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EUROPE’S ELECTRICITY MARKET DESIGN

2030 AND BEYOND

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Improving network and digital industries regulation

A CERRE REPORT AUTHORED BY

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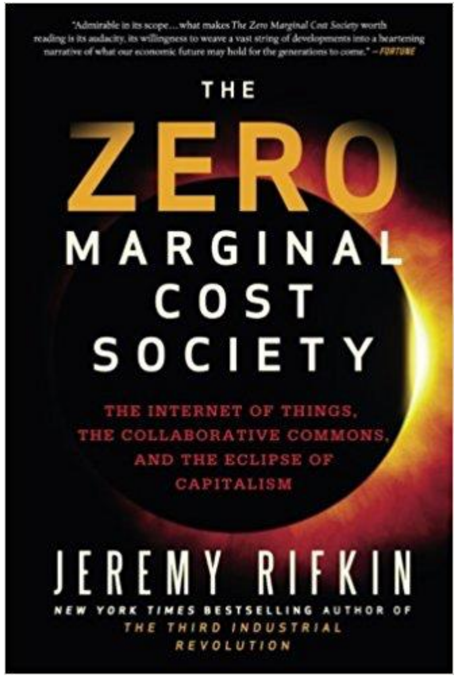
BACKGROUND IDEAS



- The **theory of electricity markets** is creaking under the rise of renewable electricity supply (RES), very high RES is potentially an 'zero marginal cost' (a la Rifkin) system.
- **Competition policy will be influenced by** market design.
- Market design is a function of which technologies we seek to support and hence **will be significantly determined by wholesale prices,** hence we will include modeling in our analysis.
- Mid-2020s prices likely to guide 2030 market design discussions in reality in Europe.

KEY QUESTIONS

A. How well is the current market design working, as the roll out of RES generation continues?

B. What limited adaptions to the current market design might be possible in the timeframe to 2025?

C. In the context of A. and B., will there be a tipping point in the current energy market, when the penetration of RES might be so high as to cause the need for a more radical market redesign to address the investment signal issue?

THREE VISIONS OF THE FUTURE

- **A continuation of the current situation,** with most generation investment being determined by government and ad hoc ancillary services solutions to financing fossil fuel plants.

- **A gradual (successful) evolution in market design,** where subsidies to RES fall, energy market prices increase and ancillary services markets become more significant to support fossil fuel power plants required for security of supply and VRE becomes self-financing in the market.

- **A radical change in market design** to move to a sustainable new arrangement, e.g. internet style rationing of electricity demand in response to system condition.

HOW ELECTRICITY MARKETS ARE MEANT TO WORK

- In theory (Stoft, 2002), **prices in energy-only markets** will cover capacity costs by inframarginal rents but also also by scarcity rents in a long-run equilibrium.
- **The price rise in this situation will only be limited** by the marginal cost of demand side response or by the value of loss load (VoLL).
- **More RES will have merit order effect** but this is not necessarily a problem.
- **High fossil fuel/carbon prices will support cleaner fossil fuel** plants.
- **Security of supply** – in the sense of insuring that supply and demand is instantaneously balanced - is supplied by the system operator (SO) through acquisition of a range of ancillary and balancing services, while **adequacy** – in the sense of having enough long term capacity on the system - can be provided by a competitive "energy only" market (as in Target Electricity Model, Newbery (2016)).

PROBLEMS WITH THE THEORY – IN THEORY AND PRACTICE (1/2)

- **Problems of demand inelasticity** (Joskow and Tirole, 2007) heightened by VRE (Cramton, 2013).
- **The social and political acceptability of scarcity prices may be low.** This leads to a root cause of the "missing money" problem: politicians and regulators tend to impose price caps in wholesale electricity markets (Hogan, 2005), implicitly or explicitly, to dampen price rises and limit the potential for market power abuse.

PROBLEMS WITH THE THEORY – IN THEORY AND PRACTICE (2/2)

- **Wholesale prices are uncertain** (e.g. due to potential price caps and other regulatory interventions) and hence investors are not able to recoup their capital costs through scarcity rents and there may be expectation of capping Neuhoff et al. (2016).

- Indeed, as Newell et al. (2012) noted, in practice, as is now well known, actual electricity markets often produce results where energy and ancillary services prices may not be sufficient to support new investment. Partly, this is because a **new investment relying on volatile market revenue streams is risky and subject to cannibalisation by future investments.**

SUGGESTED SOLUTIONS (1/3)

- Hogan (2005) proposed an improvement to the energy-only market design to address the lack of a market for reliability: to **price scarce reserve at the opportunity cost of energy through a regulated operating reserve demand curve (ORDC).**

- Joskow (2007) **concludes that a forward capacity market is needed** to ensure resource adequacy.

- Newbery (2016) noted that even if the revenue is potentially adequate to cover capital costs but is not perceived to be so by generators and/or their financiers then **there is a "missing market" problem. Hence capacity markets.**

SUGGESTED SOLUTIONS (2/3)

- A fundamentally different approach would be to shift the **focus of provision of adequate capacity away from the generators on to retailers.** A related suggestion to this is that (see Bidwell, 2005), retailers should contract for reliability options with generators, where generators agree to provide reliability at fixed prices during stress events and effectively forego price spike revenues.

- **Markets for reserve capacity,** in the form of short run operating reserve, an ORDC or a capacity market create an ancillary services market for capacity to be available on the electricity system. The performance of longer term capacity markets can be questioned.

SUGGESTED SOLUTIONS (3/3)

- **The SEM in Ireland has implemented the DS3** (Delivering a Secure Sustainable Electricity System) - 14 ancillary service products, including a new frequency response product for delivery of frequency response within 0.15 seconds. In the first competitive auction to procure these new services, offerors will be required to submit a package bid for 5 ancillary services products (around frequency response and short term operating reserve), at a discount to maximum prices published by the system operators.

- In this paper, we focus on energy and ancillary services markets. However De Vries and Verzijlbergh (2018) suggest that optimal 'market design' would co-optimise across **energy, networks and environmental objectives. So the problem markets are trying to solve is much harder in practice.**

EMPIRICAL/QUANTITATIVE MODELLING (1/2)

- Bublitz et al. (2017) summarise empirical and modelling studies that estimated quantitatively the merit-order effect. **The effect ranges from Euro -15/MWh to Euro -0.55/MWh depending on modelling assumptions,** RES technology (wind, solar, biomass etc.) and location (Germany, Spain, Ireland) and methodology (simulation, time series analysis).

- Levin and Botterund (2015) focused on ERCOT and analysed three market policies that may support resource adequacy: Operating Reserve Demand Curves (ORDC), Fixed Reserve Scarcity Prices (FRSP) and fixed capacity payments (CP). **ORDC performs well.**

EMPIRICAL/QUANTITATIVE MODELLING (2/2)

- Papavasiliou and Smeers (2017) analysed how ORDC could support flexible generation under increasing penetration of unpredictable, highly variable and non-controllable renewable supply. **They suggest that capacity markets are redundant.**

MODELLING RESULTS

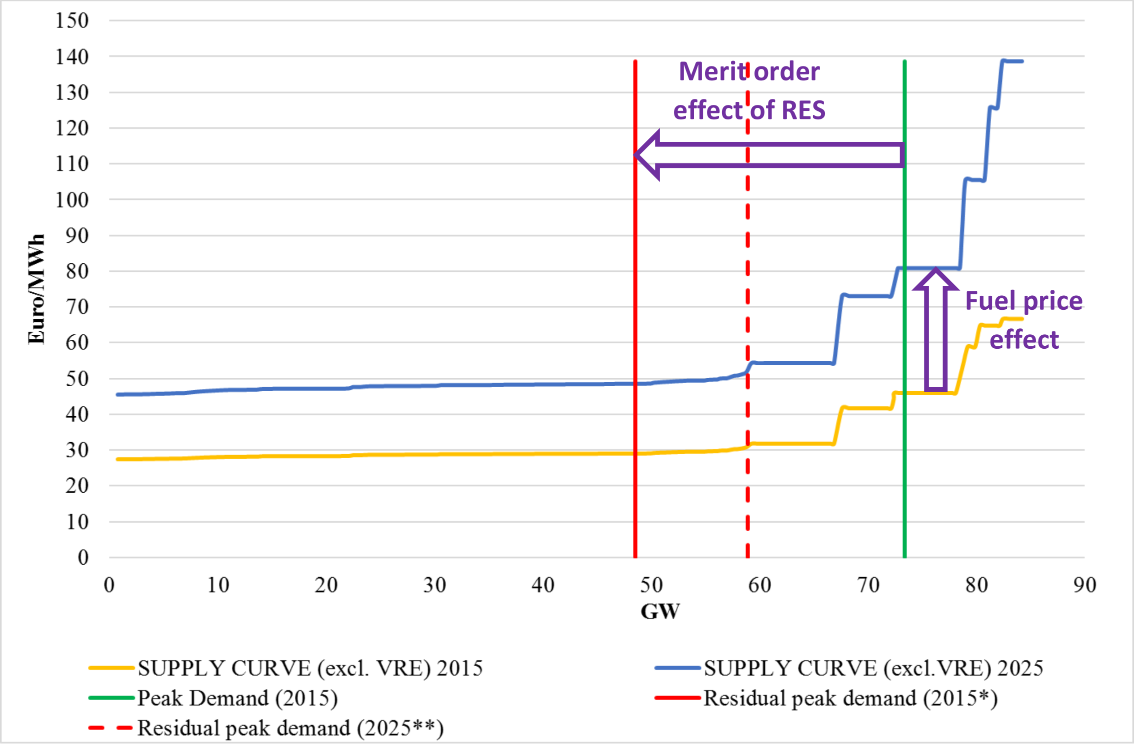
We model the market in 2025 and focus on the modelling of wholesale electricity prices.

We do this because the performance of the electricity market in 2025 would likely guide market design changes out to 2030.

Limitations of modelling:

- A tool for showing significance of the impact of certain changes.
- Any modelled scenarios cannot completely capture all of the issues.

IS A NEW MARKET DESIGN NECESSARY? (1/2)



1. An empirical question requiring some modelling
2. Depends on fossil fuel/carbon prices, VRE capacity in a generation mix

IS A NEW MARKET DESIGN NECESSARY? (2/2)

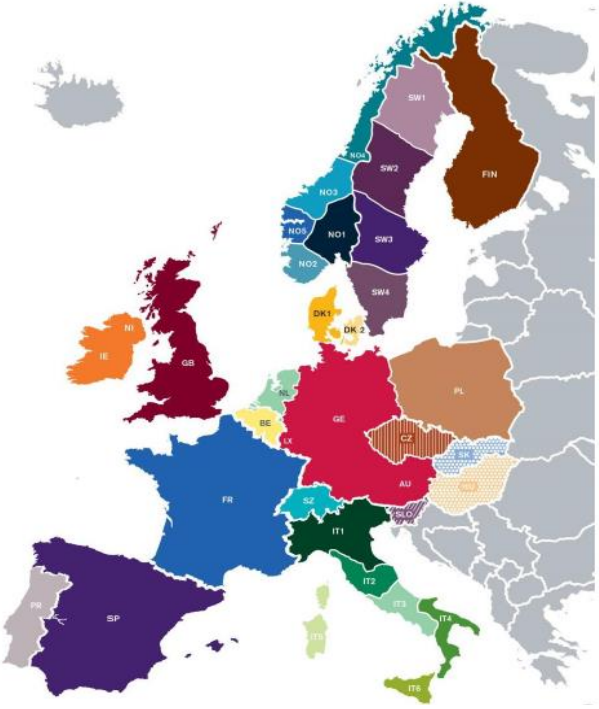
Table 1: Economics of investing in a CCGT plant in Germany: 2015-present

	2015	2016	2017	2018*
MAX hourly prices, €/MWh(e)	99.77	104.96	163.52	98.19
MEAN hourly prices, €/MWh(e)	**31.82**	**28.98**	**34.19**	**41.73**
MIN hourly prices, €/MWh€	-79.94	-130.09	-83.06	-76.01
Instances of negative hourly prices	**98**	**98**	**149**	**110**
TTF average day-ahead gas price, €/MWh(th)	21.1	15.7	17.3	25.27
EU ETS price, €/tCO2	7.5	5	5.5	20.49
Short-run marginal cost, €/MWh(e)	**44.90**	**34.24**	**37.32**	**56.76**
N hours prices > SRMC	1276	701	1404	2859
Implied capacity factor	15%	8%	16%	33%
Mean prices as % of SRMC of a CCGT	**71%**	**85%**	**92%**	**74%**
Inframarginal rent, € mn	**4**	**3**	**9**	**14**
Profit without CAPEX annuity, € mn	**(5.11)**	**(5.91)**	**0.36**	**4.90**
Profit with CAPEX annuity, € mn	**(45.20)**	**(46.00)**	**(39.73)**	**(35.19)**

1. Current market conditions do not support new gas capacity
2. With higher VRE (and hence lower mean prices) even existing CCGTs struggle

MODELLING OF 2025 ELECTRICITY MARKETS

Existing market zones in Europe



Source: Ofgem.

AT	IT-Centre-North	GB	SE3	NO5
BE	IT-Centre-South	SEM	SE4	
DK1	IT-Centre-South	NL	NO1	
DK2	IT-North	CH	NO2	
DE	IT-Sardinia	SE1	NO3	
FR	IT-Sicily	SE2	NO4	

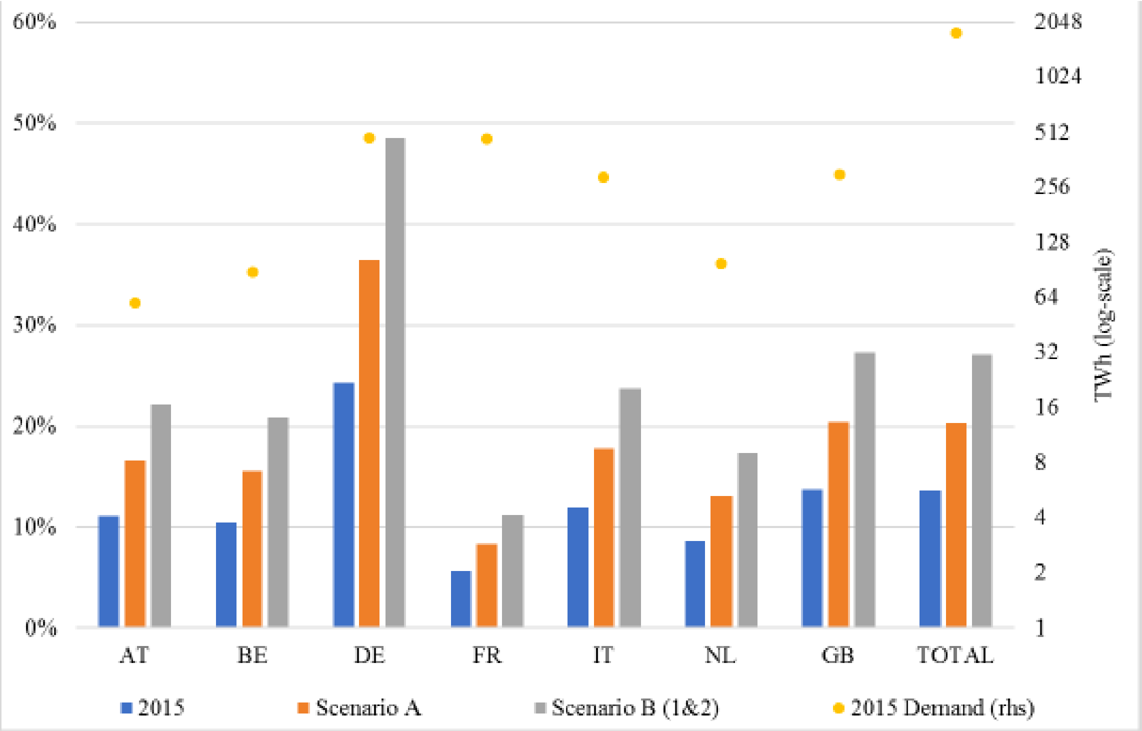
- The model is an LP, large-scale market simulation model
- Hourly resolution
- Gas, coal, oil fired generation and pump storage are modelled
- Biomass, nuclear and all other generation tech are exogenous

MODELLING SCENARIOS

<table>
<tr><th rowspan="2">Scenarios</th><th colspan="2">VRE capacity</th><th rowspan="2">Fossil fuel capacity</th><th rowspan="2">Interconnection capacity</th><th colspan="3">Fossil fuel prices</th><th rowspan="2">Carbon cost</th></tr>
<tr><th>wind</th><th>solar</th><th>Gas</th><th>Coal</th><th>Oil</th></tr>
<tr><td>Baseline</td><td colspan="2">2015</td><td>2015</td><td rowspan="6">2015</td><td>$7.9/mmbtu</td><td>$77/tonne</td><td>$83/bbl</td><td rowspan="5">€25/tCO2</td></tr>
<tr><td>A</td><td colspan="2">50% higher than baseline</td><td rowspan="2">as in baseline</td><td colspan="3" rowspan="3">as in baseline</td></tr>
<tr><td>B1</td><td colspan="2">100% higher than baseline</td></tr>
<tr><td>B2</td><td colspan="2" rowspan="4">as in B1</td><td>Partly decommissioned (see Section 7.4)</td></tr>
<tr><td>C1</td><td rowspan="3">as in baseline</td><td rowspan="2">$9.6/mmbtu</td><td rowspan="2">$82/tonne</td><td rowspan="2">$111/bbl</td></tr>
<tr><td>C2</td><td>€57/tCO2</td></tr>
<tr><td>D</td><td>unlimited</td><td colspan="4">as baseline</td></tr>
</table>

Source: fossil fuel prices are from IEA (2018).

WIND AND SOLAR CAPACITY/GEN SCENARIOS



Scenario A is a near term target which has already been reached in some of our countries such as GB

Scenario B is chosen to be roughly in line with reaching 2030 targets:

- Adding the 10% (current level) of dispatchable renewables gives us 34% of RES in total demand for main power markets in Europe by 2025
- For some countries the share of RES will be very high – DE: 48%, IT: 38%, GB: 27% by 2025

EFFECTS OF HIGH VRE (WIND & SOLAR)

1. Increases tertiary reserve requirement (due to wind & solar forecast errors)
2. Increases fast/primary response requirement (due to low inertia)
3. Depresses average wholesale electricity market price
4. Increases price volatility in wholesale electricity market

IMPACT OF HIGHER VRE ON POWER PRICES

		BE	DE	FR	IT	IT-N*	GB
Baseline	Price (Mean), Euro/MWh	50.12	49.68	51.67	50.68	51.16	50.07
	coefficient variation	11%	9%	198%	9%	9%	9%
Scenario A	Price (Mean), Euro/MWh	49.02	48.23	49.66	49.32	50.23	49.11
	coefficient variation	12%	11%	166%	12%	10%	10%
Scenario B1	Price (Mean), Euro/MWh	47.90	46.34	47.71	45.01	49.00	48.21
	coefficient variation	13%	15%	174%	36%	13%	11%

** IT-N stands for Italy North region (a separate bidding zone in Italy) representing more than half of Italy's annual electricity demand.*

- Higher RES → lower average annual prices
- Higher RES does mean higher volatility (annual basis); depends on market context

IMPACT OF FOSSIL FUEL PRICES ON POWER PRICES

		BE	DE	FR	IT	IT-N*	GB
Baseline	Price (Mean), Euro/MWh	50.12	49.68	51.67	50.68	51.16	50.07
	coefficient variation	11%	9%	198%	9%	9%	9%
Scenario B1	Price (Mean), Euro/MWh	47.90	46.34	47.71	45.01	49.00	48.21
	coefficient variation	13%	15%	174%	36%	13%	11%
Scenario C1	Price (Mean), Euro/MWh	49.95	47.97	49.52	48.40	52.91	50.40
	coefficient variation	15%	17%	167%	34%	16%	14%
Scenario C2	Price (Mean), Euro/MWh	73.20	71.63	72.64	69.00	72.88	73.36
	coefficient variation	6%	9%	114%	24%	7%	4%

** IT-N stands for Italy North region (a separate bidding zone in Italy) representing more than half of Italy's annual electricity demand*

- Impact of higher fossil fuel prices seem modest (ca. 3-7% increase)
- Higher commodity prices cancel the merit order effect of higher VRE in Italy, and GB
- High commodity and high C-price indeed increase power prices significantly

VRE'S "CAPTURED" WHOLESALE POWER PRICES

"Captured" prices by wind and solar in Germany & Italy under various scenarios

	DE				IT		
	Onshore wind	Offshore wind	Solar PV	Average wholesale price	Onshore wind	Solar PV	Average wholesale price
Baseline	44.17	44.67	43.86	49.68	45.24	45.29	50.68
Scenario A	47.87	48.86	46.39	48.23	48.96	46.76	49.32
Scenario B1	45.48	47.39	42.59	46.34	43.19	33.43	45.01
Scenario C1	46.95	49.32	43.66	47.97	46.57	36.50	48.40
Scenario C2	70.76	72.67	67.64	71.63	67.13	57.39	69.00
Scenario D	46.91	47.19	44.35	47.40	47.31	44.72	47.44

- Offshore wind can consistently achieve prices above the average wholesale prices (DE)
- Onshore wind captured prices are marginally below the actual annual average prices (DE&IT)

- Solar achieves lower prices than the actual wholesale prices
- More wind and solar capacity means lower captured prices for solar PV

ROLE OF FURTHER INTERCONNECTIONS

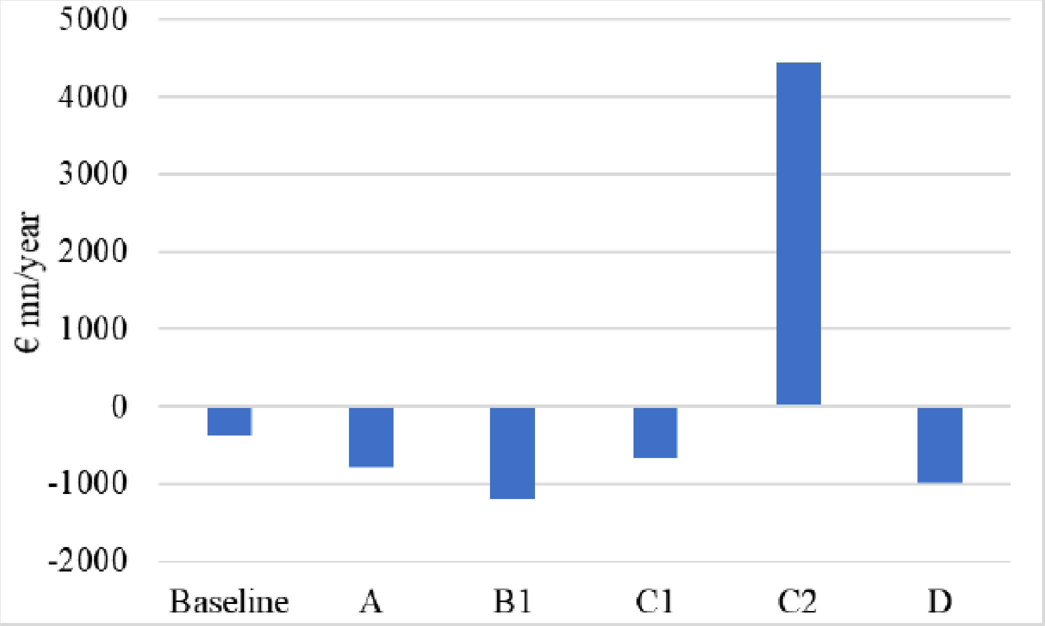
	Scenario B				
	mean	min	Max	Std. dev.	Coef. Var.
BE	47.90	23.56	320.56	6.11	13%
DE	46.34	-89.59	60.10	6.92	15%
FR	47.71	-130.09	5677.67	82.82	174%
IT	45.01	-92.77	72.67	16.25	36%
IT-N*	49.00	18.11	72.74	6.15	13%
B	48.21	35.00	60.10	5.19	11%
	Scenario D				
	mean	min	max	Std. dev.	Coef. Var.
BE	47.45	34.53	72.81	5.94	13%
DE	47.40	34.49	72.74	5.93	13%
FR	47.43	34.53	72.81	5.93	13%
IT	47.44	34.51	72.74	5.93	13%
IT-N*	47.47	34.56	72.88	5.94	13%
GB	47.46	34.53	72.74	5.93	12%

** IT-N stands for Italy North region (a separate bidding zone in Italy) representing more than half of Italy's annual electricity demand*

- More interconnections stabilise wholesale prices:
- Our results show complete convergence between key markets in Europe both in terms of price level (average, minimum and maximum levels)
- But also the price variations are reduced significantly

VRES AND MISSING MONEY

Figure 15: The size of the "Missing Money" problem under various modelled scenarios – Germany



- More VRE exacerbates the missing money problem of conventional generation
- Higher fossil fuel prices indeed help to improve overall profitability, but this still remain largely negative
- A higher carbon cost dramatically improves the profitability of conventional plants: total profit under this scenario (C2) is ca. + €4450 mn/year
- Unlimited interconnection capacity, the economics of existing conventional plants improves, but rather marginally

VRES, OVERCAPACITY AND MISSING MONEY (1/2)

Figure 17: Supply curve of conventional plants and location of unprofitable/decommissioned plants - Germany (Scenario B1)

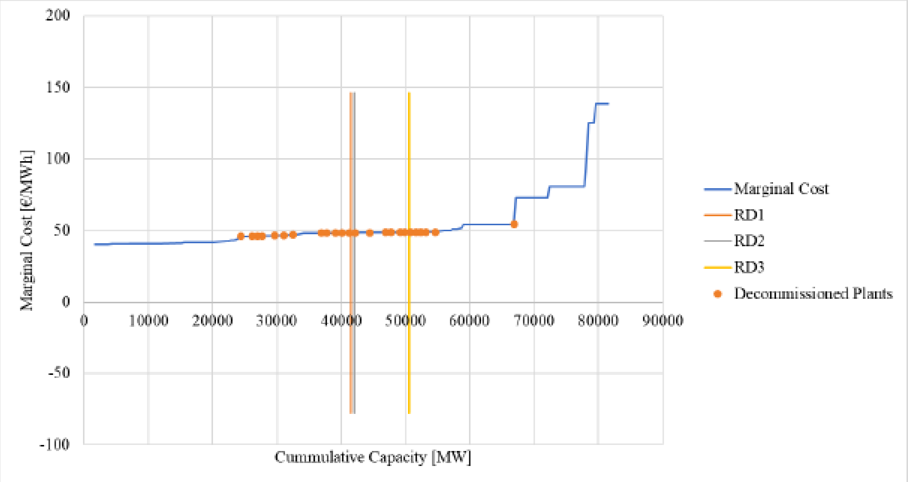
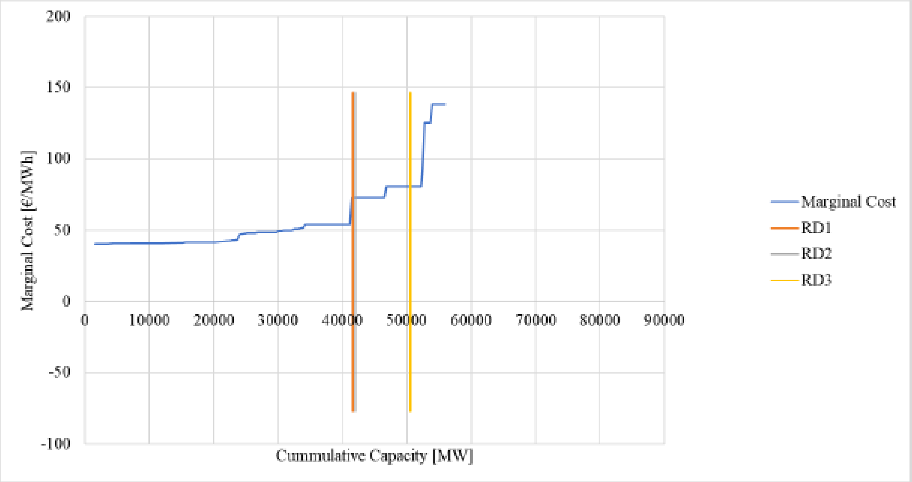


Figure 18: Supply curve of conventional plants after removing decommissioned plants - Germany (Scenario B1)



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VRES, OVERCAPACITY AND MISSING MONEY (2/2)

Table 9: Impact of decommissioning of unprofitable plants on wholesale prices

		BE	DE	FR	IT	IT-N*	GB
Baseline	Price (Mean), Euro/MWh	50.12	49.68	51.67	50.68	51.16	50.07
	coefficient variation	11%	9%	198%	9%	9%	9%
Scenario B1	Price (Mean), Euro/MWh	47.90	46.34	47.71	45.01	49.00	48.21
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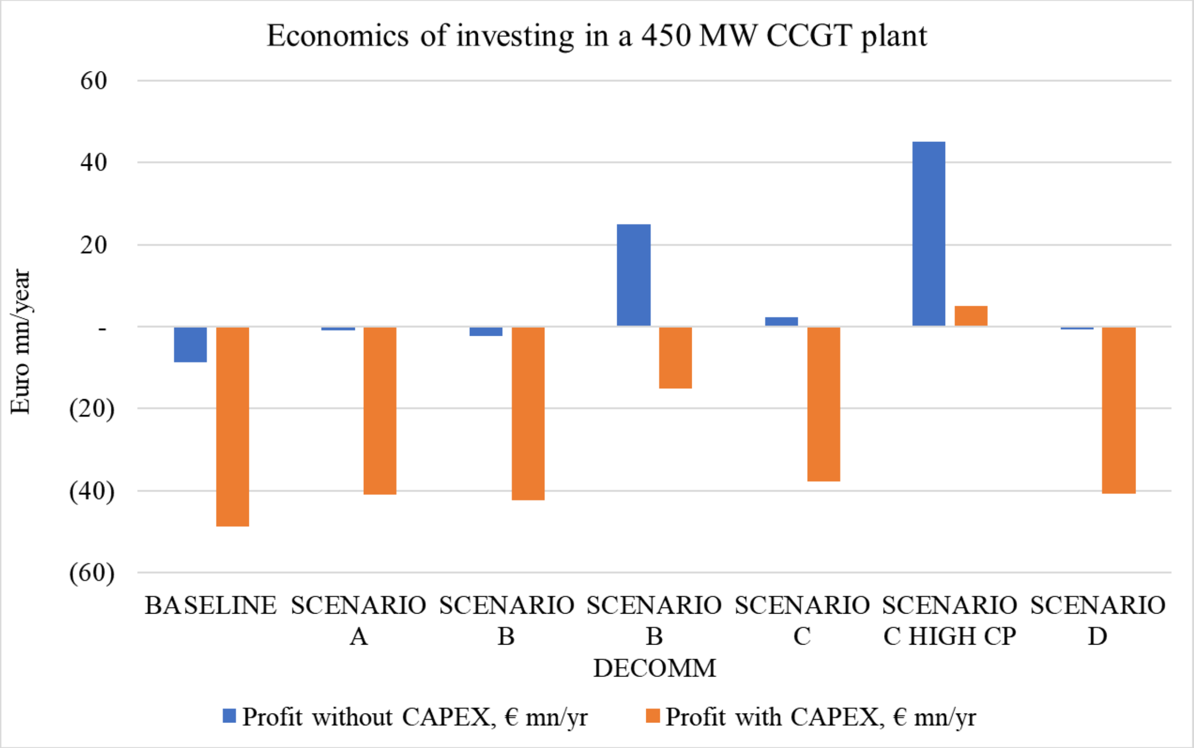
	coefficient variation	6%	9%	114%	24%	7%	4%
Scenario B2	Price (Mean), Euro/MWh	57.42	54.86	57.43	50.43	56.24	92.77
	coefficient variation	23%	26%	179%	33%	22%	281%

- Removing unprofitable plants from the power system will shift respective merit orders and hence power prices – average annual prices are now amongst the highest in all scenarios considered (exception being very high fossil fuel and carbon price, Scenario C2)
- But volatilities are also higher, in fact, highest in all our scenarios

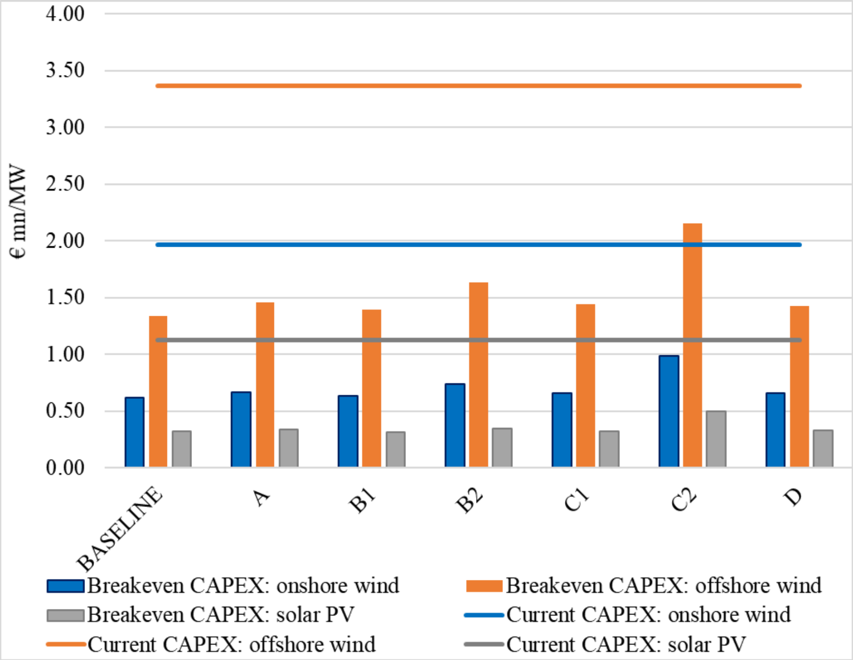
ECONOMICS OF INVESTING IN A 450 MW CCGT PLANT IN 2025 (1/2)



ECONOMICS OF INVESTING IN A 450 MW CCGT PLANT IN 2025 (2/2)

- Investment in new CCGTs under all four scenarios seems not to be feasible
- With the existing level of VRE capacities but higher expected commodity prices for 2025 (the Baseline scenario) existing CCGTs could be profitable
- Higher VRE penetration level will likely exacerbate the missing money problem for existing CCGTs.
- The power prices arising from all considered scenarios may no longer serve as a good long-run investment signal to bring new CCGT capacity on line.

THE ECONOMICS OF INVESTING IN VRE (1/2)



Reduction in CAPEX needed to breakeven for "subsidy-free" VRE under all scenarios - Germany

THE ECONOMICS OF INVESTING IN VRE (2/2)

- "Subsidy-free" wind and solar PV investment would not be feasible in all our simulated scenarios at the assumed current (2016) CAPEX level
- For onshore wind to be "subsidy-free" current CAPEX needs to fall by 50-70% by 2025
- For offshore – 35-60%;
- For solar PV – 56%-72%.

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CONCLUSIONS (1/7)

Our modelling results suggest:

- Substantial decrease in the capex needed (on 2016) for "subsidy-free" VRE.
- Solely relying on wholesale energy markets remains very challenging, even if we take a rather bullish view that by 2025 commodity markets are going to be very tight.
- CCGT required for system adequacy unlikely to be self-financing at high commodity prices.
- More VRE reduces revenue for existing CCGTs, exacerbating their missing money problem.

CONCLUSIONS (2/7)

- **Interconnection reduces volatility** but does not solve financeability problems on its own.
- **Closures of fossil fuel power plants would make a difference to market prices** - in response to low profitability - but it would put more pressure on ancillary services markets.
- **Raising carbon prices does help** and remains a good policy within the current market design.

CONCLUSIONS (3/7)

A. How well is the current market design working, as we continue with the roll out of renewables generation?

- Some combination of lower capex, higher carbon prices, higher fossil fuel prices and/or plant closures are necessary. There remain issues with volatility, cannibalisation and ancillary services of electricity. **Market design questions seem to remain.**

CONCLUSIONS (4/7)

B. Following A, what limited adaptions to the current market design might be possible in the timeframe to 2025?

- **Interventions to create capacity markets or sharpen ancillary services markets payments can help.** However these markets are fundamentally different in governance and risk to energy markets making them expensive to rely on for long-run funding for generation investment.

CONCLUSIONS (5/7)

C. In the context of A and B, will there be a tipping point in the current energy market, when the penetration of RES might be so high as to cause the need for a more radical market redesign to address the investment signal issue?

- **We do not foresee a sharp tipping point** in the current energy market.

CONCLUSIONS (6/7)

Will a radical market redesign be necessary?

Given the willingness of member states to live will largely subsidised new electricity generation from the period beginning around 2005 to 2018 a new market design seems unlikely. The market design will evolve with some significant changes in the market for ancillary services. Will these be radical – you decide!

CONCLUSIONS (7/7)

Will market designs converge across Europe?

This is an open question. One could imagine Ireland, Iberia, the UK, Greece and Germany having significantly different market configurations by 2025 given the differences in their VRE amounts and interconnection.

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