



FINANCIAL RISK AND THE TRANSITION TO A LOW-CARBON ECONOMY

TOWARDS A CARBON STRESS TESTING FRAMEWORK



Working Paper
July 2015

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2° INVESTING INITIATIVE

The 2° Investing Initiative (2°ii) is a multi-stakeholder think tank working to align the finance sector with 2°C climate goals. Our research seeks to:

- Align investment processes of financial institutions with 2°C climate scenarios;
- Develop the metrics and tools to measure the climate performance of financial institutions;
- Mobilise regulatory and policy incentives to shift capital to financing the transition to a low-carbon economy.

The association, founded in 2012, is based in Paris and New York, with projects in the US, Europe, and China. Our work is global, both in terms of geography and engaging key actors. We bring together financial institutions, companies, policy makers, research institutes, experts, and NGOs. Representatives from all of the key stakeholder groups are also sponsors of our research.

SUPPORT

This report has been produced by the 2° Investing Initiative (2°ii) with the support of the Office of the Commissioner General for Sustainable Development of the French Ministry of Ecology, Sustainable Development and Energy (CGDD/MEDDE), the UNEP Inquiry into the Design of a Sustainable Financial System, and the European Investment Bank (EIB).

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EXECUTIVE SUMMARY

The climate change challenge creates two types of potential risks for financial institutions:

- Physical changes in climate are expected to lead to both gradual modifications of climate patterns and extreme weather events. These are likely to alter the supply and demand dynamic of many industries and lead to physical damages to assets.¹ These changes in turn may translate into adaptation costs and economic loss of value. They can be labelled as *physical climate risks*;
- The mitigation of climate change as part of the transition to a low-carbon economy will alter the financial viability of a part of the capital stock and business models. The associated financial risk and opportunity may impact the performance of assets and portfolios. These types of risks can be labelled *carbon risks*.

To date, risk factors resulting from climate change and the transition to a low-carbon economy are generally not considered by mainstream risk assessment and management frameworks.

Insurance companies in particular have developed significant research on the potential impact of climate-related damages on the liability side of their balance sheet; flood insurance is a good example. At the same time, it appears that climate-related risks are currently not fully assessed on the asset side by current mainstream financial practices. The reasons for this can be summarised as follows:

- There is significant uncertainty around the exact decarbonisation trajectory of the global economy and the associated technologies driving this trajectory. Coupled with this is the high uncertainty and low credibility surrounding climate policies. Generally, the low carbon transition and +2°C climate roadmaps are not considered as reference scenarios by risk managers. Climate change issues are not on the radar screen of mainstream financial analysts focused on cyclical trends;
- An assessment of climate roadmaps suggests the distribution of risks may be skewed and involve ‘fat tails’ and ‘black swans’. These are not necessarily captured in standard valuation models and risk assessment frameworks;
- Many carbon risks are likely to appear in the medium to long term and thus may not be captured by short-term models used in most of the current risk management practices;
- Finally, gaps in data and the particular nature of carbon risks (e.g. to date driven primarily by policy) may give rise to a collective mis-assessment by financial markets.

A number of initiatives have sought to better measure carbon risks, with the help of “climate & carbon stress tests”. Many of these demonstrate that carbon risks are material in the investment chain. However, the overall materiality for financial institutions and the financial system remains unclear.

Research from a range of actors demonstrates the relevance of assessing the financial sector’s exposure to the transition to a low-carbon economy. Assessments have been performed across the investment chain and can be seen as attempts to overcome the barriers highlighted above. These scenario-based tools can be classified as a diverse family of “**climate & carbon stress tests**”, divided into ‘bottom-up’ approaches developed at the physical and corporate asset levels and ‘top-down’ approaches at financial portfolio level:

- **Physical assets:** The transition to a low-carbon economy may lead to ‘stranded assets’ that are no longer economically viable. For fossil fuels, recent research suggests that about 50% of global gas reserves, 33% of global oil reserves, and more than 80% of global coal reserves will not be burned in a 2°C economy.² A substantial carbon price, an integral part of a successful transition to a low carbon economy, will greatly impact investments and financial opportunity. Risk management around physical assets and investment decisions may come first in the form of systematic shadow carbon pricing and impairment tests for the most exposed assets and sectors.

- **Valuation of companies:** Economic impairment of physical assets is likely to impact the valuation of the listed companies that own these assets. Research in this space has looked at both the revenues and margins of companies and how valuation models themselves are impacted. A study by The CO-Firm/Allianz estimates a potential 75% hit on margins for German cement companies as a result of climate policies. Bloomberg offers a tool that models climate-related changes in market and policy variables on share prices of oil & gas companies.
- **Credit risk:** The transition to a low-carbon economy and associated future carbon constraints may also impact the creditworthiness of counterparties. Research in this domain for financial risk assessment is already underway for corporate credit ratings, notably by Standard & Poor's and Moody's, and is now emerging for sovereign debt.
- **Financial portfolios:** Risks for financial portfolios can be explored as part of strategic asset allocation models and balance sheet stress tests. Mercer developed a model to define allocation strategies for investors, on the basis of scenarios that combine both climate and carbon risks. In addition, there are a number of banks that have explored carbon risk stress-testing internally. These approaches have received less attention than bottom-up approaches, and they are not explicitly linked.
- **Financial system:** The systemic risk to financial stability associated with the transition to a low-carbon economy has not been carefully investigated to date. Such an assessment of systemic risk would require a better knowledge of climate & carbon risks at level of financial institutions. Whereas no such analysis exists yet, the topic is now being raised as a topic on the agenda of macroprudential authorities.

Financial regulators and policy makers, notably in France, the United Kingdom, and at the G20 level have started responding to the issue. This is coupled with initiatives in emerging economies in the context of a broader focus on *environmental stress testing*.

The Bank of England (BoE) Governor Mark Carney highlighted the potential risk of stranded fossil fuel assets and integrated this issue into its work on financial stability risks. The BoE has begun researching climate-related financial risks in the frame of its upcoming Climate Change Adaptation Report. The G20 asked the Financial Stability Board to explore the issue. The French Energy Transition Law, adopted by the Senate in July 2015, requires companies and financial institutions to report on climate risk. It commissioned a report on the opportunities of the implementation of a stress-test scenario representing such risks. These initiatives are first steps taken by financial regulators and supervisors to assess climate and carbon risks. They operate at three different levels: disclosure of risk exposure for assets; evidence of materiality at portfolio and financial institution levels; assessment of systemic risk.

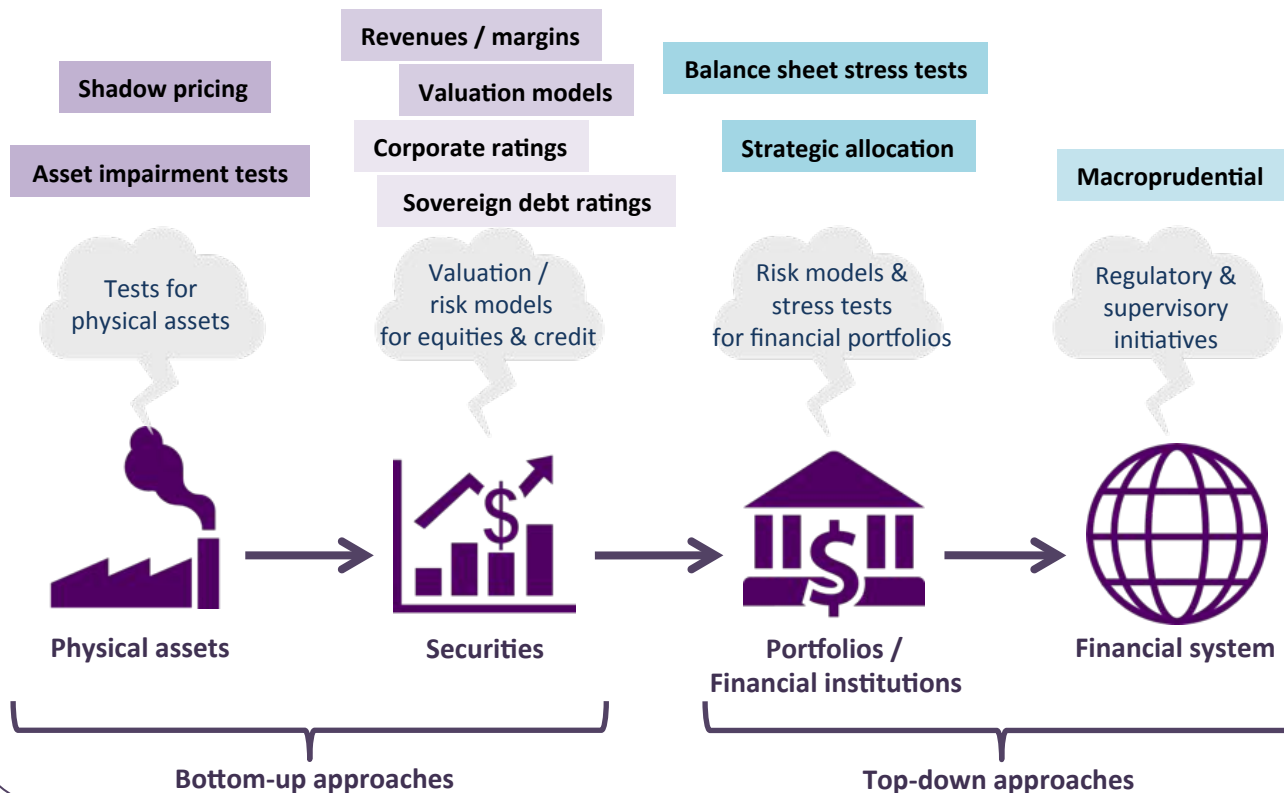
While still in their infancy, bottom-up approaches to valuation are relatively developed. However, there is still significant room to expand their role, in particular in terms of linking these approaches to top-down stress tests.

Although the conceptual framework for bottom-up approaches is in place, two key challenges remain. Concerning market risk, the main challenge is strengthening the scientific basis of the underlying assumptions, in particular the scenarios feeding valuation models and their associated inputs (e.g. margins, revenue). The impact of 2°C scenarios could also be considered using risk metrics such as Value at Risk (VaR), which emphasizes low-probability events as soon as they have a large impact. Concerning credit risk, the key challenge is integrating climate and carbon risk factors into credit risk analysis. Here, current research initiatives by credit rating agencies are likely to lead to an improvement in the near future.

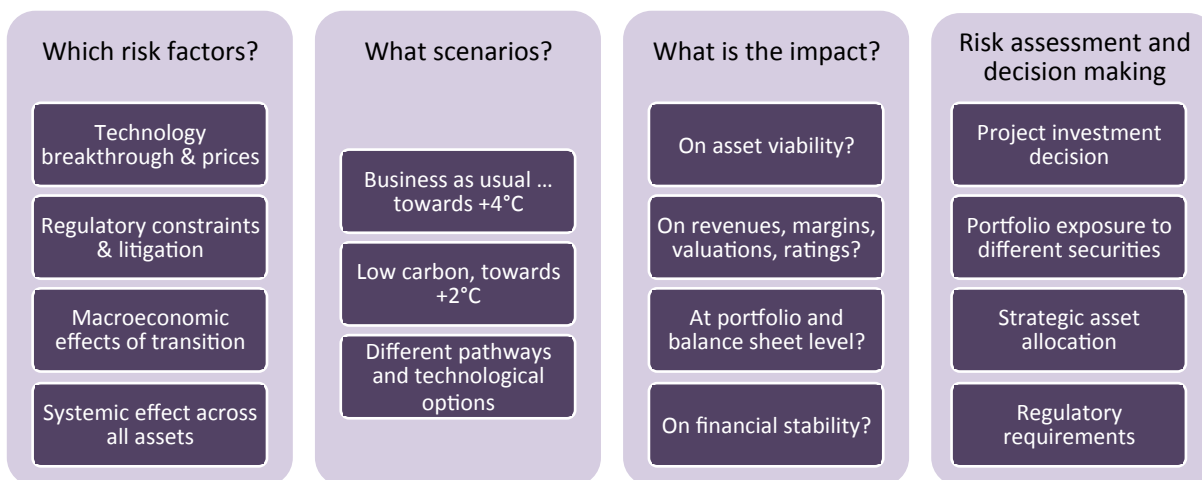
The missing step is to assess these risks for financial portfolios and institutions in a meaningful way. The development of valuation and risk models integrating climate & carbon risks at the asset level paves the way for the establishment of broader and more inclusive approaches to assess and manage these risks. An adaptation of the traditional top-down stress-testing framework would be a credible option, in so far as it is a tool designed to deal with such system-wide risk factors. In this context, the capacity to translate climate & carbon scenarios into stress-testing approaches through traditional macroeconomic and market risk factors or new dedicated risk factors would be a key enabler for financial institutions to assess their exposure to these risks.

The report shows that there is no fundamental barrier to integrating climate & carbon risks into financial risk and valuation models. In addition, addressing this challenge requires not just a focus on the models but also risk management practices, notably the underlying time horizon of risk management.

The family of 'climate & carbon stress tests' across the investment chain



Climate & carbon stress testing at a glance (see p.20-21)



The way forward

(see p.24-25)

- Integrate climate-related risk considerations in existing disclosure and transparency standards, notably with regard to time horizons**
- Establish the materiality of carbon risk at individual asset, portfolio, and balance sheet levels**
- Integrate different climate / carbon scenarios into risk and valuation models**
- Explore the systemic risk issue**
- Address climate & carbon risk issues through international cooperation**

I. INTRODUCTION – CLIMATE & CARBON RISKS

Finance sector and the environment. The idea that environmental issues can create risks for financial institutions has gained traction since the 1970s and 1980s. Industrial accidents, a more forceful response by civil society and policy makers against environmental missteps, and a growing awareness around corporate economic benefits that come from sound environmental management has put the issue of environmental risks on the radar screen of both companies and financial institutions. Broad environmental risk management is increasingly being considered by strategy departments of companies and in investment decision-making processes of financial institutions.

Within the category of environmental risks, the issue of climate change has received particular attention in the past 2-3 years.³ The growing consensus on climate change and its impacts have led to increased attention on the potential implication of climate change and the associated political response both for companies and financial institutions. Financial regulators and policy makers have started responding to this issue. The Bank of England under Mark Carney has sent letters to insurance companies asking them to respond on their climate-related risk management practice, and has put stranded assets on its agenda as part of its work on financial stability risks.⁴ Climate change risk was also on the agenda of the G7 summit in Elmau in June 2015.⁵ Regulators in emerging economies, notably China and Brazil, have put the issue on their work programmes as well.^{6,7}

Types of climate change related risks. The risks highlighted by corporates and financial institutions, as well as regulators and policy makers can be grouped into two categories:

- **Physical climate risks** arise due to changes in the climate system. Both gradual (e.g. temperature and precipitation regimes) and point-in-time (e.g. extreme events) impacts can affect exposed industries in the whole economy, either in terms of altered supply and demand dynamic, or as a result of physical damages to assets. Evidence suggests occurrences of these events are already increasing (Fig. 1). These risks generally concern all assets and portfolios.
- **Carbon risks** are defined as the family of risks associated with the transition to a low-carbon economy. These risks are usually linked to the GHG-emissions of an asset or portfolio. One prominent example for these types of risks relates to fossil fuel reserves, a significant share of which cannot be burned unabated (e.g. without capturing the GHG-emissions) under a 2°C budget (Fig. 2). Apart from the energy sector, broader economic changes related to energy use will also impact a range of other high-carbon and climate-related sectors, notably utilities, transport, and manufacturing sectors. These changes may already be visible in Europe (Fig. 3).

FIG. 1: GLOBAL EXTREME TEMPERATURE, WILDFIRE, AND DROUGHT OCCURENCES (SOURCE: 2°II, BASED ON EM-DAT DATA)⁸

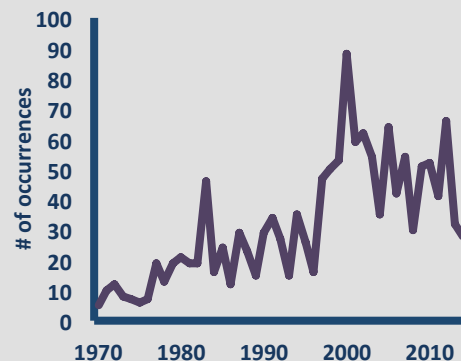


FIG. 2: PROVED FOSSIL FUEL RESERVES VERSUS 2°C BUDGET (SOURCE: IPCC 2011, IPCC 2013, ECF 2013, ADAPTED)⁹

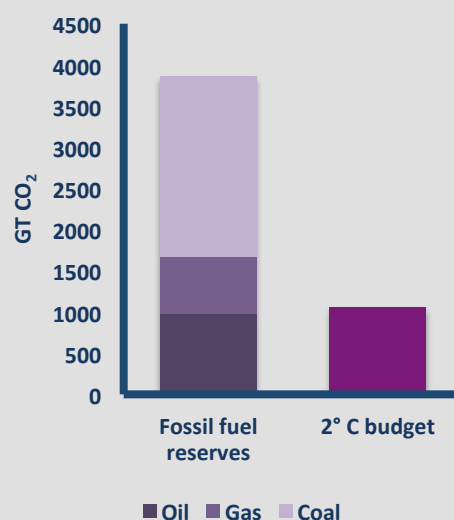
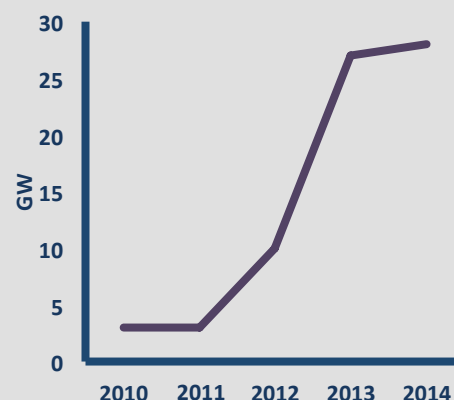


FIG. 3: COAL AND COMBINED CYCLE GAS TURBINES CLOSURES IN EUROPE (SOURCE: UBS 2015)¹⁰



Objective of the report. This working paper examines the question of the financial risk associated with the transition to a low-carbon economy. It discusses different methodological options that have been followed to date to assess and/or manage this risk, as well as the implications for financial institutions and regulators.

The focus of this paper is on non-physical risks related to climate change, which this report calls carbon risks. They include the risk of being high-carbon as the economy transitions to a low-carbon world; the risk of betting on the wrong technologies; and the risk of misunderstanding the set of diverse ‘energy transitions’ each country faces. There is also the risk of betting on a +2°C future when our current trajectory takes us to +4°C or more. Carbon risks cover all areas related to decarbonization, including energy and non-energy related risks. While an outstanding issue at least as important as carbon risks, physical climate risks are not central in this paper. They are already quite well accounted for by the insurance industry on the liability side of their balance sheet.¹¹ On the asset side of financial institutions, the issue is much less advanced (e.g. Covington and Thamotheram 2015)¹² but connecting the two is the next step of macro-scenario approaches as there is a trade-off between the level of mitigation and future physical climate risks.

Risks for whom? Carbon risks can be material across the investment chain and the entire economy. These risks may appear at each step of the chain as a function of policies, market changes, legal challenges, and reputational / social impacts (Fig. 4). Indeed, risks can be ‘passed-through’ the chain from physical assets to corporates, financial institutions, governments and civil society:

- **Physical assets** will frequently be the first step where carbon risks materialise, through the exposure of these assets to policy, legal, market, and reputational constraints. In Europe, these risks arguably have already started to materialise. Between 2010-2014, European utilities mothballed roughly 70 GW of coal and gas-fired capacity, actions at least partly due to changes in energy policies driven by climate objectives.¹³
- **Companies** can be subject to carbon risks both through the impairment of physical assets and direct constraints placed on companies through regulatory, legal, or reputational action.^{14,15} Financial institutions are exposed to these corporate risks through their listed and private equity, as well as their bond portfolios and loan books.
- **Financial Institutions** are exposed to the risks of their investees (e.g. companies, households, governments). In addition, they may also eventually face regulatory constraints directly targeting financial institutions. Carbon risk could be taken into account to build credit ratings, corporate valuation and market risk models. While much of the attention at this stage has been on companies, risks can also appear for non-corporate financial assets, notably sovereign and household debt. Carbon risks for financial institutions can be assessed using a bottom-up or a top-down approach (cf. p.14).
- **Governments and civil society** are exposed to carbon risks either directly or indirectly through the investment chain to the ultimate asset owner and in some cases the government.

Overview of report. The report is organized as follows.

- Section II will discuss whether carbon risks are being accurately assessed by financial institutions and integrated into market prices.
- Section III landscapes the current attempts to assess carbon risks at various levels of the investment chain.
- Section IV maps the implications for financial institutions and regulators.

FIG. 4: TYPES OF CARBON RISKS (SOURCE: 2°II, BASED ON UNEP-FI / WRI 2015)¹⁴



POLICY

Risks related to policies impacting the transition to a low-carbon economy



MARKET

Risks related to market changes impacting the relative profitability of high-carbon and low-carbon investments



LEGAL

Legal challenges associated with liabilities for financing high-carbon activities



REPUTATIONAL / SOCIAL

Risks related to the ‘social license’ to operate or reputational costs associated with high-carbon activities

II. LOW-CARBON TRANSITION AND RISK MODELS

2.1 ARE CARBON RISKS ALREADY ASSESSED BY FINANCIAL INSTITUTIONS?

The first question with regard to carbon risks is whether these risks are not already assessed as part of existing valuation and risk models and, by extension, priced into markets.

There is some evidence that this is at least partially the case. Griffin et al. (2015)¹⁶ find that the share prices of listed oil & gas companies did respond, albeit marginally, to the narrative created by the 2009 Meinshausen et al. article on stranded assets.¹⁷ Share prices also appeared to have responded to subsequent media coverage on carbon taxes. While the response was muted, the evidence of this article does suggest that there was a response, at least to some news. However, 'other unburnable carbon' news for example did not generate a response. Indeed, given the relative weakness of the policies behind global climate objectives, it could be argued that the response identified is 'appropriate'. More broadly, this raises the question of the reference scenario used for risk assessments and forward valuations of assets (cf. next page).

Financial institutions invest significant resources in the short-term assessment of risks to companies. A category of tools related to ESG (environmental, social, governance) factors have been developed in the past years to respond to exactly these issues (cf. focus on next page). However, the attention devoted to these categories of risks is still limited, with climate and carbon a 'sub-category' of a risk assessment framework that covers everything from climate to other environmental and social issues. Given the scope of these risks relative to their emphasis, it appears unlikely that ESG frameworks can to date fully capture carbon and climate risks.

The finance sector does not always appear to price risks correctly and will miss certain market trends. Some climate disasters may be classified as a 'preventable surprise'. When looking at carbon risks however, an in-depth analysis is needed to understand why financial markets may 'mis-assess' carbon risks.

2.2 WHY FINANCIAL INSTITUTIONS MAY NOT ACCURATELY ASSESS CARBON RISKS

Overview. This section will explore reasons as to why financial institutions may mis-assess carbon risks. The objective is not to prove, but simply to map why this is *potentially* the case. Understanding whether these risks may be mis-assessed is a key prerequisite to exploring whether and how carbon risks can be better integrated into risk assessment and management. The discussion will focus on five factors that may drive collective mis-assessment: risk & uncertainty, data, distribution, time horizons, and 'market mis-read'.

FIG. 5: IMPACT OF "UNBURNABLE CARBON" NEWS ON DAILY STOCK RETURN OF OIL&GAS COMPANIES (SOURCE: GRIFFIN ET AL. 2015)¹⁶

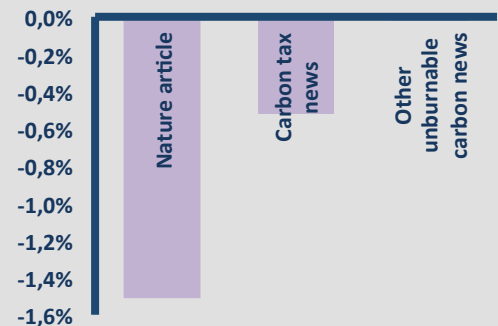


FIG. 6: WHY CARBON RISKS MAY NOT BE FULLY CAPTURED BY FINANCIAL MARKETS (SOURCE: 2°II)



RISK & UNCERTAINTY

A range of decarbonization pathways and associated roadmaps may make it difficult to assess economic trends. [→ The market failure literature associates this with the risk and uncertainty literature]



DATA

There is a lack of historic data to feed models. The future will not be a replication of the past.



DISTRIBUTION

An assessment of climate roadmaps suggest the distribution of risks may be skewed and involve 'fat tails' / black swans.



TIME HORIZONS

Many carbon risks are likely to appear in the medium- and long-term and thus may not be captured by short-term models. [→ This can relate to principal-agent problems (asymmetric information)].



MARKET MIS-READ

Carbon risks are primarily policy-driven and non-cyclical, making them distinct from traditional market risks. Hypothetically, this may make a collective mis-read more likely. [→ This can be linked to notions of bounded rationality].

FOCUS – NON-CLIMATE ENVIRONMENTAL RISKS

Overview. The growing prominence of environmental risks on financial institutions' radar screen coincides with the rise of the environmental movement more generally. Environmental risks first started being treated as a material category of risks in the 1980s (Weber, 2015).¹⁸ This can be linked both to the impact of environmental movement on corporation's abilities to pollute and to the growing backlash to individual industrial accidents. It is these two factors, policy constraints on environmentally damaging activities and industrial accidents causing environmental damage, that arguably form the two core drivers of the growing awareness of environmental risks.

Environmental risks as part of ESG assessment. Institutional investors today manage environmental risks usually through ESG (environmental, social, governance) analysis. This analysis is performed either in-house or through external data providers and consultants that seek to identify environmental risks to companies. The ESG analysis usually involves a scoring of companies on a number of different criteria among the environmental criteria (Fig. 8). ESG analysts will seek to build a comprehensive overview of the performance of companies on these criteria.

A key feature of environmental risks relative to carbon risks is that environmental risks are generally more prominently linked to event risks. These risks materialise in the form of industrial accidents that involve costs of clean-up, legal charges, impact on production, a government response, and reputational cost.

In terms of industrial accidents, the most prominent case in recent history is the BP Macondo oil spill in 2010. The oil spill led to a drop in share price of 50% within 2 months (Fig. 7) and an estimated total costs to BP of \$60 billion, including July 2015 settlement fines. BP faced costs in terms of clean-up and lawsuits from individuals, and had to record a loss in output. The incident also brought reputational damages, both to BP directly and their 'social license' to operate. This articulated itself in the political moratorium on deepwater drilling announced by Obama following the oil spill. A response to these types of risks may be a better assessment and prevention of 'preventable surprises'.

Environmental risks: agriculture case study. While many environmental risks material to companies and financial institutions articulate themselves in the form of events, environmental risks may also be more similar to carbon risks as part of a long-term non-cyclical phenomenon. This relates in particular to long-term natural resource depletion, such as the case for forestry or agriculture. The Oxford University Smith School Stranded Assets Research Programme assessed these medium- and long-term risks to agriculture under a range of different scenarios (Fig. 9).²¹

FIG. 7: BP SHARE PRICE 2000 – 2015 (YTD)
(SOURCE: BP 2015)¹⁹

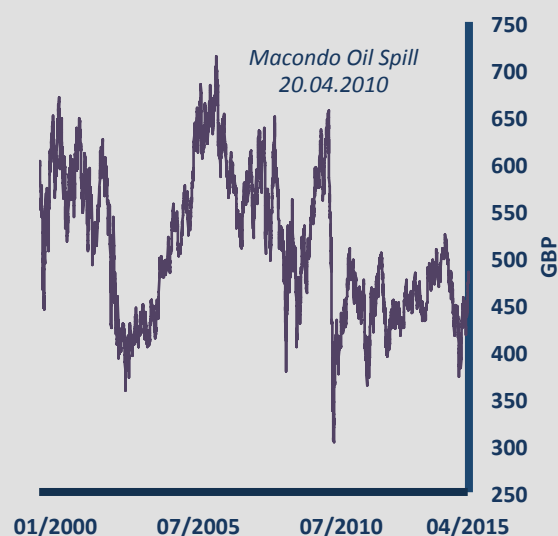
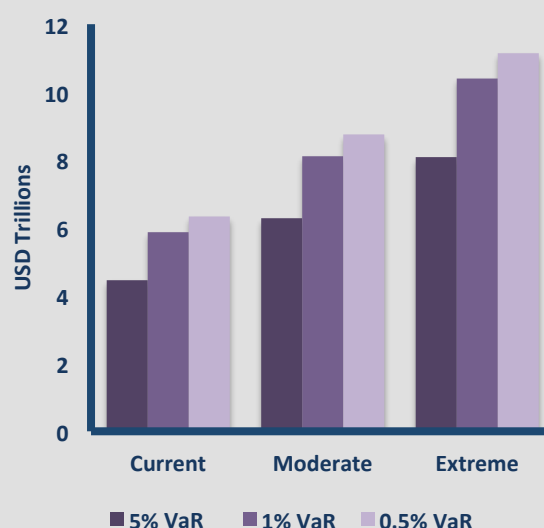


FIG. 8: ENVIRONMENTAL RISK FACTORS IN THE MSCI ESG SCORE (SOURCE: MSCI)²⁰



FIG. 9: STOCK OF INVESTED CAPITAL IN AGRICULTURE AT RISK UNDER VARIOUS SCENARIOS (SOURCE: OXFORD STRANDED ASSETS PROGRAMME 2014)²¹



Uncertainty. The growing scientific evidence around climate change has sparked both a societal and political response. While there is some form of consensus that the future is unlikely to look like today, the exact nature of that future is still highly uncertain. Beyond the intrinsic uncertainty of climate modelling, this relates to the ultimate decarbonization pathway that the global economy is able to achieve and the differences of choices at national level, both in terms of levels of GHG emission constraints and technology options that will be incentivised.²² Fig. 10 demonstrates the significant difference between the most high-carbon and low-carbon “representative concentration pathways” highlighted by the Intergovernmental Panel on Climate Change.

The difference in pathways highlights the uncertainty around the response to climate change. From an investor’s perspective, risks associated with the low-carbon transition can not be managed as the risk of a singular event. For investors seeking to manage this risk, the uncertainty is not only limited to *whether* economies decarbonize but also to *what degree* economies will decarbonize. This creates a challenge for building associated risk models.

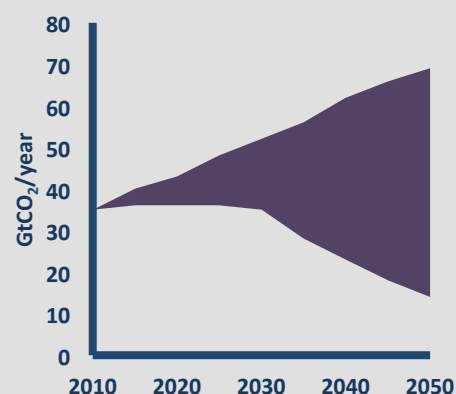
Even if investors define a decarbonization pathway, for example leading to the achievement of the political target limiting global warming to +2°C, this can be achieved through a range of different technologies at various price points. The competition, both between low- and high-carbon technologies and within low-carbon technologies (e.g. between nuclear power, wind power, solar PV), can create very different low-carbon futures. All of this is associated with very different prices and production trajectories (Fig. 11).

Data. The climate change challenge is unprecedented. Thus, no historic data can feed models, which is a strong hindrance for most modelling approaches based on statistical analysis as it is clear that the future will not be a replication of the past.

Distribution. There may be other technical challenges to carbon risk management. For example, a normal distribution of events is assumed in many valuation models, which can be challenged:

- **Skewness:** Current estimates around climate policy commitments suggest we will achieve ~3.5-4.5°C. Even if this outcome is the most likely, the odds of over-shooting or under-shooting this outcome are probably not evenly distributed. Given the 2°C political objective, it is more likely that we will under- rather than over-shoot this outcome. This also implies that risks around this trajectory are not the same on each side.
- **Fat tails:** A key element of normal distribution is that events cluster around the mean and fall off significantly. Distributions where this is not the case are said to have ‘fat tails’ or be subject to ‘black swan’ events. The financial crisis was said to have been a ‘fat tail’ event. The distribution of low-carbon roadmaps may similarly exhibit these fat tail characteristics.

FIG. 10: RANGE OF ESTIMATED FUTURE EMISSIONS UNDER VARIOUS SCENARIOS (SOURCE: IPCC 2014)^{23*}



* Scenarios are based on the four IPCC “Representative Concentration Pathways” (RCP)

FIG. 11: US CRUDE OIL SUPPLY UNDER VARIOUS PRICE SCENARIOS (SOURCE: EIA 2014)²⁴

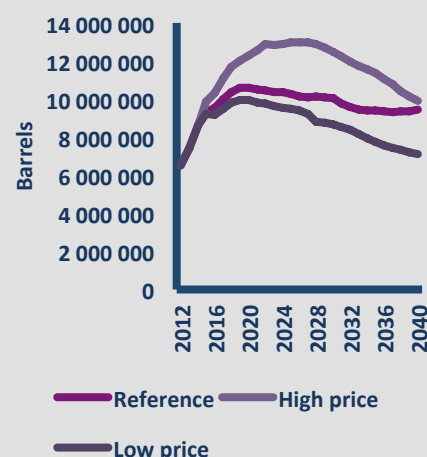


FIG. 12: NORMAL DISTRIBUTION VERSUS STYLIZED DISTRIBUTION OF CLIMATE ROADMAPS (SOURCE: 2°II)

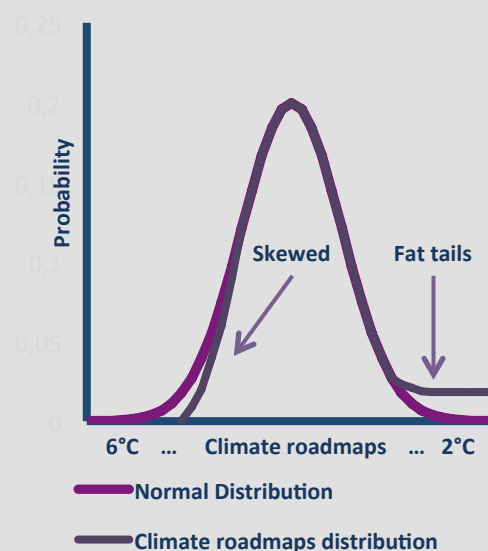


FIG. 13: STYLISTED ESTIMATED TIME HORIZONS IN THE INVESTMENT CHAIN AND LIKELY TIME HORIZON OF CARBON RISKS (SOURCE: 2°II)

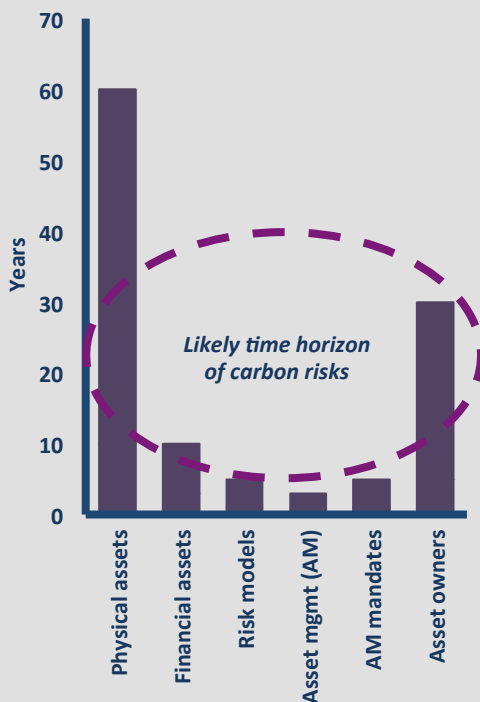


FIG. 14: IMPAIRMENT OF MORTGAGE COLLATERALIZED DEBT OBLIGATIONS BY RATING AS OF 2009 (SOURCE: FINANCIAL CRISIS INQUIRY 2011)⁵²

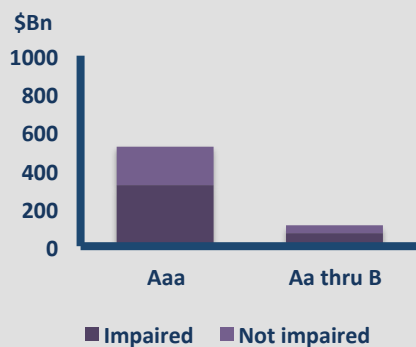
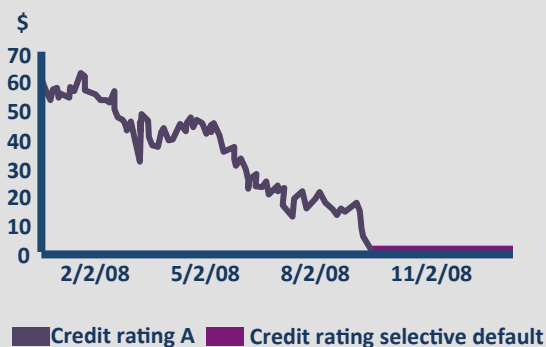


FIG. 15: LEHMAN BROTHERS SHARE PRICE AND CREDIT RATING (SOURCE: 2°II)



Time horizon. A key characteristic of carbon risks is that many of these risks are unlikely to materialise in the short-term. Long-term and gradual climate policies may only impact the majority of today's physical assets starting in 2020 or perhaps after 2025. Similarly, legal action seems unlikely in the short-term. From a financial perspective, these rather long-term risks may be material given the long life times of many physical assets related to climate change issues. Institutional investors with long-term liabilities may similarly be concerned about these risks. However, these long-term time horizons get shortened in the investment chain. Asset management mandates are usually 1-3 years and risk models are only marginally longer and sometimes even shorter, with risks after 5 years usually extrapolated based on business-as-usual assumptions.

Assuming these stylized time horizons, carbon risks may be material to physical assets and institutional investors in the medium- to long-term, but are not captured in the risk assessment and investment decision-making process of short-term asset managers or long-term investors exposed to short-term assets. This can explain a mis-assessment due to short-term time horizons. While asset managers may not consider this an actual mis-assessment, it may be material for long-term investors or financial regulators and policy makers seeking to address potential capital misallocation.

Mis-read due to bounded rationality. Finally, mis-reading may take place due to what the market failure academic literature describes as bounded or selective rationality.²⁵ Financial markets may simply collectively mis-assess trends due to behavioural issues such as herding. This mis-assessment is then in line with the more general literature on financial crises.

The most recent example for this is the global financial crisis, where financial markets collectively mis-assessed the potential impairment of subprime mortgages and other financial assets. Over half of all Aaa rated mortgage collateralized debt obligations (CDOs) from Moody's were impaired, and an even higher share of lower rated CDOs (Fig. 14). This mis-assessment can take place even up to the last minute. Lehman Brother's credit rating was not changed to selective default by S&P until the company had already filed for bankruptcy (Fig. 15).

Hypothetically the same type of mis-assessment could take place with regard to carbon risks, where the market is collectively for some behavioural reason 'on the wrong track'. While this could be argued that carbon risks are not properly assessed, the dynamic may be different. Thus, investments in the oil & gas sector are to a significant degree financed through corporate balance sheets. At least in the short-term, this implies that risks may not arise from a debt-fuelled boom, but rather a non-cyclical decline that is for behavioral reasons not captured by financial market actors. As highlighted above, it is not proven that this type of mis-assessment takes place or not. Rather, the issues presented here are meant to landscape why *potentially* there is a mis-assessment around carbon risk.

III. LANDSCAPE OF RISK & VALUATION MODELS

3.1 OVERVIEW

Climate & carbon risks and valuation models. As highlighted in the previous chapter, it is unclear whether financial markets accurately price the risks associated with the transition to a low-carbon economy. There are a number of reasons why this may not be the case.

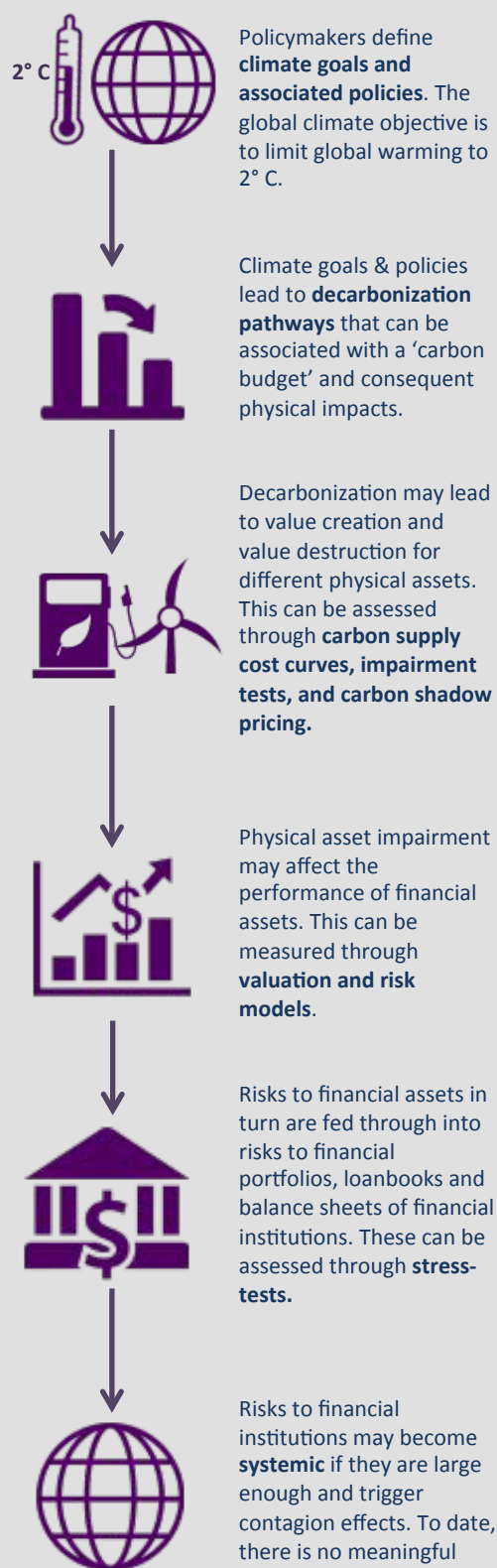
The focus of this chapter is on the current approaches to integrating carbon risks into risk and valuation models. The chapter will look at the extent to which these approaches have been developed throughout the investment chain, including risks to physical assets, financial assets, and financial portfolios. The chapter concludes with a brief mapping of current regulatory initiatives.

Options for integrating carbon risks. The current landscape of carbon risk and valuation models all take existing modeling frameworks as the basis and introduce risk factors related to the transition to a low-carbon economy. These approaches across the investment chain form a diverse family of 'climate & carbon stress tests'. They present different types of features that can be applied individually or at the same time:

- **Translating climate roadmaps into scenarios for models:** Some carbon risk and valuation models take macroeconomic forecasts such as the IEA roadmaps²⁶ and translate these into implications for financial assets. An example for this approach is the work done by Kepler-Cheuvreux on revenues of oil and gas companies.²⁷
- **Alternative assumptions around policy frameworks:** Models can use alternative assumptions not necessarily related to climate roadmaps, but to specific policies or price forecasts. Examples of this are The CO-Firm analysis on net margins.²⁸
- **Impact simulation:** Some models use a simulated shock without a direct link to decarbonization roadmaps. This relates to the approach followed by the GEF study.²⁹
- **Extending time horizons:** An alternative approach is to model risks using long-term time horizons independently of the real maturity of financial assets. Extending time horizons will lead to include physical climate risks. An example of this is the Mercer study on strategic asset allocation.³⁰

Models at each level of the investment chain. The subsequent discussion categorizes models at four levels of the investment chain: impairment tests for physical assets, valuation / risk models for equities and credit, risk models and stress-tests for financial portfolios and balance sheets, and regulatory initiatives (cf. p.6).

FIG. 16: MAPPING CARBON RISK AND VALUATION IN THE INVESTMENT CHAIN (SOURCE: 2°ii)



TAB. 1: CLIMATE & CARBON STRESS TEST FAMILY — OVERVIEW OF RISK AND VALUATION APPROACHES (2°II)

	Type of approach	Description	Examples
Physical assets	Asset impairment tests	Comparison of the value of an asset on the current balance sheet with its recoverable/fair value based on different future cash flows scenarios.	Impact of climate policies on energy intensive assets, via scenarios around energy demand, price and carbon price allow for a definition of carbon supply cost curves, as developed by the Carbon Tracker Initiative. ³¹
	Shadow pricing	A current / theoretical / forecasted price of carbon (e.g. shadow price) can be used to perform an analysis about the financial opportunity of an investment as a function of different scenarios of climate and energy policies.	Carbon shadow pricing employed by the European Investment Bank as part of its project assessment framework. ³²
Equities	Revenues / Margins	The impact of carbon risks can be assessed through a number of different indicators. Two prominent indicators that have been assessed relate to the revenues and the margins of companies. Companies can be affected by different market conditions as a function of their business models, cost structure, responsiveness, or development strategies. The impact of different future conditions on the margin structure of a company can thus be modelled.	Kepler-Cheuvreux estimated the potential lost revenues of oil and gas companies from the IEA 2°C scenario. ²⁷ Société Générale Equity Research estimated the effect on margin from the potential cost of carbon for companies and sectors based on their carbon intensity. ³³ CO-Firm/Allianz assessed the same type of net margin impact from their overall adaptive capacity. ²⁸
	Valuation models	Expected future cash flows (revenues) and net margins can work as inputs to equity valuation models. The most prominent are discounted cash flow (DCF) models. DCF modelling use representations of the future in the form of different factors (discount rate, project specific variables, economic variables, cost structure of the company, pricing power, etc.).	A number of sell-side analysts have conducted carbon related valuation studies, notably HSBC. ^{34,50} Bloomberg offers an online valuation tool for fossil fuel companies. ³⁵
Debt	Corporate credit ratings	Credit ratings illustrate the capacity of a company/government to meet its financial obligations, and its likelihood of default. Time horizons for such evaluations usually rank from 1 to 5 years, which appear to be too short to capture main carbon risks factors as of today.	S&P and Moody's have published a first series of papers on the potential implications of carbon risks on corporate credit ratings. ^{36,37} Some rating agencies currently work to integrate carbon policy risks in their rating methodologies (forthcoming).
	Sovereign debt ratings	The evaluation of credit/sovereign risk relies on the same general approach as for companies while considering different variables and risk typology. The exercise at country level is more sensitive to long-term issues relative to social, political and economic factors.	The Global Footprint Network started to work on stranded asset risk at the national level, via a set of macro factors that include physical climate risks. ³⁸
Financial institutions	Balance sheet stress tests	Stress tests are used to model the resilience of a financial portfolio/institution to risk scenarios (different probabilities and intensities). The risk factors can be defined by the institution or prescribed by supervisors. Scenarios can be built from either statistical descriptions of historical shocks, or combinations of hypothetical events. Usually, impacts of stress tests are measured on capital and liquidity. Sectorial/macro effects of low carbon transition can theoretically be modelled on GDP, inflation, interest rates, and integrated in stress tests as practiced in the banking and insurance industry. The lack of historical data and the time characteristics of carbon risk factors are a potential obstacle for a straightforward implementation of carbon stress tests.	A major international bank has begun exploring the implication of climate and carbon risks for operations and the balance sheet based on its existing financial stress testing framework. ³⁹ A large bank in China started to look at stress test models for some industries under scenarios of strengthening of environmental standards based on government plans. The Green European Foundation has commissioned a study to investigate a potential carbon bubble effect on the EU financial system. ²⁹
	Strategic allocation	An investor's strategy depends on factors such as risk appetite, time horizon, liability structure, investment objectives, etc. Its strategic asset allocation will thus rely on risk/return expectations for the different types of investable assets, which are function of a number of economic and political conditions. These conditions can clearly be influenced by the different carbon futures and pathways.	Mercer analysed how the strategic asset allocation of a long-term investor can be affected by different climate scenarios (including physical climate risks) and pathways. ³⁰ Earlier, the FRR (Fonds de Réserve des Retraites) started a similar preliminary approach. ⁴⁰
Regulation	Macro-prudential	Macroprudential analysis of the general risk to financial stability is generally based on an aggregation of stress tests at bank levels, with specific emphasis on liquidity and contagion (domino effect). The results are used for systemic stability surveillance, economic policy implication, recapitalisation plans, etc.	While no such examples exist to our knowledge as of today, the topic is now being raised, for instance by the University of Cambridge Institute for Sustainability Leadership. ⁴¹

3.2 RISK TO PHYSICAL ASSETS

Overview. In the first instance, carbon risks are associated with the economic viability of physical assets of companies, households, and governments under various decarbonization pathways. Risks from physical assets can appear from the relative costs of operating these assets and the prices in markets. Costs can either appear directly in the operation of the asset or afterwards, for example through post-facto legal, reputational, or politically-incurred changes in market and policy variables.

The analysis of carbon risks has focused less on the issue of costs and more on the expected cash flows of these assets. The cash flows of these assets are a function of the demand and price of the assets. In a low-carbon economy, physical assets with high exposure to carbon will be considered high risk (cf. next page).

Risks are particularly material for assets with long time horizons. A production / innovation cycle of 3 years (e.g. in the telecommunications sector related to cell phones) allows for a relatively flexible and rapid adaptation. Disruption is particularly damaging to long-term assets that cannot adapt. Unfortunately, climate-related infrastructure generally has a lifetime of 10, 20, 30, 40 years or more. Thus, a coal-fired power plant built in 2015 will in many cases not be viable in 20 or 30 years under a 2°C framework.

Climate and fossil fuel reserves. Fossil fuel reserves are one type of high-carbon assets with long time horizons and have arguably received the most attention in the debate on stranded assets. The potential impairment of physical assets was built on the concept of carbon budget, after the Meinshausen et al. (2009)¹⁷ article first highlighted the extent to which current fossil fuel reserves could not be burned under a 2°C economy.

The impairment of these assets can then be defined relatively simply by whether or not they will be 'productive'. Subsequent analysis suggests that only around one-fifth to one-fourth of today's proven fossil fuel reserves can be burned unabated (e.g. without some form of GHG-emissions capture / Carbon Capture and Storage, CCS) in a 2°C economy.

Recent analysis by McGlade & Ekins (2015)⁴² breaks down the specific implications for oil, gas, and coal reserves by geographic origin. The analysis suggests that 49% of global gas reserves, 33% of oil global reserves, and 82% of global coal reserves will not be burned in a 2°C economy.

These averages hide significant geographic differences. Gas and oil reserves in the United States are only marginally affected by the transition. On the other hand, Canada will only be able to burn 26% of its oil reserves unabated. The analysis references constraints by region or country, which may not apply to companies.

FIG. 17: UNBURNABLE GAS RESERVES BY REGION (SOURCE: McGLADE & EKINS, 2015)⁴²

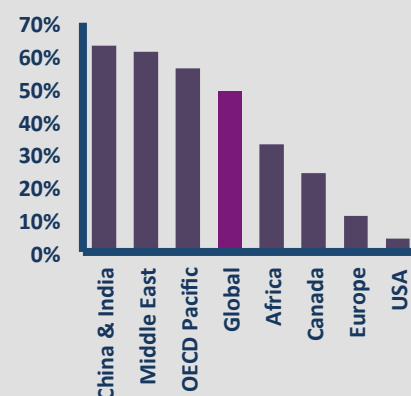


FIG. 18: UNBURNABLE OIL RESERVES BY REGION (SOURCE: McGLADE & EKINS, 2015)⁴²

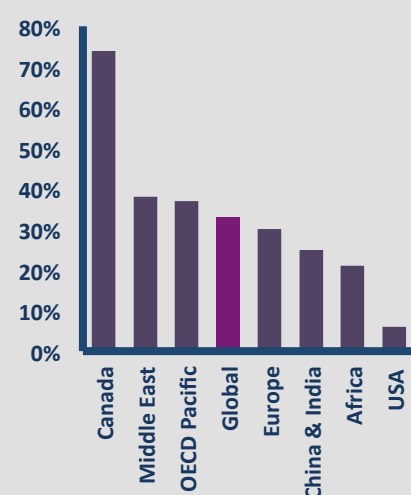
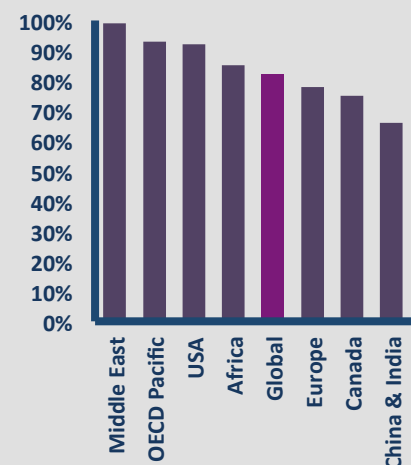


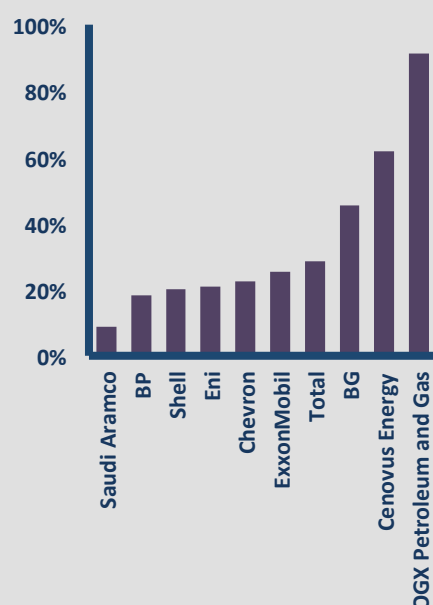
FIG. 19: UNBURNABLE COAL RESERVES BY REGION (SOURCE: McGLADE & EKINS, 2015)⁴²



CARBON SUPPLY COST CURVES

The Carbon Tracker Initiative has initiated a series of papers around the ‘carbon supply cost curves’ of fossil fuel reserves.³¹ The papers define an expected breakeven price for a decarbonization pathway, above which fossil fuel assets are likely to be stranded. The focus is on the potential impairment of assets associated with capital expenditure plans. Reports on the oil, coal and gas sector have been published.

FIG. 20: SHARE OF HIGH-COST CAPITAL EXPENDITURE OF OIL & GAS COMPANIES (SOURCE: CTI 2014)³¹



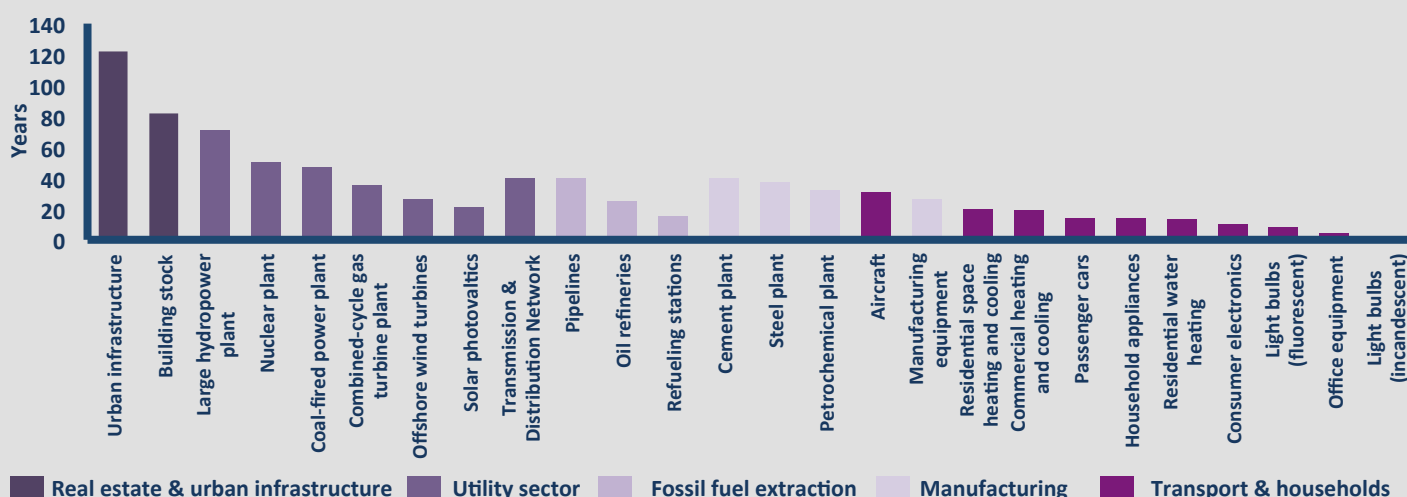
‘Stranded’ reserves by company. The Carbon Tracker Initiative has started exploring fossil fuel reserves impairment in a series of papers (cf. box on left).³¹ For the oil sector, the Carbon Tracker Initiative defined a breakeven price of \$85 / barrel above which capital expenditure plans are classified as ‘high-cost’. Fig. 20 demonstrates the range across which companies may be exposed to high-cost oil capital expenditure. High-cost projects relate in particular to oil sands exploration and production, notably in Canada, and ultra-deep offshore.

“Stranded assets” for other sectors. Beyond fossil fuel reserves, physical assets may be at risk in a range of sectors, in particular where assets have a long expected lifetime (Fig. 21). To date, analysis of physical assets in these sectors is limited and only partially addressed in the analysis of companies (cf. next page). The Oxford Smith School Stranded Assets Programme is producing an increasing body of research on these types of assets.

Shadow carbon pricing. Another way to integrate constraints related to the transition to a low-carbon economy is to assess a project investment based on its viability or opportunity under a ‘shadow carbon price’, assuming that such a price may be implemented at some point in the future. Some companies have started to introduce an internal “shadow price” of carbon in their decision-making process, either at project level or more strategic business planning level.⁴⁴ In 2013, 29 US companies reported to CDP an internal price on carbon in their business planning and investment decisions, varying from \$6 to \$60 per metric ton.⁴⁵

Public financial institutions, notably the European Investment Bank (EIB), have introduced a shadow carbon price in project assessment.⁴⁶ EIB’s approach consists of computing the GHG emissions with and without the project under assessment, and using a price of carbon to convert this difference of CO₂eq emissions into a monetary cost (positive or negative) over the lifespan of the project. The prices of carbon used by EIB reflect social cost of carbon estimates from the literature. This shadow pricing is independent of the current and projected value of carbon on emission trading schemes such as the EU-ETS, even for projects exposed to risk on carbon markets.

FIG. 21: EXPECTED LIFETIME OF VARIOUS PHYSICAL ASSETS (SOURCE: IEA 2011)⁴³



3.3 RISKS TO FINANCIAL ASSETS / EQUITIES AND CREDIT

Overview. Physical assets may be exposed to risks, but it is companies, households, or governments that will bear the burden of the associated economic loss. Models can capture the associated risks through assessing the impact of carbon risks on margins, building associated 'alternative' valuation models, such as 'carbon DCF' (discounted cash flows) models, or exploring the impact of climate change policies on credit risk.

Impact on net margins. In 2014, Allianz Global Investors and Allianz Climate Solutions in partnership with The CO-Firm and WWF Germany ran a pilot to model carbon risks in portfolio analysis (cf. box on right).²⁸ This bottom-up view helps investors identify the factors that differentiate future corporate performance such as alternative technological or business strategies. The aim was to assess the financial impact associated with carbon and energy regulation on industry and corporate return.

In a scenario based on politically plausible increases in carbon and energy prices over the next five years, regulatory costs might lower current margins for some companies. For example, this impact was particularly material for German companies (Fig. 22). If a cement company anticipates regulatory changes and takes operational measures, the negative margin impact is reduced and can even turn into a gain. It allows for an improvement of margins in the selected scenario by 4.7 EUR/t cement (Germany), 1.6 EUR/t cement (USA, California) and 2.1 EUR/t cement (China, Guangdong) respectively.

An earlier report from Société Générale Equity Research in 2007 calculated the potential cost of carbon for different companies and 25 industries, in a business-as-usual perspective of their business models, based on their modelled carbon intensity.³³ The model provided investors simple carbon risk indicators by company at a time where the short-term perspective on carbon price was upward, and materiality more perceptible.

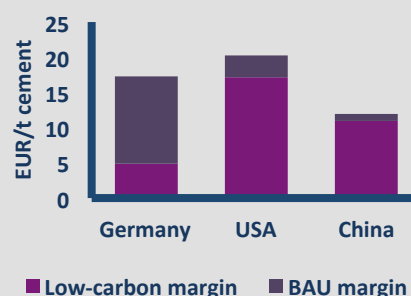
Impact on revenues. Another way to look at the impact of carbon risks on companies is to assess the impact on revenues or cash flows. Similar to the approach focused on margins, an assessment of revenues / cash flows can provide the basis for a valuation model that can define the potential impact of carbon risks on market capitalization (cf. next page).

The European broker Kepler-Cheuvreux conducted this analysis for the oil, gas, and coal sector.²⁷ The net impact of these volume and price effects under the IEA 2°C scenario would be to reduce the revenues of the oil industry by \$19.3trn until 2035, those of the gas industry by \$4trn, and those of the coal industry by \$4.9trn (all in constant 2012 USD). These estimates are relative to the IEA-defined New Policy Scenario. The impact is a function of both lower volumes and lower prices for fossil fuels (cf. box on right).

CO-FIRM NET MARGIN IMPACT²⁸

The Allianz Global Investors / Allianz Climate Solutions / CO-Firm / WWF Germany pilot carbon risks model focused on the cement and dairy industries in the US (California), China (Guangdong Province) and Germany. The model developers identified key regulatory scenarios by region and mapped the potential impact of these scenarios on each individual industry process of the sectors under review. The final step then involved assessing the adaptive capacity and cost / benefit analysis to arrive at the estimated net margin impact. The project is designed for the output to be integrated into existing valuation models. A follow-up is currently planned involving an additional 10 sectors for 2 regions.

FIG. 22: IMPACT OF CARBON RISK ON NET MARGIN OF CEMENT COMPANIES (SOURCE: CO-FIRM/ALLIANZ 2014)²⁸



KEPLER-CHEUVREUX REVENUES²⁷

Kepler-Cheuvreux compares the IEA's base-case scenario for global energy trends out to 2035 (known as the New Policies Scenario, or NPS) with its 450-Scenario (its scenario consistent with a 2°C world, 450S). Cumulative demand for fossil fuels until 2035 under the 450S would be lower by 45,000m tonnes of oil equivalent. In terms of price, the IEA sees oil prices averaging \$109/bbl (in constant 2012 \$) out to 2035 compared with \$120/bbl under the NPS, and coal \$87/tonne under the 450S versus \$105/tonne under the NPS. Gas prices are on average lower under the 450S than under the NPS (by 9% in North America, 13% in Europe, and 10% in Japan).

FOCUS – CARBON RISK FOR CREDIT

In a 2013 report, Standard & Poor's assessed the implications of future carbon constraints (policies aimed at moderating CO₂ emissions and reducing demand for hydro-carbon products) on the oil sector for medium sized, unconventional oil companies and major oil & gas producers, in a scenario where oil prices tend to decrease.³⁶ The results show a deterioration in the financial risk profiles of small non-diversified companies that could lead to downgrades over 2014-17. Majors would be less affected, thanks to better diversification and less relative exposure to high-cost projects such as oil sands.

In a recent report, Moody's analysed the effect of carbon reduction policies on companies' risk exposure for different sectors.³⁷ It appears that the coal sector is the most exposed, together with utilities and oil & gas to a lesser extent. The report explains that the credit ratings decline for the US coal sector since 2010 is partly reflecting emission reductions challenges.

Impact on sovereign debt. To date, potential carbon risks to sovereign debt is still under-explored. There is no public modelling exercise on how sovereign debt may be affected by the global transition to a low-carbon economy.

First research initiatives by S&P have focused on the climate risk for sovereign debt from a physical climate risk perspective.⁴⁷

The Global Footprint Network started to work on stranded assets risk at a national level, by looking at structural factors, policy factors and operational environment factors.³⁸

The French consultancy Beyond Ratings is currently building a model to assess risk to sovereign debt.⁴⁸ One key issue related to sovereign debt may be that in the short-term, the costs of the transition to a low-carbon economy may be high and thus create short-term fiscal strains.

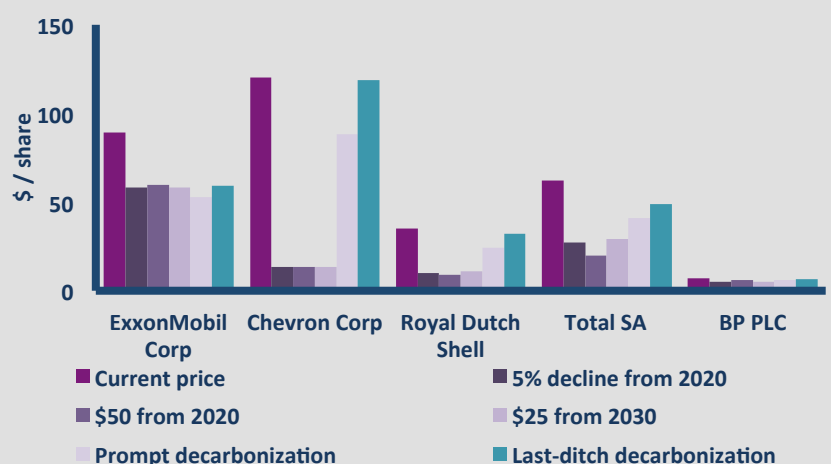
Impact on market capitalization. The first studies seeking to assess the potential impact of climate scenarios on companies valuation started 7 years ago. Carbon Trust / McKinsey (2008) showed the impact of a 2°C scenario on companies' valuations can reach up to 35% for oil companies, 44% for pure players in coal mining, and 65% for car manufacturers and aluminium producers.⁴⁹ This analysis, however, is at sector level and not company specific. A subsequent company-by-company analysis was provided by HSBC (2013), specific to the oil and gas sector.³⁴ Their results suggest that a 2°C scenario, with the associated 'stranded assets' and price effects, will impact European oil and gas companies across the board with over 40% of market capitalization at risk.

In a previous report, HSBC Global Research focused on the UK coal mining sector, using three different 'carbon future' scenarios affecting the demand of coal.⁵⁰ The results showed that significant carbon price constraints post-2020 leading to a declining coal industry could impact DCF valuations of coal assets by as much as 44%. The impact on UK major mining companies stocks value could be -7% under the most extreme scenario and as much as -15% for coal-heavy miners.

From studies to tools. The transition in risk assessment is slowly being made from studies and research analysis to tools for investors. Bloomberg launched a *Carbon Risk Valuation Tool*³⁵ to measure the potential impact on earnings and share price of five different climate-related scenarios (Fig. 23):

- 5% annual decrease in oil prices starting from 2020 relative to future prices;
- \$50 a barrel for oil from 2020;
- \$25 a barrel for oil from 2030;
- 80% decrease in EBIT fading in from 2020 and peaking in 2035; Prompt decarbonization;
- 80% decrease in EBIT fading from 2030 and peaking in 2035; Last-Ditch Decarbonization.

FIG. 23: CHANGES OF CURRENT SHARE PRICE AS A RESULT OF STRANDED ASSETS SCENARIO (SOURCE: BNEF 2014)³⁵



3.4 RISKS TO FINANCIAL INSTITUTIONS

Strategic asset allocation. In 2011, the investment consultant Mercer published the first report addressing climate change and strategic asset allocation in depth.⁵¹ The study highlighted that climate policy risks account for about 10% of total risk exposure of an average portfolio.

An enhanced version of the study was published in June 2015 (cf. box).³⁰ The approach is based on the identification of four climate risk factors (low-carbon technologies, resource availability, physical impacts and mitigation policies) and four climate scenarios (ranging from +2°C to +4°C in 2100). The model uses these parameters in addition to more traditional market assumptions. The output of the model maps each risk factor, under each scenario. It also identifies expected positive or negative movements, and the relative magnitude, for industry sectors within equities, and other asset classes, over the period 2015-2050. An important and original feature of this approach is that it covers both carbon and physical climate risks, which allows an integrated view of how a climate-related risk/return impact can affect a portfolio on the long run.

In 2008, the French public investor FRR launched a similar project targeting the definition of investment strategy, with a wider environmental perspective (climate, fossil fuel resources, biodiversity, and water).⁴⁰ The report (self-labelled as preliminary) proposed to investigate several ways to integrate environmental issues in strategic allocation, on the basis of four climate scenarios. For each, risk/return ratios were built for different asset classes, and discussed in terms of geographic and sectorial impacts. Ultimately, the preliminary report was not followed-up by further analysis, the visionary approach perhaps ahead of its time.

Technology diversification. An alternative approach that is not directly related to a risk model is assessing the diversification of financial portfolios and their associated exposure to various decarbonization roadmaps. The key challenge for financial institutions is assessing exposure not just at sector level but also for different technologies (e.g. renewable electricity generation, hybrid vehicles, electric vehicles). The 2° Investing Initiative published a first report on the issue in 2014 (cf. box).⁵³ A follow-up study exploring implications for sector and energy technology exposure in equity portfolios under various IEA scenarios is planned for the fall 2015.

Stress testing balance sheets. Some financial institutions have started exploring integration of carbon risks as part of internal risk management at balance sheet level. Most of these approaches are currently not publicly available. Given the prominence of stress-tests both in risk management and micro- and macroprudential regulation, they are an important missing piece to cover the financial institution level, and a promising avenue moving forward (cf. focus p.20-21).

GREEN EUROPEAN FOUNDATION (GEF) CARBON BUBBLE²⁹

The GEF published a study measuring the potential impact of the impairment of fossil fuel reserves on 23 European pension funds and 20 European banks. The report assumes losses on exposures to fossil fuel firms ranging from 60% on equity investments to 20% on credit.

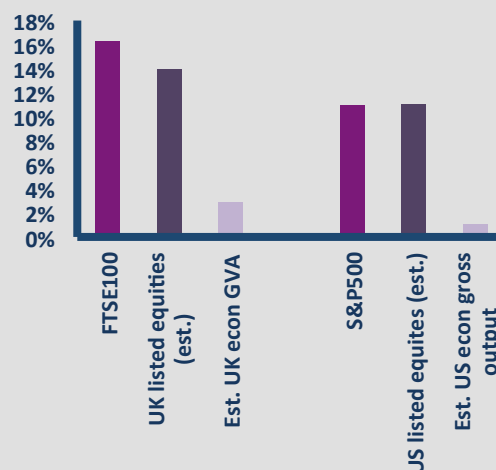
MERCER INVESTING IN A TIME OF CLIMATE CHANGE³⁰

In this 2015 report, Mercer shows that investment strategies dealing with climate change cannot be limited to asset classes allocation, but need to go down to industry sector or even sub-sector levels. Indeed, the results show large heterogeneity of climate impacts on expected returns (most extreme being between coal [-4.9% per annum] and renewables [+3.5% p.a.]), whereas portfolio level analysis averages the effects as a result of diversification.

2° INVESTING INITIATIVE (2°ii) INDEX DIVERSIFICATION⁵³

2°ii (2014) highlighted the potential exposure to idiosyncratic risks of equity portfolios by comparing the sector and energy technology diversification of cap-weighted equity indices with listed equity markets and the economy (Fig. 24).

FIG. 24: SHARE OF OIL & GAS IN INDICES, LISTED EQUITY MARKETS, AND ECONOMY (SOURCE: 2° INVESTING INITIATIVE 2014)⁵³



FOCUS – STRESS TESTING FINANCIAL INSTITUTIONS WITH CLIMATE & CARBON RISKS

Definition of stress tests. Stress testing is a tool to assess the robustness and resilience of an entity (firm, group of firms, ecosystem) to adverse conditions and shocks. In finance, a stress test is a projection of the financial situation of an institution under a scenario defined by a specific set of adverse conditions that may be the result of several risk factors over different time periods with consequences that can extend over months or years. A stress-testing framework encompasses 4 stages: identification of risk factors, scenario design and calibration, impact studies on targeted perimeter/entity, risk assessment and decision making. Today, stress testing is a key part of the internal risk management system of financial institutions. Banks use stress testing to assess the bank’s capital capacity to absorb large losses and to identify mitigation measures they can implement to reduce risk and preserve their capital. Stress testing can be used to assess operational risk, but banks mainly use it as a tool for measuring credit and market risk exposure.

The concept of “stress-testing” for financial institutions. The importance of stress testing in the micro/macro prudential financial regulation and supervision framework has grown in the aftermath of the recent financial crisis. Stress testing helps players understand and be able to respond to the exposure of both individual financial institutions (‘micro’) and the financial sector as a whole (‘macro’) to economic shocks. Concerning microprudential regulation, stress testing has become part of regulatory requirements for internal risk management and supervision in the frame of the Basel III Accord at the international level and new regulations at national or regional level (EU’s CRD IV - CRR IV). In the case of the United States, internal stress testing by covered financial institutions under the Dodd-Frank Act is mandatory. Stress tests have also been conducted in other markets, notably China, Japan, and Brazil.

FIG. 25: THE DEVELOPMENT OF STRESS-TESTS PRE / POST FINANCIAL CRISIS (SOURCE: OLIVER WYMAN 2010⁵⁴ & 2° INVESTING INITIATIVE)

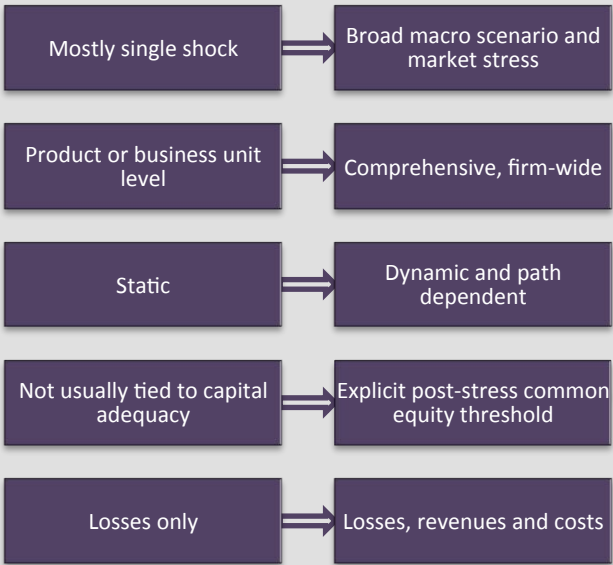


FIG. 26: PROJECTED BANK LOSSES ASSUMED IN US STRESS-TEST 2014 (SOURCE: FED 2014)⁵⁵

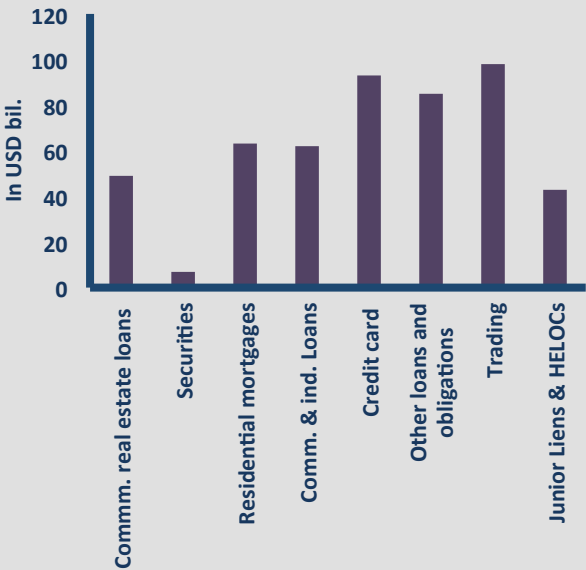
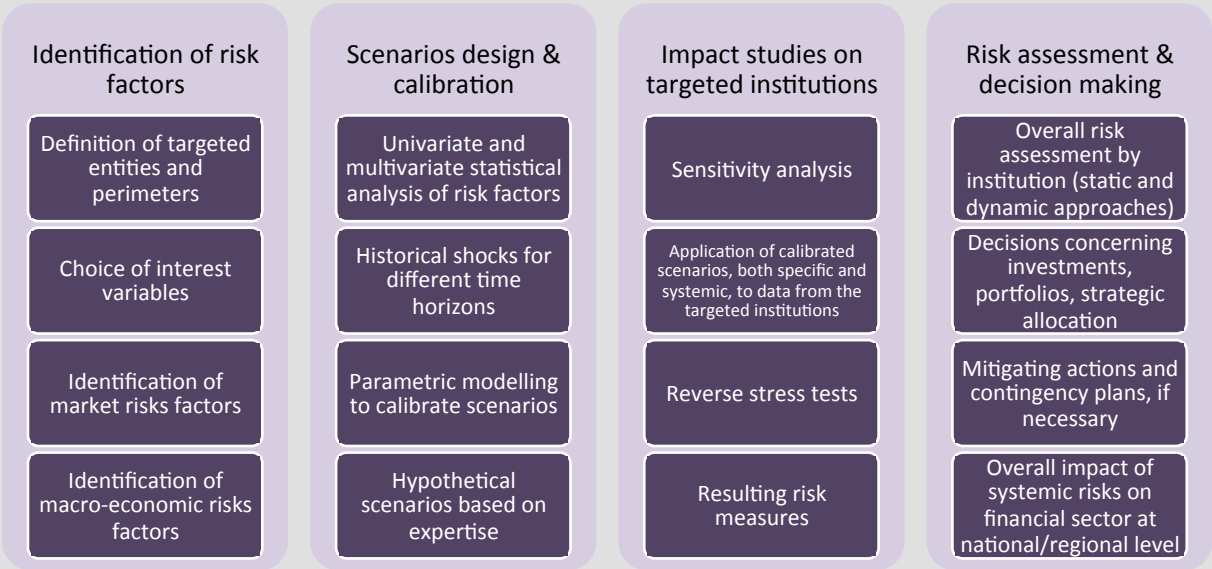


FIG. 27: STRESS TESTING FRAMEWORK (SOURCE: 2°ii)



Climate & carbon stress tests. The development of stress-testing at balance sheet level following the financial crisis has led some to suggest that stress-testing concepts should similarly be applied to climate change (e.g. in the insurance industry: ‘1-in-100 Initiative’, 2014)⁵⁶ or more explicitly carbon risks, in particular for banks (GEF, 2014).²⁹ Given the mainstream nature of stress-tests in risk management frameworks, the most effective way to mainstream carbon risk assessment may be by integrating them into balance sheet stress tests. This approach was adopted recently by a major international investment bank.³⁹

There are some underlying challenges to mixing the mainstream stress-testing approach and climate & carbon risks. First, stress-tests are usually conducted over short-term time horizons (up to 1-2 years in many cases). As outlined above, this time horizon may not be compatible with carbon risk, but this time horizon issue is not a modelling obstacle in itself. Second, stress-test scenarios rely on point-in-time ‘shocks’ to the financial system. This may be appropriate to assess the impact of some carbon risks factors: for example, market actors may decide to re-price high carbon assets based on changes in market sentiment and climate policies. Carbon risks may also be non-cyclical, as high-carbon companies slowly lose value over time. Stress-tests designed to measure cyclical shocks may have to be adjusted to capture non-cyclical and gradual shocks to markets. This also is not a fundamental barrier as macroeconomic stress scenarios include trends and gradual shocks. At this stage, these mechanisms are still under-explored, so further research is needed to completely integrate climate & carbon risks in traditional stress-testing approaches as undertaken in banks (cf. p. 25).

FIG. 28: EXAMPLES OF RISK FACTORS AND RELATED ASSESSMENT APPROACHES AVAILABLE (SOURCE: 2°ii)

Examples of climate & carbon risk factors and stress scenarios	Impact assessment on mainstream risk metrics	Existing carbon risk and valuation approaches available to feed the assessments
Individual and sectorial effects of low-carbon transition on volumes and prices	Impact assessment on market risk through market values of projects and companies	Effects of stranded assets under a +2°C scenario on companies’ valuations have been estimated in some sectors at the sector and firm levels. Valuation models allow assessment of the impact of climate scenarios on exposed companies, based on assets that can become stranded (e.g. BNEF). ³⁵
	Impact assessment on credit risk through creditworthiness and default rates	Analysis of the impact of future climate policies now gives informative insights at sector level (e.g. CO Firm/Allianz) ²⁸ and starts to inform on the creditworthiness (e.g. Moody’s, S&P). ^{36,37} While creditworthiness is still difficult to assess as a function of climate scenarios, the effect on revenues and margins becomes clearer (e.g. Kepler-Cheuvreux). ²⁷
Macroeconomic effects of the low-carbon transition on carbon and energy prices, and on GDP growth, inflation, interest rate curve in baseline, adverse and stress macro-economic scenarios (up to five years horizon), including low-carbon, provided by supervisory authorities	Impact assessment on bank activity, market and credit risks, liquidity and solvency risks	Models of carbon prices over the coming decades are commonly used (e.g. EIB ³² , Mercer), ³⁰ but this new risk factor has to be added in ‘traditional’ macroeconomic scenarios used by financial institutions and supervisors. Some approaches, using energy prices as proxies, are already embedded in classic scenarios, but, besides the link between climate scenarios and energy prices, the impact of the transition on macroeconomic variables does not appear to be fully investigated and taken into account. ⁵⁷
Systemic climate and / or carbon crisis affecting simultaneously different asset classes [correlations between asset prices are usually higher during crisis limiting diversification effects]	Assessment of liquidity and solvency risks at financial institution level and systemic risk	The potential risk/return correlations between asset classes as a result of climate scenarios can seem intuitive, as climate policies and the overall climate challenge are fundamentally cross-cutting, but no analysis is available to date at financial sector level to prove the extent to which correlations really exist, and if effects in some sectors/asset classes actually counterbalance others, for example with regard to climate-friendly investments as hedges to high-carbon investments.

BANK OF ENGLAND LETTER TO INSURANCE COMPANIES

“Under the UK Climate Change Act 2008, the Prudential Regulation Authority (PRA) received an invitation from the Department for Environment, Food and Rural Affairs (Defra) to submit a Climate Change Adaptation Report. In 2013 a project team was established to compile the Climate Change Adaptation Report and lead on the exploration of climate risks in the financial system. This team is supported by an internal working group comprising senior staff within the PRA and is part of the PRA’s Insurance Directorate. The report is set to be delivered to Defra by July 2015, for publication thereafter. This report, alongside the others resulting from the second round of Adaptation Reporting, will inform the next UK Climate Change Risk Assessment, to be laid before Parliament in 2017.”

- Bank of England Website⁵⁸

BRAZILIAN CENTRAL BANK – ENVIRONMENTAL AND SOCIAL RISKS

“The Brazilian Central Bank (BCB) enacted Resolution 4,327 on April 28, 2014, establishing guidelines for financial institutions in connection with the creation and implementation of Social and Environmental Responsibility Policies (SERP). The resolution provides for, among other things, governance strategies, regarding the management of social and environmental risk. It requires specific criteria for risk assessment only for those activities with a higher potential for causing social and environmental damages (these activities were not specified). Institutions should consider the recordkeeping of real losses due to social and environmental damages, which should be done for a minimum period of five years and any prior assessment of potential negative social and environmental impacts of new products and services, including its relation to reputational risks.”

- Mayer & Brown 2014 Legal Brief⁵⁹

3.5 REGULATION AND SUPERVISION OF FINANCIAL ACTIVITIES

Overview. To date, there are no known examples of regulators integrating carbon risks into their micro- or macroprudential risk assessment frameworks. Existing initiatives to integrate carbon risks into risk and valuation models are limited to the private sector. The lead and organizational responsibility depends on the country, resting either with the central bank, a financial regulatory authority (e.g. European Securities and Markets Association), and/or the national finance ministry.

One of reasons why regulatory action has been limited is that the evidence of short-term risks has been limited. A study from the Green European Foundation²⁹ (cf. p.25) quantified the risk at 0.4% loss of total assets in the European banking sector and 2.5% for the European pension fund sector, assuming an overnight transition to a 2°C policy framework. These numbers do not necessarily mobilize significant regulatory attention.

At the same time, this report has highlighted the significant limitations to these models. In the case of Green European Foundation study,²⁹ the study focused only on the energy sector. Other models, especially short-term stress-tests, fail to capture long-term risks, which may be highly material from a regulators or financial supervisors perspective.

In Europe, this is particularly the case given the mandate of the European Central Bank. Article 127(1) of the Treaty on the Functioning of the European Union, governing the objectives of the European System of Central Banks, states that “Without prejudice to the objective of price stability, the ECB shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union as laid down in Article 3 of the Treaty on European Union.”⁶⁰ Article 3 of the Treaty of the European Union is not limited to economic growth objectives, but a somewhat abstract set of goals including “peace, security, and the sustainable development of the Earth” (Article 3).

Existing initiatives. While financial regulators have not begun to integrate climate & carbon risks, they are beginning to respond to the issue, in particular together with a broader view on physical and non-physical climate risks. The Bank of England is currently drafting a Climate Change Adaptation Report (cf. box on left).⁵⁸ The G20 has tasked the Financial Stability Board to begin looking at the issue of climate risk.⁶¹ Initiatives are also prominent in developing and emerging economies. The Brazilian Central Bank has set guidelines for financial institutions to assess environmental and social risk, of which climate may be a part (cf. box on left).^{7,59} The People’s Bank of China, the Chinese central bank, has launched a research initiative in part instigated by the UNEP Inquiry on Designing Sustainable Financial Markets.⁶ France is currently setting into place an ambitious regulatory framework in its energy transition law (p. 24).⁶²

IV. IMPLICATIONS FOR FIs AND REGULATORS

4.1 OVERVIEW

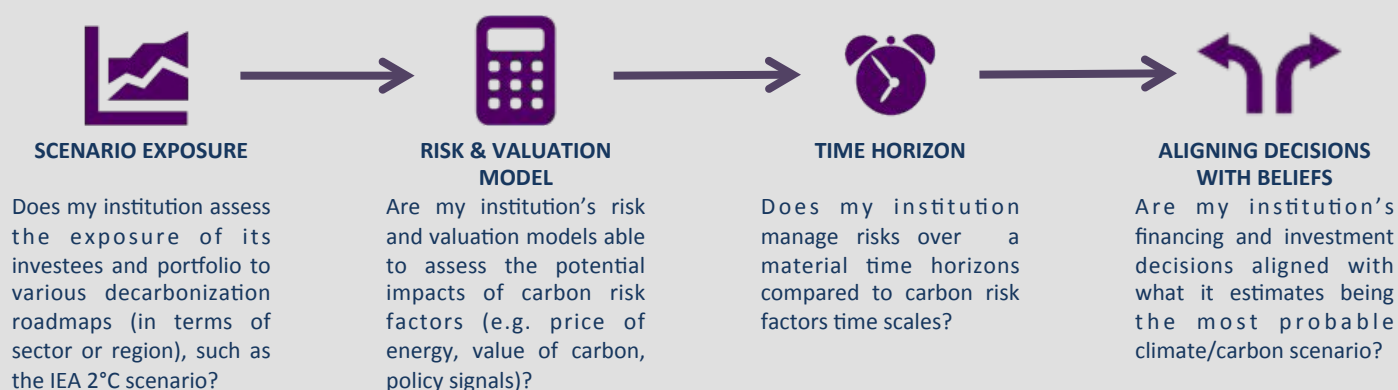
Assessing the mis-assessment of risks. The fundamental premise of the narrative on carbon risks is that these risks are currently not accurately assessed by risk and valuation models and, by extension, financial institutions. The first step then is trying to understand the extent to which these institutions accurately assess carbon risks. This can be done by tracing why a mis-assessment may take place in the first place (Fig. 29):

- **Scenario exposure:** Financial institutions may wish to explore the extent to which they are exposed to decarbonization scenarios, both in terms of industrial sectors and regions of activities.
- **Risk & valuation models:** Financial institutions can challenge the extent to which existing risk and valuation models, either implicitly or explicitly, take carbon risk factors into account.
- **Time horizon:** Financial institutions can question the time horizons over which these risks can be material and whether these horizons are consistent with those of the institution.
- **Aligning decisions with investment beliefs:** Financial institutions can see whether investment and financing decisions are aligned with the institution's investment beliefs around decarbonization pathways and the extent to which these beliefs are consistent with those of the market and policy makers.

Options today. The climate & carbon stress test family is still in its infancy and there is no existing ready-to-use system available to manage carbon risks for the financial sector. However, it appears a turning point has been reached. The discussion demonstrated that there have been significant steps in integrating carbon risks into existing risk and valuation models. While there are still question marks around the short-term materiality of these risks, there are practitioners who are ready to investigate and implement new approaches. These practitioners think carbon risk can become material in the future, if not already today. As outlined above, financial regulators both in developed and developing economies are starting to respond. While still couched in the context of a broader assessment of climate change, this work is increasingly focusing on carbon risks, as evidenced by the review in this report.

Different mechanisms are needed to assess the risk in the interest of all, from financial institutions to governments to citizens. The mobilisation of actors across the investment chain in a collaborative way can efficiently structure the new mechanisms that must be created, and improve the existing ones. Addressing issues such as data access, shared methodologies, and common scenarios, would level up the topic, which at this stage just needs a catalyst to bloom.

FIG. 29: STEPS TO UNDERSTANDING IF/HOW CARBON RISKS ARE ASSESSED IN A FINANCIAL INSTITUTION
(SOURCE:2°ii)



4.2 THE WAY FORWARD

The following maps the key factors in the way forward:

A. Integrate climate-related risk considerations in existing disclosure and transparency standards, with an emphasis on time horizons



Financial institutions

Banks and investors can already operationalize existing initiatives at a basic level to increase transparency on 'hidden' risks in financial portfolios and loan books. Financial institutions may have a key impact on both regulatory requirements and voluntary reporting frameworks. Their initiatives can demonstrate key data gaps that can be overcome, e.g. through corporate disclosure requirements.



Central banks and financial regulators

Regulators can improve disclosure and transparency standards at corporate level, for financial products, and financial institutions. From a risk perspective, better financial and non-financial reporting by companies will make it easier to assess these risks. This relates in particular to defining relevant time horizons for risk reporting, strengthening transparency around corporate impairment tests assumptions, and improving non-financial disclosure that may be relevant from a carbon risk perspective (e.g. breakdown of capital expenditure by energy technology). For impairment tests for example, companies can respond to risks based on the lifetime of their assets and disclosing the reference scenario used. Reporting can also address financial institutions. The European Commission proposed to include "a qualitative assessment of new or emerging risks relating to climate change, use of resources, and the environment" in the revision of the IORP (Institutional Occupational Retirement and Pensions) Directive.⁶⁴ This is a first step towards more quantitative assessments. The French Law on Energy Transition⁶² voted by the Low Chamber in May 2015⁶⁵ explicitly requires both financial and non financial companies to report on their exposure to climate risks; it also requires that financial institutions disclose their climate-friendly investments as well as their financed emissions (GHG footprint). Finally, it requires the government to submit a report to Parliament on the implementation of a stress-test scenario representing the risks associated with climate change. Such regulatory initiatives can easily be replicated in other countries. Strengthened reporting requirements in financial markets can also extend to financial products. Regulation could strengthen the transparency around carbon risks communicated in Key Information Documents (KIDs) to retail investors.⁶⁶



Rating agencies and data providers

Financial and non-financial data and metrics providers (e.g. CDP, rating agencies) can help close data gaps and data uncertainty through R&D, providing better transparency around carbon risk data options for investors, and demonstrating the extent to which they differ from traditional financial data.

B. Establish the materiality of carbon risk at individual asset, portfolio and balance sheet levels



Regulators, financial institutions, data and metrics providers, and research organisations

The materiality of carbon risks throughout the investment chain is still poorly understood. All market actors, from regulators to financial institutions, to data providers and civil society, need to go one step further in order to determine under which conditions the risks associated with the transition to a low-carbon economy may be material for the financial sector and how to price and respond to these risks.



The focus is particularly relevant in terms of moving from the individual asset level to the portfolio and balance sheet levels. These are to date only covered by exploratory studies. Some of this work can be done in collaboration with joint research initiatives currently being developed, such as the ET Risk project lead by the 2° Investing Initiative with the Oxford University Smith School, Carbon Tracker Initiative, The CO-Firm, S&P, Kepler-Cheuvreux and CDC Climat Research.⁶⁷ Other examples include collaborations between CDP, UN Global Compact, World Resources Institute and WWF,⁶⁸ S&P and Carbon Tracker Initiative,³⁶ The CO-Firm, Allianz and WWF-Germany,²⁸ or the Bank of England, Cambridge Initiative for Sustainability Leadership and ClimateWise.⁶⁹



The research can also focus on the broader questions, notably the 'tragedy of time horizons', which examine the extent to which traditional models are able to capture the particular brand of risks labelled as carbon risks.

C. Integrate different climate / carbon scenarios into risk and valuation models



Academia and research administrations

One key challenge to measuring carbon risks' impacts is the translation from climate goals to financial institutions (cf. p.13). A key part of this translation involves turning transition roadmaps into investment and financing roadmaps through the definition of “+2°C-compatible” portfolios. This work is currently being funded by the European Commission and led by the 2° Investing Initiative.⁷⁰ Academia may also have a key role in more fundamental research on risk models and portfolio optimization design. A research initiative at Oxford University is currently looking at building optimal ESG and climate portfolios.⁷¹



Financial institutions

Banks can build on the pilot experiments currently undertaken to integrate decarbonization scenarios into risk management frameworks. The main objective is to translate “carbon scenarios”, with their specific shocks and timeframes, into more traditional financial stress test scenarios.

The institutional investment field has seen marginal model development to date. Key next steps may include risk models but also revisiting the question of ‘optimal diversification’ (cf. p.19) and other portfolio optimization approaches.



Rating agencies and data providers

Financial data providers, rating agencies, and experts in scenario approaches can contribute both in terms of scenario building, and risk and valuation tool development. Credit rating agencies can integrate carbon risk into their models. Sell-side research analysts can explore alternative assumptions in DCF models. Portfolio optimization tools providers can upgrade their offer and investment consultants and other key actors can provide inputs into valuation models (cf. carbon risk on margin models, p.17).

D. Explore the systemic risk issue



International and Non-Governmental Organisations

Given that the topic has hardly been on the radar of financial regulatory institutions to date, a first step is for international institutions (typically UN framework) and NGOs to demonstrate why this is a regulatory issue. The UNEP Inquiry recently played such a role in China.⁶



Central banks and financial regulators/supervisors, and academia

Central banks and financial regulators can explore the question of possible systemic risk associated with the transition to a low-carbon economy, in particular with regard to questions about transmission channels (e.g. network effects, etc.), systemic market mis-pricing of risks, and questions about the efficient intermediation of capital in terms of allocation to different sectors and technologies. One way forward may be to explore further the question of what a “2°C-compatible” financial market would look like and the extent to which current financial markets are misaligned with public policy targets and global climate objectives.

E. Addressing climate & carbon risk issues as part of international cooperation



Climate risk issues are on the agenda of a number of countries and recently increasingly on the agenda of international partnerships. The G7 is debating the issue of climate change in finance both to mobilise renewable energy investment in emerging economies, recognise and address climate risk, and define the alignment of assets with climate goals.^{5,72} This assessment may also be connected to risk indicators. As outlined above, the G20 has put the issue on the agenda of the Financial Stability Board.⁶¹ Given the range of different initiatives at national and regional level, and the global connectedness of these risks, cooperating on increasing the transparency, and learning about best practice is likely to improve the ability to better measure and manage potential risks associated with the transition to a low-carbon economy.

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The 2° Investing Initiative [2°ii] is a multi-stakeholder think tank working to align the financial sector with 2°C climate goals. Our research and advocacy work seeks to:

- Align investment processes of financial institutions with 2°C climate scenarios;
- Develop the metrics and tools to measure the climate performance of financial institutions;
- Mobilize regulatory and policy incentives to shift capital to financing the transition to a low-carbon economy.

The association, founded in 2012, is based in Paris and New York, with projects in the US, Europe, and China. Our work is global, both in terms of geography and engaging key actors. We bring together financial institutions, companies, policy makers, research institutes, experts, and NGOs. Representatives from all of the key stakeholder groups are also sponsors of our research.

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This report has been produced in the frame of a partnership between the 2° Investing Initiative and the UNEP Inquiry into the Design of a Sustainable Financial System



Inquiry: Design of a Sustainable Financial System

The Inquiry into the Design of a Sustainable Financial System has been initiated by the United Nations Environment Programme to advance policy options to deliver a step change in the financial system's effectiveness in mobilizing capital towards a green and inclusive economy – in other words, sustainable development. Established in early 2014, it will publish its final report in October 2015.

More information on the Inquiry is at: www.unep.org/inquiry/ or from: Mahenau Agha, Director of Outreach mahenau.gha@unep.org

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