Large Scale Renewables: Successes and Challenges

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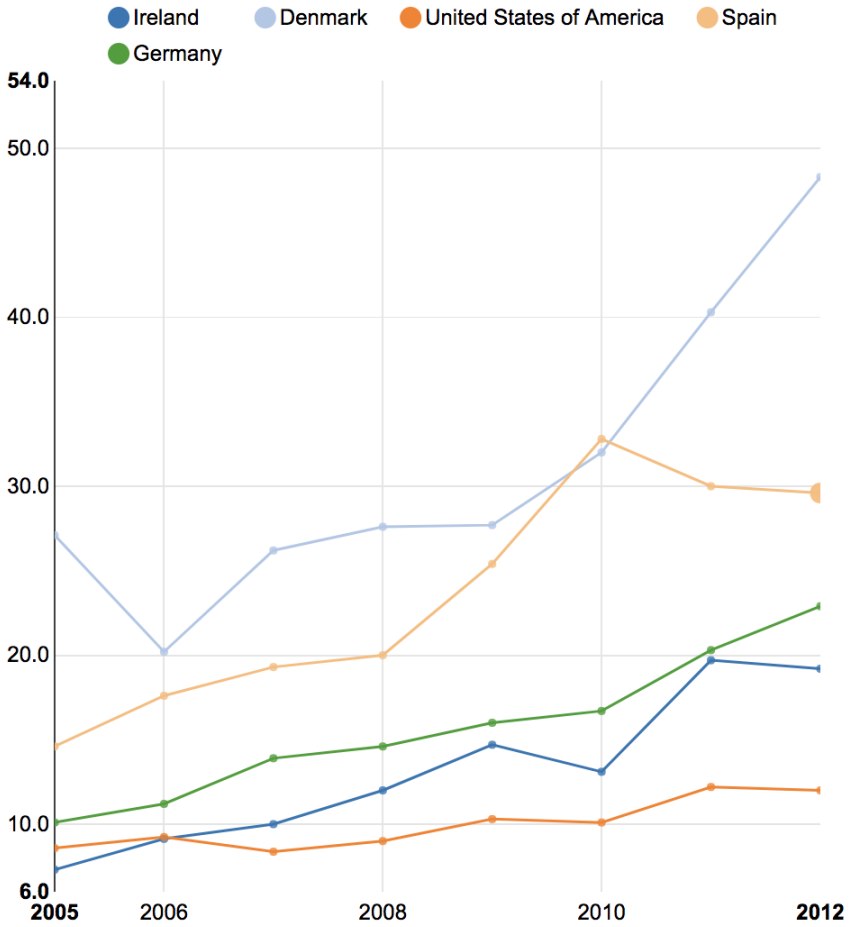
Introduction

Growth in large scale renewables

- Many countries have adopted ambitious **Renewable Energy Programs** (e.g., EU, RPS in US states) targeting minimum levels of renewable generation.
- Governments provide incentives to investment through **subsidies, production tax credits, feed-in-tariffs**, ...

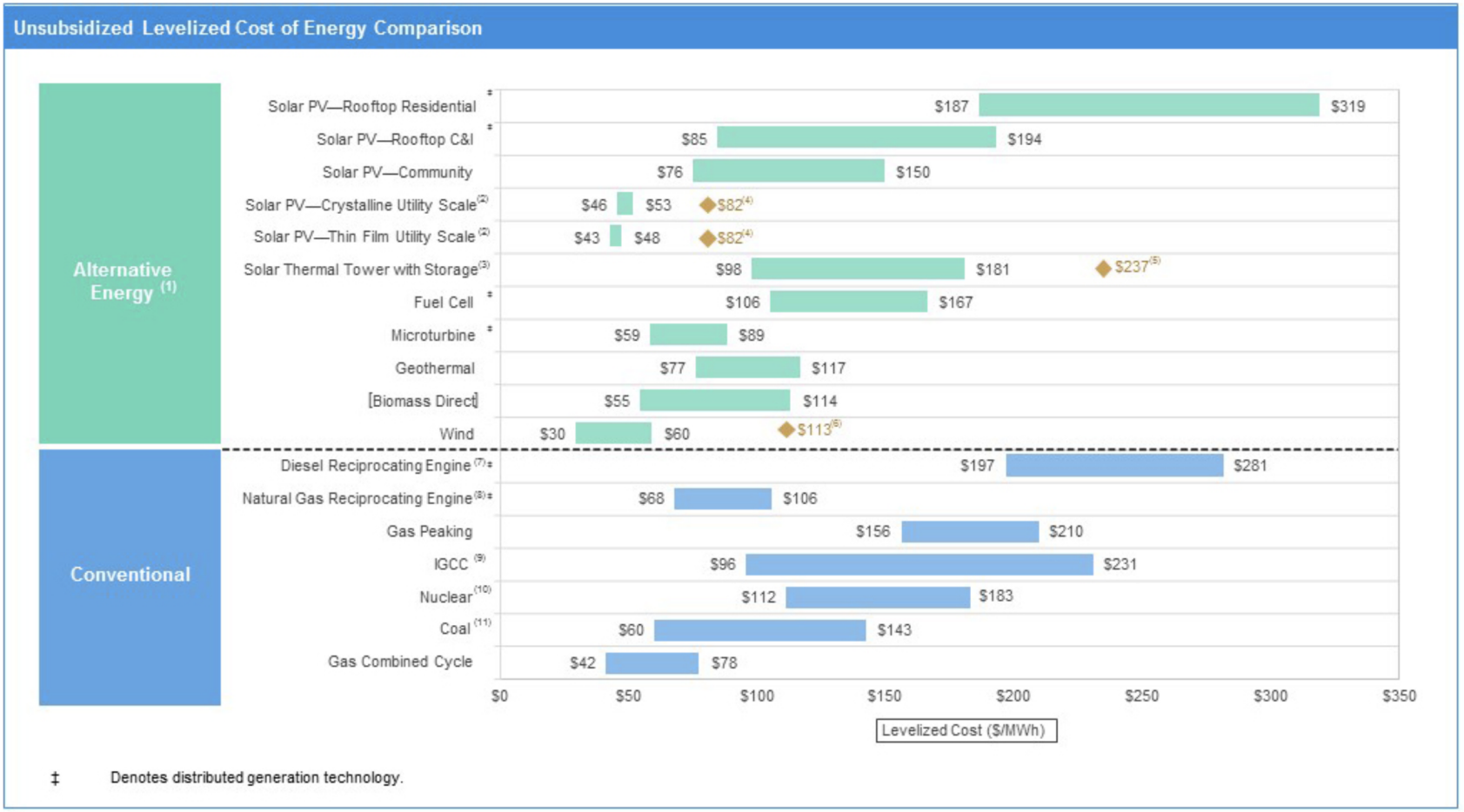
- *What are the successes?*
- *What are some of the limitations? Cautionary tales?*

Trends in renewable generation



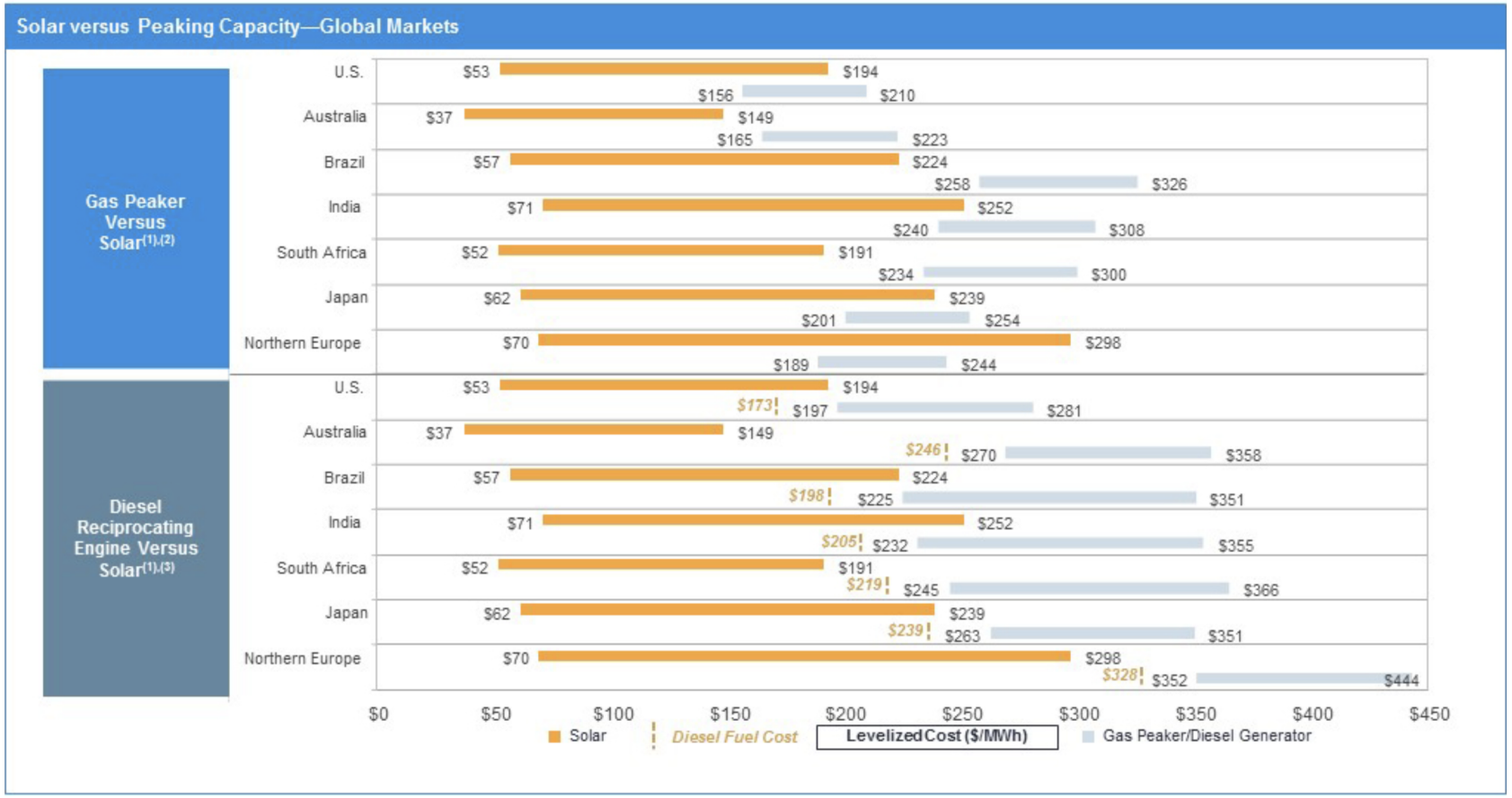
Source: GGKP. *Data source:* The World Bank: Renewable electricity (% in total electricity output) :World Bank and International Energy Agency.

Large-scale renewables a key part of the picture...



Source: Lazard.

...*potentially* even more in other economies.



Source: Lazard.

Expected growth continues

- **Levelized cost of energy** estimates (LCOEs) subject to several caveats (Joskow, 2011; Borenstein, 2012).
- Yet, given cost estimates, large scale renewables seem to have **ample potential**.

- **Subject to having an electricity grid** to support them.
  - In some developing countries, likely as part of more fragmented grids, e.g. at a more local level.
  - Utility-scale seems could potentially have advantages, in spite of implementation difficulties due to absence of infrastructure.

Successes

- Cost of renewables (and large-scale in particular) have **dramatically dropped** in the last ten years.
- Several countries have ramped up renewable transition at relatively fast pace (e.g., Germany, Spain, Texas, California), with some challenges but **no major disruptions**.
- Renewable policies have often received **wider support** than other climate policies.
  - In the United States, favored by several states that would not agree on carbon pricing.

Challenges

I will focus on two main difficulties:

1. **Operational challenges**
   - Costs of integrating renewables likely to increase as renewable penetration ramps up.
2. **Political economy challenges**
   - Wide support for these policies likely to decline as renewable penetration ramps up.

Operational challenges

Transition towards 100% renewables can be difficult

- Can **wind and solar** ensure a transition towards 100% renewable?
  - Recent controversy regarding study (Jacobson et. al, 2015) that suggested wind, solar and hydro are enough.
  - Study suggests assumptions needed are too strong, still a long way (Clack et al., 2017, `doi:10.1073/pnas.1610381114`).

- Still an **open question**, highlights how operational challenges are still part of the debate.

Understanding limits of renewables

- Previous studies have examined the impact of wind and solar on electricity markets:
  - **Engineering approach**: typically ex-ante analysis, with structural engineering model.
  - **Economics approach**: typically ex-post analysis, but for now based on limited data, structural models used to forecast into the future.
- I examine data from markets with substantial renewable penetration to quantify costs.
- Today, focus on Iberian Electricity Market (IEM).

Industry Background

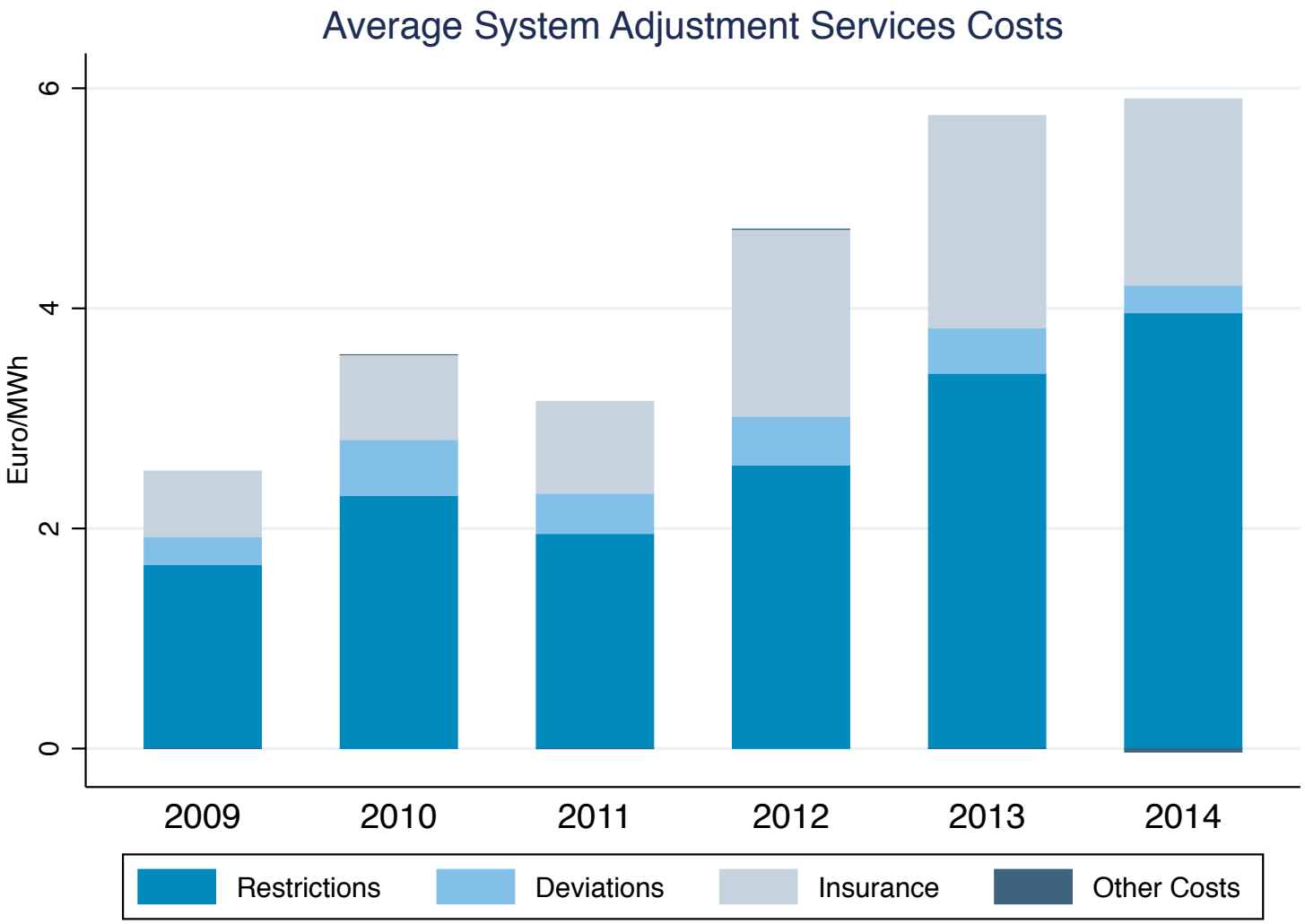
- **Supply**: generation plants (CC, thermal, nuclear, solar, wind,...).
- **Demand**: direct consumers, retailers, or others.
- **Trading**: day-ahead and sequential markets to trade power and determine marginal energy price.
- **System adjustment services**: additional charges.
  - Costs of solving technical constraints (i.e. congestion).
  - Costs of adjusting reserve or frequency-power regulation.
  - Costs of solving generation-demand deviations.

Wind tends to reduce market prices...

	(1) Price Day-Ahead	(2) Price Intra-Day 1	(3) Adjustment Cost
Wind Forecast	-2.3216	-2.2152	0.1727
	(0.0488)	(0.0527)	(0.0126)
Demand Forecast	2.0330	1.6206	-0.0026
	(0.0613)	(0.0660)	(0.0406)
Temperature	0.6794	0.3991	0.0073
	(0.0467)	(0.0519)	(0.0174)
Temperature^2	-0.0066	-0.0042	-0.0002
	(0.0004)	(0.0004)	(0.0001)
Observations	52279	52135	52279

Notes: Own elaboration based on REE and OMIE data. Included as controls are month-of-sample, hour, day-of-week.

...but not adjustment costs.



Source: Own elaboration based on data from REE.

Measuring the impacts of intermittency...

- Wind forecast and wind power's output determined by **weather shocks**, hence **exogenous**.
- Regression Specification for Intermittency:

$$C_t = \lambda_0 + \lambda_1 V_t W_t + \lambda_2 U_t W_t + \gamma X_t + \psi_t \ . \tag{1}$$

- Marginal Effects:

$$\text{MAW} = \lambda_1 \bar{V} + \lambda_2 \bar{U} \ , \tag{2}$$

$$\text{MAV} = \lambda_1 \bar{W} \ , \text{ and } \text{MAU} = \lambda_2 \bar{W} \ . \tag{3}$$

- Controls: hour, month and week day fixed effects, and actual demand.

...as more and more wind comes inline.

- Different levels of integration may have different effects.

$$C_t = \lambda_0 + \lambda_1(W_t)V_t + \lambda_2(W_t)U_t + \gamma X_t + \psi_t \ . \tag{4}$$

- Regression Specification for Intermittency:

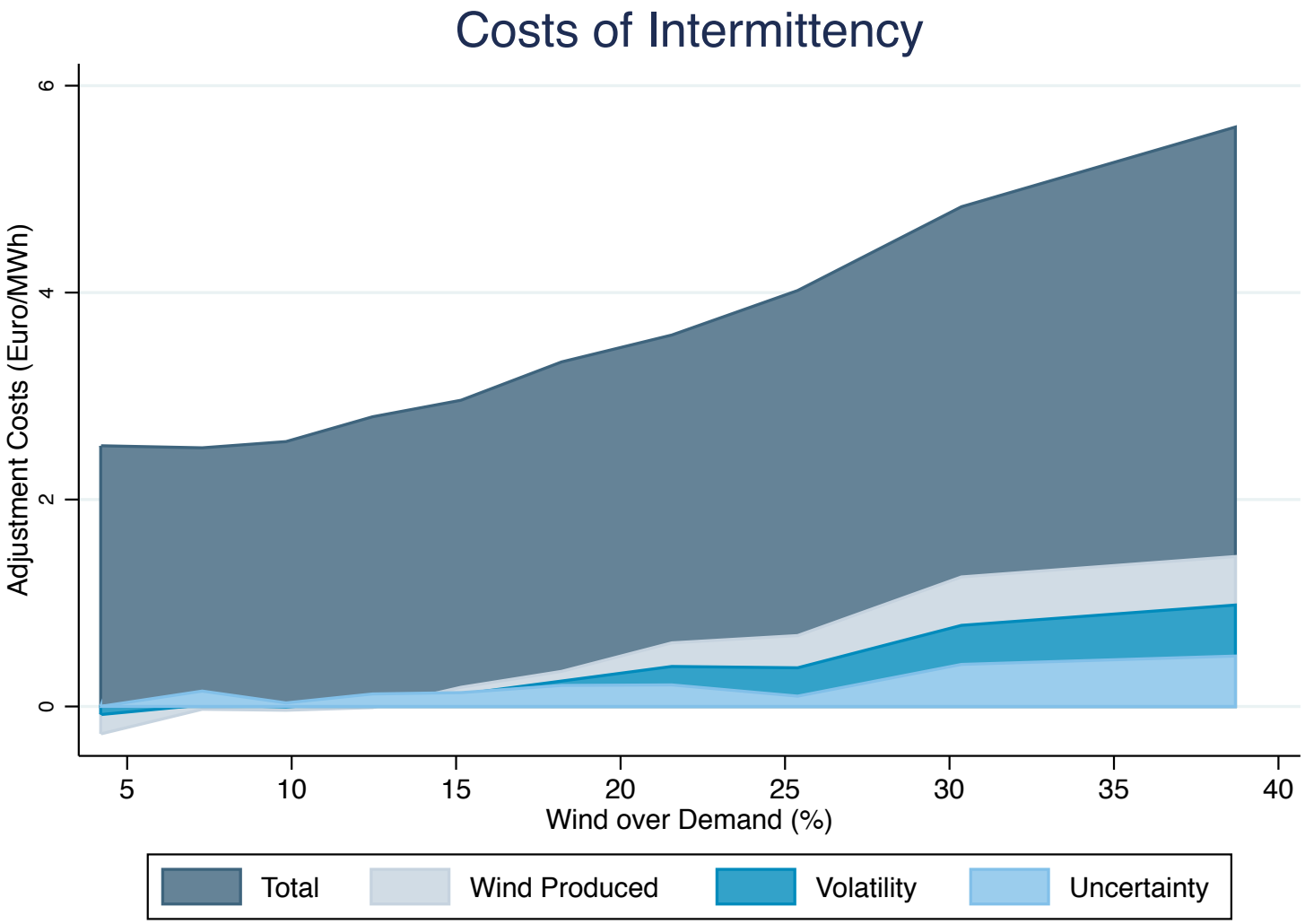
$$C_t = \lambda_0 + \sum_{d=1}^{10} \left(\lambda_{1d} V_t + \lambda_{2d} U_t\right) W_t + \gamma X_t + \epsilon_t \ . \tag{5}$$

- Marginal Effects:

$$\text{MAW}(d) = \lambda_1 \bar{V} + \lambda_2 \bar{U} \ , \tag{6}$$

$$\text{MAV}(d) = \lambda_{1d} \bar{W}_d \ , \text{ and } \text{MAU}(d) = \lambda_{2d} \bar{W}_d \ . \tag{7}$$

Average marginal effects of wind



Source: Own elaboration based on data from OMIE and REE.

Implications for renewable integration

- Higher wind penetration increases **savings** in fuel costs and emissions, but also increases **costs** of adjustment.
- Estimates of costs are **modest**, difficult to extrapolate to even larger penetration levels.

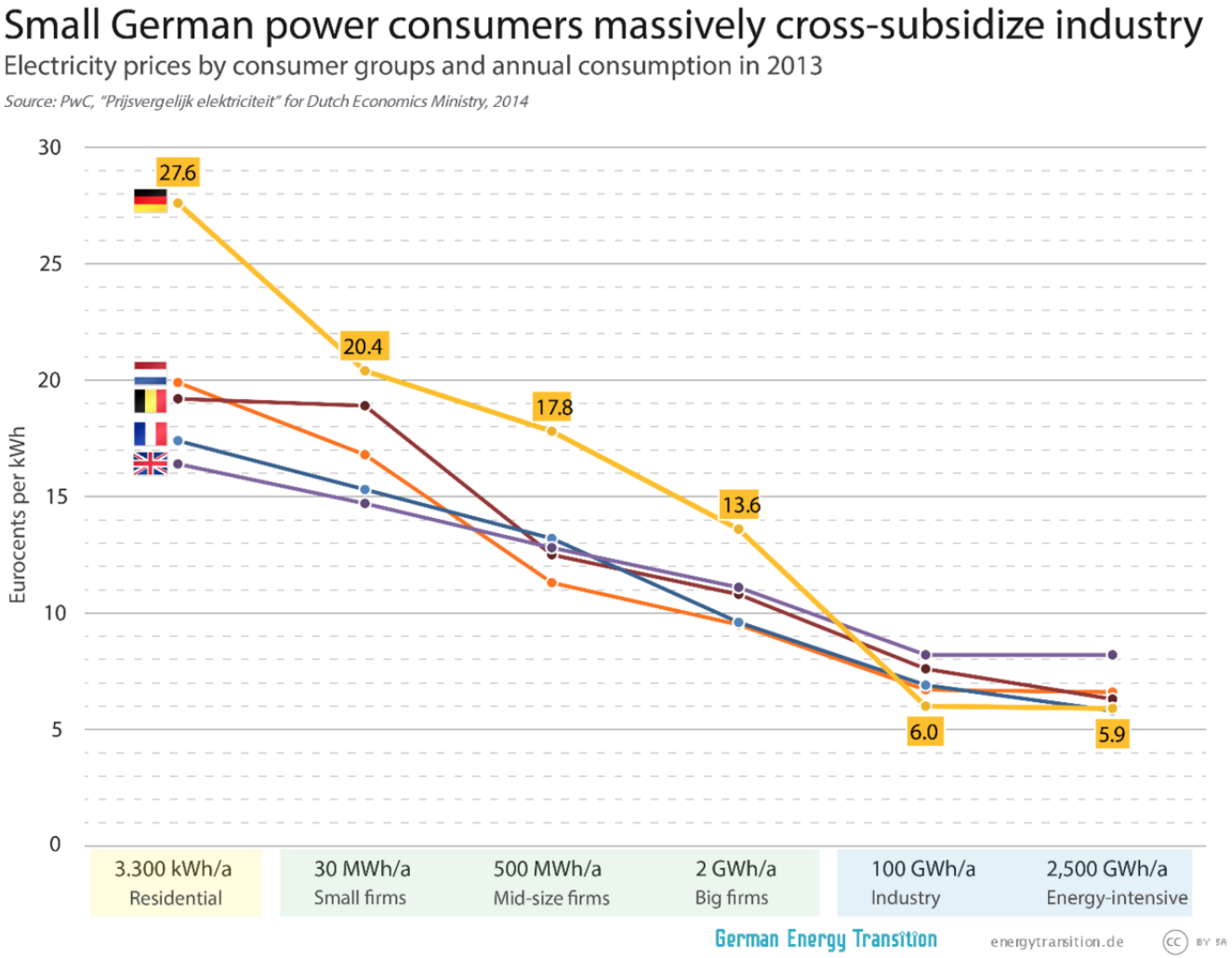
- **Solutions** for intermittency?
  - Uncertainty: more accurate forecasts?
  - Volatility: incorporate storage technology and mechanisms that make demand more sensitive (RTP), ideally in an automated fashion.

Political economy challenges

What if we circumvent technological challenges?

- Aside from operational challenges, rollout of massive amounts of renewable power **likely to face opposition**.
- At low penetration levels, relatively popular. As countries push agenda, growing opposition.
- Impacts **unevenly distributed** across several margins.
  - Stakeholders (e.g., technologies, generation vs. retail).
  - Regional heterogeneity in resources (and correlation of resources with demand).
  - Heterogeneity across consumer types, e.g. residential vs commercial.
  - Heterogeneity in consumption, e.g., across income groups.

Subsidies have substantial distributional implications



Source: energietransition.de

Distributional concerns affect viability of policies

- *Which policies can we approve?*
- *How efficient are the policies that we approve?*
  - Impossible to separate these two important questions.

Recovering fixed costs in the electricity market

- In some ways, we are back to Utilities 101.
- **Large fixed costs** to invest in renewable power, marginal costs much smaller.
- However, typically costs **recovered at the margin**.
  - Capacity payments passed-through to the retail price.
  - Feed-in tariffs passed-through to the retail price.

- One **cannot separate** efficiency from distributional question.

Some examples

1. Tension between charing residential consumers only or also **industrial sector**.
2. **Net metering** concerns about redistribution between income groups. Also concerns by traditional utilities.
3. Opposition by **traditional generation** in the presence of substantial renewable entry. Demands for bail out or countervailing subsidies.

I explore industrial-residential tension

- Integrate **two elements**:
  - Supply-side model with endogenous dispatch and capacity.
  - Demand-side model for residential, commercial and industry sectors, with tariff design.

- Use framework to consider **alternative pricing schemes** to recover renewable costs:
  - Fixed fees
  - Proportional
  - Ramsey prices

Main take away of this line of research

- **Economic theory** may justify charging renewable costs more heavily to residential consumers.
  - Ramsey theory of optimal taxation: charge the less responsive group.
- However, this is subject to **substantial assumptions**.
  - Industry would not respond with lower emissions (e.g., outside option, leakage).
  - Otherwise, better to tax the industrial sector and further climate goals.

- Even if Ramsey could be justified.... at the end of the day, policies also need to be **acceptable** to a given constituency.

Conclusion

The future of large-scale renewables

- Large-scale renewables have a **big role to play**.
  - Certainly in large connected areas.
  - But also plenty of potential in smaller systems.

- I focused on two **challenges**:
  - Operational, attenuated by better storage.
  - Political economy, attenuated by market forces due to lowering costs and reduced need for renewable support.

Thank you.

Comments? Questions?

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