

After transport, accommodation is the most energy-intensive component of the tourism industry, through its demand for heating or cooling, lighting, cooking (in restaurants), cleaning, pools and, in tropical or arid regions, the desalination of seawater. A general rule is that the more luxurious the accommodation, the more energy will be used. In a wide review of studies, energy-use in hotels range between 25 and 284 MJ/guest-night (Peeters et al. 2010). Tourism-related transport consumption of energy is related to travel mode. Coach and rail transport, cars and buses, aircraft and cruise ships have diverse energy intensities.<sup>4</sup>

There is no systematic international country dataset on energy consumption from tourism activities. The UNWTO and UNEP (2008) estimate 250 MJ per person is consumed through activities not related to travel

to the destination or accommodation on an average international tourist trip, 50 MJ per person is expended on shorter and less activity-oriented business trips and 100 MJ per person for Visiting Friends and Relatives (VFR) trips. The weighted global average of energy consumption for activities of international tourists is estimated at 170 MJ per trip, excluding transport and accommodation. As a comparison, world daily energy consumption per capita is estimated at 135 MJ (a value that includes energy generation and industry).<sup>5</sup>

Given the rising global trend for travel and the growing energy intensity of most trips, future emissions from the tourism sector are expected to increase substantially, even considering current trends in technological energy-efficiency gains in transport (air and ground) and accommodation. Tourism is estimated to create about 5 per cent of total GHG emissions (1,302 Mt CO<sub>2</sub>), primarily from tourist transport (75 per cent) and accommodation (21 per cent, mainly from air-conditioning and heating systems). A globally-averaged tourist journey is estimated to generate 0.25 tonnes of CO<sub>2</sub> (UNWTO and UNEP 2008). The World Economic Forum (WEF 2009b), using a different set of sub-sectors, estimated global GHG emissions from tourism to be 13 per cent higher (1,476 Mt CO<sub>2</sub> in 2005). The report distinguishes direct and indirect emissions from tourism, with direct emissions being defined as "carbon emissions from sources that are directly engaged in the economic activity of the tourism and travel sector." While these are included in the WEF estimate, indirect emissions are excluded, i.e. emissions from electricity usage in airline or travel agent offices, and emissions from transportation of hotel consumables, such as food or toiletries (Peeters et al. 2010). Scott et al. (2010) estimate the sector contributed between 5.2 per cent and 12.5 per cent of all anthropogenic radiative forcing in 2005.

Over the next 30-50 years, GHG emissions from the tourism sector are projected to grow substantially in a business-as-usual scenario, in large part because emissions from aviation, the most important emitter in the industry, are expected to grow by at least a factor of 2 to 3 (UNWTO and UNEP 2008, WEF 2009b). Aviation

4. For instance, in New Zealand, the total energy consumed for tourism transport and accommodation is distributed by 43 per cent for road transport, 42 per cent for air travel, 2 per cent for sea transport and 1 per cent for rail transport, with accommodation comprising the remaining 12 per cent. For local travel, coach tourism consumes the greatest energy per day, followed by camper tourists, soft comfort and auto tourists (Becken et al. 2003).

5. Own estimation with data from the International Energy Agency, available at <http://data.iea.org/ieastore/default.asp>.

and tourism are expected to account for a large share of emissions unless a major change in the emission trajectories is achieved (Peeters et al. 2010).

### Water consumption

While water use by tourism, on a global basis, is far less important than agriculture, industry, or urban domestic use, in some countries and regions, tourism can be the main factor in water consumption. In such areas, it can increase pressure on already diminished water resources and compete with other sectors as well as subsistence needs of local populations (Box 1). Tourism can also directly affect water quality, for example, through the discharge of untreated sewage or freshwater abstraction (Gössling 2010).

Global direct water consumption by international tourism (accommodation only) is estimated to be 1.3 km<sup>3</sup> per year (Gössling 2005). Available data suggests that direct water use in tourism varies between 100 and 2,000 litres per guest night, with a tendency for larger, resort-style hotels to use significantly more water than smaller, pension-like establishments or campsites. The main water-consuming factors are golf courses, irrigated gardens, swimming pools, spas, wellness facilities and guest rooms.

UNEP (2003) estimates that in the USA, tourism and recreation consume 946 million cubic metres of water per year, of which 60 per cent is linked to lodging (mostly spent on guest consumption, landscape and property management and laundry activities), and another 13 per cent is for foodservice. Total yearly water consumption

by tourism in Europe is estimated at 843 million cubic metres. Each tourist consumes 300 litres of freshwater per day on average, whereas luxury tourists can consume up to 880 litres. By comparison, average per capita residential consumption in Europe is estimated at 241 litres per day.<sup>6</sup>

### Waste management

Waste management is another increasing and well-recognised challenge in the industry. Every international tourist in Europe generates at least 1 kg of solid waste per day, and up to 2 kg/person/day for the USA (UNEP 2003). By comparison, CalRecovery and UNEP (2005) report total country waste generation, including industrial and other sources, for Austria (1.18 kg/person/day), Mexico (0.68 kg/person/day), India (0.4 kg/person/day) and the USA (2.3 kg/person/day).

Impacts are also considerable for wastewater management, even in high-income countries. In the Mediterranean region, for instance, it is commonplace for hotels to discharge untreated sewage directly into the sea (WWF 2004), with 60 per cent of water used in tourism resulting in sewage in need of disposal (GFANC 1997). In the European Mediterranean, only 30 per cent of municipal wastewater from coastal towns receives any treatment before discharge. Anecdotal evidence suggests that this is also the case in many other countries outside the European Union (Gössling 2010).

6. Author's estimation with data from AQUASTAT-FAO. Available at <http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/dbase/index.stm>.

## Box 1: Water consumption for tourism and local communities

Tourism development is concentrated in coastal areas and on small islands, where potable water is typically scarce. This scarcity can be caused by either a physical absence of freshwater, or because the necessary infrastructure or resources are lacking. A tourism-thirsty industry can secure its water needs wherever it operates, although this can create situations of stark water inequity between tourists and neighbouring communities. Tourism's water demands can even lead to the appropriation of supply to the detriment of local domestic and agricultural needs, caused by the overexploitation of aquifers and reservoirs and the lowering of groundwater tables.

In a popular resort area of one South Asian country, for example, privately-owned water tankers buy water from villages through local elites and transport it to supply nearby hotels. This leaves villagers with water supply to their communal standpipes for a

few hours a day only (Tourism Concern 2009 and 2010). Luxury resorts on an East African island are estimated to use up to 2,000 litres of water per tourist per day, almost 70 times more than the average daily domestic consumption of local people (Gössling and Hall 2006).

Golf tourism is rapidly expanding. An estimated 9.5 billion litres of water are used to irrigate the world's golf courses per day, equivalent to the daily needs of 80 per cent of the global population. One Mediterranean island, where water is so scarce it must sometimes be shipped in, is planning to increase its golf courses from three to 17, with tourism cited as the principal driver. This will involve building over agricultural land and constructing several desalination plants to ensure continual supply (Tourism Concern 2009).

Source: Tourism Concern (2010)

### Loss of biological diversity

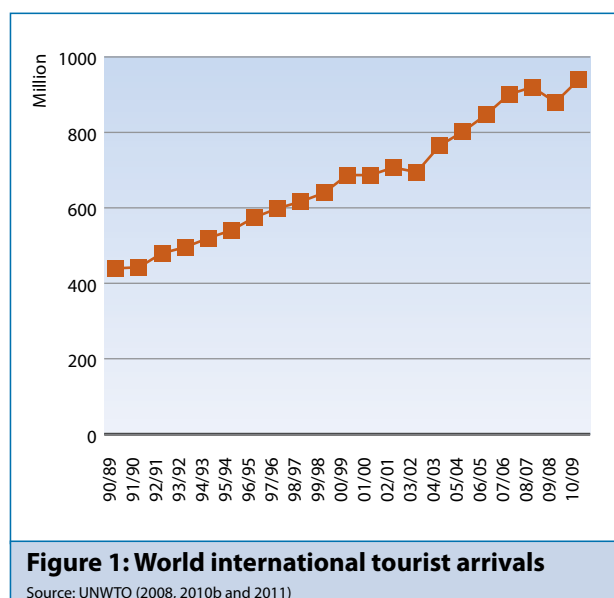
There are many examples where large-scale tourism has had detrimental effects on biodiversity, including coral reefs, coastal wetlands, rainforests, arid and semi-arid ecosystems and mountainous areas (UNWTO 2010d). Coral ecosystems have suffered strong adverse impacts from the use of coral for construction materials for hotels, over-fishing off reefs to feed tourists, sewage dumping and sedimentation from improperly managed runoff from buildings, parking lots, and golf courses. Coastal wetlands, particularly mangroves, have routinely been damaged or destroyed to build beach resorts. And in arid and semi-arid ecosystems, golf courses and other water-intensive activities have lowered water tables affecting local fauna and flora. Biodiversity will be greatly affected by the way in which tourism grows and develops, especially in developing countries (UNEP 2010). Moreover, failure to incorporate biodiversity concerns in destination planning and investment will have detrimental effects on the natural environment, increase conflict with local communities, and lead to reduced value-creation potential for both the destination and investors (notably as interest in nature-based tourism is growing rapidly around the world and represents a strategic argument for maintaining biodiverse environments, which are often tourist destinations in developing countries).

### Management of cultural heritage

Interest in unique cultures by tourists can result in adverse impacts and severe disruption for communities. There are examples of communities overrun by large numbers of visitors, commercialisation of traditions and threats to cultural survival from unplanned and unmanaged tourism. Tourism destinations are occasionally built by outsiders (usually with government approval) in areas that indigenous or traditional communities consider to be theirs, and where the development was neither desired nor locally validated. These situations lead to conflicts that make cooperation and mutual benefits nearly impossible to achieve, and instil animosities that negatively affect the local communities and the tourism destination. Frequently, the cultural issues overlap and are aggravated by environmental issues such as access to water, coastal resources and wildlife. Over the last two decades, with the growth in ecotourism and alternative travel, tourism impacts on vulnerable cultures has begun to be taken seriously by the tourism industry, governments, non-governmental organisations and the cultural groups involved (Wild 2010).

## 2.2 Opportunities

The following trends and developments provide a particularly promising space for greening tourism: (1) sizing and growth of the sector; (2) changing consumer



patterns; and (3) maximising potential for addressing local development and poverty reduction.

### Sizing and growth of the tourism sector

Tourism is one of the most promising drivers of growth for the world economy. The sheer size and reach of the sector makes it critically important from a global resource perspective. Even small changes toward greening can have important impacts. Furthermore, the sector's connection to numerous sectors at destination and international levels means that changes in practices can stimulate changes in many different public and private actors.

The tourism economy represents 5 per cent of global GDP, while it contributes to about 8 per cent of total employment. International tourism ranks fourth (after fuels, chemicals and automotive products) in global exports, with an industry value of US\$ 1 trillion a year, accounting for 30 per cent of the world's exports of commercial services or 6 per cent of total exports. Tourist arrivals have shown continuous yearly growth over the last six decades, with an average 4 per cent annual increase during 2009 and 2010. This trend has held in spite of occasional short drops from international crises, such as pandemics, recessions and terrorism. There are around 4 billion estimated domestic arrivals every year (UNWTO and UNEP 2008) and international tourism arrivals reached 922 million in 2008, dropped to 880 million in 2009, and then recovered in 2010 with 940 million (UNWTO 2011) (Figure 1). The tourism industry has been sensitive but resilient to economic, political and social global phenomena. The number of tourist trips is expected to continue to grow for the next decade, with the number of international tourist arrivals expected to reach 1.6 billion by 2020 (UNWTO 2001).

However, the economic significance of tourism is highly variable across countries. While it represents only 1.9



per cent and 3.3 per cent of GDP in Japan and Peru respectively, it represents 7.7 per cent and 10.9 per cent of GDP in South Africa and Spain respectively (UNWTO 2010c; WTTC 2010b). Regarding employment, the tourism industry contributes with 2.8 per cent, 3.1 per cent, 6.9 per cent and 11.8 per cent of total employment for the same countries (UNWTO 2010c; WTTC 2010b); in terms of investment, it accounts for 5.8 per cent, 9.9 per cent, 13 per cent, and 13.8 per cent of total investment respectively (WTTC 2010 and 2010b).<sup>7</sup>

Proportionately, tourism will grow faster in less developed countries than in developed economies in the next ten years. Destinations in emerging economies receive 47 per cent of worldwide international tourist arrivals and US\$ 306 billion in international tourism receipts (36 per cent of the global total). Moreover, growth in the decade since 2000 has been most marked in emerging economies (58.8 per cent). Market share has also grown more significantly in emerging economies (from 38.1 per cent in 2000 to 46.9 per cent in 2009). Recent trends and forecasts point to a spreading of tourism to new destinations, largely in developing countries, where there is outstanding potential to support development goals, and where new environmental and cultural attributes can make an important contribution to more sustainable tourism destinations (UNWTO 2010b).

### Changing consumer patterns

Tourist choices are increasingly influenced by sustainability considerations. For instance, in 2007 TripAdvisor surveyed travellers worldwide and 38 per cent said that environmentally-friendly tourism was a consideration when travelling, 38 per cent had stayed at an environmentally-friendly hotel and 9 per cent specifically sought such hotels, while 34 per cent were willing to pay more to stay in environmentally-friendly hotels (Pollock 2007). The Center on Ecotourism and Sustainable Development (CESD) and International Ecotourism Society (TIES) (2005) found that a majority of international tourists are interested in the social, cultural and environmental issues relevant to the destinations they visit and are interested in patronising hotels that are committed to protecting the local environment. Increasingly, they view local environmental and social stewardship as a responsibility of the businesses they support. Choice experiments conducted in Uganda conclude that biodiversity attributes increase the willingness to visit tourism attractions, independently of other factors (Naidoo and Adamowickz 2005). Research also indicates that consumers are concerned about the local environments of their travel destinations and are willing to spend more on their holidays if they are assured that workers in the sector are guaranteed ethical labour conditions in the places

they are visiting (ILO 2010b). On the other hand, Rheem (2009) argues that less than a third of American travellers indicate a willingness to pay some sort of premium for green travel, higher prices (cost premium) being seen as a demand barrier for 67 per cent of respondents.

Traditional mass tourism such as “sun-and-sand” resorts has reached a steady growth stage. In contrast, ecotourism, nature, heritage, cultural and soft adventure tourism, as well as sub-sectors such as rural and community tourism are taking the lead in tourism markets and are predicted to grow most rapidly over the next two decades. It is estimated that global spending on ecotourism is increasing at a higher rate than the industry-wide average growth. Nature-based tourism is an important economic component of the entire tourism market, including 75 per cent of Australia’s international tourism, while 42 per cent of European recreational tourists in 2000. In 2006, nature tourists contributed US\$ 122.3 billion to the USA’s tourism market (UNWTO 2010d). About 14 per cent of international visitors to South Africa in 1997 engaged in an “adventure activity” during their stay (Travel to South Africa n.d.). Of the 826,000 tourists to Kenya in 1993, 23 per cent visited national parks and reserves for wildlife safari tourism (Sindiga 1995). In 1993, the Asia-Pacific region alone reported 10 per cent of tourism revenue came from ecotourism activities (Dalem 2002).

There is empirical evidence that tourists seeking environmental and culturally differentiated destinations are willing to pay more for this experience. Inman et al. (2002) estimate this to be between 25 per cent and 40 per cent. The World Economic Forum (WEF) (2009) estimates that 6 per cent of the total number of international tourists pay extra for sustainable tourism options and 34 per cent would be willing to pay extra for them. One third to one half of international tourists (weighted toward the USA) surveyed in a CESD and TIES (2005) study said they were willing to pay more to companies that benefit local communities and conservation. Research by SNV (2009) records two studies where 52 per cent of respondents in a UK survey would be more likely to book a holiday with a company that had a written code to guarantee good working conditions, protect the environment and support local charities, while some 58.5 million US travellers would pay more to use travel companies that strive to protect and preserve the environment.

Wells (1997) presents a survey of nature-tourism willingness to pay (WTP) studies and shows that, in almost all cases, consumer surplus (private value of benefits from nature tourism) is higher than collected fees from tourists. In other words, the value of ecosystems for tourism is undervalued in many cases. For instance, Adamson (2001) estimates that 50 per cent or more of the economic value

7. See Annex 1 for an indication of the economic dimension of tourism in a country sample.



from Manuel Antonio National Park in Costa Rica is not captured in entrance fees. Willingness to pay (WTP) for entrance fees from international tourists was estimated at US\$ 12 (compared with a US\$ 6 actual entrance fee) and US\$ 6 for national tourists (compared with an actual fee of US\$ 2). Furthermore, it is estimated that the average value of coral reef opportunities for recreation and tourism is almost US\$ 68,500 per hectare per year in 2007 values, while it could reach up to more than US\$ 1 million (TEEB 2010). The maximum monetary value of ecosystem services for tourism, per hectare per year, has been estimated for coastal systems (US\$ 41,416), coastal wetlands (US\$ 2,904), inland wetlands (US\$ 3,700), rivers and lakes (US\$ 2,733) and tropical forests (US\$ 1,426) (TEEB 2010).

### **Potential for local development and poverty reduction**

Making tourism more sustainable can create stronger linkages with the local economy, increasing local development potential. Of particular and recognised importance (Hall and Coles 2008) are: purchasing directly from local businesses, recruiting and training local unskilled and semi-skilled staff, entering into neighbourhood partnerships to make the local social environment a better place to live, work and visit for all, and ability to improve the local natural environment within its areas of direct and indirect influence (Ashley et al. 2006). The move toward more sustainable tourism has been shown in a number of destinations to enhance this local development potential through several means:

1. Its ability to harness biodiversity, landscape and cultural heritage available in developing countries can play a major role in enhancing incomes and employment opportunities;
2. Tourism is a relatively labour-intensive sector traditionally dominated by micro and small enterprises with activities particularly suited for women and disadvantaged groups;
3. A tourism product is a combination of different activities and inputs produced by many sectors: enhanced spending by tourists can benefit agriculture, handicrafts, transport, water and waste management, energy efficiency and other services;
4. As tourism development at destinations requires investment in facilities such as roads, water supply, and energy, it improves the basic common infrastructure facilities required for development of other sectors and improvement of quality of life (Bata 2010); and
5. Tourism employs more women and young people than most other sectors: providing economic benefits and independence to women is very important in terms of supporting child development and breaking the cycle of poverty.

# 3 The case for investing in the greening of tourism

## 3.1 Spending in the tourism sector

Tourism drives significant investments. Adding even small percentages of investment for a greener sector results in very significant increases in investment flows. Furthermore, much new investment flow is directed toward developing countries, where increased investment could have greater impact on green outcomes. It is estimated that travel and tourism-sector investments reached US\$ 1,398 billion in 2009, or 9.4 per cent of global investment. It increased on average by 3 per cent during the last decade, notwithstanding a significant contraction in 2009 (-12 per cent). Global investment in tourism has fluctuated between 8 per cent and 10 per cent of total world investment over the last 20 years. In developing countries, such as in the Caribbean region, this figure could be as high as 50 per cent (WTTC 2010).<sup>8</sup> In OECD countries, investment in hotels, travel agencies and restaurants range from 6 per cent of national gross value added in Germany to 32 per cent in Portugal (OECD 2010).

Foreign Direct Investment (FDI) is an important source of world tourism investment. The stock of outward and inward FDI in the hotels and restaurants sector reported by UNCTAD (2009) accounts for almost 1 per cent of total FDI stock. This figure, however, does not take into account other tourism-related elements in other sectors, such as construction, transport or business activities. There is a growing focus on tourism as a generator of FDI in developing countries, where it is a priority of many Investment Promotion Agencies (IPAs). In this regard, the case of Costa Rica is illustrative as foreign investment in the tourism sector represented 17 per cent of total FDI inflows in 2009 and 13 per cent on average for 2000-2009.<sup>9</sup>

## 3.2 Benefits in employment

Tourism is human-resource intensive due to the service nature of the industry. It is among the world's top job

creators and allows for quick entry into the workforce for youth, women and migrant workers. The *wider* tourism economy provides, both directly and indirectly, more than 230 million jobs, which represents about 8 per cent of the global workforce. Women make up between 60 and 70 per cent of the labour force in the industry and half the workers are aged 25 or younger (ILO 2008). In developing countries, sustainable tourism investment can help create job opportunities, especially for poorer segments of the population.

The move toward more sustainable tourism can increase job creation. Additional employment in energy, water, and waste services and expanded local hiring and sourcing are expected from the greening of mainstream tourism segments. Furthermore, an increasing body of evidence suggests significantly expanded indirect employment growth opportunities from segments oriented toward local culture and the natural environment (Cooper et al. 2008; Moreno et al. 2010; Mitchell et al. 2009).

Tourism creates jobs directly and leads to additional (indirect) employment. It is estimated that one job in the core tourism industry creates about one and a half additional jobs in the tourism-related economy (ILO 2008). There are workers indirectly dependent on each person working in hotels, such as travel-agency staff, guides, taxi and bus drivers, food and beverage suppliers, laundry workers, textile workers, gardeners, shop staff for souvenirs and others, as well as airport employees (ILO 2008). These relationships influence the many types of workplace relationships that include full-time, part-time, temporary, casual and seasonal employment and have significant implications for employment opportunities within the sector. A study of South Africa shows that direct employment in the core tourism sector only accounts for 21 per cent of total employment creation due to tourism spending in 2008 (Pan African Research & Investment Services 2010). Available data indicate that every new job in tourism can have multiplying effects in the whole economy, as illustrated in Table 1.

8. It is worth mentioning that WTTC estimates incorporate all fixed investment expenditure by tourism service providers and government agencies, in facilities, capital equipment and infrastructure for visitors. In this sense, it could be overestimating infrastructure investments that are not tourism sector specific but affect the whole economy (for instance, road improvements or airport construction). Still, it is the only cross-country source of tourism investment data available.

9. Author's calculations with data from the Central Bank of Costa Rica. Available at [www.bccr.fi.cr](http://www.bccr.fi.cr), accessed on September 12, 2010.

For the EU 27, GHK (2007) estimates direct and indirect employment multipliers for environment-related tourism at between 1.69 and 2.13. This means that for every 100 jobs directly created in the sector, 69 more are created elsewhere in the economy as a result of indirect effects and the figure increases to 113 when induced effects are taken into account. The authors define Environment-related tourism (ERT), as activities where the natural environment (not the built environment) is responsible for influencing the choice of destination for the tourism activity, including visits to hills, mountains, coasts, farmland, woods, forests, springs, lakes and wildlife and the activities of fishing (sea, game and coarse), walking, climbing, golfing, skiing, cycling, bathing/swimming, etc.

It is estimated that sustainable tourism in Nicaragua, a destination that focuses very prominently on its culture and natural environment, has an employment multiplier of 2. That is, for every job in the tourism sector, additional local employment is created, with higher wages than the national averages (Rainforest Alliance 2009).

### 3.3 Local economic development and poverty reduction

#### Local economic development

Tourism is an important and effective driver of local economic development. Tourist spending enters the local economy to varying degrees depending principally on the structure of the tourism business and its supply chain at a destination. The economic contribution entering the economy is the local contribution and is typically measured as an average amount per tourist, and as a percentage of the total tourism spending that stays in the local economy. That which is not retained in the local economy is “leakage.” Multiplier effects are limited by leakages, which reduce the positive economic impacts of tourism. Wells (1997) reports values of leakage as a percentage of gross tourism receipts ranging from 11 per cent (Philippines) to 56 per cent (Fiji).

The income multiplier is used to describe the amount of the indirect economic activity resulting from the local contribution. The economic development potential of tourism is a direct function of the local contribution and multiplier – larger local contributions and larger multipliers each lead to greater economic activity in the local economy and there are important synergies between them. From a global perspective, Mill and Morrison (2006) review the literature on income multipliers and present a list of estimations from different countries and regions. Income multipliers can be relatively low for specific destinations such as the City of Winchester (0.19) and higher for a country such as Turkey (1.96). According to Cooper et al. (2008), tourism impacts income in different ways depending

	Total employment per single job in the tourism sector	Employment per US\$ 10,000 tourist expenditure
Jamaica	4.61	1.28
Mauritius	3.76	not available
Bermuda	3.02	0.44
Gibraltar	2.62	not available
Solomon Islands	2.58	not available
Malta	1.99	1.59
Western Samoa	1.96	not available
Republic of Palau	1.67	not available
Fiji	not available	0.79
UK (Edinburgh)	not available	0.37

**Table 1: Sample of tourism employment multipliers**

Source: Cooper et al. (2008)

on the country or region where it develops. Every US dollar spent by overnight tourists impacts income in the economy between 1.12 to 3.40 times. This high variability indicates that local economic impact development will depend on particular characteristics of the tourism business model, in particular the quantity and type of products and services sourced from the local economy.

In destinations where a large percentage of tourist needs are locally supplied (beds and linens, food and beverage, equipment and supplies, labour, tour and transportation services, souvenirs, among others), local contribution and multipliers tend to be high, and the resulting economic impact correspondingly greater. In destinations where substantial income is not captured locally, economic impact from tourism is less. This effect can vary dramatically between destinations:

■ For Granada, Nicaragua, the Rainforest Alliance (2009) reports a case study of sustainable tourism where local purchases represent only 16 per cent of total purchases;

■ For the Canary Islands, Hernández (2004) finds that 43 per cent of total tourism expenditure is supplied from outside the local economy through direct, indirect and induced imports; and

■ In New Zealand, it is estimated that 24 per cent of tourism expenditure is for imports of goods and services sold directly to tourists by retailers (Hernández 2004).

Looking at a single destination illustrates how substantial tourism's economic impact can be. For example, for Panama, Klytchnikova and Dorosh (2009) present a detailed evaluation of tourism's impact in the local economy of three different regions. The income multiplier for the tourism industry (hotels and restaurants) is the largest of all economic sectors. An additional US\$ 1 in

value added results in US\$ 2.87 total income. This large multiplier is due to strong backward linkages in terms of demand for local food products as well as forward linkages of household spending from tourism income. This gain results from consumer spending effects as incomes earned in various activities are spent in the domestic economy. In comparison, multipliers are smallest (1.30 to 1.64) in sectors such as the Panama Canal, mining and textiles where there are few production linkages (as much of the inputs are imported). In contrast, the multipliers for fruit, shellfish and other agricultural exports are especially large because much of the income earned accrues to rural households who spend a high proportion of their incomes on non-tradable goods and services in the local economy.

There is an increasingly convincing body of evidence indicating that more sustainable tourism can increase both the local contribution and multiplier effect. Within a given (or similar) destination, local contribution and multiplier increase the more the local community is involved in the tourism value chain, through the supply of products, labour, tourism services and, increasingly, green services. The few available meta-studies indicate considerably higher multipliers for natural and culturally-oriented destinations (Chang 2001). Destination-specific studies, such as (Brenes et al. 2007) for Costa Rica indicate similar effects. The logic is sound – more local purchases (substituting imports) will increase local contribution, and the income effect will be greatest when local actors are the beneficiaries of those linkages.

### Poverty reduction

When tourism-related income grows with a substantial reorientation in favour of the poor, poverty can be reduced. Thus, in 2002 the UNWTO launched the Sustainable Tourism for the Elimination of Poverty initiative (ST-EP), aimed at reducing poverty levels through developing and promoting sustainable forms of tourism.<sup>10</sup> Increased tourism, local contributions and multiplier effects can accrue to wealthy, middle income, or the poor. Therefore, interventions must be made to help poor people become part of the processes that drive the industry (ILO 2010a). Investors and developers, as well as local and national governments, play a critical role in determining the role poorer populations play in the tourism industry. The local industry can also help by engaging in and encouraging the use of local companies

for the provision of transport, services and food in order to generate local income and employment multipliers and contribute to alleviate local poverty:

■ In the case of Malaysia, Tourism Planning Research Group (TPRG 2009) describes the case of accommodation businesses and the shares of income generated and distributed across the chain. The final impact on local communities depends on the business structure and the economic activities related to tourism. In the case of the accommodation sector, most income is captured by hotel owners. However, an important share is received by small-business owners and local people involved in informal activities (Figure 2). From all tourism expenditure, 28 per cent is captured by hotels, while craft artisans obtain 5 per cent and local small businesses get 11 per cent.

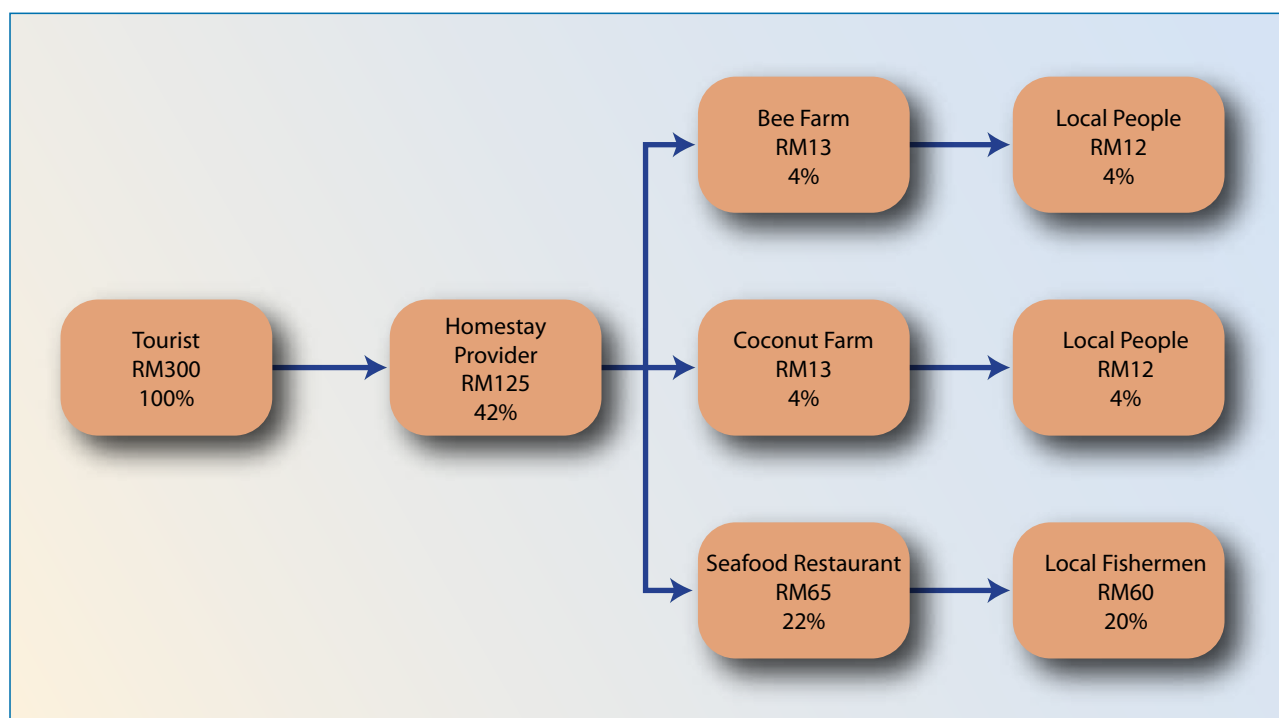
■ In Zanzibar, Tanzania, Steck et al. (2010) estimate that only 10.2 per cent of total tourism income is captured by poor local people. The study found that the industry is heavily dependent on imports for both primary supplies and staff of suitable quality, both of which are normally avenues for participation of locals.

■ In Panama, households capture 56 per cent of total local tourism income (Klytchnikova and Dorosh 2009). Which households benefit the most, however, depends on the region in which the tourism revenues are generated. In the Colón Zone, most of the gains in household incomes (63 per cent) go to urban non-poor households and only 20 per cent of the income gains accrue to poor households. In contrast, in Bocas del Toro, where poor households account for a larger share of the regional labour force, 43 per cent of the total increase in household incomes accrues to the poor while the percentage gain in household incomes is nearly the same across household groups. The results for Chiriqui Province report household income gains received by the poor of 19 per cent, although the share earned by rural households is higher (46 per cent).

Empirical studies suggest that, at best, between one-fifth and one-third of total tourist expenditure in the destination is captured by the poor from direct earnings and supply chains (Mitchell and Ashley 2007). The impact of tourism on poverty depends on various factors including employment, the skill level of the labour force, changes of prices (goods and services and factors of production), ownership of micro and small enterprises and labour-market composition. As with income effects, there is increasingly convincing evidence that more sustainable tourism (particularly in rural areas) can lead to more positive poverty-reducing effects.

■ In Costa Rica, Rojas (2009) estimated the impact of tourism on poverty levels and found that without tourism incomes the local incidence of poverty would

10. ST-EP has identified seven different mechanisms through which the poor can benefit directly or indirectly from tourism: (1) undertaking measures to increase the level of the poor working in tourism enterprises; (2) maximising the proportion of tourism spending that is retained in local communities and involving the poor in the supply process; (3) promoting the direct sales of goods and services to visitors by the poor from informal businesses; (4) establishing and managing more formal tourism enterprises by the poor, either individually or at a community level; (5) using taxes or levies on tourism income or profits with proceeds benefiting the poor; (6) supporting the poor in money or in kind, by visitors or tourism enterprises; and (7) investing in infrastructure that offers local communities the chance to gain new access to available resources (UNWTO 2004b).



**Figure 2: Accommodation linkages and tourist income distribution in Tanjong Piai, Malaysia**

Source: TPRG (2009). Note: RM=Ringgit Malaysia (1 RM=US\$ 0.30)

be higher in urban and rural sectors (Table 2). This result is consistent with other studies for the country. For instance, the Economic Commission for Latin America and the Caribbean (ECLAC 2007) estimates that tourism contributes to a reduction in poverty of 3 per cent in Costa Rica (and 1 per cent in Nicaragua). From a site comparison perspective, Brenes et al. (2007) estimated the impact of Tamarindo (mass tourism destination) and La Fortuna (natural and adventure attractions destination) and found that average monthly wages in La Fortuna (US\$ 437) were higher than in Tamarindo (US\$ 392). Moreover, they estimated a 0.64 probability of income improvement for La Fortuna inhabitants when working in the tourism sector. The evidence indicates that tourism is contributing to poverty reduction in Costa Rica, with the sustainability approach of the country as a driver of living conditions improvement.

■ In Malaysia, using a value-chain analysis, TPRG (2009) finds that economic benefits received by local people account on average for 34 per cent of total income generated by tourism. The relatively high pro-poor income share, particularly in restaurants (Table 3), may reflect various public and private initiatives to employ or involve locals in tourism business operations.

### 3.4 Environmental benefits

There is increasing motivation from both the private and public sectors to invest in making tourism more sustainable. Although the availability of global investment data specific to sustainable tourism is

currently not of a sufficient quantity to draw any robust conclusions, it is clear that there is an increased awareness of the need and value of conserving unique natural, social and cultural assets of destinations.

Private and public investment in tourism includes infrastructure (roads, airports, national parks, private reserves, hospitality installations and other sites and facilities); environmental conservation (natural attractions, beaches, mountains, rivers, biodiversity, natural barriers and endemic species); education (labour-

	With tourism income	Without tourism income
National	17.69%	19.06%
Urban	16.93%	18.40%
Rural	18.73%	20.0%

**Table 2: Impact of tourism on poverty rates in Costa Rica, 2008**

Source: Rojas (2009)

	Share in tourism revenue	Share of PPI
Accommodation and hotel meals	88.4%	7.3%
Restaurants	4.4%	47.0%
Retail	3.7%	27.0%
Tours and excursions	3.0%	18.8%
Other	0.5%	n.a

**Table 3: Breakdown of tourism income and pro-poor income (PPI) contribution in Malaysia**

Source: TPRG (2009)



force skills, including the greening of the skills base); capacity building; and technology improvements (cleaner production, sustainable management). Investment in sustainable tourism offers a wide range of opportunities, notably in the areas of water, energy, waste and biodiversity, which can generate significant returns.

There is a growing trend within the tourism industry of investment in sustainability. For instance, the Accor hotel chain has been testing environmental technologies such as photovoltaic electricity, grey water re-use and rain-water recovery. Additional capital expenditure in energy efficiency and sustainable construction and renovation projects is estimated at a relatively modest 6 per cent of total construction costs (for a 106-room hotel), with excellent returns (WTTC 2009). Sol Meliá Hotels & Resorts have institutionalised their sustainability programme with independent certification for the company, including hotels and corporate offices on an international level, and a specific budget for the strategic project of sustainable development, financed entirely by company funds (WTTC 2010).

### Energy

In hotels and other accommodation there is considerable scope for investment in energy-efficient features and services, including refrigeration, television and video systems, air conditioning and heating (particularly reduction or elimination of these systems through improved design), and laundry. Such

investments are driven by increasing energy costs; likely carbon surcharges; increasing expectations of customers (particularly from Europe and North America); technological advances with low-carbon technology; and in some cases, government incentives. Many leading airlines are exploring alternative fuel strategies, as well as changes in routing, aircraft and flight practices. The railroad industry, particularly in Europe, is positioning itself as a green and community-linking alternative to air travel. Increased energy efficiency for tourism translates as reduced operational costs, increased customer satisfaction, and higher investment in energy efficiency (through retrofits and improvements).

Evidence suggests that investment in a more efficient use of energy in the sector generates significant returns (Box 2). Hamele and Eckardt (2006) reported the results of environmental initiatives in European hotels, bed & breakfast and camping sites, on energy consumption. On average, energy costs in hotels represented about 6 per cent of their annual turnover, whereas in the best practice establishments, this expense factor typically represented 1.5-2.8 per cent. Recent studies have shown that a 6 per cent increase in investment in energy-efficient design and equipment can lower electrical consumption by 10 per cent (Six Senses 2009); low-cost water-efficient design and operation can reduce consumption by 30 per cent (Newsom et al. 2008, Hagler Bailly 1998), and that overall financial cost-recovery of a destination's green

## Box 2: Investment in energy efficiency and savings

Six Senses, a luxury hotel group, reports that the return on investment of various energy-savings measures applied in resorts located in Thailand ranges from six months to ten years:

- The energy monitoring system cost US\$ 4,500, enabling the resort to achieve 10 per cent energy savings and to identify areas for further savings;
- Investment for the mini chiller system was US\$ 130,000, which saves US\$ 45,000 annually, and thus pays off in 2.8 years;
- The heat-recovery system cost US\$ 9,000, saving US\$ 7,500 annually, corresponding to 1.2 years payback time;
- The laundry hot-water system cost US\$ 27,000, saving US\$ 17,000 annually (1.6 year payback time);
- Efficient lighting cost US\$ 8,500, resulting in US\$

16,000 savings per year, i.e. taking six months to pay back (not considering the longer life-span of the lights);

- Investment in a water reservoir was US\$ 36,000, leading to annual savings of US\$ 330,000 (less than a month payback time);
- Biomass absorption chillers cost US\$ 120,000, resulting in US\$ 43,000 saving annually, i.e. 2.8 years payback; and
- Medium voltage (6.6kV) underground electric copper cables cost US\$ 300,000. Payback is roughly 10 years from lower energy loss, but other benefits include less radiation, less power fluctuation, reduced fire risk and a prettier resort without old hanging low voltage electrical cables.

Source: Six Senses (2009)

strategy (ratio of present value savings to present value capital expenditures) can be between 117 per cent and 174 per cent for investment recovery from hotel buildings operation efficiency (Ringbeck et al. 2010).

Rainforest Alliance (2010) presents an estimate of costs and benefits of sustainable-energy management practices for a sample of 14 tourism businesses in Latin America (Belize, Costa Rica, Ecuador, Guatemala and Nicaragua) based on GSTC indicators. The energy bill was reduced in 64 per cent of companies, with average annual savings of US\$ 5,255 (maximum of US\$ 17,300). Required investment ranged from 1 per cent to 10 per cent of annual operations costs. Average investment was US\$ 12,278 (maximum US\$ 56,530). The average payback of investments is 2.3 years.

### Water

Internal water efficiency and management programmes, and investments in water-saving technology in rooms, facilities and attractions reduce costs. Greater efficiency and improved management allows for the increase of number of rooms/visitors in water-constrained destinations. With regard to the most water-consuming factor, irrigation, considerable reductions can be achieved through alternative gardening (choice of species, landscaping) as well as the use of grey water. Golf courses can be designed to require less water, and operators can measure soil moisture to help control and optimise water use. Hotels with spas and health centres can engage in a range of water-saving measures, while new hotel construction can seek to avoid pool landscapes and other water-intensive uses (Gössling 2010).

With regard to direct water use for tourists, Fortuny et al. (2008) demonstrated that many water-saving technologies relevant to hotels and other businesses have short payback times (between 0.1-9.6 years), making them economically attractive. Investments in water-saving systems, grey water reuse and rainwater collection and management systems can help reduce water consumption by 1,045 m<sup>3</sup> per year, or a 27 per cent lower volume per guest per night.

In the Rainforest Alliance (2010) study, the water bill was reduced in 31 per cent of companies, with average annual savings of US\$ 2,718 (maximum of US\$ 7,900), a particularly large number given the very low price of water charged in those countries. Required investment ranged from 1 per cent to 3 per cent of annual operations costs. Average investment was US\$ 2,884 (maximum US\$ 10,000). Average annual savings were US\$ 2,718, for a payback period of 1.1 years.

### Waste

Improved waste management provides opportunities for business and society. Lower levels of generation

improves financial return for private sector actors, and better management of that waste creates opportunities for jobs, and enhances the attractiveness of destinations. Hamele and Eckardt (2006), reporting the results of an analysis of 36 hotels in the 2 to 4-star categories in Germany and Austria, showed average values per overnight-stay for solid waste (1.98 kg) and waste water (6.03 litres). The average cost of managing these two waste streams is € 0.28 per occupied room night. In Rainforest Alliance (2010), solid waste was reduced in 71 per cent of companies, with average annual savings of US\$ 3,600.

### Biodiversity

UNEP (2010) argues that biodiversity conservation will be greatly affected by the way in which tourism grows and develops, especially in developing countries hosting biodiversity hotspots, where tourism is expected to become increasingly important. Demand growth for experiences that involve contact with wildlife and pristine (or near pristine) ecosystems and the expectations from guests that tour operators respect and protect the natural resource base are increasingly driving changes in the tourist industry. Policies of mainstream tourism are likely to change towards more effective conservation of sensitive ecosystems, driven by market demand and large operator programmes (for instance, cruise-industry guidance on coastal systems). Moreover, the increasing trends for nature-based tourism will encourage conservation and tourism revenues (including protected-area fees) to grow in tandem. Current trends towards increasing nature-based and ecotourism are likely to continue or accelerate as pristine areas become increasingly rare, leading in turn to the incorporation of natural areas in tourism development and greater transfer of benefits toward natural areas.

Conservation and restoration provides a highly profitable, low-cost investment for maintaining ecosystem services (Box 3). Avoiding loss of ecosystems by conservation, particularly of forests, mangroves, wetlands and coastal zones, including coral reefs, is a sound investment from a cost-benefit analysis. This appears to hold from both a societal investment perspective as well as a private one. The review of dozens of restoration projects worldwide concludes that restoration compared with biodiversity loss provides a benefit/cost ratio of 3 to 75 in return of investments and an internal rate of return of 7 to 79 per cent (Nellemann and Corcoran 2010).

More than 70 per cent of Latin American hotels surveyed by Rainforest Alliance (2010) support biodiversity conservation while 83 per cent of them indicate that conservation practices have created competitive advantages through operation savings, improved image and process improvements. Ringbeck et al. (2010) report significant returns of green investments in tourism

### Box 3: Strengthening the Protected Area Network (SPAN)

Strengthening the Protected Area Network (SPAN) is an initiative funded by the Global Environment Facility (GEF) designed to maximise the potential of the protected-area system in Namibia by bolstering its management and establishing partnerships. It is a six-year project with a GEF grant of US\$ 8.5 million and co-financing amounting to US\$ 33.7 million. Global Environment Facility analysis indicates that tourism in Namibia's protected areas contribute to 3.1 to 6.3 per cent of the country's GDP. Investment by the government of Namibia in the past 20 years has achieved a rate of return of 23 per cent. The government has increased the annual budget for park management and development by 300

per cent in the past four years. A quarter of the park-entrance revenue is to be reinvested in park and wildlife management through a trust fund, providing additional sustainable financing of US\$ 2 million annually. First implemented in 2007, The National Policy on Tourism and Wildlife Concessions on State Land has approved more than 20 new tourism and hunting concessions. After two years it had generated more than US\$ 1 million annually in fees payable to the government. Local communities were granted most of the concession rights in protected areas, creating revenue and jobs for local people.

Source: GEF (2009)

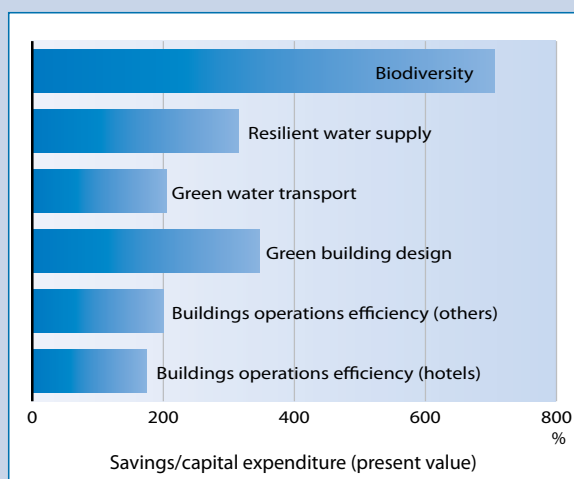
at major sun and beach destinations in Spain (Box 4). The authors estimated a present value of investments (capital expenditure) on water and energy efficiency, emissions mitigation and biodiversity conservation of US\$ 1 billion and a significantly higher present value of savings (US\$ 2.5 billion), with strongest investment recovery from biodiversity.

### 3.5 Cultural heritage

The largest single component of consumer demand for more sustainable tourism is for cultural authenticity (CESD and TIES 2005). Cultural heritage includes living cultures, both mainstream and minority, as well as historical, religious, and archaeological sites. Tourism

### Box 4: Financial cost-recovery of green programmes in tourism

Based on its experience with the greening process of one of the world's leading sun-and-beach tourist destinations (a seaside locale in Spain), Booz & Company report significant returns from investment in energy efficiency and GHG emissions, lower water consumption, better waste management practices and biodiversity conservation. The green



transformation strategy was developed after a thorough baseline analysis that showed, like most tourist destinations, unsustainable water and energy consumption patterns, problems with waste management and the risk of total depletion of key natural resources such as coral reefs and marine animals (main attractions). Capital expenditure on greening the tourism sector can quickly be offset by the savings in operation costs, which include not only the costs of greening initiatives, but also the socioeconomic effects of lost tourism revenue. Savings by reducing operation costs from green programmes, compared with the capital expenditure, range from 174 per cent (hotel buildings operation efficiency) to 707 per cent (biodiversity conservation). Private investment and public funding was used to secure sufficient funding. The greening transformation followed a three-step process, including an assessment of the destination's environmental status, the development of a green strategy and the collaborative execution of projects related to the green strategy.

Source: Ringbeck et al. (2010)

can offer opportunities for continuation, rejuvenation or enhancement of traditions and a way of life.

Culture is rarely static, and linking tourism and cultural survival may bring benefits as well as changes and challenges for a community to address. The possible socio-cultural costs and benefits of tourism to a vulnerable culture are rarely quantified. Tourism projects need to include a programme to monitor economic and cultural benefits so that vulnerable cultures can assess and manage the impacts of tourism on their communities (Wild 2010). Aside from the intangible benefits, most commentators believe that investment in cultural heritage is among the most significant, and usually profitable, investments a society, or tourism sector, can make (Box 5).

### 3.6 Modelling tourism<sup>11</sup>

To quantify the likely effects of increased investments in tourism, the green investment scenario (G2) simulated in the modelling exercise allocates on average 0.2 per cent of global GDP<sup>12</sup> (or US\$ 248 billion at constant 2010 US dollar prices) per year between 2011 and 2050 to the tourism sector, which is further disaggregated into energy, water and waste management, staff training, and biodiversity conservation.<sup>13</sup> The green investment represents 4 per cent of tourism GDP. This would most likely comprise a mixture of public as well as private investments. Assumptions of the model are presented in Annex 3 and results of simulations are detailed below.

#### Results of the simulation

The results of the simulations of the green investment scenario indicates that total arrivals of international tourists will increase by 2.8 per cent per year by 2030 and then at a lower rate of 2.5 per cent per year in the longer term to reach 2.6 billion in 2050, which is 30 per cent below the corresponding business-as-usual scenario (BAU2) due to the shift towards less frequent -but longer- trips in the green scenario.<sup>14</sup> The immediate impacts of international and domestic tourism will lead to a yearly direct tourism expenditure of US\$ 11.3 trillion on average between 2010 and 2050 in the green investment scenario (in such areas as sales in the hotel sector, hotel payments for wages and salaries, taxes, and supplies and services). These direct

expenditures have strong impacts on the destination economies resulting from various rounds of re-spending of tourism expenditure in other industries (i.e. industries supplying products and services to hotels). The total expenditure, including direct and indirect expenditures, will reach US\$ 21.5 trillion on average over the next 40 years in the green scenario. The resulting higher economic growth drives the sector GDP to grow from US\$ 3 trillion today to US\$ 10.2 trillion in 2050, exceeding the corresponding BAU scenario by 7 per cent. Direct employment in this sector is expected to grow to 580 million in the green scenario by 2050, compared with 544 million in the corresponding BAU projection. The training of these new employees requires US\$ 31 billion of investment per year on average in the next 40 years.

Despite the rising flow of tourists, the green investment will lead to significant resource conservation through considerable efficiency improvements and reduction of losses:

■ **Tourism water consumption** is projected to be 6.7 km<sup>3</sup> in 2050 in the green scenario, undercutting the corresponding BAU scenario by 18 per cent. In the meantime, additional investments are projected to increase water supply, which is essential for many tourism-dependent, water-stressed countries – on average 0.02 km<sup>3</sup> per year above BAU2 from desalination, and 0.6 km<sup>3</sup> per year from conventional sources (treated wastewater, surface and underground water) through better management over the 40-year period.

#### Box 5: Differential economic contribution from cultural areas

In Western Australia, attempts have been made to measure the economic value of cultural heritage through direct tourism expenditure, using three locations: the city of Fremantle, the city of Albany and the town of New Norcia. In order to determine the proportion of the total overnight visitor expenditure that could be directly attributable to cultural heritage, an attribution factor was generated based on data from visitor surveys and other sources. The study found that between 63 per cent and 75 per cent of a visitor's expenditure was due to the cultural heritage of the area, generating in the region of US\$ 40-US\$ 80 per visitor per day.

Source: Tourism Western Australia, available at <http://www.westernaustralia.com>, accessed on September 10, 2010

11. This section (including forecasts and simulations regarding international tourism growth) is based on the Millennium Institute's work for the Green Economy Report.

12. Tourism accounts for 5 per cent of global GDP.

13. In the G2 green investment scenario, an additional 2 per cent of global GDP is allocated to a green transformation of a range of key sectors, of which tourism is one (see Modelling chapter for more detailed explanation of scenarios and results).

14. BAU2 refers to the BAU scenario with an additional 2 per cent of global GDP per year invested according to current patterns and trends (see Modelling chapter).

■ Under the green scenario, tourism **energy supply and demand** will see both the expansion of renewables and efficiency improvements across all tourism activities. The incremental renewable-energy supply associated with tourism will be 43 Mtoe per year on average, including the expansion and introduction of renewable power generation and biofuels. On the demand side, the total energy consumption for various tourism activities will reach 954 Mtoe in 2050 under the green scenario, representing 44 per cent of avoided energy use relative to BAU2. These savings come from a mix of effective measures in individual activities – a modal shift to less carbon-intensive transport (e.g. electrified train and coach), behavioural changes (e.g. shorter-haul trips) to reduce total travel distance, better energy management (e.g. setting targets and benchmarking for hotels) – as well as across all sectors – technological advances in fuel efficiency and fewer inefficient uses due to better equipment or greater environmental awareness. More specifically, tourism transport, thanks to the transport-sector investments, will see the largest saving (604 Mtoe below the corresponding BAU scenario), followed by tourist accommodation, with 150 Mtoe of avoided consumption in 2050.

■ As a result of these energy savings, **CO<sub>2</sub> emissions** will be mitigated substantially relative to the corresponding BAU projection (-52 per cent by 2050), returning to the current level of 1.44 Gt in 2050, or 7 per cent of global emissions. The relative increase of the share of global emissions generated by tourism derives from a projected growth of tourism GDP higher than the average projected growth of global GDP. Tourism is expected to grow faster than most other sectors; and, without green investments, its environmental impacts would be much higher. By 2050, transportation is

expected to still be the principal emitter (0.7 Gt), with aviation and cars accounting for 74 per cent and 24 per cent of the reduction respectively. Accommodation, as the second-largest emitter, will account for 0.58 Gt of emissions in 2050. The remaining CO<sub>2</sub> emissions (98 Mt) are caused by other tourism activities. In addition to the mitigation of CO<sub>2</sub> emissions in the green economy, as climate is a key resource for tourism and the sector is highly sensitive to the impacts of climate change, these sustainable practices should strengthen the capacity of tourist destinations to adapt to unfavourable climatic conditions.

■ Furthermore, investment in tourism **waste management** allows for a higher rate of waste collection and reuse (recycling and recovery). In 2050, 207 Mt of waste will be generated by the tourism sector in the green scenario, compared with 180 Mt in the corresponding BAU scenario (due to higher GDP and tourist visitor nights in green scenarios). On the other hand, green investment is estimated to allow 57 Mt more reuse of waste than in the corresponding BAU scenario, therefore cutting net waste disposal (taking into consideration waste reuse) in 2050 by 30 Mt relative to BAU2.

■ These savings will result in potential avoided costs that can be reinvested in socially and environmentally responsible local activities (such as protected areas, local transportation or staff capabilities and skills), increasing the indirect and induced effects of tourism expenditure on local development. In particular, spending by visitors from wealthier regions to developing countries helps to create much-needed employment and opportunities for development, reducing economic disparities and poverty.



## 4 Overcoming barriers: enabling conditions

Tourism can have positive or negative impacts depending on how it is planned, developed and managed. A set of enabling conditions is required for tourism to become sustainable: to contribute to social and economic development within the carrying capacities of ecosystems and socio-cultural thresholds. This section presents recommendations to create the enabling environment for increased investment in sustainable tourism development, overcoming barriers in the areas of (1) private-sector orientation; (2) destination planning and development; (3) fiscal and government investment policies; (4) finance and investment; (5) local investment generation. Recommendations are based substantially on the policy recommendations of the International Task Force on Sustainable Tourism Development (ITF-STD).<sup>15</sup>

Tourism market tendencies indicate that the main drivers towards sustainable tourism investment decisions are consumer demand changes; business actions to reduce operational costs and increase competitiveness; coherent policies and regulations for environmental protection; technology improvements; private efforts for environmental and social responsibility and natural resource conservation. These are leading the transformation of the industry and determining the returns on investments.<sup>16</sup> The systemic characteristic of a sustainable tourism industry stresses the need to invest more in energy and water efficiency, climate-change mitigation, waste reduction, biodiversity conservation, the reduction of poverty, the conservation of cultural assets and the promotion of linkages with the local economy. The savings and higher returns expected from actions in those areas can simultaneously be invested in new green investment projects, creating a self-enforcing greening dynamic that could enhance competitiveness and strengthen sustainability.

A cross-cutting barrier to greener or more sustainable tourism investment is the lack of understanding and recognition of the value created for companies, communities and destinations from the greening of tourism. The sharing of knowledge, information and experiences among public, private and civil society actors is a necessary first step towards overcoming these barriers.

### 4.1 Private-sector orientation

Tourism is a heterogeneous industry<sup>17</sup> where hundreds (and sometimes thousands) of actors operate in multiple market segments, even within a single country or region. These segments include conventional and mass tourism as well as niche areas such as ecotourism, adventure tourism, rural tourism, community-based tourism, sports fishing, cruise tourism and more recently, health tourism. The principal businesses within the tourism industry are accommodation, tour operation, and transport (land, air, and aquatic). In addition, tourism has diverse linkages through several economic activities, from lodging, entertainment and recreation, to transportation, professional services and advertisement, among others.<sup>18</sup> While all can and should benefit in the medium to long term, greening will require very different actions and investments, and benefit companies in different ways – there is no single strategy or recipe for all to follow. A coherent strategy for green tourism growth must, therefore, cover all segments and activities, and the ways in which they interact.

The tourism industry is dominated by small and medium-sized enterprises (SMEs). Although online travel agencies and large conventional tour operators control an important share of international travel from Europe and North America, tourism destinations are characterised

15. The ITF-STD was comprised of members from UNEP, UNWTO, 18 developed and developing countries, seven other international organisations, seven non-governmental organisations, and seven international business associations. It was an outcome of the 2002 World Summit on Sustainable Development, which declared that “fundamental changes in the way societies produce and consume are indispensable for achieving global sustainable development”. The work of the Task Force will continue with its successor, the Global Partnership for Sustainable Tourism (<http://www.unep.fr/scp/tourism/activities/partnership/index.htm>).

16. Drivers and likely implications of sustainable investments in key strategic areas for tourism (energy, climate change, water, waste, biodiversity, cultural heritage and the local economy) are summarised in Annex 2.

17. Tourism does not fit the standard notion of an “industry” because it is a demand-based concept. It is not the producer who provides the distinguishing characteristics that determine how tourism is classified, but rather the purchaser, i.e. the visitor (OECD 2000).

18. The Tourism Satellite Account (TSA) indicates that “tourism industries comprise all establishments for which the principal activity is a tourism characteristic activity.” Tourism characteristics consumption products and tourism industries are grouped in 12 categories: accommodation for visitors, food and beverages serving activities, railway passenger transport, road passenger transport, water passenger transport, air passenger transport, transport equipment rental, travel agencies and other reservation services activities, cultural activities, sports and recreational activities, retail trade of country-specific tourism characteristic goods, and other country-specific tourism characteristic activities (see UNWTO 2010c).

by the predominance of smaller businesses. For example, close to 80 per cent of all hotels worldwide are SMEs (WEF 2009a) and, in Europe, this figure is 90 per cent.<sup>19</sup> Additionally, providers of goods and services for the industry tend to be small, local businesses. Reaching out to such a wide variety of small businesses, across numerous sectors, continents and languages is a daunting task. Without information, knowledge and tools, greening will be nearly impossible. Nonetheless, engaging these critical actors is a necessary condition for a sustainable industry. In Nepal, for instance, incentives for private-sector participation in capacity-building events and the implementation of sustainable action plans have helped to increase their access to international sustainable tourism markets, improved project performance and stimulated interest among other companies in Nepal in sustainable tourism business practices, creating synergies throughout the industry (UNEP 2008).

Organisational management is a key element of business sustainability. According to By and Dale (2010), successful management of change (political, economic, social and technological) is crucial for the survival and success of tourism SMEs, particularly with the following eight critical factors: adaptability and flexibility; commitment and support; communication and co-operation; continuous learning and improvement; formal strategies; motivation and reward; pragmatism; and the right people (skilled and motivated collaborators). Kyriakidou and Gore (2005) argue that best performing SME operations in hospitality, tourism and leisure industry share cultural features such as cooperative setting of missions and strategies, development of teamwork and organisational learning.

Tourism businesses are no different to other businesses when it comes to the criteria that must be considered in deciding whether to invest in them. However, there are some specific characteristics that will affect tourism business costs (Driml et al. 2010):

- Tourism businesses are relatively labour-intensive and therefore labour costs often make up the largest proportion of operating costs;
- The cost of inputs for capital investment and operation are higher for remote locations;
- The cost of capital will attract a premium if there is uncertainty about returns from investment in tourism;
- The price of land in tourist-desirable locations will be governed by competition with other land uses which may be able to pay more (due to higher returns);

■ Project planning and approvals cost will be high if assessment is lengthy or complex; and

■ Labour and land make up a high proportion of inputs and are subject to payroll tax and land tax.

A question is how to address these *basic* issues while making sustainable investment decisions. In this regard, the ITF-STD recommends that “tourism businesses and government institutions in charge of tourism should adopt innovative and appropriate technology to improve the efficiency of resource use (notably energy and water), minimise emissions of greenhouse gases (GHG) and the production of waste, while protecting biodiversity, helping reduce poverty and creating growth and sustainable development conditions for local communities.” The business case for investing in these areas is sound. At the private-sector level, hotel owners, tour operators, and transport services can play a key role in protecting the environment and influencing tourists to make sustainable choices. Increased public environmental awareness, including traveller awareness, has contributed to the development of a host of voluntary industry initiatives and the definition of environmental performance at the national, regional and international levels (UNEP 1998). Many larger corporations are already addressing their environmental and social impacts. In many countries, SMEs account for the vast majority of businesses and can have a significant environmental impact; however, they tend to be more reactive to addressing environmental issues (Kasim 2009). Nevertheless, increasing pressure from consumers could force them to address more impacts in order to remain competitive.

### Enabling conditions for engaging the industry

1. Tourism promotion organisations, resource management agencies and Destination Management Organizations (DMOs) should link tourism products (i.e. parks, protected areas and cultural sites) more closely with marketing positions. This will ensure a consistent and unique selling position in world tourism markets based on high-value experiences at natural and cultural sites in a compact geographical area.
2. Tourism industry associations and wider industry platforms play an important role in engaging tourism businesses in sustainability as well as developing practical tools to respond to many common challenges. As in most industries, the concept of corporate social responsibility (CSR) is increasingly recognised in the tourism sector and is being promoted by industry bodies, at the international as well as national levels. However, a formal response, including measures such as triple-bottom-line reporting, environmental management systems and certification appears to be prevalent only within

19. Available at [www.hotelenergysolutions.net](http://www.hotelenergysolutions.net), accessed on September 30, 2010.

a selection of larger firms. Smaller firms are largely outside this sphere, and diverse supplier groups may not be connected at all. Experience in many countries has shown that well designed mechanisms and tools to educate SMEs are critical, but are most effective when they are accompanied by concrete, actionable items.

3. International development institutions, such as multilateral and bilateral cooperation agencies, and Development Finance Institutions (DFIs) should engage directly to inform, educate and work collaboratively with the tourism industry to integrate sustainability into policies and management practices, and secure their active participation in developing sustainable tourism. At the national level, government and civil-society engagement should be a critical part of these efforts to coordinate action.
4. The increased use of industry-oriented decision-support tools would help speed the adoption of green practices. Hotel Energy Solutions, TourBench and SUTOUR are examples of projects designed to provide assistance to Europe's tourism enterprises to identify potential investments and cost-saving opportunities for sustainable decision making to ensure profitability and competitiveness (saving money and investment in ecological building measures and equipment with low energy consumption); provide visitor satisfaction (fulfilling their demands and expectations for high environmental quality); achieve efficient use of resources (minimising the consumption of water and non-renewable energy sources); secure a clean environment (minimising the production of CO<sub>2</sub> and reducing waste); and conserve biological diversity (minimising the usage of chemical substances and dangerous waste products).
5. The promotion and widespread use of internationally recognised standards for sustainable tourism is necessary to monitor tourism operations and management. The private sector tends to perform best when clear criteria, objectives and targets can be identified and incorporated into their investment plans and business operations. The GSTC, issued in October 2008, provides the most promising current platform to begin the process of grounding and unifying an understanding of the practical aspects of sustainable tourism, and prioritising private sector investment.<sup>20</sup> The GSTC should be adopted in order to assess industry's performance and support

policy recommendations. At a national and even sub-national level, GSTC, supported by information sharing and access to experts and experienced greening pioneers, is a critical step.

6. Economies of scale in the tourism sector could be achieved by means of *clustering*. A high environmental quality is a key input by those companies that pursue competitive advantages based on sound environmental management. In the case of tourism, the conservation of the natural capital of a country has a chainable effect and complementary influence on many firms. Clustering can strengthen backward and forward linkages in the tourism value chain and drive sustainability in the whole industry. Natural and cultural attractions are the most valuable assets for tourism development. The tourism *cluster* must become actively engaged in environmental management and conservation. Active collaboration with the public sector and community organisations will strengthen competitive position for the entire cluster. In the case of Croatia, for instance, Ivanovic et al. (2010) show that small businesses dominate the tourism market share in the total number of enterprises and generate the highest employment rates and income. However, they also show the lowest rate of productivity. This situation partly results from limited understanding of the potential benefits of clustering in tourism, including economies of scale; growth of technological and organisational know-how, and higher market share.

## 4.2 Destination planning and development

Destination planning and development strategies will be a critical determinant for the greening of tourism. Every destination is unique, and therefore each development strategy must be sensitive to the destination's unique assets and challenges, while creating a vision to deliver the destination's goals for environmental sustainability. Destination planners and policy officials are frequently unaware of the opportunities that greener tourism can bring to their destination. And even those who are aware usually lack the skills or experience necessary to build sustainability into new or ongoing destination development efforts.

Advancing greening goals through tourism planning and destination development requires the ability and institutional capacity to integrate multiple policy areas; consider a variety of natural, human and cultural assets over an extended time frame; and put in place the necessary rules and institutional capacity. A destination cannot successfully implement a green tourism strategy without the right laws and regulations in place, or the

20. The Global Sustainable Tourism Criteria Partnership began in 2007 and member organisations include the World Tourism Organization (UNWTO), United Nations Environmental Programme (UNEP), United Nations Foundation, Expedia.com, Travelocity-Sabre, and over 50 other organisations (Bien et al. 2008).

right governance structure to oversee them. Legislation should protect the environment, limit potentially harmful development, control detrimental practices, and encourage healthy behaviour. Clear rules in these areas, based on the destination strategy and its unique asset base, determine the direction, scale and scope of government and private investment in more sustainable tourism.

### Enabling conditions for greener destination planning

1. Higher-level government, community and private tourism authorities must establish mechanisms for coordinating with ministries responsible for the environment, energy, labour, agriculture, transport, health, finance, security, and other relevant areas, as well as with local governments. Clear requirements such as zoning, protected areas, environmental rules and regulations, labour rules, agricultural standards, and health requirements (particularly for water, waste and sanitation) establish clear rules of the game, and define the operating climate for investment. These decisions relate very closely to fiscal and investment considerations discussed in the following section.
2. Organisations engaged in developing tourism strategies should make use of credible scientific methods and tools encompassing economic, environmental and social approaches and assessments for sustainable development that will help stakeholders related to different components of the value chain understand their environmental and socio-cultural impacts.
3. Tourism master plans or strategies provide a supply-side approach for developing a tourism destination. Environmental and social issues must be included in these plans in order to manage the critical assets and promote greener outcomes. Green transformation programmes will be more effective if produced by a multi-stakeholder participatory planning process, as well as through the development of partnerships at local, national, regional and international levels. Multilateral environmental and social agreements and the organisations that support them should be included in the process.<sup>21</sup> Public, private and civil-society stakeholders should make a decision on the kind of tourism industry they want to consolidate in the medium and long terms, considering the possible impacts on the natural resource base and the development opportunities for the country.

Therefore, the creation of a sound institutional framework is required. Coordination among key actors and environmental regulations enforcement are key conditions. In addition, when investing in tourism sustainability, main short-, medium- and long-term objectives should be followed, based on:

- The contribution to country macroeconomic balances;
  - The creation of local direct and indirect employment;
  - The use of local raw materials and inputs;
  - The benefits created in other productive sectors (multipliers *outside* the industry);
  - The effects on local development and poverty;
  - The modernisation, diversification and sustainability of the tourism value chain; and
  - The growth of the internal and external demand for sustainable tourism.
4. When promoting sustainable tourism, a coherent destination planning policy is necessary to create a sound international reputation, a *country brand* that differentiates and positions the country competitively. According to FutureBrand (2008), while tourism is often the most visible manifestation of a country brand, it is clear that the image, reputation and brand values of a country impact its products, population, investment opportunities and even its foreign aid and funding. Therefore, a holistic nation approach is required in order to align public and private sector initiatives to create a successful country brand based on sustainability.
  5. Assessment of carrying capacity and social fabric should be considered to take into account external and internal impacts of tourism at destination. While it is difficult to evaluate due to great differences from one destination to another, maximum thresholds could be agreed on so as to provide guidance for the development of planning policies.

## 4.3 Fiscal policies and economic instruments

The greening of tourism will require a more sophisticated use of instruments within government purview, such as fiscal policy, public investment, and pricing mechanisms for different public goods.

21. For instance, these include the principles of the Global Code of Ethics for Tourism adopted by UNWTO and endorsed by the UN General Assembly as well as the recommendations and guidelines provided by Multilateral Environmental Agreements and conventions, as appropriate, including the Convention on Biological Diversity (CBD), the World Heritage Convention, the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and the Code of Conduct for the protection of children against sexual exploitation in travel and tourism.



Tourism investment from government should focus on business motivations for sustainable management as key targets. Incentives should be consistent with both environmental protection and value added creation. Market trends and competitive advantages need to be mutually reinforced. In this regard, policy coherence is a necessary condition. From a national perspective, sustainable tourism policy should address market failures (including externalities) in a consistent manner, avoiding the creation of additional distortions through government interventions. Like markets, governments can fail. Selected interventions must promote a more efficient allocation of goods and resources than would occur in the absence of government action. Social policy should address compensation and benefits to workers, access to improved opportunities, human resource development, and value chain integration strategies. In the case of sustainable tourism policies, more coherence in terms of targets (location investments, development of specific areas for destination, national and local infrastructure investments), management (institutional coordination, impact analysis studies) and incentives (effectiveness, cost-benefit, and adequacy) is required to maintain sound competitive advantages. Where possible, the use of incentives should be based on market instruments rather than command and control measures. Some forms of market failures deserve special attention, particularly those that prevent learning how new sustainable tourism businesses can be produced profitably (self-discovery externalities), impede simultaneous and integrated investments which decentralised markets cannot coordinate (coordination externalities), and omit public inputs (legislation, accreditation, transport and other infrastructure, for instance).

#### **Enabling conditions in fiscal and government investment policies**

1. In the case of tourism, policy intervention towards investment sustainability can be justified as far as enabling conditions promote the sustainable use of natural resources and therefore create positive externalities for the society. Alternative, less productive uses of natural resources (i.e. unsustainable agriculture) or possible depletion activities (i.e. housing construction) could be compensated (for their opportunity cost) with policy instruments that increase profitability for sustainable tourism businesses and generate positive environmental externalities. Free-riding (non-compliance by companies) should be avoided with an effective performance monitoring and impact evaluation mechanism. There is a need to conduct periodical evaluations and impact analysis of tourism incentives, from an economic, social and environmental perspective.
2. Defining and committing to critical government investments in the green enabling environment

plays a central role in determining private sector investment and direction. Government investments in protected areas, cultural assets, water, waste management, sanitation, transportation and energy infrastructure investments play a critical role in private sector investment decisions toward greener outcomes. Investments in public infrastructure related to tourism or investments in private tourism businesses should estimate their social and environmental impacts and adopt economic measures to compensate and offset unavoidable impacts.

3. Appropriate taxation and subsidy policies should be framed to encourage investment in sustainable tourism activities and discourage unsustainable tourism. Use of taxation is often resorted to for keeping developments in limits (for instance, taxes on use of resources and services at the destinations) and controlling the specific inputs and outputs (like effluent charges and waste services).
4. Tax concessions and subsidies can be used to encourage green investment at the destinations and facilities. Subsidies can be given on purchase of equipment or technology that reduces waste, encourages energy and water efficiency, or the conservation of biodiversity (payments for environmental services) and the strengthening of linkages with local businesses and community organisations.
5. Establish clear price signals to orient investment and consumption. The price for such public goods as water production and supply, electricity and waste management send important signals to the private sector. Governments frequently price these goods at very low levels (frequently even free) to encourage investment, only to find that low prices encourage waste, place a drain on communities and make it very costly (financially and politically) to raise prices.

#### **4.4 Financing green tourism investments**

Environmental and social investments are relatively new, and remain outside the mainstream of financial markets (particularly in developing countries). In many cases, barriers are based on misperceptions or lack of knowledge. For example, for many green investments, payback periods and amounts are not clearly established (due to limited experience with them), creating uncertainty for banks or other investors that can jeopardise financing. Also, the return on many green investments includes easily measurable components (such as energy savings), combined with more difficult



to measure components such as guest satisfaction which can make calculating returns tricky.<sup>22</sup>

In other cases, framework conditions in destination countries limit investment. For example, higher interest rates in many countries make investments that are completely viable in wealthy countries, unviable in the local environment. Another frequently cited situation found in many developing countries is that the financial regulatory systems classify environmental investments as non-productive assets, requiring banks to hold greater reserves, resulting in higher interest rates and less investment.

### Enabling conditions for finance

1. The single greatest limiting factor for SMEs in moving toward greener tourism is lack of access to capital for this type of investments. Green investments must be seen as value-adding and made on their economic and financial merits, without prejudice. This will require greater private sector awareness of the value of green investment, and also policy coordination with Ministries of Finance and regulatory authorities.
2. Regional funds for local tourism development could help overcome financial barriers for green investments where investments also generate public returns (through positive externalities). Foreign Direct Investment (FDI), private equity, portfolio investment, and other potential funding sources should be also aligned with sustainable projects and strategies for the tourism industry. Ringbeck et al. (2010) argue that not all green initiatives are financially possible for the local or national parties undertaking them, and destinations are not always able to generate enough revenue through their own resources. When local financial resource limitations exist, obtaining external funding could help ensure the long-term sustainability of investments.
3. Mainstream sustainability into tourism development investments and financing. In this regard, the Sustainable Investment and Finance in Tourism (SIFT) network is working to integrate the expectations of private investors, the leveraged strength of the financing and donor community, and the needs of developing destinations. The SIFT network aims to establish a common, voluntary standard to encourage greater sustainability in tourism investments by public, private and multilateral investors; intensify financing of sustainable tourism projects; increase sustainable investments in the tourism sector; improve capacity of developing destinations; and

22. For example, Frey (2008) found in a survey of South African tourism businesses that 80 per cent of respondents agree that responsible tourism management leads to enhanced employee morale and performance, improves company reputation and is an effective marketing tool. However, businesses are not investing sufficient time or money into changing management practices.

leverage unique knowledge and reach others. SIFT efforts should permeate to regional, national and local financial organisations (counterparts), and help integrate other global sustainable financial initiatives (e.g. UNEP FI, Equator Principles) to support green investments in tourism.

4. Establish partnership approaches to spread the costs and risks of funding sustainable tourism investments. In the case of SMEs, for example, besides sliding fees and favourable interest rates for sustainability projects, in-kind support like technical, marketing or business administration assistance, could help to offset the cash requirements of firms by offering them services at low cost. In addition, loans and loan guarantees could include more favourable grace periods, soften the requirements on personal asset guarantees or offer longer repayment periods. Loans for sustainable tourism projects could be set up with guarantees from aid agencies and private businesses, lowering risk and interest rates.

## 4.5 Local investment

As discussed above, sustainable tourism creates additional opportunities to increase local economic contribution from tourism. An often-overlooked aspect of these linkages is that they also offer opportunities for increased investment in local communities. Capitalised and formalised businesses in the tourism value chain enhance local economic opportunity (through employment, local contribution and multiplier effects) while also enhancing local competitiveness among tourists demanding greater local content. This win-win situation is recognised in the UNWTO's ST-EP initiative. Notably, many of the targeted mechanisms are investment enhancing as well as local-income enhancing.

This promotes a greater number and variety of excursions in a given destination, a "buy local" movement in food and beverages sector and growth of specialised niches. Efforts by tourism businesses to include local communities within value creation, public and private initiatives of local workers training, and the development of infrastructure and supporting industries, creates new conditions for business development, more equitable growth and less leakage. These businesses require investment, and can expect substantial growth opportunities in successful destinations.

### Enabling conditions for increasing local contribution

1. Strengthen tourism value chains to back SME investment. Destination tourism is usually stable enough to provide sufficient guarantees for investors and bankers. Long-term contracts for products and services to hotels or other anchor businesses create

suitable conditions, and simple mechanisms to monitor performance.

2. Expand the use of solidarity lending mechanisms to permit groups of local suppliers to access credit and build capital. Solidarity lending (guarantees provided by a peer group) has proven successful in fisheries, agriculture, and handicrafts – all industries of critical importance to successful sustainable tourism destinations.
3. Enhance development bank access to individuals and small businesses that are not eligible for credit, or are involved in the provision of public services (such as protected areas management, guiding, waste management, infrastructure construction, among others).
4. Establish seed funds to permit new green industries to develop locally. For example, solar collectors and photovoltaic systems can be imported as complete systems, or can be assembled locally from imported components. The latter encourages local investment and promotes local economic contribution. It also permits adaptation of the technologies to better suit local tourism needs.

## 5 Conclusions

Tourism is a leading global industry, responsible for a significant proportion of world production, trade, employment, and investments. In many developing nations, it is the most important source of foreign exchange and FDI. Tourism growth, environmental conservation, and social wellbeing can be mutually reinforcing. All forms of tourism can contribute towards a green economy transition through investments leading to energy and water efficiency, climate-change mitigation, waste reduction, biodiversity and cultural heritage conservation, and the strengthening of linkages with local communities. Making tourism businesses more sustainable will foster the industry's growth, create more and better jobs, consolidate higher investment returns, benefit local development and contribute to poverty reduction, while raising awareness and support for the sustainable use of natural resources.

The potential economic, social and environmental costs of a BAU scenario in the tourism industry are not always considered when evaluating the cost of investments toward sustainability. Concern about required investments and financing sources availability are common when considering actions for making tourism more sustainable. Nevertheless, empirical evidence shows that demand for traditional mass tourism has reached a mature stage whereas the demand for more responsible forms of tourism is booming and are predicted to be the fastest growing tourism markets in the next two decades. Tourism-market tendencies indicate that main drivers towards investment in sustainable tourism relate to consumer demand changes, actions to reduce operations costs and increase competitiveness, coherent policy and regulations, technology improvements, stronger efforts for environmental and social responsibility and natural resource conservation. These are leading transformation of the industry and determining the returns on investments.

In a BAU scenario up to 2050, tourism growth will imply increases in energy consumption (111 per cent), greenhouse gas emissions (105 per cent), water consumption (150 per cent), and solid waste disposal (252 per cent). On the other hand, under an alternative greener investment scenario (in energy and water efficiency, emissions mitigation and solid waste management) of US\$ 248 billion (i.e. 0.2 per cent of total GDP), the tourism sector can grow steadily in the coming decades (exceeding the BAU scenario by 7 per cent in terms of the sector GDP) while saving significant amounts of resources and enhancing its sustainability. The green investment

scenario is expected to undercut the corresponding BAU scenario by 18 per cent for water consumption, 44 per cent for energy supply and demand, 52 per cent for CO<sub>2</sub> emissions. This will result in potential avoided costs that can be reinvested in socially and environmentally responsible local activities – such as local transportation and staff capabilities and skills – increasing the indirect and induced effects of tourism expenditure on local development. In particular, the spending by foreign visitors from wealthier regions in developing countries helps to create much-needed employment and opportunities for development, reducing economic disparities and poverty, notably through the multiplier effect and the reduction of leakage.

Tourism can have positive or negative impacts depending on how it is planned, developed and managed. Various enabling conditions are required for transforming tourism to contribute to social and economic development within the carrying capacities of ecosystems.

To promote sustainable tourism in a green economy, the national, regional, and local economy should first provide a good investment climate, featuring security and stability, regulation, taxation, finance, infrastructure, and labour. Various tourism stakeholders should collaborate and share knowledge and tools in order to understand the overall picture of environmental and socio-cultural impacts of tourism activities at destinations. There is also a need for policy coherence, which can include economic instruments and fiscal policy to reward sustainable investments and practices and discourage the most costly externalities associated with uncontrolled tourism expansion. In the case of tourism, government and private tourism authorities should coordinate with ministries responsible for the environment, energy, agriculture, transport, health, finance, security, and other relevant areas, as well as with local governments.

By steering the direction of policy and spearheading sustainability efforts, government authorities can motivate and influence other stakeholders – both public and private – to engage in behaviour that bolsters a destination's sustainability. It is necessary that tourism promotion and marketing initiatives emphasise sustainability as a primary option. To create local development opportunities, marketing efforts should ensure access to domestic and international markets by sustainable local, small, medium, community-based and other tourism suppliers (especially in developing

countries). As the tourism industry is dominated by SMEs, it is also essential to facilitate their access to industry-oriented decision-support tools, information, knowledge as well as to capital. Partnership approaches to lower the costs and risks of funding sustainable tourism investment and in kind support to SMEs should be considered so as to facilitate the shift toward green tourism activities.

The design and implementation of a sustainable tourism *enabling environment* should be based on a sound formal and well-documented analysis. Policymakers should set baselines and measurable targets with regard to short-, medium-, and long-term results of sustainable tourism promotion and marketing. It is important to note that the success of tourism destinations should be evaluated not only in terms of arrivals but also in terms of broader economic, social and environmental drivers, as well as its impacts. Sustainable tourism policymaking should be based on sound quantitative analysis. Valuation exercises (such as choice experiments) can help identify opportunities for sustainable tourism development from the demand side. Tools such as input-output and general equilibrium models, business surveys, and the Tourism Satellite Accounts (TSA) can support policy design and business strategy. The adoption of international standards and criteria (e.g. GSTC) at a global scale is highly recommended in order to assess comparable results and unify an understanding on the practical aspects of sustainable tourism enabling prioritising of private sector investments. Further, increased adoption

of management standards for environmental and labour performance<sup>23</sup> would greatly assist tourism operators in strengthening their internal management capacity to reduce environmental impacts and protect their workers, and enhance capacity to relate to community stakeholders.

The effects of tourism can vary dramatically between destinations. More quantitative studies are necessary to clearly understand the reasons for such variations, to expand the evidence base at a national and sub-national level on tourism and local employment, procurement through local supply chains, poverty reduction, environmental benefits, and other relevant areas. Domestic tourism (in many countries the most important source of tourism income) should be further analysed. Business performance and the determinants of higher return on investment (ROI) on green investments are key variables to study.

This chapter analyses the main variables that influence tourism development and aims to demonstrate that concerted greener policies can steer the growth of the sector toward a more sustainable path, generating economic benefits, while strengthening its social and environmental context. Its findings and recommendations are addressed to all tourism stakeholders.

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23. These include the ISO 14000 series for environmental management, ISO 26000 series for social responsibility management and S.A. 8000 series for working conditions.

# Annex 1: Economic sizing of the sector

Country	Domestic tourism consumption / total tourism consumption (%)*	Tourism gross domestic product / GDP (%)*	Jobs in tourism industries / total jobs (%)*	Tourism investment / total investment (%)**
Australia	73.9	4.1	4.8	12.5
Chile	75.0	3.1	2.6	7.5
China	90.8	4.2	2.3	8.5
Czech Republic	45.3	3.0	3.3	11.0
Ecuador	69.4	4.1	1.8	12.4
Honduras	54.5	5.7	5.3	8.4
Israel	61.0	1.8	2.6	7.6
Japan	93.5	1.9	2.8	5.8
Latvia	51.4	1.9	9.0	7.4
Lithuania	56.4	2.6	2.6	9.8
Netherlands	80.8	3.0	4.3	7.3
New Zealand	56.2	12.0	9.7	15.0
Peru	74.4	3.3	3.1	9.9
Philippines	80.7	6.9	9.7	11.3
Poland	41.0	2.0	4.8	7.1
Romania	47.7	2.2	8.3	7.3
Saudi Arabia	61.5	5.0	3.9	3.9
Slovakia	44.1	2.9	7.3	11.4
Slovenia	43.0	4.9	11.5	12.0
Spain	42.3	10.9	11.8	13.8

\* Estimated with TSA country data for latest year available (mainly 2007). \*\* 2009 values.

**Table A1-1: Economic relevance of tourism in selected countries**

Source: Author's calculations with data from UNWTO (2010c) and WTTC (2010)



# Annex 2: Drivers and likely implications of investment in sustainable tourism strategic areas

Strategic area	Sustainability drivers	Likely implications
Energy	<ul style="list-style-type: none"> <li>■ Increased energy costs</li> <li>■ Likely carbon surcharges</li> <li>■ Customers expectations (particularly from Europe and North America) driving operators and entire supply chain</li> <li>■ Availability of low-carbon technology</li> <li>■ Possible government incentives</li> <li>■ Decreasing costs of renewable energy technologies</li> <li>■ Eco-labels and/or voluntary standards</li> <li>■ Regulations/legislation on energy efficiency and performance of buildings</li> </ul>	<ul style="list-style-type: none"> <li>■ Maintain or reduce operating costs for tourism operators through energy efficiency</li> <li>■ Increased customer satisfaction</li> <li>■ Investment in energy efficiency (retrofits, improvements)</li> <li>■ New energy-efficient investment stock</li> <li>■ Investment in more energy efficient features and services (such as efficient refrigeration, television and video systems, air conditioning and heating and laundry)</li> <li>■ Differentiation of operators and their value chains</li> <li>■ Modest shift toward short-haul versus long-haul tourism, with the effect increasing with energy costs (and offset to the extent efficiency is increased)</li> </ul>
Climate change	<ul style="list-style-type: none"> <li>■ Costs of GHG emissions (driven by post-Kyoto rules)</li> <li>■ Concern of customer base about carbon footprint</li> <li>■ Host government policies and priorities (climate change mitigation and energy)</li> <li>■ Uptake of corporate social responsibility (CSR)</li> <li>■ Climate change impact on tourism sites</li> </ul>	<ul style="list-style-type: none"> <li>■ Same as for energy efficiency</li> <li>■ Increased substitution of fuels toward electricity, particularly increased investment in passive solar collectors, photovoltaics and alternative fuels for vehicles</li> <li>■ Increased number of project developers orienting business strategies toward lower-carbon footprint</li> <li>■ Expectations of broader stakeholder base</li> <li>■ Demand for carbon offsets and other mechanisms to compensate for residual emissions</li> </ul>
Water	<ul style="list-style-type: none"> <li>■ Water scarcity</li> <li>■ Price for water and conflicts</li> <li>■ Expectations from travellers for responsible water management</li> <li>■ Expectations from major tour operators</li> </ul>	<ul style="list-style-type: none"> <li>■ Reduction in water costs from internal water efficiency</li> <li>■ Investments in water saving technology in rooms, facilities (such as laundry and swimming pools) and attractions (such as golf courses, gardens and water-based attractions)</li> <li>■ Increase in number of rooms/visitors in water-constrained destinations</li> <li>■ Slight advantage to destinations with more abundant water supplies in terms of variety of activities and cost of water resources</li> <li>■ Increased use of water treatment systems, at firm/project level and destination</li> </ul>
Waste	<ul style="list-style-type: none"> <li>■ Customer demand for clean destination</li> <li>■ Public opinion</li> <li>■ Degradation of water resources owing to waste dumping and waste water</li> <li>■ Pressure from major tour operators</li> </ul>	<ul style="list-style-type: none"> <li>■ Lower pollution and natural resource</li> <li>■ Improved solid waste management</li> <li>■ Reduction of open waste dumping sites and poorly managed landfills</li> <li>■ Investments in waste water management equipment, treatment and disinfection.</li> <li>■ Investment in sanitary landfills and solid waste recycling capacity</li> <li>■ Lower sewage and clean-up fees</li> </ul>
Biodiversity	<ul style="list-style-type: none"> <li>■ Increased tourist preference for experiences that involve contact with wildlife and pristine (or near pristine) ecosystems</li> <li>■ Expectations from guests that operators protect the natural resource base</li> <li>■ Government regulations regarding sensitive ecosystems such as coral reefs, coastal wetlands and forests</li> <li>■ National policies to attract resources through tourism capable of protecting critical biological habitat</li> <li>■ Ecosystem services potential for tourism revenue generation</li> </ul>	<ul style="list-style-type: none"> <li>■ Demand for nature-based tourism likely to accelerate as pristine areas become increasingly rare</li> <li>■ Increased number of policies and related practices in mainstream tourism to more effectively protect sensitive ecosystems</li> <li>■ Improved design of individual projects and destinations incorporating biodiversity conservation <i>in situ</i>, and through compensatory mechanisms</li> <li>■ Increased incorporation of natural areas in tourism development and greater transfer of benefits toward natural areas through entrance fees and Payment for Ecosystem Services (PES) schemes</li> </ul>

**Table A2-1: Drivers and likely implications of investment in sustainable tourism strategic areas**

Source: Author's compilation

Strategic area	Sustainability drivers	Likely implications
Cultural heritage	<ul style="list-style-type: none"> <li>■ Tourist preference for experiences that involve contact with authentic cultural landscapes</li> <li>■ Expectations from guests that their tourism operators respect and protect traditional culture</li> <li>■ Increased awareness of World Heritage Sites</li> <li>■ Recognition and appreciation for cultural diversity</li> </ul>	<ul style="list-style-type: none"> <li>■ Respect and recognition of traditional culture, particularly in context of assimilation into a dominant culture. Help to community members to validate their culture, especially when external influences of modern life cause the young to become disassociated from traditional life and practices</li> <li>■ Conservation of traditional lands and natural resources on which the culture has traditionally relied</li> <li>■ Help to reduce poverty within a community or cultural group. Increased opportunities for young to remain in community instead of seeking alternative opportunities in cities and towns. Meet the needs of cultural groups, such as health care, access to clean water, education, employment and income</li> <li>■ Reduced risk of losing unique cultural attributes</li> </ul>
Linkages with Local Economy	<ul style="list-style-type: none"> <li>■ Demand for more contact with local communities</li> <li>■ Greater number and variety of excursions in a given destination</li> <li>■ “Buy local” movement in food and beverages sector</li> <li>■ CSR uptake</li> <li>■ Public and private initiatives of local workers training</li> <li>■ Growth of specialised niches (ecotourism, rural tourism, adventure tourism, sports fishing, agrotourism and community-based tourism)</li> <li>■ Development of infrastructure and supporting industries</li> </ul>	<ul style="list-style-type: none"> <li>■ Concerted efforts by tourism authorities, local officials and civil society organisations to increase local content</li> <li>■ Responses by tourism operators and increasing use of indicators to track local contribution (which feed into tourism satellite accounts)</li> <li>■ Deepened supply chain in local economy, generating increased indirect employment</li> <li>■ Increased spending in local economy from income effects in direct and indirect employee consumption and purchases</li> <li>■ Improved income distribution among industry stakeholders</li> <li>■ Decreased leakage (imports of intermediate goods and foreign workers)</li> </ul>

**Table A2-1: Drivers and likely implications of investment in sustainable tourism strategic areas**

Source: Author's compilation

# Annex 3: Assumptions of the model

## 1. Tourism energy management:

25 per cent of the tourism sector green investment (on average US\$ 61 billion per year) is allocated in 2011-2050 to both energy demand reduction through efficiency improvements and increase of renewable energy supply.

**Abatement of emissions from energy use:** Emissions from tourism activities are reduced in the green scenario through efficiency improvements in tourism electricity and fuel consumption and behavioural changes towards longer stay and fewer trips, shorter travel distance and transport modal shifts (from aviation and private cars to cleaner transport, e.g. coach and electric railway). This investment adds up to US\$ 18 billion per year on average over the next forty years, or 29 per cent of the tourism energy green investment in the green investment case (G2). The same rates of efficiency gain and modal shifts as in associated GER sectors are assumed, while the assumption in increase of stay (by 0.5 per cent per year) and reduction of trips (to retain total guest nights) is based on the scenarios presented by UNWTO and UNEP (2008). The investment is estimated by using CO<sub>2</sub> abatement costs included in International Energy Agency (IEA) (2009). More specifically, for tourism transportation:

■ The length of stay is assumed to increase by 0.5 per cent per year (on average 3.7 days in 2050) instead of a 0.5 per cent decrease per year (2.5 days in 2050) in BAU, in line with the scenarios of UNWTO and UNEP (2008). To be consistent with the projected total guest nights in other scenarios, tourist arrivals in the green investment scenario are reduced. Thereby these travelling behavioural changes result in fewer but longer trips, but would not affect total number of guest nights. In addition, IEA's assumption of reduced travel is a good fit with the green tourism goal (short travel and longer stays).

■ With respect to transport modal shift and energy efficiency in the green scenario, to ensure coherence across the sectors, the same assumptions as in the GER transportation sector are used for tourism. In accordance with IEA's reports, it is assumed that by 2050 in the green scenario, 25 per cent of car travel and air travel is replaced by bus or rail. The ratio of transport energy efficiency in the green investment scenario (by 60 per cent) is based on the amount of green investment and unit abatement costs from IEA.

■ Renewable energy production: Additional investments of 71 per cent of the tourism energy green investment (or US\$ 43 billion on average per year)

between 2010 and 2050 are allocated to the introduction and expansion of renewable power generation and biofuel production. The cost assumptions are collected from IEA (2009).

## 2. Tourism water management:

0.1 per cent of the tourism-sector green investment (on average US\$ 0.24 billion per year) is allocated in 2011-2050 to both water demand reduction through efficiency improvements and increase of water supply:<sup>24</sup>

**Water efficiency improvement:** The amount of investment in water-efficiency improvement, aimed at reducing tourism water demand, is assumed to be US\$ 0.16 billion per year on average (or 65 per cent of investment in tourism water management) over the 40-year period. The unit cost is assumed to be US\$ 0.28/m<sup>3</sup>.

**Water supply:** The remaining (35 per cent) of tourism-sector water investment (US\$ 0.86 billion per year on average between 2010 and 2050) aims to increase water supply from desalination and conventional water sources:

■ Desalination: 30 per cent of water-supply investment (US\$ 0.026 billion per year on average), over the 40-year period will be invested in water desalination. The cost to supply water desalination is set at US\$ 1.1/m<sup>3</sup>.

■ Conventional water supply management: 70 per cent of the total water-supply investment (US\$ 0.06 billion per year on average) is allocated to conventional water-supply management measures, including treatment of wastewater, reservoir storage, and surface and underground water supply. The unit cost to increase conventional water supply is set at US\$ 0.11/m<sup>3</sup>.

## 3. Waste management:

13 per cent of tourism-sector green investment (on average US\$ 32 billion per year) is allocated in 2011-2050 to upstream (collection) and downstream (reuse) waste treatment:

■ Waste reuse: 8 per cent of the tourism waste investment is invested in waste recycling and recovery, totalling on average US\$ 2.4 billion per year over the next 40 years under the green investment scenario. The unit costs of recycling and compost are assumed to be US\$ 138 per tonne and US\$ 44.85 per tonne respectively.

24. The low level of investment allocated to tourism water sector is due to the relatively small amount of water consumption in tourism compared to the total of all sectors, as the same unit costs and improvement percentage are used for all water users.

■ **Waste collection:** the remaining 92 per cent of green investment in tourism waste management is allocated to improve the waste collection rate, totalling on average US\$ 30 billion per year over the next 40 years under the green investment scenario. The upstream cost of waste treatment is assumed to rise from US\$ 1,083 per tonne in 1970 to US\$ 1,695.5 per tonne in 2050.

#### 4. Training of employees:

12 per cent of tourism investment in the green investment scenario, or US\$ 31 billion on average each year between 2011 and 2050. The cost of training per employee is assumed to be US\$ 117 for 120 hours, while all new employees attend training for one year in total over the duration of their career (together with the assumption that as many as possible would be local workforce). Overall, the total cumulative cost of training one employee is assumed to reach US\$ 2,854. A variety of scenarios were simulated to study and evaluate the impacts of the variation in training cost per employee per year, in the range of between 30 per cent lower and

higher than the assumed cost (or from US\$ 1,998 to US\$ 3,711).

#### 5. Biodiversity conservation:

50 per cent of tourism investment, or US\$ 123 billion on average each year between 2011 and 2050. Three scenarios are simulated based on different biodiversity conservation costs. These are (a) US\$ 119 per hectare, assuming only forest conservation – using the average cost offered by FONAFIFO<sup>25</sup>; (b) US\$ 451 per hectare assuming the possibility to undertake forestry and agriculture on that land (based on the experience in Costa Rica, from Forestry chapter); (c) US\$ 1,380 per hectare assuming that housing and other related business opportunities can be created, based on what is offered by Amazon Carbon and Biodiversity Investment Fund (ACIF).<sup>26</sup>

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25. Fondo Nacional de Financiamiento Forestal, Costa Rica.

26. The Amazon Carbon and Biodiversity Investment Fund (ACIF) offers between US\$ 276 and US\$ 3,450 per ha, but it is a very specific case for 100,000 ha (US\$ 3,450/ha seems high for an average). As a consequence, US\$ 1,380/ha is used as a maximum value of conservation cost in this analysis.

# References

- Adamson, M. (2001). "El uso del Método de Valoración Contingente para estimar precios de las "Amenities" provistas por el Parque Nacional Manuel Antonio." *Serie Documentos de Trabajo*, N°208. Instituto de Investigaciones en Ciencias Económicas, Universidad de Costa Rica.
- Ashley, C., H. Goodwin, D. McNab, Scott, M., and Chaves, L. (2006). *Making Tourism Count for the Local Economy in the Caribbean. Guidelines for Good Practice*. Pro-Poor Tourism Partnership and the Caribbean Tourism Organization.
- Becken, S. and Hay, J. (2007). *Tourism and Climate Change: Risks and Opportunities*. Channel View Publications, Cleveland.
- Becken, S., Simmons, D., and Frampton, C. (2003). "Segmenting Tourists by their Travel Pattern for Insights into Achieving Energy Efficiency." *Journal of Travel Research*, 42(1), 48-56.
- Bien, A. et al. (2008). "Sustainable Tourism Baseline Criteria Report (2007)." Global Sustainable Tourism Criteria, version 5.0 (25 Sept08). [www.SustainableTourismCriteria.org](http://www.SustainableTourismCriteria.org).
- Bishop, J., Kapila, S., Hicks, F., Mitchell, P., and Vorhies, F. (2008). *Building Biodiversity Business*. Shell International Limited and the International Union for Conservation of Nature: London, UK, and Gland, Switzerland.
- Brenes, W., Martorell, R., and Venegas, J. (2007). *Calidad de vida en las familias y comunidades con proyectos de desarrollo turístico: un estudio de caso en dos tipos "modelos" de turismo: Tamarindo de Santa Cruz y La Fortuna de San Carlos*. San José: Estado de la Nación en Desarrollo Sostenible.
- By, R. and Dale, C. (2008). "The successful management of organisational change in tourism SMEs: initial findings in UK visitor attractions." *The International Journal of Tourism Research*, 10(4).
- CalRecovery and UNEP. (2005). *Solid Waste Management*. United Nations Environment Programme.
- Center on Ecotourism and Sustainable Development (CESD) and International Ecotourism Society (TIES). (2005). "Consumer Demand and Operator Support for Socially and Environmentally Responsible Tourism." CESD/TIES Working Paper No. 104. April 2005.
- Chang, W. (2001). *Variations in multipliers and related economic ratios for recreation and tourism impact analysis*. Unpublished Dissertation. Michigan State University. Department of Parks, Recreation and Tourism Resources. 150 pp.
- Cooper, C., Fletcher, J., Fyall, A., Gilbert, D., and Wanhill, S. (2008). *Tourism: Principles and Practice*. Essex: Pearson Education Limited. Fourth Edition.
- Dalem, A.A.G.R. (2002). "Ecotourism in Indonesia." In *Linking Green Productivity to Ecotourism: Experiences in the Asia Pacific Region*, 92-94. Tokyo: Asian Productivity Organization.
- Driml, S., Robinson, J., Tkaczynski, A., and Dwyer, L. (2010). *Tourism Investment in Australia: A Scoping Study*. Queensland: Sustainable Tourism Cooperative Research Centre.
- Economic Commission for Latin America and the Caribbean (ECLAC/CEPAL). (2007). *Turismo y Condiciones Sociales en Centroamérica: Las Experiencias en Costa Rica y Nicaragua*. Available in [www.eclac.cl/publicaciones/xml/4/28854/L779.pdf](http://www.eclac.cl/publicaciones/xml/4/28854/L779.pdf).
- "Equator Initiative." [www.equatorinitiative.org](http://www.equatorinitiative.org), retrieved on 27 November 2010.
- Fortuny, M., Soler, R., Cánovas, C., and Sánchez, A. (2008). "Technical approach for a sustainable tourism development. Case study in the Balearic Islands." *Journal of Cleaner Production*, 16, 860-869.
- FutureBrand. (2008). *Country Brand Index 2008: Insights, Findings and Country Rankings*. FutureBrand and Weber Shandwick.
- GEF. (2009). *GEF Annual Report 2009*. Global Environment Facility (GEF).
- (2010). *Behind the Numbers: A Closer Look at GEF Achievements*. Global Environment Facility (GEF).
- GHK. (2007). *Links between the environment, economy and jobs*. GHK, Cambridge Econometrics and IEEP. London.
- Gössling, S. (2005). "Tourism's contribution to global environmental change: space, energy, disease and water." In *Tourism Recreation and Climate Change: International Perspectives*, eds C.M. Hall & J Higham, Channel View Publications, Clevedon.
- Gössling, S. (2010). Background Report (Water) prepared for the tourism chapter of the UNEP Green Economy Report.
- Gössling, S. and Hall, C.M. (eds.). (2006). *Tourism and Global Environmental Change: Ecological, Social and Political Interrelationships*. Routledge, London.
- Hagler Bailly, Inc. (1998). "Assessment of Voluntary International Environmental Certification Programs." Report prepared for Jamaican Hotel and Tourist Association, Arlington, VA: Halger Bailly.
- Hall, C.M. and Coles, T. (2008). "Introduction: Tourism and international business." In T. Coles and C.M. Hall (Ed.), *International Business and Tourism: Global Issues, Contemporary Interactions*. (1-25). London: Routledge.
- Hamele, H. and Eckhardt, S. (2006). *Environmental Initiatives by European Tourism Businesses*. Instruments, indicators and practical examples. A contribution to the development of sustainable tourism in Europe. Saarbrücken: SUTOUR, TourBench, DBU, ECOTRANS.
- Hernández, R. (2004). "Impacto Económico del Turismo. El Papel de las Importaciones como Fugas del Modelo." *Sector Exterior Español*, 817.
- Hiltunen, M.J. (2007). "Environmental Impacts of Rural Second Home Tourism – Case Lake District in Finland." *Scandinavian Journal of Hospitality and Tourism*, 7(3), 243-265.
- Honey, M., Vargas, E.; Durham, W.H. (2010). Impact of Tourism Related Development on the Pacific Coast of Costa Rica; Center for Responsible Travel; [www.responsibletravel.org](http://www.responsibletravel.org).
- IEA. (2009): *World Energy Outlook (2009)*. OECD/IEA. Paris.
- ILO. (2008). *Guide for social dialogue in the tourism industry*. Sectoral Activities Programme. Working Paper 265 prepared by Dain Bolwell and Wolfgang Weinz.
- (2010a). Reducing poverty through tourism. Sectoral Activities Programme. Working Paper 266 prepared by Dain Bolwell and Wolfgang Weinz.
- (2010b). Developments and challenges in the hospitality and tourism sector. Sectoral Activities Programme. Issues paper for discussion at the Global Dialogue Forum for the Hotels, Catering, Tourism Sector (23-24 November 2010).
- Inman, C., Segura, G., Ranjeva, J., Mesa, N., and Prado, A. (2002). *Destination: Central America. A Conceptual Framework for Regional Tourism Development*. Latin American Center for Competitiveness and Sustainable Development (CLACDS). Working Paper, CEN 607.
- Ivanovic, S., Katic, A., and Mikanac, K. (2010). "Cluster as a Model of Sustainable Competitiveness of Small and Medium Entrepreneurship in the Tourist Market." *UTMS Journal of Economics*, 1 (2), pp. 45-54.
- Kyriakidou, O. and Gore, J. (2005). "Learning by example: Benchmarking organizational culture in hospitality, tourism and leisure SMEs." *Benchmarking*, 12 (3), pp 192-206.
- Klytchnikova, I. and Dorosh, P. (2009). "How Tourism can (and does) benefit the Poor and the Environment. A Case Study from Panama." In *En Breve*, 146, August, The World Bank.
- Lejárraga, I. and Walkenhorst, P. (2010). "On linkages and leakages: measuring the secondary effects of tourism." *Applied Economics Letters*, 17(5), 417-421.
- Mill, R., and Morrison, A. (2006). *The Tourism System*. Kendall/Hunt Publishing Company. Fifth Edition.
- Mitchell, J. and Ashley, C. (2007). "Can tourism offer pro-poor pathways to prosperity? Examining evidence on the impact of tourism on poverty." *Briefing Paper 22*. Overseas Development Institute.
- Mitchell, N., Rössler, M., and Tricaud, P. (2009). "World Heritage Cultural Landscapes. A Handbook for Conservation and Management." *World Heritage Papers* 26. UNESCO.



- Moreno, M., Salas, F., Otoy, M., González, S., Cordero, D., and Mora, C. (2010). Análisis de las Contribuciones de los Parques Nacionales y Reservas Biológicas al desarrollo socioeconómico de Costa Rica 2009. UNA, CINPE, SINAC. Heredia: Costa Rica.
- Naidoo, R. and Adamowicz, W. (2005) "Biodiversity and nature-based tourism at forest reserves in Uganda." *Environment and Development Economics*, 10, 159–178.
- Nellemann, C. and Corcoran, E. (eds). (2010). *Dead Planet, Living Planet – Biodiversity and Ecosystem Restoration for Sustainable Development. A Rapid Response Assessment*. United Nations Environment Programme, GRID-Arendal. [www.grida.no](http://www.grida.no).
- Newell, G. and Seabrook, S. (2006). "Factors influencing hotel investment decision making." *Journal of Property Investment and Finance*, 24(4), 279-294.
- Newsom, D. and Sierra, C. (2008). Impacts of Sustainable Tourism Best Management Practices in Sarapiquí, Costa Rica. Rainforest Alliance.
- OECD. (2000). Measuring the Role of Tourism in OECD Economies. The OECD Manual on Tourism Satellite Accounts and Employment. Paris.
- (2010). *OECD Tourism Trends and Policies 2010*. Paris: Organization for Economic Co-operation and Development.
- Pan African Research & Investment Services (PAIRS). (2010). *A Framework/Model to Benchmark Tourism GDP in South Africa: What is the role of tourism in the economy and what drives tourism in South Africa?* PAIRS.
- Peeters, P., Gössling, S., and Scott, A. (2010). Background Report (Tourism patterns and associated energy consumption), prepared for the tourism chapter of the UNEP Green Economy Report.
- Pollock, A. (2007). *The Climate Change Challenge. Implications for the Tourism Industry*. The Icarus Foundation.
- Pratt, L. and Rivera, L. (2004). Perspectivas sobre la Competitividad del Turismo Costarricense. In *Revista Fragua*, N°1, 2004.
- Rainforest Alliance. (2009). *Análisis del impacto económico de las empresas de turismo sostenible en las comunidades locales. Caso Granada, Nicaragua*. Proyecto Alianza Internacional para el Mercadeo y Comercialización de Productos y Servicios de Turismo Sostenible.
- (2010). *Buenas Prácticas de Manejo en las Empresas Turísticas: sus Beneficios e Implicaciones*. San José: Sustainable Tourism Program.
- Rheem, C. (2009). *Going Green: The Business Impact of Environmental Awareness on Travel*. PhoCusWright Inc.
- Ringbeck, J., El-Adawi, A., and Gautarn, A. (2010). *Green Tourism. A Road Map for Transformation*. Booz & Company Inc.
- Rojas, L. (2009). *Evolución e Importancia del Turismo en Costa Rica*. San José: Estado de la Nación en Desarrollo Sostenible.
- Scott, D., Peeters, P., and Gössling, S. (2010). "Can Tourism 'Seal the Deal' of its Mitigation Commitments? The Challenge of Achieving 'Aspirational' Emission Reduction Targets." *Journal of Sustainable Tourism*, 18(2).
- Sindiga, I. (1995). "Wildlife-based Tourism in Kenya: Land use conflicts and government compensation policies over protected areas." *The Journal of Tourism Studies*, 6(2).
- Six Senses. (2009). *Carbon Inventory Report. Evason Phuket 2008-2009*. Six Senses Resorts & Spas, Bangkok, Thailand.
- SNV. (2009). *The Market for Responsible Tourism Products in Latin America and Nepal*. SNV Netherlands Development Organisation.
- Spenceley, A. (2004). "Tourism Certification in Africa: Marketing, incentives and monitoring." The International Ecotourism Society, December.
- Steck, B., Wood, K., and Bishop, J. (2010). *Tourism: More Value for Zanzibar. Value Chain Analysis*. SNV, VSO, ZATI.
- TEEB. (2010). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Kumar, P. London and Washington: Earthscan.
- Toth, B., Russillo, A., Crabtree, A., and Bien, A. (2006). "Implementing Monitoring and Evaluation Systems for Impact: A Guide for Tourism Certifiers and Their Clients." TIES, [www.ecotourism.org](http://www.ecotourism.org).
- Tourism Concern. (2009). Internal trip report (India and Sri Lanka).
- Tourism Concern (2010): Personal communication.
- Travel to South Africa. "Nature-based Tourism." <http://www.satour.co.za/more/articles/naturebasedtourism.html>. Accessed 28 November 2010.
- TPRG. (2009). *The Application of Value Chain Analysis to measure Economic Benefits at Tanjong Piai, Pontian, and Johor*. Tourism Planning Research Group. Universiti Teknologi Malaysia.
- UNCTAD. (2009). *World Investment Report 2009. Transnational Corporations, Agricultural Production and Development*. New York and Geneva.
- (2010): *The Contribution of Tourism to Trade and Development*. Note by the UNCTAD secretariat. TD/B/C.I/8.
- UNEP. (2003). *A Manual for Water and Waste Management: What the Tourism Industry Can Do to Improve Its Performance*. Paris: United Nations Environment Programme.
- (2008). *Building Nepal's private sector capacity for sustainable tourism operations. A collection of best practices and resulting business benefits*. Paris: United Nations Environment Programme.
- (2010). *Are you a green leader? Business and biodiversity: making the case for a lasting solution*. Paris: United Nations Environment Programme.
- UNEP and UNDP. (2001). *Integrating Biodiversity into the Tourism Sector: A Guide to Best Practice*. Prepared for the Biodiversity Planning Support Programme (BPSP).
- UNEP and UNWTO. (2005). *Making Tourism more Sustainable. A Guide for Policy Makers*. United Nations Environment Programme and World Tourism Organization.
- UNWTO. (2001). *Tourism 2020 Vision*. Madrid: World Tourism Organization.
- (2004a). *Indicators of Sustainable Development for Tourism Destinations. A Guidebook*. Madrid: World Tourism Organization.
- (2004b). *Tourism and Poverty Alleviation: Recommendations for Action*. Madrid: World Tourism Organization.
- (2010a). *Tourism and the Millennium Development Goals*. Madrid: World Tourism Organization.
- (2010b). *UNWTO World Tourism Barometer*, 8(2), June.
- (2010c). *TSA Data around the World. Worldwide Summary*. Statistics and TSA Programme. Madrid: World Tourism Organization.
- (2010d). *Tourism and Biodiversity: Achieving common goals towards sustainability*. Madrid: World Tourism Organization.
- (2011). *UNWTO Tourism Highlights. 2011 Edition*. Madrid: World Tourism Organization.
- UNWTO and UNEP. (2008). *Climate Change and Tourism, Responding to Global Challenges*. Madrid: World Tourism Organization and United Nations Environment Programme.
- WEF. (2008). *The Travel and Tourism Competitiveness Report 2008. Balancing Economic Development and Environmental Sustainability*. Blanke, J. and T. Chiesa, (eds). Geneva: World Economic Forum.
- (2009a). *The Travel and Tourism Competitiveness Report 2009. Managing in a Time of Turbulence*. Blanke, J. and T. Chiesa, (eds). Geneva: World Economic Forum.
- (2009b). *Towards a Low Carbon Travel & Tourism Sector*. Chiesa, T. and A. Gautam (eds.). Geneva: World Economic Forum and Booz & Company.
- Wells, M. (1997). "Economic Perspectives on Nature Tourism, Conservation and Development." Environment Department Papers 55. The World Bank.
- World Bank. (2010). World Development Indicators database. <http://data.worldbank.org/data-catalog/world-development-indicators/>
- (2006). *Where is the Wealth of Nations? Measuring Capital for the 21st Century*. Washington, D.C.
- WTTC (2010). *The 2010 Travel and Tourism Economic Research*. Economic Data Research Tool. World Travel and Tourism Council. [www.wttc.org](http://www.wttc.org).
- (2010b). *Travel & Tourism Economic Impact 2010: South Africa*. Economic Data Research Tool. World Travel and Tourism Council.
- WWF. (2004). *Freshwater and Tourism in the Mediterranean*. Available at: [http://www.panda.org/downloads/europe/medpotourismreportfinal\\_ofnc.pdf](http://www.panda.org/downloads/europe/medpotourismreportfinal_ofnc.pdf)







GREEN economy



# Cities

Investing in energy and resource efficiency





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## List of acronyms

ARPU	Average revenue per user
BAU	Business-as-usual
BedZED	Beddington Zero Energy Development
BRT	Bus rapid transit
C40	Cities Climate Leadership Group
CDM	Clean Development Mechanism
CDS	City Development Strategy
CO <sub>2</sub>	Carbon dioxide
CHP	Combined heat and power
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAR	Floor area ratios
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIS	Geographic Information System
GLA	Greater London Authority
GNP	Gross National Product
HDI	Human Development Index
ILO	International Labour Organization
IOE	International Organisation of Employers
LSE	London School of Economics and Political Science
MTR	Mass Transit Railway
OECD	Organisation for Economic Co-operation and Development
PES	Payment for Ecosystem Services
R&D	Research and development
PV	Photovoltaic
UNEP	United Nations Environment Programme

# Key messages

**1. Urban development will have to fundamentally change to facilitate the transition towards a green economy.** Urban areas are now home to 50 per cent of the world's population but they account for 60-80 per cent of energy consumption and a roughly equal share of carbon emissions. Rapid urbanisation is exerting pressure on fresh water supplies, sewage, the living environment and public health, which affect the urban poor most. In many cases, urbanisation is characterised by urban sprawl and peripheralisation – which is not only socially divisive, but also increases energy demand, carbon emissions and puts pressure on ecosystems.

**2. Unique opportunities exist for cities to lead the greening of the global economy.** There are genuine opportunities for national and city leaders to reduce carbon emissions and pollution, enhance ecosystems and minimise environmental risks. Compact, relatively densely populated cities, with mixed-use urban form, are more resource-efficient than any other settlement pattern with similar levels of economic output. Integrated design strategies, innovative technologies and policies are available to improve urban transport, the construction of buildings and the development of urban energy, water and waste systems in such a way that they reduce resource and energy consumption and avoid lock-in effects.

**3. Green cities combine greater productivity and innovation capacity with lower costs and reduced environmental impact.** Relatively high densities are a central feature of green cities, bringing efficiency gains and technological innovation through the proximity of economic activities, while reducing resource and energy consumption. Urban infrastructure including streets, railways, water and sewage systems comes at considerably lower cost per unit as urban density rises. The problem of density-related congestion and associated economic costs can be addressed and offset by developing efficient public transport systems and road charges.

**4. In most countries, cities will be important sites for the emerging green economy.** This is for three main reasons. First, the proximity, density and variety intrinsic to cities deliver productivity benefits for companies and help stimulate innovation. Second, green industries are dominated by service activity – such as public transport, energy provision, installation and repair – which tends to be concentrated in urban areas where consumer markets are largest. Third, some cities will also develop high-tech green manufacturing clusters in or close to urban cores, drawing on knowledge and skill spillovers from universities and research labs.

**5. Introducing measures to green cities can increase social equity and quality of life.** Enhancing public transport systems, for example, can reduce inequality by improving access to public services and other amenities, and by helping to relieve vehicle congestion in poorer neighbourhoods. Cleaner fuel for transport and power generation can reduce both local pollution and health inequality. Reducing traffic and improving conditions for pedestrians and cyclists can help foster community cohesion, an important aspect of quality of life, which also has positive impacts on economic resilience and productivity. Evidence shows that children who live in close proximity to green space are more resistant to stress, have a lower incidence of behavioural disorders, anxiety, and depression, and have a higher measure of self-worth. Green space also stimulates social interaction and enhances human well-being.

**6. Only a coalition of actors and effective multilevel governance can ensure the success of green cities.** The most important fundamental enabling condition is a coalition of actors from the national and local state, civil society, the private sector and universities who are committed to advancing the green economy and its urban prerequisites, placing it centrally within the top strategic priorities for the city. The central task of this coalition is to promote the idea of a long-term strategic plan for the city or urban territory. Equally, it is crucial to develop strategic frameworks not just at the local and urban level, but also at regional and national levels, ensuring coordinated design and implementation of policy instruments.

**7. Numerous instruments for enabling green cities are available and tested but need to be applied in a tailored, context-specific way.** In contexts with strong local government it is possible to envisage a range of planning, regulatory, information and financing instruments applied at the local level to advance green infrastructure investments, green economic development and a multi-track approach to greater urban sustainability. In other contexts, local governments, in a more pragmatic approach, could target a few key sectors such as water, waste, energy and transport and commit those to a limited number of specific goals as a point of departure for greening urban sectors.





# 1 Introduction

This chapter makes a case for greening cities. It describes the environmental, social and economic consequences of greening urban systems and infrastructure and provides guidance to policy makers on how to make cities more environmentally friendly.

An introduction to the concept of green cities is followed by Section 2, which presents related challenges and opportunities. Section 3 analyses the economic, social, and environmental benefits of city greening, while Section 4 summarises green practices across a number of urban sectors. Section 5 offers advice on enabling conditions for green cities. Section 6 concludes the chapter.

## 1.1 Cities

A city is a social, ecological, and economic system within a defined geographic territory. It is characterised by a particular human settlement pattern that associates with its functional or administrative region, a critical mass and density of people, man-made structures and activities (OECD and China Development Research Foundation 2010). Most commonly, cities are differentiated from other settlements by their population size and functional complexity (Fellmann et al. 1996). The definition of cities varies significantly from nation to nation, and is not always dependent on population size but can also reflect administrative or historical status (Satterthwaite 2008). The definition of urban areas tends to rely more on a population minimum but varies dramatically since it is dependent on unit size designations given by individual governments, which can range from minimum thresholds of 200 to 20,000 inhabitants upwards (UN Statistics Division 2008).<sup>1</sup>

## 1.2 Green cities

Green cities are defined as those that are environmentally friendly.<sup>2</sup> Indicators measuring environmental performance can include: levels of pollution and carbon emission, energy and water consumption, water quality, energy mix, waste volumes and recycling rates, green-space ratios, primary forests, and agricultural land loss (Meadows 1999; Bruggmann 1999). Other indicators include the share of apartment living, motorisation rate, and modal share of urban

transport. Another important measure of humanity's demand on nature is the Ecological Footprint (Ewing et al. 2010).<sup>3</sup> Defining green cities by their environmental performance does not mean social equity issues are ignored. In fact, and as detailed below, greener living environments can play an important role in making cities more equitable for their residents.

There are also existing cities that are referred to as green because of their ambitious green policies, a range of green projects and a principal trajectory towards a better environmental performance. A number of cities in western Europe, the USA and Canada have pioneered green strategies.<sup>4</sup> Freiburg, a city of 200,000 inhabitants in Germany, has a long tradition of sustainable building and investment in recycling and it reduced CO<sub>2</sub> emissions per capita by 12 per cent between 1992 and 2003 (Duennhoff and Hertle 2005). Several cities in developing countries, especially in South America, have also branded themselves green. Authorities in Curitiba, Brazil introduced policies to integrate land-use and transport planning and by the 1970s the city was equipped with an innovative bus rapid transit system (Economist Intelligence Unit 2010). Singapore introduced the world's first road-charging scheme in the 1980s and it is now at the forefront of sustainable policies on waste, water and the greening of the environment (Phang 1993; Suzuki et al. 2010).

1. Satterthwaite (2008) estimates that a quarter of the world's population lives in cities below 500,000 and another quarter in urban areas below 500,000 inhabitants. He suggests that roughly two-thirds of the world's population live in rural areas and small towns. This indirectly suggests that about one-third of the global population might live in cities.

2. The greening of cities requires some, or preferably all, of the following: (1) controlling diseases and their health burden; (2) reducing chemical and physical hazards; (3) developing high quality urban environments for all; (4) minimising transfers of environmental costs to areas outside the city; and (5) ensuring progress towards sustainable consumption (Satterthwaite 1997). This chapter cuts across all five areas, but the issue of cities in relation to climate change – given its primacy in international environmental policy – is given added weight.

3. Ecological footprint measures how much biologically productive land and water area a human population or activity requires to produce the resource it consumes and to absorb its wastes, using prevailing technology and resource management practices. These areas are scaled according to their biological productivity to provide a comparable unit, the so-called global hectare.

4. While many of these initiatives have made major strides in reducing carbon emissions, it is important to note that none of these cities possesses an ecological footprint below 4 hectares per capita (UN-HABITAT 2008; own calculation by Arup) – more than twice the world average biocapacity per capita in 2006 – suggesting that there is still some way to go in implementing sustainable change.

## 2 Challenges and opportunities

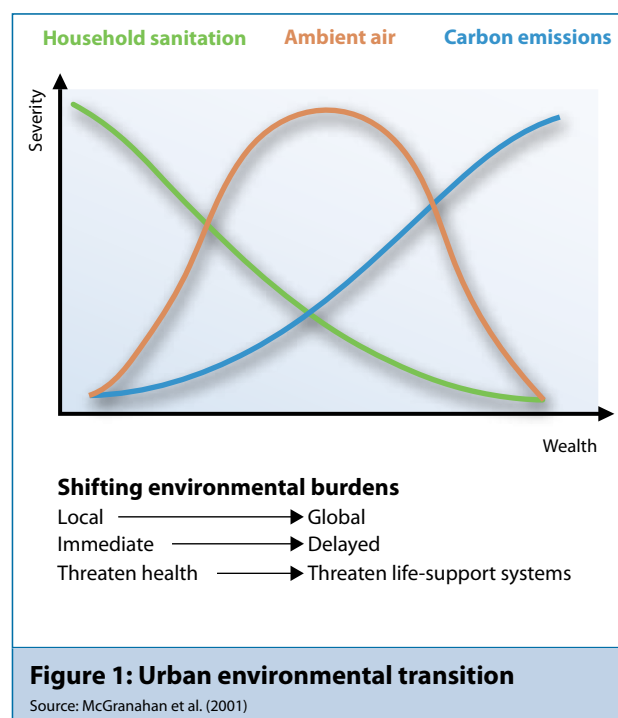
Urbanisation brings both challenges and opportunities for green cities. Challenges include the rapid pace of urbanisation and related pressure on the environment and social relations if it continues on the same trajectory (the business-as-usual or BAU model). Opportunities for green cities include the possibility to design, plan and manage their physical structure in ways that are environmentally advantageous, advance technological innovation as well as profit from synergies that exist between the constituent elements of complex urban systems.

### 2.1 Challenges

#### The rapid pace of urbanisation

In 2007, for the first time in human history, 50 per cent of the global population lived in urban areas. Only a century ago, this figure stood at 13 per cent but it is now predicted to reach 69 per cent by 2050 (UN Population Division 2006 and 2010). In some regions, cities are expanding rapidly, while in others, rural areas are becoming more urban. A significant part of this urbanisation is taking place in developing countries as a result of natural growth within cities and large numbers of rural-urban migrants in search of jobs and opportunities. Often this happens despite widespread anti-urbanisation policies, which aim to balance development and to sustain rural economies (UNFPA 2007). However, such efforts have mostly been unsuccessful and risk that urban agglomerations are left unprepared for inevitable increase in population growth. Rapid urban growth tends to overwhelm cities where the struggle to develop infrastructure, mobilise and manage resources has negative consequences for the environment.

The scale of the problem comes into sharp focus in India and China. India's urban population grew from 290 million in 2001 to 340 million in 2008 and it is projected to reach 590 million by 2030 (McKinsey Global Institute 2010). The country will have to build 700-900 million square metres of residential and commercial space a year to accommodate this growth, requiring an investment of US\$ 1.2 trillion to build 350-400 kilometres of subway and up to 25,000 kilometres of new roads per year. Similarly, China's urban population is expected to increase from 636 million in 2010 to 905 million by 2030 (UN Population Division 2010). It is predicted that by 2050 the country will need to invest 800-900 billion RMB per year to improve its urban infrastructure, about one-tenth of China's total GDP in 2001 (Chen et al. 2008). The nature

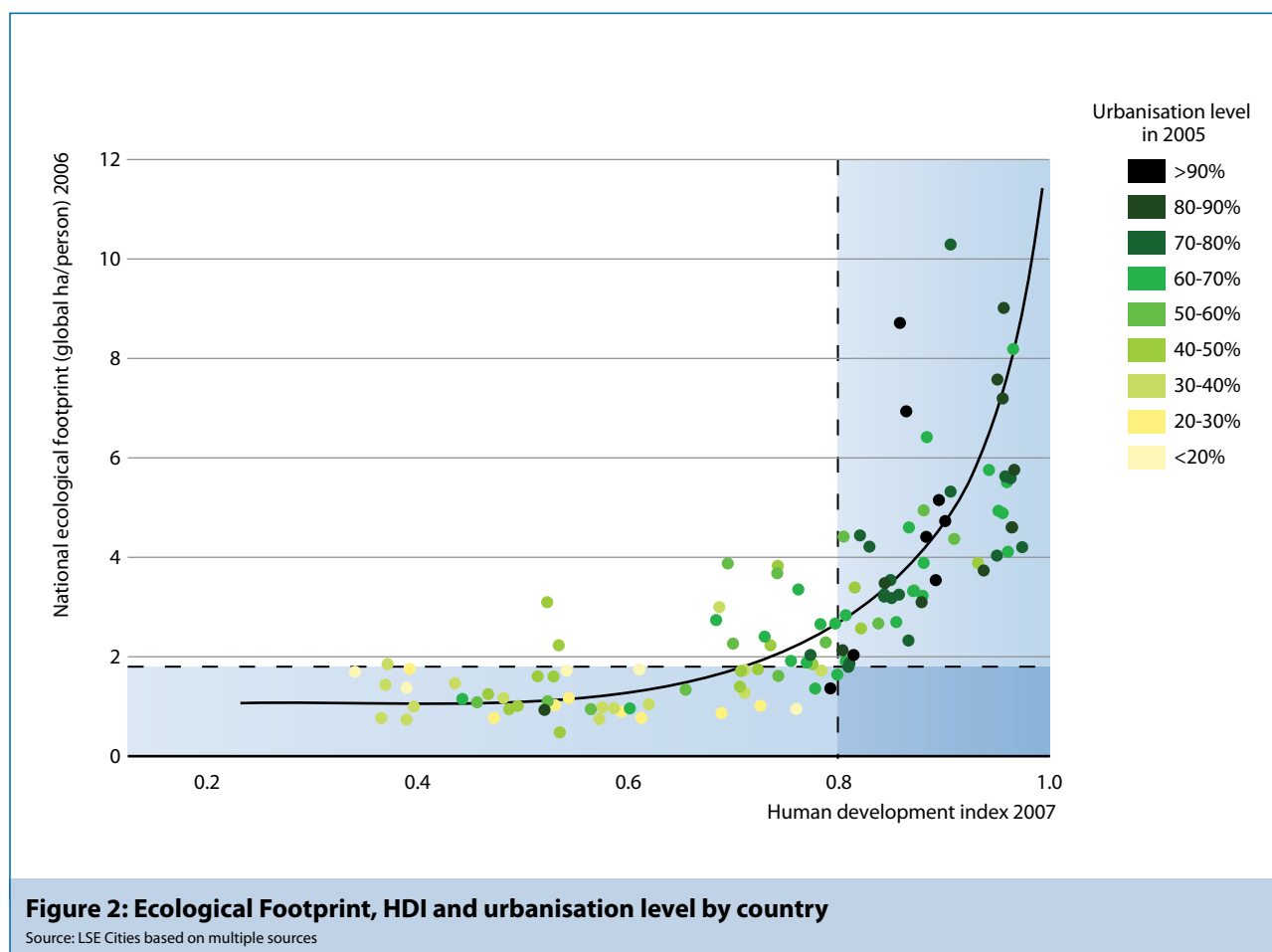


of this investment will have significant effects on the potential of Indian and Chinese cities to be green.

#### Urbanisation and the environment

Cities of different wealth levels impact the environment differently. Local environmental threats are most severe in poorer cities and relate to issues such as fresh water, sewage, health and the degradation of the living environment. As cities become more prosperous, with wider and deeper patterns of consumption and production, their environmental impacts are increasingly felt at the global level (Figure 1: Urban environmental transition).

Urban areas in prosperous economies concentrate wealth creation as well as resource consumption and CO<sub>2</sub> emissions. Globally, with a population share of just above 50 per cent but occupying less than 2 per cent of the earth's surface, urban areas concentrate 80 per cent of economic output, between 60 and 80 per cent of energy consumption, and approximately 75 per cent of CO<sub>2</sub> emissions (Kamal-Chaoui and Robert 2009; UN Population Division 2010). This pattern is not equally distributed across the globe and reflects the concentration of particular activities within individual cities. Buildings, transport, and industry – which are constituent components of cities and urban areas – contribute 25, 22, and 22 per cent, respectively, of global energy-related GHG emissions (Herzog 2009). Between 1950 and 2005, the urban population grew from 29 per cent to 49 per cent of the global population (UN Population Division – World



Urbanisation Prospects 2007), while global carbon emissions from fossil-fuel burning increased by almost 500 per cent (Boden et al. 2010).

At the national level, urbanisation goes hand in hand with increasing resource consumption, more energy intensive food supply, and ever-increasing flows of goods and people. This general trend is illustrated in Figure 2: Ecological Footprint, HDI and urbanisation level by country, which compares the National Ecological Footprint with the Human Development Index (HDI) for countries worldwide, including their urbanisation levels. The graph shows that countries with higher urbanisation levels tend to have a significantly greater ecological footprint per capita, suggesting that cities may be bad for the environment. But, the story is more complex.

Brazil, for example, maintained relatively low per capita carbon emissions despite its growing urbanisation (World Bank 2009). Other nations also raised their carbon emissions with no or little increase in urbanisation (Satterthwaite 2009).<sup>5</sup> Cities *per se* are neither drivers of climate change nor the source of ecosystem degradation;

certain consumption and production patterns as well as certain population groups within cities are.

The relationship between carbon emissions and income levels is not straightforward, either, as shown in Figure 3: Carbon emission and income for selected countries and cities. Carbon emissions are directly related to income. Per capita incomes are generally higher in cities than in rural areas, generating higher average per capita demand in major emissions sources. But this is the case only up to a certain income level, after which cities typically become more carbon-efficient compared with the average, as can be seen by the relatively low levels of CO<sub>2</sub> emissions produced by high income cities like Tokyo or Paris.

A recent survey of the energy intensity (a measure of the energy efficiency of an economy calculated as units of energy per unit of GDP) of fifty cities by the World Bank confirms differential patterns of environmental performance. From this study, it appears that the combined energy intensity of major cities like Paris, Dhaka, São Paulo, London, Hong Kong, and Tokyo, amount to about one-quarter of that of the five highest-scoring cities and less than half of a fifty-city average (World Bank 2010).

In order to better understand these variations, data on 735 cities in six regions were analysed. The results show

5. It is important to note, however, that the term urban in most countries includes any form of settlement with relatively low number of residents (thresholds typically range from anything between 200 and 20,000), and therefore does not capture the way which cities of a significant size perform in relation to these parameters.



**Figure 3: Carbon emission and income for selected countries and cities**

Source: LSE Cities based on multiple sources, see Appendix 1

that a majority of cities in Brazil, China, South Africa, India, Europe and the United States cities outperform their national average in terms of income per capita, education and employment levels. In terms of carbon emissions, energy, electricity and water consumption, dwelling and transport patterns and motorisation, however, there is a very marked difference between cities in developed and developing countries. Whereas cities in Europe, the USA and Brazil have a lower environmental impact than their respective countries, cities in India and China have a much larger impact owing to their significantly higher income levels compared with their national averages.

### The social implications of traditional urban development

Patterns of urbanisation in many areas also raise important social challenges. The traditional business as-usual (BAU) model of urban development – typical of rapidly urbanising areas – is characterized by uncontrolled, often even incentivised, horizontal expansion. This leads to urban sprawl of affluent populations with lower development densities and increased dependency on the private car and to peripheralisation of the urban poor, decreasing their access to the city and its workplaces, services and infrastructure. Typical developments further include the emergence of socially divisive neighbourhoods in the form of gated communities, shopping centres and

business districts and, a significant increase in the level of informal development with large swathes of slum housing with no access to basic services, infrastructure and sanitation. At a general level, the rapid growth of many cities coupled with insufficient resources and poor management compromises fresh water and electricity supply, waste treatment, transport, and other infrastructure provision, affecting the urban poor most.

## 2.2 Opportunities

### Structural capacity

The environmental performance of cities is dependent on a combination of effective green strategies and physical structure – urban form, size, density and configuration. They can be designed, planned and managed to limit resource consumption and carbon emissions. Or, they can be allowed to become voracious, land-hungry, all-consuming systems that ultimately damage the delicate global energy equation.

More compact urban forms, reduced travel distances and investment in green transport modes lead to greater energy efficiency. Lower surface-to-volume ratios of denser building typologies can result in lower heating and cooling loads. Greater utilisation of energy efficient utilities can contribute to lower embedded energy

demand for urban infrastructure. Cities can be structured to make use of green grid-based energy systems such as combined heat and power and micro-generation of energy as well as rainwater harvesting, access to clean water and efficient waste management. In short, effective urban planning and governance, as will be shown below, can have significant effects on sustainable urban lifestyles, making the most of urban critical mass and reducing individual patterns of consumption.

Despite a rich debate on the links between physical structure and energy use in cities, there is growing evidence that compact urban environments, with higher-density residential and commercial buildings (as opposed to low density, sprawl-like development) and a well distributed pattern of uses and an efficient, transport system based on public transport, walking and cycling reduce the energy footprint (Newman and Kenworthy 1989; Owens 1992; Ecotec 1993; Burgess 2000; Bertaud 2004). Research has shown that the so-called “compact city” model (Jenks et al. 1996) has lower per-capita carbon emissions as long as good public transport is provided at the metropolitan level (Hoornweg et al. 2011).

This relationship between urban form and energy performance also applies at the local, neighbourhood level. In Toronto, for example, a recent study found that car use and building-related emissions jumped from 3.1 tonnes of CO<sub>2</sub> per capita in some inner-city areas to 13.1 tonnes in low-density suburbs located on the edges of the city (Van de Weghe and Kennedy 2007). While the evidence does not identify an ideal size or configuration for green cities, it suggests that highly concentrated urban systems produce public transport efficiencies, and that medium-sized cities tend to perform better than very large or very small cities when it comes to public transport and energy-related efficiency (Ecotec 1993; Bertaud 2004).

Many cities around the world have recognised such structural opportunities for green cities. Copenhagen, Oslo, Amsterdam, Madrid and Stockholm (EIU 2009), together with Curitiba, Vancouver and Portland in the Americas, have all prioritised compact urban development, creating walkable urban neighbourhoods supported by accessible public transport systems. Mumbai, Hong Kong and New York are high density cities where housing, commercial, retail and leisure are in close proximity, thus limiting the length of everyday trips (from home to work). In addition, they possess efficient and extensive public transport networks. In Mumbai, these patterns are related to high levels of poverty and overcrowding, while in Hong Kong and New York they combine considerable levels of energy efficiency with high living standards.

Clearly, there is an upper limit for urban densities to deliver environmental benefits without creating

adverse social outcomes due to overcrowding and strained social infrastructure such as health or educational facilities. But if appropriately designed, cities can accommodate relatively high threshold densities even in low-income scenarios (and not just in highly serviced upper income environments). In their study on high density, low income housing in Karachi, Hasan, Sadiq and Ahmed (2010) concluded that net residential densities of up to 3,000 persons per hectare can be reached without compromising environmental or social conditions.

### **Technological potential**

Cities are incubators of innovation due to the close interaction of their residents and workers who benefit from the exchange of ideas and opportunities. In particular, they benefit from the concentration of diverse yet specialised skill-sets in research institutions, firms and service providers that can pilot and scale new technologies in an already highly networked environment. The OECD calculates, for example, that there are ten times more renewable technologies patents in urban than rural areas and that 73 per cent of OECD patents in renewable energy come from urban regions (Kamal-Chaoui and Robert 2009). The fast-growing cleantech clusters in Silicon Valley and the North East of England are both examples of “nursery cities”, fostering innovative activity (Duranton and Puga 2001). Silicon Valley business leaders have been working for years to leverage the valley’s innovation advantage in a green economy (Joint Venture Silicon Valley Network 2009). Section 4 illustrates how urban systems can be readily adapted to innovative technologies that support the transition to green cities, especially in the energy sector.

### **Urban synergy and integration potential**

Green cities can benefit greatly from synergies between their constituent parts. Recognising, for example, the interrelationship of energy systems and city fabric can lead to particular synergies, as pioneered by the Rotterdam Energy Approach and Planning (Tillie et al. 2009). In New York City, a new mechanism introduced by the Mayor combines the cleaning-up of light-to-moderately contaminated brown-field sites with urban re-development (City of New York 2010). Water-sensitive urban design, which helps to retain storm water in public spaces and parks, has increased the reliability of urban water supply in US and Australian cities (see Water Chapter).

An urban setting, which tends to support a diverse and compact pattern of production and consumption is further advantageous to advance the notion of “industrial ecology” (Lowe and Evans 1995). By optimising and synergising different industrial sectors and resource flows, outputs of one sector that become the input of



another create a circular economy (McDonough and Braungart 2002). Principles of symbioses can also help minimise or recycle waste. São Paulo's Bandeirantes landfill, for example, is sufficiently large to provide biogas that generates electricity for an entire city district (ICLEI Local Governments for Sustainability 2009a).

These opportunities have led to intensified efforts in designing cross-sectoral green city strategies when developing new districts or eco-cities. Recent examples of new green communities include the car-free neighbourhood of Vauban in Freiburg and Beddington Zero Energy Development (BedZED)<sup>6</sup> in London (Beatley 2004; Wheeler and Beatley 2004; C40 Cities 2010a). In the latter case, new homes achieved an 84 per cent reduction in energy consumption and footprints related to mobility decreased by 36 per cent. Recycling reduced waste by between 17 per cent and 42 per cent (Barrett et al. 2006).<sup>7</sup> Examples of green city districts include Amsterdam-IJburg, Copenhagen-Orestad and Hammerby Sjostad in Stockholm while eco-cities have become fashionable in several rapidly urbanising Asian countries. In recent years, high

profile investments have been made in sustainable new towns, including Tianjin Eco-City in North China, the Songdo Eco-City in Incheon, Republic of Korea and Masdar Eco-City in Abu Dhabi, but it is early days to make a comprehensive assessment of their long-term sustainability, especially given the very high capital and development costs of these show-case projects.

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6. The footprint of BedZED residents averages 4.67 global hectares (BioRegional 2009). While this is lower than the UK average of 4.89 hectares (Ewing et al. 2010) it is still more than twice the "fair share" of 2 hectares. This demonstrates the limitations of insular approaches. While BedZED enables residents to reduce their footprint on site, a lot of their ecological impact is made outside of it, in schools, at work, and on holiday. BedZED residents fly slightly more frequently than the local average, presumably due to their higher average income. These limitations, however, do not invalidate the achievements of the development, but point to the need of scaling up energy efficiency measures in wider urban settlement systems as well as the issue of energy still being comparatively cheap in high-income societies, resulting in overall unsustainable levels of energy consumption, with rebound effects partly offsetting efficiency gains due to greater overall consumption levels (Binswanger 2001).

7. In recent years, the French government has increasingly become attached to the concept of éco-quartiers and has initiated a range of projects including Quartier ZAC de Bonne in Grenoble, Quartier Lyon Confluence and Quartier du Théâtre in Narbonne (French Government, Ministère de l'écologie, du développement durable, des transports et du logement 2010).

### 3 The case for greening cities

The case for greening cities can be made in terms of inter-linked economic, social, and environmental benefits. Economically, the benefits include agglomeration economies, lower infrastructure costs and reduced congestion cost while reducing carbon emissions and other environmental pressure. Socially, the benefits include employment creation, poverty reduction and improved equity, and quality of life including improved road safety and community cohesion, among others. Environmental benefits are embedded in most of the economic and social benefits. Additional environmental benefits include reduced pollution, which helps improve public health. Another environmental benefit is the potential for improving ecosystems within urban areas.

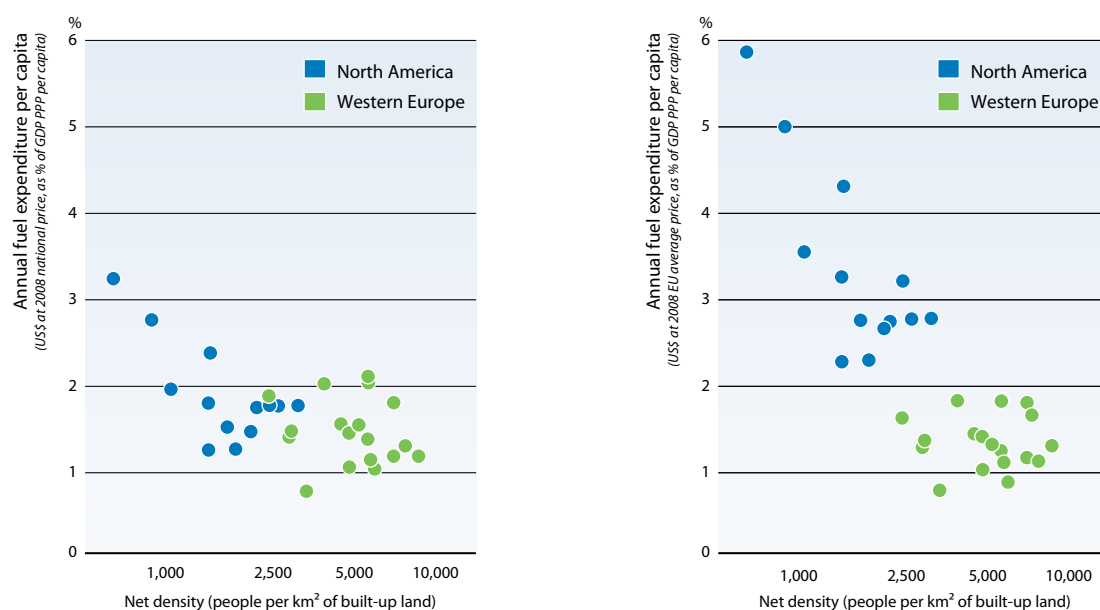
#### 3.1 Economic benefits

##### Agglomeration economies

Larger, denser cities – which help lower per capita emissions – are good for economic growth. From an economic perspective, cities matter because they bring people and things closer together, help overcome information gaps, and enable idea flows (Glaeser 2008; Krugman 1991). It is for these reasons that 150 of the world's most significant metropolitan economies produce 46 per cent of global GDP with only 12 per

cent of the global population (Berube, Rode et al. 2010). These agglomeration economies translate into productivity gains for firms, and higher wages and employment rates for workers. For many firms and workers, particularly those in service sectors, there is still a premium on face-to-face contact – to maintain trust, build relationships, and manage interactions that can not yet (and may never) be digitised (Charlot and Duranton 2004; Sassen 2006; Storper and Venables 2004). Knowledge spillovers between firms and economic agents tend to be highly localised and die away within a few miles of the urban core (Rosenthal and Strange 2003).

Agglomeration economies exist in both developed and developing countries. Empirical studies in developed countries find that doubling the employment density of an urban area typically raises its labour productivity by around 6 per cent (for a summary of the literature see Melo et al. 2009). The same basic patterns are found in developing countries, with strong evidence that urbanisation boosts productive efficiency by lowering transport costs and widening trade networks (Duranton 2008; Han 2009). Agglomeration economies can also be achieved by connecting several cities as in China's Pearl River Delta region (Rigg et al. 2009), with the additional benefit of addressing inequality between leading and lagging regions within countries (Ghani 2010).



**Figure 4: Private transport fuel expenditure and urban density of selected cities, 2008 fuel prices (left-hand graph) and EU fuel prices throughout (right-hand graph)**

Source: Kenworthy 2003 (1995/6 fuel consumption and density per city), GTZ 2009 (National 2008 fuel prices), PWC 2009 and UN 2010 (City GDP PPP per capita); see Appendix 1

	Total cost (CA\$ billion)			
	Dispersed scenario	Recommended direction	Difference	Percent difference
Road capital cost	17.6	11.2	6.4	-36
Transit capital	6.8	6.2	0.6	-9
Water and wastewater	5.5	2.5	3.0	-54
Fire stations	0.5	0.3	0.2	-46
Recreation centres	1.1	0.9	0.2	-19
Schools	3.0	2.2	0.9	-27
Total	34.5	23.3	11.2	-33

**Table 1: Infrastructure costs for different development scenarios in Calgary**

Dispersed scenario: additional 46,000 ha;  
recommended direction: additional 21,000 ha

Source: IBI Group (2009)

In developing countries, however, urbanisation may not provide the same kind of economic gains across cities and firms. For example, Brühlhart and Sbergami (2009) find that within-country agglomeration boosts GDP growth only up to national income levels of US\$ 10,000 per head. The main reason for this is that very rapid – and sometimes chaotic – urbanisation can outstrip national and city governments' ability to provide adequate infrastructure and services (Cohen 2006). Congestion could eat up the benefits of higher density as in the case of cities like Shanghai, Bangkok, Manila and Mumbai (Rigg et al. 2009). Venables (2005) similarly suggests that “the presence of increasing returns to scale in [some developing country] cities leads to urban structures that are not optimally sized”.

### Lower infrastructure and operating costs

Densification reduces the capital and operating costs of infrastructure. Evidence suggests that linear infrastructure including streets, railways, water and sewage systems as well as other utilities come at considerably lower cost per unit the higher the urban density (Carruthers and

Ulfarsson 2003). Comparing smart growth areas and dispersed, car-dependent developments, Todd Litman suggests direct cost savings between US\$ 5,000 and US\$ 75,000 for building road and utility infrastructure per household unit (Litman 2009a). A recent exercise for Calgary (IBI Group 2009) indicates cost savings beyond pure linear infrastructure but also for schools, fire stations and recreation centres (see Table 1). Similarly, a recent study of Tianjin concluded that infrastructure cost savings as a result of compact and densely clustered urban development reach 55 per cent compared with a dispersed scenario (Webster et al. 2010).

Figure 4: Private transport fuel expenditure and urban density of selected cities shows how urban density can be an essential measure for decreasing long-term operating costs. Critically, this relationship is made even stronger in the right-hand graph which standardises 2008 fuel prices at the EU average (US\$ 1.41) – in other words, it assumes that all cities in the sample face the same fuel price. It is clear that EU cities tend to be denser than North American cities and significantly more efficient in terms of fuel consumption – citizens of more sprawling North American cities tend to travel further. But even with current US fuel prices, density pays back. In the case of New York City, CEO for Cities (2010) estimates that density-related cost savings through reduced expenditure on cars and petrol translates into a green dividend of US\$ 19 billion annually.

While denser city strategies tend to promote greater energy efficiency and cheaper infrastructure, promoting transport modal shifts can deliver higher lifecycle capacity and lower running costs (see Table 2: Capacity and infrastructure costs of different transport systems). The most significant cost saving is derived from a shift away from car infrastructure towards public transport, walking and cycling. For example, at similar capacity levels, bus rapid transit (BRT) offers significant costs savings compared to traditional metro

Transport Infrastructure	Capacity [pers/h/d]	Capital costs [US\$/km]	Capital costs/capacity
Dual-lane highway	2,000	10m – 20m	5,000 – 10,000
Urban street (car use only)	800	2m – 5m	2,500 – 7,000
Bike path (2m)	3,500	100,000	30
Pedestrian walkway / pavement (2m)	4,500	100,000	20
Commuter Rail	20,000 – 40,000	40m – 80m	2,000
Metro Rail	20,000 – 70,000	40m – 350m	2,000 – 5,000
Light Rail	10,000 – 30,000	10m – 25m	800 – 1,000
Bus Rapid Transit	5,000 – 40,000	1m – 10m	200 – 250
Bus Lane	10,000	1m – 5m	300 – 500

**Table 2: Capacity and infrastructure costs of different transport systems**

Source: Rode and Gipp (2001), VTPI (2009), Wright (2002), Brilon (1994)

and regional rail. Bogotá's TransMilenio infrastructure cost US\$ 5.8 million per km, US\$ 0.34 per passenger over three years compared with estimates for metro rail with US\$ 101 million per km, US\$ 2.36 per passenger (Menckhoff 2005). As a result and unlike most public transport systems, TransMilenio is not only able to cover its costs but is making a profit (Whitelegg and Haq 2003).

A preliminary study has been carried out to provide additional information on the costs and potential savings of green city projects (Table 3: Investment and operating costs of selected green city projects). Column 3 in Table 3 contains either the project operating revenue (such as the fares collected or the sale of the collected energy) or the savings the project allowed. The savings have been calculated by looking at the difference between what would have been spent in resources without the project and what has been spent since its realisation. For example, Tokyo's water leakage control leads to savings both in terms of electricity (less of which is needed for the same amount of water reaching end-consumers) and in terms of water.

### Reduced congestion costs

Bigger, more productive cities tend to suffer from crowding and congestion, as firms and households compete for space in the most popular locations (Overman and Rice 2008). Real-world examples of urban agglomerations such as Mexico City, Bangkok and Lagos suggest that the economic advantages of being in cities tend to mitigate even severe congestion problems (Diamond 2005). Even so, however, the financial and welfare costs to cities and citizens can be substantial. In the largely urbanised European Union, these costs are 0.75 per cent of GDP (World Bank 2002). In the case of the UK, they amount to an annual costs of up to £ 20bn (Confederation of British Industry 2003). They reach even higher figures in developing countries. The costs of congestion in Buenos Aires are 3.4 per cent of GDP, in Mexico City 2.6 and in Dakar 3.4 per cent (World Bank 2002).

One proven method for controlling congestion is demand management via charging. For example, Central London's congestion charge reduced congestion by 30 per cent from February 2003 to February 2004 compared with previous years (Transport for London 2004a) and led to benefits such as the reduction in the number of trips by private vehicles entering central London (Transport for London 2004b) and a 19.5 per cent drop in CO<sub>2</sub> emissions (Beevers and Carslaw 2005). Stockholm's congestion tax also resulted in a reduction in traffic delays by one-third and a decrease in traffic demand by 22 per cent (Baradaran and Firth 2008). The annual social surplus of Stockholm's congestion tax is estimated to be in the region of US\$ 90 million (Eliasson 2008).

Many public transport projects around the world have brought about significantly reduced congestion costs, notably BRT systems such as in Bogotá and successfully emulated in Lagos, Ahmadabad and Guangzhou and Johannesburg. A synergetic interplay of compact urban form and an efficient bus system has been observed in Curitiba, which boasts the highest rate of public transport use in Brazil (45 per cent). There, reduced congestion means much less fuel is wasted in traffic jams: only US\$ 930,000, compared with an estimated US\$ 13.4 million in Rio de Janeiro (Suzuki et al. 2010).

## 3.2 Social benefits

### Job creation

Greening the cities can create jobs on a number of fronts: 1) urban and peri-urban green agriculture; 2) public transport; 3) renewable energy; 4) waste management and recycling; and 5) green construction. Green services will generally be more urban-orientated than green manufacturing or primary industry, although there will be some high-tech green manufacturing clusters in or close to urban cores, drawing on knowledge spillovers from universities and research labs. Already, the 100 largest metropolitan regions in the USA have far greater shares of low-carbon employment in wind and solar energy (both 67 per cent), energy research (80 per cent) and green buildings (85 per cent) compared with the 66 per cent share of the national population (Brookings and Battelle 2011).

At the same time, specific sectors and firms may combine remote or off-shored production with highly urbanised consumer/service/support markets. This means that there is potential for cities to grow both green tradable activity (high value, exportable) and develop greener non-tradable activities (lower value, goods and services for local consumption) (Chapple 2008). Overall, a green economy cannot be expected to create or destroy net jobs in the long run; the supply and demand for labour tend to equate in accordance with labour market conditions. In a well-functioning labour market, in the long run, increased demand for labour in one sector will put upward pressure on the going wage rate and displace labour in another sector. Labour creation in low-carbon sectors will crowd out labour creation elsewhere. Hence, although gross employment in the sector may rise in the long run, net employment across all sectors may not. In the short run, with unemployed resources, the net employment creation effect is likely to be larger.

First, there is considerable policy interest in urban and peri-urban agriculture (Smit and Nasr 1992; Baumgartner and Belevi 2001). Green urban agriculture can reuse municipal wastewater and solid waste, reduce transportation costs, preserve biodiversity and

Project	Initial capital costs (million US\$)	Operating costs (million US\$)	Operating revenue / savings (million US\$)
London Congestion Charge (2002-2010)	480	692	1,746
Bogotá Transmilenio (2000-2010)	1,970 (until 2016)	around 20/year	around 18.5/year
Copenhagen District Heating (1984-2010)	525	136.5	184
Paris Velib' (2007-2010)	96 (private investment)	4.1 (private)	3.96/year (city), 72/year (private)
Bogotá CicloRutas (1999-2006)	50.25	-	40/year (fuel savings)
Toronto Atmospheric Fund (1991-2010)	19	-	2.2
Austin Energy's GreenChoice Program	-	-	3.9 (customer energy savings in 2006)
Austing Green Building Programme (1991-2010)	-	1.2/year	2.2/year (customer energy savings)
Freiburg PV system (1986-2010)	58.6	-	-
Berlin's Energy Saving Partnership (1997-2010)	-	-	12.2 (energy bills)
Toronto Lake Water Conditioning (2002-2010)	170.4	-	9.8/year
Tokyo Water System	-	60.3/year	16.7 (electricity savings), 172.4 (leakage prevented)
San Francisco Solar Power system (2004-2010)	8	-	0.6
São Paulo waste to energy (2004-2010)	68.4	-	32.1 (from carbon credit auction)
Curitiba BRT (1980-2010)	-	182.5	201
Stockholm Congestion Charge (2007-2010)	350	-	70
NYC public plaza improvements (2008-2010)	125.8	-	-
Strasbourg's 53.7 km tram (1994-2010)	-	167.7	168.3
Copenhagen's 3% of waste to landfills (1990-2010)	-	-	0.67/year
Copenhagen offshore 160MW windfarm (2002-2010)	349	-	-
NYC Greener, Greater Buildings Plan (2009-2010)	80 (city), 16 (federal)	-	700/year (residential energy costs)
Hong Kong Combined Heat and Power plant (2006-2010)	0.9	-	0.3/year
Portland SmartTrips (2003-2010)	-	0.55/year	-
Portland LED traffic lighting (2001-2010)	2.2	-	0.335
Seoul car-free days (2003-2010)	3	-	50/year (fuel savings)

**Table 3: Investment and operating costs of selected green city projects**

Source: multiple sources, see Appendix 1

wetlands, and make productive use of green belts. The findings of national censuses, household surveys and other research suggest that “up to two-thirds of urban and peri-urban households in developing countries are involved in agriculture” (FAO 2001).

Second, transport activities typically make up a significant share of a city's employment (operationally and in infrastructure development). In many countries, public transport jobs account for between 1 per cent and 2 per cent of total employment (UNEP, ILO, IOE and ITUC 2008). In New York almost 80,000 local jobs are related to its public transport sector, in Mumbai more than 160,000 and in Berlin about 12,000 (Table 4: Urban transport employment).

Third, the International Labour Organisation research (UNEP et al. 2008) indicates that shifting from conventional to renewable energy will result in small net job losses, but cities are well-placed to benefit

from new opportunities. As well as research and development activity, renewable energy systems may often involve decentralised production, which locates power generation close to urban consumer cores. Critically, installation and servicing activities are both labour-intensive and urban-orientated. These domestic or personal service activities will be an important source of green jobs in urban areas.

Fourth, waste and recycling activity is similarly labour-intensive. A recent estimate reveals that up to 15 million people are engaged in waste collection for their livelihood in developing countries (Medina 2008). For example, in Dhaka, Bangladesh, a project for generating compost from organic waste helped create 400 new jobs in collection activities and 800 new jobs in the process of composting. Workers collect 700 tonnes/day of organic waste to obtain 50,000 tonnes/year of compost (see Waste Chapter). And in Ouagadougou, Burkina Faso, a project for collecting and recycling plastic waste has helped improve



## Box 1: Green jobs in the urban economy<sup>8</sup>

The process of making the world's cities and urban fabric greener and maintaining them in a sustainable way will bring considerable employment opportunities. Upgrading to greener infrastructure generates jobs, whether by improving roads and buildings, establishing public transport networks, repairing and enhancing drainage and sewerage systems or creating and managing efficient recycling services. Many of these jobs will require knowledge of new technologies or working practices, for example, in constructing, installing and maintaining local hydrogen fuel-cell power stations or a network of charging points for electric vehicles. Providing training and support is fundamental to the process, within local authorities and for private companies, particularly small enterprises.

In creating the jobs that will enable cities to be greener, there is a great opportunity to address urban poverty, which is widespread (and in many places increasing at a faster rate than rural poverty), particularly in developing countries. Providing job opportunities where there are few is clearly important, but to make real inroads into poverty, employment must also encompass workers' rights, their social protection and social dialogue. The

burgeoning international movement on "the right to the city" promotes community and consumers' rights but workers' rights are increasingly being recognized. Coalitions of urban workers in Brazil, for example, are helping to draw attention to and reduce informal, casualised labour. Inappropriate working and living conditions expose many urban workers to risk on a daily basis, while many do not have access to an adequate system of health care, pay for holidays and protection against loss of pay when they are unable to work. Several ILO initiatives provide a sound basis for action on improving social protection, and other efforts of communities to organise their own risk protection should be supported.

In Marikina, Philippines and through the municipal "decent work" programmes of Belo Horizonte and São Paulo, Brazil, progress has been made in improving labour conditions by establishing meaningful dialogue between workers, employers and local governments. In sum, the greening of cities can and should provide significant opportunities for decent employment, which can bring prosperity and, if carefully managed, reduce inequality and rural-urban differentials.

the environmental situation and has created jobs and income for local people (ILO Online 2007).

Fifth, many developed nations have also started looking at green construction as the largest possible employment provider. Germany's 2006 retrofitting programme created nearly 150,000 additional full-time equivalent jobs in 2006 (UNEP et al. 2008). Retrofitting existing building stocks will provide a massive

employment opportunity for many mature cities, since work is undertaken on site (see Buildings Chapter). Higher environmental standards for construction and fittings also create employment potential. The U.S. Department of Labor estimates that new standards for water heating and fluorescent lamps, among other products, could generate 120,000 jobs through to 2020 (UNEP et al. 2008). Most excitingly, green construction has also the potential of making buildings to go from being exclusively consumers of resources to becoming producers – in resources like water, energy, food and materials, or even green space.

### Poverty reduction and social equity

The World Development Report (2009) describes increasing economic density – one of the main features of a green city – as "a pathway out of poverty". Along similar lines, Nadvi and Barrientos (2004) assess the impact of clusters or agglomeration effects on poverty in several urban areas of developing countries. It is observed that these clusters are labour-intensive, informal in nature and also employ a lot of women as household-workers. Based on a study of industrial clusters in Kumasi (Ghana),

City	Persons employed (operations) in public transport sector
New York	78,393
London	24,975
Mumbai	164,043
São Paulo	15,326
Johannesburg	22,276
Tokyo	15,036
Berlin	12,885
Istanbul	9,500

**Table 4: Urban transport employment**

Source: LSE Cities based on multiple sources, see Appendix 1

8. This box was prepared based on contributions from ILO to this chapter.

Lima (Peru), Java (Indonesia), Sinus Valley (Brazil), Torren (Mexico) and Tiruppur (India), it is shown that usually there is a high rate of employment growth among mature clusters drawing the poor from rural areas. Alongside an increase in employment, this study also showed that wage levels in clusters were higher than average regional wage levels but with longer working hours.

While urbanisation has helped to reduce absolute poverty, the number of people classified as urban poor is on the rise (Ravallion et al. 2007). Between 1993 and 2002, there was an addition of 50 million poor in urban areas while the number of rural poor declined by 150 million (Ravallion et al. 2007). Urban growth puts pressure on the quality of the local environment, which disproportionately affects poorer people, such as the lack of adequate access to clean water and sanitation. This results in a huge disease burden that further affects their livelihood options. Moreover, a large proportion of the urban population is in the informal sector with: a) inadequate access to social security, including health insurance; b) homes in informal settlements in disaster-prone areas – both of which make them more vulnerable to crises. With climate change posing its own threat, the urban poor are likely to be more affected as most live in non-durable structures and in more vulnerable locations such as riverbanks and drainage systems. More generally, the poor have little if no means to reduce potential risks and prepare for the consequences of or be insured against natural disasters.

Innovative approaches to urban planning and management can make urbanisation inclusive, pro-poor and responsive to threats posed by environmental degradation and global warming. For example, enhancing public transport use can reduce inequality in access to public services and other amenities, on top of reducing carbon emissions (Litman 2002). It can also play a part in improving poorer neighbourhoods by relieving vehicle congestion (Pucher 2004). Switching to cleaner fuels for cooking, transport and power generation can minimise local pollution and reduce health inequality (Haines et al. 2007). Poor urban households in low-income nations have to spend a large proportion of their income on energy needs including food and cooking fuel (Karekezi and Majoro 2002). Introducing cleaner and more efficient sources of energy offers the potential to both reduce direct expenditure and to lower health costs connected to indoor-air pollution (Bruce et al. 2002). In Brazil, for example, an initiative in the City of Bentim to install solar heaters in housing estates for low income families resulted in 20 per cent savings in energy consumption and up to 57 per cent savings in the energy bill for the average 3 to 4 member family (ICLEI 2010b).<sup>9</sup>

9. The significant reduction in the energy bill can be explained through the fact that low energy consumption is rewarded by tax benefits. The installation of solar heaters helped the families to reach the threshold of < 90kWh/month.

Rank 2010	City	Country	QoI index 2010
1	Vienna	Austria	108.6
2	Zurich	Switzerland	108
3	Geneva	Switzerland	107.9
4	Vancouver	Canada	107.4
4	Auckland	New Zealand	107.4
6	Dusseldorf	Germany	107.2
7	Frankfurt	Germany	107
7	Munich	Germany	107
9	Bern	Switzerland	106.5
10	Sydney	Australia	106.3
11	Copenhagen	Denmark	106.2
12	Wellington	New Zealand	105.9
13	Amsterdam	Netherlands	105.7
14	Ottawa	Canada	105.5
15	Brussels	Belgium	105.4
16	Toronto	Canada	105.3
17	Berlin	Germany	105
18	Melbourne	Australia	104.8
19	Luxembourg	Luxembourg	104.6
20	Stockholm	Sweden	104.5

**Table 5: Mercer quality of living city ranking 2010**

Source: Mercer (2010)

There are other examples of how greening cities can address poverty and equity concerns. Improving sanitation and fresh water supply can reduce persistent poverty and the adverse impacts of water-borne disease (Sanctuary et al. 2005). Retrofitting older buildings in lower-income neighbourhoods can improve energy efficiency and resilience, reducing the vulnerability of poorer communities when energy prices rise (Jenkins 2010). Upgrading infrastructure in slum areas offers both health benefits and fewer adverse impacts on the environment (WHO 2009).

### Improvement in quality of life

Community cohesion is one aspect of quality of life and affects individuals, families and social groups at the neighbourhood and district level. Social relationships not only have particularly positive impacts on physical and mental health but also on economic resilience and productivity (Putnam et al. 1993; Putnam 2004). This is especially the case for disadvantaged people, as community cohesion and social inclusion are linked (O'Connor and Sauer 2006; Litman 2006).

Improving the urban environment by measures such as traffic calming and promoting walkability can help

foster a sense of community (Frumkin 2003; Litman 2006). Such changes are often designed to counteract instances of community severance, as identified by Bradbury et al. (2007):

■ *Physical barriers* whereby either spatial structures themselves prohibit interaction or certain activities cause disruption, as in the case of road traffic;

■ *Psychological barriers* that are related to the perception of certain areas determined by traffic noise and pollution or perceived danger; and

■ *Long-term social barriers* where residents change behaviour following initial disruptions and create a more sustained form of being disconnected from certain people and areas close-by. Putnam's research implies that ten minutes avoided in commuting increases time spent on community activities by 10 per cent (Putnam 2000).

Kuo et al. (1998) observed that the more trees and greenery form part of inner-city public spaces, the more these spaces are used by residents. The study also found that, compared with residents living near barren spaces, those closer to greenery enjoy more social activities, have more visitors, know more of their neighbours, and have stronger feelings of belonging. Wells and Evans (2003) found that children with nature near their homes are more resistant to stress; have lower incidence of behavioural disorders, anxiety, and depression; and have a higher measure of self-worth (Grahn et al. 1997; Fjortoft and Sageie 2000). Green space also stimulates social interaction between children (Moore 1986; Bixler et al. 2002).

A further dimension in the quality of life surrounds road safety. Road traffic accidents are the leading cause of death among young people between 15 and 19 years, according to a report published by the WHO in 2007 (Toroyan and Peden 2007; see also Transport Chapter). Road traffic collisions cost an estimated US\$ 518 billion globally in material, health and other expenditure. For many low- and middle-income countries, the cost of road crashes represents between 1-1.5 per cent of GNP and in some cases exceeds the total amount the countries receive in international development aid (Peden et al. 2004). Mohan (2002) showed that this is, in fact, underestimated and evaluated that these costs represent 3.2 per cent of India's GDP.

Some of the most effective strategies to improve pedestrian and cyclist safety include dedicated facilities and motorised vehicle speed controls. An average increase in speed of 1 km/h leads to a 5 per cent higher risk of serious or fatal injury (Finch et al. 1994; Taylor et al. 2000). Dedicated lanes for buses, bicycles and pedestrians, especially along arterial roads should also

be a priority. Evidence from the Netherlands, Bogotá and Denmark shows that restricting the space available to cars, limiting their speed and providing safe facilities for pedestrians and cyclists result in the adoption of green transport modes.

Other major attributes of green cities are also considered part of the quality of life, such as walkability, access to green spaces, cycling infrastructure and recreational facilities (HM Government, Communities and Local Government 2009). In developing countries, this may partly explain the relationship between green cities and cities with a high quality of life. Among the top 20 "quality of living cities" identified by Mercer in 2009, at least half have particularly strong green credentials (Table 5). The top five includes best-practice green cities such as Vienna, Zurich and Vancouver. In Zurich, the city's focus on public transport has been an important contribution to its favourable ranking in the Mercer survey (Ott 2002). Similarly, the integration of green space and natural elements within the city significantly enhance the quality of living.

At least in developed countries, a city's overall quality of life (or quality of place), may be linked to economic advantages, mainly as a result of greater attractiveness to skilled workers and high paying firms (HM Government, Communities and Local Government 2009; Lee 2005). Evaluation of the largest companies (more than 500 employees) in the European Union suggests that about 10 per cent of these firms consider quality of life as one of the top three attributes determining location decisions (Healey and Baker 1993 in Rogerson 1999). These decisions, it is argued, are increasingly based on so-called city "lifestyle amenities" which attract highly-skilled, mobile workers with their general flexibility in choosing living and working locations (Hasan 2008).

### 3.3 Environmental and health benefits

#### Reducing pollution and improving public health

Air pollution in cities remains a major public health burden, particularly in the developing world. In extreme cases such as Dakar, pollution-related health costs are above 5 per cent of GDP, while a range between 2 and 3 per cent is observable for several mega cities in Latin America and Asia (World Bank 2003). In urban areas globally, around 800,000 deaths per year are caused by air pollution (Dora 2007).

Many cities have already taken decisive action and significantly improved the situation. Outside Europe and the USA, cities with PM 10 levels of 20 mg/m<sup>3</sup> have a mortality rate almost 10 per cent lower than those with levels of 150 mg/m<sup>3</sup> (Dora 2007). Urban greenery provides a unique opportunity to improve air quality. In

Chicago, urban trees provided a service for air cleansing that is equivalent to US\$ 9.2 million dollars and their long-term benefits are estimated to be more than twice their costs (McPherson et al. 1994).

There is a broader set of public health issues around healthier lifestyles in cities. It is estimated that physical inactivity accounts for 3.3 per cent of all deaths globally and for 19 million disability-adjusted life-years (Bull et al. 2004). Green urban transport is a unique opportunity to link physical activity and emissions reduction by promoting walking and cycling. In Europe, more than 30 per cent of trips made by cars are for distances of less than 3 km and about half still below 5 km, in theory allowing for their replacement by cycle journeys (European Commission 1999).

It is no coincidence that cities with a long tradition of applying land-use planning, public transport strategies and a focus on public green space are among the healthiest cities in the world. Portland was rated number one of the 100 largest USA cities in meeting Healthy People 2000 goals (Geller 2003), Vancouver is first amongst the Canadian cities (Johnson 2009), Copenhagen and Munich rank amongst the top 10 healthiest and safest cities and Melbourne among the healthiest and safest in Australia (Sassen 2009).

### **Ecosystem services and risk reduction**

Urban greenery and vegetation represent a range of ecosystem services with significant wider welfare effects (TEEB 2010). A study of Toronto's Green Belt estimated the value of its ecosystem services at CA\$ 2.6 billion annually, an average of around CA\$ 3,500 per hectare (Wilson 2008).

Ecosystem services further play a critical role in risk reduction measures. Tropical cities such as Jakarta have dramatically increased their risk exposure to flooding as a consequence of local deforestation. The city's most recent floods in 2007 affected 60 per cent of the city region, killed 80 persons and forced more than 400,000 residents to leave their homes (Steinberg 2007). Similarly, the 2005 floods in Mumbai, which killed more than 1,000 people and paralysed the city for almost five days (Revi 2008) were linked to a lack of environmental protection of the city's Mithi River (Stecko and Barber 2007).

Restoration of urban ecosystems is part of the city greening effort, which can reduce the impact of freak weather conditions. Coastal regions in particular can benefit both in terms of lives and money. Mangrove re-planting in Vietnam, for example, saves US\$ 7.3 million annually on dike maintenance while it costs only US\$ 1.1 million (International Federation of the Red Cross and Red Crescent Societies 2002). More generally, an increase in the amount of green cover in urban areas not only increases a city's ability to reabsorb CO<sub>2</sub> but also ameliorates the urban heat island effect (McPherson et al. 1994).

Safeguarding natural ecosystems in cities' hinterlands is also important in reducing their exposure to risk. This is of particular relevance to fresh water supply and food security. As they have expanded, many cities have exhausted local fresh water sources and rely on importing water from their wider region. Such requirement to import water is already associated with enormous costs for cities such as Mexico City and São Paulo. In New York City, the protection of its fresh water supply has allowed the city to avoid paying US\$ 5 to US\$ 7 billion for an additional filtration plant (TEEB 2010).

## 4 Greening urban sectors

Having illustrated the general economic, social, and environmental benefits of greening cities, this section looks at examples of how the greening of specific sectors – including transport, buildings, energy, water, waste and technology – can be achieved at the city scale. Most of these sectors are addressed more broadly in the respective chapters of this report, and some of the examples below are referenced elsewhere in this chapter to support broader, cross-sectoral strategies to aid the transition to green cities.

### 4.1 Transport

Most green transport policies that follow the “avoid-shift-improve” paradigm outlined in the Transport Chapter can be found in cities. While “avoiding transport” is mostly covered by structural adjustments to the shape of cities introduced earlier, classic green transport strategies in cities primarily focus on reducing car use or at least slowing its growth. In Central London, for example, the congestion charge reduced daily vehicles trips by 65,000 to 70,000 (Transport for London 2004 b) and CO<sub>2</sub> emissions by 19.5 per cent (Beevers and Carslaw 2005). Singapore’s Electronic Road Pricing and Vehicle Quota System slowed increasing car use and motorisation (Goh 2002). Bogotá’s BRT system has contributed to a 14 per cent drop in emissions per passenger (Rogat et al. 2009). It is encouraging, therefore, to see that the BRT system has been replicated in Istanbul, Lagos, Ahmadabad, Guangzhou, and Johannesburg.

In Europe, cities are following Zurich’s example of investing in a tram system as the backbone of urban transport in preference to an expensive underground system (EcoPlan 2000). Emission standards and car sharing schemes (Schmauss 2009; Nobis 2006) have reduced car dependency while low-emission zones and timed delivery permits have helped reduce congestion and pollution (Geroliminis and Daganzo 2005).

In recent years, some cities have led efforts to electrify road-based transport, even though walking and cycling are still the greenest forms of transport. Copenhagen, Amsterdam, London, and New York are investing in pro-cycling and walking strategies. Cycle-hire schemes have changed attitudes towards cycling in London and Paris. In South America, cities such as Bogotá, Mexico City and Rio de Janeiro have instituted regular car-free days or weekend street closures (Parra et al. 2007).

### 4.2 Buildings

Tackling the energy demand of existing building stock is a priority for cities, and urban green building strategies also include more efficient use of other resources such as water and materials. As outlined in the Buildings Chapter, three principal green building strategies can be differentiated: design, technology, and behaviour-related. Particularly in a developing world context, passive design solutions to improve environmental performance are by far the most cost-effective approaches. For example, housing projects on the coast in Puerto Princesa City, the Philippines, have been designed to reduce energy demand through increased natural light, improved ventilation, the cooling effect of the roofing material, and strategic planting (ICLEI, UNEP and UN-HABITAT 2009).

Stringent building codes, mandatory energy certificates, tax incentives and loans, have had a measurable impact on energy demand in a number of European and US cities (C40 Cities 2010b). Toronto’s revolving energy fund and Austin Energy’s Power Saver Program have imposed higher energy efficiency standards for new buildings and are leading to a comprehensive retrofitting programme of existing building stock (C40 Cities 2010c, Austin Energy 2009). Berlin requires a solar-thermal strategy for all new buildings and Freiburg’s energy efficient housing standard has reduced average household energy consumption for space heating by up to 80 per cent (von Weizsäcker et al. 2009). As owners of large amounts of public property, municipal authorities are able to set an example by implementing green strategies on their own public building stock with beneficial effects on the development of a local green building market.

### 4.3 Energy

Cities uniquely concentrate energy demand and rely on energy sources beyond their boundaries. But cities have the potential to either dissipate the distribution of energy or optimise their efficiency by reducing energy consumption and adopting green energy systems including renewable micro-generation, district heating, and combined heat and energy plants (CHP). Rizhao, China has turned itself into a solar-powered city; in its central districts, 99 per cent of households already use solar water heaters (ICLEI, UNEP and UN Habitat 2009). In Freiburg, PV systems, encouraged by Germany’s generous feed-in tariff, now supply 1.1 per cent of the



city's electricity demand. A biomass CHP system and wind turbines provide for a further 1.3 per cent and 6 per cent respectively of the city's energy needs (IEA 2009).

Oslo and São Paulo have harnessed power generated by nearby hydro-electric facilities to gain a relatively high share of renewable energy. Wind and tidal power are becoming increasingly important sources of renewable energy for cities, while geothermal heat can also be exploited to provide reliable, secure, low-cost, power. Manila, located on the island of Luzon, receives 7 per cent of its electricity from geothermal sources (ICLEI, UNEP and UN Habitat 2009). A grid-based, decentralised energy system, with district heating systems can provide space and water heating for large urban complexes (like hospitals, schools or universities) or residential neighbourhoods. They can significantly reduce overall energy demand. Their efficiency further improves with combined heat and power energy generation systems. Copenhagen's district heating system, for example, supplies 97 per cent of the City with waste heat (C40 Cities 2010d).

#### 4.4 Vegetation and landscape

While cities are principally made up of buildings and infrastructure, they can contain a significant proportion of open space. Despite sustained growth, cities like Johannesburg, London and Delhi have maintained high levels of green open space (parks, public and private gardens), while others like Cairo, Tokyo or Mexico City have far lower levels of green space. Parks, protected green space and gardens, street trees and landscaping provide vital ecosystem services, acting as green lungs absorbing and filtering air pollution or as acting as filters for waste water (TEEB 2010). They also provide a habitat for wildlife and offer recreational benefits to city dwellers.<sup>10</sup> As noted above, a study of Toronto's Greenbelt identified its wetland and forests as one of its most valuable assets in terms of ecosystem services including carbon storage, habitat, water regulation and filtration, flood control, waste treatment and recreation (Wilson 2008).

In addition, the presence of green landscaped areas helps regulate natural processes, including the mitigation of local temperature extremes: a ten per cent increase in tree cover reduces cooling and heating energy use by between five per cent and ten per cent (McPherson et al. 1994). Vegetation and soft open space also play a role in decreasing stormwater volumes, thus helping cities to manage the consequences of heavy rainfall, and are

effective in helping flood protection in coastal cities. New design strategies have pioneered the use of green roofs and facades on buildings, to add to the quantity of natural (as opposed to man-made) surfaces in cities and to reduce cooling energy demand. For example, Itabashi City in Tokyo is promoting climbing plants as "green curtains" around public buildings and private homes to avoid buildings overheating in summer and to reduce the use of air conditioning (ICLEI 2009b).

#### 4.5 Water

Cities require significant transfers of water from rural to urban areas with water leakage being a major concern. Upgrading and replacement of pipes has contributed to net savings of 20 per cent of potable water in many industrialised cities. Over the last ten years alone, Tokyo's new water system has reduced water waste by 50 per cent (C40 Cities 2010e). Volumetric charging has proven most effective in incentivising more efficient water use. Many cities are introducing water meters and are shifting away from simple water access fees. A measure to maximise utility of fresh water is the cascading of water use where the waste water generated by one process can be used in another with a lesser quality requirement (Agudelo et al. 2009).

To further reduce water consumption and provide alternatives to piped water supply, rain can be harvested and used as drinking and non-drinking water. Such services can only be implemented in cities where there is a greater willingness to pay for water than in rural areas (see Water Chapter). To counter severe water shortages in Delhi, the Municipal Corporation made rainwater harvesting a requirement for all buildings with a roof area above 100 square metres and a plot area greater than 1,000 square metres. It is estimated that 76,500 million litres of water per year will be made available for groundwater recharge (ICLEI, UNEP and UN-HABITAT 2009). In Chennai, urban groundwater recharging raised the city's groundwater levels by four metres between 1988 and 2002 (Sakthivadivel 2007). Fiscal incentives have proved successful, notably Austin's tax rebates for harvesting systems saving an estimated 8.7 gallons per person per day for a single family rainwater harvesting unit (Texas Water Development Board and GDS Associates 2002).

#### 4.6 Food

The food footprint of a city has significant impacts on its green credentials, especially if one takes into account the energy use generated by transporting food from remote locations to urban marketplaces (Garnett 1996). For example, the food supply of European

10. At the macro level, strategies for greening the city protect existing green areas from development. Such measures are of particular importance along the city fringe, where urban growth boundaries in cities such as Portland and London restrict development. In Stockholm, thanks to the protection of green areas, almost the entire population lives within 300 meters of parks and green areas (City of Stockholm 2009).

cities accounts for approximately 30 per cent of their total ecological footprint (Steel 2008). More broadly, urbanisation is usually accompanied by a loss of nearby arable land and a rise in demand for processed foods by urban consumers. While there is some way to go to see a substantial reduction in the food footprints of highly consumptive cities such as London and New York, there is evidence that farmers' markets are successfully re-establishing links between inner cities and regional agriculture. Other cities benefit from their location at the heart of rich agricultural landscapes, which reduces the need for long and expensive travel of food products. In Milan, Italy, up to 40 per cent of daily produce is grown within a four-hour radius of travel, reflecting the city's proximity to the agricultural plains of the Po Valley and the Mediterranean Sea.

Approximately 15-20 per cent of the world's food is produced in urban areas, with urban crops and animal products often representing a substantial part of the urban annual food requirement (Armar-Klemesu and Maxwell 2001). The extensive role of food production in cities is a common feature of many developing world cities. Estimates suggest that 35 per cent of households of Nakuru, Kenya were engaged in urban agriculture in 1998 and nearly half of households in Kampala, Uganda in 2003 (Foeken 2006; David 2010). In Accra, Ghana 90 per cent of the city's vegetable supply is produced within the city's boundaries (Annorbah-Sarpei 1998). Successful urban agriculture projects are scattered across some Western cities, albeit usually on a small scale, making use of communal gardens, roof spaces and unused urban spaces. In shrinking cities such as Detroit, urban farms have been established in some of the areas with particularly low development pressures on land (Kaufman and Bailkey 2000).

## 4.7 Waste

By concentrating people and activities, cities have become centres of the waste economy, which plays a dominant role in a city's ecological footprint. Yet, cities have demonstrated considerable resilience in finding green solutions that reduce overall waste, increase recycling and pioneering new forms of environmentally friendly treatment of unavoidable waste. In developing world cities which typically suffer from insufficient formal waste collection, it is a large workforce of mostly informal recyclers and reclaimers,

such as the Zabbaleen in Cairo, who have implemented sophisticated reuse and recycling systems (Bushra 2000 in Aziz 2004). However, these jobs mostly do not match decent work requirements and green waste strategies in these contexts often fail to recognise the potential role of these actors (Medina 2000) and implement expensive, technology-driven recycling models (Wilson et al. 2006).

In many European cities, recycling levels are in the region of 50 per cent, while Copenhagen only sends three per cent of its waste to landfills (C40 Cities 2010f). In 1991, Curitiba established a green exchange programme (*cambio verde*) that incentivises people to exchange recyclable waste for fresh fruits and vegetables acquired by the city from local surpluses (Anschütz 1996). Composting is a further critical component for greening waste. Positive examples range from Dhaka's decentralised composting to San Francisco's municipal food composting programmes (Zurbrugg et al. 2005).

## 4.8 Infrastructure and digital technology

The assessment of digital technology on greener cities lies outside the scope of this section of the Report, but a growing body of evidence suggests that cities are the natural sites of investment in smart infrastructure to deliver more sustainable environments. Cities provide a critical mass of potential users for a wide range of IT-based services which build upon complex physical infrastructure (such as roads, rail, cabling and distribution systems). The digital infrastructure of the internet and data centres create an intelligent infrastructure that connects people to people, people to city systems and city systems to each other, allowing cities and their residents to respond to changing circumstances by adapting in near real-time and to recognise patterns to help make informed decisions.

In addition, smart transport systems are being used to tackle congestion, facilitate road user charges or supply real-time information on traffic problems. Examples include Stockholm's congestion tax and Singapore's electronic road pricing. They also facilitate bike hire schemes in many cities around the world. Amsterdam currently trials smart work centres that allow workers to use local office facilities rather than commuting to their main office (Connected Urban Development 2008).

## 5 Enabling green cities

The previous sections of this chapter confirm that the greening process is complex, fragmented and multi-layered. Enabling green cities *is* and will continue to be equally complex and piecemeal in the near future. There is no single silver bullet that can help shift cities to a green agenda but those that are flexible and diverse will be in a strong position.

This section addresses the key barriers that constrain the adoption of green policies in cities and puts forward a number of practical suggestions on the way forward, based on enabling best practices found in metropolitan regions across the globe. While a “one-size-fits-all” model is neither envisaged nor proposed, it is argued that there are common barriers and constraints in cities in developing and developed countries that need to be overcome before green development can take hold. It further suggests that a combination of political restructuring, policy innovation, market stimulation and consumer participation is essential to enable the gradual transition towards green cities in the coming decades.

Before identifying key constraints, it is important to recognise that the shift to environmental responsibility – in cities, as in all other aspects of the green economy debate – is not just a technical issue, but one that has deep cultural and political ramifications. Hence, governance and democratic accountability, together with a dynamic involvement of the private sector, need to be given equal attention in the discussion about implementation as innovations in policy, planning and regulation. Green city solutions will not be realised overnight by classic top-down or bottom-up approaches, but by the actions of a coalition of actors from the national, state and local levels, from civil society and its multiple subdivisions, from the private sector and institutions including universities, not-for-profit foundations and interest groups who share a commitment to advance the green economy in cities.

### 5.1 Barriers and constraints

This chapter has argued that there are compelling reasons why the green economy model can be adopted in cities across the world. Section 4 identified examples of best practice in cities across both advanced and developing nations, but they are a drop in the ocean with respect to the vast majority of new urban development in Africa, Asia and the Americas. Today, most cities are adopting fundamentally non-sustainable practices as

a result of a combination of the following barriers and constraints, which vary in significance according to geographical location and position with the economic and political development cycle:

■ *Fragmented governance* – lack of coordination between policy frameworks that promote green economy measures at supra-national, national, regional and metropolitan levels;

■ *Affordability* – even cost-effective green measures may be out of the reach of poorer cities, leaving them saddled with more wasteful urban infrastructure;

■ *Lack of investment* – despite wider acceptance of the relevance of the green economy to well-being, the private and public sector have not prioritised green investment in basic city infrastructure (such as green planning, public transport and housing strategies);

■ *Negative tradeoffs* – without effective policy intervention and infrastructure investment, (which promote productivity and resource efficiency) green city strategies can lead to greater congestion (of people and traffic), higher land values and costs of living;

■ *Consumer preferences* – when given a choice consumers may not be willing to adopt new models of urban living that require changes in individual and collective patterns of consumption (e.g. high-density apartment living, public transport use);

■ *Switching costs* – high short-term transition (welfare and capital) costs for businesses that shift from brown to green, leave many companies without adequate compensation to make the investment;

■ *Vested business interests* – industry dynamics in construction, road-building and infrastructure are resistant to change that challenges existing business models and threatens the potential of short-term return on investment;

■ *Risk aversion* – individuals, corporate and government organisations are resistant to any change that does not demonstrate immediate improvement in economic well-being, quality of life or enhanced status within the community;

■ *Perverse policies* – these produce underpriced goods and services, thereby encouraging overconsumption. Such policies include subsidised road infrastructure;

the failure to charge developers fully for the cost of services and infrastructure new developments require; various tax abatements encouraging home ownership and other public policy measures that facilitate urban sprawl and the use of the private car as a dominant means of transport; and

■ *Behavioural response and the rebound effect* – consumers may respond to reduced energy costs (generated by energy efficiency measures) by either increasing per capita energy consumption or by spending savings and increasing overall consumption per head.<sup>11</sup>

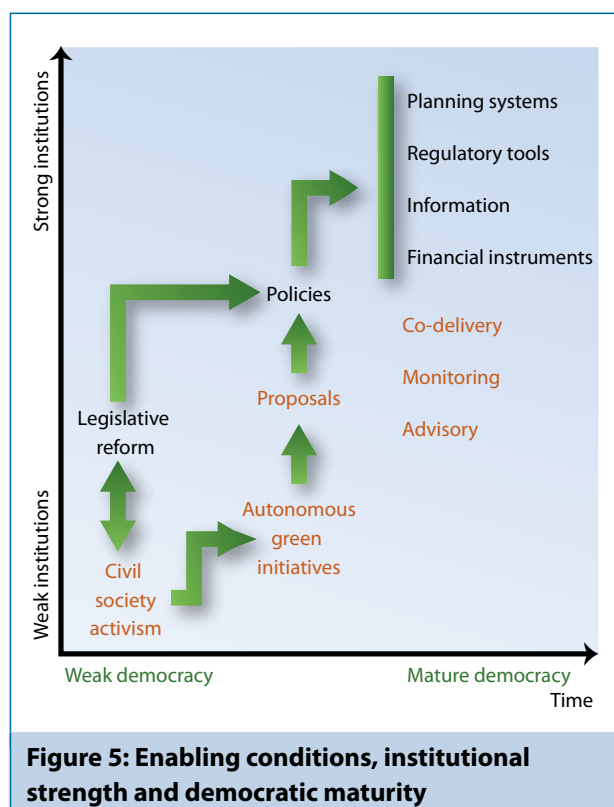
## 5.2 Enabling strategies

Overcoming this set of barriers and constraints requires a multi-faceted response across different sectors, which are addressed in turn, from governance and planning to incentives and financing.

Figure 5: Enabling conditions, institutional strength and democratic maturity illustrates the breadth of policy instruments and tools that can promote investment in greening cities. Importantly, it correlates their effectiveness over time in relation to the strength of local institutions and the strength of the democratic system in different urban contexts. By plotting the enabling conditions available in systems with both strong and weak institutions against weaker and more mature democracies, it suggests that the process of change is in most cases a long one, and requires the development of mature institutions before long-term change can be implemented, whilst recognising that civil-society activism and autonomous green initiatives can be effective in the short-to-medium term, especially in weaker institutions and less mature democracies.

All of these transition factors suggest that it is critical to develop policy frameworks not just at the local and urban level, but also at the regional and national level. More broadly, policy makers need to look at the conditions that will enable cities in different parts of the world to make the transition to green economy models *in relation* to the maturity of their own political infrastructure.

To overcome existing barriers and constraints, joining up is essential. For example, engineering solutions need to be complemented with fiscal instruments such as carbon pricing (Birol and Keppler 2000, in Allan et al. 2006) to harvest the benefits of improved technical efficiencies, while avoiding undesirable rebound effects.



**Figure 5: Enabling conditions, institutional strength and democratic maturity**

It remains difficult to achieve green city synergies which simultaneously deliver economic prosperity, reduce resource intensity and promote social inclusion because economic added value is derived from processes and regimes that fail to account properly for environmental and social externalities. Until this issue is properly addressed, it is unlikely that fundamental economic enabling conditions to advance green cities will be found.

An efficient global response to the problem of climate change will therefore entail up-front finance and technological support to enable fast-growing cities in the developing world to “leap-frog” developed world cities in planning and installing the latest, most efficient, infrastructure that will bring down resource intensity and save money for decades. But it is to governance that we first turn, to establish the principle for core enabling strategies that can bring about change.

## 5.3 Governance

Governance encompasses the formal and informal relationships linking the various institutions involved in the urban system – the local, metropolitan, regional, state, civil society and private-sector actors – and its quality depends on the depth of reciprocity, trust, and legitimacy. These are enhanced by mechanisms and opportunities to facilitate meaningful dialogue, and by well-structured organisations in civil society, the business sector and the relevant government level.

11. see Allan et al. (2006). However, von Weizsäcker et al. (2009) suggest that energy cost savings can provide households with the capital needed to invest in further energy saving measures and the State to invest in R&D in renewable energies, thus even enabling a positive feedback loop.

The practical imperatives of debating trade-offs and priorities in pursuing green city development can contribute to the maturing of governance relationships.

In contexts with strong local government it is possible to envisage a range of planning, regulatory and financing instruments to advance green infrastructure investments, green economic development and a multitrack approach to greater urban sustainability. In countries where local government is weak or marked by mistrust and disinterest due to its inefficiency and/or corruption, it is important to underscore that unless broad-based cultural movements are fostered that can shift the aspirational horizons of ordinary people, it will prove very difficult to promote and institutionalise the numerous green city reforms proposed in this chapter.

In poorer cities, the building up of such capacities is important, as is their access to financial resources for investing in the various sectors of green cities. Here it may be prudent to adopt a more pragmatic and minimalist approach, which primarily commits municipal sectors such as water, waste, energy and transport to a limited number of strategic goals. These are the major areas where the support from national governments and international organisations is needed.

Coalitions that work to advance green city principles and practices need to identify practical ways in which they can design and execute mass-based campaigns to make alternative approaches to routine consumption a desirable option for ordinary people, especially the middle and working classes but also the large segments of the population that one can term the working poor. In these contexts, it is important to drive home the connections between poverty reduction through effective slum policies, which of course can be dovetailed with aspects of green infrastructure such as decentralised systems and community maintained systems.

However, external (to the local) actors, be they funding agencies or national departments who operate through local offices, are also working on city-wide infrastructure investments and these protagonists should be targeted as well to ensure that they see the potential value of technological leap-frogging and more community-based decentralised delivery systems. But such an ideal immediately sounds naïve because these technological approaches effectively undermine the political control of national elites over local territories. In this sense, advancing effective and deep democratic institutions become a truly foundational enabling condition for green cities.

Effective governance will also come into its own through a substantive agenda or vision that is shared

by diverse stakeholders. Such a coalition can promote the idea of a long-term strategic plan for the city complementing the more conventional spatial and environmental planning instruments. For example, the internationally-based Cities Alliance (2007) promotes so-called City Development Strategies (CDS), as appropriate tools to address the nexus between sustainable economic growth and ecological preservation and restoration. They are based on the premise that local governments have little power and funding to promote or impose change, and that partnerships are the only practical way forward.<sup>12</sup>

This should be backed up by effective resource allocation and decision-making systems that demonstrate to everyone in the city that systematic progress is being achieved towards the long-term goal of becoming a green city. To date, however, city level green economy initiatives have been largely decoupled from national policy frameworks. Glaeser and Kahn (2010), in a study of US metro areas, find that the cities with the lowest per capita CO<sub>2</sub> emissions also tend to have the tightest planning restrictions. They suggest that “by restricting new development, the cleanest areas of the country would seem to be pushing new development towards places with higher emissions” (Glaeser and Kahn 2010).

To avoid a patchwork of uncoordinated targets, goals, and programmes, and to allow the most cost-effective emission reduction opportunities to be exploited, national and city initiatives need to be synchronised as part of a coordinated design and implementation of policy instruments. In the example of the USA above, the city-level coordination failure could be dealt with at national level through a personal carbon tax that internalises the environmental costs of household behaviour, including location decisions. Governance restructuring witnessed in many parts of the world often simultaneously involves devolution as well as powers shifting to supranational bodies. These processes increase the role of municipalities as independent policy actors. In addition, they play an important role in implementing national policies at the local level and in shaping the immediate living environment via long standing municipal policy instruments. However, these also need to be improved as decentralisation efforts in most developing countries, and especially in least developed countries remain deeply flawed, uneven and partial (Manor 2004).

Within this framework, it is possible to generalise from everyday practice, and suggest a potential distribution

12. “Local governments alone cannot turn a city around. They control a minuscule portion of the capital available for city building and often have an even smaller proportion of the available talent in urban innovation. Although important as catalysts and as representatives of the public interest (in theory, at least), local governments should work in partnership with private interests and civil society to change a city’s developmental direction – CDS processes are based on private, public, and civil society partnerships” (Cities Alliance 2006).



of functions within a three-tier system of governance which could help deliver green city strategies more effectively. In addition, international bodies and bilateral networks can help enabling developing country governments to invest in green cities by providing finance and by helping with technology transfer.

■ The *national/state level* creates the general conditions under which the economy works and for example, has a strong focus on social security; ensuring national policy on water; supplying infrastructure of national importance; and ensuring design standards by implementing general building regulation. In the context of a green economy, national government can set a price on carbon (carbon tax), create markets for clean technologies (carbon pricing, regulation, tax breaks), fund or enable major infrastructure investment (smart grid) and set minimum standards. Besides financing, the national level should also employ preferential policies to enable green cities.

■ The *metropolitan/regional level* includes the entire functional city-region, even though there is often a non-alignment between political boundaries and urban development. Metropolitan governance directly addresses three of the five principle categories of environmental performance (health, hazards and high quality urban environments) with a responsibility for a wide range of functions such as strategic planning, regulating waste disposal and water management, overseeing regional banks and land banks, ensuring skills training matches targets for the regional economy, promoting green transport infrastructure and operations, and setting specific building standards regarding flexible use, additional green targets and climate change adaptation. Increasingly, it is also the metropolitan level that addresses the transfer of environmental costs and sustainable consumption with targets regarding carbon reduction. In these cases, strategic actors such as publicly owned utility companies able to invest long-term or integrated, multi-modal transport agencies facilitating the greening of transport have proved to be extremely beneficial.

■ The *local/municipal borough or district level* operates for areas that might include between 100,000 to 500,000 residents and is responsible for implementing policies developed at other spheres; managing green objectives; implementing food and resource management in close consultation with residents; overseeing local policing; and providing input on socio-economic development for other spheres.

## 5.4 Planning and regulation

While the large proportion of informal practices makes planning and regulation less relevant in some cities in developing nations, they are the most common

policy instruments that shape urban development in more complex and mature political environments. In these instances, they range from strategic and land-use planning to building codes and environmental regulation. Besides regulating for desired environmental outcomes, they help to kick-start green innovation and create demand for green products at various levels.

To maximise synergies across different urban sectors, integrated planning that combines land use and urban development with other policies and cuts across the urban functional region of cities is critical in achieving greater environmental performance. The recently launched World Bank Eco2 Cities programme, for example, demonstrates why planning, finance and infrastructure imperatives are inextricably linked in a low-carbon world (Suzuki et al. 2010). This programme argues for a one-system approach to: "realise the benefits of integration by planning, designing and managing the whole urban system." On a practical level this implies that all cities need to understand their urban form and the nature and patterning of material resource flows through the urban system.

The intersections of infrastructure and the dynamics, resilience or vulnerability of urban form are crucial. As described previously, it is not untypical for poor people to live without access to various infrastructure networks in the most climate-vulnerable areas of a city (Moser and Satterthwaite 2008). Possible impacts on urban form and resource flows need to be considered when planning infrastructure investments, especially given the enormous sums required for capital expenditure in rapidly urbanising areas. More than anything else, urban sustainability will depend upon how these sums are going to be allocated.

A combined understanding of urban form and resource flows helps isolate effective actions to achieve greater overall resource efficiency. It also forces a longer-term horizon for understanding trends, the most strategic intervention points, and how to weigh up trade-offs between various spaces of an urban region. If it is based on sound data, it will hold the potential to provide a shared basis for understanding what is going on in a city, where it may be leading and what needs to be done to change the efficiency of the overall system (Crane, Swilling et al. 2010). It is only when this kind of analysis and political discussion becomes commonplace, that one can achieve a broad-based commitment to effective long-term strategic planning.

The recent UN-Habitat Global Report on Human Settlements seeks to bring planning back to the centre of urban development debates (UN Habitat 2009), reinforcing the idea of strategic spatial planning that focuses on a "directive, long range, spatial plan,

<b>Urban growth boundaries</b>	Establish clear limits to any form of building development around cities to limit urban sprawl; create green corridors that protect existing ecosystems
<b>Land-use regulation</b>	Introduce zoning regulation that prioritises development of inner-city, previously developed (brownfield) land over greenfield development at city-wide level
<b>Density regulation</b>	Provide minimum rather than maximum density standards; establish clear density standards at city-wide level (e.g. Floor Area Ratios, FAR*) in support of compact city development with a hierarchy of higher density, mixed-use clusters around public transport nodes
<b>Density bonus</b>	Provide development bonuses that allow increased development rights (i.e. extra floor area with respect to standard planning regulations) for green projects that support city-wide and local sustainability
<b>Special planning powers</b>	Establish urban development corporations or urban regeneration companies to promote and enable green projects
<b>Vehicle and traffic regulation</b>	Regulate for vehicle types, emission standards, speed limits and road space allocation that favours green transport and especially green public transport
<b>Parking standards</b>	Provide maximum rather than minimum parking standards; reduce private car parking standards to a minimum (e.g. less than one car per household) especially in areas of high public transport accessibility
<b>Car-free developments</b>	Provide planning incentives for car free developments in higher density areas with high public transport accessibility
<b>Minimum emission standards</b>	Regulate minimum carbon emission and energy efficiency standards at the local level for buildings and vehicles

**Table 6: Selected planning and regulatory instruments**

\* FAR is the most common density measure for planning purposes. It is calculated by adding all the area of residential and business floor space and dividing it by the entire area of the development site.

and broad and conceptual spatial ideas” as opposed to traditional master planning with detailed spatial designs. A central component of strategic planning is the linking-up of spatial and infrastructure plans and the promotion of public transport to drive urban compaction and accessibility. Many cities, particularly in Western Europe, have adopted strategic planning while some, including Johannesburg are turning to new planning-regulatory frameworks that serve as a basis for new approaches.

For city governments to insist on planning reform is also crucial for implementing the actions required to address the global environmental crisis. Playing those roles requires a much greater capacity for effectual planning. The planning implied is a clinical engagement with the urban form and flows of the city to identify how best to sequence, coordinate and integrate various infrastructure investments that will set the long-term course for urban efficiency, competitiveness and inclusivity.

The examples cited in previous sections of this chapter suggest that the most effective green city planning strategies have a direct impact on the shape and size of a city and its metropolitan hinterland. Reusing existing urban land while restricting urban sprawl and peripheralisation is central to the creation of sustainable urban environments, especially when retrofitting mature cities with previously developed industrial land. Increasing and maintaining urban density levels is desirable but can only be successful if associated with other services, such as high quality public transport and public space. Urban design and public space standards and a polycentric urban structure that encourages mixed-use developments

and varying densities with peaks around nodes supported by public transport are essential. To ensure environmental sustainability, there should be a policy bias against greenfield development in mature or recently established cities, until all available urban land is developed at appropriate densities. While a wide range of planning and regulatory tools exist that can be of particular relevance to the implementation of green cities, Table 6 summarises some of the most effective instruments that have brought about sustainable change in examples reviewed in this chapter.

## 5.5 Information, awareness and civic engagement

Effective planning and governance across different administrative levels requires high-quality information to raise awareness amongst urban residents to promote behaviour change. In addition, given that cities contain large consumer markets which are potentially valuable to producers of green goods and services, information is also an essential tool to influence consumer choice. But consumer preferences, in developed and developing nations, are not always green. For example, very dense urban development is not always popular in many parts of the UK and Europe (Cheshire 2008) and the North American propensity for suburbanisation is well documented.

At the same time, information and active communication on the potential benefits of greener lifestyles in cities can enable consumers to make more informed decisions. For example, in Munich new residents are given an information package on green mobility opportunities. Using such tools can also impact on the behaviour of businesses as the Indian city of Surat, one of Gujarat's

Monitoring	
<b>Environmental performance measures</b>	Introduce new accounting and benchmarking standards for environmental performance at the city level
<b>Environmental performance targets</b>	Set clear time-based and sector specific targets based on robust indicator for green city development
<b>Carbon budget</b>	Ensure that any urban development strategy or policy across all levels will have to be looked at in terms of carbon emission effects
<b>ecoBUDGET</b>	Introduce this new management system for natural resources and environmental quality measured and accounted for in a budget
<b>City Biodiversity Index</b>	Adopt a city biodiversity index which combines quantifying biodiversity, related ecosystem's services and related management
<b>Geographic Information Systems (GIS)</b>	Integrate this map based analysis tools in all processes allowing cities to better track and plan developments
Engagement	
<b>Online access</b>	Increasing internet access particularly of poorer communities while making all relevant information available online
<b>Public consultation</b>	Issue-based engagement with local communities and public debates with politicians presenting and defending development plans
<b>Local activism</b>	Harness the potential of local activism to improve quality of life and the environment through community-based projects
<b>Transparency</b>	Ensure maximum levels of transparency and advance on freedom of information legislation
<b>E-democracy</b>	Recognise role of e-governance and participation in providing information and access to monitoring and achieving sustainability targets
Awareness	
<b>Education</b>	School curriculums to include "green education" and provision of professional "green training" for public and private organisations
<b>Public campaigns</b>	Raising awareness of the advantages of green city strategies, particularly on compact city living and green transport
<b>Labelling</b>	Eco-labelling of consumer items to help consumers make more informed choices and provide additional incentives for green products
<b>Smart meters</b>	New smart monitoring and metering devices can provide real time information on resource use: Without smart metres no smart consumers
<b>Welcome packs</b>	Providing new residents with information packages on green living as behaviour can be best changed when building a new daily routine
<b>Best Practice</b>	Disseminating information on green city projects that have worked elsewhere to inform local adaptations
<b>Demonstration projects</b>	Establishment of test projects within cities to allow for better assessment and public exposure to new approaches
Table 7: Selected information-based instruments	

largest industrial centres, has shown. A combination of information and regulatory enforcement tools are used to force textile firms to reduce water pollution – saving money in the process. One large firm reduced pollution by 90 per cent, energy use by 40 per cent and chemical use by 85 per cent (Robins and Kumar 1999).

Table 7: Selected information-based instruments presents a range of informational tools covering three broad categories of monitoring, engagement and awareness. The instruments selected have either been critical to successful examples of greening cities or have gained particular prominence in the current discourse.

<b>Fuel taxes</b>	Increase fuel tax to internalise external costs of private vehicle use and to adjust demand to the road capacity
<b>Carbon pricing</b>	International, national or regional cap and trade schemes that set a maximum for carbon emissions which are being traded
<b>Pricing for ecosystem services</b>	Payments for ecosystem services (PES) that linking beneficiaries and suppliers of related services
<b>Reduce perverse incentives</b>	Cut tax reductions or incentives that encourage longer commuting (Germany) or single family housing (US)
<b>Tax incentives</b>	Provide funding or tax reductions for citizens or companies investing in renewable energy, retrofitting buildings or other green projects
<b>Road user charges</b>	Managing traffic demand and adjusting vehicle levels to available or reduced road capacities by charging private vehicle use in cities
<b>Parking charges</b>	Charging for on- and off-street parking based on market prices to reduce parking demand and release space for higher value usage
<b>Land development tax</b>	Taxing the release of new land to maximise usage and to contribute to financing green infrastructure development
<b>Land auctioning</b>	Limiting over-consumption of land by capping the release of new land to then be auctioned
<b>Licence plate auctioning</b>	Limiting the growth of private vehicles by capping at certain numbers and auctioning related licences
Table 8: Selected incentives	

<b>Taxes</b>	Cities need to be able to raise local taxes and service charges as they are the main revenues sources that can be used for public green city strategies
<b>Cost recovery</b>	Introduce user fees of municipal services to help greening these services and supporting the development of greener alternatives
<b>Land value capturing</b>	Financing public transport based on integrated “transport-property” development models
<b>Micro-financing</b>	Critical financing opportunity where micro-enterprises are involved in green city strategies, e.g. recycling developing country cities
<b>Profit-making public companies</b>	Cities to hold shares of profit making companies, e.g. utilities to allow for long-term green investments
<b>Purchasing pools</b>	Cities can also work together to purchase technology thereby bringing down the cost
<b>Carbon credits</b>	Clean Development Mechanisms (CDM) already pay for a range of green city projects in Bogotá, São Paulo and Dhaka

**Table 9: Selected financing instruments**

## 5.6 Incentives

Information alone is insufficient to change behaviour patterns; it needs to be supplemented by incentives to bring about lasting change. In part, this may be to minimise adjustment costs to citizens and firms. For example, firms and workers in brown industries may face higher prices as cities shift their industrial structures towards greener models. National and city-level policy makers need to compensate these short-term losers while recalibrating urban economies.

Incentives may be within the tax system (e.g. tax breaks or taxing environmental “bads”), other types of charges (e.g. road pricing) or payments (e.g. targeted subsidies). Subsidies were successfully used as part of the policy mix in Bavaria during the 1990s and 2000s. The state’s Future Bavaria and High-Tech initiatives spent over 4bn Euros, mainly on R&D and technology transfer around the city of Munich. The investments helped kick-start the city’s environmental technologies sector, with the city garnering Germany’s highest share of cleantech patents in 2007 (Rode et al. 2010).

Apart from providing direct economic incentives, city governments also provide public services – such as

workforce education and training, business spaces and green infrastructure. Such services not only reduce the costs to business of going green, but also shift the business environment towards one in which low-carbon activity is the norm.

At the same time, full cost pricing (internalising external environmental costs), whether as taxes or user charges is essential for inducing behaviours to be consistent with green city criteria. Full cost pricing measures have been successful in managing demand for energy, water and other resources and find increasing applications in urban contexts. Many cities in the USA have recently introduced impact fees to recover the cost of additional infrastructure, such as roads, telecommunication, or schools, necessitated by new development (Brueckner 2000). They can also help avoid negative rebound effects with over-consumption as a result of efficiency savings. Furthermore, one such measure – environmental tax – can be used to cut costs for labour, thereby proving an impetus for employment creation.

Major pricing tools in the urban context are presented in Table 8: Selected incentives, which summarises some of the most effective instruments that have brought about sustainable change in examples reviewed in this chapter.

Current job	Core training requirement	Additional low-carbon skill requirement	New low-carbon job
Electrician	Apprenticeship	Working on roofs; installation of solar PV panels	Solar PV fitter
Offshore oil or gas maintenance technician	Apprenticeship	Offshore wind technology	Offshore wind maintenance technician
Aerospace technician	Apprenticeship	Technology-specific knowledge	Wind turbine technician
Architect	Undergraduate degree, masters degree and paid work experience	Energy efficiency and zero-carbon knowledge	Low-carbon architect
City trader	Undergraduate degree	Carbon literacy, understanding or carbon trading schemes	Carbon trader
Facilities manager	No specific qualification required	Sustainability and energy management issues	Low-carbon facilities manager

**Table 10: Top-up training for low-carbon jobs**

Source: adapted from IPPR (2009)

## 5.7 Financing

Finance can be a stumbling block to the introduction of concerted policies to shift cities away from a carbon and resource-intensive metabolism. Although several sources of revenues exist, in many countries national fiscal policy prevents local authorities from raising enough capital both, locally and on international financial markets. This has been reinforced in many parts of the developing world by decentralisation reforms that have often entailed a dispersal of central government functions, without any transfer of resources and power to autonomous lower level authorities. Layered on top of this has been the competitive pressure to offer tax concessions in order to attract potential foreign and domestic investors.

Three imperatives are central to advance on green city finance. First, getting a detailed understanding of the existing financial position in terms of potential revenue. This analysis should be based on domestic and international comparison with cities of similar size. Second, city governments need to initiate various forms of partnership with local businesses and community organisations. If cities set the framework for engagement, act transparently and accept the return on investments for private actors, then there is considerable room for leveraging private-sector capital. Third, horizontal and vertical networks are required. According partnerships and coalitions allows for cross-municipal cooperation and regional and international participation in various local government policy forums.

Many of the green city investment projects are within the reach of city governments, which can leverage national or private funds to pay for the initial capital investments. In Hong Kong, the enormous costs for new urban rail infrastructure are covered by the city's principle rail operator, the MTR Corporation, which capitalises on the real-estate potential of its stations as part of an integrated rail-property development model (Cervero and Murakami 2009). In Paris and London, urban bike hire schemes are paid for privately in return for prime advertising space, while the biogas in São Paulo's landfills are a resource that is privately turned into energy and for which the city receives carbon credits. Once the initial investment has been made, these projects bring in a

steady revenue stream that can be reinvested. Some projects do not even need initial capital investments as they rely on statutory regulations, such as the green building programmes in Berlin or Austin.

Table 9: Selected financing instruments provides a general overview on financing instruments that have been central to existing green city strategies. In successful cases, many of these tools have been directly available to city governments.

A priority in any green urban planning is investment in cost-effective public transport infrastructure particularly over investment in road construction that further promotes private car use. Surface public transport such as bus rapid transit needs to play a central role particularly in lower income contexts. Non-motorised transport has to be recognised as basis of any transport system and requires greater shares of overall transport budgets.

In both developing and developed countries, another priority is investing in education and training at the city level. Training of workers in green technologies and job skills would be required to ensure that they can access green employment opportunities. Table 10: Top-up training for low-carbon jobs provides some UK examples developed by the Institute for Public Policy Research (IPPR 2009), illustrating the nature and the extent of additional training that will be required to foster a shift towards a lower-carbon economy.

For poorer cities, however, access to finance, green technologies and skills may be out of reach. This is where support in up-front finance, technology, and capacity building is needed from the national government and international community. In the case of climate change, for example, the Copenhagen Accord proposes generating US\$ 100 billion per year by 2020 in the support of climate change mitigation and adaptation in the developing world (Glemarec, Waissbein and Bayraktar 2010). Such finance would be particularly effective to enable fast growing cities in the developing world to "leap-frog" developed world cities in planning and installing efficient infrastructure that will reduce resource intensity and save money for decades.



## 6 Conclusions

Cities are where some of the world's most pressing challenges are concentrated: unsustainable resource and energy consumption, carbon emissions, pollution, and health hazards. But cities are also where hope lies. They are magnets attracting hundreds of millions of rural migrants in search for economic opportunities. The net effect of urbanisation on poverty reduction has been effective at the global level. Although urbanisation has been accompanied by increased pressure on the urban environment and the increase of the urban poor, these problems are not insurmountable.

As the nations of the world explore more sustainable development trajectories, this report argues that cities can and should play a leading role in greening economies – in both developed and developing countries. There are clear opportunities for national and city leaders to exploit urban areas to reduce carbon emissions and pollution, enhance ecosystems and minimise environmental risks.

Greening cities can also produce a set of wider economic and social benefits. First, as well as lowering per capita carbon emissions, densification as a central green city strategy tends to enhance productivity, promote innovation, and reduce the capital and operating cost of infrastructure. Densification can also raise congestion and the local cost of living, but green city strategies and interventions to subsidise housing costs can help to mitigate these.

Second, in most countries cities will be important sites for the emerging green economy. Cities' basic offer of proximity, density and variety delivers productivity benefits for firms, and helps stimulate innovation and new job creation – for example in high-tech clusters, as are already emerging in urban regions like the Silicon Valley. Much of a green economy is service-based, and will tend to cluster in urban areas where consumer markets are largest.

Third, social considerations can be fully integrated into the design of green cities. An emphasis on public transport, cycling, and walkability, for example, not only contributes to road safety and community cohesion but also works in favour of the urban low income class who rely on these transport modes much more than other segments of society. The consequently improved access to jobs, education and

medical facilities, clean energy, safe drinking water, and sanitation may hold the key to lifting the urban poor out of poverty altogether.

Greening cities is not cost free. There are tradeoffs and switching costs, creating both winners and losers. Consumer preferences are not always green. Cities may face financial, structural and technological constraints. And fragmented governance may lead to perverse outcomes of policy, if action is not carefully joined up between different spatial levels. The "rebound effect", where energy-saving innovations actually raise total energy consumption, illustrates how many of these issues come together.

These factors suggest it is critical to look at both national and urban policy levers; and at the conditions that will enable cities in different parts of the world to make the transition to green economy models. In practice, green cities will require a coalition of actors across public, private and civil society sectors – and multilevel governance models that allow these actors to come together effectively.

Numerous instruments for enabling green cities are available and tested but need to be applied in a tailored, context-specific way. In contexts with strong local government it is possible to envisage a range of planning, regulatory, information and financing instruments to advance green infrastructure investments, green economic development and a multitrack approach to greater urban sustainability. City governments need to coordinate policies and decisions with other levels of government, but more importantly, they need to be equipped with strategic and integrated planning capacities, including the capacities to choose regulatory tools and economic incentives to achieve locally appropriate green city objectives.

In poorer cities, the building up of such capacities is important, as is their access to financial resources for investing in the various sectors of green cities. Here it may be more prudent to adopt a more pragmatic and minimalist approach, which primarily commits municipal sectors such as water, waste, energy and transport to a limited number of overarching strategic goals. These are the major areas where the support from national governments and international organisations is needed.

# References

- Agudelo, C., Mels, A. and Rovers, R. (2009). "Urban Water Tissue: Analysing the Urban Water Harvest Potential." 3rd CIB International Conference on Smart and Sustainable Built Environments (SASBE), Delft. Available at: <http://www.sasbe2009.com/papers.html>.
- Allan, G., Hanley, N., McGregor, P.G., Swales, J.K. and Turner, K. (2006). *The Macroeconomic Rebound Effect and the UK Economy*. University of Stirling and University of Strathclyde.
- Annorbah-Sarpei, A.J. (1998). *Urban Market Gardens: Accra, Ghana*. The Mega-Cities Project, Publication MCP-018C.
- Anschütz, J. (1996). "Community based solid waste management and water supply projects: Problems and solutions compared, A survey of literature." UWEP Working Document 2.
- Armar-Klimesu, M. and Maxwell, D. (2001). "Accra: Urban Agriculture as an asset strategy, supplementing income and diets, A case study of Accra." in Bakker, N., Dubbeling, M., Guendel, S., Sabel Koschella, U. and de Zeeuw, H. (eds.), *Growing cities, growing food: Urban agriculture on the policy agenda. A reader on urban agriculture*. DSE, Feldafing.
- Austin Energy (2009). *Green building multifamily program guidebook*. [online] Available at: <http://www.austinenenergy.com/energy%20efficiency/Programs/Green%20Building/Participations/aegbMultifamilyGuidebook.pdf> [accessed 10 December 2010].
- Aziz, H. (2004). *Improving the livelihood of child waste pickers: Experiences with the 'Zabbaleen' in Cairo, Egypt*. WASTE, Gouda.
- Barrett, J., Birch, R., Baiocchi, G., Minx, J. and Wiedmann, T. (2006). "Environmental impacts of UK consumption: Exploring links to wealth, inequality and lifestyle." IABSE Henderson Colloquium, Cambridge.
- Baradaran, S. and Firth, D. (2008). "Congestion tax in Stockholm: An analysis of traffic before, during and after the trial and since start of the permanent scheme." Ecocity World Summit 2008 Proceedings.
- Baumgartner, B. and Belevi, H. (2001). A systematic overview of urban agriculture in developing countries. EAWAG/SANDEC, Dübendorf.
- Beatley, T. (2004). "Planning for sustainability in European cities: A review of practice in leading cities." in Wheeler, S.M. and Beatley, T. (eds.), *The Sustainable Development Reader*. Routledge, London.
- Beevers, S. and Carslaw, D. (2005). "The impact of congestion charging on vehicle emissions in London." *Atmospheric Environment*, 39, 1-5.
- Bertaud, A. (2004). "The spatial organization of cities: Deliberate outcome or unforeseen consequence?" Working Paper 2004-01. Institute of Urban and Regional Development, University of California, Berkeley.
- Berube, A., Rode, P., Just, T., Friedhoff, A., Paccoud, A., Nadeau, C., Kandt, J., and Schemm-Gregory, R. (2010). *Global Metro Monitor: The path to economic recovery*. Metropolitan Policy Program, The Brookings Institution, Washington, D.C. and LSE Cities, London School of Economics and Political Science, London.
- Binswanger, M. (2001). "Technological progress and sustainable development: What about the rebound effect?" *Ecological Economics*, 36, 1, 119-132.
- BioRegional (2009). *BedZED seven years on. The impact of the UK's best known eco-village and its residents*. BioRegional, Wallington.
- Bixler, R.D., Floyd, M.F. and Hammit, W.E. (2002). "Quantitative tests of the childhood play hypothesis." *Environment and Behavior*, 34, 6, 795-818.
- Boden, T.A., Marland, G. and Andres, R.J. (2010). *Global, Regional, and National Fossil-Fuel CO<sub>2</sub> Emissions*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.
- Bradbury, A., Tomlinson, P. and Millington, A. (2007). "Understanding the evolution of community severance and its consequences on mobility and social cohesion over the past century." Association for European Transport and Contributors. European Transport Conference 2007, Creating a Livable Environment Seminar.
- Brilon, W. (1994). "Traffic engineering and the new German highway capacity manual." *Transportation Research A*, 20, 469-481.
- Brookings and Battelle (2011) – forthcoming.
- Bruce, N., Perez-Padilla, R. and Albalak, R. (2002). *The health effects of indoor air pollution exposure in developing countries*. World Health Organization, Geneva.
- Brueckner, J. (2000). "Urban sprawl: Diagnosis and remedies." *International Regional Science Review* 23 (2), pp.160-171.
- Brühlhart, M. and Sbergami, F. (2009). "Agglomeration and growth: Cross-country evidence." *Journal of Urban Economics*, 65, 1, 48-63.
- Brugmann, J. (1999). "Is there a method in our measurement? The use of indicators in local sustainable development planning." in Satterthwaite, D. (ed.), *Sustainable Cities. The Earthscan Reader*. Earthscan, London.
- Bull, F., Armstrong T., Dixon T. Ham S., Neiman A. Pratt M. (2004). "Physical inactivity." in Ezzati M., Lopez A., Rodgers A., Murray, C.J.L. eds "Comparative quantification of health risks". World Health Organization, Geneva.
- Burgess, R. (2000). "The compact city debate: A global perspective." in Jenks, M. and Burgess, R., (eds.) *Compact cities: Sustainable urban forms for developing countries*. Spon Press, London.
- Carruthers, J.I. and Ulfarsson, G.F. (2003). "Urban sprawl and the cost of public services." *Environment and Planning B: Planning and Design*, 30, 4, 503-522.
- CEO for Cities (2010). New York City's Green Dividend. CEO for Cities, Chicago and Washington, D.C. Available at: [http://www.ceosforcities.org/work/nycs\\_green\\_dividend](http://www.ceosforcities.org/work/nycs_green_dividend)
- Cervero, R. and Murakami, J. (2009). Rail and property development in Hong Kong: Experiences and extensions. *Urban Studies Journal*, 46, 10, 2019-2043.
- Chapple, K. (2008) *Defining the Green Economy. A Primer on Green Economic Development*. UC Berkeley, Berkeley. Available at: <http://communityinnovation.berkeley.edu/reports/Chapple%20-%20Defining%20the%20Green%20Economy.pdf>
- Charlot, S. and Duranton, G. (2004). "Communication externalities in cities." *Journal of Urban Economics*, 56, 3, 581-613.
- Chen, H., Jia, B. and Lau, S.S.Y. (2008). "Sustainable urban form for Chinese compact cities: Challenges of a rapid urbanized economy." *Habitat International*, 32, 1, 28-40.
- Cheshire, P. (2008). "Reflections on the nature and policy implications of planning restrictions on housing supply. Discussion of 'Planning policy, planning practice, and housing supply' by Kate Barker." *Oxford Review of Economic Policy*, 24, 1, 50-58.
- Cities Alliance. (2006). *Guide to city development strategies. Improving urban performance*. Cities Alliance, UNEP and ICLEI, Washington D.C.
- Cities Alliance. (2007). *Livable cities: The benefits of urban environmental planning*. Cities Alliance, UNEP and ICLEI, Washington D.C.
- City of New York, Mayor Michael R. Bloomberg. (2010). *PlaNYC progress report 2010: A greener, greater New York*. Mayor's Office of Long-Term Planning and Sustainability, New York.
- City of Stockholm. (2009). "The City of Stockholm's Climate Initiatives. Environment Administration, City of Stockholm." Available at: [www.stockholm.se/international](http://www.stockholm.se/international) [accessed 10 December 2010]
- Cohen, B. (2006). "Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability." *Technology in Society*, 28, 63-80.
- Confederation of British Industry (2003). *Is transport holding the UK back?* CBI Report, London.
- Connected Urban Development (CUD). (2008). "Smart work centers: Will they work?" *CUD blog* [blog] 3 December, Available at: <http://www.connectedurbandevelopment.org/blog/?p=22> [accessed 10 December 2010].
- Crane, W., Swilling, M., Thompson-Smeddle, L. and De Witt, M. (2010). "Towards urban infrastructure sustainability." in Pieterse, E., (ed.) *Counter-Currents: Experiments in sustainability in the Cape Town region*. Jacana Media, Johannesburg.
- C40 Cities. (2010a). "Freiburg, Germany – an inspirational city powered by solar, where a third of all journeys are by bike." [online] Available at: [www.c40cities.org/bestpractices/transport/freiburg\\_ecocity.jsp](http://www.c40cities.org/bestpractices/transport/freiburg_ecocity.jsp) [accessed 10 December 2010].
- C40 Cities. (2010b). "C40 Cities: Best Practices – Energy." [online]

Available at: [www.c40cities.org/bestpractices/energy/](http://www.c40cities.org/bestpractices/energy/) [accessed 10 December 2010].

C40 Cities (2010c). "Toronto, Canada – Toronto's Atmospheric Fund makes sustainability affordable." [online] Available at: [www.c40cities.org/bestpractices/energy/toronto\\_fund.jsp](http://www.c40cities.org/bestpractices/energy/toronto_fund.jsp) [accessed 10 December 2010].

C40 Cities (2010d). "Copenhagen, Denmark: 97% of Copenhagen city heating supplied by waste heat." [online] Available at: [www.c40cities.org/bestpractices/energy/copenhagen\\_heat.jsp](http://www.c40cities.org/bestpractices/energy/copenhagen_heat.jsp) [accessed 10 December 2010].

C40 Cities (2010e). "Tokyo, Japan – World leader in stopping water leakage." [online] Available at: [www.c40cities.org/bestpractices/water/tokyo\\_waterworks.jsp](http://www.c40cities.org/bestpractices/water/tokyo_waterworks.jsp) [accessed 10 December 2010].

C40 Cities (2010f). "Copenhagen, Denmark – Copenhagen's waste plan 2008: Copenhagen puts only 3% of waste into landfill." [online] Available at: [www.c40cities.org/bestpractices/waste/copenhagen\\_landfill.jsp](http://www.c40cities.org/bestpractices/waste/copenhagen_landfill.jsp) [accessed 10 December 2010].

David, S., Lee-Smith, D., Kyaligonza, J., Mangeni, W., Kimeze, S., Aliguma, L., Lubowa, A. and Nasinyama, G. (2010). "Changing trends in urban agriculture in Kampala." in Prain, G., Karanja, N. and Lee-Smith, D., (eds.) *African urban harvest: Agriculture in the cities of Cameroon, Kenya and Uganda*. Springer and Ottawa IDRC, New York.

Diamond, J. (2005). *Collapse: How societies choose to fall or survive*. Penguin, London.

Dora, C. (2007). "Health burden of urban transport: The technical challenge." *Sādhanā*, 32, 4, 285–292.

Dünhoff, E. and Hertle, H. (2005). "Ergebnisse der CO<sub>2</sub>-Bilanzierung für die Stadt Freiburg 1992 bis 2002 / 2003." IFEU, Heidelberg.

Duranton, G. and Puga, D. (2001). "Nursery cities: Urban diversity, process innovation and the life cycle of products." *American Economic Review*, 91, 5, 1454–1477.

Duranton, G. (2008). "Viewpoint: From cities to productivity and growth in developing countries." *Canadian Journal of Economics / Revue canadienne d'économie*, 41, 3, 689–736.

EcoPlan (2000). "The famous Zurich U-Bahn." [online] (Updated 20 March 2000) Available at: <http://www.ecoplan.org/politics/general/zurich.htm> [accessed 10 December 2010].

ECOTEC Research and Consulting Limited. (1993). "Reducing transport emissions through planning." HMSO, London.

Economist Intelligence Unit. (2009). "European Green City Index: What makes a city a winner?" Study sponsored by Siemens. First presented in Copenhagen.

Economist Intelligence Unit. (2010). "Latin American Green City Index: Assessing the environmental performance of Latin America's major cities." Study sponsored by Siemens. Siemens AG, Germany.

Eliasson, J. (2008). "Lessons from the Stockholm congestion charging trial." *Transport Policy*, 15, 6, 395–404.

European Commission. (1999). "Cycling: the way ahead for towns and cities." Office for Official Publication of the European Communities, Luxembourg.

Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A. and Wackernagel, M. (2010). *The ecological footprint atlas 2010*. Global Footprint Network, Oakland.

FAO. (2001). "Urban and peri-urban agriculture: A briefing guide." SPFS/DOC/27.8, Revision 2, *Handbook Series* Volume III. FAO, The Special Programme for Food Security, Rome. Available at: [www.fao.org/fileadmin/templates/FCIT/PDF/briefing\\_guide.pdf](http://www.fao.org/fileadmin/templates/FCIT/PDF/briefing_guide.pdf) [accessed 10 December 2010].

Fellmann, J.D., Getis, A. and Getis, J. (1996). "Human geography: Landscapes of human activity." Brown and Benchmark.

Finch D.J., Kompfner P., Lockwood C.R. and Maycock G. (1994). Speed, speed limits and accidents. TRL Project Report 58. TRL, Crowthorne.

Fjørtoft, I. and Sageie, J. (2000). "The natural environment as a playground for children. Landscape description and analyses of a natural playscape." *Landscape and Urban Planning*, 48, 1/2, 83–97.

Foeken, D. (2006). "To subsidize my income – Urban farming in an East African town." Brill, Leiden and Boston.

French Government, Ministère de l'écologie, du développement durable, des transports et du logement. (2010). "Eco Quartiers." Available at: <http://www.developpement-durable.gouv.fr/Eco-Quartiers,7162.html>

Frumkin, H. (2003). "Healthy places: Exploring the evidence." *American Journal of Public Health*, 93, 9, 1451–1456.

Garnett, T. (1996). *Growing food in cities: A report to highlight and promote the benefits of urban agriculture in the UK*. National Food Alliance and SAFE Alliance, London.

Geller, A.L. (2003). "Smart growth: A prescription for liveable cities." *American Journal of Public Health*, 93, 9, 1410–1415.

Geroliminis, N. and Daganzo, C. F. (2005). "A review of green logistics schemes used in cities around the world." UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence. Institute of Transportation Studies, UC Berkeley.

Ghani, E. (2010). *The poor half billion in South Asia: What is holding back lagging regions?* OUP, New Delhi.

Glaeser, E. (2008). *Cities, agglomeration and spatial equilibrium*. OUP, Oxford.

Glaeser, E.L. and Kahn, M.E. (2010). "The greenness of cities: Carbon dioxide emissions and urban development." *Journal of Urban Economics*, 67, 3, 404–418.

Glemarec, Y., Waissbein, O. and Bayraktar, H. (2010). *Human development in a changing climate: A framework for climate finance*. UNDP, New York.

Goh, M. (2002). "Congestion management and electronic road pricing in Singapore." *Journal of Transport Geography*, 10, 1, 29–38.

Haines, A., Smith, K., Anderson, D., Epstein, P., McMichael, A., Roberts, I., Wilkinson, P., Woodcock, J. and Woods, J. (2007). "Policies for accelerating access to clean energy, improving health, advancing development and mitigating climate change." *The Lancet*, 370, 9594, 1264–1281.

Han, Z. (2009). "A model of clustering process in low income economies." *International Journal of Business and Management*, 4, 12, 46–51.

Hasan, L. (2008). "On measuring the complexity of urban living." PIDE Working Paper No.46. Pakistan Institute of Development Economics, Islamabad.

Hasan, A., Sadiq, A. and Ahmed, S. (2010). "Planning for high density in low-income settlements. Four case studies from Karachi." *Human Settlements Working Paper Series*. Urbanization and Emerging Population Issues 3. IIED, London and UNFPA, New York.

Healey and Baker (1993). *European Real Estate Monitor*. London: Healey and Baker.

Herzog, T. (2009). "World Greenhouse Gas Emissions in 2005." WRI Working Paper. World Resources Institute, Washington, D.C. Available at: [http://pdf.wri.org/working\\_papers/world\\_greenhouse\\_gas\\_emissions\\_2005.pdf](http://pdf.wri.org/working_papers/world_greenhouse_gas_emissions_2005.pdf) [accessed 10 December 2010].

HM Government, Communities and Local Government. (2009). "World class places: The Government's strategy for improving quality of place." Department for Culture, Media and Sport, and Communities and Local Government, London.

Hoornweg, D., Ruiz-Nunez, F., Freire, M., Palugyai, N., Villaveces, M. and Herrera, E.W. (2007). "City indicators: Now to Nanjing." Policy Research Working Paper Series, 4114. The World Bank, Washington, D.C.

Hoornweg, D., Sugar, L. and Trejos Gomez, C. L. (forthcoming at date of print). "Cities and Greenhouse Gas Emissions: Moving Forward." Environment & Urbanization.

IBI Group. (2009). "The implications of alternative growth patterns on infrastructure costs." Plan It Calgary, Calgary.

ICLEI. (2009a). "Case Study 97: Turning pollution into profit: the Bandeirantes landfill gas to energy project." ICLEI Local Governments for Sustainability, Bonn.

ICLEI. (2009b). "Itabashi: Leader in green curtain movement." [online] Available at: <http://www.iclei.org/index.php?id=9853>.

ICLEI. (2010a). "Cities in a post-2012 climate policy framework: ICLEI Global Reports." ICLEI Local Governments for Sustainability, Bonn.

ICLEI (2010b). "Solar heaters in low-income housing: energy and financial savings." Available at: [http://www.iclei.org/fileadmin/user\\_upload/documents/Global/case\\_studies/ICLEI\\_Case\\_Study\\_Betim\\_112\\_August\\_2010.pdf](http://www.iclei.org/fileadmin/user_upload/documents/Global/case_studies/ICLEI_Case_Study_Betim_112_August_2010.pdf)

ICLEI, UNEP and UN-HABITAT. (2009). *Sustainable urban energy planning: A handbook for cities and towns in developing countries*. UN-HABITAT.

IEA. (2009). "Cities, towns and renewable energy: Yes in my front yard." IEA Publications, Paris.

IFRC – International Federation of the Red Cross and Red Crescent Societies. (2002). *World disasters report 2002*. IFRC, Geneva.

ILO Online. (2007). "Green jobs initiative in Burkina Faso: From waste to wages." International Labour Organization. [online] Available at: [www.ilo.org/global/about-the-ilo/press-and-media-centre/insight/WCMS\\_084547/lang-en/index.htm](http://www.ilo.org/global/about-the-ilo/press-and-media-centre/insight/WCMS_084547/lang-en/index.htm). [accessed 10 December 2010].

IPPR. (2009). "The future's green: Jobs and the UK low-carbon transition." Global Carbon Network Working Paper. IPPR / GCN, London. Jenkins, D.P. (2010). "The value of retrofitting carbon-saving measures into fuel poor social housing." *Energy Policy*, 38, 2, 832–839.



- Jenks, M., Burton, E. and Williams, K., eds. (1996). "The compact city: a sustainable urban form?" *Spon Press*, London and New York.
- Johnson, T. (2009). "Canada's healthiest cities 2009." *Best Health Magazine Online*. [online] Available at: [www.besthealthmag.ca/get-healthy/health/canadas-healthiest-cities-2009](http://www.besthealthmag.ca/get-healthy/health/canadas-healthiest-cities-2009). [accessed 10 December 2010].
- Joint Venture Silicon Valley Network. (2009). "Climate prosperity. A greenprint for Silicon Valley." TDA, San Jose.
- Kamal-Chaoui, L. and Robert, A. (2009). "Competitive cities and climate change." *OECD Regional Development Working Papers 2009/2*. OECD, Public Governance and Territorial Development Directorate.
- Karekezi, S. and Majoro, L. (2002). "Improving modern energy services for Africa's urban poor." *Energy Policy* 30, 11-12, 1015-1028.
- Kaufman, J. and Bailkey, M. (2000). "Farming inside cities: Entrepreneurial urban agriculture in the United States." Lincoln Institute of Land Policy Working Paper.
- Kuo, F.E., Sullivan, W.C., Levine Coley, R. and Brunson, L. (1998). "Fertile ground for community: Inner-city neighbourhood common spaces." *American Journal of Community Psychology*, 26, 6, 823-851.
- Krugman, P. (1991). "Increasing returns and economic geography." *Journal of Political Economy*, 99, 3, 483-99.
- Lee, N. (2005). "Ideopolis: Knowledge cities: A review of quality of life measures." *The Work Foundation*.
- Litman, T. (2002). "Evaluating transportation equity." *World Transport Policy and Practice*, 8, 2, 50-65.
- Litman, T. (2006). "Cities connect: How urbanity helps achieve social inclusion objectives." Paper presented at Metropolis Conference, Toronto, Canada, 14 June 2006. Victoria Transport Policy Institute, Victoria. [online] Available at: <http://www.vtpi.org/citiesconnect.pdf> [accessed 10 December 2010]
- Litman, T. (2009a). "Understanding smartgrowth savings. What we know about public infrastructure and service cost savings, and how they are misrepresented by critics." Victoria Transport Policy Institute, Victoria. [online] Available at: [http://www.vtpi.org/sg\\_save.pdf](http://www.vtpi.org/sg_save.pdf) [accessed 10 December 2010]
- Litman, T. (2009b). "Community cohesion as a transport planning objective." Victoria Transport Policy Institute, Victoria. [online] Available at: <http://www.vtpi.org/cohesion.pdf> [accessed 10 December 2010]
- Lowe, E.A. and Evans, L.K. (1995). "Industrial ecology and industrial ecosystems." *Journal of Cleaner Production*, 3, 1-2, 47-53.
- Manor, J. (2004). "Democratisation with inclusion: political reforms and people's empowerment at the grassroots." *Journal of Human Development*, 5, 1, 5-29.
- McDonough, W. and Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. North Point Press, New York.
- McGranahan, G., Jacobi, P., Songsore, J., Surjadi, C. and Kjellen, M. (2001). *The Citizens at Risk. From Urban Sanitation to Sustainable Cities*. Earthscan, London.
- McPherson, E.G., Nowak, D.J., and Rowntree, R.A., (eds.). (1994). "Chicago's urban forest ecosystem: Results of the Chicago urban forest climate project." Gen. Tech. Rep. NW-186. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, PA.
- Meadows, D. (1999). "Indicators and information systems for sustainable development." in Satterthwaite, D., (ed.) *The Earthscan reader in sustainable cities*. Earthscan, London.
- Medina, M. (2000). Scavenger cooperatives in Asia and Latin America. *Resources, Conservation and Recycling*, 31, 1, 51-69.
- Medina, M. (2008). The informal recycling sector in developing countries. *Gridlines*, Note No. 44. Public-Private Infrastructure Advisory Facility (PPIAF), Washington, D.C.
- McKinsey Global Institute. (2010). *India's urban awakening: Building inclusive cities, sustaining economic growth*. McKinsey Global Institute.
- Melo, P., Graham, D. and Noland, R.B. (2009). "A meta-analysis of estimates of urban agglomeration economies." *Regional Science and Urban Economics*, 39, 3, 332-342.
- Menckhoff, G. (2005). *Latin American experience with Bus Rapid Transit*. Paper presented at the Annual Meeting of the Institute of Transportation Engineers, Melbourne.
- Mercer (2009). *Mercer's 2009 quality of living survey highlights*. [online] (Updated 26 May 2010) Available at: [www.mercer.com/qualityofliving](http://www.mercer.com/qualityofliving) [accessed 10 December 2010]
- Mohan, D. (2002). *Social cost of road traffic crashes in India*. Proceedings First Safe Community Conference on Cost of Injury. Viborg, Denmark, October 2002, 33-38.
- Moore, G.T. (1986). Effects of the spatial definition of behaviour settings on children's behaviour: A quasi-experimental field study. *Journal of Environmental Psychology*, 6, 3, 205-231.
- Moser, C. and Satterthwaite, D. (2008). Towards pro-poor adaptation to climate change in the urban centres of low- and middle-income countries. *Human Settlements Working Paper Series Climate Change and Cities*, 2. IIED, London.
- Nadvi, K. and Barrientos, S. (2004). *Industrial clusters and poverty reduction*. United Nations Industrial Development Organization (UNIDO), Vienna. Available at: <http://www.unido.org/index.php?id=o24736>
- Newman, P. and Kenworthy, J. R. (1989). *Cities and automobile dependence: a sourcebook*. Gower Technical, Aldershot.
- Nobis, C. (2006). "Carsharing as key contribution to multimodal and sustainable mobility behavior: Carsharing in Germany." *Transportation Research Record: Journal of the Transportation Research Board*, 1986, 89-97.
- O'Connor, K. M. and Sauer, S. J. (2006). "Recognizing social capital in social networks: Experimental results." *Johnson School Research Paper Series*, 18-06.
- OECD and China Development Research Foundation. (2010). *Trends in urbanisation and urban policies in OECD countries: What lessons for China?* OECD Publishing, Paris.
- Ott, R. (2002). "The Zurich experience." in Greater London Authority, *Alternatives to congestion charging. Proceedings of a seminar held by the Transport Policy Committee*. GLA, London.
- Overman, H. and Rice, P. (2008). *Resurgent cities and regional economic performance*. SERC Policy Papers. London School of Economics, London.
- Owens, S. (1992). "Energy, environmental sustainability and land-use planning." in Breheny, M., (ed.) *Sustainable development and urban form*. Pion, London.
- Parra, D., Gomez, L., Pratt, M., Sarmiento, O.L., Mosquera, J. and Triche, E. (2007). Policy and built environment changes in Bogotá and their importance in health promotion. *Indoor and Built Environment*, 16, 4, 344-348.
- Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A.A., Jarawan, E. and Mathers, C. (eds) (2004). *World report on road traffic injury prevention*. World Health Organization, Geneva.
- Phang, S.-Y. (1993). "Singapore's motor vehicle policy: Review of recent changes and a suggested alternative, transportation research part A." *Policy and Practice*, 27, 4, 329-336.
- Pucher, J. (2004). "Public transportation." in Hanson, S. and Giuliano, G., (eds.) *The geography of urban transportation*. Guilford Press, New York. Putnam, R.D. (2000). *Bowling alone: The collapse and revival of American community*. Simon & Schuster, New York.
- Putnam, R.D. (2004). "Education, diversity, social cohesion and 'social capital'." Note for discussion submitted at the 'Raising the quality of learning for all' meeting of OECD education ministers, Dublin, 18-19 March 2004. Available at: [www.oecd.org/dataoecd/37/55/30671102.doc](http://www.oecd.org/dataoecd/37/55/30671102.doc) Putnam, R.D., Leonardi, R. and Nanetti, R. (1993). *Making democracy work: Civic traditions in modern Italy*. Princeton University Press, Princeton.
- Ravallion, M., Chen, S. and Sangraula, P. (2007). "New evidence on the urbanization of global poverty." *Population and Development Review*, 33, 4, 667-701.
- Revi, A. (2008). "Climate change risk: an adaptation and mitigation agenda for Indian cities." *Environment and Urbanization*, 20, 1, 207-229.
- Rigg, J., Bebbington, A., Gough, K., V., Bryceson, D. F., Agergaard, J., Fold, N. and Tacoli, C. (2009). "The World Development Report 2009 reshapes economic geography: geographical reflections." *Transactions of the Institute of British Geographers*, 34, 2, 128-136.
- Robins, N. and Kumar, R. (1999). "Producing, providing, trading: Manufacturing industry and sustainable cities." *Environment and Urbanization*, 11, 2, 75-94.
- Rode, P. and Gipp, C. (2001). *Dynamische Räume: Die Nutzungsflexibilisierung urbaner Mobilitätsräume am Beispiel der Berliner Innenstadt, (Dynamic spaces: Temporary use of urban street space)*. Technical University, Berlin.
- Rode, P., Nathan, M., von Streit, A., Schwinger, P. and Kippenberg, G. (2010). "Munich Metropolitan Region. Staying ahead on innovation." Conference Paper. LSE Cities, London.

- Rogat, J., Hinostroza, M. and Ernest, K. (2009). "Promoting sustainable transport in Latin America through mass transit technologies." *Colloque international Environnement et transports dans des contextes différents, Ghardaïa, Algérie, 16-18 fév. 2009*. Actes, ENP (ed.) Alger, p.83-92.
- Rogerson, R.J. (1999). "Quality of life and city competitiveness." *Urban Studies* 36, 5-6, 969-985.
- Rosenthal, S. and Strange, W. (2003). "Geography, industrial organisation and agglomeration." *Review of Economics and Statistics*, 85, 2, 377-393.
- Sakthivadivel, R. (2007). "The groundwater recharge movement in India." in Giordano, M. and Villholth, K., (eds.) *The agricultural groundwater revolution: Opportunities and threats to development*. International Water Management Institute, Colombo and CAB International, Wallingford.
- Sanctuary, M., Tropp, H., Berntell, A., Haller, L., Bartram, J. and Bos, R. (2005). *Making water a part of economic development*. Stockholm International Water Institute (SIWI), Stockholm.
- Sassen, S. (2006). "Four dynamics of urban agglomeration." Cambridge Econometrics Conference: Greater cities in a smaller world, 3-7 July 2006, Cambridge.
- Sassen, S. (2009). "Cities in today's global age." *SAIS Review*, 29, 1, 3 34.
- Satterthwaite, D. (1997). Sustainable cities or cities that contribute to sustainable development? *Urban Studies*, 34, 10, 1667-1691.
- Satterthwaite, D. (2008). "Cities' contribution to global warming: Notes on the allocation of greenhouse gas emissions." *Environment and Urbanization*, 20, 2, 539-549.
- Satterthwaite, D. (2009). "The implications of population growth and urbanization for climate change." *Environment and Urbanization*, 21, 2, 545-567.
- Schmauss, A. (2009). "Car2go in Ulm, Germany, as an advanced form of car-sharing." European Local Transport Information Service (ELTIS). [online] Available at: [www.eltis.org/PDF/generate\\_pdf.php?study\\_id=2121&lan=en](http://www.eltis.org/PDF/generate_pdf.php?study_id=2121&lan=en) [accessed 10 December 2010].
- Smit, J. and Nasr, J. (1992). "Urban agriculture for sustainable cities: Using wastes and idle land and water bodies as resources." *Environment and Urbanization*, 4, 2, 141-152.
- Stecko, S. and Barber, N. (2007). "Exposing vulnerabilities: Monsoon floods in Mumbai, India." Case Study prepared for UN-HABITAT (2007) *Revisiting Urban Planning: Global Report on Human Settlements 2007*. Earthscan, London. Available at: <http://www.unhabitat.org/grhs/2007>
- Steel, C. (2008). *Hungry city*. Chattoo and Windus, London.
- Steinberg, F. (2007). "Jakarta: Environmental problems and sustainability." *Habitat International*, 31, 354-365.
- Storper, M. and Venables, A. (2004). "Buzz: Face to face contact and the urban economy." *Journal of Economic Geography*, 4, 4, 351-370.
- Suzuki, H., Dastur, A., Moffatt, S., Yabuki, N. and Maruyama, H. (2010). *Eco2 Cities: Ecological cities as economic cities*. The World Bank, Washington D.C.
- Taylor M., Lynam, D. and Baruya, A. (2000). *The Effects of Driver's Speed on the Frequency of Road Accidents*. TRL Report 421. Transport Research Laboratory, Crowthorne, England.
- TEEB (2010). *The economics of ecosystems and biodiversity: Mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB*.
- Texas Water Development Board and GDS Associates (2002). *Quantifying the effectiveness of various water conservation techniques in Texas*. GDS Associates. Available at: [http://www.twdb.state.tx.us/rwpg/rpgm\\_rpts/2001483390.pdf](http://www.twdb.state.tx.us/rwpg/rpgm_rpts/2001483390.pdf)
- Tillie, N., van den Dobbelsteen, A., Doepel, D., Joubert, M., de Jager, W. and Mayenburg, D. (2009). "Towards CO<sub>2</sub> neutral urban planning: Presenting the Rotterdam Energy Approach and Planning (REAP)." *Journal of Green Building*, 4, 3, 103-112.
- Toroyan, T. and Peden, M. (eds) (2007). *Youth and Road Safety*. World Health Organization, Geneva.
- Transport for London (2004a). *Congestion charging Central London: Impacts monitoring. Second Annual Report*. Transport for London, London.
- Transport for London. (2004b). *TfL Publish C-Charge Annual Report*. Transport for London. [online] Available at: [www.tfl.gov.uk/static/corporate/media/newscentre/archive/4339.html](http://www.tfl.gov.uk/static/corporate/media/newscentre/archive/4339.html) [accessed 10 December 2010]
- UNEP, ILO, IOE and ITUC. (2008). *Green jobs: Towards decent work in a sustainable, low-carbon world*. UNEP, Kenya.
- UNFPA (2007). *State of World Population 2007: Unleashing the potential of urban growth*. United Nations Population Fund, New York.
- UN-HABITAT. (2008). *State of the World's Cities Report 2008/09*. Harmonious Cities, Earthcan, London.
- UN-HABITAT. (2009). *Planning sustainable cities: Global report on human settlements 2009*. Abridged Edition. Earthscan, London. Available at: <http://www.unhabitat.org/downloads/docs/GRHS2009Abridged.pdf> [accessed 10 December 2010].
- UN Population Division. (2006). *World Urbanisation Prospects: The 2005 Revision. Executive Summary, Fact Sheets, Data Tables*. UN, Department of Economic and Social Affairs, New York.
- UN Population Division (2010). *World urbanisation prospects: The 2009 revision*. UN Department of Economic and Social Affairs, New York.
- UN Population Fund. (2007). *The state of world population 2007: Unleashing the potential of urban growth*. United Nations Population Fund, New York.
- UN Statistics Division (2008). *Demographic Yearbook 2008*, <http://unstats.un.org/unsd/demographic/products/dyb/dyb2008.htm>
- Van de Weghe, J. and Kennedy, C.A. (2007). "A spatial analysis of residential greenhouse gas emissions in the Toronto Census Metropolitan Area." *Industrial Ecology*, 11, 2, 133-144.
- Venables, A.J. (2005). "Spatial disparities in developing countries: cities, regions, and international trade." *Journal of Economic Geography*, 5, 1, 3-21.
- Von Weizsäcker, E., Hargroves, K., Smith, M.H., Desha, C. and Stasinopoulos, P. (2009). *Factor Five*. Earthscan, London.
- VTPI (2009). *Transportation cost and benefit analysis: Techniques, estimates and implications*. Victoria Transport Policy Institute. [www.vtpi.org/tca/](http://www.vtpi.org/tca/)
- Webster, D., Bertaud, A., Jianming, C. and Zhenshan, Y. (2010). "Toward efficient urban form in China." Working Paper No. 2010/97. World Institute for Development Economics Research (WIDER). UNU-WIDER.
- Wells, N.M. and Evans, G.W. (2003). "Nearby nature: A buffer of life stress among rural children." *Environment and Behavior*, 35, 3, 311-330. Wheeler, S.M. and Beatley, T., (eds.) *The Sustainable Development Reader*. Routledge, London.
- Whitelegg, J. and Haq, G., (eds.). (2003). *The Earthscan reader in world transport policy and practice*. Earthscan, London.
- WHO (2009). *Global health risks: Mortality and burden of disease attributable to selected major risks*. World Health Organization, WHO Press, Geneva.
- Wilson, D., Velis, C. and Cheeseman, C. (2006). "Role of informal sector recycling in waste management in developing countries." *Habitat International*, 30, 797-808.
- Wilson, S.J. (2008). *Ontario's wealth, Canada's future: Appreciating the value of the greenbelt's eco-services*. David Suzuki Foundation, Vancouver.
- Woodcock, J., Banister, D., Edwards, P., Prentice, A.M. and Roberts, I. (2007). "Energy and transport." *The Lancet*, 370, 9592, 1078-1088.
- World Bank (2002). *Cities on the move: A World Bank urban transport strategy review*. The World Bank, Washington.
- World Bank (2009). *The 2009 little green data book*. The World Bank, Washington, D.C.
- World Bank (2010). *Cities and climate change: An urgent agenda*. The World Bank, Washington, D.C.
- Wright, L. (2002). *Bus Rapid Transit, sustainable transport: A sourcebook for policy-makers in developing cities*. Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ), Eschborn.
- Zurbrugg, C., Drescher, S., Rytz, I., Sinha, M. and Enayetullah, I. (2005). "Decentralised composting in Bangladesh, a win-win situation for all stakeholders." *Resources, Conservation and Recycling*, 43, 281-292.



# Appendix 1 – Data sources

## 1.1 General Sources

Boden, T.A., Marland G. and Andres, R.J. (2010). *Global, regional, and national fossil-fuel CO<sub>2</sub> emissions*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001\_V2010. [http://cdiac.ornl.gov/trends/emis/tre\\_glob.html](http://cdiac.ornl.gov/trends/emis/tre_glob.html)

Mercer (2010). *Quality of Living City Rankings*. Go to [www.mercer.com](http://www.mercer.com) and follow the document links.

UN Development Programme (2010). *Human Development Report database*. [online] Available at: <http://hdr.undp.org/en/statistics/data/> [accessed 10 December 2010].

UN Population Division (2006). *World Urbanisation Prospects: The 2005 Revision. Executive Summary, Fact Sheets, Data Tables*. UN, Department of Economic and Social Affairs, New York. Available at: [http://www.un.org/esa/population/publications/WUP2005/2005WUP\\_Highlights\\_color.pdf](http://www.un.org/esa/population/publications/WUP2005/2005WUP_Highlights_color.pdf).

UN Population Division (2008). *World Urbanisation Prospects: The 2007 Revision Population Database*. [online] Available at: <http://esa.un.org/unup/index.asp> [accessed 10 December 2010]

UN Population Division (2010). *World Urbanisation Prospects: The 2009 Revision Population Database*. [online] Available at: <http://esa.un.org/unpd/wup/index.htm> [accessed 10 December 2010].

World Bank. *World Development Report Database*. [online] Available at: <http://wdronline.worldbank.org/> [accessed 10 December 2010].

World Resources Institute (2010). *Climate Analysis Indicators Tool*. [online] Available at: <http://cait.wri.org/> [accessed 10 December 2010].

World Resources Institute (2007). *Earthtrends*. [online] Available at: <http://earthtrends.wri.org/> [accessed 10 December 2010].

## 1.2 Regional Analysis

### Brazil

Brazilian Institute of Geography and Statistics (IBGE). *Demographic Census 2000*. [online] Available at: <http://www.sidra.ibge.gov.br/cd/default.asp> [accessed 10 December 2010].

Brazilian Institute of Geography and Statistics (IBGE). *National Household Survey 2005 (PNAD)*. [online] Available at: <http://www.sidra.ibge.gov.br/pnad/default.asp> [accessed 10 December 2010].

Brazilian Ministry of Cities, National Transit Department (DENATRAN). *Car ownership database*. [online] Available at: <http://www.denatran.gov.br/frota.htm> [accessed 10 December 2010].

UN Development Programme, Brazil Country Office. *Brazilian Atlas of Human Development. Metropolitan Human Development Index*. [online] Available at: [http://www.pnud.org.br/atlas/ranking/Ranking\\_RM.xls](http://www.pnud.org.br/atlas/ranking/Ranking_RM.xls) [accessed 10 December 2010].

### South Africa

South African Cities Network. *Sustainable cities report 2009*. Go to [www.sacities.net](http://www.sacities.net) and follow the document links.

South African Department of Transport. *National Household Travel Survey 2003*. Go to <http://transport.dot.gov.za> and follow the document links.

Statistics South Africa. *StatsOnline*. [online] Available at: [www.statssa.gov.za](http://www.statssa.gov.za) [accessed 10 December 2010].

Sustainable Energy Africa. *State of energy in South African cities 2006: Setting a baseline*. Sustainable Energy Africa, Westlake. Go to [www.cityenergy.org.za](http://www.cityenergy.org.za) and follow the document links.

Sustainable Energy Africa. *Sustainable energy: Towards*

*productive cities*. Available at: <http://www.cityenergy.org.za/files/resources/energy%20data/00Intro.pdf> [accessed 10 December 2010].

### China

China Statistical Yearbooks (go to <http://chinadataonline.org/>): National; Provincial: Shanghai, Beijing, Chongqing, Tianjin; City (sub-prefecture level): Shenzhen, Xian, Wuhan, Wenzhou, Guangzhou, Qingdao, Changchun, Shenyang, Hangzhou, Wuxi, Shaoxing, Changzhou, Jiaxing, Xinjiang, Pudong, Nantong, Anqing, Baotou, Changsha, Chengdu, Dalian, Danyang, Dongguan, Fuzhou, Guangan, Guilin, Guiyang, Haikou, Handan, Harbin, Hohhot, Huizhou, Jiangyin, Jilinc, Jinan, Jinhua.

### India

Census of India. *Census of India 2001*. [online] Available at: <http://www.censusindia.net/> [accessed 10 December 2010]

Center for Sustainable Transport India. [online] Available at: <http://www.cstindia.org/> [accessed 10 December 2010].

The India National Council of Applied Economic Research (NCAER) and FCR (2008). *The next urban frontier: Twenty cities to watch*. Available at: <http://www.ncaer.org/popuppages/EventDetails/E7Aug2008/Presentation.pdf> [accessed 10 December 2010].

Singh, S.K. (2005). Review of Urban Transportation in India. *Journal of Public Transportation*, 8, 1, 79-97.

### Europe

European Commission, Eurostat. *General and regional statistics, Urban Audit*. [online] Go to [www.epp.eurostat.ec.europa.eu](http://www.epp.eurostat.ec.europa.eu) and follow the document links.

Economist Intelligence Unit (2009). *European Green City Index*. Siemens AG, Munich. Go to [www.siemens.com/greencityindex](http://www.siemens.com/greencityindex) and follow the document links.

International Energy Agency (IEA) (2009). *Energy Balances of OECD Countries, 2009 edition*. IEA Publications, Paris.

Additional sources: Brussels-Capital Region Health and Social Observatory; Statistical Yearbook of the Czech Republic; Polish Central Statistical Office, Concise Yearbook of Poland 2009; General Secretariat of the National Statistical Service of Greece; Statistics Catalonia

### USA

NASA/U.S. Department of Energy/Purdue University (2007). *The Vulcan Project database*. [online] Available at: <http://www.purdue.edu/eas/carbon/vulcan/research.php> [accessed 10 December 2010].

United States Census Bureau (2010). *American Community Survey, 2005-2007 3-Year Estimates*. [online] Available at: [http://factfinder.census.gov/servlet/DatasetMainPageServlet?\\_program=ACS&\\_submenuid=datasets\\_2&\\_lang=en](http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ACS&_submenuid=datasets_2&_lang=en) [accessed 10 December 2010].

United States Census Bureau. Topologically Integrated Geographic Encoding and Referencing system (TIGER). *Metropolitan Statistical Area Cartographic Boundary Files*. [online] Available at: [http://www.census.gov/geo/www/cob/bdy\\_files.html](http://www.census.gov/geo/www/cob/bdy_files.html) [accessed 10 December 2010].

United States Department of Labor. *Bureau of Labor Statistics*. [online] Available at: [www.bls.gov](http://www.bls.gov) [accessed 10 December 2010].

United States Department of Commerce, Bureau of Economic Analysis. *U.S. Economic Accounts*. [online] (Updated 14 December 2010) Available at: [www.bea.gov](http://www.bea.gov) [accessed 10 December 2010].

United States Geological Survey, Land Cover Institute. *National Land Cover Dataset 1992*. [online] (Updated May 2010) Available at: <http://landcover.usgs.gov/natl/landcover.php> [accessed 10 December 2010].

### 1.3 Figures and Tables

#### I. Ecological Footprint, HDI and urbanisation level by country

Global Footprint Network. *National Ecological Footprint database*. [online] Available at: [http://www.footprintnetwork.org/images/uploads/2009\\_Data\\_Tables\\_hectares.xls](http://www.footprintnetwork.org/images/uploads/2009_Data_Tables_hectares.xls) [accessed 10 December 2010].

UN Development Programme. *Human Development Report database*. [online] Available at: <http://hdr.undp.org/en/statistics/data/> [accessed 10 December 2010].

UN Population Division (2010). *World Urbanization Prospects: The 2009 Revision Population Database*. [online] Available at: <http://esa.un.org/unpd/wup/index.htm> [accessed 10 December 2010].

#### II. Carbon emission and income for selected countries and cities

Hoornweg, D., Sugar, L. and Trejos Gomez, C. L. (forthcoming at date of print). Cities and Greenhouse Gas Emissions: Moving Forward. *Environment & Urbanization*

International Monetary Fund (IMF) (2010). *World Economic Outlook Database, October 2010*. [online] Available at: <http://www.imf.org/external/pubs/ft/weo/2010/02/weodata/index.aspx> [accessed 10 December 2010].

PricewaterhouseCooper (2009). Which are the largest city economies in the world and how might this change by 2025? *UK Economic Outlook November 2009*. [online] Available at: [http://www.pwc.co.uk/pdf/ukeyo\\_largest\\_city\\_economies\\_in\\_the\\_world\\_sectionIII.pdf](http://www.pwc.co.uk/pdf/ukeyo_largest_city_economies_in_the_world_sectionIII.pdf) [accessed 10 December 2010].

UN Population Division (2010). *World Urbanization Prospects: The 2009 Revision Population Database*. [online] Available at: <http://esa.un.org/unpd/wup/index.htm> [accessed 10 December 2010].

#### III. Fuel expenditure and urban density, 2008 fuel prices

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) (2009). *International Fuel Prices, 6th Edition – Data Preview*. [online] Available at: <http://www.gtz.de/de/dokumente/en-international-fuel-prices-data-preview-2009.pdf>

Kenworthy, J. (2003). *Transport Energy Use and Greenhouse Gases in Urban Passenger Transport Systems: A Study of 84 Global Cities*, Presented to the international Third Conference of the Regional Government Network for Sustainable Development, Notre Dame University, Fremantle, Western Australia, September 17-19, 2003

PricewaterhouseCooper (2009). Which are the largest city economies in the world and how might this change by 2025? *UK Economic Outlook November 2009*. [online] Available at: [http://www.pwc.co.uk/pdf/ukeyo\\_largest\\_city\\_economies\\_in\\_the\\_world\\_sectionIII.pdf](http://www.pwc.co.uk/pdf/ukeyo_largest_city_economies_in_the_world_sectionIII.pdf) [accessed 10 December 2010].

UN Population Division (2010). *World Urbanization Prospects: The 2009 Revision Population Database*. [online] Available at: <http://esa.un.org/unpd/wup/index.htm> [accessed 10 December 2010].

#### IV. Investment and operating costs of selected green city projects

Asia-Pacific Environmental Innovation Strategies (APEIS). *Research on Innovative and Strategic Policy Options (RISPO), Good Practices Inventory*. TransMilenio Bus Rapid Transit System of

Bogota, Colombia. Available at: [http://cmapspublic2.ihmc.us/rid=1211030483752\\_937220900\\_6795/Bogota%20Rapid%20Transit%20Good%20Practices%20Inventory.pdf](http://cmapspublic2.ihmc.us/rid=1211030483752_937220900_6795/Bogota%20Rapid%20Transit%20Good%20Practices%20Inventory.pdf) [accessed 10 December 2010].

Bogota Capital District, Transmilenio S.A. *Estado de actividad financiera, economica, social y ambiental del 01 de enero al 31 de diciembre de 2009*. Transmilenio, Bogota. Available at: [http://www.transmilenio.gov.co/AdmContenidoUpload/administrador.contenido/Files/InformacionFinanciera/EstadosFinancieros/ACT\\_DIC\\_2009.pdf](http://www.transmilenio.gov.co/AdmContenidoUpload/administrador.contenido/Files/InformacionFinanciera/EstadosFinancieros/ACT_DIC_2009.pdf) [accessed 10 December 2010].

Centralkommunernes Transmissionsselskab (CTR) (2007). *Annual Report and Financial Statements 2007*. CTR, Frederiksberg. Available at: [http://www.ctr.dk/Images/Årsberetninger/Aarsberetning\\_2007\\_Engelsk.pdf](http://www.ctr.dk/Images/Årsberetninger/Aarsberetning_2007_Engelsk.pdf) [accessed 10 December 2010].

Compagnie des Transports Strasbourgeois (2008). *Rapport d'Activité 2008*. CTS, Strasbourg. Available at: <http://www.cts-strasbourg.fr/Portals/0/PDF/entreprise/Rapport%20activite%202008.pdf> [accessed 10 December 2010].

C40 Cities (2010). Austin, U.S.A.: *Austin's renewable energy program reduces CO2 emissions by 370,257 tons a year*. [online] Available at: [http://www.c40cities.org/bestpractices/renewables/austin\\_renewable.jsp](http://www.c40cities.org/bestpractices/renewables/austin_renewable.jsp) [accessed 10 December 2010].

C40 Cities (2010). Austin, U.S.A.: *Austin's green building program facilitates the construction of sustainable buildings*. [online] Available at: [http://www.c40cities.org/bestpractices/buildings/austin\\_standards.jsp](http://www.c40cities.org/bestpractices/buildings/austin_standards.jsp) [accessed 10 December 2010].

C40 Cities (2010). Berlin, Germany: *Energy Saving Partnership Berlin (ESP) – An effective and innovative model to reduce CO<sub>2</sub> and energy costs without expenses for building owners*. [online] Available at: [http://www.c40cities.org/bestpractices/buildings/berlin\\_efficiency.jsp](http://www.c40cities.org/bestpractices/buildings/berlin_efficiency.jsp) [accessed 10 December 2010].

C40 Cities (2010). Bogotá, Colombia: *Bogotá's CicloRuta is one of the most comprehensive cycling systems in the world*. [online] Available at: [http://www.c40cities.org/bestpractices/transport/bogota\\_cycling.jsp](http://www.c40cities.org/bestpractices/transport/bogota_cycling.jsp) [accessed 10 December 2010].

C40 Cities (2010). Copenhagen, Denmark: *97% of Copenhagen city heating supplied by waste heat*. [online] Available at: [http://www.c40cities.org/bestpractices/energy/copenhagen\\_heat.jsp](http://www.c40cities.org/bestpractices/energy/copenhagen_heat.jsp) [accessed 10 December 2010].

C40 Cities (2010). Copenhagen, Denmark. *Copenhagen's waste plan 2008: Copenhagen puts only 3% of waste into landfill*. [online] Available at: [http://www.c40cities.org/bestpractices/waste/copenhagen\\_landfill.jsp](http://www.c40cities.org/bestpractices/waste/copenhagen_landfill.jsp) [accessed 10 December 2010].

C40 Cities (2010). Copenhagen, Denmark. *One of the largest off-shore wind farms in the world powers 150,000 Danish households*. [online] Available at: [http://www.c40cities.org/bestpractices/renewables/copenhagen\\_wind.jsp](http://www.c40cities.org/bestpractices/renewables/copenhagen_wind.jsp) [accessed 10 December 2010].

C40 Cities (2010). Freiburg, Germany: *an inspirational city powered by solar, where a third of all journeys are by bike*. [online] Available at: [http://www.c40cities.org/bestpractices/energy/freiburg\\_ecocity.jsp](http://www.c40cities.org/bestpractices/energy/freiburg_ecocity.jsp) [accessed 10 December 2010].

C40 Cities (2010). Paris, France: *Velib – a new Paris love affair*. [online] Available at: [http://www.c40cities.org/bestpractices/transport/paris\\_cycling.jsp](http://www.c40cities.org/bestpractices/transport/paris_cycling.jsp) [accessed 10 December 2010].

C40 Cities (2010). Stockholm, Sweden. *Stockholm to introduce congestion charge – trial cut CO<sub>2</sub> by 14%, traffic by 25%*. [online] Available at: [http://www.c40cities.org/bestpractices/transport/stockholm\\_congestion.jsp](http://www.c40cities.org/bestpractices/transport/stockholm_congestion.jsp) [accessed 10 December 2010].

C40 Cities (2010). Tokyo, Japan: *World leader in stopping water leakage*. [online] Available at: [http://www.c40cities.org/bestpractices/water/tokyo\\_waterworks.jsp](http://www.c40cities.org/bestpractices/water/tokyo_waterworks.jsp) [accessed 10 December 2010].

C40 Cities (2010). Toronto, Canada: *Lake water air conditioning reduces energy use by 90%*. [online] Available at: [http://www.c40cities.org/bestpractices/energy/toronto\\_energy.jsp](http://www.c40cities.org/bestpractices/energy/toronto_energy.jsp) [accessed 10 December 2010].

C40 Cities (2010). Toronto, Canada: *Toronto's Atmospheric Fund makes sustainability affordable*. [online] Available at: [http://www.c40cities.org/bestpractices/energy/toronto\\_fund.jsp](http://www.c40cities.org/bestpractices/energy/toronto_fund.jsp) [accessed 10 December 2010].

C40 Cities (2010). San Francisco, U.S.A.: *Largest city-owned solar power system in the United States*. [online] Available at: [http://www.c40cities.org/bestpractices/buildings/sanfrancisco\\_eco.jsp](http://www.c40cities.org/bestpractices/buildings/sanfrancisco_eco.jsp) [accessed 10 December 2010].

C40 Cities (2010). Sao Paulo, Brazil.: *Sao Joao and Bandeirantes Landfills*. [online] Available at: <http://www.c40cities.org/docs/casestudies/waste/sao-paulo-landfill.pdf> [accessed 10 December 2010].

C40 Cities (2010). *Hong Kong: Combined Heat and Power Generation System*. [online] Available at: [http://www.c40cities.org/bestpractices/energy/hongkong\\_chp.jsp](http://www.c40cities.org/bestpractices/energy/hongkong_chp.jsp) [accessed 10 December 2010].

C40 Cities Climate Leadership Group. *Portland, USA: SmartTrips Portland*. [online] Available at: [http://www.c40cities.org/bestpractices/transport/smart\\_trips\\_portland.jsp](http://www.c40cities.org/bestpractices/transport/smart_trips_portland.jsp) [accessed 10 December 2010].

C40 Cities Climate Leadership Group. *Portland, U.S.A.: Portland replaces 1,000 traffic intersection signals with LED lights, saving millions of kilowatt-hours per year*. [online] Available at: [http://www.c40cities.org/bestpractices/lighting/portland\\_led.jsp](http://www.c40cities.org/bestpractices/lighting/portland_led.jsp) [accessed 10 December 2010].

C40 Cities Climate Leadership Group. *Seoul, South Korea: Seoul car-free days have reduced CO<sub>2</sub> emissions by 10% annually*. [online] Available at: [http://www.c40cities.org/bestpractices/transport/seoul\\_driving.jsp](http://www.c40cities.org/bestpractices/transport/seoul_driving.jsp) [accessed 10 December 2010].

Demery, J. (2004). *Bus Rapid Transit in Curitiba: An Information Summary*. Publictransit.us, Special Report No.1. [online] Available at: <http://www.publictransit.us/ptlibrary/specialreports/sr1.curitibaBRT.pdf> [accessed 10 December 2010].

New York City Council – Finance Division (2009). *Budget Report: Analysis of the Fiscal 2010 Preliminary Budget and Fiscal 2009 Preliminary Mayor's Management Report for the Department of Transportation*. [online] Available at: [http://www.council.nyc.gov/html/budget/PDFs/budget\\_report\\_dot\\_3\\_12\\_09.pdf](http://www.council.nyc.gov/html/budget/PDFs/budget_report_dot_3_12_09.pdf) [accessed 10 December 2010].

New York City Global Partners' Innovation Exchange (2009). *Best Practice: NYC Greener, Greater Buildings Plan*. [online] Available at: [http://www.nyc.gov/html/unccp/gprb/downloads/pdf/NYC\\_GreenBuildings.pdf](http://www.nyc.gov/html/unccp/gprb/downloads/pdf/NYC_GreenBuildings.pdf) [accessed 10 December 2010].

New York City Global Partners' Innovation Exchange (2010). *Best practice: Landfill emissions control, Sao Paulo*. [online] Available at: [http://www.nyc.gov/html/unccp/gprb/downloads/pdf/SaoPaulo\\_landfills.pdf](http://www.nyc.gov/html/unccp/gprb/downloads/pdf/SaoPaulo_landfills.pdf) [accessed 10 December 2010].

Transport for London (TfL). *Transport for London Congestion Charging, Greater London Authority Act 1999, Schedule 23, Four Year Programme, 2006*. [online] Available at: [http://www.tfl.gov.uk/assets/downloads/Four\\_Year\\_Programme\\_2006.pdf](http://www.tfl.gov.uk/assets/downloads/Four_Year_Programme_2006.pdf) [accessed 10 December 2010].

## V. Urban transport employment

**Berlin:** Berliner Verkehrsbetriebe (BVG). [online] Available at: <http://www.bvg.de/index.php/de/3901/name/BVG+Zahlenspiegel.html>

**Istanbul:** İstanbul Elektrik Tramvay ve Tünel İşletmeleri Genel Müdürlüğü (İETT). [online] Available at: <http://www.iett.gov.tr/en/section.php?sid=57>

**Johannesburg:** Joburg – Vision and Strategy. [online] Available at: [http://www.joburg-archive.co.za/city\\_vision/AnnualReport02Ch2.pdf](http://www.joburg-archive.co.za/city_vision/AnnualReport02Ch2.pdf)

**London:** Transport for London. [online] Available at: <http://www.tfl.gov.uk/microsites/pensions/documents/tfl-pension-fund-review-2009.pdf>

**Mumbai, bus:** Tata Institute of Fundamental Research. [online] Available at: <http://www.tifr.res.in/~xvincamp/mumbai.htm>

**Mumbai, rail:** Mumbai Metropolitan Region Development Agency. [online] Available at: <http://www.regionalplan-mmrd.org/N-4.pdf>

**New York City:** Manhattan Institute for Policy Research. [online] Available at: <http://assembly.state.ny.us/Minority/20090629/report.pdf>

**São Paulo, bus:** São Paulo Transporte (SPTrans). [online] Available at: [www.sptrans.com.br/pdf/empresas\\_credenciadas/REGULAMENTO\\_CRED\\_004\\_09.pdf](http://www.sptrans.com.br/pdf/empresas_credenciadas/REGULAMENTO_CRED_004_09.pdf)

**São Paulo, metro:** Companhia do Metropolitano de São Paulo (2008). *Relatório da administração – 2008*. [online] Available at: <http://www.metro.sp.gov.br/empresa/relatorio/2008/raMetro2008.pdf>

**São Paulo, rail:** Companhia Paulista de Trens Metropolitanos (CPTM). [online] Available at: [http://www.cptm.sp.gov.br/e-contabeis/Balanco\\_Patrimonial\\_2008.pdf](http://www.cptm.sp.gov.br/e-contabeis/Balanco_Patrimonial_2008.pdf)

**South Africa:** Department of Trade and Industry (1999). *Labour Statistics: Survey of total employment and earnings*. [online] Available at: <http://www.thedti.gov.za/econdb/P0271.htm>

**Tokyo, bus and subway:** Tokyo Metropolitan Government, Bureau of Transportation. [online] Available at: <http://www.kotsu.metro.tokyo.jp/english/images/pdf/organization.pdf>

**Tokyo, metro:** Tokyo Metro. [online] Available at: <http://www.tokyo-metro.jp/global/en/about/outline.html>



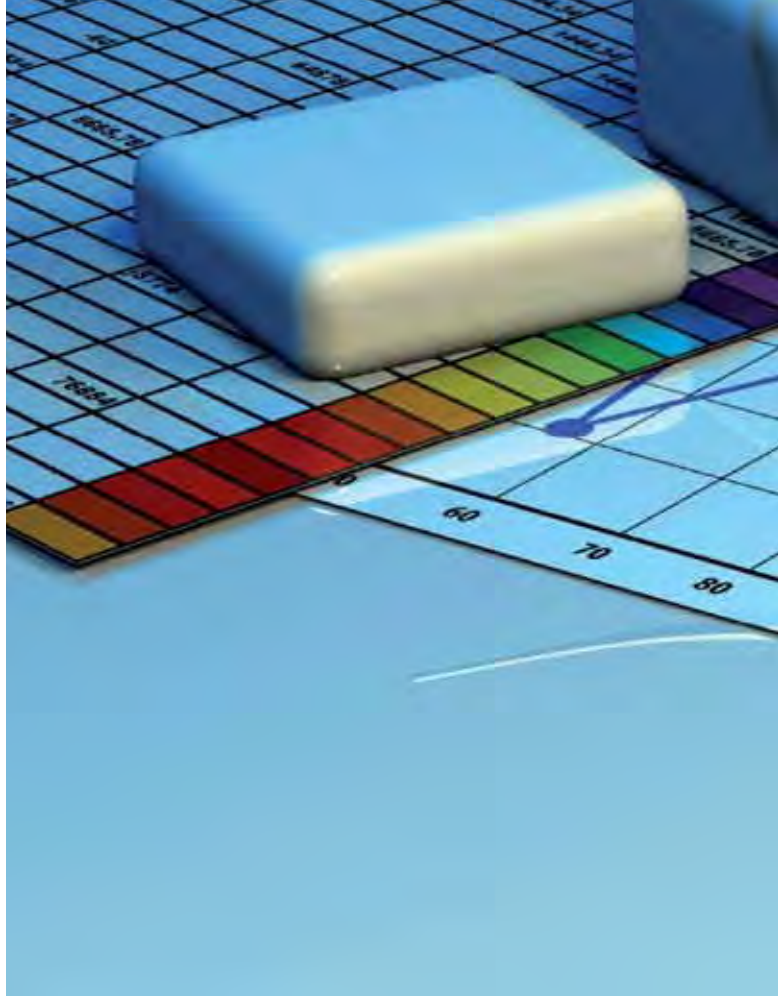


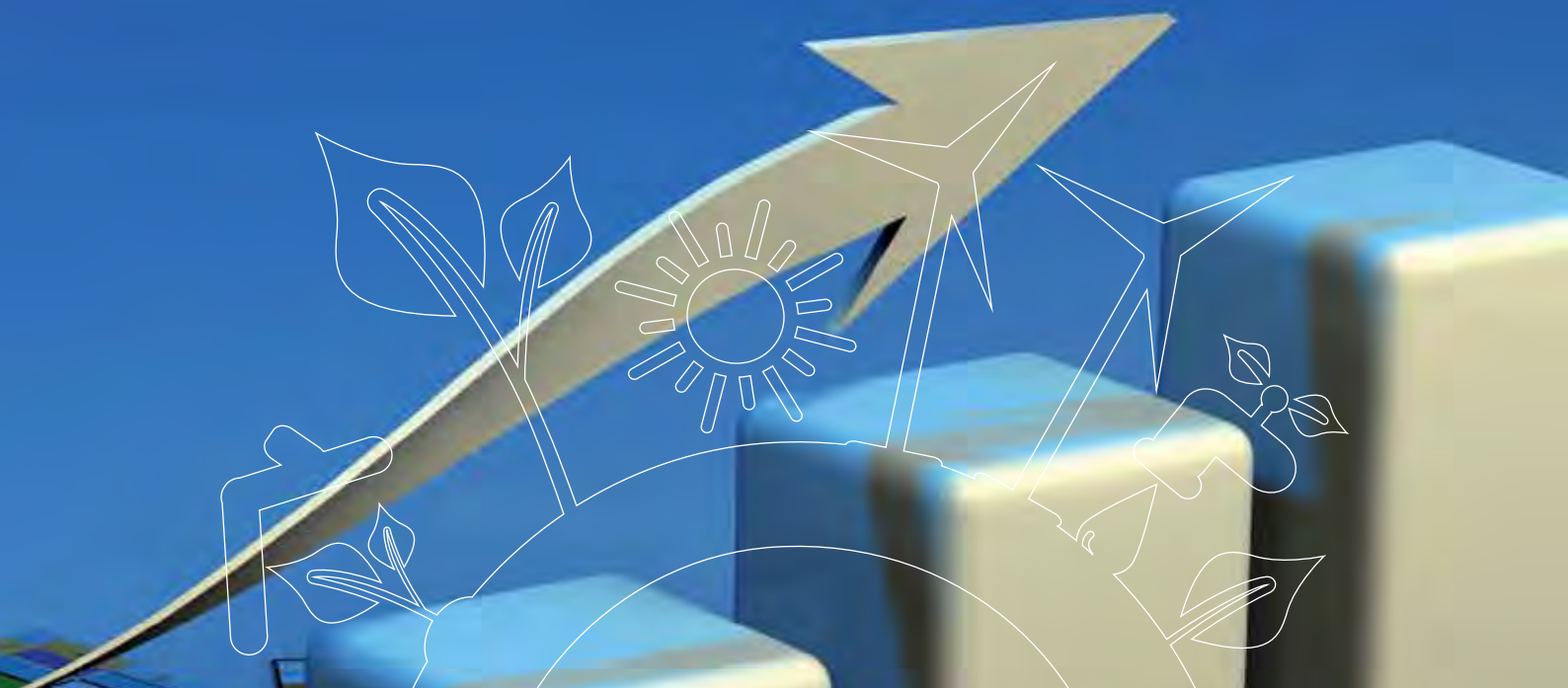




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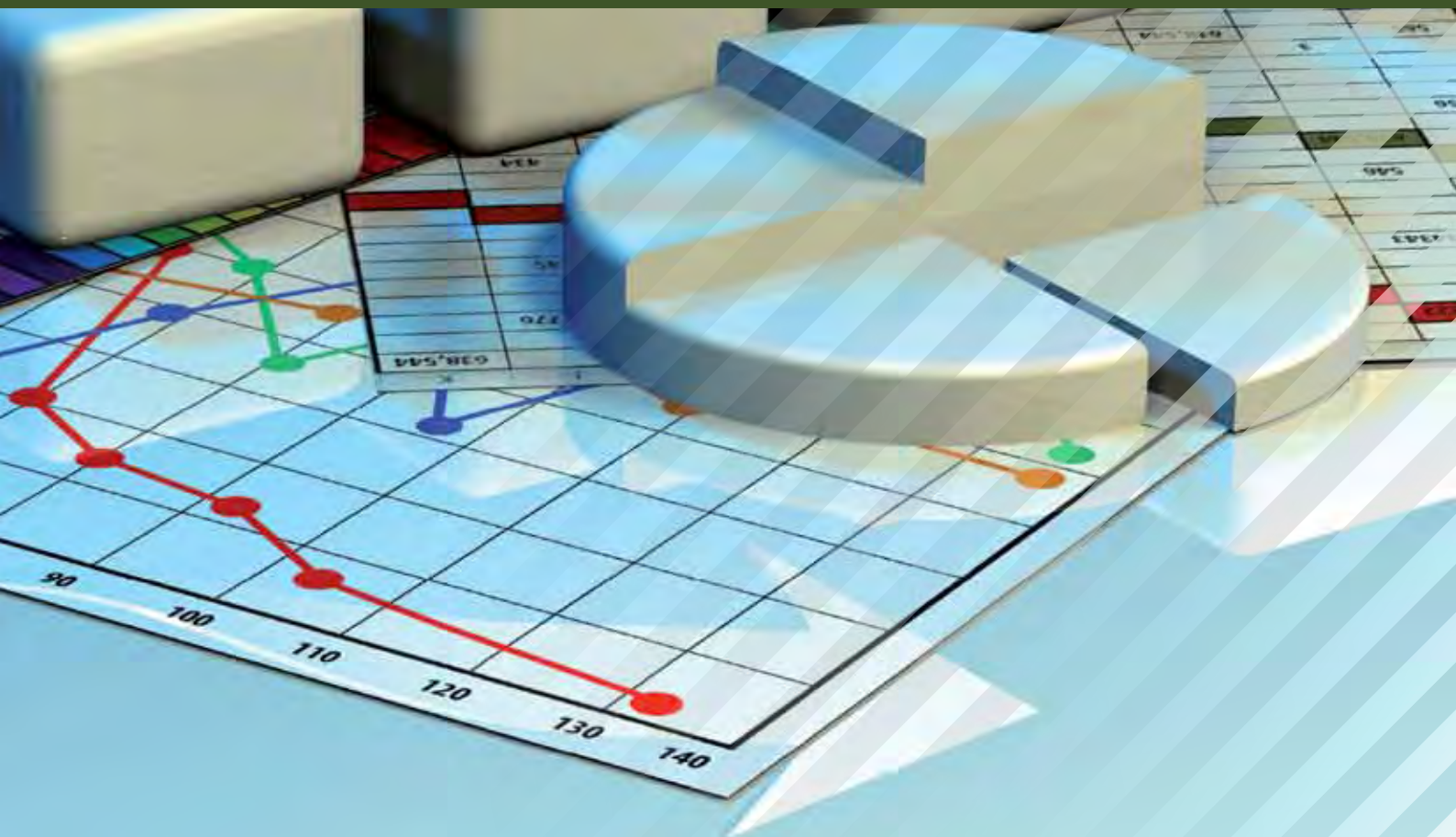
Supporting the transition to a global green economy





# Modelling global green investment scenarios

Supporting the transition to a global green economy



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## List of acronyms

AR4	Fourth Assessment Report of the IPCC
BAU	Business-as-usual
CCS	Carbon capture and storage
CD	Cobb-Douglas
CGE	Computable General Equilibrium
CLD	Causal loop diagram
CO <sub>2</sub> -eq	Carbon dioxide equivalent
DC	Disaggregated Consistency
ETP	Energy Technology Perspectives
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statistical Database
GDP	Gross Domestic Product
GER	Green Economy Report
GFN	Global Footprint Network
GGND	Global Green New Deal
GHG	Greenhouse gas
HDI	Human Development Index
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
Lge	Litres of gasoline equivalent
MDGs	Millennium Development Goals
ME	Macro-Econometric
MoMo	Mobility Model (Transport Model of IEA)
Mtoe	Million tonnes of oil equivalent
NDP	Net Domestic Product
O&M	Operations and maintenance
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
RE	Renewable energy
ROI	Return on investment
SD	System Dynamics
T21	Threshold 21 model
TFP	Total factor productivity
UNEP	United Nations Environment Programme
WDI	World Development Indicators
WEO	World Energy Outlook
WPP	World Population Prospect

# Key messages

**1. A Green Economy grows faster than a brown economy over time, while maintaining and restoring natural capital.**

Quantitative modelling for the Green Economy Report demonstrates that greening can not only generate increases in natural capital, but also produce a higher rate of Gross Domestic Product (GDP) growth – a classical, if outdated, measure of economic performance. Gross Domestic Product in the green scenario is projected to overtake business-as-usual (BAU) within ten years. An adjusted measure of net domestic product, accounting for both physical capital depreciation and also for natural capital depletion, achieves this result even earlier, indicating that a green economy offers improved and integrated capital management.

**2. Business-as-usual can only deliver development gains at an unaffordable price.** Under a BAU scenario, which replicates historical trends and assumes no fundamental changes in policy or external conditions to alter the trends, development benefits in terms of GDP growth and poverty reduction may continue for some time. But, these development gains would be achieved at an unaffordable price. Business-as-usual continues on the current high carbon intensity development path, with its associated environmental impacts, especially in terms of the long-term concentration of atmospheric greenhouse gases (GHG), which would approximate 1,000 ppm CO<sub>2</sub>-eq by 2100, resulting in temperature increases most likely around 4 degrees centigrade (as per IPCC scenarios A1B and A2). In addition, BAU would also significantly draw down natural capital assets; the results indicate that the global ecological footprint would be more than two times the available bio-capacity of the earth.

**3. A green economy promotes pro-poor growth and achieves energy and resource efficiency.**

A green economy strengthens pro-poor economic growth through building up natural capital, on which the livelihood of the poor depends. In a green investment scenario, 2 per cent of global GDP is allocated to greening the energy, manufacturing, transport, buildings, waste, agriculture, fisheries, water and forests sectors. In the simulations, these investments help to, by 2050, potentially double fish stocks, and increase forestland by one-fifth, as compared to BAU. They would also reduce use of fossil fuels by 40 per cent, and demand for water by about 20 per cent, relative to BAU. By maintaining and building up natural capital and mitigating resource scarcity, these investments would provide the basis for enhanced human well-being, and sustained economic growth over the next 20 to 40 years, at least as strong as BAU with considerably reduced downside risks.

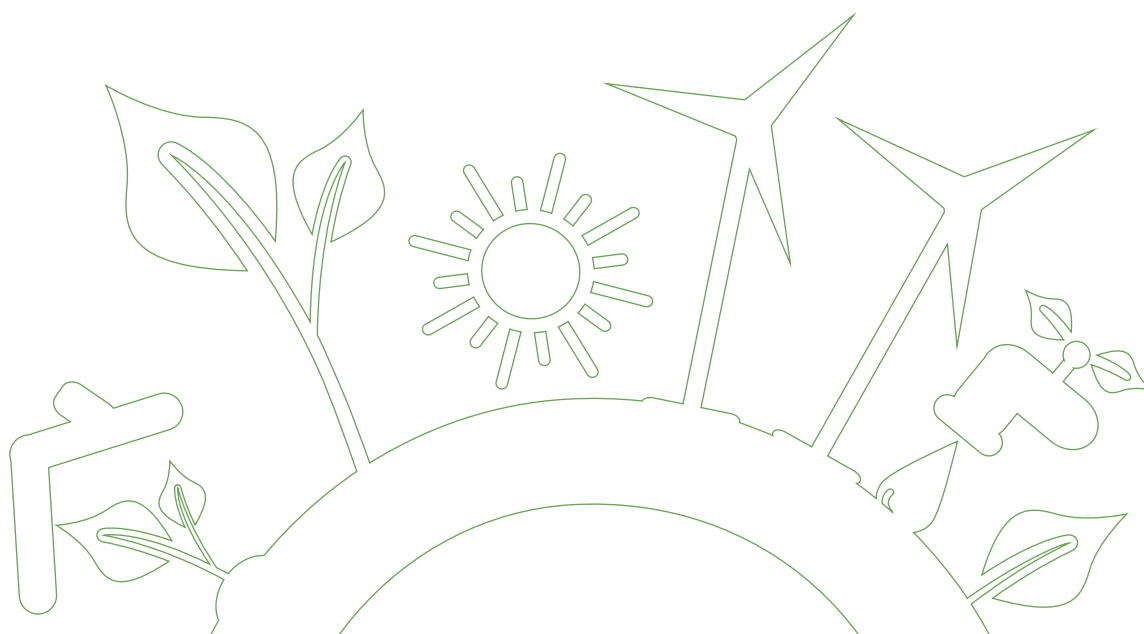


**4. A green economy has the potential to create additional jobs in the medium to long run.**

A shift to a green economy also means a shift in employment, which, at a minimum, should not lead to a net loss of jobs. The jobs created will at least make up for the losses that would be incurred from transforming environmentally unsustainable activities. In the short- and medium-term, the net direct employment under green investment scenarios may decline due to the need to reduce excessive resource extraction in sectors such as fisheries. But between 2030 and 2050, these green investments would create employment gains to catch up with and likely exceed BAU, under which employment growth will be further constrained by resource and energy scarcity and the impact of climate change.

**5. The greening of most economic sectors would reduce GHG emissions significantly.** With about 1.25 per cent of global GDP invested in raising energy efficiency across sectors and expanding renewable energy, including second generation biofuels, global energy intensity would be reduced by 36 per cent by 2030 and annual volume of energy-related CO<sub>2</sub> emissions would decline to 20 Gt in 2050 from 30.6 Gt in 2010. Including the potential carbon sequestration of green agriculture, a green investment scenario is expected to reduce the concentration of emissions to 450 ppm by 2050, a level essential for having a reasonable likelihood of limiting global warming to the threshold of 2 degrees centigrade.

**6. A green economy sustains and enhances ecosystem services.** Green investments in the forestry and agricultural sectors would help reverse the current declines in forestland, rejuvenating this important resource to about 4.5 billion hectares over the next 40 years. Higher yields from investing in green agriculture would reduce the amount of land used for crops and livestock in 2050 by 6 per cent compared with projected BAU trends, while producing more food. Soil quality would rise by a quarter on average in 40 years. In addition, investments to increase water supply and expand access, while improving management, would provide an additional 10 per cent of global water supply in both the short- and long-term, and also contribute to sustaining groundwater and surface water resources. In the fisheries sector, the reduction of excessive capacity would help fish stocks to recover by 2050 to 70 per cent of their total level in 1970, as compared with a projected further decline to 30 per cent of the 1970 level under BAU. These investments in “ecological infrastructure” help to restore the earth’s bio-capacity and also to enhance human well-being.



# 1 Introduction

This chapter describes the modelling exercise conducted for the entire Green Economy Report (GER) and presents its results. The modelling was to test the hypothesis – which gave rise to this report – that investing in the environment delivers positive macroeconomic results, in addition to improving the environment. The modelling tool used is the Threshold 21 World model (T21-World), which comprises several sectoral models integrated into a global model. The sectoral models are at the core of the modelling exercise supporting the analysis carried out by the authors of the GER. The modelling traces the effects of investing various amounts of GDP in green – as opposed to business-as-usual (BAU) – economic activities in terms of stimulating the economy, improving resource efficiency, lowering carbon intensity, and creating jobs.

The next section describes the key issues that need to be addressed by a modelling framework that tries to quantify the challenges of moving towards a green economy. The third section describes key features of the modelling structure. This is followed by a section describing the assumptions underlying the various scenarios: a BAU scenario with no additional

investment, two BAU scenarios with increased levels of investment, but no change in energy and environmental policies (BAU1 and BAU2), and two green scenarios which combine the higher levels of investment with improved environmental policies (G1 and G2). After that, a fifth section describes the results of the various scenarios. This is followed by a short concluding section. Additional technical details are provided in an Annex as well as in the separate Technical Background Material.

It should be noted that all sector chapters in this report have, to a varying extent, made use of the results from the modelling exercise presented here. Although the modelling includes a number of scenarios, the sector chapters generally compare only one green scenario, G2, with the corresponding BAU2 scenario, in addition to describing relevant aspects of the baseline BAU scenario. The G2 scenario is more relevant as it explicitly aims to reduce CO<sub>2</sub> emissions sufficiently to achieve an atmospheric concentration of 450 ppm, as well as a number of other policy targets in the areas of nutrition, fisheries management, reducing deforestation, water availability and waste management.

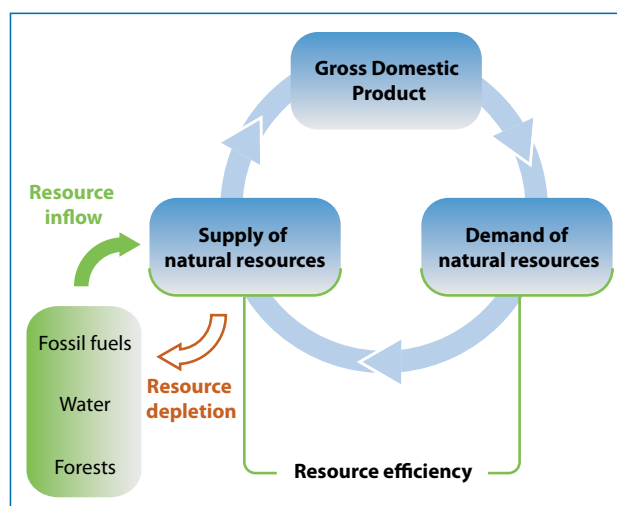
## 2 Understanding the green economy

The key drivers of a green economy, as represented in the global model developed for the analysis carried out in the GER, are stocks and flows of natural resources in addition to the stocks and flows of capital and labour which are important in any long-term economic model. Stocks are accumulations of inflows and outflows (as forests are the accumulation of reforestation and deforestation). In the T21-World model, moreover, capital and labour are needed to develop and process natural resource stocks. Thus, three key factors transform natural resources into economic value added: the availability of capital (which accumulates through investments and declines with depreciation), labour (which follows the world demographic evolution, especially the age structure, and labour force participation rates), and stocks of natural resources (which accumulate with natural growth – when renewable – and decline with harvest or extraction). Examples of the direct impact of natural resources on GDP are the availability of fish and forest stocks for the fishery and forestry sectors, as well as the availability of fossil fuels to power the capital needed to catch fish and harvest forests, among others. In this respect, the T21 model accounts for both monetary and physical variables representing each sector in a coherent and consistent manner. Other natural resources and resource-efficiency factors affecting GDP include water stress and waste recycling and reuse, as well as energy prices, all of which are endogenously determined.

The analysis carried out in the GER focuses on the transition towards a green economy, characterised by high resource-efficiency and low-carbon intensity, assessing the needs for a short- to medium-term transition and evaluating the impacts of a longer-term green economic development. Emphasis is therefore naturally put on stocks because they define the state of the system, as highlighted by projections of many key indicators for sustainability, such as the ecological footprint.<sup>1</sup> In fact, longer-term sustainable growth is related to the sustainable management of natural resources, such as water, land and fossil fuels. Increasing the efficiency of use and curbing waste of such resources would reduce the decline of stocks, or even support their growth in certain cases. In this respect, understanding the relationship between stocks and flows is crucial (e.g. the concentration of emissions in the atmosphere may keep increasing, even if yearly emissions are kept constant or decline. Carbon concentration will decline only if yearly

emissions are below the natural sequestration capacity of forests and land, among others).

The economic growth of recent decades, while profiting from the contribution of natural resources, did not allow stocks to regenerate (as has been illustrated by the Millennium Ecosystem Assessment). For instance, today only 25 per cent of the commercial fish stocks, mostly of low-priced species, are underexploited (FAO 2008) and some 27 per cent of the world's marine fisheries had already collapsed by 2003 (Worm et al. 2006); oil production has reached its peak and is declining in most countries (EIA 2009), and global peak oil is expected to take place between now and 2015 according to some (ASPO-USA 2010) or after 2030 according to others



**Figure 1: The relations between economic growth and natural resources**

Natural resources are both a driver and a possible constraint of economic growth. The higher GDP, the higher demand for natural resources; growing demand leads to higher production, which depletes stocks – all else being equal. Declining stocks, on the other hand, reduce potential medium- to longer-term production of natural resources, potentially constraining economic growth. Resource efficiency is promoted in the GER, to reduce demand and improve the management of supply. The rebound effect is also taken into consideration, as it normally reduces the intended benefits of efficiency improvements by increasing demand.

1. The ecological footprint is a measure of humanity's demand on nature. It represents how much land and water area a human population requires to regenerate the resources it consumes and to absorb its wastes (GFN 2010).

(IEA 2009); water is becoming scarce and water stress is projected to increase with water supply satisfying only 60 per cent of world demand in 20 years (McKinsey 2009); agriculture saw increasing yields primarily owing to the use of chemical fertilisers (FAOSTAT 2009), which, on the other hand reduced soil quality (Muller and Davis 2009) by almost 10 per cent relative to 1970 levels, and did not curb the growing trend of deforestation-remaining at 13 million hectares per year in 1990-2005 (FAO 2009).

There has been a long-standing perception among both the general public and policy makers that the goals of economic growth, environmental protection, national and energy security involve a complex set of trade-offs, one against another (Brown and Huntington 2008; CNA 2007; Howarth and Monahan 1996). This study aims at analysing the dynamic complexity of the social, economic, and environmental characteristics of our world with the goal of evaluating whether green investments can create synergies and

help move toward various green economy goals: resilient economic growth, job creation, low-carbon development and resource efficiency.

By adopting an integrated approach focused on the interaction of stocks and flows across sectors, this chapter examines the hypothesis that a correct management of natural resources does not necessarily imply accepting lower economic growth going forward. Instead, it explores the question of whether equal or higher growth could be attained with a more sustainable, equitable and resilient economy, in which natural resources would be preserved through more efficient use. This initial framing is in contrast with a variety of sectoral reports focused on energy and climate change mitigation scenarios. By way of contrast, the green economy approach supports both growth and low-carbon development, by reducing emissions and conserving stocks in the short-term to profit from their healthier state in the future.

# 3 Modelling the green economy

National governments often formulate long-term development objectives and a strategic approach to achieving them articulated in a development plan. A description of policies and measures to achieve the stated development goals forms the basis for shorter-term decision-making, such as the expenditure and revenue-raising plans reflected in the annual budget. Quantitative models have been developed to approximate the relationships among policy measures and development objectives.

## 3.1 A characterisation of modelling approaches

Over the last 40 years, a variety of applied models and modelling methods have been developed to support national planning. Among those tools, the most commonly used today include: Disaggregated Consistency (DC) models, Computable General Equilibrium (CGE) models, Macro-Econometric (ME) models and System Dynamics (SD) models.<sup>2</sup> These methods have proven useful to different degrees for various kinds of policy analyses, especially for mid-short-term financial planning. While recent global developments have stressed the importance of jointly addressing the economic, social, and environmental dimensions of development, most of the methods mentioned above do not effectively support integrated long-term planning exercises.

More specifically, CGE models are based on a matrix of flows concept, where actors in the economy interact according to a specified set of rules and under predetermined equilibrium conditions (Robinson et al. 1999). Initially conceived to analyse the economic impact of alternative public policies, e.g. those that work through price mechanism, such as taxes, subsidies, tariffs, recent CGE models include social indicators (Bussolo and Medvedev 2007) and environmental ones (OECD 2008). Macro-Econometric (ME) models are developed as combinations of macroeconomic identities and behavioural equations, estimated with econometric methods (Fair 1993), and they are largely used by national and international financial organisations to support short and mid-term macroeconomic policy analysis, such as general fiscal and monetary policies. Disaggregated Consistency (DC) models consist of a combination of

spreadsheets representing the fundamental national macroeconomic accounts, and enforcing consistency among them; well-known examples of such category of models include the World Bank's RMSM-X (Evaert et al. 1990) and the International Monetary Fund's FPF (Khan et al. 1990), mostly used to analyse the macroeconomic impact of adjustment programmes. The three methods described above focus primarily on the economic aspects of development, and in general are not designed to support integrated, long-term planning exercises.

As a technique to analyse a variety of development issues (Saeed 1998), including national policy analysis (Pedercini and Barney 2009), the methodology of systems dynamics (SD), conceived in the late 1950s at the Massachusetts Institute of Technology (MIT), has greatly evolved over the last 25 years (see Forrester 1961 for early examples on the use of this methodology). Specifically, the SD method has been adopted in various instances to analyse the relationship between structure and behaviour of complex, dynamic systems. In SD models, causal relationships are analysed, verified and formalised into models of differential equations (see Barlas 1996), and their behaviour is simulated and analysed via simulation software. The method uses a stock and flow representation of systems and is well suited to jointly represent the economic, social, and environmental aspects of the development process.

## 3.2 The Threshold 21 World model

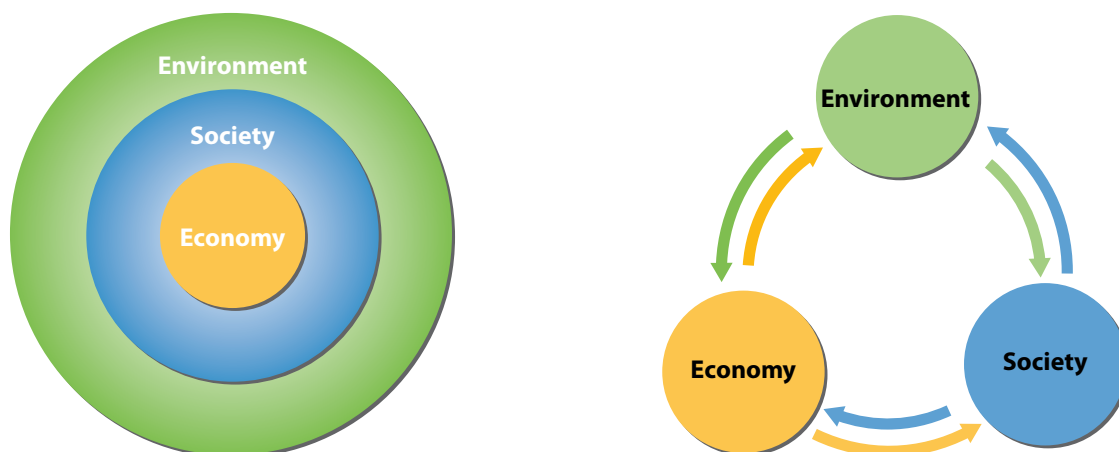
The approach proposed uses system dynamics as its foundation and incorporates optimisation (for technical choice in the energy sector), econometrics (for parameters of production functions) in the construction of the model, and simulations to illustrate possible alternative futures.

The model developed for the GER, largely drawing upon the Threshold 21<sup>3</sup> family of models created by the Millennium Institute (see, among others, MI 2005, Bassi 2010b), builds on assumptions (structural and numerical) from existing detailed sectoral economic and physical models into a comprehensive structure that generates scenarios of what is likely to happen throughout an integrated economic, social, and environmental system (see Figure 2).

2. For more information on models for national development, planning see Pedercini (2009).

3. The name Threshold 21 comes from the belief that the 21st century is going to be a threshold period for humankind.





**Figure 2: Conceptual overview of T21-World**

The environment, society and the economy represent the highest level of aggregation in the model (see left). Although our environment encompasses society and the economy, for simplicity we represent them separately in this report, to highlight the interconnections existing across them (see right).

By generating systemic, broad and cross-sectoral scenarios over time that address environmental, economic, and social issues in a single coherent framework, the global model simulates the main short-, medium- and longer-term impacts of investing in a green economy. As a global model without regional or national disaggregation, changes in geographical patterns of economic activity, social characteristics or environmental impacts are not explicitly represented (as explained in Annex 1). Furthermore the global model does not address explicitly the responsibilities or reactions of different actors, particularly governmental authorities. The most important contribution of this model is its systemic structure that includes endogenous links within and across

the economic, social, and environmental sectors (all defined at a global aggregate level) through a variety of feedback loops.<sup>4</sup> Most existing models focus on one or two sectors, but make exogenous assumptions about other sectors that affect and are affected by the sector under consideration. Using endogenous formulations instead improves consistency over time and across sectors, because changes in the main drivers of the system analysed are reflected throughout the model and analysis through feedback loops.

4. Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself (Roberts et al. 1983).

## 4 Scenario definition and challenges

The model was used to simulate two green investment scenarios – promoting resource efficiency and low-carbon development – to be compared with BAU or baseline scenarios that favour a more conventional use of resources and fossil fuels.

The BAU case replicates history over the period 1970–2009, and assumes no fundamental changes in policy or external conditions going forward to 2050. This scenario is set up and calibrated to reflect baseline projections of various existing sectoral models and reports on population, economy, energy, transport and water, including among others: United Nations' World Population Prospects (WPP) (UNPD 2009), World Bank's World Development Indicators (WDI) (WB 2010), OECD's Environmental Outlook to 2030 (OECD 2008), FAO's FAOSTAT (FAO 2010) and State of World's Forests (FAO 2009), McKinsey's Charting Our Water Future report (McKinsey 2009), IEA's World Energy Outlook 2010 (IEA 2010), Sustainable Production of Second Generation Biofuels (IEA 2010), Transport, Energy and CO<sub>2</sub> (IEA 2009) and Energy Technology Perspectives (IEA 2010) and Global Footprint Network (GFN) reports (GFN 2010).

The two green scenarios (G1 and G2) assume increased investments over the period 2010 to 2050, and these are contrasted with two respective business-as-usual scenarios (BAU1 and BAU2) in which the same amounts of investments are simulated, but allocated according to existing patterns.<sup>5</sup> Green scenarios simulate additional investments that increase resource efficiency and reduce carbon intensity while creating jobs and stimulating economic growth. Efficiency improvements driven by investments can be achieved both directly - through the construction of more efficient infrastructure and adoption of resource-saving technologies - and indirectly - through technological advances due to relevant research and development. Examples include investments in renewable energy (e.g. power supply) and energy-efficiency improvements. Further, investments are allocated to reduce deforestation and increase reforestation, or to reduce extractive capacity in the fishery sector and support the restoration of fish stocks.

5. Two different methods were developed to simulate green economy investments and analyse them. (1) The first approach simulated additional investments, both green and following business-as-usual, across sectors. (2) The second approach shifts investments from business-as-usual to green. In this case investments are practically reallocated to green investment across sectors. The first approach is presented in this chapter. A comparison of the results obtained through the simulation of both methods is presented in section I, Technical Background Material. In brief, our analysis indicates that when using the same assumptions, results of the simulations do not significantly differ from each other for most variables.

The green scenarios build on and extend the recommendation of UNEP's Global Green New Deal Policy Brief (UNEP 2009), which called for a significant portion of the stimulus packages – at least 1 per cent of GDP – to be channelled towards investments in a range of green sectors. As a response to the multiple crises facing the world, such an investment was proposed as a means to revive the global economy, while embarking on a new low-carbon, resource-efficient growth path. At the global level, commitments fell well short of this target, although the Republic of Korea and China both stand out as countries that allocated more than 5 per cent of GDP, in the form of their stimulus packages, to investments in green sectors. The Republic of Korea also extended this programme into its medium-term "Five-Year Green Growth Plan" (2009–2013), which devotes 2 per cent of GDP to investments in climate change and energy, sustainable transport and the development of green technologies. The green scenarios here represent a similar strategy of embedding green investments and enabling policy framework into a long-term commitment.

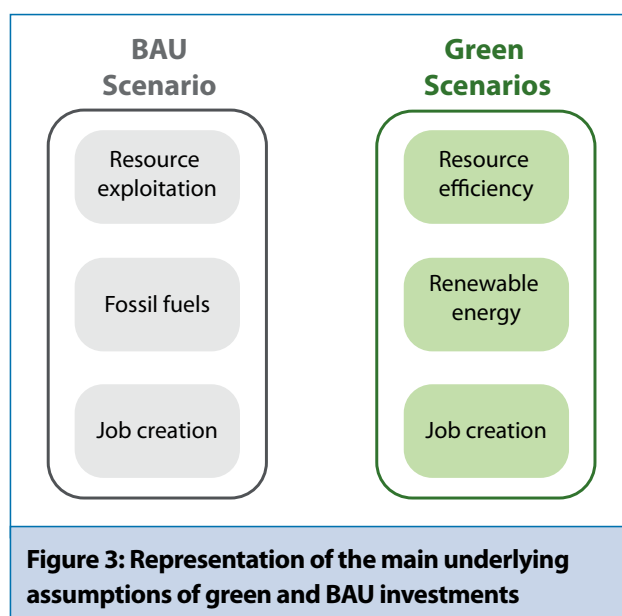
As stated, the BAU1 and BAU2 scenarios assume additional investments, as in the green cases, but project the continuation of the current trends for resource use and energy consumption, among others. More specifically, these scenarios assume that no additional investments – relative to BAU – will be allocated to the expansion of renewable energy, that agriculture will continue to rely on chemical fertilisers, and that deforestation will not be curbed.<sup>6</sup> Instead, growth will be attained through resource exploitation, including draw down of fossil fuels, fish and forest stocks.

The comparison of green and BAU scenarios for selected sectors and actions are listed in Figure 3 and Table 1.

The G1 and G2 green investment scenarios are constructed for different purposes and emphases,<sup>7</sup> but are not meant to be exhaustive in terms of the potential breadth and extent of scenarios. The 1 per

6. The BAU does already incorporate, though indirectly, current trends in investments in such sectors, but does not anticipate major changes in those trends.

7. A variety of additional investment scenarios could be easily simulated and analysed. On the other hand, for simplicity and to present a solid analysis that could be easily compared with other leading studies, the 1 per cent and 2 per cent cases were selected. Investment scenarios beyond 2 per cent of GDP were also carefully assessed, and discarded due to lack of information on (1) potential feasible reductions in energy and material consumption and (2) related costs (e.g. carbon abatement cost) beyond peer reviewed and published estimates. For instance, if carbon abatement were to be pushed beyond IEA's estimations, assumptions on the marginal costs of doing so would need to be made by the authors. In our analysis instead, we rely on existing estimates, to be consistent and coherent with state of the art research across sectors.



cent case (G1) is an experimental exercise to clarify and illustrate the concept of green economy – as it assumes an about equal allocation of funds across the sectors analysed – and to compare the projected impacts of the implementation of a green economy strategy with, among others, climate scenarios such as IEA's 450 case. On the other hand, the 2 per cent case (G2) can be considered more relevant and coherent. In this case, current key issues, such as climate change, water scarcity and food security, determine the allocation of the investment across sectors. Being central to addressing climate change, energy investments are prioritised in this scenario to reach the emissions targets of IEA's 450 and BLUE Map scenarios. It is important to note that, for the most part and unless otherwise stated, the sectoral chapters in the GER refer to G2 as the green investment scenario.

More specifically, these scenarios include investments in agriculture, fisheries, forestry, water, waste and energy, also allocated across sectors, such as industries, transportation, buildings and tourism. Cities are also analysed. More details on the scenarios follow:

**Scenario G1:** assumes that 1 per cent of global GDP is channelled annually through green investment. In this green scenario, 1 per cent of GDP is generally divided equally among the sectors, each receiving 10 per cent of the green investment, with some exceptions, as highlighted in Table 2, depending on specific sectoral targets. This distribution of funds serves to illustrate the broader benefits of greener investments, providing national leaders facing socio-economic and environmental challenges with insights on likely impacts of increasing green investments. For cities, in addition to analysing the impacts of global investment on urban settings, we simulate the allocation of 1 per cent of urban GDP to expand public transport, being key to cities' socio-economic as well as spatial development.

**Scenario G2:** assumes that 2 per cent of global GDP is channelled annually through green investments. In this scenario, priorities are driven by sectoral policy targets, emphasising energy and climate change (which according to the IEA would require approximately 1 per cent of global GDP through 2030 to reduce emissions to 450 ppm concentration, and limit global warming to 2° C). As a consequence, a higher share of GDP is allocated to energy (both demand and supply measures) and the remainder is shared across the remaining sectors (e.g. agriculture, forestry, fishery, waste and transport infrastructure).

The investments under G1 and G2 take place on an annual basis over the period 2010-2050, implying a concerted but gradual shift in shifting the economy's capital stock and reducing potential: costs of premature obsolescence. Scenarios BAU1 and BAU2 also assume additional investments of 1 per cent and 2 per cent of GDP, as is the case with G1 and G2, but these are allocated across the economy in a BAU context, without targeting specific sectors. Generally, the effects of G1 and G2 are evaluated in comparison to projections under BAU1 and BAU2 (the additional BAU scenarios), respectively.

Sector and objective	BAU Scenarios <sup>a</sup>	Green Scenarios
<b>Agriculture</b> Yield increase	Higher utilisation of chemical fertilisers	Expansion of conservation agriculture, using organic fertilisers, among others
<b>Energy</b> Expansion of power generating capacity	Thermal generation (fossil fuels)	Renewable energy power generation
<b>Fisheries</b> Increase production	Expansion of the vessel fleet, pushing catch in the short-term	Reduction of the vessel fleet, investing in stock management to increase catch in the medium- and longer-term
<b>Forestry</b> Increase production	Increase deforestation	Curb deforestation and invest in reforestation (expanding planted forests)
<b>Water</b> Manage supply and demand	Increase water supply through higher withdrawal	Invest in water efficiency measures, water management (including ecosystem services) and desalination

<sup>a</sup> Refers to BAU1 and BAU2 with additional investments allocated to match existing patterns.

**Table 1: Comparison of scenarios for selected sectors and objectives**

## 4.1 Defining investments and methodology

It is worth noting that a variety of policies are simulated together with the allocation of investments to green sectors. In fact, our scenarios account for both public and private investments, and assume that the total amount allocated is effectively spent across sectors. For this reason, when we refer to investment, we consider both public and private expenditure. The former can be represented by fiscal policies to stimulate the purchase of more efficient capital (e.g. tax rebates for purchasing a fuel efficient car, or a refrigerator) and the latter is the actual private expenditure to make the purchase. In addition, investment is generally referred

to here in its economic sense as increases to fixed capital, including infrastructure.<sup>9</sup> It will be important to develop criteria and indicators that can be used to monitor relevant investments under eventual green investment scenarios.

In the modelling exercise, the source of funding for green investments is not explicitly defined. This is due to the fact that different governments, facing different constraints and being characterised by very heterogeneous contexts, may prefer to rely on different policies and schemes to support the transition to a green economy.

Sector	Share of green investment		Share of GDP		Sectoral targets
	G1	G2	G1	G2	
Agriculture	10	8	0.1	0.16	Increase nutrition levels to 2800-3000 Kcal/person by 2030 (FAO 2009).
Buildings	10	10	0.1	0.2	Increase energy efficiency to reach energy consumption and emissions reduction targets set in IEA's BLUE Map scenario (IEA 2008).
Energy (supply)	15	26	0.15	0.52	Increase the penetration of renewable energy in power generation and primary energy consumption to reach targets set in IEA's BLUE Map scenario (IEA 2008).
Fisheries	10	8	0.1	0.16	Restore fish stock to potential reach the maximum sustainable yield set by FAO by 2050.
Forestry	3	2	0.03	0.03	Phase in a 50% reduction in deforestation by 2030, and increase planted forests to sustain forestry production.
Industry	6	3	0.06	0.06	Increase energy efficiency to reach energy consumption and emissions reduction targets set in IEA's BLUE Map scenario (IEA 2008).
Tourism	10	10	0.1	0.2	
Transport	16	17	0.16	0.34	Expand public transport and increase energy efficiency to reach energy consumption and emissions reduction targets set in IEA's BLUE Map scenario (IEA 2008).
Waste	10	8	0.1	0.16	Reducing 70% of waste that goes to landfill through proper implementation of 3Rs.
Water	10	8	0.1	0.16	Attain the MDGs for water and reduce water intensity (reduce consumption and increase supply) (see McKinsey 2010).
<b>Total</b>	<b>100</b>	<b>100</b>	<b>1%</b>	<b>2%</b>	
Power and fuel efficiency*	33	35	0.33	0.71	

**Table 2: Allocation of investments across sectors in the G1 and G2 scenarios**

**as a share of total investment and GDP (2011 – 2050 average) and sectoral targets of green scenarios<sup>8</sup>**

\* This category includes all energy efficiency investment (both fuel and power) implemented across sectors. These include most, but not all, investments allocated to buildings (residential, commercial and agriculture), industry, tourism and transport. In addition, the impacts of the green investment scenario for sectors for which the investment concentrates exclusively on energy efficiency - buildings, industry - are not presented separately below, but are captured under energy.

8. Investments allocated to cities are not presented in this table. Modelling work on cities has proven difficult to carry out due to the lack of data on a variety of key variables, including water and energy consumption. Emphasis was therefore put only on transport, as indicated in the Cities Chapter, given its relevance to urban development.

9. For some sectors, including natural-resource based sectors, such as agriculture, forestry and fisheries, investments included under the green investment scenarios do have a broader character, including expenditure on programmes (both capital and operating costs) to restore or maintain natural capital. These can also be considered as investments in natural capital in an economic sense, even though such investments have an indirect nature.

Further, as opposed to several studies that only provide information on “net costs” (or required additional investments),<sup>10</sup> disaggregated capital costs and savings (or avoided costs) are used in T21-World. This approach is useful because as capital costs are an immediate expenditure, as opposed to operational savings – that are accumulated over the lifetime of capital – it allows the model to calculate the actual capital formation that corresponds to the additional investment simulated in the green and BAU1, 2 scenarios.

As indicated above, the calculation of required capital investment and operational costs includes a detailed assessment of costs associated with various technologies (capital) and their required inputs (e.g. energy). For instance, we account for the capital and O&M cost of a wind turbine, which, on a per MW basis, is often similar to the cost of a coal-fired plant. On the other hand, wind does not require fuel inputs and does not generate emissions, but it is an intermittent source of energy with a relatively low capacity factor when compared to coal. All these factors are considered in our analysis to break down as much as possible the costs and savings related to green investments.

Determining both the gross and net cost of moving toward a green economy has various purposes. These include the need to estimate (and disaggregate) present costs and future benefits for the key actors involved, both in economic terms and expressed as preservation of natural resource stocks. Also, it supports

the further evaluation of the impact of policy options in light of the associated opportunities and risks. For instance, if a government has set an environmental goal (e.g. reducing emissions below 1990 levels) and decides to rely considerably on incentives (e.g. tax breaks or discounts) to support the shift from old to new capital and/or to more sustainable consumption, the buy-in of households and the private sector will be a key factor defining the success or failure of the policy. In this case, the government risks missing the targets and goals for emissions reduction; at the same time, if the private sector does not participate as expected, the economic expenses of the government (and the private sector) would also be less. This policy option normally targets negotiated goals to mitigate the economic burden on households and the private sector. As an alternative case, when governments set mandates, the buy-in of households and private sector is assured by law, and the economic cost is either shared (if incentives are put into place) or fully sustained by households and the private sector. In this case emphasis is put on reaching the policy target (through mandates) and costs can be more easily estimated knowing that both economic actors (public or private, in different ways) will have to sustain the costs associated with the full implementation of the mandate.

This study serves primarily to quantify the impacts of investments, identify opportunities and avoid dead ends. Given that similar policies will be more or less successful in different countries, the global study is focused on the value of allocating funds to greener investments, providing a broad range of information to national policy makers, as presented in the following sections. Additional information on funding options and enabling conditions (i.e. required policy frameworks) are available in the respective chapters.

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10. When considering the cost of purchasing, for instance, a more efficient refrigerator, the net cost is calculated as capital expenditure minus savings occurred in the operation of the refrigeration (i.e. savings originating from the reduced energy consumption). This is the case of McKinsey Cost Curves (for water see McKinsey 2009).



# 5 Results of the simulations and analysis

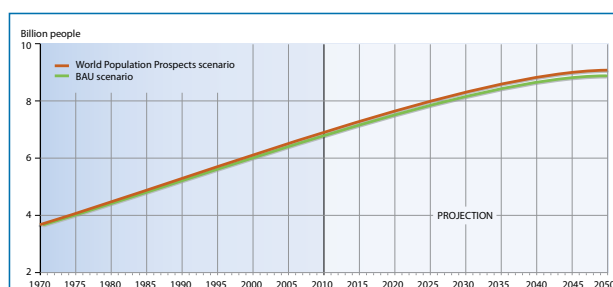
## 5.1 Baseline projection (BAU)

The baseline projection of the T21-World model is modelled on the assumption that current trends will continue, with only minor progress shifting to a green economy (e.g. high energy use and emissions and continued unsustainable exploitation of natural resources). Total population is projected to grow by 29 per cent in the period 2010 – 2050, reaching 8.9 billion people, matching historical data from WDI and future projections from WPP (Figure 4). These WPP projections are based on continuing declines in fertility, and dependent on population policies and programmes, including universal access to sexual and reproductive health. When looking at the population pyramid, we see that when under-five mortality rates decline and life expectancy increases the population will become more equally distributed across age cohorts. Employment is projected to increase to 4.6 billion in 2050, driven by economic growth.<sup>11</sup> Real GDP, endogenously simulated by the model, is in fact projected to grow by 2 per cent per year on average between 2010 and 2050, reaching US\$ 151.3 trillion, or US\$ 17,068 per capita, using 2010 as the constant US dollar base year,<sup>12</sup> which compares to historical data from WDI. As a result of economic growth, the proportion of people living below the poverty line will decline to 16.8 per cent in 2020 and 11.1 per cent in 2050 and the income distribution will improve over time, with more people being lifted out of poverty and into higher income classes.<sup>13</sup>

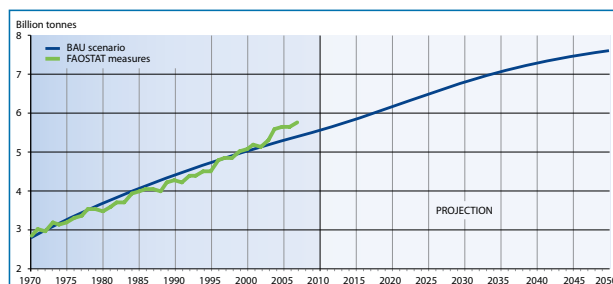
In line with the overall GDP growth, the value added generated by agriculture, industry and service sectors is projected to increase by 0.7 per cent, 1.9 per cent, and 2.1 per cent per year on average respectively between

2010 and 2050, accounting for 1.4 per cent, 23.4 per cent, and 75.2 per cent of real GDP in 2050. At this time, the share of total employment by sector will be: 32.3 per cent (agriculture), 23 per cent (industry), 39.3 per cent (service), and more specifically, 0.3 per cent (fisheries), 0.5 per cent (forestry), 2.5 per cent (transportation), 0.4 per cent (energy), 0.5 per cent (waste) and 1.1 per cent (water). In the agriculture sector, total volume of crop yield (Figure 5) has increased by 1.8 per cent per annum between 1970 and 2009, following FAOSTAT values, and is projected to continue to grow by 0.8 per cent per year for the next 40 years. As a result, a projected 36 per cent growth in crop production value between 2010 and 2050 will improve the average nutrition level by 7 per cent over the simulation period. The fishery sector and forestry industry will contribute 0.04 per cent and 0.6 per cent of global GDP by 2050, with an average growth rate of -1.6 per cent and 0.3 per cent per year.

Owing to the growth of population and GDP, the world's primary energy demand will grow by over 57 per cent in the coming decades, reaching 19,733 Mtoe in 2050. To meet the rising demand, the production



**Figure 4: Simulation of population in BAU compared with population values of WPP**

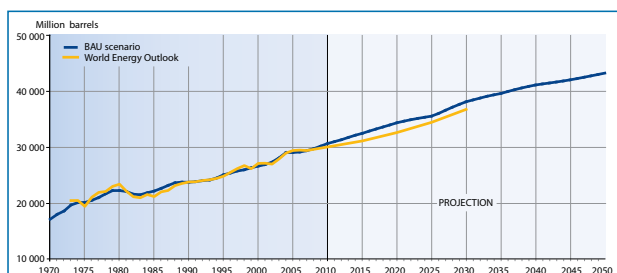


**Figure 5: Simulation of total volume of crop yield in BAU compared with values of FAOSTAT**

11. Note that although the T21-World model does not incorporate an explicit labour market, it does not assume full employment.

12. Note: All monetary values in the chapter are presented in constant 2010 US dollars.

13. T21-World projects income but not inequality. Gini coefficients are assumed, following historical trends, and income distribution in this chapter indicates how many people are living in each income class, including those below the poverty line. As a result, changes in projected poverty levels are largely driven by the simulated level of income (endogenously determined and impacted by the investment assumed). We estimate poverty levels using economic indicators (e.g. income), but do also consider access to basic services (without calculating an aggregated indicator accounting for social and monetary factors at once). Since it is unfair to reduce poverty to monetary poverty only, we consider social aspects as well in broader poverty-related considerations.



**Figure 6: Simulation of oil demand in BAU compared with values of WEO\***

\*For past and future projections, the model fits well with WEO values in terms of oil demand-R-square of 98.3 per cent and average point-to-point deviation 0.69 per cent.

of fossil fuels, nuclear and renewable energy will increase from 10,174 Mtoe, 755 Mtoe and 1,620 Mtoe respectively in 2011, to reach 16,073 Mtoe, 1,089 Mtoe, and 2,577 Mtoe respectively in 2050, with the share of fossil fuels remaining at 81 per cent throughout 2050.

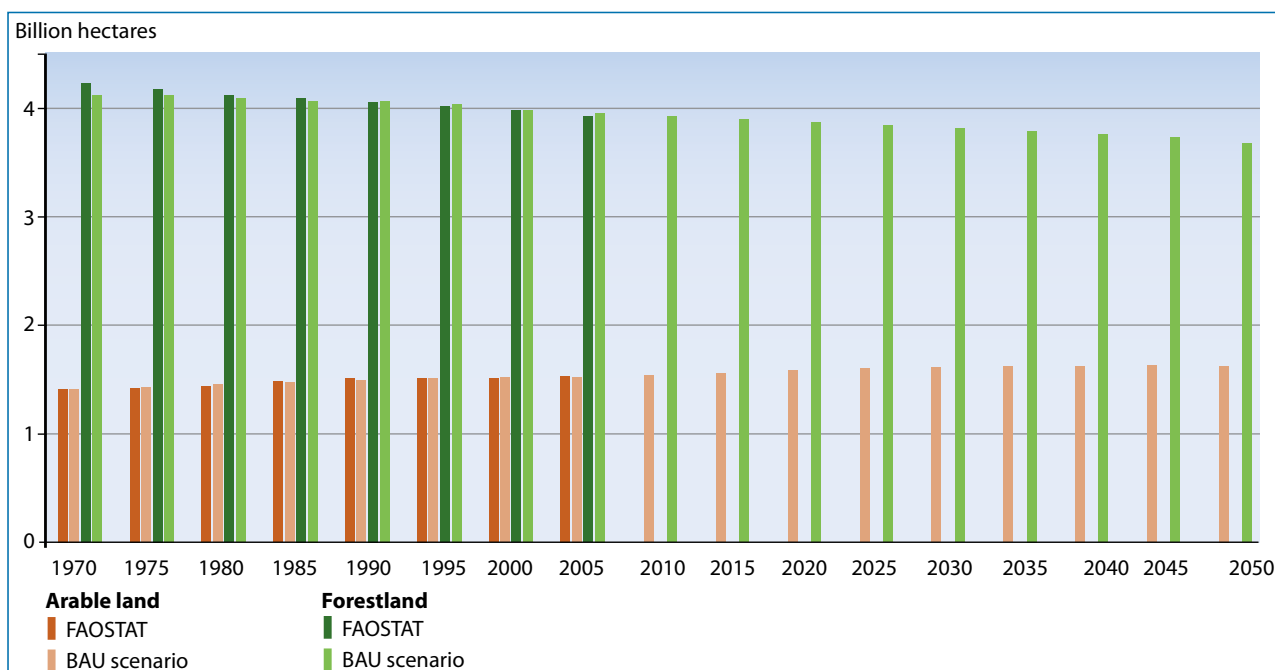
For oil demand, among other fossil fuels, the simulated trends of growth in BAU and corresponding WEO values are illustrated in Figure 6. The projection of oil price follows IEA's WEO, and increases faster after 2030, due to the peak of conventional oil projected to take place after 2035.

Driven by the same factors, total water consumption is projected to reach 8,141 km<sup>3</sup> in 2050 – 70 per cent above its current value – with total water supply heavily relying on groundwater reservoirs and streams well beyond sustainable withdrawals. This production level would probably compromise aquifers, increasing salt-water infiltration in coastal areas and forcing massive migrations.

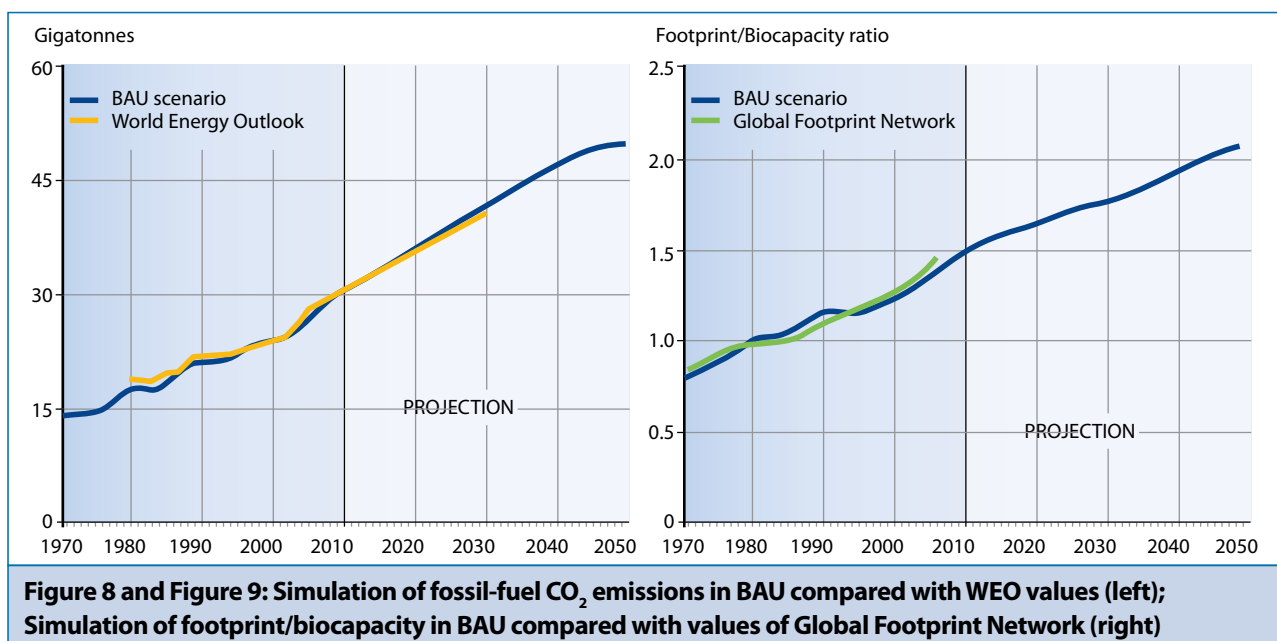
Concerning land use, total agricultural land will expand to 5.4 billion hectares by 2050, with pasture and arable land growing by 11 per cent and 6 per cent between 2010 and 2050. The harvested area in turn will reach 1.3 billion hectares by 2050, a 9 per cent increase relative to 2010 to meet the increasing food demand. In addition, settlement land will grow by 0.7 per cent per year on average, reaching 226 million hectares in 2050. Correspondingly, forestland will suffer from an average net loss of 6 million hectares per year and a deforestation rate of 15 million hectares per year, with only 3.7 billion hectares of forestland left by 2050. As a result, the total carbon storage in forests will decline by about 7 per cent between 2010 and 2050. The fishery sector will also face challenges such as declining stocks. The total amount of fish caught is projected to decline by as much as 46 per cent between 2010 and 2050, due to overcapacity and ineffective management of the industry and natural resources.

Finally, owing to the larger population and higher income, the world is expected to generate over 13.2 billion tonnes of waste in 2050, 19 per cent higher than the amount in 2009.

As a consequence of these trends, total world CO<sub>2</sub> emissions are projected to increase throughout the simulation, with fossil fuel emissions reaching about 50 billion tonnes (Gt) per year in 2050, 71 per cent above 2009 and 138 per cent above 1990 emission levels (Figure 8). This increase corresponds also to a 26 per cent reduction in global carbon intensity (calculated as emissions per US\$ of GDP) between 2009 and 2050. The transport sector, as a major emitter, will account of 13 Gt



**Figure 7: Simulation of arable land and forestland in BAU compared with values of FAOSTAT**



**Figure 8 and Figure 9: Simulation of fossil-fuel CO<sub>2</sub> emissions in BAU compared with WEO values (left); Simulation of footprint/bioclacity in BAU compared with values of Global Footprint Network (right)**

of CO<sub>2</sub> emissions per year in 2050, doubling the current level (see Table 3 below for transport emissions in BAU and corresponding IEA's projections). With this level of emissions, the long-term concentration of atmospheric greenhouse gases will approximate 1,000 ppm by 2100, and likely remain in the range of 855 ppm to 1,130 ppm CO<sub>2</sub>-eq, as projected by the IPCC for scenarios A1B and A2. In addition, over the next 40 years, the ecological footprint will reach 25 billion hectares, consuming more than twice the bioclacity of the planet (i.e. sustainable natural supply). In fact, the ratio of ecological footprint to bioclacity rises to 2.1 in 2050 from 0.81 in 1970 and 1.5 in 2009 (Figure 9).

On top of the impacts estimated in this study, according to current state of the art research, the projected BAU trends for emissions and ecological footprint are not sustainable and will trigger considerable negative consequences on society, economy and environment.

A long-term concentration of atmospheric greenhouse gases of about 1,000 ppm CO<sub>2</sub>-eq would have an extremely low probability (<5 per cent) of restricting global warming to 2°C. It is more likely that the temperature increase will approximate 4°C, ranging between 1.7°C and 5.5°C (see A1B and A2 scenarios from IPCC (2007) AR4). In such a scenario, the negative impacts will be many and varied, including, according to the IPCC, consequences for water supply, food production, human health, the availability of land and ecosystems. In particular, by 2050, hundreds of millions of people will face increasing water stress; sea-level rise will accelerate coastal storm surges, leading to land loss and erosion and intrusion of saltwater into surface and groundwater; 15 to 40 per cent of species will face extinction with 2°C of warming; crop yields, especially in Africa, will decline, probably leaving hundreds of millions without the ability to produce or purchase sufficient food. Developing

Mt/year	2010		2020		2030		2050	
Transport mode	* MoMo	BAU	* MoMo	BAU	* MoMo	BAU	* MoMo	BAU
<b>Total emissions</b>	<b>6,221</b>	<b>6,989</b>	<b>7,573</b>	<b>8,387</b>	<b>9,308</b>	<b>10,175</b>	<b>12,709</b>	<b>12,991</b>
Cars	2,826	3,084	3,557	3,945	4,494	5,129	6,652	6,923
Buses	424	485	443	511	453	518	470	505
Other passenger road	157	185	180	220	209	248	291	314
Trucks	1,211	1,375	1,364	1,513	1,603	1,750	2,143	2,157
Passenger rail	29	32	34	39	41	44	57	60
Freight rail	127	138	137	155	143	157	152	168
Air	721	972	1,030	1,229	1,451	1,507	1,864	1,995
Water	727	718	827	776	915	822	1,080	868

**Table 3: Transport emissions by mode in business-as-usual scenarios of GER and IEA**

\* Source: MoMo Transport Model (IEA, 2009)

countries are the most vulnerable to climate change impacts. As many of the effects of climate change depend on the degree of adaptation, which itself will be determined by income levels and market structure, these countries have fewer resources to adapt socially, technologically and financially. It is estimated in Stern's Review of the Economics of Climate Change (2006) that climate change will impose an overall cost equivalent to 0.5 to 1 per cent of world GDP per annum by the middle of the century if no emission mitigation measures are taken in the short- and medium-term. Further, the report indicates that if we start to take strong action now to achieve a stabilisation between 710ppm and 445ppm CO<sub>2</sub>-eq by 2050, the global average macro-economic costs for GHG mitigation are between negative 1 per cent and positive 5.5 per cent of global GDP, which is equivalent to slowing average annual global GDP growth by about 0.12 per cent per year.

In the GER BAU scenario, the feedback effects from natural resource depletion are sufficiently important that the annual rate of world GDP growth gradually

falls from about 2.7 per cent per year in the period 2010-2020 to 2.2 per cent in 2020-2030 and further to 1.6 per cent in 2030-2050.

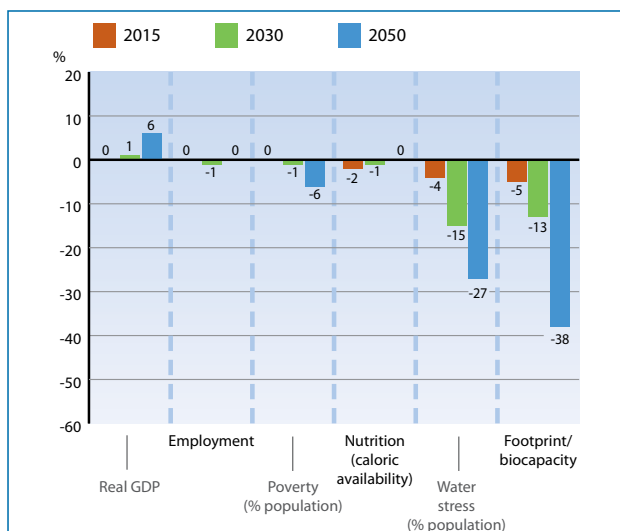
## 5.2 Green economy projections

Investing various additional proportions of GDP in the green economy or following BAU has various impacts throughout society, economy and the environment. Despite difficulties in estimating global impacts of investments, we were able to calculate the general repercussions on GDP and estimate employment, avoided costs and state of natural resources for most of the sectors analysed in the GER. The main impacts of simulating green and additional business-as-usual investments in various scenarios are highlighted in Table 4, Figure 10 and Figure 11.

Generally, the green economy scenarios show the beginning of the marked decoupling of natural resource uses from economic growth (see Figure 12). In fact, the key difference between green and additional BAU

		2011	2015					2020				
	Unit		BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
Additional investment	US\$ bn/year	0	763	1,535	0	760	1,524	885	1,798	0	883	1,789
Real GDP	US\$ bn/year	69,334	78,651	79,306	77,694	78,384	78,690	91,028	92,583	88,738	90,915	92,244
GDP per capita	US\$/person/year	9,992	10,868	10,959	10,737	10,832	10,874	12,000	12,205	11,698	11,983	12,156
Annual GDP per capita growth rate	%/year	1.8%	2.1%	2.3%	1.8%	2.1%	2.2%	1.9%	2.1%	1.7%	2.0%	2.2%
Consumption per capita	US\$/person/year	7,691	8,366	8,435	8,264	8,338	8,370	9,236	9,394	9,004	9,224	9,357
Population below US\$2/day	%	19.5%	18.1%	17.9%	18.3%	18.1%	18.1%	16.4%	16.2%	16.9%	16.5%	16%
Total employment	billion people	3.2	3.4	3.4	3.4	3.4	3.4	3.7	3.7	3.6	3.7	3.7
Energy intensity	Mtoe/US\$ bn	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.17	0.16	0.21
Fossil fuel CO <sub>2</sub> emissions	Gt/year	30.6	33.3	33.6	32.9	32.0	30.7	36.6	37.1	35.6	33.2	30.3
Footprint/bioproductivity	Ratio	1.5	1.6	1.6	1.6	1.5	1.5	1.7	1.7	1.6	1.6	1.4
Continued.		2011	2030					2050				
Additional investment	US\$ bn/year	0	1,137	2,334	0	1,150	2,388	1,616	3,377	0	1,719	3,889
Real GDP	US\$ bn/year	69,334	116,100	119,307	110,642	117,739	122,582	164,484	172,049	151,322	174,890	199,141
Annual GDP per capita growth rate	US\$/person/year	9,992	14,182	14,577	13,512	14,358	14,926	18,594	19,476	17,068	19,626	22,193
GDP per capita	%/year	1.8%	1.5%	1.6%	1.3%	1.7%	2.0%	1.6%	1.7%	1.4%	1.5%	2.2%
Consumption per capita	US\$/person/year	7,691	10,916	11,220	10,401	11,052	11,488	14,312	14,991	13,138	15,106	17,082
Population below US\$ 2/day	%	19.5%	13.9%	13.5%	14.6%	13.7%	13.2%	10.4%	9.8%	11.4%	9.8%	8.4%
Total employment	billion people	3.2	4.1	4.2	4.1	4.1	4.1	4.7	4.8	4.6	4.8	4.9
Energy intensity	Mtoe/US\$ bn	0.18	0.15	0.15	0.15	0.13	0.12	0.13	0.13	0.13	0.08	0.07
Fossil fuel CO <sub>2</sub> emissions	Gt/year	30.6	42.7	43.8	40.8	35.6	30.0	53.7	55.7	49.7	29.9	20.0
Footprint/bioproductivity	Ratio	1.5	1.8	1.8	1.8	1.6	1.4	2.2	2.2	2.1	1.4	1.2

**Table 4: Main indicators, BAU and green investment scenarios**



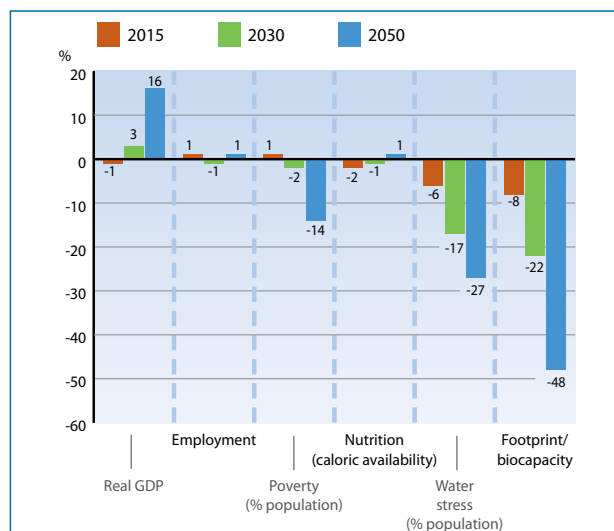
**Figure 10: Results of the G1 scenario relative to the BAU1 case in 2015, 2030 and 2050 (per cent)\***

\* Footprint-biocracy ratio (or biocracy ratio): the ratio of ecological footprint over biological capacity. The biological capacity (or biocracy) is the ability of an ecosystem to produce resources it consumes and to absorb wastes generated by humans (GFN 2010).

investments is created by the projected future of stocks of natural resources (see Box 1, based on section VI in the Technical Background Material, which presents the changes in natural resource stocks in more detail, including estimates of changes in the value of natural capital assets and adjusted net domestic product – NDP). Business-as-usual scenarios push consumption, stimulating economic growth in the short- and medium-term, thus exacerbating known historical trends of depletion of natural resources. As a consequence, in the longer-term, the decline of natural resources (e.g. fish stocks, forestland and fossil fuels) will have a negative impact on GDP (i.e. through reduced production capacity, higher energy prices and growing emissions) and results in a lower level of employment. Additional consequences may include large-scale migration driven by resource shortages (e.g. water), faster global warming and considerable biodiversity losses.

The green scenarios, by promoting investment in key ecosystem services and low-carbon development, show slightly slower economic growth in the short- to medium-term, but faster and more sustainable growth in the longer-term. In this respect, the green scenarios show more resilience, by lowering emissions, reducing dependence on volatile fuels and using natural resources more efficiently and sustainably. In other words, the green economy investment scenarios take the earth off of the collision course it is currently on with biophysical constraints. A more detailed summary of key results across sectors is presented below.

Worth noting, while BAU investments show a higher return on investment (ROI) in the short- and medium-term, green investments indicate higher economic ROI in the longer-term, outperforming BAU investments by



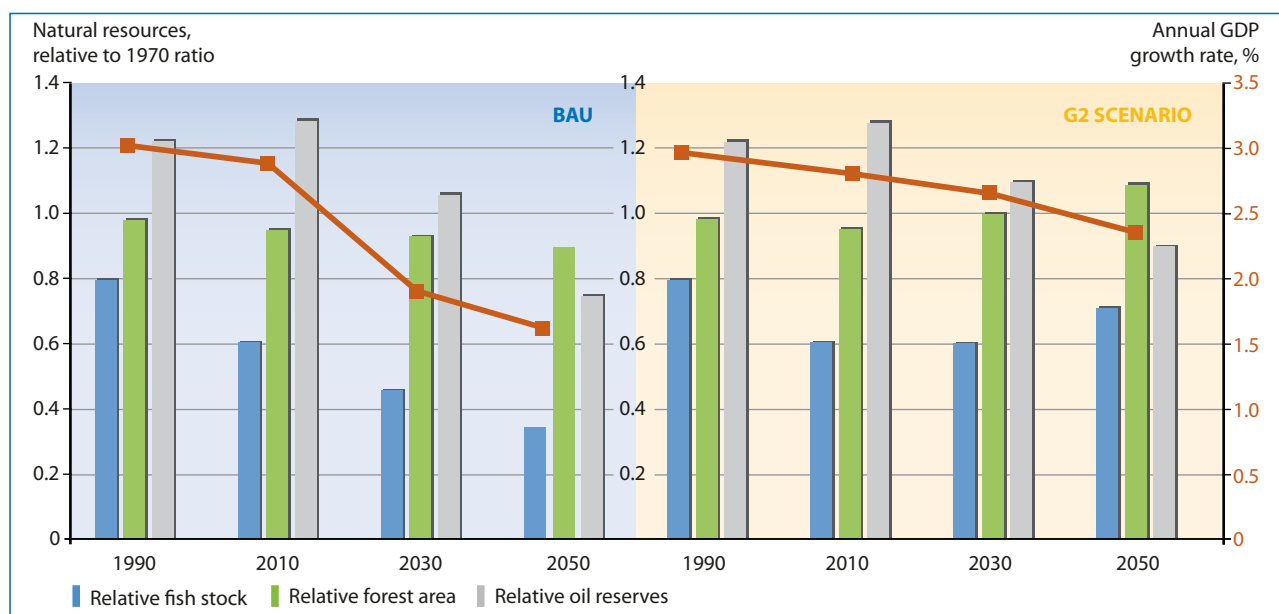
**Figure 11: Results of the G2 scenario in 2015, 2030 and 2050 relative to BAU2 (per cent)**

over 25 per cent throughout 2050-yielding, on average by 2050 over US\$ 3 for each US\$ invested. Also, both investments yield positive economic returns after about nine to 11 years in the green cases and seven to 9 years in BAU scenarios. More specifically, it can be observed that BAU investments will drive faster economic growth – in terms of total and per capita GDP<sup>14</sup> – than the green alternatives in the short-term, with only marginal difference in social improvements (poverty reduction, employment, nutrition). In the medium- to longer-term, however, the economic and social development in a green economy is expected to outperform the BAU cases. Moreover, the green scenarios always see lower negative impacts on the environment (e.g. energy intensity, emissions and footprint), which will contribute to the faster medium- to longer-term economic growth observed in green scenarios relative to BAU ones.

Results of the BAU and green scenarios indicate that global real GDP would reach between US\$ 175 and US\$ 199 trillion by 2050 respectively in the G1 and G2 scenarios, which exceeds the US\$ 164 in the BAU1 and US\$ 172 trillion in BAU2 cases, by 6 per cent and 16 per cent respectively. The average annual growth rate reaches, on average, 2.3-2.7 per cent between 2010 and 2050 in the green scenarios, although the relevant comparison is to the BAU1 and BAU2 scenarios. These latter scenarios see faster economic development in the short to medium term, with 2.3 per cent to 2.4 per cent annual growth rate between 2010 and 2050. However, GDP in the BAU1 and BAU2 scenarios in 2050 is lower than in G1 and G2, due to natural resource depletion and the higher energy costs (Figure 13). This can partly be seen in calculations of NDP adjusted for depreciation of both fossil fuel and fish stocks (see

14. Even by this limited, conventional measure, which does not represent progress nor wealth (See Box 1).





**Figure 12: Trends in GDP growth rate (right axis) and stocks of natural resources (left axis: oil discovered reserves, fish stock and forest stock, relative to 1970 levels), in the BAU and G2 scenarios**

Stocks are better managed and saved for future generations in G2, while supporting GDP growth already in the medium- and longer-term.

Box 1). Economic development in a green economy pushes total employment up to 4.8-4.9 billion in the G1 and G2 scenarios (3 per cent to 5 per cent above BAU) (see Table 4). Depending on the investment simulated, and its timing, the total net direct employment in green sectors may decline in the short-term (primarily due to a decline in the fishery and forestry sector employment<sup>15</sup>), to then converge or rise above BAU employment in the medium to long run. The employment gain is projected to range from 134 million to 238 million for the G1 and G2 scenarios, depending on the projected growth of sectors that depend on natural resources.<sup>16</sup> In the additional BAU scenarios, employment is expected to range between 97 million and 176 million higher than BAU in 2050, which assumes, perhaps optimistically, that the trend of depletion of natural stocks does not inhibit production and employment growth. On the other hand, when accounting for the indirect employment effect across the economy as well (jobs created or lost in sectors depending on the ones analysed in more details in this study, e.g. fish distribution), we observe a growth in the range of 149 million to 251 million jobs for green

scenarios and 126 million to 223 million for BAU1 and BAU2 scenarios respectively by 2050. The results highlight the need to confront transition costs of greening, particularly with regard to retraining and repositioning labour for a lower carbon future.

More specifically on short-term impacts, world GDP will be slightly higher (less than 1 per cent in 2015 and 2020) in the additional BAU scenarios, relative to green cases. In 2020, total GDP in both scenarios will reach about US\$ 91-92 trillion, or 2.5 per cent to 4 per cent above BAU. In accordance, total employment will be 8-21 million (or 0.2 per cent to 0.6 per cent) lower in a green economy than in BAU1 and BAU2 cases, respectively by 2020, while it will be 2 to 3 per cent higher in G1 and G2 when only net direct employment in green sectors is considered.

Pressure on natural resources increases as GDP grows, and tends to slow the rate of GDP growth in both BAU1 and BAU2. Lower soil quality, higher water stress and fossil fuel prices all impact GDP negatively, in turn impacting indicators such as the HDI. Natural resources have varied impacts on the ecological footprint, which pushes resource use to 2.2 times what the planet can sustainably generate by 2050 in the BAU2 case, from 1.5 times in 2010 and 1.7 times in 2020. In the G1 and G2 scenarios, while investments support the transition to a lower carbon and more resource efficient economy, they generate higher GDP, as well as greater energy and water demand than would otherwise have been the case. As a consequence, the impact of green investments on resource conservation will be

15. Employment in the fisheries sector, when adopting the second approach proposed in the Fishery Chapter (i.e. the reduction of fishing capacity will affect primarily large vessels and industrial production), will be reduced by only 1-1.2 m people in the short-term – as opposed to a loss of about 10 m direct jobs. In this case, employment in the fishery sector in the longer-term will be largely above the BAU cases.

16. As noted above, the T21-World model does not assume full employment. In addition to the further details on employment per sector are presented below, an additional analysis of employment impacts based on contributions by the ILO can be found at [www.ilo.org/wcmsp5/groups/public/@ed\\_emp/@emp\\_ent/documents/publication/wcms\\_152065.pdf](http://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_152065.pdf).

partially offset by the additional GDP and associated consumption. Synergies, as explained below, can be found in investments in energy efficiency and renewable energy among others, because they generate a net reduction in fossil fuel demand, which in turn pushes prices below the BAU projection and generates considerable savings (or avoided costs) over time, despite the impact of the rebound effect.

As a result of green investments, global energy demand and CO<sub>2</sub> emissions will be mitigated considerably by 2050 relative to BAU (Figure 14). Even without explicitly modelling and analysing the positive impacts on emissions of transitioning to conservation agriculture,<sup>17</sup> we project a concentration in the range of 500-600 ppm in the green scenarios.<sup>18</sup> This indicates a moderate to unlikely probability that global warming will be limited to 2°C, as indicated in the IPCC AR4 report (IPCC 2007). More specifically, the projections result in a 36 per cent reduction in global energy intensity by 2030 in the G2 case, with the annual volume of energy-related CO<sub>2</sub> emissions declining to 30-20 Gt in 2050 from 30.6 Gt in 2010, also a 40 per cent and 60 per cent below BAU in 2050 for the G1 and G2 scenarios respectively, which is more significant than the short-term mitigation (reducing BAU by 3 to 6 per cent in 2015 and 7 to 15 per cent in 2020). Non-energy related emissions from fertiliser use, deforestation and harvested land will be lower than BAU by 16 to 25 per cent, 33 per cent and 1 per cent in 2015, and 45 to 68 per cent, 55 per cent and 4 per cent, respectively in 2050. It is worth noting when considering the enactment of a cap and trade mechanism with carbon prices aligned with the recent US domestic proposal (reaching US\$ 77 per tonne of CO<sub>2</sub> by 2030 and US\$ 221 by 2050, in constant US dollars at 2010 prices), that the reduction in emissions from the green economy investment would represent a savings in avoided permit costs of about US\$ 1000-1,650 billion per year on average between 2012 and 2050.

Finally, under the green economy scenarios, the ecological footprint will also improve in the medium to long run after a slight increase in the short-term, with the biocapacity ratio reaching 1.5 (or 4 per cent to 6 per cent below BAU) in 2015 and then stabilising at 1.4-1.2 throughout 2050, well below 2.0 in the BAU and 2.21-2.4 in the BAU1 and BAU2 scenarios (See Figure 15), and years of life expectancy lost due to emissions will be reduced by 3.6 per cent and 7 per cent on average in the G1 and G2 cases.

17. Due to the lack of global estimations on soil carbon absorption under conservation agriculture practices.

18. The concentration of emissions could be lowered to 450 ppm when accounting for the potential carbon sequestration of organic and conservation agriculture. Conservative estimates for the annual global sequestration potential of OA amount to 2.4-4 Gt CO<sub>2</sub>-eq, while other estimates point at a potential of 6.5-11.7 or even more (see Müller and Davis (2009); Nelson et al. (2009)).

Since the green investments simulated have economic impacts (e.g. GDP), as well as social (e.g. employment, poverty) and environmental impacts (e.g. energy consumption, emissions, land and water management), the context in which they are applied are particularly relevant to the analysis. Developing countries, such as sub-Saharan countries, facing extreme poverty and considerable challenges in reaching the Millennium Development Goals (MDGs) (World Bank 2007), are heavily dependent on agriculture and highly vulnerable to climatic changes. Improving socio-economic conditions, through higher access to water and energy, but also improved nutrition, and the efficient utilisation of natural resources are key goals of green economy strategies in these countries. Developing countries strive to improve productivity and increase their economic resilience in order to sustain strong economic growth. Here, energy and resource efficiency are key to longer-term development. Equatorial nations, often endowed with oil and other natural resources, are a good example: being a net exporter of resources these countries can profit from a reduction in domestic demand, and by preserving forest and other stocks of natural resources - possibly through payments for ecosystem services - can maintain Earth's biodiversity stocks. Finally, developed countries can more actively contribute to technology development and become a solid example of how mature economies can become resource efficient and reduce their carbon path, while creating jobs.

### Agriculture

In the case of the green investment scenarios, the additional investment in the agriculture sector (US\$ 118-US\$ 198 billion per year on average in 2011-2050 in G1 and G2, respectively) is allocated to more extensive use of organic fertiliser, agricultural research and development, pest control, and food processing. In these scenarios, the volume of agricultural (crop) production (excluding livestock forestry and fishery), is projected to increase by 7 to 11 per cent in 2030 and 11 to 17 per cent in 2050 compared with BAU.<sup>19</sup> Relative to BAU1 and BAU2, value added in the green cases will be between 3 and 5 per cent in 2030 and in the range of 5 to 9 per cent in 2050. This development is mainly due to higher yield per hectare (15 to 22 per cent higher than BAU and 6 to 10 per cent than additional BAU scenarios by 2050, with BAU1 and BAU2 having a higher yield than the green scenarios in the short- to medium-term only), driven by improved soil quality (thanks to the extensive use of organic fertilisers), R&D efforts and effective pest control. As is presented in Figure 16, natural crop yield per hectare depends on a number of primary factors, with the actual effective

19. When assuming that a price premium could be applied to certified products, or those goods originating from sustainable agriculture practices, the total value of agricultural GDP in the G1 and G2 cases would be on average 28 per cent higher than BAU1 and BAU2 and 40 per cent higher than BAU. This calculation assumes, among others, that producers have access to markets that demand (or reward) sustainable practices.

## Box 1: Changes in natural capital stocks

Conventional economic indicators, such as GDP, provide a distorted lens on economic performance particularly since such measures fail to reflect the extent to which production and consumption activities may be drawing down natural capital. By either depleting natural resources, or degrading the ability of ecosystems to deliver economic benefits, in terms of provision, regulating or cultural services, economic activity may be based on the depreciation of natural capital. Various alternative approaches to adjusting the system of national accounts and aggregate economic indicators are being refined and discussed at the international level (e.g. Integrated Environmental and Economic Accounting – SEEA<sup>1</sup>).

The T21 model tracks the evolution of various natural resource stocks over time as highlighted in Figure 12 and in more detail in section VI of the Technical Background Material. The green economy scenarios are characterised by investment in and recovery of these stocks, providing a basis for sustained income gains over the medium- to longer-term.

It is insightful to undertake some additional calculations, using relatively simplistic assumptions, to generate some sense of the potential economic magnitude of the improved management of natural capital. The table below presents changes in the value of three resource stocks-fossil fuels, forests and fisheries-over the short- and medium-term in both absolute terms and relative to GDP. The change in physical values for fossil fuels and fish is valued using estimates of the economic value (unit rent), and for forests, using estimates from TEEB. Following the methodology employed by the World Bank (2006), these estimates of depreciation (or appreciation-where changes below are positive), these amounts can be seen as reflecting additional components of a measure of negative net savings in global wealth (as could be represented in asset accounts following system of national accounts).

According to these calculations, annual drawing down fossil fuel stocks is equivalent to 1.8 per cent of current GDP. Under BAU, this remains roughly the same in the short-term and then rises in the medium- to longer-term. The G1 and G2 scenarios reverse this trend with this depreciation, as a ratio to GDP, declining over the period 2010-2050, reaching 0.5 per cent of GDP by 2050 under G2, reflecting the marked reduction in fossil fuel dependence of the global economy in this scenario.

Lower and upper bound values of the value of the depreciation of natural capital in the form of forest land are presented due to the wider range of uncertainty concerning global reference values (see section VI, Technical Background Material, which makes use of results from TEEB research). Current depreciation of forestland is thus estimated at between US\$ 2.8 billion and US\$ 2.6 trillion - spanning three orders of magnitude - which is between 0.01 per cent and 5.4 per cent as a proportion of GDP. Note that the higher range estimates are comparable to, and indeed well above, those for fossil fuels. The green scenarios considerably reduce this loss within the short-term and turn it around into modest positive growth - or appreciation instead of depreciation - by 2050.

Similar improvements can be seen in fish stocks. The current estimate of depletion of this natural asset is valued at US\$ 116 billion per year, which is -0.24 per cent when expressed as a ratio to GDP. The green scenarios succeed in reducing this lost and over the medium- to longer-term, stabilising it or turning into a net appreciation.

Although a range of results is only presented for forest resources, due to the wide range of existing measures, the estimates for fossil fuels and fish could also be developed into ranges. These would, however, probably not have the same degree of variability as those for forests.

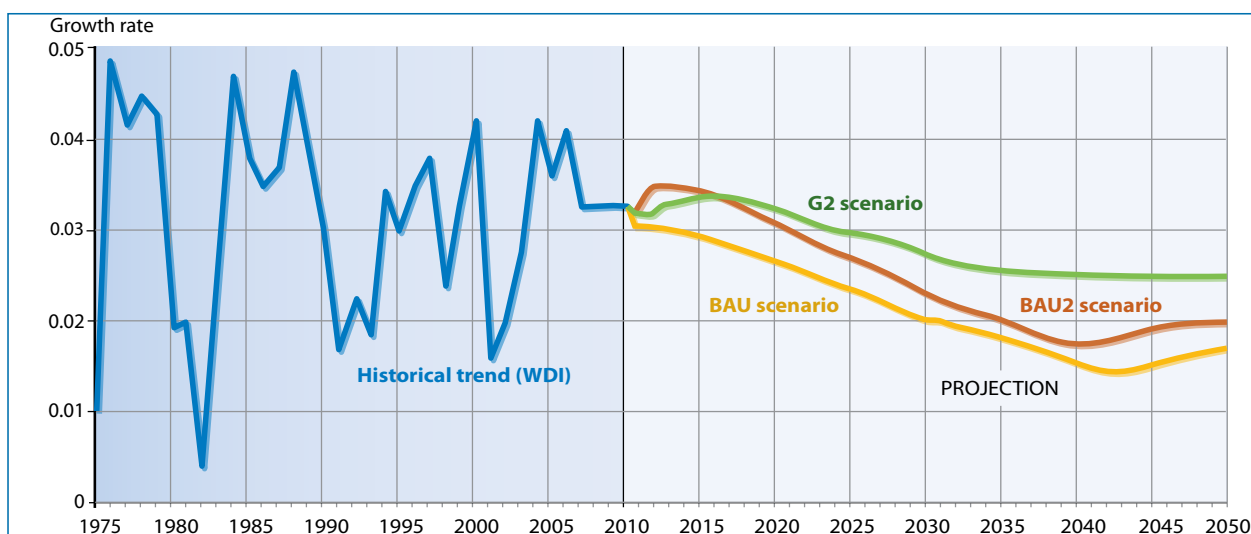
It is important to bear in mind that even though the results are presented in a way that makes comparison between the estimated depreciation of the different assets comparable, this should be done and interpreted with care. In particular, the three assets are not substitutes for each other. Fossil fuels are a source of energy. Forests, including how they are valued here, provided a range of provisioning and regulating services, both locally but also much more widely, including even globally. Fisheries provide a major source of protein and employment to a substantial proportion of the world's population but many of these people would not be able to substitute forests for fisheries as a source of food and livelihoods, or vice-versa.

In general, the results underline the substantial economic significance of how the world is currently managing its natural capital, as well as the potential gains that can be won from pursuing a green economy strategy. This allows the global economy to invest in natural capital that is critical for sustained well-being, while reducing the dependence on fossil fuels.

		2011	2015					2020				
	Unit		BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
Real GDP	US\$ billion/year	69,334	78,651	79,306	77,694	78,384	78,690	91,028	92,583	88,738	90,915	92,244
NDP	US\$ billion/year	59,310	69,082	69,625	68,244	68,898	69,174	79,700	80,981	77,705	79,766	81,007
Change in fossil fuel stocks	US\$ billion/year	-1,212	-1,447	-1,471	-1,413	-1,309	-1,221	-1,730	-1,788	-1,645	-1,392	-1,163
	ratio to GDP	-1.8%	-1.8%	-1.9%	-1.8%	-1.7%	-1.6%	-1.9%	-1.9%	-1.9%	-1.5%	-1.3%
Change in fish stocks	US\$ billion/year	-160	-151	-151	-149	-77	-36	-141	-141	-134	-46	1
	ratio to GDP	-0.24%	-0.19%	-0.19%	-0.19%	-0.10%	-0.05%	-0.16%	-0.15%	-0.15%	-0.05%	<0.01%
Adjusted NDP	US\$ billion/year	57,992	67,533	68,052	66,733	67,515	67,878	77,875	79,097	75,973	78,305	79,771
		2011	2030					2050				
	Unit		BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
Real GDP	US\$ billion/year	69,334	116,100	119,307	110,642	117,739	122,582	164,484	172,049	151,322	174,890	199,141
NDP	US\$ billion/year	59,310	100,686	103,215	96,006	102,638	107,133	139,621	145,483	128,599	149,887	172,198
Change in fossil fuel stocks	US\$ billion/year	-1,212	-2,616	-2,787	-2,373	-1,692	-1,127	-4,705	-4,972	-4,312	-2,306	-979
	ratio to GDP	-1.8%	-2.3%	-2.3%	-2.1%	-1.4%	-0.9%	-2.9%	-2.9%	-2.8%	-1.3%	-0.5%
Change in fish stocks	US\$ billion/year	-160	-122	-122	-116	-9	52	-91	-91	-88	40	142
	ratio to GDP	-0.24%	-0.11%	-0.10%	-0.10%	-0.01%	0.04%	-0.06%	-0.05%	-0.06%	0.02%	0.07%
Adjusted NDP	US\$ billion/year	57,992	97,988	100,345	93,558	100,939	105,930	134,855	140,450	124,231	147,509	171,129

Box 1 cont. Notes: The results here, based on calculations presented in section VI of the Technical Background Material, consist largely of supplementary calculations using T21 model results on evolution of physical natural resource stocks over time and complementing that with data from other studies. Adjusted net domestic product (NDP) deducts the changes in the value of fossil fuel and fish from NDP\*.

\* See <http://unstats.un.org/unsd/envaccounting/seea.asp>



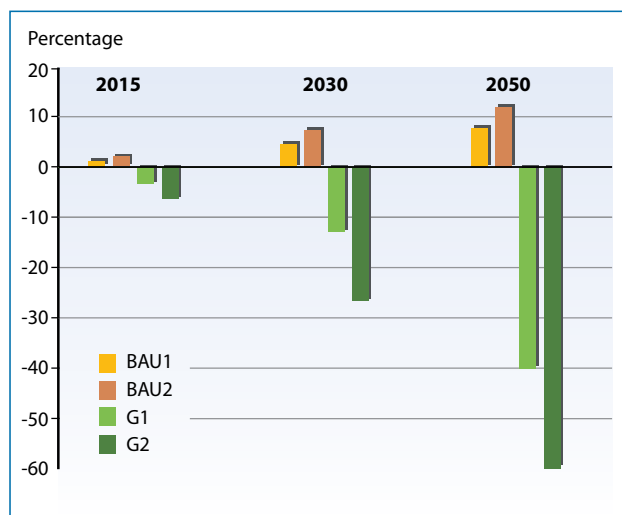
**Figure 13: Trends in annual GDP growth rate, historical data (WDI, 2009) and projections in BAU, BAU2 and G2 scenarios**

yield being further affected by pre-harvest losses (in addition, post-harvest losses will reduce the amount of final food supply).<sup>20</sup>

Higher yields allow using a lower amount of land, 4 per cent less than BAU and 6.2 per cent less than additional BAU cases in 2050. As a result, the quantity

of calories consumed per person in the green cases will be higher than BAU and additional BAU investment scenarios, especially in the longer-term, by 4 to 7 per cent and 1 per cent to 1.4 per cent by 2030 respectively, reaching close to 3,100 Kcal/person/day. By 2050 the overall quality of nutrition is projected to rise by 9 to 13 per cent relative to BAU, with 3,250 and 3,380 Kcal being consumed per person per day. In line with the agricultural production increase in the green scenarios, employment in the agriculture sector will reach 1.62

20. Causal loop diagrams (CLD) for each sector modelled and analysed in the GER are presented in section VII, Technical Background Material.



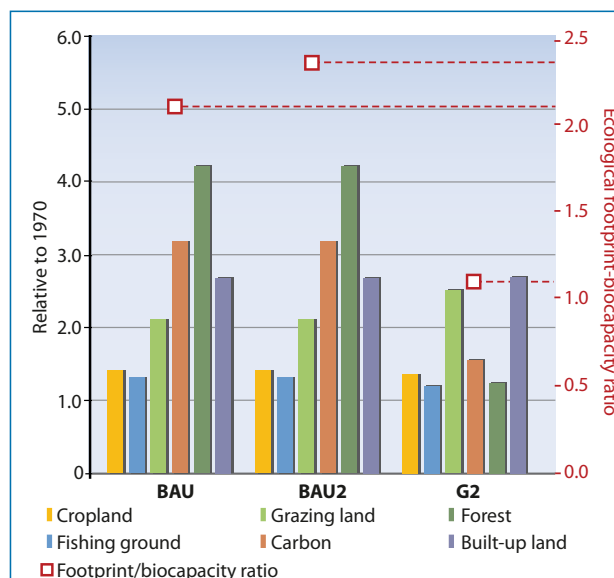
**Figure 14: Fossil fuel CO<sub>2</sub> emissions in additional BAU and green scenarios relative to the BAU case (selected years)**

billion and 1.7 billion in 2050 in the G1 and G2 cases respectively, well above the BAU1 (1.6 billion), BAU2 (1.66 billion) and BAU (1.5 billion) scenarios.

In line with the medium- to long-term improvements, the same trends are observed in the short-term, albeit to a lesser extent, with crop production and nutrition being 3.3 to 5.1 per cent and 1 to 2 per cent higher than BAU in 2015. Soil quality, in particular, will rise by only 1 to 2 per cent in five years compared to 10 to 14 per cent and 21 to 27 per cent in 20 and 40 years due to the delayed effect of more sustainable agriculture practices.

It can be argued that green investments should be allocated to agriculture more predominantly where this sector is a major driver of economic and social development. This is the case of sub-Saharan countries, among the least developed countries in the world, where investments in the promotion of more sustainable agriculture could increase yields and production, also improving nutrition and food security. As an exercise, if all investments simulated in the primary sector (including agriculture, fishery and forestry) were allocated to agriculture-based countries, the value added per capita of rural inhabitants would grow on average by around US\$ 600 per year, or US\$ 1,450 when considering only the rural poor population.<sup>21</sup> Even if only 20 per cent of these investments were to reach agriculture-based countries, increasing per capita GDP by US\$ 118 and US\$ 290 per person per year for rural population and rural poor respectively, it would still be an important increase considering that GDP per capita in agriculture-based countries in 2005 was US\$ 524 per year. A disaggregated agricultural sector, for example most simply between

21. Population estimates and trends were calculated using data published in the 2008 World Development Report (World Bank 2008).



**Figure 15: Composition of ecological footprint in 2050 in various scenarios, relative to 1970 value (left), and indication of the projected footprint-bioproductivity ratio in 2050 (right)**

smallholder agriculture of developing countries and high external input agriculture typical of industrialised countries, would provide an even clearer picture of the potential equity benefits of such investments.<sup>22</sup>

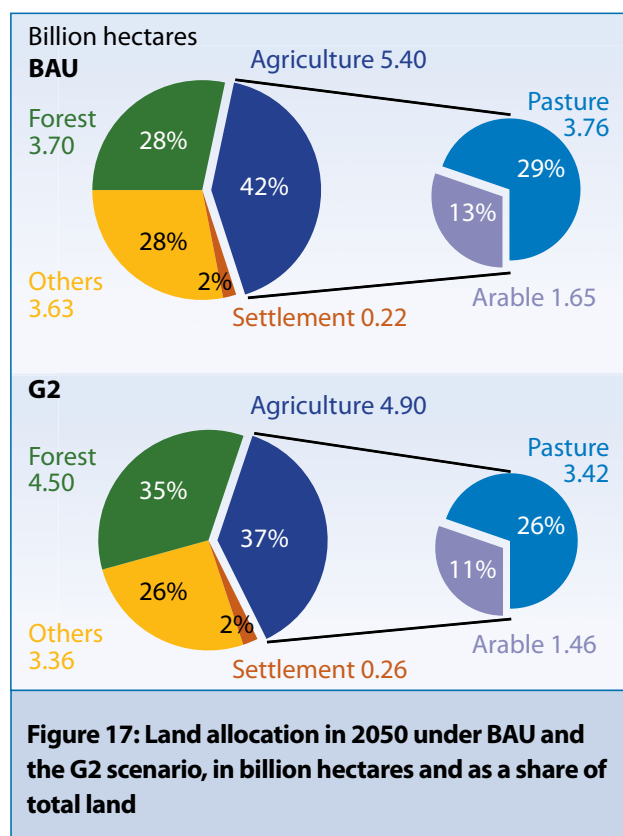
### Forestry

In the green economy scenarios, green investment in the forestry sector, totalling US\$ 40 billion per year on average between 2010 and 2050, is allocated to both deforestation reduction and reforestation. The average annual deforestation rate of natural forests in the green scenarios is projected to be 50 per cent lower than BAU between 2010 and 2030 (Figure 17 and Figure 18). With the deforestation rate declining to 6.7 million hectares per year from 2030 in the green cases, an estimated 283 million hectares (or 8 per cent) of natural forest area is saved. Additional green investments will considerably increase reforestation (planted forest) to 19 million hectares per year in 2050. Thus, planted forests will be 497 million hectares (or 143 per cent) more than BAU by then, providing sufficient resources for forestry production to exceed baseline projections in the longer-term (after 2015). In accordance with the forestry production growth in green scenarios, forestry employment will reach 30 million people in 2050, which is 20 per cent above BAU. As a result of the enhanced reforestation and avoided deforestation efforts, total forestland is projected to reach 4.5 billion hectares over the 40-year period, outperforming the BAU case by 21 per cent. This will allow 502 Gt of carbon to remain in

22. The feasibility depends primarily on the availability of adequate data and this is being explored in further versions of the model.







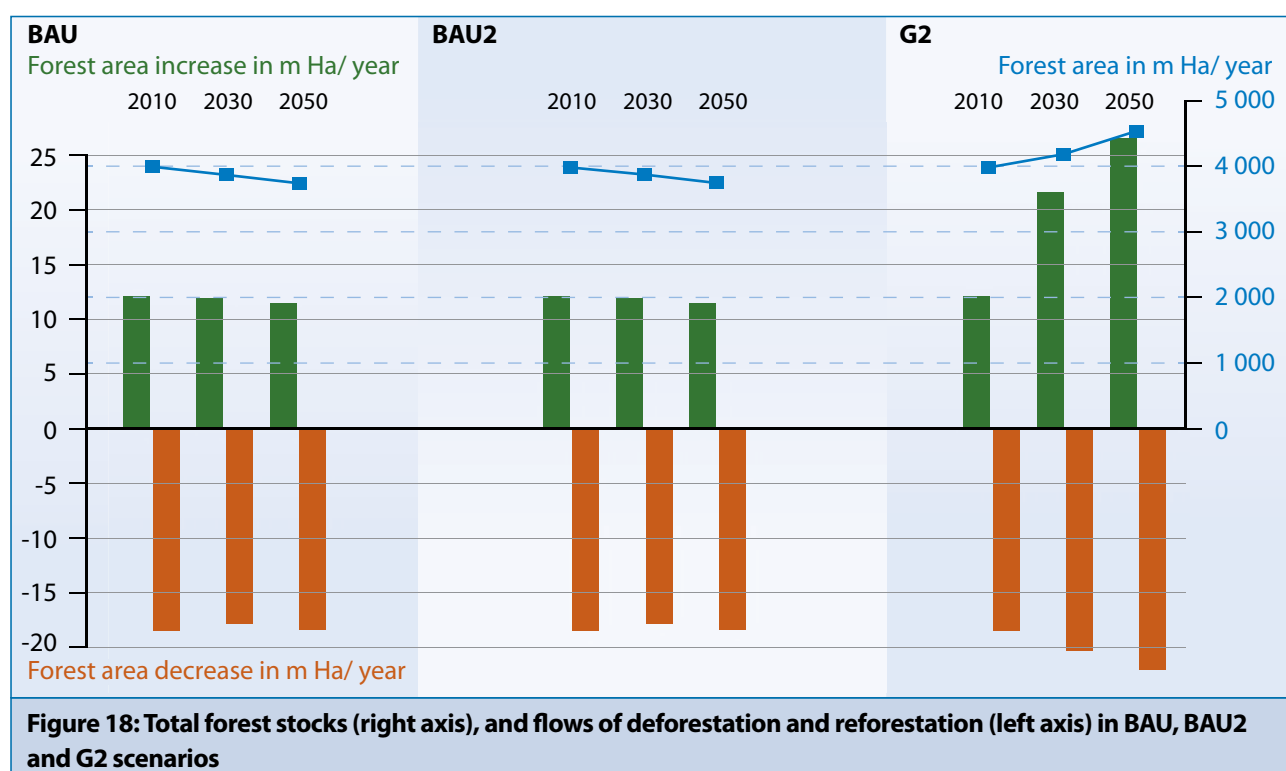
Forests are very important for many countries, where both their harvesting and preservation are important economic drivers. In certain cases, waste land could be converted to forests over time, without negative impacts on agriculture and settlements. Simultaneously, better control measures would reduce the rate of deforestation, limiting the rapid depletion of forestland and natural resources.

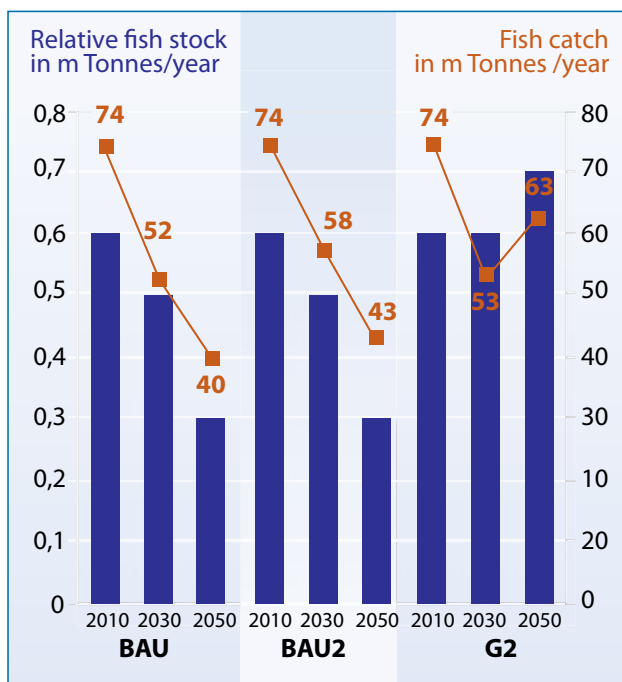
### Fisheries

The green investment in fisheries, (US\$ 118-198 billion per year over the next 40 years) is allocated to three areas: 1) vessel buyback programmes to prevent over-capacity of fishing, 2) retraining and relocation of fisheries employment, and 3) fisheries management to support fish-stock regeneration. In these green scenarios, the fishery sector will also move toward sustainability through a reduction in vessel capacity and investments in the management of fish stocks.<sup>23</sup> With the withdrawal of vessels between 2011-2020, fishing capacity will be 26 per cent lower than BAU by 2020. This will cause the global fish catch to drop to 50 million tonnes by 2017, considerably lower than current levels – and one-fourth lower than BAU – but a necessary step to restore the fish stock, which would halt its decline and level off around 2020. Once the decline of the fish stock is curbed and investments are freed up to promote better management of the industry, the fish catch could grow well above the projected 50-63 million tonnes in 2050 in the G1 and G2 cases, with 2 to 4 per cent more catch per year on average than BAU between 2010 and 2050.

While lower fishing capacity will reduce direct employment in the short-term (by 19-20 million people in 2020 under G1 and G2 relative to 24 million under BAU and 29 million in 2011), higher stock levels and better management of the sectors are projected

23. Fish stock represents the total number of fish. Modelled as a stock variable, its value changes by accumulating fish birth and reducing by fish death per year, and is dependent on values of previous year. Similarly, forest and agricultural land stocks represent sizes of land areas for forests and agricultural production, that changes by annual conversion among types of land. Other stocks include resources of fossil fuels and water sources.





**Figure 19: Fish stock relative to 1970 level (left axis) and fish catch (right axis) in BAU, BAU2 and G2 scenarios**

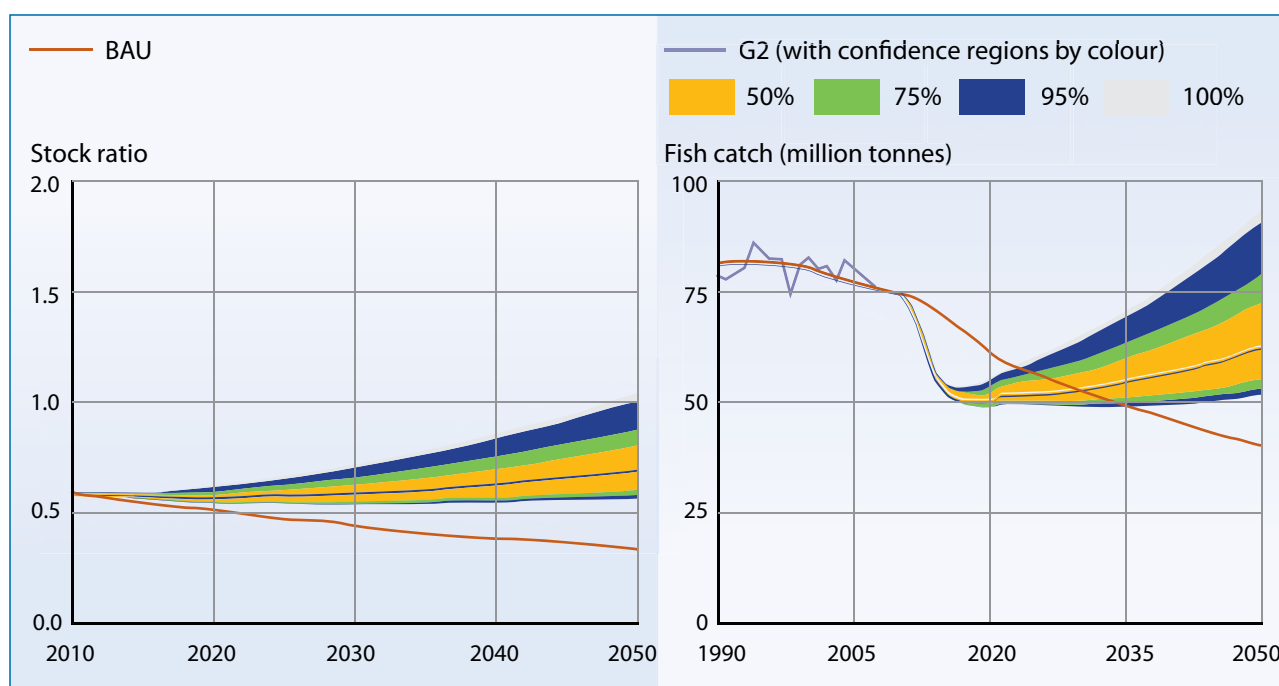
to lead to 27 to 59 per cent higher employment level in the green scenarios relative to the baseline by 2050.<sup>24</sup> On the other hand, additional BAU investments,

24. Employment in the fisheries sector, when adopting the alternative approaches proposed in the Fishery chapter (e.g. the reduction of fishing capacity will affect primarily large vessels and industrial production), will be reduced by only 1–1.2 million people in the short-term – as opposed to a loss of about 10 million direct jobs. In this case, employment in the fishery sector in the longer-term will be largely above the BAU scenarios.

assumed to be allocated to current business practices, will further deplete fish stocks, expected to be largely exploited by 2050 (it is estimated that only 56 per cent and 33 per cent of the fish available in 1970 will be in place by 2015 and 2050), leaving few resources for what could be currently considered cost-effective fish catch (Figure 19). Here again, the results indicate the need to offset transition costs in the short run to reach higher productivity and employment levels in the future under a green economy scenario.

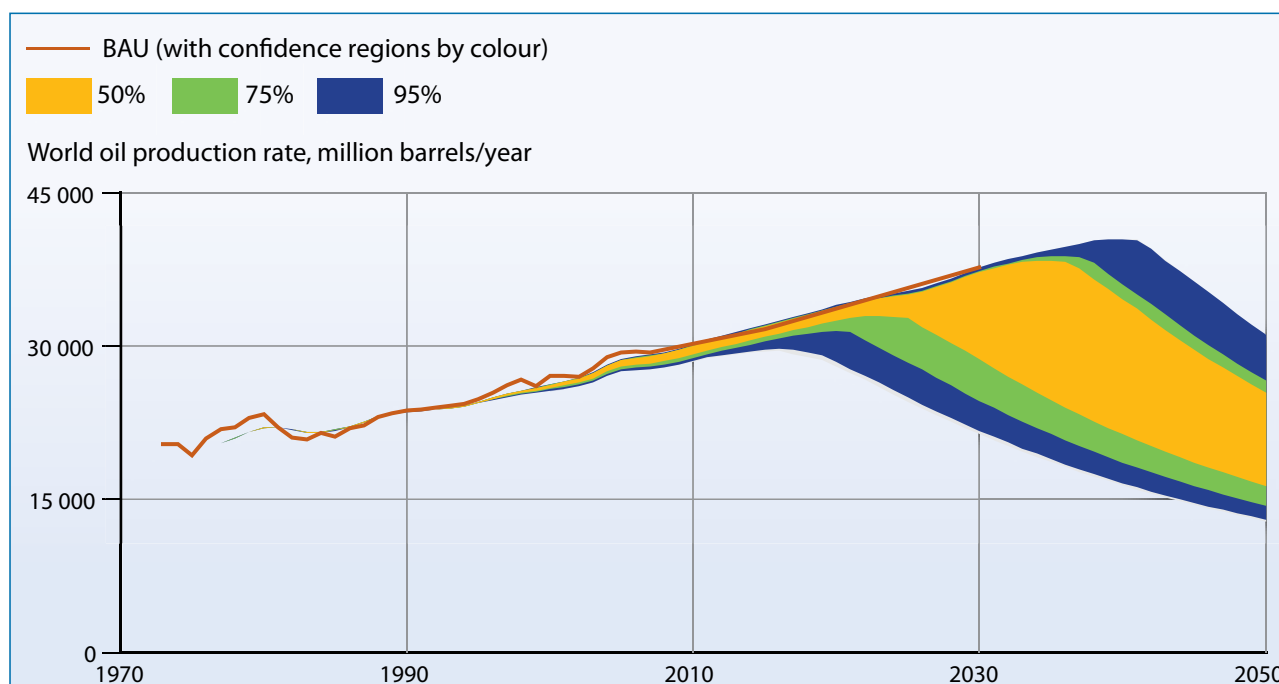
To carefully evaluate the effectiveness of investments in the fishery sector, a variety of scenarios were simulated where the cost (effectiveness) of fish-stock management interventions are assumed at between US\$ 354 and US\$ 1,180 per ton (BAU is US\$ 736, or a 1:4 ratio of cost/benefit), following a random uniform distribution. The results of the corresponding changes in fish stock and fish catch are presented in Figure 20.

In the two extreme scenarios, the global fish stock in 2050 will respectively return to the 1970 level (lowest cost case) and current level - around half of 1970 volume - (highest cost case). In the G2 scenario, around 70 per cent of the amount of fish resources in 1970 is available by 2050, which drops to a mere 30 per cent under BAU, where no additional stock management activities are assumed. As a result, the world fish catch will recover, after a short-term decline, to the relatively wide range of between 50 million tonnes and 90 million tonnes per year in 2050,



**Figure 20: Results of the sensitivity analysis for (a) fish stock relative to 1970 level (left) and (b) fish catch in tonnes/year (right)<sup>21</sup>**

<sup>21</sup> Area in yellow: 50 per cent of the range of scenarios in the sensitivity analysis, green for 75 per cent, blue for 95 per cent and grey for 100 per cent.



**Figure 21: Global conventional oil production scenarios considered in the GER**

"World oil production rate": Annual conventional world oil production, in million barrels/year.

exceeding the baseline volume in early 2020s and in 2035 under the two scenarios.

## Energy

The green investment in energy will contribute to both the supply side (expansion of low-carbon power generation and biofuel production), and the demand side (energy efficiency improvements for end-use energy demand, involving industry, transport and buildings sectors). It is worth noting that synergies are found under an early peak-oil scenario (see also Bassi et al. 2010), where the increased efficiency and a faster transition beyond fossil fuels, driven by green investments, will reduce energy prices below BAU throughout the simulation period, making the economy more resilient and sustaining economic growth. A variety of scenarios were simulated to study and evaluate the impacts of the timing of several conventional oil production trends. The total amount of resources and reserves was changed to endogenously obtain world oil production. While a more detailed analysis is available in Bassi et al. (2010), the range of scenarios analysed is presented in Figure 21.

## Energy supply

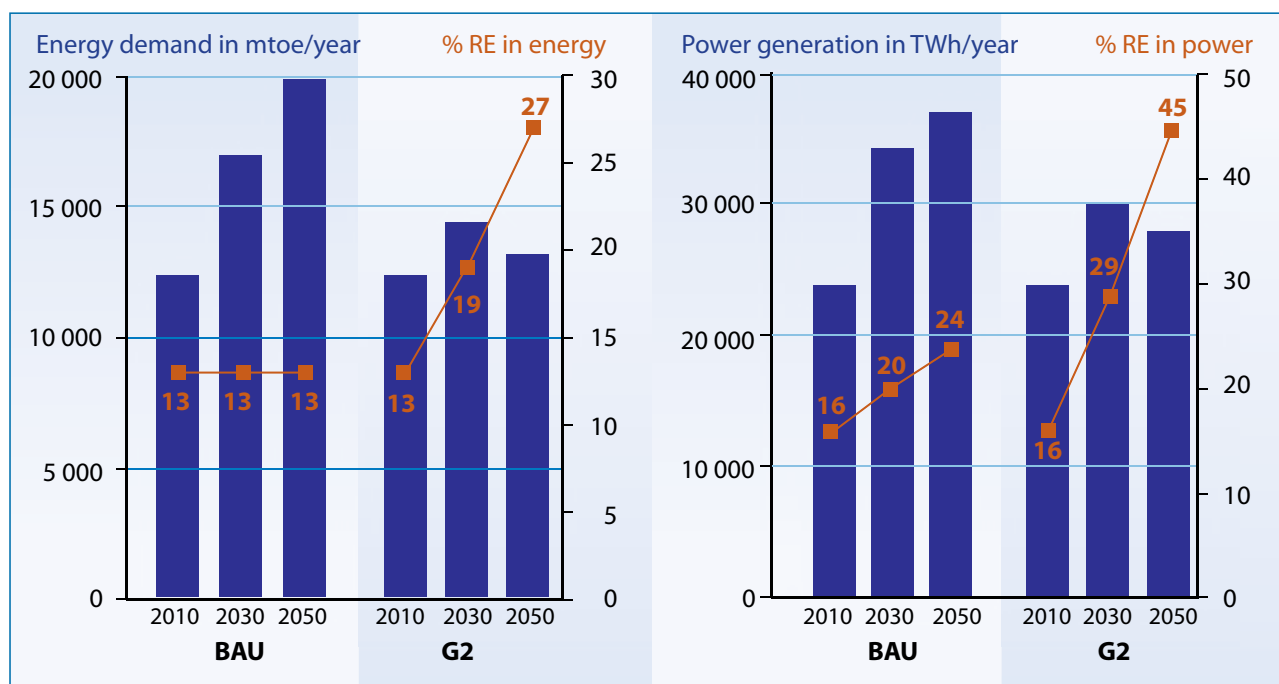
In the green economy scenarios, the energy supply sector will receive green investment of US\$ 174 - US\$ 656 billion per year between 2010 and 2050 to expand biofuel production and power generation using renewables and advanced technologies (such as CCS).

The substitution of green investment in clean energy for additional BAU investments in carbon intensive energy sources will increase the penetration rate of renewables

to 19 to 27 per cent of total primary energy demand by 2050, compared with 13 per cent under BAU and 12 per cent in the BAU2 scenario.

In the power sector, the capacity of power generation by energy sources in green cases will reach: 1.7 TW (hydro), 204 GW (waste), 955-1515 GW (wind), 38-54 GW (geothermal), 655-1304 GW (solar), 8-21 GW (tidal), and 3-16 GW (wave) in 2050 respectively. As a result, these renewable sources of energy will account for 29 to 45 per cent of total electricity generation by 2050, significantly higher than the 24 per cent in BAU and 23 per cent under BAU2. The share of fossil fuels, coal in particular, will decline accordingly to 34 per cent in 2050, compared with 64 per cent in the BAU scenario, mostly owing to the expansion of renewables (Figure 22 and Table 5).

The green scenarios are expected to see the introduction and major expansion in second generation biofuels. In 2025 and 2050, the production of second generation biofuels is projected to reach 151-490 billion litres of gasoline equivalent (lge) and 254-844 billion lge, contributing to 4.2 to 16.6 per cent of world liquid fuel production by 2050 (8.4 to 21.6 per cent when first generation biofuels are considered). Between 12 per cent and 37 per cent of agricultural and forestry residues would be needed in the G1 and G2 scenarios respectively. In case residues above 25 per cent are not available or usable (as indicated by the IEA 2010), marginal land is assumed to be used. Between 330,000 and 1 million jobs would be created for biofuels and agriculture residues, and the figure would increase up to 3 million if a mix of agricultural residues and conventional feedstocks is



**Figure 22: Trends in BAU and G2 scenarios (a) in total energy consumption (left axis) and renewable penetration rate (right axis), (b) power generation (left axis) and renewable penetration rate in power sector (right axis)**

used. Additional scenarios were simulated to test the impacts of variations in the labour intensity of second-generation biofuels, for which very few estimates were found (e.g. Bio-era 2009). The values considered range from 1/6 and 1/3 of the employment of first generation biofuels. Also considered is a scenario where second generation biofuel share the same labour intensity as first generation biofuels. In the first case, the range considered would result in projected biofuel employment to grow rapidly and reach between almost 3 million and 4 million in 2050, compared with 3.1 million in G2 and 2 million under BAU. On the other hand, assuming that the labour intensity of biofuels does not change with the introduction of second generation biofuels, total employment would reach 7.7 million by 2050.

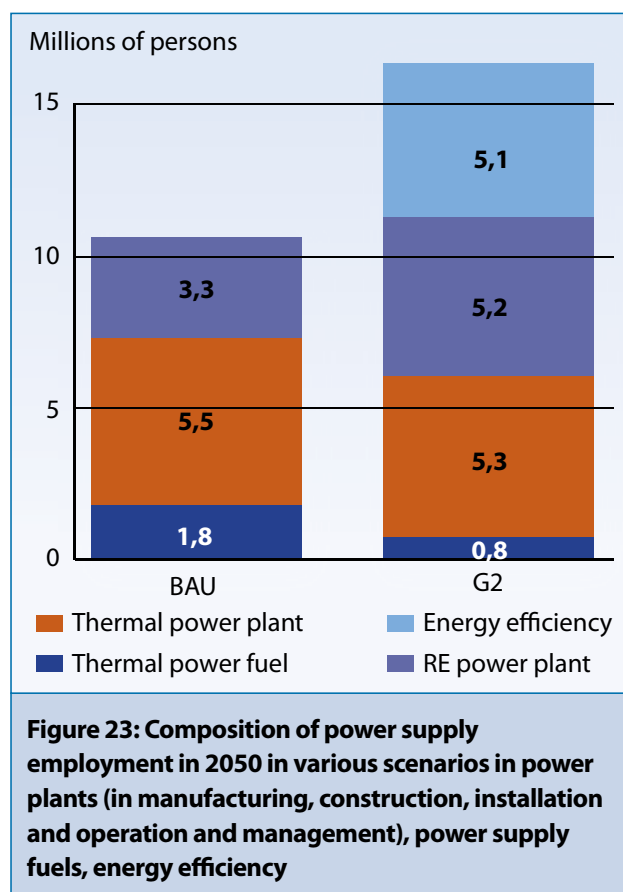
The total employment in the energy sector is projected to slightly decrease over time in the BAU scenario, reaching 18.6 million by 2050 against 19 million in 2010, owing to increasing labour productivity in fossil fuel extraction and processing. In the green scenarios, short-term net job creation is observed (for both G1 and G2) primarily due to the higher labour intensity of renewable energy versus thermal power generation. In the longer-term instead, the G1 case shows lower employment levels than BAU (4 per cent below BAU in 2050), while the employment in the G2 case (23.3 million) will be higher than the BAU1 scenario (19.5 million), and will greatly outperform the BAU (18.6 million) by almost 26 per cent when energy efficiency jobs are considered (Figure 23).

%	2030				2050	
	*WEO	GER	*WEO	GER	*ETP	GER
<b>Scenarios</b>	Reference	BAU	450	G2	BLUE Map	G2
Coal	29	31	19	25	15	15
Oil	30	28	27	24	19	21
Gas	21	23	21	23	21	25
Nuclear	6	6	10	8	17	12
Hydro	2	2	3	3		4
Biomass and wastes	10	8	14	12	29	16
Other RE	2	3	5	5		8
<b>Total</b>	100	100	100	100	100	100

**Table 5: Comparison of energy mix in 2030 and 2050 in various GER and IEA scenarios**

Source: WEO 2010 (IEA 2010); ETP 2010 (IEA 2010)





Considering short-term impacts of the green investment, the energy sector will see the expansion of renewable energy with less significant improvements compared with the longer-term: the renewable energy penetration rate will rise to 19 to 22 per cent in power supply and 14 to 17 per cent in total energy supply by 2020, from 18 per cent and 13 per cent respectively in BAU. By then, green investments will push the production of second-generation biofuels up to 133-424 billion lge, creating 1.5-1.9 million jobs (12 per cent to 40 per cent above BAU) in biofuel production. As a result, total energy employment will be 5.5 per cent higher in G2 (21 million) than the baseline (20 million), but 2 per cent lower than BAU in G1 (19 million). These figures include the 0.25-0.62 million jobs created by 2020 through energy- efficiency improvements.

### Energy demand

Additional green investments, totalling US\$ 277-US\$ 651 billion per year over the next 40 years, are allocated to improve efficiency for end-use energy demand, especially in power use (across sectors) and in fuel use in industry (see also HRS-MI 2009) and transport (transport investments are analysed in a separate section looking at the expansion of the public transport network as opposed to increased efficiency).

These energy savings efforts are projected to curb total primary energy demand by 4 to 6 per cent, 10 to 15

per cent and 26 to 34 per cent by 2020, 2030 and 2050 respectively compared with BAU, reaching 14,120-13,709 Mtoe in 2020, 15,107-14,269 Mtoe in 2030 and 14,562-13,051 Mtoe in 2050.<sup>25</sup> Total fossil fuels demand will decline by 6 to 12 per cent relative to BAU in 2020, and 22 to 41 per cent relative to BAU and up to 28 per cent to 48 per cent relative to BAU1 and BAU2 by 2050, driven by the expansion of the public transportation network (rail and buses) and by improvements in energy efficiency (e.g. in the industrial and buildings sector), as well as the increased use of renewable energy and waste, as mentioned above (IEA 2008).

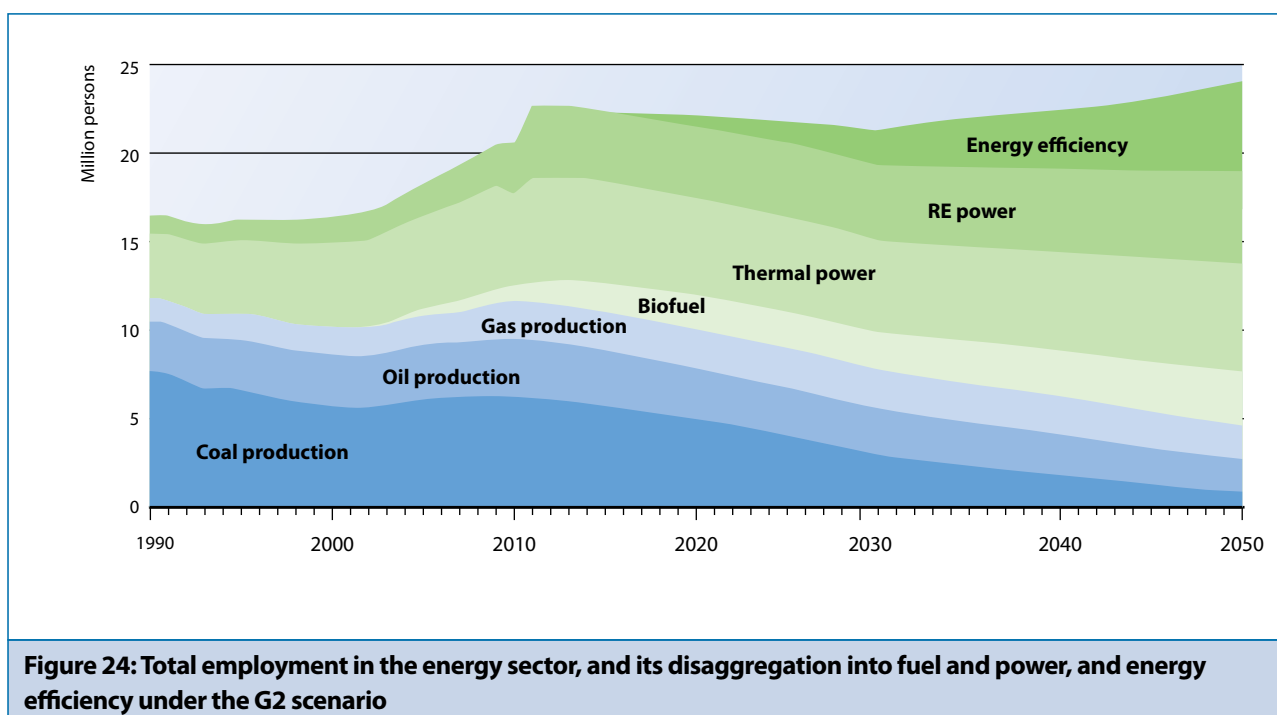
The lower energy consumption will generate considerable savings on energy expenditure (e.g. avoided capital and fuel costs in the power sector will result in savings averaging US\$ 415-US\$ 760 billion per year between 2010 and 2050).

Furthermore, green investments allocated to energy efficiency are expected to create an additional 2.9-5.1 million jobs by 2050, causing the total energy employment in G2 to reach 23.4 million in 2050, above the baseline by 26 per cent (Figure 23 for power-sector employment and Figure 24 for a detailed breakdown of energy employment).

### Transport

The green investments in the transportation sector, totalling US\$ 187-US\$ 419 billion per year over the 40-year period, will be allocated both to improve energy efficiency across all transport modes, as mentioned above, and to support the shift from private transport to public or non-motorised (e.g. walking or cycling) transport. In 2050, private cars account for only one-third of total passenger travel - in terms of passenger-km/year - almost cutting the baseline percentage in half, resulting in a reduction in the number of cars by 34 per cent relative to BAU. Accordingly, the shares of passenger travel carried by trains and buses increase drastically to 18 per cent and 35 per cent by 2050 in the G2 scenario. The combination of this modal transition, further energy efficiency improvements and expected changes in total travel volume is expected to lead to energy savings in almost all transport modes - between 57 and 75 per cent for cars and 40 to 65 per cent overall in the green economy scenarios relative to BAU. This outweighs the slight increase in rail and bus energy consumption (Table 6). As a consequence, total CO<sub>2</sub> emissions from transport energy use are expected to decline to 7.8-4.6 Gt per year in 2050 in the green scenarios, compared with around 13 Gt per year in the baseline. By then, cars will account for

25. As a point of comparison, energy efficiency in OECD countries has reduced projected growth in energy consumption by 56 per cent over the 30-year period, 1973-2004 (IEA 2008).



a declining share of the emissions from 53 per cent under BAU to 38 per cent in the green scenarios. Primarily as a result of the job gains in public transport expansion, total employment in the green scenarios will increase to 124-130 million in 2050 (or 5 to 10 per cent above the baseline).

In the short-term, private cars will account for 41 per cent of passenger travel due to green investments in 2020 compared with around half under BAU, allowing the share of rail transport to grow to 11 per cent from 7 per cent in BAU. As a result, the total energy consumption of automobiles is curbed by 28 per cent relative to BAU, resulting in a 20 per cent reduction in total energy consumption and emissions from all vehicles by 2020. At the national level we find synergies in allocating investments to increase fuel efficiency, expanding and electrifying the rail network. If non-thermal power sources are adopted, this leads to reduced liquid fuel demand, higher efficiency and lower carbon intensity. At the same time, the economy and employment will benefit from infrastructure construction and reduced congestion but short-term increases in emissions are

possible due to the higher demand of iron and steel, among other things.

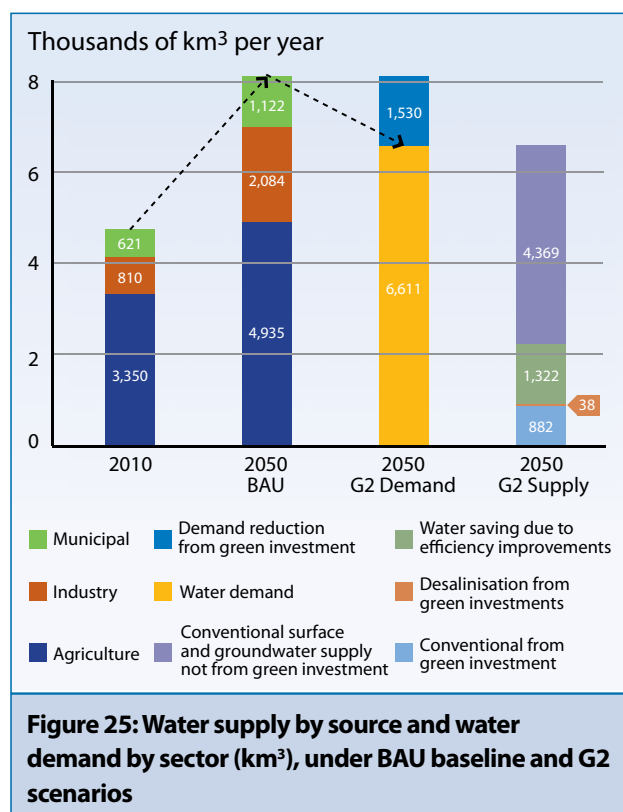
### Water

In the green economy scenarios, US\$ 118 - US\$ 198 billion per year is invested on average between 2010 and 2050 in the water sector to expand the access to potable water and water services, to improve water-use efficiency, and to increase water supply through desalination and supply management measures. With these investments, water demand will be curbed by about 24 per cent to 19 per cent in the G1 and G2 scenarios by 2050 relative to BAU (3 per cent by 2015 and 13 to 12 per cent in 2030). This reduction is mainly a result of increased water efficiency in the agriculture sector as well as investments in the industrial and municipal sectors. Furthermore, investments to manage and increase supply and improve access to water will support the preservation of groundwater and surface water, contributing to about 10 per cent of global water demand both in the short- (2015) and longer-term

Mtoe/year	2020		2030		2050	
Scenario	* WEO/450 Scenario	G2	* WEO/450 Scenario	G2	* IEA's BLUE Scenarios	G2
Total transport energy consumption	2,710	3,155	3,182	3,139	2,100-3,200	2,163
in which oil	2,483	2,699	2,891	2,526		
in which biofuel	193	427	245	580	400-800	874

**Table 6: Transport energy consumption in green scenarios of GER and IEA, in selected years**

Source: \* WEO/450 Scenario: WEO 2010 (IEA 2010); IEA's BLUE Scenarios: Transport energy and CO<sub>2</sub> (IEA 2009)



(2050) (Figure 25). In accordance with the higher availability of fresh water resources in the green economy scenarios, the fraction of population under water stress will increase to 60 per cent in 2020 and stabilise in the long-term to around 62 per cent in 2050, compared to 67 per cent in the baseline. Water-sector employment will reach 40-43 million in 2050, which is 24 to 19 per cent below BAU owing to the reduction in total water consumption, but it is still 30 to 38 per cent higher than the 2010 level. In the short-term, employment will remain about the same, 34 million in 2015 under the green and BAU scenarios. It is worth noting that investments in the water sector could have considerable impacts in developing countries, where interventions to improve sanitation would considerably increase access to potable water, and higher expenditure

in infrastructure could result in more efficient use of water and increasing agricultural yields - contributing to poverty reduction, especially in rural areas.

In the case of lower precipitation in the decades to come, water stress is projected to be higher and to have more serious impacts on, among others, agriculture production. More specifically, with precipitation being 10 per cent below BAU by 2050, water stress is expected to affect nearly 70 per cent of the population in 2050. Under this scenario, green investments will reduce water stress by about 6 per cent, reaching 64 per cent.

## Waste

In the green economy scenario, a total of US\$ 118 - US\$ 198 billion per year on average is invested in the waste sector to increase the waste collection rate and promote recycling and composting practices. The higher collection rate of wastes (around 82 to 83 per cent between 2010 and 2050) as well as the projected economic development in the green scenarios are projected to increase the total usable waste volume in BAU and green scenarios by 2 to 3 per cent in 2020 and 9 to 12 per cent in 2050. However, owing to the significant improvement in waste recovery (e.g. recycling rate is 7 per cent in green scenarios, 2.2 per cent in BAU and additional BAU cases in 2050), the annual amount of waste directed to landfills in the green scenarios will be much lower than the BAU scenario by 2050. Thanks to the improvements in upstream waste treatment, its employment will reach 25-26 million jobs in 2050, which is 2-3 million higher than under BAU (the employment gain in 2020 is 0.4-0.54 million). It is worth mentioning the contribution of recycling to reducing energy demand and emissions as well as production costs - positively affecting industrial GDP.

## 6 Conclusions

The simulation of future scenarios with an integrated cross-sectoral model highlights the characteristics of the green economy approach and provides an assessment of the global impacts of green investments, relative to BAU. These impacts are summarised below.

Undertaken at the global level, this analysis necessarily does not reflect different national or regional circumstances, which should be an area for additional work. Among other aspects, such analysis will need to pay attention to the means and ability of governments to direct investment at the scale envisaged, including necessary international financial flows.<sup>26</sup>

The projections in the additional BAU investment scenarios (BAU1 and BAU2), are for increases in GDP and employment, but accompanied by a growing depletion of natural resources. More specifically, water stress will worsen, impacting population growth, agriculture and industrial production. A larger number of vessels in the fishery sector will allow fish catch to rise in the short-term but fall in the medium- to longer-term, limited by a considerable decline of fish stocks in capture fisheries in the next 40 years. The increased use of chemical fertilisers is projected to increase yields in the agriculture sector in the short-term at the expenses of a longer-term decline of soil quality. This will require more land - converted from forest area to farmland - to feed the growing population. Moreover, the increasing use of fossil fuels projected in the additional BAU scenarios will further jeopardise energy security and tend to slow economic growth, through higher energy (especially oil) prices. As a consequence of high fossil fuel dependency and deforestation, CO<sub>2</sub> emissions are projected to grow beyond BAU over the 40-year period. As a consequence, while GDP will still grow, its pressure on natural resources will increase, pushing our ecological footprint to over two times the available biocapacity by 2050 and atmospheric carbon concentrations to over 1,000 ppm by 2100.

In the green economy scenarios, one observes significant efficiency improvements, resource conservation and carbon mitigation, which contribute to stronger and more resilient economic growth in the medium- and long-term. The

sustainable management of natural resources, resulting from a reduction in fishing capacity, a decline in deforestation, the promotion of organic fertiliser and a reduction in fossil fuel use, will allow the restoration of stocks of key natural resources, or greatly mitigate their depletion. For example, fish stocks, forestland and soil quality are estimated to increase by 64 to 106 per cent, 21 per cent and 21 to 27 per cent respectively relative to BAU by 2050, with clear benefits for the productivity of these sectors. In addition, the efficiency improvement of water and energy use in a number of sectors will considerably curb the consumption of these resources (below BAU by 34 to 50 per cent for fossil fuels and 24 to 19 per cent for water in 2050) and avoid negative consequences arising from their depletion. With increased carbon sequestration from forests, the potential sequestration from conservation agriculture (still to be estimated in detail), and the substitution of traditional energy resources with low-carbon alternatives, CO<sub>2</sub> and GHG emissions, will be considerably lower than BAU over the next 40 years.

Increasingly decoupled from the consumption of natural resources, GDP growth under a green scenario is expected to surpass that under BAU in the medium- to long-term. Taking into account the improved maintenance of natural capital in the G1 and G2 scenarios, an adjusted measure of net domestic product would probably perform even more favourably relative to the BAU scenarios (see Box 1). Driven primarily by green investments and the subsequent push to economic development, total net direct employment in the sectors analysed in this chapter is projected to be lower than additional BAU cases in the short-term, and to then rise above all BAU scenarios in the medium to long run (2-3 per cent above BAU1 and BAU2 scenarios, respectively, and 8 to 14 per cent above BAU in 2050). When total employment is considered, the green scenarios are expected to converge to the corresponding BAU cases in the longer-term, and exceed BAU by 3 to 5 per cent in 40 years. These results point to the need for policies that recognise and manage the transition costs involved in moving towards a green economy, with a focus on an equitable distribution of costs and benefits that emerge from new opportunities.

26. Such issues are discussed in more detail in the chapters on enabling conditions and finance.

		2011	2015					2020				
	Unit	BAU	BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
<b>Economic sector</b>												
Real GDP	US\$ bn/year	69,334	78,651	79,306	77,694	78,384	78,690	91,028	92,583	88,738	90,915	92,244
GDP per capita	US\$ bn/year	9,992	10,868	10,959	10,737	10,832	10,874	12,000	12,205	11,698	11,983	12,156
Agriculture production *	US\$ bn/year	1,921	1,965	1,967	1,945	1,963	1,976	2,066	2,071	2,035	2,146	2,167
Crop	US\$ bn/year	629	674	677	657	679	691	713	718	690	726	744
Fishery	US\$ bn/year	106	101	101	99	73	75	95	95	88	69	72
Forestry	US\$ bn/year	748	718	718	718	740	740	747	747	747	840	840
Livestock	US\$ bn/year	439	471	471	471	471	471	511	511	511	511	511
Industry production	US\$ bn/year	17,168	19,304	19,457	19,146	19,363	19,439	22,091	22,444	21,727	22,330	22,642
Services production	US\$ bn/year	50,245	57,382	57,882	56,604	57,058	57,275	66,871	68,068	64,975	66,439	67,434
Consumption	US\$ bn/year	53,368	60,539	61,044	59,803	60,334	60,569	70,066	71,263	68,303	69,979	71,002
Investment	US\$ bn/year	15,966	18,874	19,798	17,892	18,240	18,502	21,847	23,118	20,435	21,157	21,689
Additional investment	US\$ bn/year	0	763	1,535	0	760	1,524	885	1,798	0	883	1,788
<b>Social sector</b>												
Total population	billion people	6.9	7.2	7.2	7.2	7.2	7.2	7.6	7.6	7.6	7.6	7.6
Calories per capita	Kcal/P/D	2,787	2,829	2,857	2,791	2,834	2,865	2,887	2,946	2,802	2,897	2,955
Population below \$2/day	%	19.5%	18.1%	17.9%	18.3%	18.1%	18.1%	16.4%	16.2%	16.9%	16.5%	16.2%
HDI	Index	0.594	0.600	0.601	0.600	0.600	0.601	0.610	0.611	0.608	0.611	0.613
Total employment	million people	3,187	3,407	3,419	3,392	3,420	3,441	3,685	3,722	3,641	3,676	3,701
Agriculture	million people	1,075	1,119	1,123	1,113	1,147	1,167	1,185	1,200	1,167	1,215	1,244
Industry	million people	662	725	728	723	722	721	803	810	796	793	790
Services	million people	1,260	1,366	1,371	1,361	1,357	1,357	1,491	1,506	1,476	1,465	1,461
Fisheries	million people	29	28	28	28	21	21	27	27	24	19	20
Forestry	million people	21	20	20	20	21	21	21	21	21	24	24
Transportation	million people	70	75	75	74	79	79	79	80	78	85	85
Energy	million people	19	20	20	20	20	21	20	20	20	19	21
Waste	million people	20	20	20	20	20	21	21	21	21	21	21
Water	million people	31	34	34	34	33	33	37	37	37	35	35
<b>Environmental sector</b>												
Forest land	billion ha	3.9	3.9	3.9	3.9	4.0	4.0	3.9	3.9	3.9	4.0	4.0
Arable land	billion ha	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Harvested area	billion ha	1.20	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Unit	BAU	BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
Water demand	km <sup>3</sup> /Yr	4,864	5,264	5,275	5,251	5,079	5,081	5,767	5,792	5,737	5,357	5,375
Waste generation	Mtonnes/year	11,238	11,514	11,527	11,475	11,607	11,660	11,836	11,864	11,775	12,002	12,084
Total landfill	billion tonnes	7.9	8.4	8.4	8.4	8.0	8.0	9.0	9.0	9.0	7.6	7.7
Fossil fuel CO <sub>2</sub> emissions	Mtonnes/year	30,641	33,269	33,557	32,867	31,966	30,746	36,556	37,069	35,645	33,231	30,323
Footprint/bioproductivity	Ratio	1.5	1.6	1.6	1.6	1.5	1.5	1.7	1.7	1.6	1.5	1.4
Primary energy demand	Mtoe/year	12,549	13,589	13,674	13,470	13,315	13,245	14,926	15,086	14,651	14,120	13,709
Coal production	Mtoe/year	3,620	4,098	4,150	4,026	3,975	3,858	4,592	4,671	4,435	4,202	3,907
Oil production	Mtoe/year	3,838	4,059	4,079	4,028	3,847	3,704	4,344	4,398	4,264	3,907	3,591
Natural gas production	Mtoe/year	2,715	2,886	2,897	2,869	2,840	2,804	3,233	3,259	3,195	3,107	2,980
Nuclear power	Mtoe/year	755	807	807	807	820	848	869	869	869	897	956
Hydro power	Mtoe/year	257	279	279	279	280	280	309	309	309	310	311
Biomass and waste	Mtoe/year	1,077	1,132	1,132	1,132	1,208	1,372	1,202	1,203	1,201	1,289	1,484
Other renewables	Mtoe/year	286	328	328	328	344	378	377	377	377	410	481
RE share of primary demand	%	13%	13%	13%	13%	14%	15%	13%	13%	13%	14%	17%

**Table 7: Main indicators in BAU and green investment scenarios**

\* Note: Agriculture production includes production of crops, livestock, fisheries and forestry products. All monetary values are presented in constant 2010 US dollars.



2011			2030					2050				
	Unit	BAU	BAU1	BAU2	BAU	G1	G2	BAU1	BAU2	BAU	G1	G2
<b>Economic sector</b>												
Real GDP	US\$ bn/year	69,334	116,100	119,307	110,642	117,739	122,582	164,484	172,049	151,322	174,890	199,141
GDP per capita	US\$ bn/year	9,992	14,182	14,577	13,512	14,358	14,926	18,594	19,476	17,068	19,626	22,193
Agriculture production *	US\$ bn/year	1,921	2,259	2,268	2,219	2,383	2,421	2,545	2,559	2,494	2,773	2,852
<i>Crop</i>	US\$ bn/year	629	786	795	752	806	836	898	913	849	941	996
<i>Fishery</i>	US\$ bn/year	106	83	83	75	69	76	61	61	57	72	91
<i>Forestry</i>	US\$ bn/year	748	803	803	803	918	918	870	870	870	1,038	1,039
<i>Livestock</i>	US\$ bn/year	439	588	588	588	589	590	716	715	718	721	726
Industry production	US\$ bn/year	17,168	27,629	28,311	26,831	28,614	29,692	37,738	39,218	35,571	41,455	46,588
Services production	US\$ bn/year	50,245	86,212	88,727	81,592	86,742	90,469	124,201	130,272	113,258	130,661	149,701
Consumption	US\$ bn/year	53,368	89,364	91,833	85,163	90,626	94,354	126,606	132,429	116,476	134,616	153,282
Investment	US\$ bn/year	15,966	27,872	29,808	25,479	27,401	28,825	39,493	42,996	34,847	40,704	46,831
Additional investment	US\$ bn/year	0	1,137	2,334	0	1,150	2,388	1,616	3,377	0	1,719	3,889
<b>Social sector</b>												
Total population	billion people	2,787	2,973	3,050	2,840	3,001	3,093	3,178	3,273	2,981	3,238	3,382
Calories per capita	Kcal/P/D	19.5%	14%	14%	15%	14%	13%	10%	10%	11%	10%	8%
Population below \$2/day	%	0.594	0.630	0.633	0.626	0.635	0.643	0.671	0.680	0.663	0.688	0.714
	<b>Unit</b>	<b>BAU</b>	<b>BAU1</b>	<b>BAU2</b>	<b>BAU</b>	<b>G1</b>	<b>G2</b>	<b>BAU1</b>	<b>BAU2</b>	<b>BAU</b>	<b>G1</b>	<b>G2</b>
HDI	Index	0.594	0.630	0.633	0.626	0.635	0.643	0.671	0.680	0.663	0.688	0.714
Total employment	Mn people	3,187	4,137	4,204	4,057	4,108	4,143	4,739	4,836	4,613	4,762	4,864
<i>Agriculture</i>	Mn people	1,075	1,331	1,371	1,284	1,351	1,393	1,580	1,656	1,489	1,618	1,703
<i>Industry</i>	Mn people	662	923	931	915	907	900	1,064	1,067	1,059	1,051	1,042
<i>Services</i>	Mn people	1,260	1,663	1,680	1,643	1,629	1,622	1,837	1,851	1,813	1,836	1,843
<i>Fisheries</i>	Mn people	29	23	23	21	19	21	17	17	16	20	25
<i>Forestry</i>	Mn people	21	23	23	23	26	26	25	25	25	30	30
<i>Transport</i>	Mn people	70	89	90	87	100	98	99	120	122	117	130
<i>Energy</i>	Mn people	19	19	19	19	18	20	19	19	19	18	23
<i>Waste</i>	Mn people	20	22	22	22	22	23	24	24	23	25	26
<i>Water</i>	Mn people	31	43	44	43	37	38	43	44	43	43	44
<b>Environmental sector</b>												
Forest land	billion ha	3.9	3.8	3.8	3.8	4.1	4.1	3.7	3.7	3.7	4.5	4.5
Arable land	billion ha	1.6	1.6	1.6	1.6	1.5	1.5	1.6	1.6	1.6	1.5	1.5
Harvested area	billion ha	1.20	1.27	1.27	1.27	1.25	1.25	1.31	1.31	1.31	1.26	1.26
Water demand	km3/Yr	4,864	6,735	6,784	6,668	5,810	5,889	8,320	8,434	8,141	6,220	6,611
Waste generation	Mtonne/Yr	11,238	12,445	12,499	12,342	12,785	12,946	13,400	13,505	13,201	14,305	14,783
Total landfill	billion Tonnes	8	10	10	10	6	6	12	12	12	1	2
Fossil fuel CO <sub>2</sub> emissions	Mtonne/Yr	30,641	42,669	43,785	40,835	35,635	29,967	53,703	55,684	49,679	29,943	20,039
Footprint/ biocapacity	Ratio	1.5	1.8	1.8	1.8	1.6	1.4	2.2	2.2	2.1	1.4	1.2
Primary energy demand	Mtoe/year	12,549	17,407	17,755	16,832	15,107	14,269	21,044	21,687	19,733	14,562	13,051
Coal production	Mtoe/year	3,620	5,447	5,636	5,143	4,126	3,660	7,512	7,930	6,602	2,677	2,049
Oil production	Mtoe/year	3,838	4,910	5,019	4,726	4,026	3,478	4,968	5,102	4,727	3,770	2,724
Natural gas production	Mtoe/year	2,715	3,901	3,951	3,816	3,578	3,218	4,906	5,000	4,744	4,114	3,239
Nuclear power	Mtoe/year	755	968	968	968	1,024	1,151	1,089	1,089	1,089	1,179	1,500
Hydro power	Mtoe/year	257	373	373	373	374	377	459	459	459	461	467
Biomass and waste	Mtoe/year	1,077	1,341	1,342	1,339	1,447	1,709	1,525	1,524	1,528	1,687	2,079
Other renewables	Mtoe/year	286	467	467	467	532	676	584	584	584	673	992
RE share of primary demand	%	13%	13%	12%	13%	16%	19%	12%	12%	13%	19%	27%

**Table 7: Main indicators in BAU and green investment scenarios (continued)**

\* Note: Agriculture production includes production of crops, livestock, fisheries and forestry products. All monetary values are presented in constant 2010 US dollars.

	2015		2020		2030		2050	
	1% case	2% case	1% case	2% case	1% case	2% case	1% case	2% case
<b>Economic sector</b>								
Real GDP	-0.3	-0.8	-0.1	-0.4	1.4	2.7	6.3	15.7
GDP per capita	-0.3	-0.8	-0.1	-0.4	1.2	2.4	5.6	13.9
Agriculture production *	-0.1	0.5	3.9	4.7	5.5	6.7	9.0	11.4
<i>Crop</i>	0.6	2.1	1.7	3.6	2.6	5.2	4.9	9.0
<i>Fishery</i>	-27.6	-26.1	-27.1	-23.9	-15.9	-7.6	17.8	47.5
<i>Forestry</i>	3.0	3.0	12.5	12.5	14.4	14.4	19.4	19.5
<i>Livestock</i>	0.0	0.0	0.0	0.0	0.2	0.3	0.7	1.6
Industry production	0.3	-0.1	1.1	0.9	3.6	4.9	9.9	18.8
Services production	-0.6	-1.0	-0.6	-0.9	0.6	2.0	5.2	14.9
<b>Social sector</b>								
Total population	0.0	0.0	0.0	0.0	0.2	0.3	0.7	1.6
Calories per capita	0.2	0.3	0.3	0.3	0.9	1.4	1.9	3.4
Population below \$2/day	0.3	0.7	0.1	0.4	-1.3	-2.4	-6.0	-14.3
HDI	0.0	0.0	0.2	0.3	0.9	1.5	2.5	5.1
Total employment	0.4	0.6	-0.2	-0.6	-0.7	-1.5	0.5	0.6
<i>Agriculture</i>	2.5	3.9	2.5	3.7	1.5	1.6	2.4	2.8
<i>Industry</i>	-0.4	-0.9	-1.3	-2.5	-1.8	-3.3	-1.2	-2.4
<i>Services</i>	-0.6	-1.0	-1.7	-2.9	-2.1	-3.5	0.0	-0.4
<i>Fisheries</i>	-27.6	-26.1	-27.1	-23.9	-15.9	-7.6	17.8	47.5
<i>Forestry</i>	3.2	3.2	12.7	12.7	14.6	14.6	19.8	19.9
<i>Transport</i>	6.0	5.5	7.5	6.7	10.1	10.0	3.0	6.4
<i>Energy</i>	0.1	6.8	-3.1	3.2	-5.9	4.8	-6.3	21.0
<i>Waste</i>	0.8	1.2	1.4	1.9	2.7	3.6	6.8	9.5
<i>Water</i>	-3.5	-3.7	-7.1	-7.2	-13.7	-13.2	-25.2	-21.6
<b>Environmental sector</b>								
Forest land	1.3	1.4	3.2	3.3	7.9	8.1	21.1	21.2
Arable land	-1.1	-1.1	-2.6	-2.6	-5.8	-5.8	-11.4	-11.4
Harvested area	-0.3	-0.3	-0.7	-0.7	-1.7	-1.6	-3.8	-3.7
Water demand	-3.5	-3.7	-7.1	-7.2	-13.7	-13.2	-25.2	-21.6
Waste generation	0.8	1.2	1.4	1.9	2.7	3.6	6.8	9.5
Total landfill	-5.3	-4.9	-15.6	-15.1	-39.0	-38.3	-87.6	-87.2
Fossil fuel CO <sub>2</sub> emissions	-3.9	-8.4	-9.1	-18.2	-16.5	-31.6	-44.2	-64.0
Footprint/biocracy	-5.0	-7.5	-7.1	-12.5	-12.8	-21.5	-37.8	-47.9
Primary energy demand	-2.0	-3.1	-5.4	-9.1	-13.2	-19.6	-30.8	-39.8
Coal production	-3.0	-7.0	-8.5	-16.4	-24.3	-35.1	-64.4	-74.2
Oil production	-5.2	-9.2	-10.1	-18.4	-18.0	-30.7	-24.1	-46.6
Natural gas production	-1.6	-3.2	-3.9	-8.5	-8.3	-18.6	-16.1	-35.2
Nuclear power	1.6	5.0	3.2	10.0	5.9	19.0	8.3	37.8
Hydro power	0.1	0.3	0.2	0.6	0.3	1.0	0.4	1.8
Biomass and waste	6.7	21.2	7.2	23.4	7.9	27.4	10.6	36.4
Other renewables	4.9	15.2	8.7	27.3	13.8	44.7	15.2	69.9
RE share of primary demand	7.5	20.5	12.4	32.5	24.3	57.5	58.7	129.1

**Table 8: Comparison (per cent) of main indicators in G1 scenario relative to BAU1 scenario (1 per cent case), and G2 scenario relative to BAU2 scenario (2 per cent case)**

\* Note: Agriculture production includes production of crops, livestock, fisheries and forestry products.

# Annex 1. Technical specifications of the Threshold 21 (T21) World model

Finding that currently available national and global planning models are either too detailed or narrowly focused, and perhaps too decision oriented and prescriptive, this study proposes an approach that a) extends and advances the policy analysis carried out with existing tools by accounting for the dynamic complexity embedded in the systems studied, and b) facilitates the investigation and understanding of the relations existing between energy and society, economy and the environment. This is crucial, since understanding the characteristics of real systems, feedback, delays and non-linearity is fundamental for the correct representation of structures, whose behaviour is outside their normal operating range (Sterman 2000; see also Figure 1). The inclusion of cross-sectoral relationships - social, economic and environmental - allows for a wider analysis of the implication of policies by identifying potential side effects or longer-term bottlenecks for development. In other words, a policy can have very positive impacts for certain sectors and create issues for others. Also, successful policies in the longer-term may have negative short-term impacts, for which mitigating actions may be designed and implemented.

As indicated earlier, the approach proposed uses System Dynamics as its foundation and incorporates various methodologies, such as optimisation (in the energy sector) and econometrics (in the economic sectors). The integrated global model is used to: (1) provide an integrated analysis and evaluation of investment choices; (2) generate projections of future developments (though acknowledging that long-term accurate projection cannot easily be produced, even when simulating a large number of endogenous key variables (Sarewitz 2000); (3) increase the understanding of the relations underlying the system analysed; and (4) and bring consistency to models.

The Threshold21 (T21) World model (T21-World) is structured to analyse medium- long-term development issues. The model integrates in a single framework the economic, the social, and the environmental aspects of development planning. T21-World modelling structure includes both monetary and physical indicators, to fully analyse the impacts of investments on natural resources, low-carbon development, economic growth and job creation. Key characteristics of the model are highlighted below.

**Boundaries:** Variables that are considered an essential part of the development mechanisms, object of the research, are endogenously calculated. For example, GDP and its main determinants, population and its main determinants, and the demand and supply of natural resources are endogenously determined. Variables that have an important influence on the issues are analysed, but those that are only weakly influenced by the issues analysed or that cannot be endogenously estimated with confidence are exogenously represented.

**Granularity:** The T21-World model presented in this chapter is a global model, with no regional or national disaggregation; although, the model is routinely developed for specific countries, and is applicable at other scales such as communities.<sup>27</sup> Nonetheless, the main social, economic and environmental variables of T21-World are disaggregated in considerable detail. For example, population is divided into 82 age-cohorts and 2 genders, and the age-gender distinction is used in most social indicators; production is divided into industry, services and agriculture, this last further divided into crops, fishery, animal husbandry and forestry; land is divided into forest, agriculture, fallow, urban and desert. Finally, given its level of aggregation, the model is generally based on global average values for variables such as unit costs and prices.

**Time horizon:** T21-World is built to analyse medium-to long-term development issues. The time horizon for simulation begins in 1970 and extends to 2050. Beginning the simulation in 1970 ensures that, in most cases, the historical patterns of behaviour characterising the issues being investigated can be replicated by the model.

**Modules, sectors and spheres:** T21-World is a relatively large model, which includes more than 200 stock variables and several thousand feedback loops. Because of its size and level of complexity, the structure of the model has been reorganised into smaller logical units, called modules. A module is a structure, whose internal mechanisms can be understood in isolation from the rest of the model.<sup>28</sup> The 80 modules comprising T21-

27. As it is emphasised later on in the text, although it is possible to understand the internal mechanism of a specific module in isolation from the rest of the model, the fully understanding of its functioning and relevance requires studying its role in the whole model's structure.

28. For more information, see Bassi and Baer (2009), Bassi and Yudken (2009), Bassi and Shilling (2010), Bassi et al. (2009a, 2009b, 2010), Magnoni and Bassi (2009), Pedercini and Barney (In Press), Yudken and Bassi (2009).

Society	Economy	Environment
Population	Agriculture	Land
Nutrition	Fishery	Water
Education	Forestry	Energy
Employment	Industry	Waste
Poverty	Services	Emissions
Public infrastructure	Economic accounts	Footprint

**Figure A1: Spheres and sectors of T21-World**

World are grouped into 18 sectors: 6 social, 6 economic and 6 environmental sectors, as listed in Table 9. Sectors are groups of one or more modules of similar functional scope. For example, the water sector groups both the water demand and water supply modules. Finally, for convenience in summarising and communicating the results, society, economy and environment are known as the three spheres of T21-World. All sectors in T21 belong to one of the three spheres,<sup>29</sup> depending on the type of issue they are designed to address. Modules are built to be in continuous interaction with other modules in the same sector, across sectors, and across spheres.<sup>30</sup> Table 9 lists the spheres, sectors and modules of T21-World.

The Social sphere of T21-World contains detailed population dynamics organised by gender and age cohort. Fertility is a function of the level of income and education and mortality rates are determined by the level of income and the level of access to basic health care. Access to education and health care services, nutrition, employment and basic infrastructure are also represented in this sphere. Access to basic social services is used – in addition to income – to determine poverty levels in a broad sense. Social development is highly connected to economic performance in T21-World. As economic conditions improve, a higher proportion of expenditure is allocated to health care and education, among others, increasing labour productivity and, thus, faster economic growth.

The Economy sphere of the model contains several major production sectors (agriculture, fishery, forestry, industry and services). Production is generally characterised by modified Cobb-Douglas production functions (See Box A1) with inputs of labour, capital, and technology, with the specification varying from sector to sector. Agriculture, fishery and forestry production is highly influenced by the availability and quality of

natural resources. While capital and labour contribute to production, the stock of fish, forest and the quality of soil – together with water availability for agriculture – are also important determinants of output in these sectors.

For this reason T21-World tracks the physical flow of key natural resources, endogenously calculating depletion and its impacts on production.<sup>31</sup> Further, production in the three major economic sectors is influenced by social factors, such as life expectancy and education level, included in the calculation of total factor productivity (TFP) together with the impact of natural resources availability and energy prices. These feedback effects are sufficiently important that in the business-as-usual scenario, the annual rate of world GDP growth gradually falls from about 2.7 per cent per year in the period 2010–2020 to 2.2 per cent in the period 2020–2030 and further to 1.6 per cent in the period 2030–2050.

The Environment sphere tracks land allocation, water, waste and energy demand and supply. T21-World calculates also air emissions (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, SO<sub>x</sub> and greenhouse gas) and the ecological footprint. Economic activities and demographic growth create increasing pressure on natural resources, while at the same time allowing for development of better and more efficient technologies. In the case of energy, stocks of fossil fuel resources and reserves are explicitly and endogenously modelled. These stocks are among the primary drivers of fossil fuel prices, which are calculated by taking into account short and longer term trends. Fossil fuel prices, in turn, influence oil exploration and discovery as well as energy demand, and, as a consequence, oil recovery – creating a variety of feedback loops (see Bassi 2009, and section III in the Technical Background Material for more details).

In order to validate the model, both structural and behavioural tests were carried out. On the structural validation, T21-World and its sectors were designed based on existing state-of-the-art sectoral models with updated data. The knowledge gained through the review of these models was then translated into T21-World, exogenous inputs were replaced with endogenous ones, and causal relations were explicitly represented in a disaggregated manner. The new structure of each sector was then verified and validated comparing the behaviour of the model against historical data (normally from 1970 until 2008). More detailed analyses were then performed to identify and analyse the causal relations included in the model and the relevance of exogenous assumptions (or drivers), through the simulation of sensitivity analyses for

29. In certain country customisations, with energy being a key area of analysis and using a variety of modules, we represent it as the 4th sphere of T21.

30. Causal loop diagrams (CLD) highlighting the main structural components of each sector modelled and analysed in the GER are presented in section VII, Technical Background Material.

31. There is no requirement imposed, even in the green investment scenarios, that stocks reach an equilibrium state.

## Box A1: The Cobb-Douglas production function in T21 for agriculture, industry and services macro sectors

The classic form of the CD production function is expressed as following:

$$Y = A \times K^\alpha \times L^{(1-\alpha)}$$

Where here the traditional technology term,  $A$ , is used to represent a series of factors affecting total factor productivity (TFP; as in a growth accounting approach),  $K$  represents the stock of capital, and  $L$  represents labour. The constant  $\alpha$  represents the elasticity of output to capital: the ratio between the percentage change of output and the percentage change of an input. The elasticity of output to labour is set to  $1-\alpha$ , assuming that there are constant returns to scale (the production function is thus first order, homogeneous). In T21 the standard CD production function is transformed into a more transparent algebraic form, and TFP is expanded to include several different elements.

The equation used to estimate industry production is as shown below:

$$y_i^t = y_i^0 \times ric_t^\alpha \times ril_t^\beta \times fpi_t$$

Where  $y_i^t$  is the current industry production,  $y_i^0$  is the initial industry production,  $ric_t$  is the relative industry capital (relative to 1970),  $ril_t$  is the relative industry labour and  $fpi_t$  is the industry total factor productivity. Moreover,  $\alpha$  is the elasticity of capital and  $\beta$  is the elasticity of labour. The T21 takes an approach whereby total factor productivity is comprised of a number of components related to human and natural capital. Thus, total factor productivity in industry  $fpi_t$  is determined by a range of human and natural capital related components, including health (relative life expectancy  $rle_t$ ), education (relative years of schooling  $rys_t$ ), energy (relative oil price  $rop_t$ ), relative waste recycle rate  $rwr_t$ , and relative water stress  $rws_t$ . The total factor productivity of industry is calculated as follows, with relative oil price and water stress having a negative impact on productivity, reflecting the negative effects that scarcities of these have on industrial production, either through higher prices or other costs that have to be incurred to compensate:

$$fpi_t = rys_t^\alpha / rop_t^\epsilon \times rle_t^\beta \times rwr_t^d \times rws_t^e$$

The equation used to estimate agricultural production is defined in terms of yield, still determined by a transformed Cobb-Douglas production function, uses different inputs for TFP. The equation below is used to estimate natural yield per hectare. Effective crop yield is the natural crop yield per hectare minus yield lost due to pest diseases. By multiplying the harvested area by effective crop yield per hectare, we determine the total crop yield. Total crop yield multiplied by crop value added gives agriculture (food processing) production, or the total value added.

$$y_t = y_{t-1} \times rc_t^\alpha \times rl_t^\beta \times f(R \& D, sq, f_t, 1/ws)$$

Where  $y_t$  is the current natural crop yield per hectare,  $y_{t-1}$  is the initial natural crop yield per hectare,  $rc_t$  is the relative capital, and  $rl_t$  is the relative labour. Where  $f$  is the effect of  $R \& D$  (relative research and development),  $sq$  (relative soil quality),  $f_t$  (relative fertiliser use) and  $ws$  (relative water stress) on crop yield. Moreover,  $\alpha$  is the elasticity of capital and  $\beta$  is the elasticity of labour. Labour in the agriculture production function represents human capital that consists of quantity and quality of labour. The quantity of labour is agriculture employment while quality of labour is determined by literacy (average years of schooling) of the labour force and health conditions (life expectancy).

selected variables (e.g. availability of reserves and resources, or the elasticity of GDP to oil prices). Further, extreme condition tests, feedback loop analysis as well as unit consistency tests were performed on all models. Further, boundaries as well as structural (i.e. causal relations and equations) and parameter consistency tests were normally checked with experts in the field analysed. Overall, the structure of the models presented in the five studies presents less detailed disaggregation but higher dynamic complexity (cross sectoral relationships and feedback loops) when compared with other existing models (e.g. MARKAL,

in the energy sector). In other words, each sector developed for the studies is relatively simple when taken in isolation, and the complexity comes out of the feedback loops built into the model across modules and sectors.

Concerning behavioural validation, over 450 social, economic and environmental variables were simulated against history. Historical projections generally match well with data, as partly illustrated in Figures 5, 6, 8 and 9, and, as shown in section III in the Technical Background Material. During the modelling process particular



emphasis was given to the analysis of the performance of aggregated indicators, and details were added and more carefully addressed in the models of the specific sectors analysed in the GER - where adding granularity was useful to provide insights on the impact of selected investments. Furthermore, future projections were compared with those from other organisations, as shown in section III of the Technical Background Material, including among others, the IEA, FAO, World Bank, UNIDO, United Nations Population Division, United Nations Statistics Division, and McKinsey & Company.

Finally, it is worth mentioning at the outset that the model has several limitations relative to the breadth of the GER. T21-World is a global model (with no regional or national disaggregation, and no explicit representation of trade) that focuses on medium- to longer term trends. In addition, T21-World includes only a limited amount of feedbacks linking GHG emissions to health and economic activity, and accounts for a limited number of natural resources (e.g. details on stock of non-fuel minerals are not included in the model). Further, the model does not quantify biodiversity and does not fully capture a number of important features of the labour market (while labour force, employment figures and income are calculated endogenously, disaggregated real wages by sector are not estimated and the quality of work, or “decent work”, could not be determined with confidence). Finally, the capital and financial markets are not specifically modelled, and T21-World uses a supply-side approach to production, although in many cases both demand and supply are calculated at the sectoral level.<sup>32 33</sup>

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32. Other existing models used to support medium- to longer term planning exercises and analysis face similar issues, and often have very narrow boundaries compared to T21-World. OECD models employed to project scenarios presented in their environmental outlook do not explicitly account for the labour market and unemployment, and World Bank budgetary frameworks often do not single out capital and financial markets. Sectoral models - normally based on case studies - exist, but there is little agreement on the extent to which these relate to other sectors and dynamic projections of future trends are normally missing. More details on model specifications are provided in various sections of the Technical Background Material.

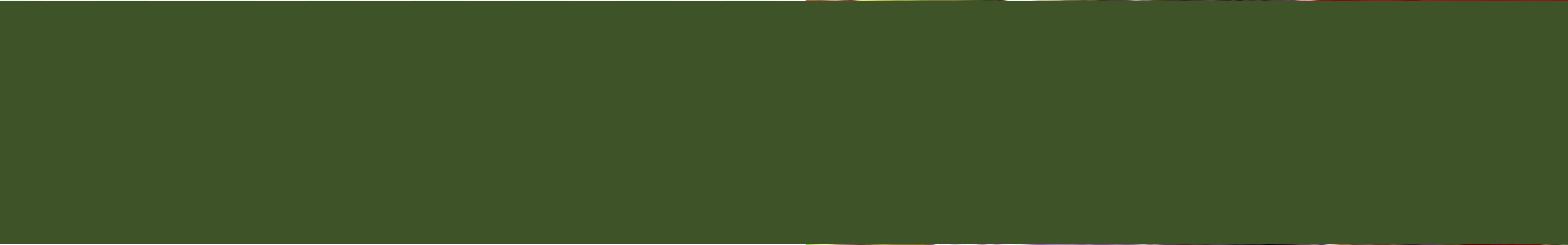
33. More information on T21, and several customizations and country applications can be found at [www.millennium-institute.org](http://www.millennium-institute.org). Selected publications include: Bassi (2010a, 2011), Bassi and Baer (2009), Bassi and Yudken, (2009, Forthcoming), Bassi and Shilling (2010), Bassi et al. (2009a, 2009b, 2010), Cimren et al. (2010), Magnoni and Bassi (2009), Yudken and Bassi (2009).

# References

- Association for the Study of Peak Oil and Gas ASPO-USA. "Peak Oil Basics". Available at: [www.aspousa.org/index.php/peak-oil/peak-oil-202/](http://www.aspousa.org/index.php/peak-oil/peak-oil-202/).
- Badiou, A. (2000). "Ethics; An Essay on the Understanding of Evil", translated by Peter Hallward. New York, Verso.
- Barlas, Y. (1996). "Formal Aspects of Model Validity and Validation in System Dynamics." *System Dynamics Review*.
- Bassi, A.M., (2010a). "Evaluating the use of an integrated approach to support energy and climate policy formulation and evaluation", *Energies* 3(9):1604-1621. doi:10.3390/en3091604
- Bassi, A.M. (2011). "A Context-Inclusive Approach to Support Energy Policy Formulation and Evaluation". Regional Environmental Change, 11(2), Page 285-295. DOI 10.1007/s10113-010-0139-z
- Bassi, A.M. (2009). *An Integrated Approach to Support Energy Policy Formulation and Evaluation*. PhD Dissertation, System Dynamics Group, Department of Geography, University of Bergen, Norway. 2009. ISBILLION: 978-82-308-0908-2.
- Bassi, A.M. (2010b). "Reflections on the Validity of System Dynamics Integrated Simulation Models: the case of T21 and MCM." Currently submitted to Sustainability.
- Bassi, A.M., Baer, A.E. (2009). "Quantifying Cross-Sectoral Impacts of Investments in Climate Change Mitigation in Ecuador." *Energy for Sustainable Development*, 13(2009)116-123.
- Bassi, A.M., J.S. Yudken (Forthcoming). "Climate Policy and Energy-Intensive Manufacturing: A Comprehensive Analysis of the Effectiveness of Cost Mitigation Provisions in the American Energy and Security Act of 2009". *Energy Policy*, doi:10.1016/j.enpol.2011.06.023
- Bassi, A.M., and Yudken, J.S. (2009). "Potential Challenges Faced by the U.S. Chemicals Industry Under a Carbon Policy." *Sustainability*, 1(2009)592-611. Special issue on "Energy Policy and Sustainability".
- Bassi, A.M., and Shilling, J.D. (2010). "Informing the US Energy Policy Debate with Threshold 21." *Technological Forecasting & Social Change*, 77 (2010) 396-410.
- Bassi, A.M., Harrison J., Mistry, R. (2009a). "Using an Integrated Participatory Modelling Approach to Assess Water Management Options and Support Community Conversations on Maui." *Sustainability*, 1(4), 1331-1348. Special issue on "Sustainable Water Management".
- Bassi, A.M., Schoenberg, W., Powers, R. (2010). "An integrated approach to energy prospects for North America and the Rest of the World." *Energy Economics*, 32 (2010) 30-42.
- Bassi, A.M., Z. Tan and S. Goss, (2010). "An Integrated Assessment of Investments to Improve Global Water Sustainability". *Water*, 2(4), 726-741. doi:10.3390/w2040726
- Bassi, A.M., Yudken, J.S., Ruth, M. (2009b). Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors. "Energy Policy" 37(2009)3052-3060
- Bio Economic Research Associates BIO-ERA. (February 2009). "U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030."
- Brown, S. P. A., and Huntington, H. G. (2008). "Energy Security and Climate Change Protection: Complementarity or Tradeoff?" *Energy Policy*, (2008) Vol. 36, No. 9.
- Bussolo, M., Medvedev, D. (2007). "Challenges to MDG achievement in low income countries: lessons from Ghana and Honduras". World Bank Policy Research Working Paper 4383, Washington DC.
- Cimren, E., A.M. Bassi, J. Fiksel, (2010). "T21-Ohio, a System Dynamics Approach to Policy Assessment for Sustainable Development: A Waste to Profit Case Study." *Sustainability* 2(9), 2814-2832. doi:10.3390/su2092814
- CNA Corporation (2007). "National Security and the Threat of Climate Change". Alexandria, VA.
- DeGeus, A.P. (1992). "Modelling to Predict or to Learn?" *European Journal of Operational Research*, 59(1), p. 1-5.
- Dreyfus, H. (2001). *On the Internet: Thinking in Action*. Routledge Press.
- Evaert, L., Garcia-Pinto, F., and Venutur, J. (1990). *A RMSM-X model for Turkey, Volume 1*. Policy, Research, and External Affairs working paper no. WPS 486, The World Bank.
- Fair, R. C. (1993). "Testing Macroeconometric Models". *The American Economic Review*, 83(2): 287-293.
- Fishbone, L.G., Giesen, G., Goldstein, G., Hymmen, H. A., Stocks, K. J., Vos, H., Wilde, D., Zöcher, R., Balzer, C., Abilock, H. (1983). *User's Guide for MARKAL*. IEA Energy Technology Systems Analysis Programme, Upton, NY.
- Food and Agriculture Organization of the United Nations FAO (2008). *The State of World Fisheries and Aquaculture*, 2008. Rome.
- Food and Agriculture Organization of the United Nations FAO (2009). *The State of World's Forests*, 2009. Rome.
- Food and Agriculture Organization of the United Nations FAO (2009). *World agriculture: Towards 2030/2050*. Rome.
- Food and Agriculture Organization of the United Nations FAO (2010). "FAOSTAT". Rome.
- Forrester, J. W. (1961). *Industrial Dynamics*. Productivity Press, Cambridge, MA.
- Forrester, J. W. (2002). *Road Maps: A Guide to Learning System Dynamics*. System Dynamics Group, Sloan School of Management, MIT, Cambridge, MA.
- Forrester, J. W. (2008). *System Dynamics – The Next Fifty Years*. System Dynamics Review.
- Global Footprint Network (GFN). Available at: [www.footprintnetwork.org/en/index.php/GFN](http://www.footprintnetwork.org/en/index.php/GFN).
- High Road Strategies and Millennium Institute HRS-MI (2009). "Climate Policy and Energy - Intensive Manufacturing: the Competitiveness Impacts of the American Energy and Security Act of 2009". Arlington, VA.
- Howarth, R. B. and Monahan, P.A. (1996). "Economics, Ethics and Climate Policy: Framing the Debate". *Global and Planetary Change*, Vol. 11, No. 4, p. 187-199.
- Intergovernmental Panel on Climate Change IPCC (2007). "Fourth Assessment Report (AR4)". Geneva.
- International Energy Agency IEA. (2004). *World Energy Outlook 2004*. Annex C – World Energy Model. Paris.
- International Energy Agency IEA. (2008). *Energy Technology Perspectives (ETP) 2008*. Paris.
- International Energy Agency IEA. (2009). *Transport, Energy and CO<sub>2</sub>: Moving Toward Sustainability*. Paris.
- International Energy Agency IEA. (2009). *World Energy Outlook 2009*. Paris.
- International Energy Agency IEA. (2010). *Energy Technology Perspectives (ETP) 2010*. Paris.
- International Energy Agency IEA. (2010). *World Energy Outlook 2010*. Paris.
- International Energy Agency IEA, and OECD. (2010). *Sustainable Production of Second-Generation Biofuels*. Paris.
- International Labour Organization ILO. (January 2009). *Global Employment Trends Report 2009*. Geneva.
- International Institute for Applied Systems Analysis IIASA. (2001). *Model MESSAGE*. Command Line User Manual, Version 0.18.
- International Institute for Applied Systems Analysis IIASA. (2002). "Achieving a Sustainable Energy System."
- Haque, N.U., Khan, M.S., and Montiel, P. (1990). "Adjustment with Growth: Relating the Analytical Approaches of the IMF and the World Bank." *Journal of Development Economics*, 32: 155-79.
- Lewis, W.A. (2003/1966). *Development Planning: The Essentials of Economic Policy*. New York, Routledge.
- Goldstein, G., Loulou, R., Noble, K. (2004). "Documentation for the MARKAL Family of Models." IEA Energy Technology Systems Analysis Programme.
- Magnoni, S. and Bassi, A.M. (2009). "Creating Synergies from Renewable Energy Investments, a Community Success Story on Lolland, Denmark." *Energies* 2009, 2(4), 1151-1169. Special issue on "Energy Economics".
- McKinsey & Company and 2030 Water Resources Group. (2009). *Charting Our Water Future*. Washington, DC.
- Meadows, D. (1980). "The Unavoidable A Priori." Excerpt from Randers. *Elements of the System Dynamics Method*.
- Millennium Institute. (2005). "Threshold 21 (T21) Overview." Arlington, VA.

- Morecroft, J.D.W. (1992). "Executive Knowledge, Models and Learning." *European Journal of Operational Research*, 59(1), p. 70-74.
- Müller, A. and Davis, J. S. (2009) "Reducing Global Warming: The Potential of Organic Agriculture." Policy Brief, no.31.5.2009, Rodale Institute.
- Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M., Lee, D. (2009). *Climate Change: Impact on agriculture and costs of adaptation 2009*. Food Policy Report 21. Washington, D.C. International Food Policy Research Institute (IFPRI).
- Organisation for Economic Cooperation and Development OECD (2008). *Environment Outlook to 2030*. Paris.
- Pedercini, M. (2009). *Modelling Resource-Based Growth for Development Policy Analysis*. PhD Thesis, University of Bergen, Norway, 2009.
- Pedercini, M. and Barney, G.O. (2010). "Dynamic analysis of interventions designed to achieve Millennium Development Goals (MDG): The Case of Ghana." *Socio-Economic Planning Sciences*, 44 (2), 89-99.
- Pretty, J. N., Noble, A.D, Bossio, D., Dixon, J., Hine, R.E., Penning de Vries, F.W.T., and Moriso, J.I.L. (2006). "Resource-Conserving Agriculture Increases Yields in Developing Countries." *Environmental Science and Technology*, Vol. 40, No. 4.
- Roberts, N., Andersen, D.F., Choate, J., Deal, R.M., Garet, M.S. and Shaffer, W.A. (1983). *Introduction to Computer Simulation*. Addison-Wesley, p. 16, Reading, MA.
- Robinson, S., Yunes-Naude, A., et al. (1999). "From stylized to applied models: Building multisector CGE models for policy analysis." *The North American Journal of Economics and Finance*, 10(1): 5-38.
- Saeed, K. (1998). *Towards Sustainable Development: Essays on System Analysis of National Policy*, Aldershot, UK, Ashgate Publishing Company.
- Sarewitz, D. (2000). *Science and Environmental Policy: An Excess of Objectivity*. Columbia University, Center for Science, Policy, and Outcomes. Also in *Earth Matters: The Earth Sciences, Philosophy, and the Claims of Community*. Prentice Hall, p. 79-98, edited by Robert Frodemen (2000), New Jersey.
- Sterman, J. D. (1988). "A Skeptic's Guide to Computer Models." in Barney, G. O. et al. (eds.), *Managing a Nation: The Microcomputer Software Catalog*. Boulder, CO: Westview Press, 209- 229, 1988.
- Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modelling for a Complex World*. Irwin/McGraw-Hill, Boston.
- Stern, N. H. and Great Britain Treasury. (2007). *The Economics of Climate Change: the Stern review*. Cambridge University Press, Cambridge, UK; New York, NY.
- United Nations Development Programme UNDP, UNDESA and World Energy Council. (2000). *World Energy Assessment 2000*. New York.
- United Nations Environment Programme, UNEP. (2009). *Global Green New Deal Policy Brief*. Available at: [www.unep.ch/etb](http://www.unep.ch/etb).
- United Nations Population Division UNPD. (2009). *World Population Prospects: The 2008 Revision*. New York, NY.
- US Department of Energy, Energy Information Administration EIA. (2009). "International Energy Statistics." Available at: <http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm>. Accessed on October 2009.
- World Bank. (2009). "World Development Indicators Database (WDI)." <http://data.worldbank.org>
- Worm, B., Boris Worm, B. Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C. Halpern, B.S., Jackson, J.B, Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson R. (2006). "Impacts of Biodiversity Loss on Ocean Ecosystem Services." *Science*, 314: 787-790.
- Yudken, J.S., and Bassi, A.M. (2009). "Climate Change and US Competitiveness." *Issues in Science and Technology*, Fall Issue 2009.









# Enabling conditions

Supporting the transition to a global green economy



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## List of acronyms

APEC	Asia-Pacific Economic Cooperation
BIT	Bilateral Investment Treaty
CSR	Corporate social responsibility
DTIS	Diagnostic trade integration study
FSC	Forest Stewardship Council
G20	Group of Twenty
GDP	Gross Domestic Product
GHG	Greenhouse gas
GRI	Global Reporting Initiative
ICT	Information and Communication Technology
ITC	International Trade Centre
MDG	Millennium Development Goal
MEA	Multilateral Environmental Agreement
MSC	Marine Stewardship Council
NAFTA	North American Free Trade Agreement
NGO	Non-governmental organisation
ODS	Ozone depleting substance
OECD	Organisation for Economic Co-operation and Development
PES	Payment for Ecosystem Services
PFI	Private Finance Initiative
PIC	Prior informed consent
PROCOP	São Paulo State Industrial Pollution Control Programme (Brazil)
PROPER	Programme for Pollution Control, Evaluation and Rating (Indonesia)
R&D	Research and development
REDD	Reducing Emissions from Deforestation and Forest Degradation
SCP	Sustainable consumption and production
SME	Small and medium-sized enterprise
TRIPS	WTO Agreement on Trade-Related Aspects of Intellectual Property Rights
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
WTO	World Trade Organization
WWF	World Wide Fund for Nature



# Key messages

**1. Enabling a green economy means creating a context in which economic activity increases human well-being and social equity, and significantly reduces environmental risks and ecological scarcities.**

Changing the economic environment in this way is an ambitious undertaking which requires a holistic set of policies to overcome a broad range of barriers across the investment landscape. This chapter identifies six key areas of policy-making which most governments will need to focus on in order to correct the incentive structures in current, unsustainable markets and to alter investment landscapes in the short to medium-term. It also raises the question of whether classical measures of economic performance, such as Gross Domestic Product (GDP) growth, are adequate for assessing wealth creation and human well-being in the transition to a green economy.

**2. Carefully designed investment and spending can stimulate the greening of economic sectors.**

While the bulk of green economy investment will ultimately have to come from the private sector, the effective use of public expenditure and investment incentives can play a useful role in triggering the transition to a green economy. A number of sector chapters in the report recommend public investments in infrastructure and public services to enable green markets and ensure more efficient use of the environment and natural resources. Governments can also stimulate markets by using sustainable public procurement practices that create high-volume and long-term demand for green goods and services. This sends signals that allow firms to make longer-term investments in innovation and producers to realise economies of scale, leading in turn to the wider commercialisation of green goods and services, as well as more sustainable consumption. Investment and spending for a green economy, however, require regular assessments to ensure equity, transparency, accountability and cost effectiveness.

**3. Taxes and market-based instruments are powerful tools to promote green investment and innovation.**

Significant price distortions exist that can discourage green investments or contribute to the failure to scale up such investments. In a number of economic sectors, negative externalities, such as pollution, health impacts or loss of productivity, are typically not reflected in costs, thereby reducing the incentive to shift to more sustainable goods and services. A solution to this problem is to internalise the cost of the externality in the price of a good or service via a corrective tax, charge or levy closer to the source of the pollution or, in some cases, by using other market-based instruments, such as tradable permit schemes. Also, markets establishing payments for providing ecosystem services, such as carbon sequestration, watershed protection, biodiversity benefits and landscape beauty, can influence land use decisions by enabling landholders to capture more of the value of these environmental services than they would have done in the absence of the scheme.

**4. Government spending in areas that deplete environmental assets is counterproductive to a green economy transition.**

A number of the sector chapters highlight how poorly managed government spending can represent a significant cost to countries. Artificially lowering the price of goods through subsidisation can encourage inefficiency, waste and overuse, leading to the premature scarcity of valuable finite resources or the degradation of renewable resources and ecosystems. Such outdated subsidies can also be socially unfair. Moreover, they can reduce the profitability of green investments: when subsidisation makes unsustainable activity artificially cheap or low risk, it biases the market against investment in green alternatives. Reforming environmentally harmful and economically costly subsidies can therefore bring both fiscal and environmental benefits. However, short-term support measures accompanying the reform may be necessary to protect the poor.

### **5. A well-designed regulatory framework creates incentives that drive green economic activity.**

The sector chapters in this report emphasise that a robust regulatory framework at the national level, as well as the effective enforcement of legislation, can be a potent means of driving green investment. Such a framework reduces regulatory and business risks and increases the confidence of investors and markets. The use of regulations is often necessary to address the most harmful forms of unsustainable behaviour, either by creating minimum standards or prohibiting certain activities entirely. In particular, standards can be effective in promoting markets for sustainable goods and services and can induce efficiency and stimulate innovation, which can have a positive effect on competitiveness. Standards may, however, pose a challenge to market access for small and medium-sized enterprises, particularly from developing countries. It is, therefore, crucial for countries to balance environmental protection through the use of standards and other regulations with safeguarding market access.

### **6. Investing in capacity building and training is essential to support a transition to a green economy.**

The capacity to seize green economic opportunities and implement supporting policies varies from one country to another, and national circumstances often influence the readiness and resilience of an economy and population to cope with change. A shift towards a green economy could require the strengthening of government capacity to analyse challenges, identify opportunities, prioritise interventions, mobilise resources, implement policies and evaluate progress. Training and skill enhancement programmes may also be needed to prepare the workforce for a green economy transition. Temporary support measures may, therefore, be required to ensure a just transition for affected workers. In some sectors, support will be needed to shift workers to new jobs. In developing countries, inter-governmental organisations, international financial institutions, non-governmental organisations, the private sector and the international community as a whole can play a role in providing technical and financial assistance to facilitate the green economy transition.

### **7. Strengthened international governance can assist governments to promote a green economy.**

Multilateral environmental agreements, which establish the legal and institutional frameworks for addressing global environmental challenges, can play a significant role in promoting green economic activity. The Montreal Protocol on the Substances that Deplete the Ozone Layer, for instance, led to the development of an entire industry focused on the destruction and replacement of ozone-depleting substances. The international trading system can also have significant influence on green economic activity, enabling or obstructing the flow of green goods, technologies and investments. If environmental resources are properly priced at the national level, then the international trading regime allows countries to sustainably exploit their comparative advantage in natural resources that benefits both the exporting and importing country. Finally, an active role by governments in international processes, such as the United Nations Conference on Sustainable Development in 2012 (Rio+20) and the United Nations Environmental Management Group's work on green economy, can promote coherence and collaboration in the transition to a green economy.



# 1 Introduction

A green economy focuses on improving human well-being and reducing social inequity over the long term, while not exposing future generations to significant environmental risks and ecological scarcities. It seeks to do this in two ways. First, by increasing investment in the sustainability of ecosystem services upon which much of the world's poor depend, it ensures that the environment can continue to be used for the benefit of current and future generations. Second, by basing strategies for economic growth on the sustainable use of natural resources and the environment, a green economy generates the long-term jobs and wealth that are needed to help eradicate poverty. A green economy also recognises that conventional economic indicators, such as GDP, may provide a distorted lens for economic performance. This is because such indicators fail to reflect the extent to which production and consumption activities may be drawing down natural capital.

The various sector chapters of this report have demonstrated that while there is a clear economic case for promoting a green economy, certain enabling conditions need to be created and maintained so that private sector actors will have an incentive to invest in green economic activity. This chapter focuses on these enabling conditions, and in particular, explores the measures that can be used to create them.

Enabling conditions are defined as conditions that make green sectors attractive opportunities for investors and businesses. If the right mix of fiscal measures, laws, norms, international frameworks, know-how and infrastructure is in place, then the green economy should emerge as a result of general economic activity. In addition to these policies, creating the right conditions in the investment environment requires a combination of capacity, information, dissemination of good policy practice, social assistance, skills, general education and awareness to make sure that green measures are well designed, implemented, enforced and understood, without causing unintended impacts or being prevented by practical or political challenges.

Enabling conditions can be created by a wide range of actors and institutions, including, first and foremost, governments, but also intergovernmental organisations (IGOs), international fora such as the Asia-Pacific Economic Cooperation (APEC) forum or the Group of Twenty (G20) Finance Ministers and Central Bank Governors, multilateral environmental agreements

(MEA), such as the United Nations Framework Convention on Climate Change (UNFCCC), international and national non-governmental organisations (NGOs), unions, and private sector actors from international conglomerations and large firms to small and medium-sized enterprises (SMEs).

This chapter focuses on the changes that could feasibly be introduced in the short to medium term by governments at all levels, from the executive power to particular ministries (such as those responsible for environment, finance and the general economy), and provincial and local authorities. The chapter provides a survey of the main categories of policy tools available to governments to promote a transition to a green economy. It begins with a discussion of five key areas of policy-making that have been highlighted in the previous chapters as creating the enabling conditions that support a green economy transition:

1. using *public investment and spending* to leverage private investment, including public infrastructure projects, green subsidies and sustainable public procurement;
2. using *market-based instruments, such as taxes and tradable permits* to level the playing field and provide market incentives in order to promote the greening of key sectors;
3. implementing *subsidy reform* in areas that deplete and degrade natural capital;
4. designing a country's *regulatory framework of legislation, institutions and enforcement* to channel economic energy into environmentally and socially valuable activity; and
5. the role of *international frameworks* that regulate economic activity, including the international trading system, in driving a green economy.

The chapter concludes with a discussion of additional supporting measures that may be required, namely, capacity building and investment in training and education. A summary of the enabling conditions identified in the sector chapters of this report is included in Annex 1. Given their importance and complexity, measures related to finance are discussed in a separate chapter.

## 2 Key policy tools

The sections below outline the main categories of policy tools that governments may use to promote a transition to a green economy. As an introductory remark, it is worth noting that green economy strategies and related timeframes will vary based on a country's circumstances. The mix of policy tools, and the timeframes for their implementation, will consequently vary from one country to another. Moreover, a country's particular transition strategy may arise as a result of government decisions at the most senior level or may instead emerge gradually from initiatives being taken at a sectoral or sub-sectoral level by ministries and local government authorities, as well as in response to innovation from the private sector and civil society. Given these factors, it is not possible or advisable to prescribe a single green economy policy mix that is relevant and applicable to all countries. Rather, in supporting a green economy, transition countries will likely prioritise their choice of policy based on a number of factors, including:

■ *Existing development plans and commitments.* These include state economic and development plans, national sustainable development strategies, poverty reduction strategies, and strategies for meeting the Millennium Development Goals (MDGs). To avoid duplication, policy tools for a green economy should complement and contribute to these existing strategies;

■ *National circumstances.* These include the cost and abundance of labour and capital, environmental and natural resource endowments, the extent of locked-in capital stock, availability of renewable energy resources, institutional capacity and governance strengths and weaknesses, political stability, demographic profile, and the strength of the private sector and social actors;

■ *Sub-national differences.* In many cases, the greening of key sectors will have differential impacts on rural and urban areas, or different sub-national regions. Regions with pressing environmental or social problems might be targeted as a focus for green development;

■ *Culture and traditions.* These factors can influence a community's material aspirations and consumer behaviour, thereby affecting a country's path to a green economy. More broadly, culture and traditions will in many cases require long-term attention to ensure a just transition; and

■ *Costs and timescales of different policies.* In some sectors, there are quick wins that can be targeted and achieved on a relatively short time scale. Elsewhere, medium- to long-

term preparation might be needed to overcome technical and political economy challenges. In some circumstances, such as the design of cities or investments in renewable energy, there might also be pressing reasons to act now to prevent significant future losses despite high financial and political costs in the short term.

A careful analysis of the above factors will also assist countries in assessing the feasibility of implementing a given policy reform or tool. No matter which policies are prioritised, the existence of robust institutions – at a national and an international level – is vital. Strong institutional capacity provides the basic functions for the effective design, implementation and operation of any policy intended to enable a green economy: consistent, science-based measurement, analysis and decision-making; inclusive consultation and strategic planning; monitoring the performance of policies and economic actors; adaptation of policies where necessary; enforcement of laws; transparency and accessibility regarding information of interest to citizens; and existence of systems that ensure the accountability of decision-makers. The need for strong institutional capacity reinforces the importance that should be placed on the international community to provide technical and financial assistance for building such capacities in developing countries.

### 2.1 Promoting investment and spending in areas that stimulate a green economy

While the bulk of green economy investment will ultimately have to come from the private sector, in some situations the careful use of public expenditure and investment incentives can play an important role in enabling markets to incentivise green economic activity. Such situations might include the need to overcome market barriers or the need to act quickly, due to fear of locking in unsustainable assets and systems, or of losing valuable natural capital that people depend on for their livelihoods. Three important focuses for public spending are: (a) the promotion of innovation in new technologies and behaviours that are vital to green markets; (b) investment in common infrastructure that is required for certain green innovations to flourish; and (c) fostering infant green industries, as part of a strategy to build comparative advantage and drive long-term employment and growth.

Public expenditure can be harnessed in a number of ways to alter the operation of markets. Many of these

measures are already being used by governments to support investments more generally in the economy, but can be targeted specifically and strategically at changing market dynamics for green projects, sectors or investors. Considerable caution is needed, however, in considering such strategies: fiscal resources are scarce and it is not possible or advisable for governments to try to spend their way out of an unsustainable economy. Ultimately, if it is to enable markets, the short-term use of public expenditure should be prudently applied in ways that alter market dynamics in the long-term. Choosing which green investments to support, for example, is not an easy task; governments have a chequered record of choosing specific technologies and goods as winners. Such decisions are particularly difficult in the context of immature technologies. Comprehensive analysis of national conditions and a range of potential interventions can help determine what to support and how – from investing in infrastructural improvements that will enable rural communities to embrace conservation agriculture, to establishing feed-in tariffs that will foster an infant renewable energy industry. Although situations vary, most interventions should:

- Be aligned with sustainable development priorities, taking into account possible impacts across economic sectors;
- Be aligned, where possible, with strategies to strengthen a country's national comparative advantage;
- Not replicate or support investments that are likely to be made anyway;
- Be solution-neutral, avoiding designating specific technologies or firms as champions, and allowing market forces to best determine how green outcomes can be achieved;
- Be strategically targeted to have long-term impacts on market dynamics, that will continue after the funding is withdrawn; and
- Be designed with mechanisms to control costs.

The following section discusses in more detail some of the ways in which additional public expenditure might be applied, as well as how existing expenditure can be harnessed to stimulate markets through sustainable public procurement.

### Public expenditure measures

There are a variety of measures that governments can use to promote investment in the green economy. Several of these measures can be considered a subsidy. Subsidies are not just direct financial transfers, but also include advantages such as exemptions from taxes or

regulations, accelerated depreciation of assets, or below-market access to government-owned resources. A number of the sector chapters in this report recommend that subsidies should be used to help promote innovation, establish green common infrastructure and foster green infant industries (see Box 1).

Government subsidies for innovation may be needed where market barriers dissuade private investments, or where accelerating the development of an innovation is clearly in the public good. Innovation – in its broadest sense, transformational improvements in meeting social needs – includes not only the development and deployment of new technologies, but also the modification of technologies to new contexts and the development of new behaviours. Governments can “push” innovation by providing subsidies to parts of the research and development (R&D) chain, from basic research in universities to applied research in labs and industry, often on a cost-sharing basis. In addition to subsidising R&D, governments are increasingly offering support for the demonstration of projects with costs that are too high to attract private investors. Alternatively, policies can be designed to “pull” innovation, by creating clear demand for, say, a certain technology in the marketplace, such that the private sector has a strong incentive to drive the innovation process.

“Pull” policies overlap with green industrial policy more generally – that is to say, policies dedicated to the creation or fostering of green markets. This might involve the creation of common infrastructure required to green economic activity, such as smart grids, or affordable access to broadband internet connections. It could also involve targeted support to key green industries. Short-term support from governments can give businesses the time they need to achieve competitiveness through a range of factors, such as reducing costs through learning-by-doing and producing at economies of scale, or establishing a customer base through market recognition. Packages of investment incentives are also often used to attract foreign direct investment or retain large domestic investors. This can be particularly important for the stimulation of local sourcing and the transfer of skills and technology to domestic businesses.

There are a large number of mechanisms that governments regularly employ to this end. Foregoing government revenue is one such example. Turkey, for instance, offers reduced licence fees for entities applying for licences to construct renewable energy facilities and provides deductions for the rent and right of access and usage of the land during the investment period (Gaupp 2007). Tax incentives are another variant of this type of support. A number of municipalities in India, for instance, have established a rebate in the property tax for users of solar water heaters. In some cases this rebate is 6-10 per



## Box 1: Investing in green infrastructure

A number of sector chapters in this report recommend specific public investments in infrastructure or public services that enable green markets and more efficient use of the environment and natural resources. Improving the physical and telecommunications infrastructure of agricultural communities, for example, can stimulate growth in sustainable agricultural markets and provide employment and development opportunities in rural areas.

It is estimated that the vast majority of green infrastructure investment will take place in developing countries to address issues related to the quality and availability of essential economic goods and services including energy, water, sanitation and transport (UNEP 2010b). These investment choices will have a significant bearing on future patterns of economic development and environmental conditions, and can therefore

have a considerable impact on the transition to a green economy.

Globally, it is estimated that from 2008-2009 some US\$ 512 billion out of US\$ 3.3 trillion in public funds committed to government stimulus packages was earmarked for low carbon and environmental infrastructure investments (Barbier 2010b). For example, in January 2009, at the height of the global recession, the Republic of Korea launched its national Green New Deal plan. At a cost of around US\$ 36 billion, or approximately 3 per cent of GDP, the initiative aims to create 960,000 jobs based on green infrastructure projects and public services. The low-carbon projects include developing railroads and mass transit, fuel efficient vehicles and clean fuels, energy conservation and environmentally friendly buildings. Additional projects aim to improve water management and ecological protection (Barbier 2010a).

cent of the property tax (Ministry of New and Renewable Energy of India 2010). Similarly, accelerated depreciation is often used to encourage the production of energy from renewable sources. It allows an investor to depreciate the value of eligible fixed assets at a higher rate, which reduces the investor's taxable income. In Mexico, investors in environmentally sound infrastructure have benefited from accelerated depreciation since 2005, and in Hong Kong, buyers of environmentally friendly vehicles benefit from a reduction in registration tax and other tax incentives (National Ecology Institute of Mexico 2007; Environmental Protection Department of Hong Kong).

Loan support is also common, either through favourable lending conditions (such as loan guarantees or less stringent repayment conditions) or low-cost financing (such as subsidised interest rates or soft loans). These types of measures have been successfully implemented in both developed and developing countries. In Brazil, for instance, the São Paulo State Industrial Pollution Control Programme (PROCOP), established in 1980, provided preferential credit and technical assistance to polluters, making the pre-treatment process less burdensome. The project was funded by the state government and the World Bank and administered by the state pollution control agency, CETESB, and it is considered to have played an important role in encouraging environmental pollution control activities and improving environmental quality in São Paulo, Brazil (Benjamin and Weiss 1997).

Many countries also provide legislative support to favoured industries. The establishment of mandates can guarantee a market for producers, such as the European Commission's Renewable Energy Directive, which requires EU countries to source 20 per cent of their energy from renewables by 2020. Feed-in tariffs operate in a similar fashion, by requiring electricity suppliers to purchase renewables-based electricity from producers at a certain price.

The important thing to note, however, is that none of these policies are free – they all use up scarce fiscal resources, and are vulnerable to capture by industry. The essence of green industrial policy should be that government investments are targeted at helping infant industries mature, are closely monitored, and are strictly time-limited (see Ensuring rational public expenditure for more information).

As an alternative to committing additional funding to the stimulation of green industry, governments can also focus on how their *existing* spending is being used – namely, sustainable public procurement. Procurement of goods and services by governments and state-owned enterprises usually represents a large proportion of total public spending. Analysis in 2001 estimated that OECD countries spent between 13-20 per cent of their GDP on procurement of such goods and services as buildings, rail and road infrastructure, cleaning and other services, and purchases of office supplies and energy (IISD 2008).

Although less data is available regarding procurement in developing countries, literature suggests similar and, in some cases, higher percentages: 8 per cent of GDP in Kenya and Tanzania; 30 per cent in Uganda (Odhiambo and Kamau 2003); 35 per cent in South Africa; 43 per cent in India; and 47 per cent in Brazil (IISD 2008). By committing to purchase goods which meet certain criteria for sustainability, governments can therefore represent a powerful force of market demand.

Like many of the subsidy mechanisms identified above, government demand for green goods and services can provide businesses with a high-volume and long-term buyer. The market signal allows firms to make longer term investments in innovation, and allows producers to realise economies of scale, lowering costs. In turn, this can lead to the wider commercialisation of green goods and services and thereby promote sustainable consumption. One study examining 10 product groups found that the most advanced sustainable public procurement programmes in Europe reduced the carbon footprint of procurement by an average of 25 per cent (Pricewaterhouse Coopers, Significant and Ecofys 2009). Unlike most other subsidies, it can be achieved largely through the reorientation of existing spending. It also provides governments with a valuable tool to demonstrate their commitment to sustainable development. Nearly all developed countries have some kind of sustainable public procurement policies, and many developing countries, such as India, Chile, South Africa and Vietnam, are in the process of establishing their own (Perera, Chowdhury and Goswami 2007) (see Box 2).

### Ensuring rational public expenditure

There are a number of challenges associated with the implementation of public expenditure measures, and these challenges can be particularly pronounced in

countries with limited institutional capacity. In some cases, governments may lack the capacity to design effective incentives and incentive schemes, or to implement and monitor the measures. In other cases, governments may lack the technical expertise to ensure that an asset is constructed and operated (or a service provided) in the most cost-effective and sustainable way, or there may be a lack of available public funds. A number of innovative initiatives have been launched to overcome these constraints (see Box 3).

Given the institutional capacity that is often required to ensure that a public expenditure measure is effective and leads to a desired outcome, it is important to carefully assess what type of measure should be used. The various measures discussed above have their strengths and weaknesses and the choice of measure depends in large part of the overall policy objective. For instance, direct spending to support the development of environmentally sound technologies may in some cases be preferable to tax incentives because it can be difficult to ensure that expenditure in the form of tax incentives promotes innovation that generates social rather than private benefits (UNEP 2010b). Nevertheless, where the tax incentive supporting technology development is based on performance and rewards the best observed practices, the instrument is likely to be efficient (OECD 2010b).

In some cases, performance incentives may be more suitable for ensuring that economic activity is green. These incentives can be used to help reduce the cost of adherence to environmental and social standards without compromising those standards. For example, several regional investment incentives in India, the Philippines, Chile and Costa Rica have established funds for the certification of management systems on environmental and social performance. The International Organization

## Box 2: The Marrakech Task Force on Sustainable Public Procurement

The Marrakech Task Force on Sustainable Public Procurement was launched by the government of Switzerland in 2005, and is one of seven task forces in the Marrakech Process on Sustainable Consumption and Production, led by UNEP and the United Nations Department of Economic and Social Affairs (UN DESA). It is an international initiative to promote sustainable public procurement in developing and developed countries. Since 2008, its objective has been to roll out an approach for the implementation of sustainable public procurement in 14 countries, with pilot projects currently being conducted in Mauritius, Tunisia,

Costa Rica, Colombia, Uruguay, Chile and Lebanon. The approach consists of first assessing a country's procurement status; identifying the legislative framework for procurement and possibilities for integrating social and environmental criteria into procurement activities; carrying out a market readiness analysis to scope the existing supply-side capacity in sustainable goods and services; and finally the development of a country-based sustainable public procurement policy, including a capacity-building programme for sustainable public procurement officers (UNEP 2010c; UNEP 2010d).

for Standardization estimates that these measures have played an important role in the uptake of the ISO 14000 series on environmental management and the ISO 14065 series on greenhouse gas monitoring in lower income countries and small organisations (IISD 2009).

Despite their potential for kick-starting a green economy, once incentives and subsidies have been created, they can be difficult to remove as recipients have a vested interest in their continuation. In general, governments can try to keep expenses to a minimum by designing subsidies that are time-bound and with cost control in mind. For example, depending on the support mechanism, this might include regular programme reviews, with agreed conditions for adjustment, as well as caps on total spending and clear sunset provisions (Victor 2009). Moreover, an International Energy Agency (IEA) analysis of subsidies for renewable energy suggests that, where countries aim to stimulate private investment in a sector, it is important that the support is stable and predictable, gives certainty to investors, and is phased out over time in order to motivate innovation (OECD/IEA 2008).

In terms of sustainable public procurement, one of the biggest hurdles facing governments is that environmentally and socially preferable goods and services can have higher up-front costs than less sustainable alternatives. This is especially true where markets for green alternatives are still in their infancy. There are a number of strategies to reduce these costs, such as:

- Focusing on goods and services, which promise lower overall costs in the short-to-medium term once their efficiency gains in running costs are taken into account;

- Considering long-term leasing of items such as electronic equipment, vehicles and furniture, which transfer the costs of maintenance, repair, upgrading and replacement back to the suppliers;

- Transforming tenders for individual products into tenders for integrated services; and

- Exploring cooperative contracts and central purchasing platforms, through which the purchases of many agencies can be collectively negotiated to obtain sizable bulk discounts.

## 2.2 Addressing environmental externalities and market failures

Supporting a green economic transition will require that governments address existing market failures, including where markets are completely lacking, as is the case for many ecosystem services, or when markets fail to account for the true costs and benefits of the economic activity. Unsustainable economic activity often enjoys a price advantage when there is a negative externality; that is, where the production or consumption of goods and services has negative spill-over effects on third parties, the cost of which is not fully reflected in market prices. In essence, an externality means that the market price of an unsustainable good or service is lower than its actual social costs, with the difference borne primarily by people other than the buyer and seller. For instance, in a number of economic sectors, such as transportation, negative externalities such as pollution, health impacts or loss of productivity, are typically not reflected in costs. The situation for waste is similar, where the full cost associated with the handling

### Box 3: Private finance initiatives

Where governments lack the technical expertise to ensure that an asset is constructed and operated (or a service provided) in the most cost-effective and sustainable way, or where the availability of public funds is limited, one alternative is private finance initiatives (PFIs). Under a PFI arrangement, a tender is advertised specifying what asset or service a government would like to achieve, including criteria for promoting sustainable development objectives. It then selects the best bidder and enters into a contract where the design, finance and construction are all provided by the private sector, often through a consortium of enterprises. The logic is that by integrating these functions in one package, sustainable design

and green technologies can be planned for in an integrated manner and better efficiencies can be achieved. A variant on this model is co-investment, whereby the public sector provides a share of the project capital.

The advantage of the PFI model is that it allows the private consortium to operate the asset for a substantial period of time, thus harnessing their ingenuity and efficiency and often creating cost savings. PFIs also involve extensive risk transfer to the private sector and, as a result, greater cost certainty for the government. Of course this comes at a cost – the private sector will not bear the risk without being compensated.

## Box 4: Feed-in tariffs

Feed-in tariffs can be a powerful market-based instrument to reduce greenhouse gas emissions, enhance energy supply security, and enhance economic competitiveness. A feed-in tariff is regulated by the government and makes it mandatory for energy companies responsible for operating the national grid to purchase electricity from renewable energy sources at a pre-determined price that is sufficiently attractive to stimulate new investment in the sector (UNEP 2010e).

Feed-in tariffs are the most common policy used by governments to promote renewable power generation. Of the 83 countries that currently have renewable energy policies, at least 50 countries – both developed and developing – and 25 states/provinces have feed-in tariffs. Over half of these

tariffs have been adopted since 2005 (REN21 2010).

Analysis of the use of feed-in tariffs in the European Union suggests that the tariffs achieve greater renewable energy penetration than other market based instruments, and do so at lower costs for consumers (European Commission 2008). In Kenya, it is expected that a recently revised feed-in tariff policy will stimulate around 1300 MW of electricity generation capacity, contributing significantly to energy security in the country. Moreover, the Kenyan feed-in tariff is expected to stimulate the building of renewable energy infrastructure as well as lead to the implementation of projects to increase the capacity of sugar companies for biomass-based cogeneration, thereby contributing to employment and development in rural areas (UNEP 2010e).

and disposal of waste is usually not reflected in the price of a product or waste disposal service. Aside from the problem of basic fairness, this is a problem because in order for markets to efficiently allocate resources, prices need to accurately reflect the full social costs of economic activity.

This section looks at how market incentives might be altered by improving price signals through the use of environmentally-related taxes and other market-based instruments (see Boxes 4 and 5). In so doing, the enabling condition of a more level playing field would be established between green activities and their

## Box 5: Peak pricing

Peak pricing is a pricing technique commonly used by electricity distributors, whereby electricity usage charges are higher during periods of peak demand. This gives electricity consumers an incentive to reduce consumption, at least during peak periods. Peak pricing has been used by developed and developing countries. For instance, in 1987, peak pricing was introduced in some areas of China to address the country's electricity supply shortages, and led to a variation in the cost of hydropower between dry and rainy seasons (Zhao 2001).

Congestion pricing is a similar technique, used to manage traffic congestion. One of the earliest examples of congestion pricing is Singapore's road-charging scheme, which subjects road users to a congestion fee each time they enter a cordoned area. Road charges vary depending on traffic conditions at the pricing points (Land Transport Authority of Singapore 2011). The scheme has

proven successful in managing the congestion of Singapore's roads (Keong 2002). Congestion pricing is a useful mechanism for making users aware of the negative externalities of road transport, such as air and noise pollution, environmental degradation and delays, as these costs are internalised so that consumers are obliged to pay for their contribution to traffic congestion. The economic rationale is that congestion charges encourage users to consider cheaper alternatives, such as travelling during off-peak times, or switching to public transport.

Peak pricing and congestion pricing can encourage electricity and road users to reduce their consumption. Furthermore, peak pricing may facilitate increases in the proportion of electricity supplied by renewable sources, by enabling electricity distributors to manage periods when renewable energy supply is low, such as during periods of low wind or sunlight.

## Box 6: Environmental taxes and innovation

In a recent study, the OECD found that placing a price on pollution creates opportunities for innovation as firms seek out cleaner alternatives. For instance, in Sweden the introduction of a tax on NO<sub>x</sub> emissions led to a dramatic increase in the adoption of existing abatement technology – from 7 per cent of the firms adopting the technology prior to the tax to 62 per cent the following year. Taxation has an advantage over more

prescriptive instruments, such as regulations, by encouraging innovation across a range of activities from the production process to end-of-pipe measures. The study also found that the design of the measure is of critical importance. Taxes that are levied closer to the source of pollution (e.g. taxes on CO<sub>2</sub> emissions versus taxes on motor vehicles) provide greater opportunities for innovation (OECD 2010b).

unsustainable competitors. In addition to their price effects, some of these policies also have the potential to increase public revenue, which could make an important contribution to the financing of a green economy. Generally, the key actors involved in creating this change are governments, although, as will be made clear in the subsequent discussion, there are challenges regarding data, implementation and politics that other actors can help overcome.

### Environmentally related taxes

As noted above, failing to reflect environmental externalities in prices makes it harder for sustainable alternatives to compete, biasing the market against investment in green sectors and retarding the development of green economic activity. A solution to this problem is to use pricing techniques to internalise the cost of the externality in the price of a good or service via a corrective tax, charge or levy, also sometimes referred to as full-cost pricing. Another solution is to use other market-based instruments, such as tradable permit schemes.

Environmentally related taxes can be broadly broken down into two categories: “polluter pays” focused on charging producers or consumers at the point that they are responsible for the creation of a pollutant; and “user

pays”, which focuses on charging for the extraction or use of natural resources. Such taxes can provide clear incentives to reduce emissions and use natural resources more efficiently. Environmentally related taxes have also been shown to be particularly effective in stimulating innovation (see Box 6).

The revenue raised from environmental taxes can be used to mitigate the damage done by unsustainable production and consumption; to promote green economic activity; or to contribute to other priority spending areas. The overall tax burden can be kept unchanged by lowering incentive-distorting taxes simultaneously with the introduction of environmentally related taxes. This can help make green taxes politically more acceptable and may also result in a double or even triple dividend – a reduction in pollution at the same time as an increase in efficiency and, possibly, employment (Green Fiscal Commission 2009) (see Box 7).

### Tradable permit schemes

Like taxes, other market-based instruments, such as tradable permits, are being increasingly used to address a range of environmental issues. As opposed to taxes which fix a price for pollution and then allow the market to determine the level of pollution, tradable permit

## Box 7: Green tax shifts – A double dividend for jobs and the environment

Governments can use taxes to put a price on pollution and the use of scarce natural resources, and, at the same time, maintain the same amount of overall tax revenue by proportionately reducing taxes on socially beneficial activity, such as human labour. A study by the International Labour Organization (ILO) on the impact on the global labour market found that

imposing a price on carbon emissions and using the revenue to cut labour costs by lowering social security contributions would create 14.3 million net new jobs over a period of five years, which is equivalent to a 0.5 per cent rise of world employment (ILO 2009). Even carbon-intensive industries see an increase in employment (ILO 2009).



schemes, including cap-and-trade systems, first establish an overall level of pollution allowed and then let the open market determine the price. Tradable permit schemes were first introduced by countries several decades ago and have gained renewed attention more recently given their application for addressing climate change. For instance, the Kyoto Protocol provides countries with the ability of trading greenhouse gas emissions reduction credits. In total, the Protocol resulted in 8.7 billion tonnes of carbon traded in 2009 with a value of US\$ 144 billion (World Bank 2010).

Likewise, markets establishing payments for providing ecosystem services such as carbon sequestration, watershed protection, biodiversity benefits and landscape beauty, have gained considerable attention over the last several years. Payments for ecosystem services (PES) schemes aim to influence land use decisions by enabling landholders to capture more of the value of these environmental services than they would have done in the absence of the scheme (Barbier 2010a). The evidence on the effectiveness of PES schemes in reducing deforestation has been mixed. A number of studies looking at national PES schemes in Costa Rica and Mexico found that much of the land being put under payments was not at risk of being converted because of its low opportunity costs (Muñoz-Piña et al. 2008; Sanchez-Azofeifa et al. 2007; Robalino et al. 2008).

As the contribution of deforestation and forest degradation to greenhouse gas emissions has become better understood, the potential to create an international PES scheme related to forests and carbon has become a key focus of international climate negotiations. The scheme, coined REDD (Reducing Emissions from Deforestation and Forest Degradation) and more recently as REDD+, which adds conservation, sustainable management of forests and enhancement of forest carbon stocks to the list of eligible activities, represents a multilayer PES scheme with transfers of finance between industrialised countries and developing countries in exchange for emission reductions.

The sums of money being estimated for full implementation of REDD+ are in the tens of billions of US dollars worldwide. The amounts committed for preparation activities and bilateral programmes greatly exceed what has been provided so far in PES, providing grounds for optimism that this new mechanism can capture and transfer important new resources for ecosystem services provided by forests. Although PES will not be the only strategy used by governments to achieve forest-based emission reductions, it is likely to be important.

### **Ensuring effective use of environmentally related taxes**

The sector chapters in this report identify many promising applications for environmentally related taxes and

market-based instruments to internalise environmental externalities such as the cost of greenhouse gases, industrial pollutants, impacts of fertiliser and pesticide use, waste, and the over-exploitation of common resources such as fisheries, forests and water.

Environmentally related taxation on some level has been used successfully by countries around the world since the 1970s and 1980s, including China, Malaysia, Columbia, Thailand, the Philippines and Tanzania (Bluffstone 2003). China, for example, developed an extensive system of charges since the late 1970s, which raised over US\$ 2 billion in revenues by 1994 (OECD 2005). Likewise, levies on natural resource extraction are common practice and many developing countries are highly dependent on revenues from resource extractive industries (UNEP 2010b).

There are some key issues to bear in mind when considering the use of environmentally related taxation instruments. For one, their applicability is often limited to unsustainable economic activity that governments would like to reduce or better manage, not to those activities they want to eliminate entirely. In cases where the activity should be prohibited, regulatory measures are typically a more appropriate instrument than taxes. It is also well recognised in taxation literature that to be most effective, taxes should be levied at the point where the externality is created, and to the extent possible, set at a rate equal to the cost of the externality (UNEP 2010b; Roy 2009).

In reality, it is not always possible to meet these objectives rigorously. Setting taxes at the correct level, for example, requires regular monitoring of externalities and undertaking studies to estimate their cost. Where tax rates are set higher than the amount strictly needed for internalisation of the externalities, the end result can be a socially sub-optimal resource allocation in which value-generation that involves sustainable levels of pollution or resource extraction is foregone. Likewise, it is not always possible to directly tax the externality in question. In some cases, proxies are used, such as a road tax as a proxy for a CO<sub>2</sub> emissions tax. However, these taxes may fail to discriminate between the different amounts of externalities generated by actors engaged in the same activity, such as the aforementioned road tax which is insensitive to more and less efficient car engines.

As with subsidy reform, although the overall aim of a green tax will be to increase welfare, this net gain will almost certainly mask individual winners and losers within an economy. It is widely recognised, for example, that high-carbon industries such as cement or steel manufacturing would find it difficult to compete with international rivals if carbon pricing were only implemented in their country of operation. Similarly, low-income households are sensitive to any price

increases, energy use being a higher portion of their total incomes, and might be unduly affected by a new tax. Any increase to the overall tax burden will have some negative effect on economic output. For these reasons, comprehensive research is usually needed to estimate how green taxes will affect an economy and to help design complementary policies that can ease transition.

Experience with existing environmentally related taxes shows that these dilemmas are commonly overcome by introducing tax exemptions to certain economic sectors. Although these may be effective political solutions, they risk weakening the incentive effect of the tax. Carbon tax exemptions for high-carbon producers, for example, often carve out exactly those firms that are contributing most powerfully to the problem. The best alternative would be international agreements – globally, regionally or sectorally – to tax externalities at a specific level, thus offsetting competitiveness concerns. An intermediary step towards this end-point might be to agree on minimum levels of taxation of certain externalities; or, via regional agreements, to simply begin by agreeing on lists of externalities to tax, but leaving the rate of taxation up to member countries to determine. Any remaining impacts could be dealt with by recycling tax revenues into aid for industry restructuring. A portion of this might involve support for capacity reduction, including welfare payments for unemployed workers and retraining schemes. Where international agreements cannot be reached, countries with ambitious internalisation policies might alternatively be able to negotiate conditions for the use of a border tax on imports in the World Trade Organization (WTO), thus mitigating any competitiveness impacts.

Similar solutions are often proposed for offsetting any negative social impacts: tax revenues can be re-channelled into social welfare safety nets or other welfare-enhancing programmes, potentially allowing governments to make the final outcome socially progressive, as opposed to simply neutral. As with subsidy reform, it is vital that social impacts are properly assessed before implementation to ensure that the right flanking measures are in place to deliver socially just outcomes. It is equally important that such complementary policies be well communicated if they are to help overcome political opposition to change. Governance is also a significant issue and public support for green taxation can be increased if governments introduce effective measures to ensure transparency and accountability. It should be noted that the practice of earmarking – committing to recycle revenues for particular purposes, often politically effective at increasing popular support for green taxes – is generally considered to place excessive constraint on public finances, particularly assuming that the share of revenue sourced from environmentally related taxation is to increase substantially (UNEP 2010b).

A green tax shift is another strategy for minimising or indeed entirely offsetting the economic costs of increased environmentally related taxation. Revenues are re-channelled by reducing taxes on things that promote economic and social well-being, such as jobs, incomes and profits (Green Fiscal Commission 2009). The goal is a double dividend that decreases losses in environmental capital at the same time as boosting employment. In the 1990s and the early 2000s, modest green tax shifts took place in a number of European countries, with broadly positive outcomes in energy demand, CO<sub>2</sub> emissions, employment and GDP.

## 2.3 Limiting government spending in areas that deplete natural capital

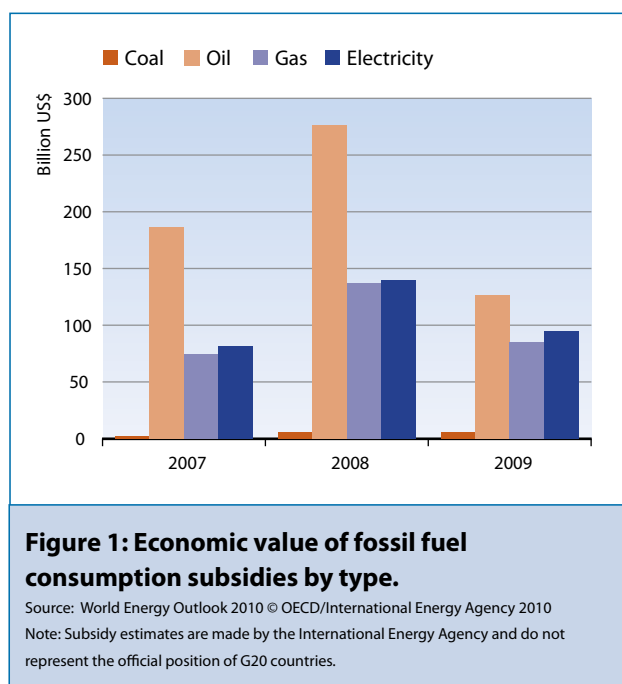
As noted earlier, subsidies are any form of preferential treatment that is provided by governments to producers or consumers. In their most obvious form, they are direct financial transfers that, for example, reduce the price of a good. However, support can be transferred in many other ways, such as tax rebates, exemption from legal obligations or below-market prices for access to government land (GSI 2010). They are a popular policy instrument for many governments because the mechanisms to implement subsidies do not require much administrative capability, and they can be used to win political support by appealing to specific lobby groups or the perceived needs of the general populace.

### Environmentally harmful subsidies

Although, as noted above, there are legitimate reasons for using subsidies in some cases, they can be environmentally harmful in other cases. Moreover, once they have been created, subsidies are hard to remove, and they entail a high opportunity cost. According to analysis by the World Bank, a large number of countries spend more on fuel subsidies than they do on public health (World Bank n.d.). When spending is linked to product prices or volatile markets, it can increase to levels far beyond those originally intended.

An International Monetary Fund (IMF) survey of 42 developing and emerging market economies showed that rising oil prices in 2007 led to an average increase in explicit subsidies equal to 1.5 per cent of GDP and implicit subsidies equal to 4 per cent of GDP (Mati 2008). Sometimes the cost of subsidies is paid for with the long-term deterioration of important public services. In some countries, utility companies are expected to absorb the cost of subsidising basic goods like electricity and water, leading to insufficient investment in maintenance and asset renewal (Komives et al. 2005).

Subsidies can also encourage poor environmental and resource management. Artificially lowering the price of



goods through subsidization encourages inefficiency, waste and overuse, leading to the premature scarcity of valuable finite resources or the degradation of renewable resources and ecosystems. For instance, global subsidies to fisheries have been estimated at US\$ 27 billion annually, at least 60 per cent of which have been identified as harmful, and are thought to be one of the key factors driving over-fishing (Sumaila et al. 2010). It is estimated that depleted fisheries result in lost economic benefit in the order of US\$ 50 billion per year, more than half the value of global seafood trade (World Bank/FAO 2009).

Subsidies reduce the profitability of green investments. When subsidization makes unsustainable activity artificially cheap or low risk, it biases the market against investment in green alternatives. Fossil fuel consumption subsidies were an estimated US\$ 557 billion worldwide in 2008 and production subsidies accounted for an additional US\$ 100 billion (IEA/OPEC/OECD/World Bank 2010) (see Figure 1). By artificially lowering the cost of using fossil fuels, such subsidies deter consumers and firms from adopting energy efficiency measures that would otherwise be cost-effective in the absence of any subsidies. Indeed, there is consensus that these subsidies pose a significant barrier to the development of renewable energy technologies (UNEP 2008a; World Bank 2008; el Sobki, Wooders and Sherif 2009). Moreover, it is estimated that phasing out all fossil fuel consumption and production subsidies by 2020 could result in a 5.8 per cent reduction in global primary energy demand and a 6.9 per cent fall in greenhouse gas emissions (IEA/OPEC/OECD/World Bank 2010).

Subsidies can be of questionable benefit to the poor. Subsidies are often created to benefit low-income households, but unless the aid is targeted the majority of

the spending often flows to higher income households (UNEP 2010b). Similarly, subsidies intended to support small-scale businesses are often captured by large firms (Environmental Working Group n.d.). In other cases, subsidies in developed countries actively harm the poor. The level of government support provided to agricultural producers in OECD countries, for example, estimated at US\$ 265 billion in 2008 (OECD n.d.), is significantly trade distorting, causing large welfare losses in developing countries. Similarly, half of global subsidies to fisheries are provided by developed countries, distorting prices and costs in favour of developed country fishing industries (Sumaila and Pauly 2006). It has been estimated that removing subsidies and tariffs to cotton alone would increase real incomes in sub-Saharan Africa by US\$ 150 million per year (Roubini Global Economics 2009).

### Reforming harmful subsidies

The difficulty of reforming subsidies is practical and political: careful policy implementation is needed to offset undesired secondary impacts, and a combination of strong political will and compensatory policies may be necessary to overcome opposition from vested interests. In some cases, subsidy reform can negatively affect the welfare of the poor, and flanking measures will be required to ensure a socially neutral or ideally progressive outcome.

Subsidies are complicated and often poorly understood. The total support granted to a sector can come from a large number of programmes, given by different arms and levels of government, and the economic, environmental and social outcomes are complex to unravel. A consistent, methodical approach is for governments to adopt a three-stage process of: (i) defining their subsidies; (ii) measuring them; and (iii) evaluating them against the objectives of reform. Such an approach establishes which subsidies are harmful and helps decide priorities for implementation (GSI 2010).

Existing reporting and monitoring of subsidies varies considerably. It is most extensive and internationally standardised in agriculture, but in other sectors, such as energy and fisheries, it is weak. Every three years, WTO Members are required to provide new and full notifications of which subsidies are granted or maintained in all sectors, but reporting rates are low, notifications are often submitted late and there are problems with accuracy and completeness of data (Thöne and Dobroschke 2008).

Although national governments should theoretically have a strong interest in tracking their subsidy spending, as it facilitates the rational use of resources, there is often a lack of political will to act because of the way subsidies benefit vested interests. Where governments find it difficult to act for practical or political reasons, NGOs and IGOs can help fill the gap. Support can also be

offered from international forums and peers. Additional mechanisms, such as a template to facilitate and encourage full subsidy reporting to the WTO, have been suggested as a way to remove obstacles to monitoring (Steenblik and Simón 2011).

The next step is to design a strategy for the implementation of subsidy reform. Although the underlying argument for reform is that it will improve overall welfare, there will be winners and losers. For example, the removal of harmful fishery subsidies helps to encourage the management of a valuable resource, improving the likelihood that it will permit a lower but sustainable level of employment in the long term and liberate revenue that can benefit the economy elsewhere. Another common impact of subsidy reform is to increase the price of goods that have been subsidised. Although low-income groups typically benefit from only a small share of subsidies, they spend a larger proportion of their income on basic goods, including food, water and energy, and can be disproportionately affected if subsidies for these goods are removed. In some cases, careful policy sequencing may be required, to ensure that the poor can access reasonably priced alternatives to subsidised goods and services, as a prerequisite for subsidy removal.

The uneven distribution of the benefits and costs of subsidy reform explains why there is usually strong political opposition. Complementary measures need to be designed to offset some of these concerns, such as short-term restructuring aid for industries, support and retraining for workers and welfare transfers for the poor (see the section on Supporting Actions for

more information). These types of programmes should include substantial stakeholder consultation and are likely to take considerable amounts of time and effort in countries that do not already have the resources and systems in place. The IMF recommends a gradual reform strategy and suggests a number of potential short-term support measures, including the maintenance of subsidies that are most important to the budgets of the poor – mainly by replacing subsidies to producers with targeted consumption subsidies to poor households, and the redirection of funds into high priority areas for public spending, such as healthcare or education (see Box 8). Given the ultimate importance of stakeholder buy-in, a strong communication strategy is needed to reassure affected groups that they will be supported.

The third and final step is ongoing monitoring and review, essential to determine the effectiveness and any unintended consequences of subsidy reform, and whether the mitigation policies – especially financial support – are reaching their intended beneficiaries and achieving their objectives. If mitigation measures are designed with time boundaries or maximum levels of spending, it can help avoid their becoming entrenched and enable the government to adapt them to changing circumstances.

## 2.4 Establishing sound regulatory frameworks

The sector chapters in this report emphasise that certain regulatory reforms at the national level, such as those regarding property rights, traditional environmental

### Box 8: Energy subsidy reform in action

*Cash transfers* – When Indonesia reduced its energy subsidies and raised fuel prices in October 2005, the government established a year-long programme to transfer unconditional quarterly payments of US\$ 30 to 15.5 million poor households. Considering its quick implementation, the programme is considered to have operated well (Bacon and Kojima 2006). The same move was taken when fuel prices were raised in May 2008, with US\$ 1.52 billion being allocated to cash transfers to low-income households (IISD 2010).

The proxy means testing method that was used to identify poor households when reforming subsidies was subsequently used in the government's design and trial of an ongoing conditional cash transfer programme, the Hopeful Family Program (Program Keluarga Harapan), intended to increase

the education and health of poor communities (IISD 2010). Payments are made to female household heads through post offices on the condition that they meet requirements to use health and education services (Hutagalung et al. 2009; Bloom 2009).

*Microfinance* – In Gabon, the impact of subsidy reform was offset by using liberated revenue to help fund microcredit programmes for disadvantaged women in rural areas (IMF 2008).

*Basic services* – When Ghana reformed its fuel subsidies, fees for attending primary and junior-secondary schools were eliminated and the government made extra funds available for primary healthcare programmes concentrated in the poorest areas (IMF 2008).



command and control regulations, and standards, as well as the effective enforcement of these laws, can be important in driving green investment. This section considers key national regulatory tools identified by the sector chapters in this report.

A well-designed regulatory framework can create rights and incentives that drive green economic activity, remove barriers to green investments, and regulate the most harmful forms of unsustainable behaviour, either by creating minimum standards or prohibiting certain activities entirely.

Regulations provide the legal basis that government authorities can rely on for monitoring and enforcing compliance. A well-designed regulatory framework can reduce regulatory and business risks, and increase the confidence of investors and markets. It is often better for businesses to work to clear and effectively enforced standards, and not have to deal with uncertainty or face competition from those who do not comply with the rules (Network Heads of European Protection Agencies 2005). Moreover, regulations may also be particularly appropriate where market-based instruments are not applicable or appropriate, such as where no market exists for ecosystem services (UNEP 2010b).

In many cases, the challenge is not to establish new regulations but to better align existing regulatory frameworks with government objectives to promote green economic activity. Good practice in regulation involves periodic review, and when this is undertaken it should be fact-based, analytically rigorous and should promote procedural and legal certainty by being timely, transparent and non-discriminatory. To use regulatory tools to promote green economic activity in key sectors, it is important to first establish the extent to which existing regulatory frameworks are aligned with policy objectives. This makes it possible to decide which laws should be amended and whether or not any new legislation is needed. The sector chapters of this report have identified a number of areas where regulatory frameworks need to be better aligned with environmental and social development objectives. Although they may be more or less relevant depending on the regulatory frameworks of different countries and jurisdictions, they are illustrative of the type of problems and solutions that find their source in legislation.

Designing fair and effective rules and regulations requires a deep understanding of the regulated sectors. Such rules should seek to be open to encourage and enable trade, investment and financing. The Manufacturing chapter, for example, notes that some industries are highly heterogeneous, making them difficult to regulate without being too soft or too severe. As regulators work

with firms to establish appropriate rules, there is also the risk of “regulatory capture”, where the resulting legislation is more in the commercial than the public interest. Even where a regulation is well-designed, adequate institutional capacity is nevertheless essential to ensure that as little administrative burden as possible is placed on businesses.

### Standards

Standards can be effective tools for achieving environmental objectives and enabling markets in sustainable goods and services. This is because they inform consumers about products and production processes, and create or strengthen demand for sustainable products. Technical standards (i.e. requirements on products and/or processes and production methods) are mainly developed and implemented at the national level, although standards that aim at enhancing energy efficiency and that set targets for emission reductions are also developed internationally. The requirements may be based on the design or the particular characteristics required, such as many biofuel standards, or they may be performance-based, as is the case with many energy efficiency standards (WTO-UNEP 2009). Mandatory standards, in particular, can be very effective in achieving a desired outcome.

In some cases, environmental regulation can drive innovation and economic growth. Companies innovate in response to, for example, tighter waste regulations by changing product design and production processes so that they generate less waste (Network Heads of European Protection Agencies 2005). It has been argued that countries with high environmental standards often have market-leading firms and record better economic performance than countries with lower standards. This is because higher standards can induce efficiency and stimulate innovation, which can have a positive effect on competitiveness for those needing to comply with the standards (Porter 1990).

Nonetheless, the development of standards poses some risks. In many cases, it can be difficult to establish a standard with certainty. Even if an appropriate standard can be found, as time passes it can create a “ceiling of mediocrity”, failing to adequately promote further improvements in performance if there are no mechanisms for regular review and revision (Smith 2008). Complex standards also risk discriminating against small and medium-sized enterprises, particularly in developing countries, which often lack adequate resources to comply with legislation and demonstrate compliance to regulatory authorities.

### Property laws and access rights

In a number of chapters – Agriculture, Forests, Fisheries and Water – a common message emerges: unless people have clear rights over a resource, they will lack the incentive



to manage it well. In the case of agriculture, an absence or weakness of legal rights over a piece of land gives farmers little reason to manage it for the long term (Goldstein and Udry 2008). Access rights can also have important effects on the management of a resource: there is little incentive for individual actors to make sustainable use of fisheries and water resources, for example, when they know that other users may simply increase their own appropriations. This is the classic tragedy of the commons problem, and it can lead to degradation of the ecosystems, which are the basis of much economic activity and well-being, especially in developing countries and among the world's poor (Nellemann et al. 2009).

In addition to strong property laws that promote sustainable resource management, zoning regulations can be crucial in coordinating and integrating green infrastructure investments. While zoning regulations have long been used in developed countries, they remain a relatively underused policy tool in developing countries. Establishing strong zoning regulations, therefore, presents developing countries with the opportunity to establish clear geographical limits around cities to restrict urban sprawl. Well-designed zoning regulations can also be instrumental to create green corridors that protect ecosystems or to prioritise the development of the poorest areas of a city in an environmentally sustainable manner.

Property laws and zoning regulations are politically challenging to establish and change. The legal provision of rights also requires substantial administrative and judicial capacity, sometimes requiring modern technologies to enforce. These political and institutional challenges can come up against an additional layer of complexity when national legislation overlaps with international legislation, as in the case of transboundary fish stocks and cross-border water sources.

### **Negotiated and voluntary agreements**

Not all rules and regulations are created by legislation; exceptions include negotiated and voluntary agreements, and industry self-regulation. These measures are established by governments negotiating with firms, or by one or more firms taking voluntary action themselves, and usually consist of non-binding commitments to certain standards or principles. They can be a useful complement to government rules and regulations as they take away some of the burden of information and administrative costs from government authorities. Moreover, they can be in the interest of businesses if they involve cost-savings (eco-efficiency) or create positive branding. First-mover advantage, and potentially lower legal and regulatory risks, may also motivate industry participants to enter into voluntary agreements or set up a voluntary regulation (Williams 2004).

The risk of regulating via negotiated and voluntary agreements is that they can result in unambitious targets that would be achieved anyway, and some research has questioned their environmental effectiveness and economic efficiency, especially where government involvement is low (OECD 2003b). Nonetheless, a number of such agreements, such as Indonesia's Program for Pollution Control, Evaluation and Rating (PROPER), show that in the appropriate circumstances they can deliver significant environmental benefits (Blackman 2007). In the end, they are not a substitute for government regulatory capacity, since without the credible threat of regulation as a fall-back option there is little incentive to comply with voluntary approaches, and they still require government capacity to assess their effectiveness against their objectives.

### **Information-based tools**

The sector chapters in this report also identify a wide number of information-based tools that can be used to help promote a green economy. Awareness campaigns, for example, can raise general understanding about a particular issue and can be important in pushing through difficult political solutions. They can be government-led, as in the case of independent commissions to research and raise awareness about a given issue, or NGO initiatives like the Greenpeace Stop Climate Change campaign (Green Fiscal Commission n.d.; Ranjan 2009; Greenpeace n.d.). Information programmes can teach people basic skills as well, and promote behaviour that reinforces green economy objectives.

Governments might also introduce regulations to make the provision of certain information mandatory, to enable consumers and investors to more effectively assess the sustainability performance of firms, including their ecological and carbon footprints (see Finance chapter for further detail.) There are also examples of voluntary certification and labelling that have become an industry norm on their own merits before being made a legal requirement, such as the City of Vancouver's energy and emissions targets for buildings (Coleman and Stefan 2009). Moreover, corporate social responsibility (CSR) programmes and tools have become commonplace in many companies and are influencing the ways in which these companies and their suppliers conduct business (Box 9).

## **2.5 Strengthening international governance**

In addition to national laws, there are also a number of international and multilateral mechanisms that regulate economic activity. The following section describes those mechanisms that can play an important role in a transition to a green economy.

### Multilateral environmental agreements

Multilateral Environmental Agreements (MEAs) tend to focus on regulating unsustainable economic activity with standards or prohibitions. The negotiating process usually begins with the collective recognition of an environmental problem, and moves forward with discussions to agree on the nature of the issue, shared needs and goals, and finally ends with the development of a draft text. In some cases, the process results in legally binding obligations and mechanisms to encourage compliance, and in others only a declaration of principles or aspirations (UNEP 2006).

Multilateral Environmental Agreements can play a significant role in promoting green economic activity. They can be the only viable solution to the governance of some global common resources and, even when they result in relatively soft commitments, they nonetheless establish important principles and norms, and increase monitoring and information flows. Although many of the major global environmental issues have been tackled already by MEAs, there is still much room for proactive multilateral policy-making, whether in improving existing MEAs or creating new agreements. The Fisheries

chapter, for example, highlights the need to create regional fisheries management organisations that have the “teeth” to properly manage the use of fish stocks, and a recent analysis of the Basel Convention, identified by the Waste chapter as an important regulatory tool, argues that its prior informed consent (PIC) system and compliance committee can and should be strengthened (Andrews 2009).

One MEA with the potential to influence the transition to a green economy is the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC’s Kyoto Protocol has already stimulated growth in a number of economic sectors, such as renewable energy generation and energy efficient technologies, in order to address greenhouse gas emissions. However, the future of the climate regime is still uncertain as negotiations are mired in the difficult process of designing an architecture to come into force after the Kyoto Protocol’s first commitment period ends in 2012.

As regulatory tools, MEAs can be more or less effective, and more or less difficult to agree, depending on how they are designed and the issue in question. The

## Box 9: Voluntary private sector action and corporate social responsibility

Corporate social responsibility (CSR) is a reflection of the duty of the private sector “[...] to contribute to the evolution of equitable and sustainable communities and societies”, as outlined in the Johannesburg Declaration on Sustainable Development (paragraph 27). It requires a voluntary commitment to enhanced accountability for social, environmental and economic impacts across an organisation’s operations and products. Such voluntary commitment by leading companies can serve to complement and pave the way for eased introduction of new regulation and market instruments to green national economies. One such example is corporate initiatives on ecological footprinting and related labelling, which can benefit from recognition and incentives by government bodies. CSR initiatives can also serve to boost the policy goal of sustainable consumption and production (SCP), driving improved efficiency in the use of ecosystem services and reducing resource degradation, pollution and waste.

Leading companies are increasingly adopting CSR as an integral element of their business strategies, recognising that CSR can yield tangible business benefits. Such benefits include cost savings, greater

access to capital, enhanced productivity, enhanced product quality (through enhanced employee morale and better working conditions), attraction and retention of human resources, enhanced reputation and brand, and reduced legal liability (Googins et al. 2007).

CSR can also increase the accountability and transparency of organisations to society through the use of a variety of communication instruments, including stakeholder engagement, product information and reporting systems. Reporting trends today are moving towards the development of integrated environmental, social and governance reporting (see, for instance, the revision process by the Global Reporting Initiative (GRI) of its guidelines for sustainability reporting, available at [www.globalreporting.org](http://www.globalreporting.org)). In addition, international management standards such as the ISO 14000 series on environmental management and the recently adopted ISO 26000 on social responsibility offer an increasingly referenced framework for action. For example, ISO 26000 provides basic guidance on the underlying principles of social responsibility to promote a common understanding and consistent practices.

Montreal Protocol, for example, is widely considered to be one of the most successful MEAs (see Box 10). A part of this success is due to its skilful drafting, which enabled flexible solutions and included provisions for common but differentiated responsibilities, as well as the creation of robust financing through the establishment of a Multilateral Fund to assist developing countries to comply with the control measures of the Protocol, in particular with the incremental costs of implementation. The Montreal Protocol also succeeded because of the nature of the problem being regulated: it could focus on a specific range of products for which substitutes could be developed, and conferred relatively large benefits to politically influential players at relatively low costs (Sunstein 2007). With a more complex issue like climate change – which has impacts across industries, comes at high cost and disputed benefits, and involves challenges such as the allocation of emission rights and the financing of adaptation – it has proven to be much harder to reach collective consensus.

Even when the process is relatively smooth, the effectiveness of MEAs is sometimes hampered by relatively weak enforcement mechanisms. Few MEAs result in punitive action, and most compliance mechanisms consist of self-reporting and facilitation measures – an area where, again, some MEAs could perhaps be strengthened (UNEP 2006).

### International trade law

The multilateral trading system can have significant influence on green economic activity, enabling or obstructing the flow of green goods, technologies and investments. Much of trade's influence – for good or for bad – depends on the types of domestic policies discussed elsewhere in this chapter. If environmental resources are properly priced at the national level, then the international trading regime should allow countries to sustainably exploit their comparative advantage in natural resources for mutual gain. Analysis in the Water chapter illustrates, for example, the potential for water-scarce regions to relieve pressure on local supplies by importing water-intensive products from water-abundant regions. Similarly, if domestic regimes and policies are in place that allow poor countries to fully exploit the potential gains from trade liberalisation, then trade can be a powerful driver of development and poverty alleviation.

At least part of the influence of trade stems from the internationally agreed rules by which international trade is conducted. The current WTO Doha Round negotiations include issues that could support the transition to a green economy. For example, negotiations are currently focused on the removal of fisheries subsidies, which often contribute directly to overfishing. Trade negotiators are also discussing the reduction of

## Box 10: The Montreal Protocol

The implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer has been successful in not only controlling substances that deplete the ozone layer but also in driving a green economy. To date, the international convention has reduced the production and consumption of nearly 100 industrial chemicals known as ozone depleting substances (ODS) by more than 97 per cent (UNEP Ozone Secretariat 2010). Most ODS have high global warming potential, and the phasing out of many of these chemicals has had the additional benefit of reducing greenhouse gas emissions by about 11 billion tonnes CO<sub>2</sub>-equivalent per year, which is 5-6 times the reduction target of the Kyoto Protocol for the period 2008-2012 (Velders et al. 2007). It is estimated that the implementation of the projects in developing countries that have been approved to date under the Montreal Protocol's funding mechanism – the Multilateral Fund (see [multilateralfund.org](http://multilateralfund.org)) – will result in climate mitigation co-benefits estimated at more than 3 billion tonnes of CO<sub>2</sub>-equivalent (GtCO<sub>2</sub>-eq) at a cost of around US\$1/tonne CO<sub>2</sub>-eq.

Other benefits derived from the implementation of the Montreal Protocol include savings associated with reduced ultraviolet radiation damage to crops, livestock and materials, and the avoidance of cancer and eye cataracts in humans. For example, the United States Environmental Protection Agency (US EPA) recently reported that the Protocol will result in the avoidance of more than 22 million additional new cataract cases for those born between 1985 and 2100 in the US alone (US EPA 2010).

The Montreal Protocol has also generated considerable economic and social benefits, including the creation of opportunities in the replacement and phase-out of unwanted ODS, the production of ODS substitutes, the development and marketing of ozone and climate friendly equipment, and in the creation and funding of National Ozone Units in developing countries (Multilateral Fund Secretariat 2010). The benefits from the Montreal Protocol are expected to grow as countries are now committed to phasing out hydrochlorofluorocarbons (HCFCs) and replace these with climate and ozone friendly alternatives.

tariff and non-tariff barriers on environmental goods and services. A World Bank study found that trade liberalisation could result in a 7 to 13 per cent increase in trade volumes in these goods (World Bank 2007). Likewise, the ongoing negotiations to liberalise trade in agriculture could yield green economy benefits. These negotiations are expected to lead to a reduction in agricultural subsidies in some developed countries that should stimulate more efficient and sustainable agricultural production in developing countries. It is essential, nonetheless, that developing countries are supported through capacity building to fully exploit the potential gains from trade liberalization (see Box 11).

The trade rules governing intellectual property rights (IPRs) and the use of standards and labeling by governments have important implications for the transition to a green economy. Rules regarding the enforcement of IPRs are included in most modern trade agreements. Proponents of strong IPR rules argue that they can help foster a green economic transition by providing incentives for innovators, who can be more certain that their investment in R&D will be rewarded. This is particularly important at a time when new clean technologies are urgently needed; it has been estimated that almost 36 per cent of the reductions in carbon emissions needed by 2020 could be achieved through the application of new technologies in the energy, transport, buildings and industry sectors (Tomlinson 2009).

On the other hand, IPRs create barriers to the transfer of the very technologies and innovations to which

they give rise. Although the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) was designed to take into account the need for balance between innovation and dissemination, noting the need for “maximum flexibility” with regard to least-developed country Members, many sector chapters in this report identify IPRs as an important barrier to the development of green markets. Moreover, some studies note that the TRIPS Agreement has come under criticism for failing to adequately serve the needs of developing countries (Foray 2009).

The use of standards and voluntary labeling schemes is another trade-related area of importance from a green economy perspective. Such tools can be effective for achieving environmental objectives and enabling markets in sustainable goods and services by informing consumers about products and production processes. In the manufacturing sector, for example, standards often “push” the market by requiring manufacturers to meet minimum guidelines, and these are often complemented by voluntary eco-labelling schemes to “pull” the market by providing consumers with relevant information to make informed purchasing decisions. The Forest Stewardship Council (FSC), for example, provides internationally recognised standard-setting, trademark assurance and accreditation services for companies, organisations and communities. The Forests chapter identifies certification as having the largest influence on forest policy over the last decade. Similarly, the Marine Stewardship Council (MSC) recognises and rewards sustainable fishing by working with fisheries and commercial partners to give

## Box 11: Trade-related capacity building

Trade is considered to be one of the major global engines of development, and the sector chapters in this report identify many ways that the trade system can facilitate green markets, from enabling the more efficient use of resources to the transfer of important technologies. But one of the greatest criticisms of the trade system is that many countries lack the capacity that would let them take advantage of these potential gains. There is, however, an existing model that has been designed to address these challenges: the Integrated Framework for Trade-Related Technical Assistance to Least-Developed Countries, or simply, the IF.

The IF – now the enhanced IF – was inaugurated in 1997 at the WTO High Level Meeting on Integrated Initiatives for Least-Developed Countries’ Trade Development, and involves a collaboration of the IMF, the International Trade Centre (ITC), United Nations Conference on Trade and Development

(UNCTAD), United Nations Development Programme (UNDP), World Bank and WTO.

The IF involves a diagnostic phase, where the host country government works in close cooperation with technical experts to identify barriers to increased integration into the global trading system. The resulting diagnostic trade integration studies (DTIS) not only identify challenges but also solutions. Typical solutions include policy changes, such as new laws and regulations; investments in infrastructure, such as new transportation corridors, customs facilities and equipment; or skills capacity building, such as training for trade negotiators. The host country then prioritises those elements of the DTIS that most closely fit with national priorities, mainstreaming the recommendations in their national development planning.

Source: IF Secretariat (2009)



buyers and consumers an easy way to find seafood from a sustainable source (MSC 2009).

More generally, standards and voluntary labelling schemes can also play an important role in sustainable public procurement. Although it is generally considered bad practice for procurement officials to require compliance with a particular standard – companies might have high sustainable credentials without being part of the specified standard, or as part of another accreditation programme – they are often used by procurers to identify good-practice criteria for the evaluation of a good or service's sustainability.

Although standards and labelling schemes can be powerful instruments to drive a green economy, they can also create barriers for small and developing country producers who may not have adequate resources to prove compliance, or for whom the standards are inappropriate. For instance, Uzbek farmers seeking certification in the French organic fruit and vegetable market are reported to have faced compliance costs higher than the national GDP per capita (Vitalis 2002). Elsewhere, water-use standards based on limited water availability in one country have proven to be inappropriate for others where the water availability situation is entirely different (Vitalis 2002). From a trade perspective, the concern is that standards – and mandatory standards in particular – could hinder access by developing country exporters to lucrative markets in developed countries. Yet improving market access for developing country products is essential for development. It is therefore critical to find the right balance between environmental protection and safeguarding market access. Multilateral dialogue and negotiations, whenever possible, are essential to ensure that this balance is met.

Moreover, as noted in the Forests chapter, it may be possible for standard bodies to support a step-wise approach – setting benchmarks for companies that measure their progress towards sustainable criteria and giving them support in planning and building capacity to achieve higher standards (Morrison et al. 2007). Official development assistance can also be used to help developing country exporters successfully meet stringent standards in their main export markets.

### **International investment framework**

The international investment framework is made up of a web of treaties between states, and contracts

between states and private investors, that describe rights and obligations regarding foreign investments. State to state agreements, such as bilateral investment treaties (BITs), regional investment treaties and investment chapters in trade agreements like the North American Free Trade Agreement (NAFTA), provide rights and protections to investors from covered states. Contracts between a state and an investor, often called investment contracts or host government agreements, set out the rights and obligations of the investor and the host state, including the conditions applied to the operations of a single investor and its subsidiaries in the agreeing host country. Host government agreements are most common in developing countries, where often there are fewer general regulations covering investment rights.

An increasing number of recently signed regional trade agreements incorporate environmental considerations in their respective investment chapters. The agreements may expressly promote investment activity that is undertaken in a manner sensitive to environmental concerns, as is the case with the New Zealand–Malaysia free trade agreement. Certain agreements, such as the Canada–Jordan free trade agreement, also seek to promote the enforcement of domestic environmental laws and to ensure that such laws are not derogated from for the purposes of encouraging investment or trade. Although environmental considerations feature increasingly in the international investment framework, many investment treaties and investment contracts do not expressly promote sustainable over unsustainable investments (Mann et al. 2005). A key concern regarding investment contracts, for example, stems from “stabilisation clauses” – provisions in host government agreements that freeze legislation at a certain point in time or that require host states to compensate in case of changes in the law that adversely affect profits. Concerns have been raised that such clauses limit a state's ability to regulate effectively so as to protect the environment and human rights (Shemberg 2008), and this could have consequences for the promotion of a green economy where regulations are established to drive green growth. It is therefore important that both the benefits and constraints associated with international investment frameworks are properly understood when they are negotiated to ensure they support a green economic transition.



### 3 Supporting actions

Depending on their level of development, countries will have a different range of capacities to implement the types of policies discussed in the preceding sections of this report and to cope with the change entailed by a green economic transition. In particular, robust institutions, including the policies, practices and systems that allow for the effective functioning of an organisation or group, are vital to the success of government policies intended to green key sectors (UNDP 2009). A strategy to enable increased green economic activity must therefore include efforts to improve capacities to implement policies and to manage change.

More specifically, countries may need assistance with regard to resources, technical expertise, training, technology development and diffusion, political backing and other kinds of aid from a broad range of actors, including inter-governmental organisations, international financial institutions, bilateral aid agencies, multilateral companies and non-governmental organisations.

#### 3.1 Supporting capacity building and the strengthening of institutions

UNDP has identified five basic functional capacities of governments that determine the outcome of development efforts. They include a government's capacity to: engage stakeholders; assess a situation and define a vision; formulate policies and strategies; budget, manage and implement policies; and evaluate outcomes (UNDP 2009). These generic functional capacities will all be called on to successfully make a green economic transition.

Three of the most important capacity-building issues that are emphasised across the sector chapters are improved information-based capabilities, the need for integrated planning, and adequate enforcement of policy requirements and laws.

The importance of research, data collection and data management cannot be understated. The sector chapters of this report establish that there is already a substantial amount of information about the status of natural resources and ecosystems and how they contribute to economic well-being, as well as the green economic opportunities that can be exploited in every sector of the economy. Nonetheless, a common message is that these generalities need to be carefully nuanced with respect to specific national and local conditions. In addition to technical and human capital, this requires

the development of institutions that adopt a consistent, science-based approach to the assessment and analysis of environmental resources. Hard or soft rules must also exist to ensure that scientific analysis is appropriately factored into policy decision-making and that feedback loops enable ongoing learning and adaptation. Information and Communication Technologies (ICTs) may also play an important role in supporting data collection and research (see Box 12).

Information is also an important issue for good governance. In policy planning processes, awareness of the needs, concerns and knowledge of stakeholders, and interaction on this basis, is vital to ensure socially optimal outcomes. Once objectives are stated and measurable, and the operation of policies is being monitored, the provision of information is also necessary to ensure policy effectiveness and accountability (see the modelling chapter for more information about indicators and measurement). Data also needs to be credibly evaluated and used as the basis for any policy adaptation.

Amassing sufficient information to inform good policy-making is not an easy task. It often requires increased financial resources, improved administrative capacity, technical training and access to technology, as well as developing institutions that allow for the effective functioning of the research and consultation processes, and their interaction with policy-making decisions.

Strategic integrated planning is equally important. Most sector chapters emphasise the need for a holistic approach to policy-making to ensure decisions are aligned with the overall objectives of a green economy. This includes the development of processes and norms to systematise taking into account how policies in one sector might affect others; carefully assessing decisions that have long-term consequences; incorporating skills development policies; and using an appropriate mix of policy tools to achieve a given objective.

Research on the use of multiple policy tools confirms that different combinations of informational, regulatory and market instruments can be more or less effective and efficient in different situations (OECD 2007). The most striking illustration of this principle is in the Cities chapter, which concludes that urban planning has significant, often unalterable impacts on the costs of living and ecological efficiency. Similarly, in promoting renewable energy technologies, it is now well recognised that the establishment of income support

## Box 12: Harnessing Information and Communication Technologies (ICTs)

### ICTs enabling the green economy

Over the past two decades, the products and services produced by the information and communication technologies (ICTs) sector have been catalysts for economic growth. They have enabled productivity gains and transformed production processes, markets and industries in both developed and developing countries. A recent study found that internet-related consumption and expenditure – the central nervous system of the digital economy – is bigger than agriculture or energy. The study also found that the internet's total contribution to global GDP is bigger than the GDP of Spain or Canada, and is growing faster than Brazil's (McKinsey Global Institute 2011).

There is growing recognition among ICT policy-makers and stakeholders that ICTs can be powerful enablers of the green economy through the transformation of economic infrastructures, industry sectors, and social behaviours. They can:

- Increase the efficiency of production and consumption in energy, transportation, building and manufacturing sectors, through the deployment of smart systems. It is estimated that ICTs could reduce global GHG emissions by 15 per cent by 2020, compared to a business-as-usual (BAU) scenario with a 2002 baseline (The Climate Group 2008).
- Wholly or partially “de-materialise” physical products, services and processes, resulting in significant reductions in energy and materials consumption. Examples include paper saving through electronic billing; greater use of tele-work arrangements; and virtual meetings in the public and private sectors.
- Increase access to education, health care and other public services; create new opportunities for social interaction and cultural expression; and facilitate participation in public life.

Future applications of ICTs could enable green economic activity in other ways. The development of new kinds of networks that include objects in the natural environment – commonly referred to as the Internet of Things – would enhance the capacity of public and private actors to monitor all manner of natural and human systems in real time, as well as to manage the operations and impacts of these systems in more sustainable ways. This would have implications for many sectors, including: natural systems providing ecological goods and services; agriculture; forestry; energy; transportation; and buildings and their facilities.

Notwithstanding, policy-makers should also recognise that ICTs come with sustainability challenges too – for example, by increasing overall demand for non-renewable energy and

material resources. The ICT sector has also become a major source of toxic pollution through e-waste and GHG emissions. Such effects need to be carefully balanced against the gains of ICTs, and mitigated where possible, to best promote green economic activity.

### Enabling ICTs

As with a number of green technologies, governments need to create the right enabling environment that will allow ICTs to flourish. This requires close collaboration between government agencies responsible for ICT and green economy initiatives, along with their respective stakeholder communities. Government interventions to enable ICTs to contribute to a green economy include:

- *Universal, affordable access to broadband networks and services.* To a large extent, this objective can be achieved through regulatory frameworks that encourage private investment, promote competition among broadband service providers, ensure open network access to creators of broadband applications and content, and protect the rights of consumers to access broadband services, applications and content of their choice – a policy generally known as “net neutrality”. However, experience also shows that providing access to broadband networks in some geographic areas is uneconomic, and that broadband service is unaffordable for some groups. In such circumstances, many governments have subsidised broadband network deployment and service access through various forms of public investment, subsidies and regulatory requirements.
- *Transition to IPv6.* Internet Protocol version 6 (IPv6), a new addressing system, was developed more than a decade ago to succeed IPv4. Although it provides the virtually unlimited number of addresses that will be needed to support the deployment of smart systems and innovations such as the Internet of Things, its take-up has been slow. Public procurement can have a powerful effect in enabling a smooth transition to IPv6 by stimulating demand for IPv6 products and services. Regulatory requirements can also have a powerful effect.
- *Confidence and trust in the online environment.* Policy-makers need to develop robust legal frameworks, regulatory arrangements, and enforcement mechanisms that will protect personal privacy and the rights of citizens and consumers, combat cybercrime, ensure the security and stability of electronic networks, and balance the rights of users and creators of information products and services. Industry can also contribute, by developing codes of practice that help protect consumers, and developing tools that allow internet users to manage their online identities.

alone might be insufficient or unnecessarily expensive if policy-makers fail to take into account issues such as the grid infrastructure or obstructive planning permission processes (OECD/IEA 2008).

Enforcement of laws and regulations is another area of importance. The effectiveness of any policy tool is dependent upon a chain of actors and institutions working together to ensure it is appropriately implemented – from verifying the use of appropriate award of tenders in sustainable public procurement to ensuring that environmentally related taxation is being levied on relevant economic activity. Financial, administrative and technical capacity is required to adequately monitor compliance, and robust institutions, including social and cultural norms, as well as enforcement organisations with adequate authority, are needed to ensure that the appropriate penalties can be levied where protocol and regulations are violated.

Intergovernmental organisations, international financial institutions, NGOs, the private sector, and the international community as a whole can play a role in providing technical and financial assistance in developing countries. Enabling a smooth transition to a green economy will require a sustained international effort by these actors. The United Nations Conference on Sustainable Development summit in 2012 (Rio+20) provides an invaluable opportunity for the international community to promote green economy action given that one of the two themes for the summit is “a green economy in the context of sustainable development and poverty eradication” (General Assembly Resolution 64/236). The commitment and action by governments, international organisations and others over the next two years will determine whether the summit provides the impetus and direction required for driving the transition.

In addition, the United Nations and its partners have a long history of supporting national capacity building and training activities and can utilise this expertise to support national green economy efforts. Current efforts are underway within the UN system through the Environmental Management Group to harmonise green economy support at the national level. Under this initiative, 32 organisations from the UN system are developing an inter-agency assessment report on how the expertise of the different UN agencies, funds and programmes can contribute to supporting countries in the transition to a green economy (Environmental Management Group 2010).

Moreover, South-South cooperation is critical: many developing country experiences and successes in achieving a green economy can provide valuable impetus, ideas and means for other developing countries to address similar concerns – particularly given the impressive

gains and leadership that have been demonstrated in practice (UNEP 2010e). South-South cooperation can thus increase the flow of information, expertise and technology at a reduced cost. More broadly, as countries take steps towards a green economy, formal and informal global exchanges of experiences and lessons learned can prove a valuable way to build capacity.

### 3.2 Investing in training and education

Training and skill enhancement programmes will be needed to prepare the workforce for a green economy transition. A joint study between UNEP, ILO and other partners found that the impact on workers from a green economic transition will vary greatly depending on the specific economic sector and country in question. In some cases, the transition could mean that jobs would be lost, and in other cases, it is expected that new green jobs would be created. Available studies on a sectoral and economy-wide level suggest that, on balance, there will be more jobs in a green economy (UNEP 2008b). Renewable energy, for example, creates more jobs per dollar invested, per unit of installed capacity and per unit of power generated than conventional power generation. Likewise, public transport tends to generate more employment than reliance on individual cars and trucks (UNEP 2008c). It is also estimated that the pace of green job creation is likely to accelerate in the future (UNEP 2008b).

Rather than replacing existing jobs with entirely new green jobs, however, it is the content of the jobs (e.g. the way the work is performed and the skills of the workers) that will often change (ILO 2008). A skilled workforce is a prerequisite for a green economy, and it may be necessary to focus education efforts on aligning skills with the needs of the labour market. This is particularly relevant for the so-called STEM (science, technology, engineering, and mathematics) disciplines. A number of jobs throughout the economy are expected to be transformed to respond to a more energy and resource efficient economy. For instance, builders will remain in the same employment, but start to provide new, green services. These shifts signal the need for training and skill enhancement of the workforce.

Current shortages in skilled labour could frustrate efforts by governments to transition to a green economy and deliver the expected environmental benefits and economic returns. For instance, almost all energy sub-sectors lack skilled workers with the most pronounced shortages found in the hydro, biogas and biomass sectors. Shortages are also pressing for manufacturing in the renewable energy industry, particularly for engineers, operation and maintenance staff and site management (UNEP 2008b). Given this, it is essential that governments work with employers to close the current

skills gap and anticipate the future workforce needs for a green economy transition.

In addition to re-skilling workers, there is a need to ensure managers develop the new perspectives, awareness and capacities required for ensuring a smooth transition. A recent OECD study noted that “[b]usinesses will need to ensure that their managers are able to learn and understand the new skills needed to respond to the changes taking place within their realms of responsibility; to develop more green-oriented managerial capacities; as well as to make adequate use of the skills their staff has obtained” (OECD 2010c).

For many countries and businesses, particularly small and medium-sized enterprises, support from governments, inter-governmental organisations and non-governmental organisations in re-skilling workers and management will be required. It is also important to remember that while some groups and regions will make significant gains in the transition to a green economy, others will incur substantial losses. In those cases where jobs will be lost, support will be needed to shift workers to new jobs or provide social assistance. In the fisheries sector, for example, fishermen may need to be trained for alternative livelihoods, which could include participation in the rebuilding of fisheries stocks.

## 4 Conclusions

Even when there is a clear economic case for green investments, enabling conditions are generally needed. This chapter has identified five key policy-making areas which could feasibly be introduced by government at all levels in the short-to-medium term, with a view to driving the innovative and transformational change which could arise from collaboration between different sectors on the green economy in the longer term.

The first of these, public investment and spending, can be important in the short term to attract green investment and promote the development of green markets, especially where alternative policy tools are practically or politically impossible. A second key area of policy-making is the use of environmentally related taxes and other market-based instruments to address environmental externalities and market failures. A number of innovative measures, including tradable permit schemes and feed-in tariffs, have been successfully used by governments in recent years to speed the transition to a green economy.

The chapter also discusses the importance of reforming government subsidies that are environmentally harmful. Although reforming such subsidies is challenging, a number of good practice examples exist, illustrating that reform is clearly possible. The two other key areas for policy-making – improving regulatory frameworks

and strengthening international governance – focus on the importance of national and international laws and regulations in stimulating green economic activity.

The chapter makes clear that capacity building is needed for the effective implementation of policy tools, such as in the areas of research, data collection, data management, consultation and enforcement, with the role of institutions being particularly important to the effectiveness of policy. Support is also needed to ensure that workers are fairly treated, that the labour market is prepared to meet the demand for green jobs, and that the groups most vulnerable to change receive adequate compensation.

Overall, it is clear that a wealth of policy options exist for governments to enable the greening of key sectors and that implementing strategies for greening the economy will involve a broad suite of measures and appropriate indicators to measure progress. The challenge now is to set priorities at the country level and to identify strategies for how to green key sectors in ways that are aligned with existing commitments to sustainable development and poverty eradication. The need for detailed policy design – based on the lessons of experience, a deep knowledge of local context and full consultation – should not be underestimated, but neither should the breadth of areas for action and the ultimate rewards.



# Annex 1 – Enabling conditions: A sector overview

The following table summarises the enabling conditions that have been identified by the sector chapters in this report. It explains how each condition can enable green economic activity and be created by various measures, as well as identifying the sectors in which each measure may be particularly

important. The conditions are grouped into five themes – finance, governance, market, infrastructure and information. There is, unavoidably, some overlap among these groupings. In addition, the list of measures should be considered illustrative and not exhaustive.

Enabling condition	Rationale: How it enables	Measures that can create the enabling condition	Sectors in which these measures are particularly important
<b>Finance</b>			
Increased availability of finance for governments and businesses in green sectors	In order for green businesses to emerge and expand, adequate levels of private investment need to be available. It may also be necessary to increase the availability of public finance so that a range of policy tools can be used to leverage private finance.	See Finance chapter	
		Note also: The following policy tools, used primarily for their ability to correct price distortions, can also increase levels of available public finance:	→ All
		Subsidy reform	→ Agriculture, Renewable Energy, Fisheries, Forests, Manufacturing, Water
		Environmentally related taxation, other tax instruments, fees and charges, tradable permits	→ Agriculture, Buildings, Renewable Energy, Fisheries, Forests, Manufacturing, Transport, Waste, Water
<b>Governance</b>			
A network of laws and norms that encourage long-term and efficient management and use of natural resources and environmental protection	The right combination of rights, responsibilities, laws, incentives and agreements can encourage environmental protection and the rational use of natural resources, which can help to ensure the sustainability of the economic activities that rely on these resources. National and international organisations can be instrumental in the management of these laws and norms.	Strategic, integrated planning (e.g. establishing 'vision' for the future of particular sectors); baskets of complementary policies; considering the effects of policies across sectors and at local, provincial, national and international levels; stakeholder recognition and consultation, etc.	→ All
		Design of property rights and ecosystem access laws	→ Agriculture, Fisheries, Water
		Rules and regulations, standards or prohibitions (e.g. vehicle engine efficiency standards, zoning laws in cities, outlawing bottom-trawling, food safety standards, waste disposal laws)	→ All
		Negotiated and voluntary agreements	→ Buildings, Cities, Forests, Manufacturing, Tourism, Waste
		International cooperation on agreements, laws and organisations needed for the development of green goods and services (e.g. reducing concentration of market power in international agricultural value chains; preferential access for imports from low income countries; reform of international fishing laws)	→ Agriculture, Fisheries, Renewable Energy, Transport, Water, Waste

Enabling condition	Rationale: How it enables	Measures that can create the enabling condition	Sectors in which these measures are particularly important
Laws and norms that encourage technology transfer	Access to technology can be instrumental to the improved management of the environment and natural resources, helping sustain the economic activity that relies on them. It can also create new economic opportunities.	Design of intellectual property rights →	Agriculture, Renewable Energy, Transport
		Removal of trade barriers to the transfer of green technologies; international cooperation on green technology transfer →	Agriculture, Renewable Energy, Transport, Water
Improved administrative and technical capacity in government and other organisations	In some cases, governments may need to enlarge their administrative and technical capacities as a prerequisite to enacting policies that stimulate investment in green economic activity.	Investments in technical and administrative capabilities →	Fisheries, Manufacturing, Renewable Energy, Transport, Waste
		International cooperation (e.g. Bali Strategic Plan for Technology Support and Capacity Building, etc.) →	Fisheries, Transport, Waste, Water
Improved transparency and accountability	Transparency and accountability are pillars of good governance. They allow for monitoring and evaluation of policies intended to stimulate green investment, and in this way can help ensure that policies are efficient and effective at achieving their objectives.	Monitoring and evaluation as a component of other policies →	All
		Transparency to make information about decision-making and spending available in a user-friendly way →	Cities, Forests, Transport
		Accountability mechanisms as a component of policies (e.g. critical reviews, performance targets) →	All, Forests
		See Modelling chapter for information about measurement indicators →	All
Effective enforcement of laws	Unless laws can be adequately enforced, they may partially or fully fail to alter investments flows towards green economic activity.	Create adequate enforcement incentives (e.g. adequately priced fines for non-compliance) →	Cities, Fisheries, Forests, Manufacturing, Waste
		Develop capacity to enforce →	Fisheries, Forests, Manufacturing
Market			
Green economic activity is encouraged by government support	In some sectors, direct support may be required to effect immediate change (especially where there is lengthy capital stock turnover) or to support infant green industries. This support must be carefully designed to avoid expensive or otherwise perverse and unintended outcomes.	Increased funding for the innovation chain (e.g. research, development, deployment, information-sharing) →	Agriculture, Cities, Manufacturing, Renewable Energy, Waste
		Green subsidies, e.g. PPPs, low-interest loans, feed-in tariffs, investment incentives, exemption from certain regulation, stewardship jobs, support for green SMEs, etc. →	Agriculture, Buildings, Cities, Fisheries, Forests, Manufacturing, Renewable Energy, Transport, Waste
		Sustainable public procurement →	Agriculture, Buildings, Cities, Renewable Energy, Waste
Policy support for green sectors is clear, predictable and stable	Investors may be cautious of industries that rely on policy support. Investment can increase if support of green sectors is predictable, clear and has long-term stability.	Investment-grade policy design (e.g. long-term guarantees, predictable changes, gradually phased out support, etc.) →	Renewable Energy, Transport

Enabling condition	Rationale: How it enables	Measures that can create the enabling condition	Sectors in which these measures are particularly important
Prices that reflect true costs of goods and services	When the price of an unsustainable good or service does not reflect its true social cost, it is more likely to be used to excess, leading to overexploitation of natural resources, inefficiency and waste. Prices that reflect true costs can make green opportunities relatively more attractive for businesses and investors alike.	Reform of harmful subsidies	→ Agriculture, Fisheries, Forests, Manufacturing, Renewable Energy, Water
		Environmentally related taxation, other tax instruments, certificate trading markets, fees and charges	→ Agriculture, Buildings, Cities, Fisheries, Forests, Manufacturing, Renewable Energy, Transport, Waste, Water
		Payments for ecosystem services	→ Agriculture, Forests
Infrastructure			
Existence of key green infrastructure	Some sectors require specific pieces of infrastructure that are a prerequisite for further investment, e.g. electricity grids able to handle large fluctuations in supply, telecommunications services that provide farming data.	Public works programmes; policy structure similar to green subsidies (e.g. PFIs, PPPs, low-interest loans, feed-in tariffs, etc.)	→ Agriculture, Cities, Fisheries, Renewable Energy
Information			
Increased data and analysis about ecological conditions	Policy must be informed by accurate information, and in most cases data collection needs to be improved.	See Modelling chapter for information about measurement indicators	→ Agriculture, Fisheries, Tourism, Transport, Waste
A workforce equipped with the skills needed to take advantage of green opportunities	As many of the innovations in green sectors require particular skills and knowledge, the workforce will need to adapt to take advantage of new opportunities.	Retraining and support schemes for workers using new techniques or changing employment to new sectors (e.g. workshops, secondary and tertiary education)	→ Agriculture, Cities, Fisheries, Manufacturing, Tourism, Transport, Waste
		Support to encourage the take-up of new technology	→ Renewable Energy, Transport
		Local, national, regional and international knowledge-sharing and skills workshops, participatory learning	→ Agriculture, Tourism, Waste
Increased awareness about sustainability challenges	Increased awareness of sustainability challenges will increase popular demand for green goods and services, and for policies that support them.	Educational initiatives, e.g. a government vision for the green economy, information campaigns, material in state education	→ Agriculture, Buildings, Fisheries, Forests, Tourism, Transport, Waste
Increased information about life-cycle costs of goods and services	Increased information about the life-cycle costs of goods and services helps consumers choose which products they would prefer to buy and can increase the market share of green good and services.	Label and certification schemes, green audits, or legal requirements for disclosure, designed to be affordable and verifiable	→ Agriculture, Buildings, Forests, Manufacturing, Tourism, Waste

# References

- Amézquita Díaz, D. (2007). "Los tributos y la protección ambiental". Available at: <http://www2.ine.gob.mx/publicaciones/libros/398/amezquita.html>.
- Andrews, A. (2009). "Beyond the Ban – Can the Basel Convention Adequately Safeguard the Interests of the World's Poor in the International Trade of Hazardous Waste". *Law, Environment and Development Journal*, Vol. 5, Issue 2, pp. 167.
- Bacon, R., and Kojima, M. (2006). "Coping with Higher Oil Prices". World Bank, Washington, D.C..
- Barbier, E.B. (2010a). "A Global Green New Deal: Rethinking the Economic Recovery". Cambridge University Press, Cambridge.
- Barbier, E.B. (2010b). "A Global Green Recovery, the G20 and International STI Cooperation in Clean Energy". *STI Policy Review*, Vol. 1, Issue 3, pp.1-15.
- Benjamin, A. H. and Weiss, C. (1997). "Economic and Market Incentives as Instruments of Environmental Policy in Brazil and the United States". *Texas International Law Journal*, Vol. 32, pp. 67-95.
- Blackman, A. (2007). "Discussion Paper: Voluntary Environmental Regulation in Developing Countries: Fad or Fix?". Resources for the Future, Washington, D.C..
- Bloom, K. (2009). "Conditional Cash Transfers: Lessons from Indonesia's Program Keluarga Harapan". Asian Development Bank presentation.
- Bluffstone, R. (2003). "Environmental Taxes in Developing and Transition Economies". *Public Finance and Management*, Vol. 3, Issue 1, pp. 143-175.
- Coady, D., Grosh, M., and Hoddinott, J. (2004). "The Targeting of Transfers in Developing Countries: a Review of Lessons and Experience". World Bank, Washington, D.C..
- Colbourne, L. (2008). "Sustainable Development and Resilience Think Piece for the SDC". Sustainable Development Commission, London.
- Coleman, C., and Stefan, S. (2009). "Effective Green Building Policy – The City of Vancouver Case". Globe-Net. Available at: <http://www.sustain.ubc.ca/sites/default/files/uploads/pdfs/cirs/Effective%20Green%20Building%20Policy.pdf>.
- Cosbey, A. (2010). "Are There Downsides to a Green Economy? The Trade, Investment and Competitiveness Implications of Unilateral Green Economic Pursuit". Available at: [http://www.unctad.org/trade\\_env/greenecomony/RTR20/part2RTR.pdf](http://www.unctad.org/trade_env/greenecomony/RTR20/part2RTR.pdf).
- Cox, A. (2007). "Easing Subsidy Reform for Producers, Consumers and Communities". In OECD, Subsidy Reform and Sustainable Development: Political Economy Aspects. OECD, Paris.
- El Sobki, M., Wooders, P., and Sherif, Y. (2009). "Clean Energy Investment in Developing Countries: Wind Power in Egypt". International Institute for Sustainable Development, Winnipeg.
- Environmental Management Group. (2010). First Meeting of the Issue Management Group on a Green Economy (organized in Partnership with the World Bank and the IMF), 23-24 March 2010. Available at: <http://www.unemg.org/Portals/27/Documents/IMG/GreenEconomy/FirstMeeting/IMG1Summary.pdf>. Retrieved 20 January 2010.
- Environmental Protection Department of Hong Kong. Available at: [http://www.epd.gov.hk/epd/english/environmentinhk/air/air\\_maincontent.html](http://www.epd.gov.hk/epd/english/environmentinhk/air/air_maincontent.html).
- Environmental Working Group. (undated). "Government's Continued Bailout of Corporate Agriculture". Farm Subsidy Database. Available at: <http://farm.ewg.org/summary.php>. Retrieved 5 May 2010.
- European Commission. (2008). "Commission Staff Working Document: The Support of Electricity from Renewable Energy Sources". Accompanying document to the Proposal for a Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources. pp. 57.
- Foray, D. (2009). "Technology Transfer in the TRIPS Age: The Need for New Types of Partnerships between the Least Developed and Most Advanced Economies". International Centre for Trade and Sustainable Development, Geneva.
- Forest Stewardship Council. (2010). Available at: <http://www.fsc.org/>.
- Frohwein, T. and Hansjürgens, B. (2005). "Chemicals Regulation and the Porter Hypothesis: A Critical Review of the New European Chemicals Regulation", *Journal of Business Chemistry*, Vol. 2, Issue 1, pp. 19-36.
- Gaupp, D. (2007). "Turkey's New Law on Renewable Energy Sources within the Context of the Accession Negotiations with the EU". *German Law Journal*, Vol. 8, pp. 413-416.
- Global Subsidies Initiative. (2010). "Policy Brief. Defining Fossil-Fuel Subsidies for the G-20: Which Approach is Best?". Global Subsidies Initiative, Geneva.
- Goldstein, M., and Udry, C. (2008). "The Profits of Power: Land Rights and Agricultural Investment in Ghana". *Journal of Political Economy*, Vol. 166, Issue 6, pp. 981-1022.
- Googins, et al. (2007) "Beyond Good Company: Next Generation Corporate Citizenship". Palgrave Macmillan.
- Green Fiscal Commission. (2009). "Lessons from Two Green Tax Shifts in the United Kingdom". Green Fiscal Commission, London.
- Green Fiscal Commission. "Welcome". Available at: <http://www.greenfiscalcommission.org.uk/>. Retrieved 14 May 2010.
- Greenpeace. "Stop Climate Change". Available at: <http://www.greenpeace.org/international/en/campaigns/climate-change/>. Retrieved 1 May 2010.
- Grosh, M., del Ninno, C., Tesliuc, E., and Ouerghi, A. (2008). "For Protection and Promotion: The Design and Implementation of Effective Safety Nets". World Bank, Washington, D.C..
- Hutagalung, S., Arif, S., and Suharyo, W. (2009). "Problems and Challenges for the Indonesian Conditional-Cash Transfer Programme – Program Keluarga Harapan (PKH)". Social Protection in Asia, SMERU Institute, Jakarta.
- International Energy Agency. (2010). "World Energy Outlook 2010". International Energy Agency, Paris.
- IEA, OPEC, OECD and World Bank. (2010). "Analysis of the Scope of Energy Subsidies and the Suggestions for the G-20 Initiative". Joint Report Prepared for Submission to the G-20 Summit, 26-27 June 2010, Toronto.
- Integrated Framework Secretariat. (2009). "About the Integrated Framework". Available at: <http://www.integratedframework.org/about.htm>. Retrieved 14 May 2010.
- International Institute for Sustainable Development. (2008). "Building Accountability and Transparency in Public Procurement". International Institute for Sustainable Development, Winnipeg.
- International Institute for Sustainable Development. (2009). "Towards Sustainable Outsourcing: A Responsible Competitiveness Agenda for IT-enabled Services". International Institute for Sustainable Development, Winnipeg.
- International Institute for Sustainable Development. (2010). "Lessons Learned from Indonesia's Attempts to Reform Fossil Fuel Subsidies". International Institute for Sustainable Development, Winnipeg.
- International Labour Organization. (2008). "Global Challenges for Sustainable Development: Strategies for Green Jobs", International Labour Organization Background Note for the G-8 Labour and Employment Ministers Conference, May 2008, Japan.
- International Labour Organization. (2009). "World of Work Report 2009: The Global Jobs Crisis and Beyond". International Labour Organization, Geneva.
- International Monetary Fund. (2008). "Fuel and Food Price Subsidies: Issues and Reform Options". International Monetary Fund, Washington, D.C.
- Keong, C.K. (2002). "Road Pricing: Singapore's Experience", pp 9. Singapore Land Transport Authority, Singapore. Available at: [http://www.imprint-eu.org/public/Papers/IMPRINT3\\_chin.pdf](http://www.imprint-eu.org/public/Papers/IMPRINT3_chin.pdf).
- Komives, K., Foster, V., Halpern, J., and Wodon, Q. (2005). "Water, Electricity and the Poor: Who Benefits from Utility Subsidies?". World Bank, Washington D.C.

- Land Transport Authority of Singapore (2011). Available at: [http://www.lta.gov.sg/motoring\\_matters/index\\_motoring\\_erp.htm](http://www.lta.gov.sg/motoring_matters/index_motoring_erp.htm).
- Lienemeyer, M. (2006). "Restructuring Aid to the Steel Industry of New EU Member States". In OECD, *Subsidy Reform and Sustainable Development: Economic, Environmental and Social Aspects*. OECD, Paris.
- Mann, H., von Moltke, K., Peterson, L., and Cosbey, A. (2005). "IISD Model International Agreement on Investment for Sustainable Development". International Institute for Sustainable Development, Winnipeg.
- Marine Stewardship Council. (2009). "Net Benefits: The First Ten Years of MSC Certified Sustainable Fisheries". MSC, London.
- Martinez-Fernandez, C., Hinojosa, C., and Miranda, G. (2010). "Green Jobs and Skills: Labour Market Implications of Addressing Climate Change, Local Employment and Economic Development (LEED) Programme". OECD, Paris.
- Mati, A. (2008). "Managing Surging Oil Prices in the Developing World". IMF Survey Magazine. Available at: <http://www.imf.org/external/pubs/ft/survey/so/2008/pol032008a.htm>. Retrieved 4 May 2010.
- McKinsey Global Institute. (2011). "Internet matters: The Net's sweeping impact on growth, jobs and prosperity". Available at: [http://www.mckinsey.com/mgi/publications/internet\\_matters/index.asp](http://www.mckinsey.com/mgi/publications/internet_matters/index.asp).
- Ministry of New and Renewable Energy of India. (2010). "Annual Report 2009-2010". Available at: <http://www.mnre.gov.in/annualreport/2009-10EN/index.htm>.
- Morrison, K., Méthot, P., and Bastin, D. (2007). "Legality Standards and Stepwise Approaches to Sustainable Forest Management in Central Africa: Challenges of Coordination and Communication". World Resources Institute, Washington, D.C..
- Multilateral Fund Secretariat. (2010). "Status of Implementation of Delayed Projects and Prospects of Article 5 Countries in Achieving Compliance with the Next Control Measures of the Montreal Protocol" (UNEP/OzL.Pro/ExCom/62/6).
- Muñoz-Piña, C., Guevara, A., Torres, J.M. and Braña, J. (2008). "Paying for the Hydrological Services of Mexico's Forests: Analysis, Negotiations and Results". *Ecological Economics*, Vol. 65, Issue 4, pp. 725-736.
- National Ecology Institute of Mexico. (2004). "Incentivos fiscales vigentes: arancel cero y depreciación acelerada para inversiones que reporten beneficios ambientales". Available at: <http://www2.ine.gob.mx/publicaciones/libros/304/arancel.html>.
- National Ecology Institute of Mexico. (2007). "Incentivos fiscales vigentes: arancel cero y depreciación acelerada para inversiones que reporten beneficios ambientales".
- Nellemann, C., Corcoran, E., Duarte, C., Valdés, L., de Young, C., Fonseca, L., et al. (2009). "Blue Carbon: The Role of Healthy Oceans in Binding Carbon". UNEP and GRID-Arendal, Norway.
- Network of Heads of European Protection Agencies. (2005). "The Contribution of Good Environmental Regulation to Competitiveness". Available at: [http://www.foeeurope.org/activities/sustainable\\_europe/Environment\\_Competitiveness\\_European\\_Environment\\_Protection\\_Agencies.pdf](http://www.foeeurope.org/activities/sustainable_europe/Environment_Competitiveness_European_Environment_Protection_Agencies.pdf).
- Odhiambo, W., and Kamau, P. (2003). "Lessons from Kenya, Tanzania and Uganda", Working Paper No. 208. Public Procurement. OECD, Paris.
- OECD. (undated). "Agricultural Policy Reform". Available at: [http://www.oecd.org/document/53/0,3343,en\\_2649\\_37401\\_43071413\\_1\\_1\\_1\\_00.html](http://www.oecd.org/document/53/0,3343,en_2649_37401_43071413_1_1_1_00.html). Retrieved 4 May 2010.
- OECD. (2003a). "The Environmental Performance of Public Procurement: Issues of Policy Coherence". OECD, Paris.
- OECD. (2003b). "Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Usage in Policy Mixes". OECD, Paris.
- OECD. (2003c). "Capacity Building for Effective Competition Policy in Developing and Transitioning Economies". OECD Journal of Competition Law and Policy, Vol. 4, Issue 4, pp. 1560-7771.
- OECD. (2004). "Environmental Performance Review of Sweden". Available at: <http://browse.oecdbookshop.org/oecd/pdfs/browseit/9704091E.PDF>. Retrieved 20 January 2011.
- OECD. (2007). "Instrument Mixes for Environmental Policy". OECD, Paris.
- OECD. (2009a). "Conference proceedings: ICTs, the Environment and Climate Change". Proceedings of the High-Level OECD Conference, 27-28 May 2009, Helsingør.
- OECD. (2009b). "Measuring the Relationship between ICT and the Environment". OECD, Paris.
- OECD. (2009c). "Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment". OECD, Paris.
- OECD. (2010a). "Interim Report of the Green Growth Strategy: Implementing our Commitment for a Sustainable Future". Available at: <http://www.oecd.org/dataoecd/42/46/45312720.pdf>. Retrieved 25 November 2010.
- OECD. (2010b). "Taxation, Innovation and the Environment". OECD, Paris.
- OECD. (2010c). "Green Jobs and Skills: The Local Labour Market Implications of Addressing Climate Change". OECD, Paris.
- OECD and IEA. Climate Change Database. Available at: <http://www.iea.org/textbase/pm/?mode=cc>.
- OECD and IEA. (2008). "Deploying Renewables: Principles for Effective Policies". International Energy Agency, Paris.
- OECD and IEA. (2010). "World Energy Outlook". International Energy Agency, Paris.
- Perera, O., Chowdhury, N., and Goswami, A. (2007). "State of Play in Sustainable Public Procurement". International Institute for Sustainable Development: Winnipeg.
- Porter, M. E. (1990). "The Competitive Advantage of Nations". *Harvard Business Review*, pp. 73-93.
- Pricewaterhouse Coopers, Significant and Ecofys. (2009). "Collection of Statistical Information on Green Public Procurement in the EU: Report on Data Collection Results". Pricewaterhouse Coopers International Limited.
- Ranjan, A. (August 2009). "Parikh Heads New Committee to Resolve Issue of Petroleum Product Pricing". Indian Express. Available at: <http://www.indianexpress.com/news/parikh-heads-new-committee-to-resolve-issue-of-petroleum-product-pricing/507700/0>. Retrieved 1 May 2010.
- Renewable Energy Policy Network for the 21st Century (REN21). (2010). "Renewables 2010: Global Status Report". REN21 Secretariat, Paris.
- Robalino, J., Pfaff, A., Sanchez, F., Alpizar, C. L. and Rodriguez, C.M. (2008). "Deforestation Impacts of Environmental Services Payments: Costa Rica's OPSA Program 2000-2005". Discussion Paper Series on Environment for Development and Resources for the Future, presented at the World Bank Workshop on the Economics of REDD, 27 May 2008. Washington D.C..
- Roubini Global Economics. (2009). "The Doha Trade Round is Worth Fighting For". The Global Macro Economist. Available at: [http://www.roubini.com/globalmacro-monitor/258052/the\\_doha\\_trade\\_round\\_is\\_worth\\_fighting\\_for](http://www.roubini.com/globalmacro-monitor/258052/the_doha_trade_round_is_worth_fighting_for). Retrieved 4 May 2010.
- Roy, R. (2009). "Scope for CO2 Based Differentiation in Motor Vehicle Taxes". Working Party on National Environmental Policies, OECD, Paris.
- Sanchez-Azofeifa, G.A., Pfaff, A., Robalino, J.A. and Boomhower J.P. (2007). "Costa Rica's Payment for Environmental Services Program: Intention, Implementation, and Impact". *Conservation Biology*, Vol. 21, Issue 5, pp. 1165-1173.
- Shemberg, A. (2008). "Stabilization Clauses and Human Rights". Research project conducted for the International Finance Corporation and the United Nations Special Representative to the Secretary-General on Business and Human Rights. International Finance Corporation.
- Smith, S. (2008). "Environmentally Related Taxes and Tradable Permit Systems in Practice". OECD, Paris.
- Steenblik, R., and Simón, J. (2011). "A New Template for Notifying Subsidies to the WTO". Global Subsidies Initiative, Geneva.
- Strietska-Ilina, O., Hofmann, C., Haro, M., and Jeon, S. (2011). "Skills for Green Jobs: A Global View". International Labour Organization, Geneva. Available at: [http://www.uncsd2012.org/rio20/content/documents/wcms\\_159585.pdf](http://www.uncsd2012.org/rio20/content/documents/wcms_159585.pdf).
- Sumaila, U.R., Khan, A.S., Dyck, A.J., Watson, R., Munro, G., Tyedmers, P., and Pauly, D. (2010). "A Bottom-up Re-estimation of Global Fisheries Subsidies". *Journal of Bioeconomics*, Vol. 12, pp. 201-225.
- Sunstein, C. (2007). "Of Montreal and Kyoto: A Tale of Two Protocols". *Harvard Environmental Law Review*, Vol. 31, pp. 1-65.



The Climate Group. (2008). "Smart 2020: Enabling the low carbon economy in the information age." Prepared for the Global e-Sustainability Initiative. Available at: <http://www.smart2020.org>.

Thomas, K. (2007). "Investment Incentives: Growing Use, Uncertain Benefits, Uneven Controls". Global Subsidies Initiative, Geneva.

Thöne, M., and Dobroschke, S. (2008). "WTO Subsidy Notifications: Assessing German Subsidies Under the Global Subsidies Initiative Notification Template Proposed for the WTO". Global Subsidies Initiative, Geneva

Tomlinson, S. E. (2009). "Breaking the Climate Deadlock. Technology for a Low Carbon Future". E3G, the Climate Group and the Office of Tony Blair. Available at: [http://www.theclimategroup.org/\\_assets/files/Technology\\_for\\_a\\_low\\_carbon\\_future\\_full\\_report.pdf](http://www.theclimategroup.org/_assets/files/Technology_for_a_low_carbon_future_full_report.pdf) and [http://blair.3cdn.net/fbcbeebcd4c5b6955\\_kum6b3jap.pdf](http://blair.3cdn.net/fbcbeebcd4c5b6955_kum6b3jap.pdf).

UNCTAD. (2008). "Capacity-building on Competition Law and Policy for Development: A Consolidated Report". United Nations, New York and Geneva.

UNDP. (2009). "Capacity Development: A UNDP Primer". (K. Wignaraja, Ed.). UNDP.

UNEP. (2006). "Training Manual on International Environmental Law". UNEP.

UNEP. (2008a). "Reforming Energy Subsidies: Opportunities to Contribute to the Climate Change Agenda". UNEP, Paris.

UNEP. (2008b). "Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World". Worldwatch Institute, Washington, D.C..

UNEP. (2010a). "Elaboration of Ideas for Broader Reform of International Environmental Governance". Information Note from the Co-Chairs of the Consultative Group. Available at: <http://www.unep.org/environmentalgovernance/Portals/8/ElaborationBroaderReformIEG.pdf>. Retrieved 25 November 2010.

UNEP. (2010b). "Driving a Green Economy Through Public Finance and Fiscal Policy Reform". Available at: <http://www.unep.org/greenconomy/Portals/30/docs/DrivingGreenEconomy.pdf>.

UNEP. (2010c). "Capacity Building for Sustainable Public Procurement". UNEP, Paris.

UNEP. (2010d). "Marrakech Task Force on Sustainable Public Procurement". UNEP, Paris.

UNEP. (2010e). "Green Economy Success Stories from Developing Countries". UNEP, Geneva.

UNEP Ozone Secretariat. (2010). "Key Achievements of the Montreal Protocol to Date: Information Kit". Available at: [http://ozone.unep.org/Publications/MP\\_Key\\_Achievements-E.pdf](http://ozone.unep.org/Publications/MP_Key_Achievements-E.pdf).

UNEP and UNCTAD Capacity Building Task Force. (2010). "Organic Agriculture: Opportunities for Promoting Trade, Protecting the Environment and Reducing Poverty". Available at: <http://www.unep.ch/etb/publications/Organic%20Agriculture/OA%20Synthesis%20v2.pdf>.

United Nations General Assembly Resolution 64/236.

U.S. Environmental Protection Agency. (2010). "Protecting the Ozone Layer Protects Eyesight". US EPA Office of Air and Radiation, Washington, D.C.

Velders, G.J.M., Andersen, S.O., Daniel, J.S., Fahey, D.W., and McFarland, M.. (2007). "The Importance of the Montreal Protocol in Protecting Climate". Proceedings of the National Academy of Sciences, Vol. 104, Issue 12. Available at: <http://www.epa.gov/ozone/downloads/PNAS.pdf>.

Victor, D. (2009). "The Politics of Fossil Fuel Subsidies". Global Subsidies Initiative, Geneva.

Vitalis, V. (2002). "Private Voluntary Eco-labels: Trade Distorting, Discriminatory and Environmentally Disappointing". Background Paper for the Round Table on Sustainable Development. OECD, Paris.

Williams, A.D. (2004). "An Economic Theory of Self-Regulation". Working Paper. London School of Economics, London.

World Bank. (undated). "Subsidies and Energy Pricing". Available at: <http://go.worldbank.org/TVNNG8LH10>. Retrieved 4 May 2010.

World Bank. (2007). "Warming Up to Trade: Harnessing International Trade to Support Climate Change Objectives". World Bank, Washington, D.C..

World Bank. (2008). "International Trade and Climate Change: Economic, Legal and Institutional Perspectives". World Bank, Washington, D.C..

World Bank. (2009). "Appendix C: Distributional Incidence of Subsidies". In Climate Change and the World Bank Group, Phase 1: An Evaluation of World Bank Win-Win Energy Policy Reforms. World Bank, Washington, D.C..

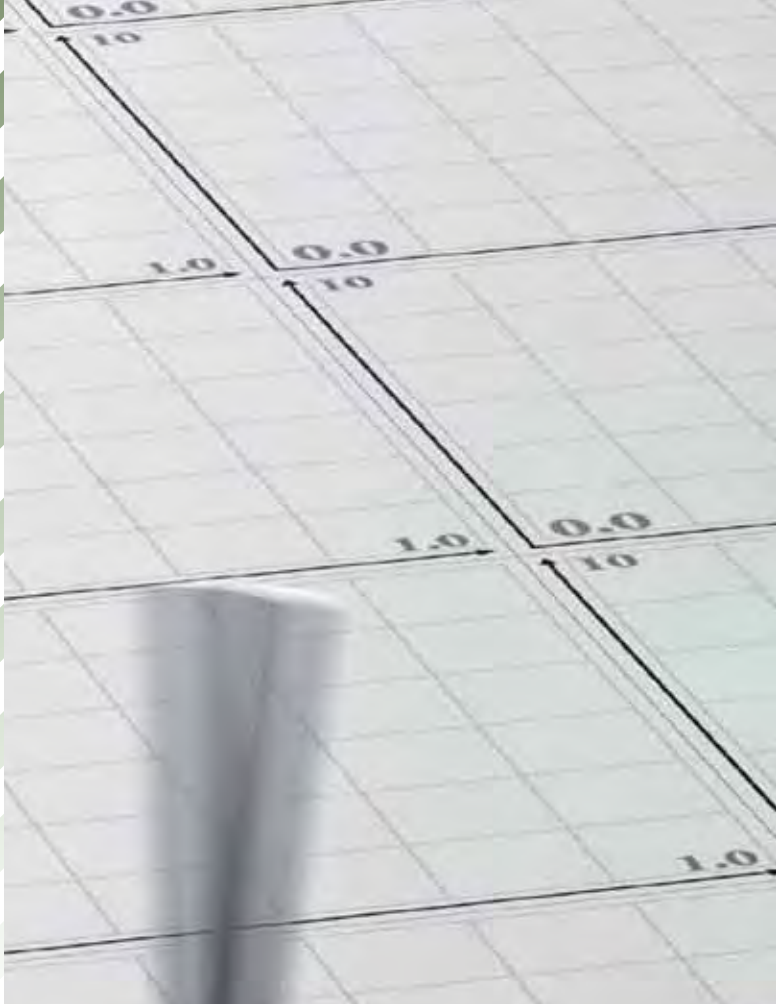
World Bank (2010). "State and Trends of the Carbon Market 2010". World Bank: Washington, D.C..

World Bank and FAO. (2009). "The Sunken Billions – The Economic Justification for Fisheries Reform". World Bank, Washington, D.C..

WTO and UNEP. (2009). "Trade and Climate Change". Available at: [http://www.wto.org/english/res\\_e/booksp\\_e/trade\\_climate\\_change\\_e.pdf](http://www.wto.org/english/res_e/booksp_e/trade_climate_change_e.pdf).

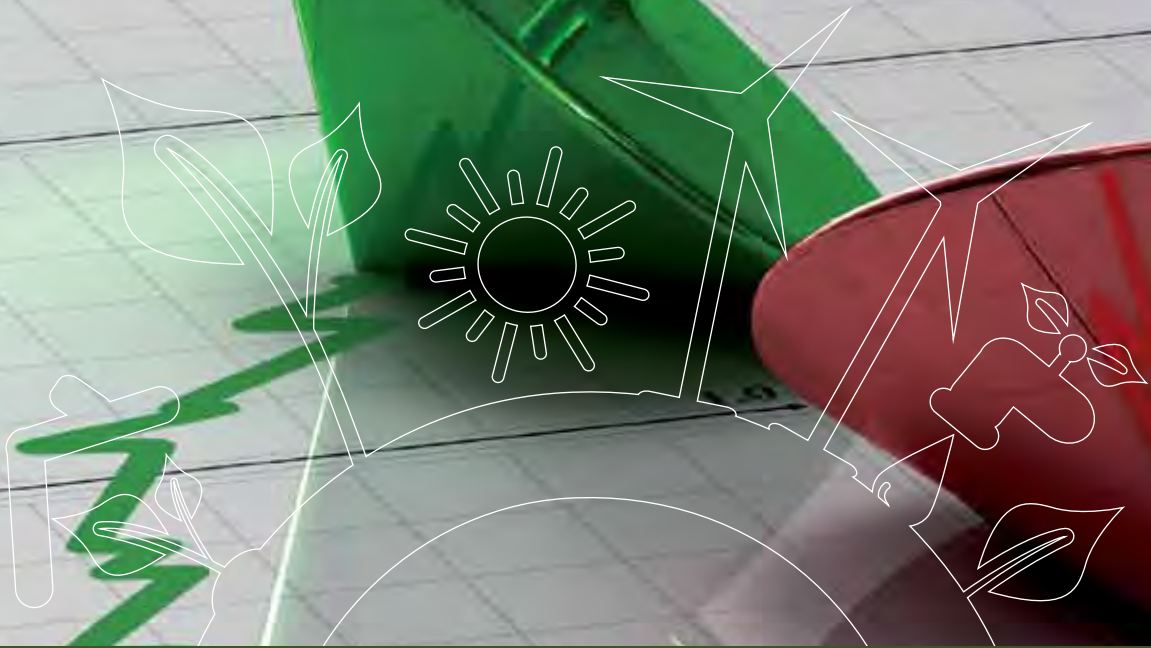
Zhao, J. (2001). "Reform of China's Energy Institutions and Policies: Historical Evolution and Current Challenges". John F. Kennedy School of Government, Belfer Center for Science and International Affairs, Harvard University, pp. 19. Available at: <http://belfercenter.ksg.harvard.edu/files/zhao.pdf>.







GREEN <sup>growth</sup>economy



# Finance

Supporting the transition to a global green economy



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## List of acronyms

A/R	Afforestation and Reforestation	MFIs	Microfinance Institutions
ADB	Asian Development Bank	NAMAs	Nationally Appropriate Mitigation Measures
AUM	Assets under management	ODA	Official Development Assistance
BAU	Business-as-usual	OECD	Organisation for Economic Co-operation and Development
BCBS	The Basel Committee on Banking Supervision	PE	Private equity
BES	Biodiversity and Ecosystem	PFMs	Public Financing Mechanism
BIS	The Bank for International Settlement	PRI	United Nations-backed Principles for Responsible Investment
CCX	Chicago Climate Exchange	R&D	Research and Development
CDM	Clean Development Mechanisms	REDD	Reducing Emissions from Deforestation and Forest Degradation
CERC	Search Results Central Electricity Regulatory Commission	REN21	Renewable Energy Policy Network for the 21st Century
COP	Conference of Parties	RICS	The Royal Institution of Chartered Surveyors
DFI	Development Finance Institutions	SWFs	Sovereign wealth funds
EBRD	European Bank for Reconstruction and Development	TEEB	The Economics of Ecosystems and Biodiversity
EIB	European Investment Bank	UNDP	United Nations Development Programme
ESG	Environmental, Social and Governance	UNEP FI	United Nations Environment Programme Finance Initiative
EU ETS	EU Emissions Trading System	UNEP SBCI	United Nations Environment Programme Sustainable Buildings and Climate Initiative UNEP
FDI	Foreign Direct Investment	SEFI	United Nations Environment Programme Sustainable Energy Finance Initiative
FMO	The Netherlands Development Finance Company	UNFCCC	United Nations Framework Convention on Climate Change
FSB	Financial Stability Board	UOT	Universal Ownership Theory
G20	Group of Twenty	US SEC	U.S. Securities and Exchange Commission
GEF	Global Environment Facility	VC	Venture capital
GDP	Gross Domestic Product	WBCSD	The World Business Council for Sustainable Development
GHG	Greenhouse gas	WEF	World Economic Forum
GIB	Green Investment Bank	WFE	World Federation of Exchanges
GRI	Global Reporting Initiative	WRI	World Resource Institute
IEA	International Energy Agency	WWF	World Wide Fund for Nature
IFC	International Finance Corporation		
IFLS	International Financial Services London		
IIRC	International Integrated Reporting Committee		
IMF	International Monetary Fund		
IPCC	Intergovernmental Panel on Climate Change		
KfW	German Development Bank		
KP	Kyoto Protocol		
MDGs	Millennium Development Goals		

# Key messages

**1. A global green economy transformation will require substantial financial resources.**

Indicative figures such as those from the International Energy Agency's (IEA) scenarios for halving worldwide energy-related CO<sub>2</sub> emissions by 2050 and on modelling, in this report, show additional investments required will likely be in the range of 1 to 2.5 per cent of global Gross Domestic Product (GDP) per year from 2010 to 2050. A considerable amount of investment will be needed in energy supply and efficiency, particularly in greening the transport and buildings sectors.

**2. Financial investment, banking and insurance are the major channels of private financing for a green economy.**

The financial services and investment sectors control trillions of dollars that could potentially be directed towards a green economy. More importantly, long-term public and private institutional investors, banks and insurance companies are increasingly interested in acquiring portfolios that minimise environmental, social and governance risks, while capitalising on emerging green technologies. Microfinance has a potentially important role at the community and village level to enable the poor to invest in resource and energy efficiency as well as increase their resiliency to risk.

**3. Opportunities exist to meet the financing needs of a green economy.**

The rapid growth and increasingly green orientation of capital markets, the evolution of emerging market instruments such as carbon finance and microfinance, and the green stimulus funds established in response to the economic slowdown of recent years, are opening up space for large-scale financing for a global green economic transformation. But these flows are still small compared to investment needs and must be scaled up quickly if the transition to a green economy is to jump-start in the near term. Concentrated pools of assets, such as those controlled by pension systems and insurance companies, the US\$ 39 trillion-plus controlled by the high net worth community and the growing assets of sovereign wealth funds will need to support the green economy in coming decades.

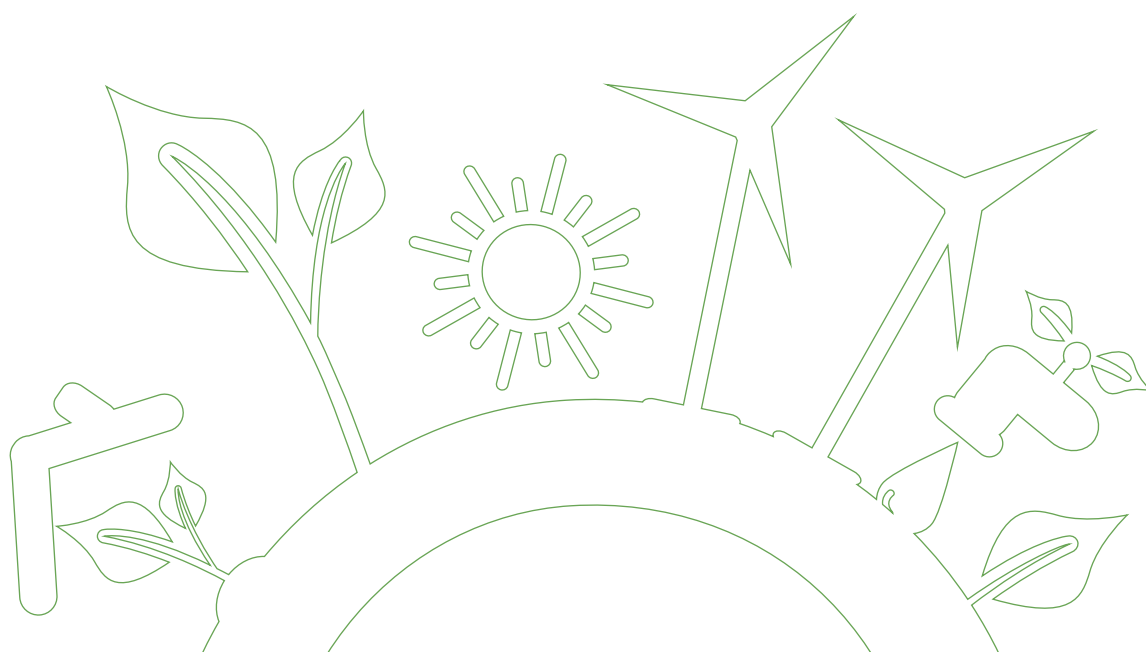
**4. Advances in disclosure and sustainability reporting are increasing transparency and driving change.**

In 2009, the global market size for institutional assets was estimated at just over US\$ 121 trillion. Of the actively managed components of these assets, controlled by a broad range of large institutional investors, some 7 per cent was subject to the integration of environmental, social

and governance (ESG) considerations. Considering the environmental costs attributable to business and human activity – estimated at more than US\$ 6 trillion in 2008 – much more transparency is needed. Scaling up resources for investment adhering to ESG principles is urgent and will require innovation and leadership by business and industry, collective action and public-private approaches as well as supportive regulatory frameworks.

**5. The role of the public sector is indispensable in freeing up the flow of private finance towards a green economy.** Governments should involve the private sector in establishing clear, stable and coherent policy and regulatory frameworks to facilitate the integration of ESG issues into financial and investment decisions. In addition, governments and multilateral financial institutions should use their own resources to leverage financial flows from the private sector and direct them towards green economic opportunities.

**6. Public finance is important for triggering a green economic transformation, even if public resources are significantly smaller than those of private markets.** The role of public development finance institutions (DFIs) in developed and developing countries in supporting the transition to a green economy could be strengthened further. Development Finance Institutions can adopt the goal of supporting development of the green economy, allocate significant proportions of their new lending towards financing green economy transition projects and link it to specific targets such as reduction in greenhouse gas (GHG) emissions, access to water and sanitation, biodiversity promotion and poverty alleviation. Policies can be designed to improve the “green efficiency” of their portfolios, for example, by examining the carbon and ecological footprints of their investment portfolios. In addition, DFIs can jointly define protocols for green due diligence, as well as standards and goals for sectors in which they have a major influence, such as transport, energy and municipal finance.





# 1 Introduction

## 1.1 Scope of this chapter

The earlier chapters of this report have highlighted how the successful emergence of a green economy is critically dependent on new approaches to finance and investment. Innovation is needed to consistently deliver dramatically higher volumes of annual investment in key segments of the green economy market. The vast majority of this investment will need to come from the private financial sector, supported by the enabling actions of farsighted policy makers, as well as the catalytic role of development finance institutions (DFIs) and supranational bodies such as the United Nations.

The quality of this investment – such as tenor and risk/return requirements – is arguably just as important as the quantity. As a result, many other interrelated issues need to be considered. For example, partnership is needed to support pre-investment market development and formulate cost-effective policy-based incentives that facilitate private sector investment in the green economy. International accounting practices need to evolve to incorporate environmental externalities. New

instruments need to be developed for risk-sharing and financial intermediation. These new instruments could enable more private investors – ranging from individual savers to large pension funds representing thousands of people – to participate in financing the transition to a green economy.

This chapter examines how the green economy is currently being financed and explores the priorities and potential methods for increasing this investment. The chapter seeks to make the case for scaling up financing available for the transition to a green economy and amplifying the financial sector's role as an agent of change.

The analysis emphasises investing, lending by banks, and insuring - focused primarily on private sector sources of finance. In addition, reference is made to the enabling and complementary role of governments, DFIs and other non-private sector entities. There is already significant momentum in this field, but greater challenges lie ahead. This chapter also examines the main challenges, opportunities and key enabling conditions for progress.

## 2 The state of play

### 2.1 The scale of the challenge

#### Estimated investment needs up to 2050

There is no complete estimate yet of resources needed to make the transition to a green economy. One indication of green investment gaps for low-carbon energy supply and energy efficiency at the global level is provided by the IEA Energy Technology Perspectives 2010, based on CO<sub>2</sub> emission reduction targets. This high-end estimate does not include other aspects such as resource efficiency across sectors. The IEA BLUE Map scenario aims to halve worldwide energy-related CO<sub>2</sub> emissions by 2050. Investments required from 2010 to 2050 in this scenario are US\$ 46 trillion higher – an increase of 17 per cent – than what is required in the Baseline scenario. This corresponds to approximately US\$ 750 billion per year up to 2030 and US\$ 1.6 trillion per year from 2030 to 2050 (IEA 2010).

Additional investment needs under the BLUE Map scenario – which increases projected global investment needs to US\$ 316 trillion by 2050 – are dominated by the transport sector, which take up 50 per cent of total additional investments, particularly in the area of alternative vehicle technologies. The buildings sector absorbs 26 per cent of the additional investment, energy supply 20 per cent and industry 4 per cent. These indicative amounts correspond, on average, to the scenarios modelled for the Green Economy Report, which analysed investments averaging US\$ 1.35 trillion per year over 2010 to 2050, across a range of sectors – not just those related to greenhouse gas (GHG) emissions.

Alternatively, an earlier IEA study estimated (IEA 2009) that over the next 30 thirty years, US\$ 1 trillion annually is required to enable the world's energy infrastructure to maintain and extend the supply of power to more people (US\$ 500 billion) and to finance the transition to a low carbon, cleaner energy infrastructure (a further US\$ 500 billion). The projected annual shortfall to drive this low-carbon transition in developing economies alone is US\$ 350 billion. While relying heavily on an industrial approach to reducing carbon emissions, the IEA estimates can be considered as a high-end estimate of annual investment needs and correspond to a range of 1 to 2 per cent of global GDP.

Estimates by the private financial sector also underline the scale of the challenge. The World Economic Forum (WEF 2010a) and Bloomberg New Energy Finance calculate that clean energy investment must rise to US\$ 500 billion

per year by 2020 to restrict global warming to 2°C. HSBC estimates the transition to a low carbon economy will see a total growth in cumulative capital investments of US\$ 10 trillion between 2010 to 2020 (HSBC 2010).

Furthermore, the concept of “additionality” is fundamentally important. In the context of the UN Framework Convention on Climate Change (UNFCCC); additionality refers to an effort that is supplemental to the business-as-usual (BAU) scenario in at least two areas: the additionality of financial contributions of developed countries beyond BAU official development assistance (ODA) to assist climate change adaptation in developing countries; and the additionality of investment to reduce GHG beyond BAU. Additionality of financial resources to the widely agreed target for ODA of 0.7 per cent of developed country gross domestic product (GDP) is the contribution that developing countries seek from developed nations as a key element of a global resolution of climate change problems in the context of the UNFCCC and the Kyoto Protocol (KP) (UNFCCC 1998). Despite a decade of attempts to define additionality, the concept continues to be poorly understood and its application contested. However, additionality is likely to continue to be an important criterion for climate finance beyond 2012.

#### Breakdown by sector

Given the pioneering and cross-cutting nature of research on greening the economy, the quantification of the demand for finance and investment to support a global green economy for each major economic sector is a work in progress. However, the data in Table 1, drawn from information in the sectoral chapters of this Green Economy Report (GER), give a broad range of estimated annual investments required to make this transition. The spread of targets illustrates the need for common metrics for finance and investment in this arena, to allow proper comparisons. (See disclosure requirements discussed in Section 5 of this chapter, Greening Global Finance & Investment: Enabling Conditions.)

Based on a range of specific sectoral policy targets, the Green Economy Report modelling allocates investments totalling 2 per cent of global GDP across the range of given sectors, with the heaviest emphasis in transforming key sectors such as buildings, transport, and energy. These investment allocations are largely consistent with assessments taken from other sources, such as IEA and estimates associated with achieving the MDGs. The estimated annual investment for all sectors

Sector	Green Economy Report investment allocation 2011 (US\$ bn/yr., see Note 1)	Investment assessment (US\$ bn/yr., see Note 1)	Details
Agriculture	108		Target: increase and maintain nutrition levels to 2800 to 3000 Kcal/person by 2030
Buildings	134		Target: increase energy efficiency to reach energy consumption and emissions targets set in IEA's BLUE Map scenario
		308	IEA ETP 2010 BLUE Map scenario, Additional (see Notes 3 and 4).
Energy (supply)	362		Target: increase penetration of renewables in power generation and primary energy consumption to at least reach targets set in IEA's BLUE Map scenario
		233	IEA ETP 2010 BLUE Map scenario, additional (see Notes 3 and 4).
		500	World Economic Forum (2010a) estimate of annual spending on clean energy necessary by 2020 to restrict the increase in global average temperatures to 2°C
		611	European Renewable Energy Council and Greenpeace Energy [R]evolution (2010) Advanced Revolution scenario estimate of average global investment in renewable energy to 2007 to 2030 (see Note 5).
		460 – 1,500	HSBC (2010) estimate of total investments in low carbon energy generation (supply) and energy efficiency and management (demand), required to build a low-carbon energy market by 2020 (see Note 6).
Fisheries	108		Achieve maximum sustainable yield by an aggregate world cut in fishing effort of 50 per cent by decommission of vessels, reallocation of labour force, and fisheries management.
		90 – 280	Same (from Global Economy Report fisheries chapter analysis).
Forestry	15		Target: 50 per cent reduction in deforestation by 2030 as well as increased planted forests to sustain forestry production.
		37	Effective management of the existing network of protected forests and 15 per cent of land area in each region (Balmford et al. 2002) – adjusted for inflation.
		2 – 30	REDD+ (more an assessment of potential flow of funds).
Industry	76		Target: increase energy efficiency to reach energy consumption and emissions targets set in IEA's BLUE Map scenario.
		50 – 63	IEA ETP 2010 BLUE Map scenario, additional (see Notes 3 and 4).
Tourism	134		
Transport	194		Target: increase energy efficiency to reach energy consumption and emissions targets set in IEA's BLUE Map scenario, and expand public transport.
		325	IEA ETP 2010 BLUE Map scenario, Additional (see Notes 3 and 4).
Waste	108		Target: reduce the amount of waste going to landfills by at least 70 per cent.
Water	108		Target: Meet Millennium Development Goal (MDG) to halve the number of people without access to water and sanitation by 2015, plus reduce water intensity (without quantitative target).
		18	Meet MDG to halve the number of people without access to water and sanitation by 2015 (Hutton and Bartram 2008).
		50	Meet world's water needs (2030 Water Resources Group, McKinsey).
Total	1,347	1,053 – 2,593	(See Note 2).

## Notes to Table 1:

1. All amounts are annual investment figures; Green Economy Report investment allocation in 2010 dollars; IEA investment needs are in 2007 dollars (difference should be considered negligible relative to imprecision of estimates). The GER investment portfolio allocates investments totalling 2 per cent of global GDP across the range of given sectors, with a number of specific sectoral targets, which are described in the details column. These will rise over the period 2011 to 2050 as economic growth proceeds to reach US\$ 3.9 trillion in 2050 (in constant 2010 dollars). Investment needs are assessments generally taken from other sources, but many of which have influenced the allocation of the Green Economy Report investment portfolio, especially IEA.
2. For the investment assessment under the right-hand column, the range of total investments corresponds to the sums of low and high estimates per sector.
3. Most IEA figures are simple averages of estimated total investment over 2010 to 2050; however, it appears that lower investments are projected for earlier years, and higher figures for later years.
4. The figures for IEA Energy Technology Perspectives (2010) BLUE Map Scenario represent only the additional investment, totalling an average of US\$ 1.15 trillion per year, and do not include the projected investments for the reference scenario, which involves investments to meet increased energy demand through a continuation of existing investment trends.
5. The European Renewable Energy Council and Greenpeace's Advanced [R]evolution scenario have a key target for the reduction of CO<sub>2</sub> emissions down to a level of around 10 gigatonnes per year by 2050, and a second objective of phasing out of nuclear energy. The [R]evolution scenario has similar target, but assumes a technical lifetime of forty years for coal-fired power plants, instead of 20 years; the estimated average global investment needed for this scenario is US\$ 450 billion (European Renewable Energy Council and Greenpeace 2010).
6. These estimates are for HSBC's Conviction scenario, which projects "the most likely pathway to 2020", which sees the EU meeting renewable but not energy efficiency targets, limited growth in clean energy in the USA, and China exceeding current clean energy targets. This scenario does not correspond to any specific climate policy target. In addition to the supply of low carbon energy, this estimate also includes energy efficiency investments that would be undertaken in transport, buildings and industry sectors. In terms of the breakdown, HSBC estimates that US\$ 2.9 trillion will be required between 2010 and 2020 in total for low carbon energy supply and US\$ 6.9 trillion for energy efficiency and management.

**Table 1: Annual green economy investment by sector**

	Total assets of international banking (2009)/ Global bank assets (2008)	Total assets under management in 2009 (covering public equities, real estate, bonds, asset-backed securities, etc.)	Premium volume (2008)
Global market size	Approx. US\$ 34 trillion (BIS) / approx. US\$ 97.4 trillion (IMF, BIS, etc.)	Approx. US\$ 80 trillion (IFLS Research)	Approx. US\$ 4.3 trillion (Swiss Re, IFLS Research)
Share committed to sustainability	Approx. US\$ 50 trillion of bank assets signed commitment to sustainability	Approx. US\$ 25 trillion of assets signed to PRI (UNEP FI/PRI)	In excess of US\$ 500 billion of insurance premium volume committed to sustainability

Notes to Table 2:

1. The figures in this table are indicative and should be interpreted with caution due to existence of other industry collaboration initiatives that provide frameworks for commitment to sustainability. Therefore, the share of respective global markets committed to sustainability could be higher.
2. Financial institution types covered in the asset management classification in this table include pension funds, insurance funds, mutual funds, sovereign wealth funds, private equity and hedge funds.
3. Shares committed to sustainability are rough estimates and provide an indication of financial institutions engagement to sustainability (e.g. commitment to statement and principles of UNEP FI/PRI).
4. Total assets of banks committed to sustainability given in this table also include assets held by banks via various investment instruments and in a few cases include insurance instruments.

**Table 2: Selected indicators of the global market size by sector and the share committed to sustainability, 2008-2009 (banking, investment and insurance sectors)**

Sources: The Bank for International Settlement (Securities statistics and syndicated loans 2007-2009), IMF (Global Financial Stability Report 2009), TheCityUK, Swiss Re, UNEP FI and PRI

2008 AUM figures in US\$ billions	Total signatory internally active AUM	Internally active assets subject to integration via PRI signatories	Share of signatory internally active AUM subject to integration	Market size	Share of total market subject to integration by PRI signatories*
Listed equity (developed markets)	2,264	1,337	59%	27,107 <sup>a</sup>	5%
Listed equity (emerging markets)	308	185	60%	5,313 <sup>a</sup>	4%
Fixed income-sovereign	3,430	690	20%	24,596 <sup>b</sup>	3%
Fixed income-corporate issuers	1,978	883	45%	6,380 <sup>b</sup>	14%
Private equity	232	105	45%	2,492	6%
Listed real estate or property	289	74	26%	694 <sup>d</sup>	14%
Non-listed real estate or property	303	239	79%	10,915 <sup>e</sup>	3%
Hedge funds	210	25	12%	1,500	2%
Infrastructure	67	39	59%	19,900 <sup>f</sup>	0.2%
<b>Total</b>	<b>9,081</b>	<b>3,578</b>	<b>39%</b>	<b>98,897</b>	<b>4%</b>
2009 AUM figures in US\$ billions	Total signatory internally active AUM	Internally active assets subject to integration via PRI signatories	Share of signatory internally active AUM subject to integration	Market size	Share of total market subject to integration by PRI signatories*
Listed equity (developed markets)	3,674	2,525	69%	37,500 <sup>a</sup>	8%
Listed equity(emerging markets)	700	478	68%	9,589 <sup>a</sup>	6%
Fixed income-sovereign	5,253	1,579	30%	30,232 <sup>b</sup>	6%
Fixed income-corporate issuers	2,437	1,373	56%	7,329 <sup>c</sup>	22%
Private equity	201	122	61%	2,337	9%
Listed real estate or property	297	172	58%	678 <sup>d</sup>	34%
Non-listed real estate or property	497	418	84%	10,256	5%
Hedge funds	188	36	19%	1,700	5%
Infrastructure	71	63	89%	21,600 <sup>f</sup>	0.4%
<b>Total</b>	<b>13,317</b>	<b>6,766</b>	<b>51%</b>	<b>121,220</b>	<b>7%</b>

a. Split developed and emerging markets by MSCI country membership. Deduct listed real estate by market capitalisation weighting. b. Sovereign plus quasi-sovereign. c. Corporate plus high yield but excluding asset backed. d. Figures for public equity. e. Figures for private debt, public debt and private equity. f. Estimated total stock of infrastructure assets in public ownership.

\* This per cent conservatively underestimates the findings of the survey. In fact, the numerator does not include the externally managed funds, to avoid some double counting. Moreover, the market size in the denominator includes passive managed funds, which instead are not measured in the numerator as not necessarily subject to Principle 1.

**Table 3: ESG integration for internally actively managed AUM (assets under management)<sup>1</sup> relative to total investment market**

Source: Principles for Responsible Investment (2010)

1. Assets Under Management (AUM) - market value of assets that an investment company manages.

for the period 2011 to 2050 based on the 2 per cent of GDP green economy scenario is nearly US\$ 1.35 trillion on average. For the nine sectors covered, excluding fisheries, the estimate for the lower range for annual investment 2011 to 2050 is almost US\$ 1.2 trillion per year. This estimate rises to over US\$ 3.4 trillion per year, a high-end estimate that applies to later decades, when global GDP is presumably much higher.

The table clearly demonstrates very significant overall investment needs to transition the green economy as well as the considerable range for some key sectors, such as energy, to move towards a more sustainable basis for economic growth. It shows in particular the large volumes of resources required to expand and transform the inventory of built capital, in the form of energy supply, public transport, and energy and resource-efficient buildings. The table also shows the resources required to change to a sustainable way of managing natural capital assets such as forests, fisheries and agricultural lands.

It is estimated that more than 80 per cent of the capital needed to address climate change issues in future decades will come from the private sector (Parry et al. 2009), highlighting the significant role of the private sector in the transition to a green economy. The message for both policy makers and the financial services sector is clear: to achieve this transition by 2050, substantial financial resources, including public, private, hybrid and new blended approaches, will have to be mobilised. In addition, private resources and capital markets will have to play an instrumental role in providing the required finance and investment. This will require appropriate regulatory frameworks comprising a rich policy mix to stimulate demand for these funds, together with targeted flanking policies to protect households below the poverty line from possible unintended consequences on the costs of basic goods and services.

### Tracking new trends in finance and investment flows

The roles of lending, investment, insurance and public finance all remain critical in greening different economic sectors and establishing more resource efficient societies. While global ODA often processed by government-owned agencies dropped (United Nations 2008), DFI was estimated to be around US\$ 108 billion in 2010, and annual private finance went into the trillions (TheCityUK

2011). The critical role for public finance lies in being a catalyst, early stage investment provider, co-sharer of risk and guarantor of public infrastructure and services. As far as private finance is concerned, the relative size of lending, investment and insurance as well as their commitment to sustainability is provided in Table 2.

The tracking and precise quantification of financial and investment flows to greening and social responsibility, across asset classes, geographies and sources (public, private, public-private, and hybrid) is a work in progress. Some asset classes, notably cleaner energy technologies, already have sophisticated and globally recognised methods in place to accurately capture annual global flows. These are highlighted later in this chapter. The following section provides a snapshot of how investment capital from the world's largest institutional investors is starting to flow to the green economy, but is not comprehensive in its coverage given the information, data, and methodological challenges for what, in many cases, are nascent green economy-related asset classes.

At the global level, the quantification of how ESG considerations are integrated into various asset classes; for example, listed equity (developed and developing markets), fixed income (sovereign), fixed income (corporate), private equity, real estate and property (listed and non-listed), hedge funds and infrastructure, only commenced systematically in 2008, thanks to the United Nations-backed Principles for Responsible Investment (PRI). In 2009, it was estimated that the global market size for overall actively and passively managed assets<sup>2</sup> was just over US\$ 121 trillion, up from nearly US\$ 99 trillion in 2008 (PRI 2010). Of these assets, controlled by a broad range of large institutional investors (such as pension funds, sovereign wealth funds, insurance companies, and foundations), the internally actively managed component of the investable universe, some 4 per cent (US\$ 3.578 trillion) in 2008, rising to 7 per cent (US\$ 6.766 trillion) in 2009, were subject to integration of ESG considerations (see Table 3 for a complete breakdown).

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2. Active management of assets refers to a strategy where a portfolio manager makes specific investments with the aim to outperform an investment benchmark index. Passive management refers to a strategy where a portfolio manager makes investments in line with a pre-determined investment strategy.



## 3 Emerging investment in the green economy

### 3.1 From crisis to opportunity

In recent years, a broad range of financial developments have emerged that support the transition to a green economy. Despite the turbulence in world markets and the lack of an international regulatory framework to direct finance towards a green economy, capital markets have continued to evolve in ways that can help foster a green transition. Some examples include:

- The arrival of cleaner energy technologies as new asset class and the four-fold increase in new investment in sustainable energy from US\$ 46 billion in 2004 to US\$ 162 billion annually by 2009 (UNEP SEFI 2010);

- The creation of carbon markets where the value of annual trading volumes rose to US\$ 122 billion by;

- 2009. Studies estimate that emissions were reduced by around 120m to 300m tonnes in the first three years of the European Union Emissions Trading System (Pew Center on Global Climate Change 2008); and

- The possibility of new markets associated with more effective management of natural resources, the provision of integrated urban environmental infrastructure and low carbon transport systems for cities, as well as low carbon industrial, commercial and residential property.

As indicated in the previous section, private capital sources are estimated to supply more than 80 per cent of the investment required for the transition to a low carbon economy. Access to capital and the magnitude of the necessary investment remains significant. The ability of public and private finance to interact within stable and resilient capital markets will be a key determinant if capital is to be provided at a sufficient scale to finance the transition to a green economy in a timely manner. Given the significant role that private capital sources are expected to play in the transition to a low-carbon economy, the smart deployment of public funds supported by a coherent policy framework will have a pivotal role in catalysing and leveraging greater private investment in a green economy. In the post-crisis government stimulus packages, some US\$ 470 billion out of US\$ 3 trillion-plus in public funds committed (HSBC 2009) to head off a severe global depression

was earmarked for low-carbon and environmental infrastructure investments.

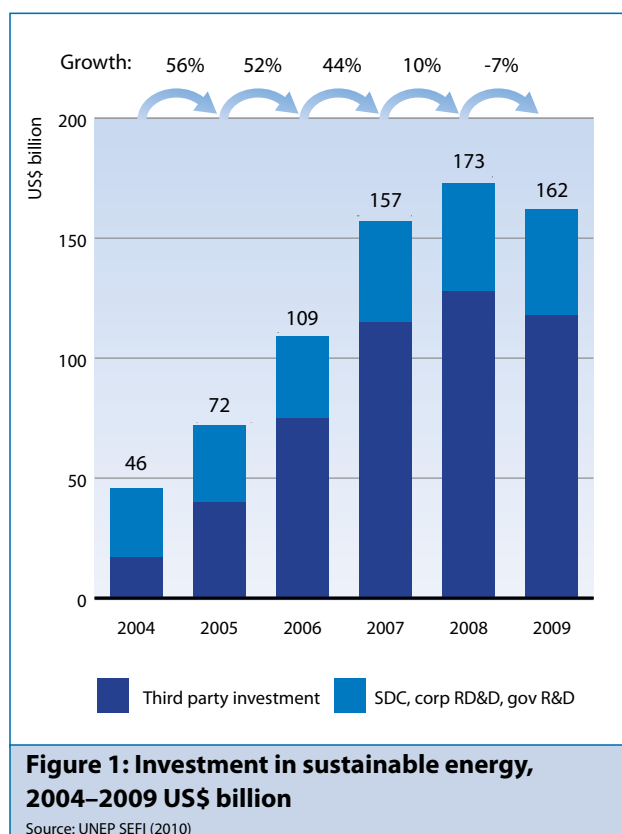
Together with these recent developments, the role of multilateral financial institutions (MFIs), such as the World Bank, International Finance Corporation (IFC), and the thirty-plus regional MFIs, national development banks, as well as export credit and investment guarantee agencies, will be critical in fostering new and emerging niches in financial markets as private finance and investment adjust to and gain confidence in evolving green economy policy frameworks. Importantly, to archive best environmental and social outcomes, incentives should be designed and used in areas with the greatest potential for reducing GHG emissions along with job creation and other green economy objectives. .

### 3.2 New markets and instruments

#### Renewable energy

The renewable energy sector is by far the largest destination for green investment in the GER scenarios. Financial markets have already been mobilising substantial amounts. A total of around US\$ 557 billion of capital was deployed to the renewable energy market between 2007 and mid-2010 (UNEP SEFI 2010). This market has seen a four-fold increase in new investment from US\$ 46 billion in 2004 to US\$ 162 billion annually in 2009 (see Figure 1). The US\$ 30 billion fast track financing pledged at the 2009 United Nations Climate Change Conference in Copenhagen (COP 15) has also focused greater business and investor interest in this market (see Box 1). Furthermore, analysts expect financial flows to this market to increase considerably in coming years. One recent study indicates that the low-carbon energy market size will reach US\$ 2.2 trillion by 2020 (HSBC 2010).

Institutional investors, despite being considered risk averse and conservative, provided some 65 per cent of the finance for renewable energy in 2008 to 2009, contributing US\$ 192 billion out of a total of US\$ 294 billion. The remainder was spread among venture capital (VC)/private equity (PE), and research and development (R&D) sources, with some public stimulus money in 2009, offsetting a decline in VC/ PE funds (UNEP SEFI 2010). Notably, the Cleantech Group predicted that 2010



would end up as the second largest year on record for VC investment in clean technology with a full year total of about US\$ 7.3 billion, less than the US\$ 8.5 billion raised in 2008, but well ahead of the US\$ 5.7 billion raised in 2009 (Cleantech Group and Deloitte 2010). The increase in VC and PE investments in renewables will likely have a multiplier effect over time by sending signals of steady sectoral growth to other capital sources.

However, the obstacles remain considerable to scaling up investment in this sector to the levels required for a global green economy. Currently, renewables supply less than 5 per cent of the primary energy for power generation globally. The barriers to increasing this figure are financial and economic and include:

- Higher upfront costs, capital-intensive nature of projects and the use of subsidies for conventional energy;
- Political and regulatory; generally, policies do not favour renewable technologies;
- Environmental and social; for example, planning objections;
- Technical; for example, the intermittent nature of renewable technologies, and;
- The scale of the projects, mainly higher transaction costs.

Overcoming these barriers will require a more supportive and stable policy and regulatory framework (UNEP FI 2004).

A recent report by the World Economic Forum (WEF) and Bloomberg New Energy Finance estimated that moving to a low-carbon energy infrastructure and restricting projected global warming to below 2°C will require global investment in clean energy of approximately US\$ 500 billion per year by 2020 (WEF 2010a). HSBC similarly concluded that building the low-carbon energy market would require total capital investments of US\$ 10 trillion between 2010 to 2020 (HSBC 2010). However, public and private investment in clean energy in 2009 was far below needed levels. Furthermore, given the expected geographic shift of the global economy, as much as US\$ 400 billion of climate change mitigation, including investment into energy, will have to flow to the developing and emerging world (World Bank 2010a).

### Emergence of green property as an asset class

Property investments have a considerable influence on both financial markets and carbon emissions. The outlook for green property investment is encouraging. The estimated significant growth in ESG integration levels in listed real estate and property from 26 to 58 per cent (see Table 3), the successful launching and closing of over 18 “improver” property funds from 2006 to 2010 financing the energy efficiency retrofitting of commercial buildings (Preqin 2004-2010), numerous green property development funds, and the increasing preference of occupants for green offices and residences are key indicators of green property becoming an emerging and increasingly attractive asset class.

The built environment, through its construction and use accounts for 40 per cent of both global energy use and carbon dioxide emissions. It is responsible for 30 per cent of raw materials usage and 20 per cent of water usage (UNEP SBCI 2007). Buildings have also been identified as the greatest potential source of carbon mitigation at lowest cost (IPCC 2007). Many actions that investors and occupiers of property can take to reduce overall environmental and social impacts, including improving the environmental efficiency and social utility of investable properties (UNEP FI PWG 2011b), are low cost, estimated to be worth around US\$ 12 trillion globally, (DTZ Research MiP 2009). Such actions are immediately economic – a good example of eco-efficiency (Ceres 2010).

There is growing recognition of a range of economic and financial drivers to enhance the environmental credentials of existing buildings in rental and equity markets. For example, a 2009 report (RICS 2009) found an aggregate premium in rental rates for buildings with a sustainable rating of 3 per cent per square foot, or

above 6 per cent adjusted for building occupancy levels. In terms of selling prices, the report found a premium in the order of 16 per cent. Further, empirical evidence of such valuation differentials is growing (RICS 2009). The business case for green property investment has emerged strongly with a considerable effect on the operation of the market. However, vast opportunities remain to scale up green property investment.

It is also increasingly being argued that collectively, ever more stringent regulations, rising energy prices and changing occupier and investor preferences will increasingly affect the context within which property investment and letting decisions take place (UNEP FI PWG 2011a). As a result, the expectation is growing that, over time, greener buildings will experience higher net income growth through lower depreciation and lower operational costs, and as a result, be viewed as less risky. Enforceable regulations that drive higher environmental standards, greater consistency between fiscal incentives

and policy objectives/targets for GHG reductions in buildings, and the promotion of metrics systems that are more compatible, simpler, more relevant to investors and more capable of capture across whole portfolios will be critical in accelerating the greening of property market.

### **Forestry – Reducing Emissions from Deforestation and Forest Degradation (REDD+)**

For the financial services and investment community, understanding and developing prospective markets related to biodiversity and ecosystems services (BES) is challenging. The coverage of actual demand and the estimates of potential market value for the banking, insurance and investment community are poor. However, several recent initiatives have begun to frame the potential in nascent existing markets and prospective future ones. For example, the 2008 value of the bio-carbon market was estimated by the Ecosystem Marketplace to be at US\$ 37 million (see Table 4). This estimate includes the increasingly important concept of REDD+ (see Box 2).

## **Box 1: Copenhagen fast track financing – a status update**

The Copenhagen Accord notes developed countries' commitment to provide fast track financing of US\$ 30 billion for the 2010 to 2012 period and building to US\$ 100 billion per year by 2020.

This fast track financing will enhance action on mitigation, including Reducing Emissions from Deforestation and Forest Degradation (REDD), adaptation, technology development and transfer, and capacity building. Fast track financing will not only enhance implementation of the UNFCCC by developing countries between now and 2012, but also aims to help them prepare for sustained implementation beyond 2012. It is thus often referred to as enabling readiness for the post 2012 period. It will also provide lessons for climate financing over the longer term. The fundamental questions regarding the issue of fast track financing today are:

■ **Commitments at the country level** According to the World Resources Institute (WRI), country pledges today add up to roughly US\$ 27.9 billion;

■ **Are funds being disbursed or earmarked?** Of the total of US\$ 30 billion, only approximately US\$ 5 billion have been committed in national budgets and allocation plans, and only thirty-two concrete programme activities have been earmarked to be supported by these funds. Developed countries, therefore, still have much to do to concretise their

pledges to remain credible regarding their financing commitments;

■ **Are funds dedicated towards climate financing new and additional?** At the time of writing of this report, it remains unclear as to whether the funds pledged will be entirely additional to existing commitments in the areas of climate change mitigation and adaptation in developing countries or, more broadly, ODA. However, some pledged funds will be additional. It appears that most, if not all, funding denominated as fast track financing under the Copenhagen Accord will be counted towards developed countries' ODA efforts and reported as such to the OECD's DAC (Development Assistance Committee) office. Past ODA efforts by developed countries have repeatedly been criticised for not reaching the target of 0.7 per cent of GDP, commonly referred to as a level of ODA commitments towards which developed countries should aim; and

■ **Will public fast track money leverage private climate finance?** Most, if not all, of the programmes put forward as qualifying for fast track financing aim at increasing the institutional capacity and readiness of developing countries to initiate climate change mitigation activities, rather than at directly reducing GHG emissions. These types of activities usually lack a commercial dimension or potential for private participation and, as such, will not be able to attract or generate private climate financing.

BES asset class	Market value	Year	Market type	Source
Biodiversity mitigation/offsets	US\$ 1.8 – 2.9 billion	2008	Cap-and-trade/ voluntary	Ecosystem Marketplace, 2009
Bio-carbon:				
Voluntary over-the-counter (forestry carbon), incl. REDD+	US\$ 31.5 million	2008	Private voluntary	Ecosystem Marketplace, 2009
Chicago Climate Exchange – forest carbon	US\$ 5.3 million	2008	Private voluntary	
Clean Development Mechanism (CDM) – afforestation/reforestation	US\$ 0.3 million	2008	Cap-and-trade	
Cosmetics, personal care, pharmaceuticals: bio-prospecting contracts	US\$ 30 million	2008	Private voluntary	The Economics of Ecosystems and Biodiversity study (TEEB) D3
Certified agricultural products, incl. Non-Timber Forest Products (TFPs)	US\$ 40 billion	2008	Private voluntary	Bishop et al., 2008. Building Biodiversity Business.
Certified forest products – Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC)	US\$ 5 billion (FSC certified products)	2008	Private voluntary	TEEB D3
Payments for Watershed Services (private voluntary)	US\$ 5 million (various pilots e.g. Costa Rica, Ecuador)		Private voluntary	TEEB D3
Payments water-related ecosystem services (government)	US\$ 5.2 billion	2008	Public	TEEB D3
Other payments for ecosystem services (government-supported)	US\$ 3 billion	2008	Public	TEEB D3
Private land trusts, conservation easements (e.g. North America, Australia)	US\$ 8 billion (in the USA alone)	2008	Public	TEEB D3

**Table 4: Market potential for various BES asset classes**

Source: UNEP FI BES (2010)

REDD+ and related initiatives, such as new insurance products related to forest carbon, (see Box 3) demonstrate an increased understanding of the potential market scale for financial services and the policy steps needed to facilitate development of such markets. Appropriate, clear and consistent global and national policy frameworks will be critical if the BES market is to be developed at scale. For many mainstream insurers, insurance premiums for managed forests barely reach the scale to classify it as a market per se. However, given the right global policy choices within climate negotiations in the coming years, the carbon market in forests could reach US\$ 90 billion by 2020 (CDC Mission Climat 2008).

### Green bonds

The green bond market is still relatively small, but has the support of triple AAA rated institutions and growing momentum. Bonds are a very regular means for governments, institutions and even large corporations to raise debt (borrow money) from the capital markets. In recent years, the term green bonds, or sometimes clean energy bonds or climate bonds, has been increasingly featured in discussions about finance for clean development<sup>3</sup>. Green bonds are simply a variant of general bonds wherein the issuer of the bond guarantees to use the money raised for some specific environmental purposes. They are designed to particularly attract investors who wish to lend money for these purposes.

The market for green bonds is still very limited. Although issuance of green bonds is relatively small in size, current issues provide an encouraging example. EIB and the World Bank (see Table 5) issued various green and climate-friendly bonds between 2007 to 2010 valued at US\$ 1 billion and US\$ 1.5 billion respectively. Additionally, the IFC has issued four-year US\$ 200 million fixed-rate green bonds for 2010 to 2014 to finance renewable energy and energy efficiency projects in developing countries. In 2010, the ADB and African Development Bank both issued their first Clean Energy Bonds.

While issuances of green bonds from the multilateral development banks have garnered much of the recent attention, green bonds have also been used at a municipal level to finance green projects. For example, in the United States, a green bond is a type of tax-exempt municipal bond, issued by organisations and local governments that have been qualified by the US federal government to do so. The full name for these green bonds is a Qualified Green Building and Sustainable Design Project Bond. These green bonds are meant to promote environmentally friendly land use and development, for example, the Destiny USA retail complex in New York that expects to have all of its energy needs met by renewable sources.

The global market size of bonds in emerging markets alone stood at US\$ 79 billion in 2009 (IMF 2009), which suggests a greater potential for green bonds, for example, energy efficiency bonds for large scale retrofitting of composite urban units. High-grade fixed income investments, such as bonds, represent a promising instrument for

3. The Climate Bonds Initiative is a project established in 2009 by the Network for Sustainable Financial Markets (NSFM) operating as a joint project of NSFM and the Carbon Disclosure Project. [http:// climatebonds.net](http://climatebonds.net).



## Box 2: Overview of REDD+

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low- carbon paths to sustainable development. REDD+ goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

Much of protecting existing forests (REDD+) or reforesting areas (afforestation and reforestation – A/R) is achievable at considerably lower costs than other abatement technologies, and brings immense potential co-benefits such as biodiversity conservation and watershed protection – “free” services with an estimated value of up to US\$ 1 trillion/year by 2100. Nevertheless, achieving this potential will require considerable investment, estimated at a minimum of US\$ 17 to 33 billion per year just to halve the rate of tropical deforestation by 2030 (The Eliasch Review 2008). Investment on this scale is unlikely to come from governments alone, and thus active participation of private sector financial institutions is essential. This in turn depends on making protection and enhancement of forests investable while intensifying efforts to accurately measure and report on carbon stored in forests. The main investment sources in the forestry sector in general (i.e. other than in the context of climate mitigation) are private (93 per cent) representing about 1.5 per cent of global direct investment (UNEP FI 2011a and UNEP FI 2011b).

The forestry sector, REDD+, and A/R can be of interest to financial institutions if they can not only be profitable, but to also diversify lending, insurance and investment portfolios. This sector can also be of interest to financial institutions because of political and associated reputational imperatives. A range of political, market and general business risks need to be

considered. Risk mitigation tools available to financial institutions to make REDD+ and A/R projects more attractive include guarantees, insurance, and bonds.

Although negotiations are still ongoing at UNFCCC level about the exact shape and structure of a REDD+ mechanism, around 40 countries are already engaging in REDD+ strategy development (Phase 1) and pilot activities. It is expected that private sector finance for REDD+ will scale up as initial reforms and institutional strengthening take effect and REDD+ programmes are scaled up (Streck et al. 2010). The five current scenarios that are on the table within international climate negotiations include

Scenario 1: National crediting under a UNFCCC agreement.

Scenario 2: Sub-national or project crediting under a UNFCCC agreement.

Scenario 3: The nested approach as hybrid solution between Scenarios 1 and 2.

Scenario 4: International fund with national-level incentive payments.

Scenario 5: Voluntary markets only (no international REDD agreement).

The most promising policy option for private sector involvement in REDD seems to be the nested approach described in Scenario 3. In the absence of a global climate agreement, market players need to be prepared to make use of the opportunities within the voluntary market, or dedicated national cap-and-trade schemes that allow for REDD offsets (e.g. future US scheme and/or EU ETS Phase 3).

Source: UNEP FI

mainstreaming institutional investors to deploy larger amounts of investment in the environmental sector. With bond holdings representing 31 per cent of financial assets worth US\$ 39 trillion in 2009 (Capgemini 2009), high net worth individuals represent a significant segment of potential demand for green bonds.

Equally, the public sector at the national and international levels should support the growth of these emerging segments by funding research and promotional activities to foster a better understanding of green bond

markets, green commodity markets, and environmental and social stock exchanges. The Climate Bonds Initiative, a global civil society network launched in 2009, develops policy proposals for governments, finance and industry, and develops advice on large-scale climate mitigation opportunities suitable for long-term debt finance (The Climate Bonds Initiative 2009).

### Carbon markets

Carbon markets comprise one of the key areas of green finance and provide an important discovery mechanism for



Issue (Rating)	Amount	Maturity Date	Coupon	Investors
Inaugural Issue Swedish Krona (SEK) denominated Green Bond (Aaa/AAA)	2.85 billion SEK (in three tranches)	November 2014	3.5 per cent p.a.	Swedish National Pension Funds Skandia Life UN Staff Pension Fund Others
First US\$ denominated Green Bond (Aaa/AAA)	US\$ 300 million	April 2012	Floating rate	State of California
Third World Bank Green Bond (Aaa/AAA)	US\$ 180 million (in two tranches)	December 2013	2 per cent p.a.	California State Teachers Retirement System (CalSTRS) Swedish National Pension Funds Swedish insurance provider SEB Trygg Liv UN Staff Pension Fund, Others
Fourth World Bank Green Bond (Aaa/AAA)	NZD 150 million	January 2015	5.23 per cent S.A.	Japanese investors
IFC Inaugural Green Bond (Aaa/AAA)	US\$ 200 million	April 2014	2.25 per cent p.a.	Details not available

**Table 5: Recent green bond issues by the World Bank Group**  
Source: World Bank and IFC websites

the price of carbon. In total, 8.7 billion tonnes were traded in 2009 (see Figure 2), with a value of US\$ 144 billion (US\$ 123 billion in allowance-based cap-and-trade) trading and US\$ 21 billion in project-based deals under instruments such as the CDMs. The largest carbon market by far is the European Union Emissions Trading System (EU ETS), the annual value of which rose to US\$ 122 billion in 2009.

There is considerable uncertainty about the future structure of carbon markets following an inconclusive

outcome to the 2009 UN Climate Change Conference in Copenhagen and a stalemate on establishing a national carbon trading scheme in the US (TheCityUK 2010). Primary CDM transactions, making up the bulk of the project market, nearly halved to 211 million tonnes in 2009 from 404 million tonnes in 2008, due to difficulties in accessing finance, lack of bankability of CDM and Joint Implementation (JI) credits after 2012, and ever lengthening delays in the CDM process (see Figure 2).

### Box 3: Building an insurance market for forest carbon

Carbon markets have not tackled emissions from the loss of natural forests. There are several concerns: the issues of likely permanence, additionality, leakage, measuring and monitoring, and risks of project-based changes in carbon stocks or GHG emissions. It is a significant gap in mitigation - as much as 20 per cent of anthropogenic GHGs are estimated to originate from land use change. Unlike the reduction or avoidance of GHG emissions with all other types of mitigation activities, GHG sequestration into biomass is non-permanent. Sooner or later, the sequestered carbon will be re-released into the atmosphere. In the case of forestry this can happen due to natural hazards, land-use decisions and other events (UNEP FI 2008).

To date, regulators have treated forest-based GHG permits as temporary, which has greatly reduced their value and thus demand. In the voluntary certificate sector, the approach for addressing non-permanence is to require projects to maintain adequate buffer reserves of non-tradable carbon credits to cover unforeseen losses in carbon stocks.

Another alternative is the deployment of insurance and other financial risk management instruments to guarantee the permanence of carbon sequestered

through forests. This means that the land occupied by the buffer would be available for a variety of purposes. In principle, the loss of carbon from a forest is insurable, and the use of financial tools is superior economically. Private sector providers of forest insurance focus on plantations, not public and natural forests. The primary reason is the more sophisticated risk management systems (e.g. watchtowers and firebreaks, fire-fighting personnel, equipment and procedures) in place for privately owned forests, where there is a clear financial interest. Even for plantations, the total acreage insured is low.

The main reasons for the lack of demand are its high exposure to catastrophic losses (exacerbated by climate change); low demand and inadequate pricing; and insufficient risk management, compounded by the possibility of moral hazard. Also, forest risks require specialist knowledge, and the valuation of forest carbon is difficult. While forest insurance products have been underwritten via traditional, indemnity-based insurance policies, some are also exploring the viability of alternative risk transfer and financing solutions including catastrophe bonds. There is some evidence that public sector forest insurance has been successful, for example, in Japan.

Source: UNEP FI (2008)

One sign of this was the change in fortunes of the Chicago Climate Exchange (CCX), which announced in October 2010 that it would be ending its operations as a clearing house for a voluntary cap-and-trade scheme among industrial members. At its inception in 2003, CCX was viewed as a proving ground, and at one time more than 400 members, including many large utilities and to learn how a cap-and-trade system would work. Their emission reductions accounted for about 88 per cent of the nearly 700 million metric tonnes of carbon dioxide reduced by CCX since 2003 (Chicago Climate Exchange 2011). Carbon offsets account for the rest. The voluntary members' scheme was scheduled to terminate in 2010 and, after cap-and-trade legislation failed to pass in the US Senate, renewal was deemed infeasible. The exchange will continue trading voluntary carbon offsets, a different kind of contract created by projects, such as planting trees, to reduce carbon dioxide or other GHGs.

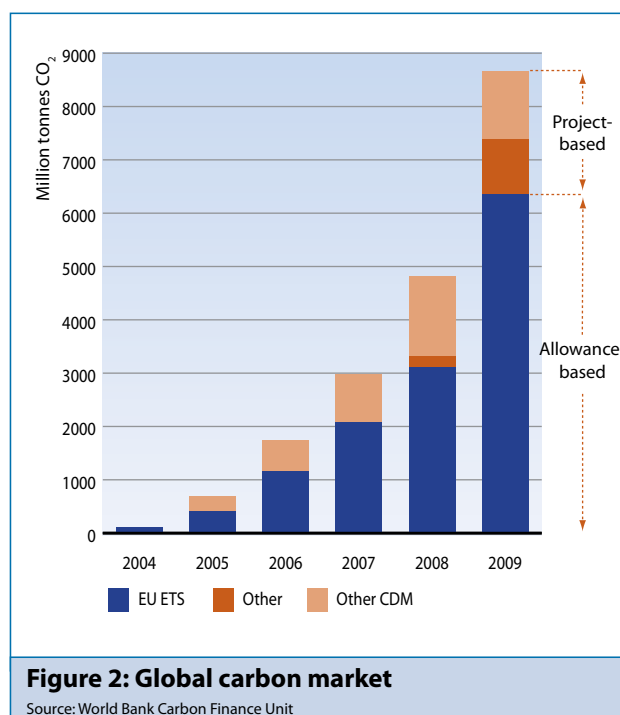
In the U.S. Regional Greenhouse Gas Initiative (RGGI), a mandatory programme capping power plant CO<sub>2</sub> emissions in 10 north-eastern states, permit volumes exchanged slumped to 36 million metric tonnes in the third quarter of 2010, down from 329Mt in the same period of 2009 (Bloomberg New Energy Finance 2009). However, in addition to regulatory uncertainty, carbon markets have flaws (Dag Hammarskjöld Institute 2009). Within the UNFCCC system key issues are the credibility of offsets from industrial gas projects under the CDM and the surplus in emissions allowances held by former Soviet countries. However, the EU seems determined to continue with its own scheme. The potential for evolution of the EU ETS system is explored in the final section of this chapter. It is noteworthy that in the first three years of trading, emissions in Europe were estimated to have been reduced by around 120 to 300 million tonnes (Pew Center on Global Climate Change 2008).

New initiatives such as the UK's Green Investment Bank are also providing potential foundations for more co-financing and risk sharing between the private banking sector and public entities (see Box 4).

### Low carbon transport

Measurement of finance flowing into low carbon transport is challenging. The measures required for increasing financial flows in this sector are different in developed and developing countries. In developed countries low carbon solutions would need to be grafted on to existing transport networks.

In the UK for example, two-thirds of GHG emissions savings under road transport would come from more efficient and low carbon vehicles, particularly electric/plug-in hybrid vehicles (Parliament Committee on Climate Change, UK 2010). Given the current state of electric car technology, to develop an electric car market would only require



### Box 4: Green Investment Bank, UK

In 2010, the UK government announced that it would create a £ 1 billion Green Investment Bank (GIB) that would make direct financial interventions to help the government meet its ambitions for green infrastructure. Although at the time of writing the specific governance structure of the GIB were still unpublished, it is expected to have a mandate to deliver and debt products, and share the risk in financing green infrastructure where the market on its own currently cannot adequately accommodate such a risk. Areas of investment are expected to include the offshore wind sector and the carbon capture and storage (CCS) industry. The UK government is also reported to be examining types of de-risking products for construction and operating phases to help the private sector introduce cheaper forms of low- risk capital. As well as reducing risk to mobilise additional capital in the market, the GIB will also seek to make a return on investment and to reinvest the proceeds into further green infrastructure financing. It has also been suggested that the GIB take a role in developing marketplace standards for green bonds by creating environmental integrity standards that would increase the product's credibility with institutional investors.

transitional financial support from government for car purchase and investment in a battery recharging network. The battery charging infrastructure could be a largely home-based network and would enable 240,000 electric cars to be on the road in the UK by 2015, rising to 1.7 million by 2020.

This is similar to the Japanese government's objective to achieve a 15 to 20 per cent market share of electric and plug-in hybrid cars by 2020. Once the electric/plug-in hybrid vehicle penetration is at these levels, it is likely that the private sector finance could be relied on to complete the conversion.

However, in developing countries, there may be an opportunity to avoid the private car centred model of transport and provide sustainable, high quality mass transport sooner, and at less cost (Sakamoto, Dalkmann, and Palmer 2010). Public finance is, and will remain, the core source of funds, using both domestic and international flows, such as ODA and export credits.

### **Improved waste management**

Sustainable waste management is a major issue in human society and a growing source of efficiency savings in industrial management. Around 4 billion tonnes of waste are produced around the world each year of which scarcely one-quarter is thought to be recovered or recycled, including many secondary materials that can substitute for raw materials that are becoming increasingly scarce (Veolia Environmental Services 2009).

From being primarily a local activity, the scale of sustainable waste operations has mushroomed with the emergence of worldwide markets for a number of secondary materials, such as scrap and paper, for which 2007 and 2008 revenues matched those for raw materials, such as steel and paper pulp. This industry for industrial, municipal, and hazardous waste is served by a range of public municipal agencies and private sector enterprises. Together with the other economic activities associated with waste, from collection to recycling, it would appear to represent a world market of some € 300 billion, shared about evenly between municipal waste, and industrial and construction waste.

Finally, institutional investors are also playing a part. For example, former US President Bill Clinton has announced an investor-led survey of how companies use and track plastic in their businesses. Investors with more than US\$ 5 trillion in assets under management (AUM) are to back the Plastic Disclosure Project (PDP). The first PDP survey is scheduled for the first half of 2011 (McCabe 2010) and, as suggested by its name, is similar to the successful Carbon Disclosure Project, which sends out a detailed questionnaire to firms on their carbon emissions, targets and mitigation strategies.

### **Improved freshwater provision**

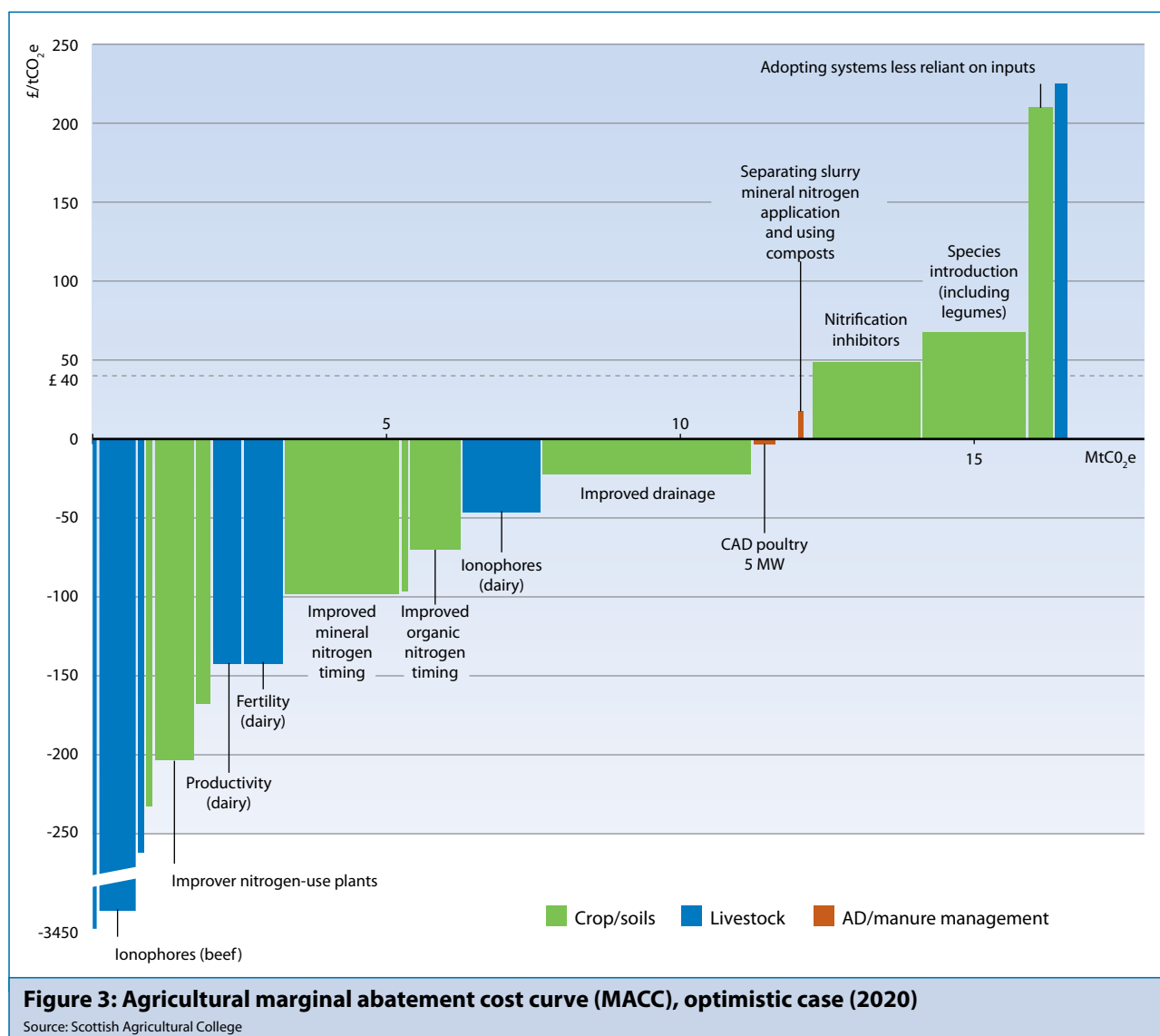
While public water companies provide most water and wastewater services worldwide, the number of people served by private water companies has grown significantly in the last two decades. As water infrastructure is very capital-intensive, private sector investment or support for public investment via bonds financed by investors is increasingly important. Private financing for infrastructure to produce freshwater is one area of potential significance for a green economy.

Currently, 95 per cent of global potable water is financed and provided by the public sector (OECD 2004). However, limited renewable freshwater resources and greater human water withdrawals are increasingly causing water stress and severe scarcity. About 2.8 billion people (UN MDGs 2008) endure some form of water scarcity of which 1.2 billion live under conditions of physical water scarcity and 1.6 billion people live in areas of economic water scarcity, where the costs of water provision have been rising. New infrastructure and improved water treatment technologies are central in improving water supply and wastewater management. The Camdessus Panel (World Water Council 2003) estimated the funding gap in the water sector for developing countries and emerging markets alone to amount to US\$ 100 billion per year — the bulk of which is for household sanitation, wastewater treatment, treatment of industrial effluents, irrigation and multipurpose schemes. Private finance would have to at least double to close the public investment gap in the water sector.

### **Sustainable agriculture**

Until recently, agriculture has been ignored by financial market participants focused on sustainability. However, global demand for agricultural commodities is now pressing on supply and high-tech has entered the agricultural laboratories. It has also become clear that farming is a highly polluting industry and poses significant equity issues. The perception that agriculture is now a potentially risky, but profitable, opportunity has begun to attract the attention of the sustainability component of the finance sector. This report is unable to offer any reliable global estimates of green finance currently flowing into sustainable agriculture as a whole. However, the examples of responsible finance for palm oil and GHG reduction in the UK may be illustrative.

Global production of palm oil has doubled over the last decade to over 36 million metric tonnes per year and is expected to double again by 2020. In 2008, when prices were especially high, the market in crude palm oil was worth more than US\$ 25 billion. About 80 per cent is used for food, for example, margarine (WWF International and Profundo 2008). Sustainable palm oil production can help to meet the world's growing demand for edible oils and generate income and employment for rural economies in tropical regions.



However, unsustainable practices in parts of the industry have had serious impacts, such as forest clearances that destroy rich natural ecosystems and release huge volumes of GHGs into the atmosphere. There have also been social issues such as native communities being unwillingly dispossessed of their land. Because such problems may entail the risk of financial penalties, client default and reputation risk, many commercial banks have strengthened their risk assessment policies on palm oil loans, and have developed written policy statements on palm oil, noting that a responsible palm oil policy needs to cover the full range of companies involved in the palm oil sector, including upstream companies as the producers of crude palm oil and downstream companies involved in refining, trading and use of palm oil products.

In most OECD countries, the GHGs emitted by the agricultural sector are significant and comprise mainly of methane and nitrous oxide, which interact with soil and microbial processes in ways that are not completely understood (Climate Change Task Force UK 2010).

Also, the actors are many, dispersed and small, so that measuring emissions and enforcing regulations are not easy. Thus, increasing attention is being given to market-based instruments such as tradable emission permits. To that end, the UK has developed a Marginal Abatement Cost Curve (MACC) for UK agriculture (see Figure 3).

This exercise identified a technical potential of 9 MtCO<sub>2</sub>-eq (metric tonnes of carbon dioxide equivalent) that could be abated at negative cost (i.e. this would save money for farmers under the assumptions used in the MACC), with an additional 4 Mt CO<sub>2</sub>-eq below £ 40/t CO<sub>2</sub>-eq. This indicates a scenario for GHGs policy, characterised by taxes and subsidies or a cap-and-trade scheme, with up to 6 Mt CO<sub>2</sub>-eq potentially available for abatement by 2020 (Climate Change Task Force UK 2010), a market of over € 100 million. Because the biggest reductions may come from the least efficient and least aware operators, linking environmental performance to improved profitability is likely to be effective and should also prove to be an attractive business model for financial institutions.

## 4 Opportunities and challenges in financing the green economy

Section 2 showed that current financial flows into a green economy need to be dramatically scaled up while Section 3 showed that innovative financial mechanisms have emerged for many environmental and natural resource areas and have begun to channel funds to them. This section identifies some of the key barriers to scaling up these flows throughout the typical life cycle of investments from pre-investment to final exit, and suggests ways to remove them.

### 4.1 Addressing the full cost of externalities

If the costs of environmental degradation and social harm remain external to the costs of business and investment activity, then the risk/reward equation that underpins so much of financial services and investment activity will continue to promote environmentally and socially unsustainable business practices and financial activity. For most of the period in which a formal investment industry has evolved over the past 200 years, ESG issues were not considered in the investment policy-making and decision-making processes of most mainstream financial institutions.

One of the primary reasons for this omission was that externalities – costs that are external to a company's balance sheet such as pollution or destruction of ecosystem services – have simply not been assessed, priced or accounted for in traditional market activity and the associated investment processes that have supported that activity. Analysis in the recent TEEB business report (TEEB for Business 2010) confirmed that standard business valuation techniques for most part still fail to capture the values of basic ecosystem services. In addition, criteria employed in accounting to ensure relevant and reliable financial reporting are framed in a way that typically excludes intangible issues such as impacts and dependencies on ecosystems and biodiversity.

The failure to internalise the wide and diverse range of environmental and social externalities prevents larger amounts of capital flowing into a green economy. While governments, through their regulatory activities (direct regulation, environmental taxes, user charges, and tradable permit systems) and budgetary activities (payment for environmental services) will play a major

role to address these externalities, voluntary initiatives within the financial and investment sectors can contribute also. While externalities remain unaccounted for in investment activity, the risk/reward equation that underpins most capital market activity makes the dramatic scaling up of financial flows to a green economy infeasible in the short-term. In recent years, however, some of the world's largest investors have begun to focus on the questions of fiduciary responsibility and fiduciary legal issues in the context of ESG matters (see Box 5). In particular, it is in the interests of large, diversified institutional investors that own a fairly representative sample of the global economy – so-called universal owners – to act to reduce negative externalities (see Box 6). While interest around the universal ownership theory continues to grow, it has yet to attain mainstream status and there are some dissenting views with respect to the overall thesis.

Most recently, there have been attempts to put a price on the damage caused by business to human health, the degradation of ecosystems, and the depletion of natural resources. Avoiding these costs represents one of the main benefits to society from greening the economy. For example, UN-backed research found that the human use of environmental goods and services in 2008 caused an estimated US\$ 6.6 trillion in environmental costs, equal to 11 per cent of the global economy (UNEP FI and PRI 2010). As the economic perils of a broad range of the “slow failures” or “creeping risk” (WEF 2010b) become more apparent, there is an accelerating need for capital markets and financial institutions to understand how natural and social value at risk will impact their investments in both the short and long-term.

A strategic commitment to capture these values and incorporate their consideration in internal decision making can help pave the way for greater capital flows to a green economy. Focused public policy action will speed up this process. The need to understand natural and social value at risk and its implications for economies poses a series of complex questions for the financial services sector, as well as for the broader business community. These questions are crucial for those parts of the financial system, such as the pensions and investment sector, which need to protect and grow assets over the long term.



## Box 5: Financial materiality and fiduciary responsibility (KfW Symposium 2008)

In 2003, a group of asset managers (UNEP FI AMWG 2004-2009) collectively representing US\$ 1.7 trillion in AUM began to reconsider the financial materiality of a range of ESG issues that until then had traditionally been overlooked or undervalued by many investment approaches. Over subsequent years, the process yielded three major reports that have transformed thinking within the investment world.

In the Materiality Series (UNEP FI Materiality Series 2004 to 2010) mainstream financial analysts explored the relevance of a range of ESG issues, such as climate change, occupational and public health, human labour and political rights, and both corporate trust and governance, across a range of commercial and industrial sectors. The sectors included aviation, the auto industry, aerospace and defence, chemicals, food and beverage, forest products, media, non-life insurance, pharmaceuticals, property, and utilities. What the Materiality Series was so effective in doing was to hold the coming-out ball for the idea that ESG (particularly environmental and social) factors have financial relevance, and are as useful in constructing a synthesis of management quality as strictly financial factors.

The Materiality Series also helped lay the groundwork for the development of the PRI, now backed by more than 900 institutional investors representing US\$ 25 trillion in assets<sup>4</sup>. The third and, to date, final report in the series focused on climate change and was published just two months ahead of the December 2009 United Nations Climate Change Conference in Copenhagen. The report mainly takes the form of a review of key financial analyst research on climate change.

Along with the growing acceptance of the financial materiality of ESG issues, parallel work was undertaken to show that considering ESG issues in investment policy making and decision making was consistent with legal frameworks that govern the fiduciary duty of many institutional investors to act

in the best interests of their beneficiaries. In October 2005, a landmark legal interpretation covering the nine major capital market jurisdictions opened up a new potential for the world's largest institutional investors to consider ESG issues in their investment processes (UNEP FI and Freshfields Bruckhaus Deringer 2005). In fact, the interpretation argued that the appropriate consideration of ESG issues – from both risk and reward standpoints – was an obligation in most major capital market jurisdictions and mandated by law in some. The Freshfields Report greatly strengthened the case within the investment industry around the need for investors to fully integrate material ESG considerations in all aspects of their investment processes. In short, this work moved the discussion forward on the need for key market actors to integrate, account for and price the risks associated with a broader range of externalities than had previously been the case in investment practice. The Freshfields legal interpretation was followed in 2009 by the Fiduciary II (UNEP FI 2009) report that built on the initial interpretation. The Fiduciary II report concludes that ESG issues should be embedded in the legal contract between asset owners and asset managers, with the implementation of this framework being governed via ESG-inclusive reporting to asset owners. It also makes a case that advisors to institutional investors, such as asset managers and investment consultants, have a duty to proactively raise ESG issues with their clients, and that those who do not open themselves to potential legal liabilities.

Finally, the study argues that responsible investment should be the default position for all investment arrangements. To achieve this the fiduciary duty should be aligned better with environmental and social dimensions. This evolving process that seen ESG issues being embedded in the thinking around fiduciary responsibility and legal considerations goes to the very heart of many investment policy making and decision making processes.

## 4.2 Providing pre-investment finance

At least 83 countries now have some type of policy designed to promote sustainable energy, but only a few have seen scaled-up investment in renewable energy

and energy efficiency operations (REN21 2010). Analysis suggests that one of the most important barriers to scaling up is the lack of pre-investment finance. Figure 4 demonstrates the phases of investment, from public grants, VC funding, and production subsidies required to develop a new renewable energy technology to the point that it can begin to demonstrate a track record and attract second stage funding. Figure 5 shows the private

4. The Principles for Responsible Investment (PRI), launched in April 2006, is an investor initiative backed by United Nations Environment Programme Finance Initiative and the UN Global Compact. [www.unpri.org](http://www.unpri.org)

financing mechanisms used to address financing gaps, which might be through an Initial Public Offering (IPO) or project finance loans from banks. The term “Valley of Death” is often used during the phase discussed above to describe the difficulties of accessing commercial finance between the initial VC investment and the demonstration, or from demonstration to commercial rollout with secondary VC investment.

The diagrams show where public grants or specific subsidies are essential. One can conclude that the private sector is capable of providing finance in more mature stages of commercial development, but is less reliable for early-stage finance where VC/PE operates. It demonstrates the need for a potential sharing of risk at the initial stages between private and public investors, for example, by providing incentives for private investment in the early deployment of new technologies or by improving the capacity of the insurance market.

## Box 6: The universal owner theory explained

The universal owner theory (UOT) concerns a solution to an important contradiction in the investment system: short-term rewards for some are potentially available where externalities, such as climate change, ecosystems destruction or ignoring the rule of law are not adequately accounted for. However, in the longer term these externalities may undermine the value of investments for all. Emerging work around the UOT is deepening our understanding and starting to quantify the economic, financial and investment implications of externalities along the investment chain.

A joint UNEP FI/PRI report on the subject estimated that the equivalent of US\$ 6.6 trillion of damage was externalised in 2008, or 11 per cent of the value of the US\$ 60 trillion global economy (UNEP FI and PRI 2010). Without action, the cost of environmental and social externalities relative to the value of the global economy is projected to increase by 62 per cent from 2008 to 2050. If environmental externalities are not addressed, the damage incurred annually continues over time and accumulates. The study also found that companies in the MSCI All Country Index are associated with over US\$ 1 trillion in environmental externality costs annually. This equates to 5.6 per cent of the market capitalisation of companies in the Index, and 56 per cent of their earnings. Environmental externalities could present a financial risk to universal owners invested in equity markets.

Source: UNEP FI/PRI (2010)

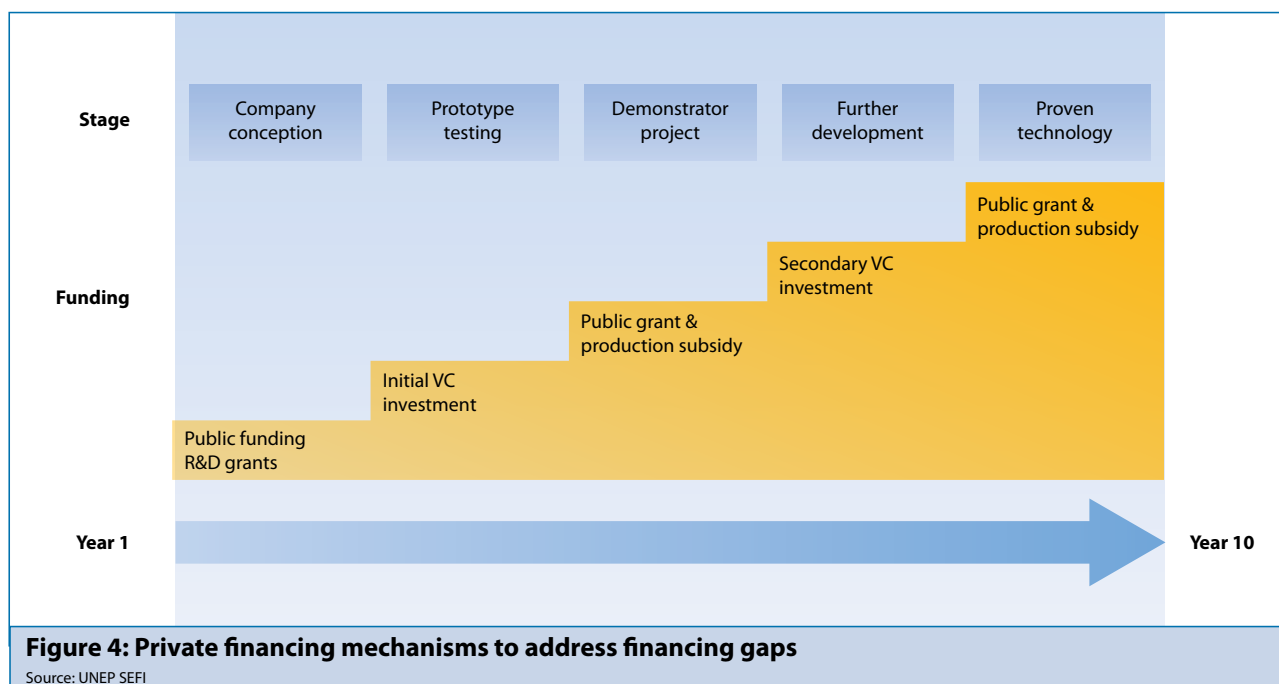
## 4.3 Integrating ESG risks into financial and investment decision making

To date, the degree to which ESG risks are factored explicitly into banking considerations is limited, largely due to the difficulties in establishing the financial materiality of such risks. Although public policy shifts have set processes in motion to strengthen the financial materiality of a range of these risks (see Box 7), there is a significant lag between a clear reflection of such risks in public policy at global, regional and national levels and its integration into the inner workings of the financial system. For the banking sector, this particularly relates to understanding and quantifying the credit risk, for example, linked to the likelihood of new regulation, and default implications of these emerging risks as well as the negative impact on collateral.

Also, the speed with which financial institutions are able to transfer risk into the system by removing the liability from their own balance sheet is an important factor in the assessment of how these emerging risks impact banking operations and the degree to which they are financially material for individual institutions. A 2006 report (UNEP FI and EcoSecurities 2006) concludes that in many cases for North American banks there was no link between bank lending and climate change risks because of the short average maturity of such loans and the speed with which banks transferred loans off their own balance sheet.

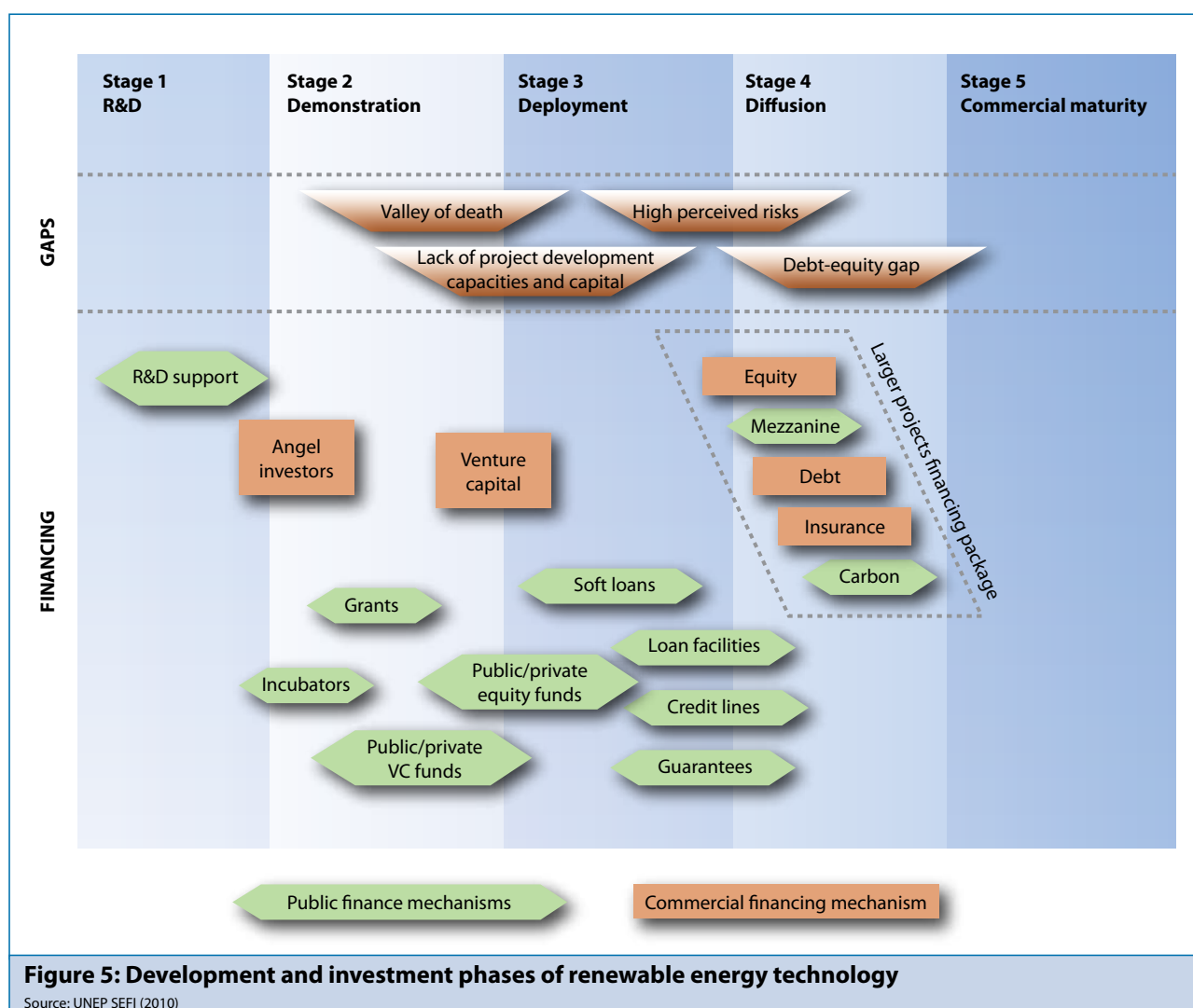
If the information that investors receive is shallow and short-term then their investment decisions can show similar characteristics, which is why the finance and investment community is demanding more data on ESG issues such as carbon emissions from the entities in which they invest. This type of sustainability/ESG reporting (hereafter “sustainability reporting”) has grown exponentially in recent years, for example, the GRI Financial Services Sector Supplement and Equator Principles. However, methodologies and international norms can still be improved. There are now significant moves towards more integrated reporting. To that end, in July 2010 the International Integrated Reporting Committee (IIRC) was formed to try and create a globally accepted framework for accounting for sustainability – a framework that brings together financial and ESG information in a clear, concise, consistent and comparable format. This issue is also being discussed by global stock exchanges.

However, the link between improved accounting and reporting and actual business practices is somewhat weak. Some 1,100 financial institutions (UNEP FI and PRI) now support United Nations-backed principles and statements that advocate firm steps towards a sustainable financial system and a responsible approach to investment, but progress in putting these statements into practice can be inconsistent and, in many cases,



embryonic. As stated earlier in this chapter, over 900 investment organisations managing more than US\$ 25 trillion of assets have now signed the PRI. The results of the PRI's annual assessment survey shows that US\$ 6.7

trillion of the PRI signatories actively managed assets, accounting impressively for some 51 per cent of such assets managed by PRI supporters, were subject to ESG integration in 2009. However, this represents only



around 7 per cent of the overall market of institutionally managed assets (PRI 2010).

Although progress remains slow, there is also evidence in the PRI's Annual Assessment Survey of how the asset owners that lead this initiative are catalysing change throughout the investment chain. For example, 87 per cent of the investment managers that participated in the survey now have an overall investment policy that addresses ESG issues, and 66 per cent of asset owner signatories now put specific ESG considerations into their contracts with managers and investment advisors.

The banking sector has also shown positive signs of reform. In the late spring of 2010, the sector was warned that post crisis, "private players will be held accountable to new and stricter standards of economic integrity and prudent management" (Trichet 2010). An international body, the Basel Committee on Banking Supervision (BCBS), part of the Bank for International Settlements (BIS)<sup>5</sup>, plays a key role internationally to define the rules

5. The Bank for International Settlements was established 17 May 1930, and is the world's oldest international financial organization. The BIS fosters international monetary and financial cooperation and serves as a bank for central banks. <http://www.bis.org/about/index.htm>

governing how banks handle risk to bolster the stability and resilience of the financial system, while ensuring sufficient lending to foster economic growth. The executive summary of the BCBS's consultative document – Basel III – on major banking reforms states, "A strong and resilient banking system is the foundation for sustainable economic growth, as banks are at the centre of the credit intermediation process between savers and investors" (BCBS 2009).

Moreover, banks provide critical services to consumers, small and medium-sized enterprises, large corporate firms and governments who rely on them to conduct their daily business, both at a domestic and international level. Considering a broader range of environmental and social risks into banking processes and disciplines such as those governed by the BCBS would have profound implications for the banking sector and would catalyse the transition to a green economy.

### 4.4 Expanding green insurance

The insurance industry is uniquely placed in our economies as a private market mechanism for the

### Box 7: Banking risks around climate change

As carbon liabilities become internalised within accounting and financial systems, banks will be affected increasingly both directly through impacts on the value of their own capital and indirectly through changes to the value and risk profiles of the loan portfolios of institutions and the collateral held against those loans. Climate change creates concerns at the macro prudential level in terms of its long-term systemic risks that jeopardise whole regions, economies and industries.

Climate change also creates concerns at the micro prudential level in terms of risks embedded in the financing and investment undertaken by banks. The policy, legislative and regulatory changes underway in many countries to more fully account for a broader range of ESG risks will also strengthen the fiduciary duty (UNEP FI AMWG 2009) and fiduciary legal (UNEP FI & Freshfields Bruckhaus Deringer 2005) arguments that call for a full and proactive effort to integrate financially material risks in all aspects of investment policy making and investment decision making.

These changes have implications for banks, as well as the many other forms of financial intermediaries that exist along the investment chain. In previous guidance, the BCBS has sought to "promote a more forward-looking

approach to capital supervision, one that encourages banks to identify the risks they may face, today and in the future, and to develop or improve their ability to manage those risks" (UNEP FI AMWG 2009). It is in this forward looking perspective where full consideration by the BCBS of financially material ESG issues are required, such as the risks posed by climate change, resource scarcity and the destruction of ecosystems, as well as governance issues related to micro and macro prudential regulation. Aligning Basel regulations and standards with ESG issues carries the promise of a stable, resilient and robust financial system that can deliver capital for green projects and initiative.

Including a full range of ESG considerations in the capital, adequacy requirements of banks will be a significant step to align the worldwide banking system with the needs of a future green economy. Post crisis, and following criticisms that the Basel II framework was ineffective, the BCBS, under a G20 mandate from the Financial Stability Board (FSB) is in the vanguard of efforts to reassess the resilience of the banking system. To this end, a review of many of the key supervisory requirements was initiated in 2009. The opportunity to reinforce the importance of ESG issues into ongoing Basel Committee considerations remains current as the standards-setting pursues well into the next two years.

sharing of risk, with the global pooling of what would be risks otherwise borne solely by individuals and entities estimated at roughly US\$ 400 trillion (UNEP FI IWG 2009). As this risk pooling is integral to the efficient functioning of markets, economies and societies, the insurance industry is a key focus of regulators and policy makers. The risk pooling afforded is only possible with investors' willingness to put capital at risk; hence, value creation is necessary for its continued existence. The convergence of public and private interests in the insurance industry is nowhere more apparent than in the risks and opportunities presented by ESG issues.

The insurance – including reinsurance – community, with its expertise in assessing, pricing and managing risk and freeing the flow of risk capital, can play a critical role to support the emergence of a green economy agenda across business, industry and the markets. It is important to understand that insurance is not only a risk transfer mechanism to compensate financial losses, but also a risk management mechanism because insurers carry out loss prevention and loss mitigation measures in conducting their business. The insurance industry, therefore, has an unparalleled capacity to understand and engineer approaches and mechanisms to manage emerging ESG risks.

As such, the industry is a strong lever for the transition to a green economy due to its size, the extent of its reach into the community and the significant role it plays in the economy, not only in the risk management and risk transfer spheres, but also as an investor through the vast pool of insurance company reserves. In 2008, worldwide premium volume for life and non-life insurance business combined exceeded (Swiss Re 2009) US\$ 4.2 trillion, making insurance the largest industry in the global economy. The industry's global AUM in 2010 stood at US\$ 24.6 trillion (TheCityUK 2011). Table 6 highlights the premium make-up of the global insurance industry in 2008, and also gives an indication of the insurance gap between developed and developing regions.

The insurance industry has long been in the vanguard of understanding and managing risk, and has served as an important early warning system for society by amplifying risk signals. For example, the insurance and reinsurance community were amongst the first financial service organisations to engage in and explain the long-term economic risks posed by climate change (UNEP FI 1995). In addition to the threats posed by global warming, insurers today are communicating strong risk signals stemming from a wide range of ESG issues such as biodiversity loss and ecosystem degradation, water scarcity, poverty, emerging manmade health risks, ageing populations, child labour and corruption (UNEP FI IWG 2007). Because certain risks are too large to be borne by an individual insurer, these risks are spread

across the industry in a complex risk-sharing system comprising many players, with the underlying principle of "one for all, all for one" that has supported social and economic development throughout human history. Insurers, reinsurers and retrocessionaires, are all risk carriers, as they put capital at risk and ultimately pay claims. Insurance agents and insurance brokers provide services to insureds and insurers. Similarly, reinsurance brokers and reinsurance underwriting agents provide services to insurers, reinsurers and retrocessionaires. The common denominator for agents and brokers in the system is that they are all intermediaries who act as channels in spreading risks. There are other service providers, such as catastrophe model vendors, loss adjusters, and rating agencies, but they are not directly involved in the risk-sharing process.

Over the last two decades, the insurance industry has also witnessed the emergence of insurance-linked securities, such as catastrophe bonds, where risk carriers have transferred peak risks in their portfolios to the capital markets by securitising, for example, their accumulated risk exposure in a specific territory due to natural hazards. Through loss prevention and mitigation, carrying risks, and as major investors, the insurance industry has protected society, catalysed finance and investments, shaped markets and underpinned economic development. However, the importance of the insurance industry as a driver of a green economy is poorly understood by policy makers, the broader business community and the wider public.

Uniquely positioned to understand the fundamental nature of emerging risks to communities, the global economy, whole industry sectors and its own investments, the insurance industry is now starting to explore the commercial viability of conceiving, developing and rolling out new products and services that address global sustainability issues (UNEP FI IWG 2007). The insurance industry is also beginning to realise the potential of microinsurance – insurance for low-income people – as both a prime business opportunity and a powerful tool for financial inclusion and sustainable development. Potential new markets include insurance for emerging manmade health risks and the protection of natural resources, in particular, biodiversity and ecosystems (e.g. forests) and water. The insurance industry is also awakening to the fact that acting sustainably, as in the cases of internal resource efficiency and the recycling of damaged assets, saves money and is a concrete way of leading by example (see examples in Box 8).

Clearly, insurance companies are unique entities. Their insurance and investment operations are highly intricate systems, with many players and functions, creating an industry that is not readily or fully understood by many



Region	Premium volume (US\$ million)	Real growth	Share of world market (%)	Premiums as per cent of GDP (penetration)	Premiums per capita (US\$) (density)
America	1,450,749	-2.4	33.98	7.29	1,552.7
North America	1,345,816	-3.1	31.52	8.54	3,988.8
Latin America and Caribbean	104,933	8.4	2.46	2.53	175.8
Europe	1,753,200	-6.2	41.06	7.46	2,043.9
Western Europe	1,656,281	-6.9	38.79	8.33	3,209.2
Central and Eastern Europe	96,919	9.0	2.27	2.79	299.2
Asia	933,358	6.6	21.86	5.95	234.3
Japan and newly industrialised Asian economies	675,109	3.8	15.81	10.41	3,173.2
South and East Asia	229,036	16.3	5.36	3.20	65.5
Middle East and Central Asia	29,213	4.7	0.68	1.45	110.3
Oceania	77,716	8.6	1.82	7.02	2,271.9
Africa	54,713	4.9	1.28	3.57	55.6
World	4,269,737	-2.0	100.00	7.07	633.9
Industrialised countries	3,756,939	-3.4	87.99	8.81	3,655.4
Emerging markets	512,799	11.1	12.01	2.72	89.4
OECD	3,696,073	-3.2	86.56	8.32	3,015.2
G7	2,925,946	-4.4	68.53	8.96	3,930.2
EU, 27 countries	1,616,461	-6.7	37.86	8.28	3,061.3
NAFTA	1,364,839	-3.0	31.97	8.10	3,065.7
ASEAN	45,493	0.4	1.07	2.99	85.1

**Table 6: World Insurance in 2008**

Source: Swiss Re (2009)

## Box 8: Insuring against the worst for the best

Drought is a major risk in Ethiopia where 85 per cent of the population is dependent on smallholder, rain-fed agriculture. Less than 0.5 per cent have insurance. Climate change is threatening agricultural output as rainfall becomes less predictable, and many run the risk of falling into debt or having to sell assets. The use of index-based weather insurance can significantly improve lives.

Through the Horn of Africa Risk Transfer for Adaptation project, Swiss Re has been working with Oxfam America and Columbia University to protect the rural poor against drought risk. The project engages farmers in community-led, locally-designed climate adaptation initiatives such as reforestation and crop irrigation projects, where they earn premiums by making and using compost, constructing water-harvesting structures, planting nitrogen-rich trees and vetiver grasses. This unique risk management approach has allowed rural households, many led by women, to benefit from

insurance. Since its launch in 2008, uptake has increased from 200 households in the first year to 1,300 in 2010. The project now covers five villages, two climatic zones, and four crop varieties.

HSBC Insurance's Green Insurance products in Brazil are linked to investment to preserve forests. For motor insurance, HSBC commits to preserving 88 m<sup>2</sup> of forest for five years; and for home insurance, 44 m<sup>2</sup> for the same period. The calculations are based on the environmental footprint of an automobile or residence during that period. HSBC has already invested nearly R\$ 8 million (US\$ 4.8 million) preserving 3,000 hectares of Atlantic Seaboard Rainforest, equivalent to roughly 4,800 soccer fields and about 1 per cent of remaining pristine Araucaria forest. The work is carried out with the NGO, Sociedade de Pesquisa em Vida Selvagem. Funds are disbursed to landowners, each receiving a monthly sum for areas to be preserved and a forestry management plan.

stakeholders. It is crucial for insurers to generate income from both sides of the house at all times – prudent and disciplined risk management, underwriting and investment management are key processes to sustain profitability and long-term value creation. ESG issues are relevant to both the insurance and investment sides as risks posed by ESG issues can undermine the solvency of an insurance company and the long-term economic health of the insurance industry and its partners, ranging from insureds – households, businesses, and governments – to the entities financed by insurance capital. Thus, it is imperative for insurers, regulators, and policy makers to collectively address ESG issues in the insurance industry.

The main reasons that adversely affect the insurability of risks can be classified as supply-side and demand-side barriers. The supply-side barriers include volatility in the occurrence of claims, particularly for weather-related insurance. This can be smoothed to some extent with reinsurance, but this raises the related barrier of inferior data quality. Poor data on climate change related hazards and exposures means that uncertainty is much greater and this makes the private insurance and reinsurance market less willing to participate in risk-

bearing. Geographical, economic and climate data tend to be poorer for developing countries and access to such information is often prohibitively costly.

There are also regulatory barriers. A balance needs to be found between regulatory control of the market to protect consumers and flexibility in managing insurance operations in response to a changing risk landscape. Overly rigid insurance regulations will deter private insurers or result in suboptimal insurance solutions. Also, it is important that public control of the risk management framework (land development, safety regime, etc.) is maintained. Equally important, regulators must set a reasonable standard of care for policyholders to avoid moral hazard, that is adopting very risky practices in the belief that regulators will restrict insurers' freedom to modify policy terms. A final difficulty is high administrative expenses, a major problem for policyholders with only few assets because conventional insurance products have relatively high overheads. Simplified products can help solve this.

Some demand-side barriers can be overcome by the private sector through time; others may need public sector intervention. The most significant is probably low

## Box 9: Mobilising private investment into sustainable energy in India

India has the fifth largest installed renewable capacity in the world. In 2009, private investments of renewables in India amounted to US\$ 2.3 billion ranking India in the top ten G20 members, while VC/private equity financing stood at US\$ 100 million (Pew Charitable Trust and Clean Energy Economy 2010). This has been driven by a suite of policy measures at state and federal level that have included:

- Clear short and medium-term targets have been identified for renewable energy and energy efficiency amounting to 14 GW of new renewable energy capacity by 2012, and an ambitious plan to install 20 GW of solar energy by 2022 (Pew Charitable Trust and Clean Energy Economy 2010), financed through a national system of gradually increasing renewable purchase obligations (RPO) for power utilities combined with gradually decreasing feed-in tariffs;

- Feed-in tariffs and tax allowances for solar photovoltaic (PV) and solar thermal power, supplemented with support for PV manufacturing in special economic zones (CERC website) have been implemented. These policies led to US\$ 18 billion in new solar PV manufacturing investment plans or proposals by private companies;

- A renewable portfolio standard for utilities has been set up, starting at 5 per cent in 2010, rising to 15 per cent in 2020. One state has already enforced penalties on utilities not complying with the standard;

- Nationwide energy conservation codes are in place for residential buildings, hotels, and hospitals with centralised hot water systems, requiring at least 20 per cent of water heating capacity from solar;

- The National Mission on Energy Efficiency (NMEF) will initiate trading in energy certificates for several industrial sectors. NMEF will have two funds one to provide guarantees to banks providing loans to energy efficiency projects and the other to support investments in the manufacturing of energy efficient products and provision on energy efficiency services. The trading scheme will potentially generate transactions close to US\$ 15 billion by 2015; and

- A coal tax of US\$ 1 per tonne was put in place in 2010 to feed the National Clean Energy Fund. India depends on coal for 66 per cent of its energy needs and this tax would generate annual revenue of US\$ 600 million.

## Box 10: Microfinance, environmental and social risk management and sustainable opportunities

The Netherlands Development Finance Company (FMO) is one of the largest bilateral private sector development banks worldwide and has helped to finance and manage sustainable microfinance projects in countries such as Kenya, Nepal, Mongolia, Cambodia, and Bolivia.

For example, in Nepal, FMO has financed the Clean Energy Development Bank Ltd. (CEDB). CEDB is a Nepalese development bank that provides access to finance for small and medium-sized entrepreneurs in agriculture, industry, trade and other productive business. CEDB's key focus is to invest in clean energy through its innovative renewable energy products, including mini and medium-sized hydropower projects, as well as solar and biogas projects that provide rural communities with the sustainable electricity/energy that is so crucial for private sector development. CEDB also provides microfinance loans to individuals in rural areas through MFIs and its own branch networks.

Similarly, FMO has invested in K-Rep Bank, a Kenyan microfinance institution (MFI) involved in financing implementation of a broad range of programmes with environmental and social themes such as:

- Small piped community water and sanitation projects;
- Household rain harvesting/water storage tanks;
- Integrated solid waste management in urban informal settlements;

- Small hydro-power/community water supply;
  - Eco sanitation – pay-per-visit toilets in peri-urban areas;
  - Installation of solar lighting system for schools in the rural areas;
  - Wind powered systems for water pumping;
  - Household biogas; and
  - Use of composted manure in kitchen gardening.
- FMO provides an innovative MFI Sustainability

Guidance toolkit for all MFIs that wish to reduce environmental and social risks. FMO has also developed and introduced the mechanism of a sustainability pricing incentive, usually an interest reduction, as part of a loan agreement. As an example, FMO has agreed upon a pricing incentive with the El Salvadorian Federation of Credit Associations and Workers' Banks (Fedecredito). The trigger to award the interest reduction is the timely development and implementation of a portfolio-wide environmental and social risk management system across Fedecredito banks.

The implementation of practical environmental and social risk management measures within micro and SME finance and the success stories of specific MFI/SME sustainability financing demonstrate that MFIS and SME banks may substantively contribute to a green economy.

risk awareness, particularly in the case of low frequency, high severity events. In the case of catastrophe insurance, the introduction of compulsory catastrophe insurance by governments may be an important element in overcoming this problem. It is often stated that premiums are unaffordable. This may be a signal from the private insurance market that the risk is very high and unsustainable, there is great uncertainty, the scale of operations is too small, or more risk management by at-risk parties is needed.

The insurance industry has an unparalleled capacity to understand and engineer approaches and mechanisms to manage ESG risks as they emerge, and has served as an important early warning system for society by

amplifying risk signals. Steps towards improving risk knowledge, including perhaps better use of technology to measure risk accurately, and more consumer education to drive demand for sustainable insurance products, can help the insurance industry overcome the barriers and become a leader in mobilising financial flows to the green economy (PSI forthcoming).<sup>6</sup>

6. Principles for Sustainable Insurance Initiative (PSI) is a group of leading global insurance companies that are members of United Nations Environment Programme Finance Initiative are currently spearheading the Principles for Sustainable Insurance Initiative, which will establish a global best practice sustainability framework for the insurance business, and a global initiative of insurers tackling sustainability risks and opportunities. These principles will be launched at the 2012 UN Conference on Sustainable Development (Rio+20 Earth Summit).

## 4.5 Creating public-private mechanisms

The lack of adequate public financing is also an important barrier to increasing the flow of green investment. Public financing is justified by the positive externalities expected from a green economy and it can be important for leveraging private investment. For example, it has been established that US\$ 1 of public investment spent through a well-designed public finance mechanism (PFM) can leverage between US\$ 3 to US\$ 15 of private sector money (UNEP & Partners 2009). However, simply having one or several disparate policies in place is not enough to catalyse a fresh supply of capital at scale. The example from India (see Box 9) shows that an array of well-orchestrated policy instruments, mechanisms and responsive institutions are needed to catalyse finance along the innovation continuum.

In 2009, UNEP and its partners explored which types of PFMs could be effective in mobilising funds from the institutional investors into low carbon infrastructure, particularly in developing countries (UNEP & Partners 2009). Five key barriers were identified, together with remedial PFMs. A case was made that investment-grade policies to mobilize the private financial sector for the energy revolution needed to be ambitious (Chatham House 2009) and should:

- Adopt legally enforceable targets and schedules for the adoption of renewable energy on a rolling 15 year programme and within a framework for the stabilisation of global GHG emission concentrations;
- Refocus energy policy: adopt full-pricing for non-renewables in a progressive schedule; provide a tapered support programme for renewables, gradually eliminating subsidies; and simplify and clarify the regime for renewable energy projects and carbon finance;
- Align other policies, particularly transport, development, education with climate change policy;
- Keep key financial institution decision makers well-informed about climate change and renewable energy technologies; and

- Ensure that multilateral and national public sector financial institutions support the transfer of renewable technologies adequately (UNEP FI 2004).

## 4.6 Scaling up microfinance for a green economy

Opportunities for sustainable lending are also prevalent at the microlevel. In addition to its well-known success in helping to provide sustainable livelihoods and reduce poverty, microfinance has recently been extended to such areas as drinking water and sanitation and small-scale decentralised energy systems (see Box 10). Growing in maturity and tested by global economic crisis, the microfinance industry in recent years has seen higher intensity of credit and liquidity risks, along with greater competition, volatility and systems integrity issues as more financial intermediaries are involved. This underlines the need to move from crisis management to more systemic and comprehensive risk management systems as the industry matures. The experience also shows the importance of developing meaningful partnerships and alliances with organisations involved in the relevant industry, for example the agrifood, value chain (ADB 2008).

Microinsurance products provide the potential to help households, SMEs and other “micro agents” at local level to adapt to challenges such as climate change. For example, the first microlevel rainfall insurance in the world was launched in India in 2003, through close collaboration among BASIX, an Indian MFI (microfinance institution), the World Bank, and private insurers and reinsurers. The pilot scheme has been viewed as an impressive success because all the stakeholders gain: government by reduced relief payments and social problems, and easier budgeting; the insurer by fulfilling its social insurance quota; the MFI complements its client services and reduces the default rate on its loans; the poor farmers receive reliable protection for their income and assets; and overseas development agencies avoid disruption from emergency relief calls, and can claim speedier assistance for clients.

## 5 Greening global finance and investment: enabling conditions

### 5.1 Setting policy and regulatory frameworks

Regulatory frameworks across capital markets are critical to channel financial resources at scale towards a green economy. The gaps between high policy, national laws and a financial and capital market system that fully internalises green economic thinking, although narrowing, remain significant. The legislative, regulatory and quasi regulatory systems, including the supervisory bodies and credit rating agencies that govern financial services, are at best a work in progress and are at worst poorly designed and not fit-for-purpose for a green economy. These systems are important because they transmit green policy goals along the investment chain and into the processes of financial intermediation, and through them into the real economy. It is also important to note that there is a compressed timetable in which to create a policy framework to address these gaps. Climate change and resource scarcities are already starting to adversely impact social and economic development as well as environmental integrity. Annual economic losses associated with climate change and natural disasters topped US\$ 150 billion a year in 2005 (Munich RE 2009) and a credible scenario (UNEP FI CCWG 2007) has suggested that with BAU, a US\$ 1 trillion loss in a given year by 2040 is possible.

However, it is important to note that the formal linkages of financial and sustainability-focused policy making at the highest level are still relatively new. The first formal gathering of Finance Ministries to discuss climate change only took place in December 2007 in a meeting parallel to the United Nations climate summit in Bali, Indonesia, when Ministers or high-level financial policy makers from 38 countries gathered for two days. The convening in 2010 by UN Secretary General Ban Ki-moon of a High-Level Panel to explore the financing response to climate change is a much-welcomed development.

This section briefly sets out to describe some of the proposed standards and policy initiatives to help integrate non-traditional “creeping risks” such as climate change and resource scarcity into financial policy making. These include frameworks for enhanced environmental and social disclosure within the investment sector and codes for green lending and environmental liability.

It is clear that sound public policies and enabling regulatory frameworks are indispensable for freeing up the flow of private finance towards a green economy. The risk/reward equation still works unfavourably for would-be green investors. Governments should involve the private sector in establishing stable and coherent policy and regulatory frameworks that require the integration of environmental, social, and governance issues in financial policy making. In addition, governments and multilateral financial institutions should use their own resources to leverage the financial flow from the private sector towards the fledgling green economic opportunities.

### 5.2 Enhanced environmental and social disclosure

Investors demand full ESG disclosure from companies so that risks can be monitored. The same approach can be applied to the finance and investment practitioners. For example, this year 40 per cent of signatories to the PRI disclosed in full their annual assessment of how they are implementing responsible investment. The ground prepared by this voluntary initiative is now being closely examined by financial markets and regulators worldwide. The UK has introduced the Stewardship Code – a “comply or explain” code for institutional investors to report on their stewardship activities.

Guidance by the GRI and others on sustainability and integrated reporting provides an opportunity for both private and public financial institutions to disclose their management approach to a green economy agenda and report progress in applying ESG criteria. Combined with targeted stakeholder engagement, this can improve management’s ability to effectively consider the direct and indirect impacts and footprint of the services they provide. This requires building capacity in the use of recognised indicators and metrics for proper assessment, comparison and finance benchmarking. Public and private banks could be encouraged to measure the net contribution of their activities to climate change, biodiversity loss and the green economy at large. Policies can be designed to improve their green efficiency, for example by examining and reporting the carbon and ecological footprint of their investment portfolios.



Related standards that can be linked with requirements for disclosure on progress include governance codes for stock exchanges, green lending and investing standards, green standards for SWFs, environmental liability standards, and mandatory endorsement of voluntary finance and investment codes. When such standards and progressive policy are combined the effects can be impressive, as is the case in the rapid progress of the green finance sector in China (see Box 11).

### 5.3 Supporting institutions and facilities

Policy frameworks also need to support institutions and facilities that can finance the transition to a Green Economy. Key areas of focus include market-based instruments (i.e. emissions trading schemes, payment for ecosystem services schemes, etc.), green bond

markets, listing rules and corporate ESG performance, the role of DFIs, greening sovereign wealth funds, and fiscal policies.

**Market-based instruments: Emissions trading schemes** Emissions trading schemes are still new to financial markets and early pilots such as the EU Emission Trading System (EU ETS) have proved useful, but need improvements if they are to be more effective. Domestic and international policies in both developed and developing countries need to ensure strong and sustained price signals on carbon emissions and create well-designed carbon markets that avoid an over-abundance of permits or a lack of enforcement capacity.

Expanding and deepening the international carbon market will need to include greater clarity on the future interplay of the CDM, Joint Implementation projects, and emerging credit mechanisms such as Nationally

#### Box 11: Greening the finance sector in China

Chinese policy makers have in recent years introduced green credit guidance for the country's banking sector and environmental liability guidance for the insurance industry. China's leading banks are working to operationalise revised credit assessment systems across their main business lines. Also, the country's city-based commercial banks, rural banks and cooperatives are involved in greening the country's credit system. Similarly, 20 of the country's insurers are actively exploring new environmental liability insurance products and services, while a series of pilot environmental insurance initiatives have been carried out with a number of provincial and municipal authorities around the country.

The China Banking Regulatory Commission (CBRC) is tasked with regulating and supervising banks and non-bank financial institutions. In 2007, CBRC introduced Energy Conservation and Emission Reduction regulations requiring financial institutions to establish an organisational framework and internal procedures to advance green criteria. Among other things, the CBRC's regulations require a senior banker in each regulated institution to be responsible and accountable for green credit as well as to boost lending to the renewable energy and green sectors.

The CBRC sees two roles for the institutions it regulates. First, through lending to facilitate new energy sectors such as wind and solar. Second, by imposing restrictions on clients that are non-

compliant with environmental laws and regulations and by withdrawing existing lending in extreme cases. Banks are required to submit a report to CBRC annually to outline their advances in the area of green credit and in turn the regulator reports developments to the State Council. The CBRC encourages its regulated institutions to apply international protocols that support sustainability in financial services.

The role of international financial institutions in supporting the greening of the Chinese financial sector is important. For example, the Industrial Bank of China, Pudong Development Bank, and Beijing Commercial Bank have worked closely with the IFC to advance energy efficiency projects. The IFC provides guarantees and assists the banks in preparing for CDM projects. The Industrial Bank of China estimates that over two years the reduced CO<sub>2</sub> emissions from its energy efficiency projects is equivalent to the total emissions of the Beijing taxi fleet.

On the banking side, ICBC, the largest bank in the world by market capitalisation, has created a Green Credit Policies Department in an effort to become the leading green bank in China. In addition, the bank is active in disaster relief and rural education. On green credit, ICBC classifies clients into nine categories and has a colour coding system – black, green, red, and grey – to assess eligibility for credits.

Appropriate Mitigation Actions (NAMAs) and REDD+ (Box 2).

Also, the different regional schemes must ensure consistency and comparability on how emissions and offsets are measured, verified and reported, and must avoid the growth of an opaque carbon derivatives market that might have harmful systemic consequences. Under Phases I and II of the EU ETS, emissions allowances were distributed free, partly to avoid carbon leakage from industrial production relocating offshore. However, this led to windfall profits for some firms, and has been subject to gaming by heavy industry to ensure that the emissions caps were not too challenging. The consequence has been a rather low carbon price and a muted effect on emission levels themselves compared to what is deemed to be required.

However, the European system is evolving. In 2010, the European Commission worked to adopt decisions governing critical aspects of Phase III of the EU ETS for the period 2013 to 2020. These include the introduction and operation of an auctioning system for emission permits in mainstream sectors, as well as the amount and distribution of free allowances to sectors exposed to carbon leakage, i.e. competition from countries without emissions limits. There is also the prospect of revising the European emission reduction objective upwards from -20 per cent to -30 per cent by 2020, in line with the EU's objective of avoiding dangerous climate change, which is considered to be a temperature increase of 2°C (CDC Climate Research 2010).

### Green bond markets

As discussed earlier in this chapter, the green bond market is growing rapidly. An increasing number of multilateral development banks are issuing these products, which are also being issued at the municipal level. There is also collaboration with the corporate sector. For example, in April 2010 the European Investment Bank (rated Moody's: Aaa/S&P: AAA) and Daiwa Securities Group announced a € 300 million issuance of Climate Awareness Bonds to finance the bank's future lending projects in the fields of renewable energy and energy efficiency.

Clearly, policy frameworks need to be flexible enough to support the differing ideas emerging and the scale required. If green bonds are to reach the scale required to finance a transition to a green economy, then they run the risk of endangering the AAA ratings of the multilateral development banks that issue them. These institutions can only raise so much additional debt before it could affect their credit rating, which is preciously guarded by their treasury departments. This is also true of developed countries, especially in light of recent very high deficits and consequent heavy borrowings during the financial crisis.

Bond issues in the hundreds of millions and even low billions are within a scale that should not present fundamental problems. However, consideration of the tens or hundreds of billions of bond issues needed in the green scale-up are a different matter. This issue needs to be addressed by policy makers and regulators. To some extent, it will be mitigated by improvements in the global economy and as governments and financial institutions worldwide repair their balance sheets.

Local institutions may also need human capital support in moving to the needed scale. Given the risk taken on by bond issuers and the need to get low-cost capital flowing, the question is who is best placed to make quick and good decisions to put capital to work in green investments that earn adequate returns. To help close the "green gap", much lower cost-of-capital debt ultimately needs to be available to the sponsors and developers of green projects. This likely means it needs to be channelled through local financial institutions in the developing countries where these projects exist. This needs to occur efficiently and with as little as possible lost in carrying costs charged by these intermediaries. Some argue for asset-backed and rated bonds to be issued directly by major project developers. This alternative may develop over time.

### Listing rules and corporate ESG performance

As the central marketplaces between buyers and sellers of equity securities and other assets, exchanges can – and often do – play a key role in promoting enhanced corporate ESG disclosure and performance (World Federation of Exchanges 2009).

Globally, exchanges provide approximately 50 different sustainability indices, ranging from the generalist FTSE4Good Index to the specialised Deutsche Börse's DAXglobal® Alternative Energy index. Exchanges such as BM&FBovespa in Brazil, the Johannesburg Stock Exchange, and Bursa Malaysia also help to drive the availability of ESG information through corporate awareness raising, and integrated corporate governance guidelines. In several markets, such as South Africa, Malaysia and China, exchanges have worked with regulators to incorporate ESG disclosure requirements into listing rules and company law.

Exchanges that have taken such initiatives have so far had mixed results in terms of positive reinforcement from investors. In addition, companies often highlight the fact that mainstream investment analysts need to pay closer attention to ESG issues (UNEP FI and WBCSD 2010). Nevertheless, at a global level the quantity and quality of ESG disclosure by listed companies is highly variable and has significant gaps. There is growing pressure from some investors under the framework of the PRI to strengthen regulation on ESG disclosure. One

outcome of this, for example, is that in January 2010, the US SEC issued interpretive guidance on existing SEC disclosure requirements as they apply to business or legal developments relating to the issue of climate change. The following areas are examples of where climate change may trigger disclosure requirements::

■ **Impact of legislation and regulation (US SEC 2010):** When assessing potential disclosure obligations, a company should consider whether the impact of certain existing laws and regulations regarding climate change is material. In certain circumstances, a company should also evaluate the potential impact of pending legislation and regulation related to this topic;

■ **Impact of international accords:** A company should consider and disclose, when material, the risks or effects on its business of international accords and treaties relating to climate change;

■ **Indirect consequences of regulation or business trends:** Legal, technological, political, and scientific developments regarding climate change may create new opportunities or risks for companies. For instance, a company may face decreased demand for goods that produce significant GHG emissions or increased demand for goods that result in lower emissions than competing products. As such, a company should consider, for disclosure purposes, the actual or potential indirect consequences it may face due to climate change related regulatory or business trends; and

■ **Physical impacts of climate change:** Companies should also evaluate for disclosure purposes the actual and potential material impacts of environmental matters on their business.

#### **Development finance institutions**

Providing long-term public funding at home and abroad, Development Finance Institutions (DFIs) can play a significant role in supporting key elements of the emerging green economy. Issues such as climate change, energy security, and food security were a key consideration in the decision of shareholder governments to provide significant capital increases to the key multilateral development banks in 2010. DFI's include:

■ Multilateral DFIs such as the World Bank, the IFC, the Inter-American Development Bank, the ADB, the African Development Bank, the EBRD, and the EIB, which in 2009 were reported to have committed US\$ 168 billion (World Bank 2010b);

■ Bilateral DFIs, such as KfW group, which is German government-owned, with two subsidiaries focused on international development finance; AFD, a French

government-owned bank focused on developing and emerging countries and the French Overseas Communities; FMO, an entrepreneurial development bank founded by the Dutch government, targeting the private sector in developing countries; CDC, a UK government-owned institution, providing investment capital for business in particularly Sub-Saharan Africa and South Asia; and the Japan Bank for International Cooperation/ Japan International Cooperation Agency; and

■ National DFIs such as the Development Bank of Southern Africa, a South African government-owned bank focused on infrastructure development in South Africa and its sub-region; the Brazilian Development Bank, which is government-owned and finances development in Brazil and expansion of national companies abroad; the Caisse des Dépôts group, a public investor supporting the economic development of France; and the Overseas Private Investment Corporation, which is US government-owned and supports US business at home and abroad.

Some of these institutions belong to more than one category. For example, the KfW is both a major domestic financial institution and a strong international development bank. Within this group of banks, many provide loans, both concessional and non-concessional, to governments only. But a growing number fund sub-regional entities, state-owned corporations, and private sector businesses.

These Foreign Direct Investments (FDI) play a critical role in funding macroeconomic policies, sectoral policies, major infrastructure projects, and private sector development. Their contribution to greening national economies is already significant. They fund major sectors such as water, renewable energy, forestry, and agriculture. DFIs have been instrumental in mainstreaming microfinance and supporting the development of private industries in risky green sectors at early stages of development. But their role could be strengthened further, taking advantage of the prominent position they occupy in the funding of domestic investment programmes. Steps in this direction would include better identification of green economy aspects in their strategic targets, greater share of their activities devoted to these aspects, better measurement and reporting methodologies, improved cooperation among themselves, and sharing of best practices.

Governments are in a position to officially task these institutions to support green economy development, backed by concrete goals and targets. Carbon emissions reduction, access to water and sanitation, biodiversity promotion, etc., could become official goals for DFIs, in addition to poverty alleviation (UNDP 2007/2008) and infrastructure financing.

Development banks also have a major indirect or direct influence through the conditionalities they tie their funding to and through the due diligence they practice, for instance when they fund private corporations. They also provide technical assistance to public and private institutions. The three categories of institutions can collaborate in defining standard protocols for green due diligence, and work on standards and goals for sectors in which they have a major influence, such as municipal finance, transport, and energy. Domestic and some international DFIs play a major role in municipal finance and housing. These are two critical areas for the green economy: developing green practices for local municipalities and greening the housing sector, especially social housing.

The shareholders of the private sector dedicated DFIs, or the private sector arms of development banks, could consider promoting even further their traditional role in incubating and developing nascent green markets. Given the shortage of equity, a barrier even higher for green activities than access to credit, this could include additional support for cleantech private equity and green VC funds in developing countries. They could also play a greater role in further influencing the private banking sector, providing dedicated credit lines to green market activities at low interest rates and incentives for public and commercial banks to move their services towards green economy goals.

At the international level, some – such as the World Bank – focus solely on sovereign finance, which is

## Box 12: Caisse des Dépôts and its long-term investment model

The group Caisse des Dépôts, a French public financial institution, is defined by law as a long-term investor serving the public interest and economic development. It has integrated ESG criteria upstream in its investment decision making process, as well as in its shareholder's activities through a constant dialogue with the companies listed on the stock exchange market in which it holds shares. The Caisse des Dépôts model is now widely recognised. A first global forum gathering the main public financial institutions comparable to Caisse des Dépôts was held in Morocco in early 2011 to examine the potential of this model to be replicated and address long-term economic needs.

What characterises long-term investors such as Caisse des Dépôts is their robust capital base, which enables them to absorb short-term financial fluctuations. As such, they are in a position to address green economy financing challenges from R&D to production. They can foster innovation by financing platforms that gather research centers and private companies in order to value technological breakthroughs in the fields of eco-innovation and renewable energies. Long-term investors also have the capacity to finance projects yielding revenues only as of five to ten years. Caisse des Dépôts has created such a platform and since 2008 is implementing a € 150 million investment plan in several fields, such as photovoltaic solar energy, biomass, windmills, and water power, to contribute to France's efforts to cut its GHG emissions by 20 per cent.

The bank has also joined forces with other long-term investors in the framework of the Long-Term

Investment Club and created with its partners – Cassa Depositi e Prestiti, KfW Bankengruppe, and the EIB – two investment funds in the infrastructure sector. One of them, the 2020 Marguerite fund for energy, climate change and infrastructures, is dedicated to the EU-27 zone and committed to invest in renewable energies for 35 to 45 per cent of the total size of the fund. The other, InfraMed, is focused on the Union for the Mediterranean zone. The management of both follow a philosophy of long-term investments, which means:

- The investments are stable for 20 years and no core sponsor may transfer its shares during the lock-up period of 10 years;
- The investments are stable for 20 years and no core sponsor may transfer its shares during the lock-up period of 10 years;
- The incentives of the advisory team are based on long-term performance criteria and are fully consistent with the general principles of long-term performance endorsed by the G20; and
- In terms of governance, a good balance between the interests of the investors and the autonomy of the advisory team is sought. For the InfraMed fund, strict ESG criteria are applied on the basis of the EIB requirements.

The experience of European long-term investors could serve as a basis for building up a doctrine for responsible public investment in the green economy.



lending and other support to governments. Others, like the IFC and the EBRD, are wholly or mainly concerned with private sector development in emerging markets, and invest on commercial terms. DFIs deploy a range of instruments including debt financing, equity investment, guarantees, and trade finance programmes. Multilateral development banks also leverage grant funding from donor governments or entities such as the GEF and provide technical assistance and advisory services.

The DFI community also includes long-term investors, such as the French CDC, the Italian CdP, Germany's KfW, and the Moroccan CDG, characterised by a low reliance on short-term market liquidity thanks to stable resources, often comprised of regulated or guaranteed deposits, long-term savings products or long-term borrowing. These institutions typically have a robust capital base, stemming mainly from reserve accumulation, which enables them to absorb short-term fluctuations in financial markets. As such they can invest in – often illiquid – capital or debt instruments that yield a profitable return in the long run, such as those issued by companies operating in sectors such as general interest utilities, infrastructures or renewable energies (see Box 12).

The World Bank's operations range from the integration of climate change issues into sectoral strategies to the management of specialised investment funds and raising capital for project finance through green bonds. In the private sector arena, the IFC provides a suite of finance and advisory services ranging from energy efficiency financing facilities for intermediation by local

banks, to support for low carbon investment indices and the issuance of green bonds. As a global fund dedicated to the environment, the GEF (see Box 13) provides funding to cover the incremental or additional costs associated with transforming a project with national benefits into one with global environmental benefits. Its Earth Fund targets private sector engagement through public private partnerships. Up to 2009, the GEF has invested US\$ 2.7 billion to support climate change mitigation projects in developing countries and economies in transition, and leveraged another US\$ 17.2 billion in project co-financing. With its longer term focus, it can provide critical support in scaling up green economy projects in areas such as climate, water, land, forest and chemicals management.

The EBRD's Sustainable Energy Initiative (SEI) has an investment target of € 3 billion to € 5 billion from 2009 to 2011, with a corresponding carbon reduction target of 25 to 35 million tonnes of CO<sub>2</sub> equivalent per annum. Amongst other activities, EBRD has emerged as the dominant investor in renewable energy in its region of operations – Central and Eastern Europe, and Central Asia – concentrating primarily on wind power. Like the World Bank Group, the EBRD has also begun to increase its focus on climate change adaptation by developing new tools to integrate adaptation risk into project due diligence and structuring, as well as financing infrastructure projects such as flood defence schemes. IFC, EBRD and other DFIs are also collaborating on protocols for GHG assessment and several of them report publicly on the annual emission reductions and emission increases associated with new projects signed each year.

### Box 13: The Global Environment Facility (GEF)

The Global Environment Facility (GEF), the world's largest public environmental fund, provides grants to developing countries and countries with economies in transition for projects related to biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. The GEF serves as a financial mechanism for the UN conventions on Biological Diversity, Climate Change, Persistent Organic Pollutants and Desertification. The GEF partners with ten intergovernmental agencies, including UNEP, UNDP and the World Bank as implementing agencies. The latter has also served as the Trustee of the GEF Trust Fund since 1994. Established in 1991, the GEF is today the largest funder of projects to improve the global environment. The GEF has

allocated US\$ 9.2 billion, supplemented by more than US\$ 40 billion in co-financing, for more than 2,700 projects in more than 165 developing countries and countries with economies in transition. Through its Small Grants Programme (SGP), the GEF has also made more than

12,000 small grants directly to nongovernmental and community organisations, totalling US\$ 495 million. Grants can be awarded up to a US\$ 50,000 ceiling with an average grant typically about US\$ 25,000 per project. The small grants network which has been designed to empower local communities make investment choices that have the multiple benefit of generating green jobs at home while protecting the global environment.



Development finance institutions can play a key role in incubating and developing nascent markets. They have been instrumental over the last decade in supporting microfinance to the extent that it is now a relatively mature asset class. Current activities in frontier sectors include support for cleantech private equity and VC funds in developing countries, and an increasing emphasis on solutions for poor consumers.

### **Greening sovereign wealth funds (SWFs)**

The growth of state-owned investment funds willing to invest globally is relatively new, but already significant in its impact. While there are concerns about the growing influence of SWFs – such as their capacity for exploiting market inefficiencies and a lack of transparency – these funds can play a major role in financing the green economy transition.

Support should go towards helping SWFs to incorporate climate risk considerations directly and systematically into their actual stock selection and portfolio construction processes, as is the case with the example of the Norwegian Pension Fund Global (see Box 14). Suggestions such as the creation of mutual green funds

invested in by collaborating SWFs – such as Brazil's Amazon Fund launched in 2008 to solicit international donations to save the Amazon forest – are also worth considering.

Like pension funds, SWFs tend to have a long-term horizon. As a result, SWFs have a clear interest in improving the environmental performance of companies and other entities in which they invest, so as to enhance their long-term returns and better manage risk and reputation.

## **5.4 Fiscal policies**

Green Economy fiscal policy options fall into five broad categories. These cover environmental tax reforms and instruments such as carbon taxes, tax exemptions and reductions; broader and robust pollution charges; green subsidies, grants and subsidised loans to reward environmental performance; removing environmentally harmful subsidies; and direct public expenditure on infrastructure. They can serve, among other things, to address high upfront investment costs. This smart

### **Box 14: Norwegian Pension Fund Global**

The Norwegian Pension Fund Global, one of the largest SWFs in the world, has a broad ownership in approximately 8,400 companies worldwide. The fund is largely passively invested and holds an average ownership share of 1 per cent in each company it is invested in. The fund is a universal owner with a long investment horizon, and inherently has a clear financial interest in companies taking good corporate governance and environmental and social issues duly into account. Fiduciary responsibility for the fund also includes safeguarding widely shared ethical values. In the area of environmental issues, including climate change mitigation and adaptation, the fund employs the following tools:

#### **Research**

The Norwegian Ministry of Finance, acting as principal for the fund, currently participates in a climate change and strategic asset allocation research project between the investment consultancy Mercer and 13 other large international pension funds from Europe, North America, Asia, and Australia. A report from this project was published in February 2011.

#### **Environmental investment programme**

The Norwegian Finance Ministry has established a new investment programme for the fund that will

focus on environmental investment opportunities, such as climate-friendly energy, improving energy efficiency, CCS, water technology, and the management of waste and pollution. The investments will have a clear financial objective (Norwegian Ministry of Finance 2010). At the end of 2009, over NOK 7 billion had been invested under this programme, a faster escalation than originally assumed (Norwegian Ministry of Finance 2011).

#### **Dialogue with companies**

The pension fund's manager, Norges Bank through its asset management department Norges Bank Investment Management (NBIM), has set out its expectations on companies' climate change management. As a long-term investor, it is of vital importance that the fund is able to evaluate the degree to which a specific company is exposed to the risks and opportunities that arise from climate change, both in its direct operations and across its supply chain. NBIM considers companies' efficient adaptation to this transition to be a significant factor when protecting the financial assets of the fund, and expects companies to develop a well-defined climate change strategy.

combination can also be mutually reinforcing, for example, using taxes to reinforce the impact of other instruments such as standards and subsidies. In the field of building and construction (see the Buildings Chapter), tax credits can be used to boost green or energy-efficient development, and the renovation of investment property.

The cases of tax incentives and subsidies show that it is not simply about new incentives, but also about making sure that existing incentives do not support unsustainable activities. Some approaches and reforms are more difficult to implement than others. For example, the creation of green subsidies or removing environmentally harmful subsidies is often technically and politically difficult, especially when public finances are stretched and subsidy removal is thought to have adverse impacts on poor households. Also, the reality of the mainstream financial sector is that it remains wedded to serving the finance, investment and insurance needs of the brown economy and traditional infrastructure needs across heavy industry, power generation and transportation – a classic case of vested interests.

For example, it is estimated that the removal of the US\$ 500 billion in subsidies underpinning the fossil fuel sector globally could boost the global economy by around 0.3 per cent (UNEP 2010), a clear mid to long-term benefit for financial service institutions. Yet, in the short to mid-term, removing such subsidies fundamentally changes the risk/reward equation for the entire fossil fuel sector. Thus, their phase-in would need to be gradual and flanking measures put in place targeted on protecting the poor from potentially adverse impacts.

Achieving an optimal configuration of public policy and investment choices in infrastructure that acts to “crowd in” rather than “crowd out” private finance and investment – for example, building a smart electricity grid – will be a requirement to create long-term capital

stock that supports the green economic transition (UNEP 2010). As noted earlier, between 15 to 20 per cent of the US\$ 3 trillion global public stimulus packages pledged in response to the financial crisis, upward of US\$ 470 billion, was earmarked for green economy spending, including significant amounts for job-creating green infrastructure projects.

These investments are not confined to short-term responses to the financial and economic crisis, however, and new thought is being given beyond the recovery to ensuring a lasting transition. For example, during the 12th five-year plan period starting 2011, the Chinese government will invest US\$ 468 billion in green sectors compared to US\$ 211 billion over the last five years, with a focus on three sectors: waste recycling and re-utilisation; clean technologies; and renewable energy. With this amount of public investment, China’s environmental protection industry is expected to continue growing at an average of 15 to 20 per cent per year and its industrial output is expected to reach US\$ 743 billion during the new five-year period, up from US\$ 166 billion in 2010. The multiplier effect of this emerging sector is estimated to be 8 to 10 times larger than other industrial sectors.

In countries where public financing based on tax revenues and governments’ ability to borrow from capital markets are constrained, reform of subsidies and taxation policies can be used to open fiscal space for green investments. Subsidies in the areas of energy, water, fisheries and agriculture, for example, reduce the prices and encourage excessive use of the related natural capital. At the same time, they impose a recurrent burden on the public budget. Phasing out such subsidies and introducing taxes on the use of energy and natural resources can enhance efficiency while strengthening public finance and freeing up resources for green investments. Removing subsidies in these four sectors alone, for example, would save between 1 to 2 per cent of global GDP every year.

## 6 Conclusions

The financial sector's role in facilitating progress towards sustainable development has evolved considerably since the concept first received global attention at the UN Conference of Environment and Development in Rio de Janeiro in 1992. The intervening years have seen significant developments, ranging from successful partnership initiatives such as the UNEP Finance Initiative<sup>7</sup> and the PRI<sup>8</sup> to the integration of ESG factors in asset ownership and significant growth in private sector flows to niche asset classes such as microfinance, clean technology and sustainable energy. Investors are increasingly moving from responsible investment (do no harm) to sustainable investment (investment in solutions to sustainability challenges).

A global transition towards a green economy will require substantial redirection of investment to increase the current level of public and private sector flows to key priority areas, the bulk of which will need to be mobilised through financial markets. Analysis and modelling conducted for the Green Economy Report suggests that the level of additional investment needed is between 1 to 2.5 per cent of global GDP per year from 2010 to 2050. Currently, green economy investment is well below 1 per cent of global GDP.

The vast majority of the investment that needs to be re-directed to the green economy will need to come from the private financial sector if key sustainable development goals are to be achieved in the necessary time scales. National and international public sector resources are significantly smaller than those of the global financial market. Following the 2008 to 2009 financial crisis, the BIS has projected a high debt/GDP ratio for many major economies for the next twenty years. As a consequence, public funds available for a shift to a green economy are likely to be far below the level required. Developing countries, with the exception of the most vibrant emerging economies, will have limited fiscal options to support a green economy.

If a robust business case can be created and properly demonstrated, for example, by governments fully implementing the "polluter pays" and "user pays"

principles agreed by OECD countries, then arguably some of this re-deployment of capital will occur naturally as investors pursuing enlightened self-interest shift their assets from less attractive brown economy (based on fossil fuels) activities. Opportunities for scaling up green finance exist across the market, especially in sectors such as renewable energy or green property, and in mainstream finance through the growing trend towards consideration of ESG issues and accounting for environmental externalities. However, less mature and nascent segments of green economy finance – such as REDD+ or sustainable energy services for the poor – will require patient and wise incubation.

However, public financing is essential for the transition to a green economy and more than justified by the positive externalities that would be generated. The role of public finance in supporting a green economy was demonstrated by the green components of the massive fiscal stimulus packages launched by G20 countries in responding to the financial and economic crisis, which broke out in 2008. Out of the US\$ 3 trillion of the stimulus funds, more than 15 per cent was allocated to green sectors or to greening brown sectors.

Public financing for green investments is not confined to short-term responses to the financial and economic crisis. The Republic of Korea, for example, has included public funds for green investments in the country's five-year development plan. In many least developed countries, however, public financing covering tax revenues and governments' ability to borrow directly from capital markets is seriously constrained. In these countries, international and regional development banks should explore how they can increase development finance that supports agreed priorities for green investment.

Green stimulus packages and agile financial markets alone are unlikely to unlock the scale of private finance needed for the transition to a green economy. Sound public policies and enabling regulatory frameworks are also indispensable. Although an increasing number of financial institutions are becoming interested in a green economy, the majority of market players remain wedded to the traditional, brown economy. This is largely due to inadequate policy and regulatory frameworks that fail to provide a level playing field. The risk/reward equation still works unfavourably for would-be green investors.

Governments should involve the private sector in establishing stable and coherent policy and regulatory

7. In 2010, 200 banks, insurers and investment organizations were signatories to the United Nations Environment Programme Finance Initiative. <http://www.unepfi.org>

8. A further 900 investment organizations, including service organizations, support the UN-backed Principles for Responsible Investment. <http://www.unpri.org/principles>

frameworks that would better integrate environmental, social, and governance issues in investment decisions and financial policy making. In addition, governments and multilateral financial institutions should use their own resources to leverage the financial flows from the private sector and direct them towards the fledgling green economic opportunities.

In the lead up to the Rio+20 Earth Summit in Brazil in 2012, there is a need to establish clear and workable frameworks, including regulation where necessary, to rebalance the risk/reward equation for financial and investment practitioners in favour of green investment. It is clear that across banking, investment and insurance

– the core activities of the world's financial system – significant changes in philosophy, culture, strategy and approach, notably the overwhelming dominance of “short-termism”, will be required if capital and finance are to be reallocated to accelerate the emergence of a green economy. At the same time, fundamental aspects of international accounting systems and capital market disciplines, as well as our understanding of fiduciary responsibility in investment policy making and investment decision making, will need to evolve to fully integrate a broader range of ESG factors than takes place today. Without these changes, the pricing signals and incentives that could support the transition to a green economy will remain weak.

# References

- BCBS. (2009). *Strengthening the resilience of the banking sector – consultative document*. The Basel Committee on Banking Supervision. Basel.
- Bloomberg New Energy Finance. (2009). *Fortifying the Foundation: State of the Voluntary Carbon Markets 2009*. Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, T. A Report by Ecosystem Marketplace & New Carbon Finance. 2009.
- Cappgemini and Merrill Lynch Wealth Management . (2009). *World Wealth Report 2009*. Available at: <http://www.ml.com/media/113831.pdf>
- CDC Climate Research. (2010). *Tendances Carbone*, No. 50. Available at: [http://www.bluneuxt.fr/publications/TendancesCarbone/TCN.50\\_09.2010\\_En.pdf](http://www.bluneuxt.fr/publications/TendancesCarbone/TCN.50_09.2010_En.pdf)
- CDC Mission Climat. (2008). *Reducing emissions from deforestation and degradation: what contribution from carbon markets?* Climate Report. Issue, N. 14. September 2008. Available at: [http://www.cdcclimat.com/IMG/pdf/14\\_Etude\\_Climat\\_EN\\_Deforestation\\_and\\_carbon\\_markets.pdf](http://www.cdcclimat.com/IMG/pdf/14_Etude_Climat_EN_Deforestation_and_carbon_markets.pdf)
- Central Electricity Regulatory Commission, India. Available at: <http://www.cercind.gov.in/>
- Chatham House. (2009). *Unlocking Finance for Clean Energy: The Need for 'Investment Grade' Policy*. Hamilton, K. Available at: [http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/1209pp\\_hamilton.pdf](http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/1209pp_hamilton.pdf)
- Chicago Climate Exchange. (2011). Fact Sheet, v1.0, June 30 2011. Available at: [https://www.theice.com/publicdocs/ccx/CCX\\_Fact\\_Sheet.pdf](https://www.theice.com/publicdocs/ccx/CCX_Fact_Sheet.pdf)
- Cleantech Group and Deloitte. (2010). 3Q 2010 Investment Monitor. Available at: <http://info.cleantech.com/Download3Q2010IAbstract.html>
- Climate Change Task Force. (2010). *Agriculture Industry GHG Action Plan: Framework for Action*. UK. Available at: [http://www.agindustries.org.uk/document.aspx?fn=load&media\\_id=3739&publicationId=2473](http://www.agindustries.org.uk/document.aspx?fn=load&media_id=3739&publicationId=2473)
- CLIMATEFOCUS. (2010). *Options for managing financial flows from REDD+* Streck, C., et al. Available at: [http://www.climatefocus.com/documents/files/options\\_for\\_managing\\_financial\\_flows\\_from\\_redd.pdf](http://www.climatefocus.com/documents/files/options_for_managing_financial_flows_from_redd.pdf)
- Dag Hammarskjöld Foundation. (2009). *Carbon Trading: How it works, why it fails*. Critical Currents. Gilbertson, T. and Reyes, O. No. 7. November 2009. Available at: [http://www.dhf.uu.se/pdfiler/cc7/cc7\\_web.pdf](http://www.dhf.uu.se/pdfiler/cc7/cc7_web.pdf)
- DTZ Research MiP Database. (2009). *Money into Property Global 2009*. Available at: <http://www.dtz.com/Global/Research/Money+into+Property+Global+2009>
- European Renewable Energy Council and Greenpeace. (2010). *Energy [R]evolution: a Sustainable World Energy Outlook*. 3rd edition 2010 World Energy Scenario. Available at: <http://www.greenpeace.org/international/Global/international/publications/climate/2010/fullreport.pdf>
- Fernando, Nimal A. (2008). *Managing Microfinance Risks: Some Observations and Suggestion*. Asian Development Bank. Manila. Available at: <http://www.adb.org/Documents/Papers/Managing-Microfinance-Risks/Managing-Microfinance-Risks.pdf>
- Hawley, J. P. and Williams, A. T. (2000). *The Rise of Fiduciary Capitalism: how institutional investors can make corporate America more democratic*. University of Pennsylvania Press. Philadelphia.
- HSBC Centre of Climate Change Excellence. (2009). *Building a green recovery*. Available at: [http://www.hsbc.com/1/PA\\_1\\_1\\_S5/content/assets/sustainability/090522\\_green\\_recovery.pdf](http://www.hsbc.com/1/PA_1_1_S5/content/assets/sustainability/090522_green_recovery.pdf)
- HSBC Global Research. (2010). *Sizing the Climate Economy*. Available at: <http://www.research.hsbc.com/midas/Res/RDV?ao=20&key=wU4BbdYRmz&n=276049.PDF>
- IEA. (2010). *Energy Technology Perspectives: Scenarios & Strategies to 2050*. International Energy Agency. Available at: <http://www.iea.org/techno/etp/etp10/English.pdf>
- IEA. (2009). *World Energy Outlook 2009*. International Energy Agency. Available at: <http://www.worldenergyoutlook.org/2009.asp>
- IMF. (2009). *Global Financial Stability Report: Responding to the Financial Crisis and Measuring Systemic Risks*. International Monetary Fund. April 2009. Washington D.C.
- IPCC. (2007). *IPCC Fourth Assessment Report: Climate Change 2007 (AR4)*. Intergovernmental Panel on Climate Change. Available at: [http://www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data\\_reports.shtml](http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml)
- McCabe, J. (2010). "Plastic use no longer under wraps as Clinton launches investor initiative." *Environmental Finance*, 23 September 2010.
- Mercer LLC and Ceres. (2010). *Energy Efficiency and Real Estate: Opportunities for Investors*. Available at: <http://www.ceres.org/resources/reports/energy-efficiency-and-real-estate-opportunities-2009>
- Munich RE. (2009). *TOPICS GEO: Natural catastrophes 2009. Analyses, assessments, positions*. Available at: [http://www.munichre.com/publications/302-06295\\_en.pdf](http://www.munichre.com/publications/302-06295_en.pdf)
- Norwegian Ministry of Finance. (2010). *GPFG Responsible Investment*. Available at: [http://www.regjeringen.no/upload/FIN/brosjyre/2010/spu/english\\_2010/index.htm](http://www.regjeringen.no/upload/FIN/brosjyre/2010/spu/english_2010/index.htm)
- Norwegian Ministry of Finance. (2011). *The National Budget for 2011*. Available at: [http://www.statsbudsjett.no/upload/Statsbudsjett\\_2011/dokumenter/pdf/Summary.pdf](http://www.statsbudsjett.no/upload/Statsbudsjett_2011/dokumenter/pdf/Summary.pdf)
- OECD. (2004). *Financing Water and Environmental Infrastructure for all – Some Key Issues*. Global Forum on Sustainable Development, 2004.
- Parliament Committee on Climate Change. (2010). *Meeting carbon budgets – ensuring a low-carbon recovery*. 2nd Progress Report to Parliament Committee on Climate Change. June 2010. London. Available at: [http://downloads.theccc.org.uk/0610/pr\\_meeting\\_carbon\\_budgets\\_full\\_report.pdf](http://downloads.theccc.org.uk/0610/pr_meeting_carbon_budgets_full_report.pdf)
- Parry, M. et al. (2009). *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*. International Institute for Environment and Development. London, UK.
- Pew Center on Global Climate Change. (2008). *The European Union's Emissions Trading System in Perspective*. Ellerman, A. Denny. Joskow, Paul L. 2008.
- Pew Charitable Trust and the Clean Energy Economy. (2010). *Who's winning the clean energy race? Growth, Competition and Opportunity in the World's Largest Economies*. G-20 Clean Energy Factbook 2010. Available at: [http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Global\\_warming/G-20%20Report.pdf](http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Global_warming/G-20%20Report.pdf)
- Preqin. (2004-2010). Quarterly Fundraising Update series and Wealth Bulletins. Available at: [www.preqin.com](http://www.preqin.com)
- Principles for Responsible Investment. (2010). *Report on Progress 2010: An analysis of signatory progress and guidance on implementation*. Available at: [http://www.unpri.org/files/2010\\_Report-on-Progress.pdf](http://www.unpri.org/files/2010_Report-on-Progress.pdf)
- Renewable Energy Policy Network for the 21st Century. (2010). *Renewables 2010: Global Status Report*. Available at: [http://www.ren21.net/Portals/97/documents/GSR/REN21\\_GSR\\_2010\\_full\\_revised\\_per\\_cent\\_20Sept2010.pdf](http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised_per_cent_20Sept2010.pdf)
- RICS. (2009). *Doing well by doing good?* The Royal Institute for Chartered Surveyors. London. Available at: [http://www.rics.org/site/scripts/download\\_info.aspx?fileID=5763](http://www.rics.org/site/scripts/download_info.aspx?fileID=5763)
- Sakamoto, K., Dalkmann, H., and Palmer, D. (2010). *A Paradigm Shift Towards Sustainable Low-Carbon Transport: Financing the Vision ASAP*. Institute for Transportation and Development Policy. New York. Available at: [http://www.itdp.org/documents/A\\_Paradigm\\_Shift\\_toward\\_Sustainable\\_Transport.pdf](http://www.itdp.org/documents/A_Paradigm_Shift_toward_Sustainable_Transport.pdf)
- Scottish Agricultural College. (2010). *Review and update of UK marginal abatement cost curves for agriculture*. The Committee on Climate Change. August 2010. Available at: [http://downloads.theccc.org.uk/s3.amazonaws.com/0610/pr\\_supporting\\_research\\_SAC\\_agriculture.pdf](http://downloads.theccc.org.uk/s3.amazonaws.com/0610/pr_supporting_research_SAC_agriculture.pdf)
- Swiss Re. (2009). *World Insurance in 2008: life premiums fall in the industrialized countries – strong growth in emerging economies*. Sigma No. 3/2009. Available at: [http://media.swissre.com/documents/sigma3\\_2009\\_en.pdf](http://media.swissre.com/documents/sigma3_2009_en.pdf)
- TEEB [The Economics of Ecosystems and Biodiversity] for Business. (2010). Executive Summary. United Nations Environment Programme, et al. Nairobi/Bonn. Available at: <http://www.teebweb.org/Portals/25/Documents/TEEB%20for%20Business/TEEB%20for%20Bus%20Exec%20English.pdf>
- The Eliasch Review. (2008). *Climate change: financing global forests*. Available at: <http://www.official-documentation.gov.uk/document/other/9780108507632/9780108507632.pdf>
- TheCityUK. (2010). *Carbon Markets 2010*. Available at: [http://www.thecityuk.com/media/173627/carbon\\_percent20markets\\_per\\_cent\\_202010.pdf](http://www.thecityuk.com/media/173627/carbon_percent20markets_per_cent_202010.pdf)



- ThCityUK. (2011). *Fund Management 2011*. Financial Market Series London. Available at: <http://www.thecityuk.com/assets/Uploads/Fund-Management-2011.pdf>
- Trichet, Jean-Claude. (2010). Keynote speech. The 9th Munich Economic Summit. 29 April, 2009. Available at: <http://www.ecb.int/press/key/date/2010/html/sp100429.en.html>
- United Nations. (2008). *The Millennium Development Goals Report*. New York, US. Available at: [http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2008/MDG\\_Report\\_2008\\_En.pdf#page=](http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2008/MDG_Report_2008_En.pdf#page=)
- UNFCCC. (1998). *Identifying, analysing and assessing existing and potential new financing resources and relevant vehicles to support the development, deployment, diffusion and transfer of environmentally sound technologies*. Interim report by the Chair of the Expert Group on Technology Transfer. Available at: <http://unfccc.int/resource/docs/2008/sb/eng/inf07.pdf>
- UNDP. (2007/2008). *The Human Development Report 2007/2008 – Fighting climate change: Human solidarity in a divided world*. United Nations Development Programme. Available at: [http://hdr.undp.org/en/media/HDR\\_20072008\\_EN\\_Complete.pdf](http://hdr.undp.org/en/media/HDR_20072008_EN_Complete.pdf)
- UNEP. (2010). *Driving a Green Economy through public finance and fiscal policy reform*. Available at: <http://www.unep.org/greenconomy/Portals/30/docs/DrivingGreenEconomy.pdf>
- UNEP FI. (1995). *Statement of Environmental Commitment by the Insurance Industry*. Available at: <http://www.unepfi.org/statements/ii/index.html>
- UNEP FI. (1997). *Statement by Financial Institutions on the Environment and Sustainable Development*. Available at: <http://www.unepfi.org/statements/ii/index.html>
- UNEP FI. (2004). *CEO Briefing: Renewable Energy*. June 2004 Available at: [http://www.unepfi.org/fileadmin/documents/CEO\\_briefing\\_renewable\\_energy\\_2004.pdf](http://www.unepfi.org/fileadmin/documents/CEO_briefing_renewable_energy_2004.pdf)
- UNEP FI. (2008). *Making Forests Competitive: Exploring insurance solutions for permanence*. Concept Paper. Climate Change Working Group and Asset Management Working group. Available at: [http://www.unepfi.org/fileadmin/documents/Exploring\\_Insurance\\_Solutions\\_for\\_Permanence.pdf](http://www.unepfi.org/fileadmin/documents/Exploring_Insurance_Solutions_for_Permanence.pdf)
- UNEP FI. (2009). *Fiduciary responsibility: Legal and practical aspects of integrating environmental, social and governance issues into institutional investment*. Available at: <http://www.unepfi.org/fileadmin/documents/fiduciaryII.pdf>
- UNEP FI. (2011a). *REDDy-Set-Grow: A briefing for financial institutions – Opportunities and roles for financial institutions in forest carbon markets*. Part I. Biodiversity and Ecosystems Workstream and Climate Change Working Group. Available at: <http://www.unepfi.org/fileadmin/documents/reddysetgrow.pdf>
- UNEP FI. (2011b). *REDDy-Set-Grow: Private sector suggestions for international climate change negotiators – Designing an effective regime for financing forest-based climate change mitigation*. Part II. Biodiversity and Ecosystems Workstream and Climate Change Working Group. Available at: <http://www.unepfi.org/fileadmin/documents/reddysetgrowII.pdf>
- UNEP FI AMWG. (2004-2009). *Materiality Series. The Materiality of Social, Environmental and Governance Issues to Equity Pricing*. June 2004. Available at: [http://www.unepfi.org/fileadmin/documents/amwg\\_materiality\\_equity\\_pricing\\_report\\_2004.pdf](http://www.unepfi.org/fileadmin/documents/amwg_materiality_equity_pricing_report_2004.pdf)
- Show Me the Money: Linking Environmental, Social, and Governance Issues to Company Value*. July 2006. Available at: [http://www.unepfi.org/fileadmin/documents/show\\_me\\_the\\_money.pdf](http://www.unepfi.org/fileadmin/documents/show_me_the_money.pdf)
- The materiality of climate change: how finance copes with the ticking clock*. October 2009. Available at: <http://www.unepfi.org/fileadmin/documents/materiality3.pdf>
- UNEP FI BES. (2010). *CEO Briefing: Demystifying Materiality Hardwiring Biodiversity and Ecosystem Services into Finance*. Biodiversity and Ecosystem Services Workstream. Available at: [http://www.unepfi.org/fileadmin/documents/CEO\\_DemystifyingMateriality.pdf](http://www.unepfi.org/fileadmin/documents/CEO_DemystifyingMateriality.pdf)
- UNEP FI CCWG. (2007). *Declaration on Climate Change by the Financial Services Sector*. Climate Change Working Group. Available at: [http://www.unepfi.org/fileadmin/documents/cc\\_statement\\_jun2007.pdf](http://www.unepfi.org/fileadmin/documents/cc_statement_jun2007.pdf)
- UNEP FI and EcoSecurities. (2006). *Global climate change: risk to bank loan*. Available at: [http://www.unepfi.org/fileadmin/documents/global\\_climate\\_change\\_risk.pdf](http://www.unepfi.org/fileadmin/documents/global_climate_change_risk.pdf)
- UNEP FI and Freshfields Bruckhaus Deringer. (2005). *A legal framework for the integration of environmental, social and governance issues into institutional investment*. Available at: [http://www.unepfi.org/fileadmin/documents/freshfields\\_legal\\_resp\\_20051123.pdf](http://www.unepfi.org/fileadmin/documents/freshfields_legal_resp_20051123.pdf)
- UNEP FI IWG. (2009). *The Global State of Sustainable Insurance: Understanding and integrating ESG factors in insurance*. Insurance Working Group. Available at: <http://www.unepfi.org/fileadmin/documents/global-state-of-sustainable-insurance.pdf>
- UNEP FI IWG. (2007). *Insuring for Sustainability: Why and how the leaders are doing it*. Insurance Working Group. Available at: [https://www.allianz.com/staticresources/en/responsibility/media/documents/v\\_1275078369000/insuring\\_for\\_sustainability.pdf](https://www.allianz.com/staticresources/en/responsibility/media/documents/v_1275078369000/insuring_for_sustainability.pdf)
- UNEP and Partners. (2009). *Catalysing low carbon growth in developing economies: Public finance mechanisms to scale up private sector investment in climate solutions*. Available at: [http://www.unepfi.org/fileadmin/documents/catalysing\\_lowcarbon\\_growth.pdf](http://www.unepfi.org/fileadmin/documents/catalysing_lowcarbon_growth.pdf)
- UNEP FI and PRI. (2010). *Universal Ownership: Why environmental externalities matter to institutional investors*. Available at: [http://www.unepfi.org/fileadmin/documents/universal\\_ownership.pdf](http://www.unepfi.org/fileadmin/documents/universal_ownership.pdf)
- UNEP FI PWG (2011a). *Implementing Responsible Property Investment Strategies*. Available at: [http://www.unepfi.org/fileadmin/documents/responsible\\_property\\_toolkit4.pdf](http://www.unepfi.org/fileadmin/documents/responsible_property_toolkit4.pdf)
- UNEP FI PWG. (2011b). *An Investors' Perspective on Environmental Metrics for Property*. Property Working Group Available at: <http://www.unepfi.org/fileadmin/documents/EnvironmentalMetrics.pdf>
- UNEP FI and WBCSD. (2010). *Translating ESG into sustainable business value – key insights for companies and investors*. Available at: <http://www.unepfi.org/fileadmin/documents/translatingESG.pdf>
- UNEP SBCI. (2007). *Buildings & Climate Change: Status, Challenges and Opportunities*. Available at: <http://www.unep.org/sbci/pdfs/BuildingsandClimateChange.pdf>
- UNEP SEFI. (2010). *Global Trends in Sustainable Energy Investment in 2010*. Available at: <http://sefi.unep.org/english/globaltrends2010.html>
- US SEC. (2010). *Interpretive Guidance on Disclosure Related to Business or Legal Developments Regarding Climate Change*. Securities and Exchange Commission. Washington D.C.
- Veolia Environmental Services. (2009). *From waste to resource - an abstract of world waste survey*. Chalmin, P. and Gaillochet, C. November, 2009. Available at: [http://www.veolia-environmentalservices.com/veolia/ressourcesfiles/1/927,753,Abstract\\_2009\\_GB-1.pdf](http://www.veolia-environmentalservices.com/veolia/ressourcesfiles/1/927,753,Abstract_2009_GB-1.pdf)
- World Bank. (2010a). *World Development Report 2010: Development and Climate Change*. Available at: <http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1226014527953/WDR10-Full-Text.pdf>
- World Bank. (2010b). *World Development Indicators*. Available at: <http://data.worldbank.org/sites/default/files/wdi-final.pdf>
- World Economic Forum. (2010a). *Green Investing 2010 – Policy Mechanisms to Bridge the Finance Gap*. Available at: [http://www3.weforum.org/docs/WEF\\_IV\\_GreenInvesting\\_Report\\_2010.pdf](http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2010.pdf)
- World Economic Forum. (2010b). *Global Risks 2010: A Global Risk Network Report*. Executive Summary. p.6. Available at: [http://www3.weforum.org/docs/WEF\\_IV\\_GreenInvesting\\_Report\\_2010.pdf](http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2010.pdf)
- World Federation of Exchanges. (2009). *Exchanges and Sustainable Investment*. Siddy, D. Available at: <http://www.world-exchanges.org/sustainability/WFE-ESG.pdf>
- World Water Council. (2003). *Financing Water For All*. Executive Summary. World Panel on Financing Water Infrastructure. Available at: [http://financingwaterforall.org/fileadmin/wwc/Library/Publications\\_and\\_reports/CamdessusReport.pdf](http://financingwaterforall.org/fileadmin/wwc/Library/Publications_and_reports/CamdessusReport.pdf)
- WWF International and Profundo. (2008). *The Palm Oil Financing Handbook*. Available at: [http://assets.panda.org/downloads/the\\_palmoil\\_financing\\_handbook.pdf](http://assets.panda.org/downloads/the_palmoil_financing_handbook.pdf)





# Conclusions



# Conclusions

Moving towards a green economy has the potential to achieve sustainable development and eradicate poverty on an unprecedented scale, with speed and effectiveness. This potential derives from two concurrent changes. First, there is a changed playing field in which our world and the risks we face have materially changed. These changes require a fundamental rethinking of our approach to the economy. Second, there is a growing recognition that the natural environment forms the basis of our physical assets and must be managed as a source of growth, prosperity and well-being.

As this report has argued, reallocating public and private investments – spurred through appropriate policy reforms and enabling conditions – is needed to build up or enhance natural capital such as forests, water, soil and fish stocks, which are particularly important for the rural poor. Green investments will enhance new sectors and technologies that will be the main sources of economic development and growth of the future: renewable energy technologies, resource and energy efficient buildings and equipment, low-carbon public transport systems, infrastructure for fuel efficient and clean energy vehicles, and waste management and recycling facilities. Complementary investments are required in human capital, including greening-related knowledge, management and technical skills to ensure a smooth transition to a more sustainable development pathway.

One of the major findings of this report is that a green economy supports growth, income and jobs, and that the so-called trade-off between economic progress and environmental sustainability is a myth, especially if one measures wealth as stocks of useful assets, inclusive of natural assets, and not narrowly as flows of produced output. The results of the report indicate that in the short term, economic growth under a green scenario may be less than under business-as-usual. However, in the longer term – 2020 and beyond – moving towards a green economy would outperform business-as-usual by both traditional measures (GDP growth) as well as more holistic measures (per capita growth).

The report also finds that in a number of important sectors, such as agriculture, buildings, forestry and transport, a green economy delivers more jobs in the short, medium and long-term than business-as-usual. In sectors where capital is severely depleted, such as fisheries, greening will necessitate the loss of income and jobs in the short and medium-term to replenish natural stocks, but this will prevent the permanent

loss of income and jobs. In such cases, transitional arrangements are needed to protect workers from negative impacts on their livelihoods.

Although the bulk of the investments required for the green transformation will come from the private sector, public policy will also play a leading role in overcoming distortions introduced by perverse subsidies and externalised costs. In addition, public investment will be required to jump-start an effective transition to a green economy.

There is much more private capital available than the financial resources of the public sector. However, many developing countries have limited access to private capital. A large amount of the funds needed for green investments at scale in the initial stages of the transition towards a green economy must come from new and innovative financing mechanisms. In this regard, the new Green Climate Fund and nascent REDD+ funding mechanisms offer significant hope for achieving the finance required. Where national budgetary conditions are limited, multilateral development banks are ideally positioned to offer financial assistance to enable these countries to embark on a green development trajectory.

## Directions for further research

This report has analysed the enabling conditions required to mobilise investment, and the potential benefits of this investment in greening the world economy. It has provided fresh perspectives on the synergistic relationships between investing in low-carbon, resource efficient technology and socially inclusive economic growth.

Inevitably, as new research is provided new boundaries of knowledge and gaps are found. A number of areas where further research will be needed to provide more specific guidance on a green economy transformation have emerged in the process of writing this report. These areas include research to answer the following questions, among others:

**1. How to manage a smooth and fair transition from a brown economy to a green one at global level?** In this report, responses to transitional issues have focused on capacity building, training and educational efforts. Also important, however, is how countries should set an appropriate pace for a transition from the predominantly brown economy to a green one. Many countries are facing rigidities of an infrastructure and industrial base that was developed under the brown economic model.

In many cases, due to this rigidity, the inertia of moving along the brown economy path is likely to continue for some time. How should the move towards a green economy take such inertia into account?

## **2. How to ensure that green policies are not used as a pretext for trade protectionism?**

This report has identified the positive role trade can play in facilitating the transfer and deployment of environmental technologies across countries. It has also cautioned against using green economy policies as a pretext for trade protectionism. Practical solutions are needed to manage emerging conflicts. In some countries, “buy local” can arguably be a green economy policy, as reduced need for transport may reduce the ecological footprint. However, this type of policy can have adverse impact on the exports of other countries, including those that need foreign exchange to import goods that are essential for reducing poverty and improving living standards.

Another emerging conflict surfaces because countries that provide state support to green economic sectors such as renewable energy technologies give domestic enterprises a competitive edge in the export of these technologies. The question arises: Is it possible to ensure fair trade, while recognising the need for state interventions in jump-starting the transition to a green economy?

## **3. How to measure progress in the transition to a green economy?**

The various chapters of this report have used a wide range of indicators to highlight:

- The extent of the challenges, for example, levels of CO<sub>2</sub> emissions and the number of people lacking access to energy;
- The extent of the opportunities, such as the size of the market for more resource efficient and low-carbon technologies;
- Policies established, such as renewable energy targets; and,
- Policy outcomes, such as the rate of recycling achieved, as well as the material and energy intensity of production and consumption.

Although different sectors will need different matrices to measure progress towards greening, at a national economy level there is a need for aggregates to inform policy making. At the moment, such aggregates are not fully developed or agreed upon by the statistical community. Further research is needed on what are

the limited number of indicators that can measure the progress countries have made in transforming their economic structure from brown to green, including more adequate indicators for measuring economic prosperity and wealth creation beyond GDP.

## **Towards a green economy**

This report marks a first step in outlining key issues for moving towards a green economy at a national and global level. In summary, it has found that a green economy values and invests in natural capital. Ecosystem services are better conserved, leading to improved safety nets and household incomes for poor rural communities. Ecologically friendly farming methods improve yields significantly for subsistence farmers. Improvements in freshwater access and sanitation, and innovations for non-grid energy (solar electricity, biomass stoves, etc.), add to the suite of green economy strategies, which can also help alleviate poverty.

A green economy substitutes clean energy and low-carbon technologies for fossil fuels, which addresses climate change, creates decent jobs and reduces import dependencies. New technologies promoting energy and resource efficiency provide growth opportunities in new directions, offsetting brown economy job losses. Resource efficiency in both energy and materials use becomes a driving proposition, be it in better waste management, more public transportation, green buildings or less waste along the food chain.

Regulations, standards and targets are important to provide direction. However, developing countries must be allowed to move at their own speed, respecting their development objectives, circumstances and constraints. Developed nations have a key role to play in building skills and capacity in developing countries and in creating an international market and legal infrastructure for a green economy.

Enabling conditions have to be managed and adequate finance provided for a successful transition to a green economy. Both are eminently achievable. Environmentally and socially harmful subsidies are a deterrent and should be phased out. However, in select circumstances and over defined periods, rational use of subsidies can facilitate the transition to a green economy. Taxes and other market-based instruments can be used to stimulate the necessary investment and innovation for funding the transition. The scale of financing required for a green economy transition is large, but it can be mobilised by smart public policy and innovative financing mechanisms.

A green economy can generate as much growth and employment as a brown economy, and outperforms



the latter in the medium and long-run, while yielding significantly more environmental and social benefits. Of course, there are many risks and challenges along the way. However, the biggest risk of all is to remain with the status quo and not engage in a transition towards a green economy.

Moving towards a green economy will require world leaders, civil society and leading businesses to collaboratively engage in this transition. It will require a sustained effort on the part of policy makers and their constituents to rethink and redefine traditional measures of wealth, prosperity and well-being.



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Towards a Green Economy is among UNEP's key contributions to the Rio+20 process and the overall goal of addressing poverty and delivering a sustainable 21st century.

The report makes a compelling economic and social case for investing two per cent of global GDP in greening ten central sectors of the economy in order to shift development and unleash public and private capital flows onto a low-carbon, resource-efficient path.

