Der Marktwert von Ökostrom und Prognosen

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AWES | 9. März 2016 | hirth@neon-energie.de

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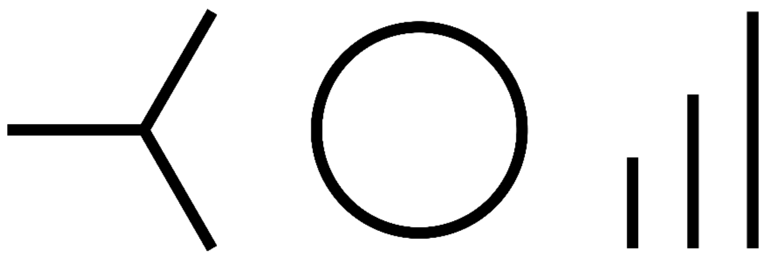
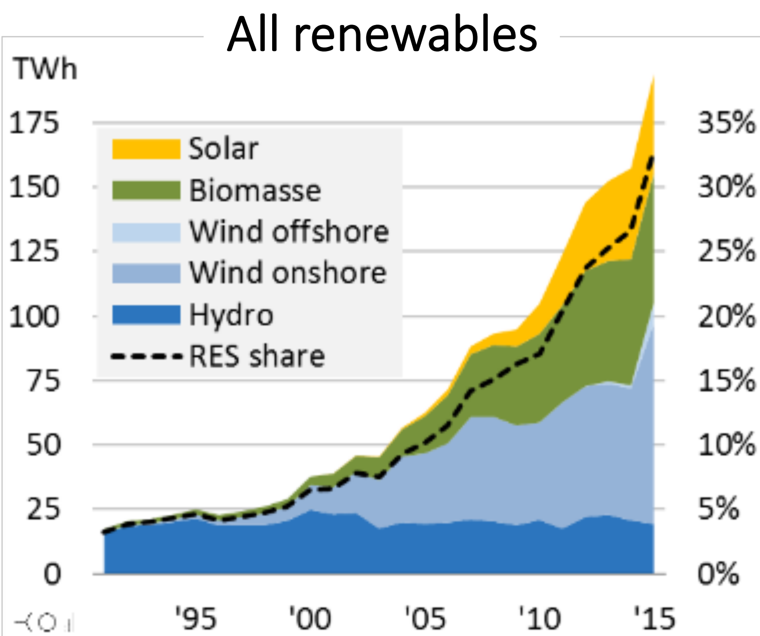
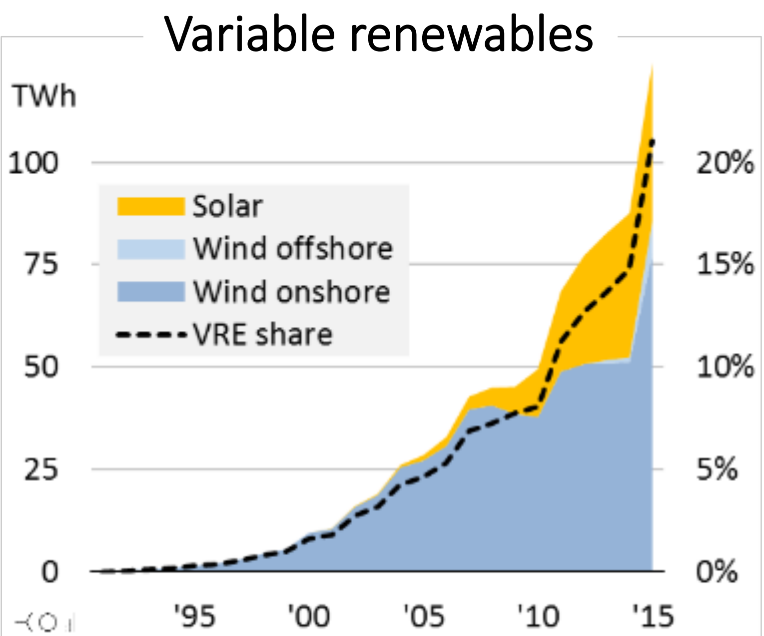
neon neue energieökonomik



Renewables supply 33% of German electricity demand



Neon analysis. Based on data from BMWi, AG Energiebilanzen, BDEW, BWE, BSW, IEA.



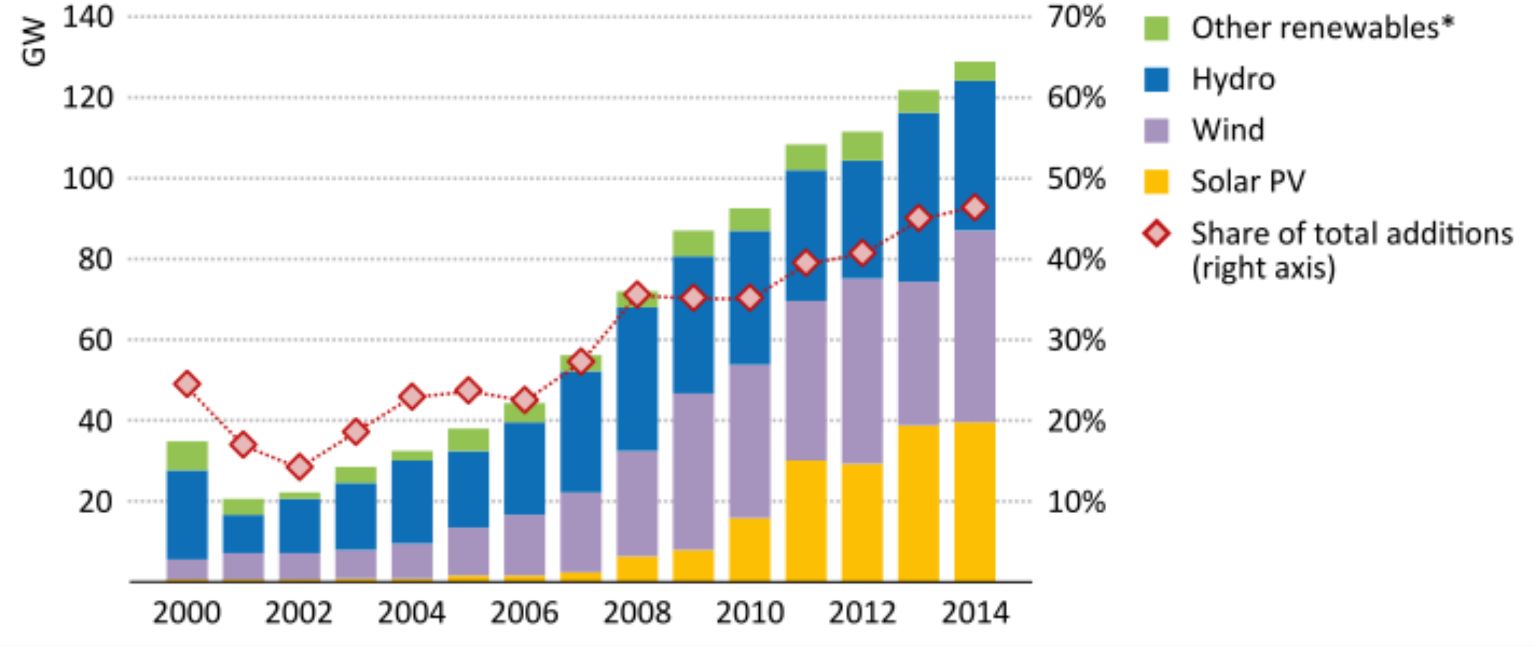
Neon analysis. Based on data from BMWi, AG Energiebilanzen, BDEW, BWE, BSW, IEA.

Renewables supply 32% of German electricity consumption (30% of supply).

Wind and sun – variable renewables VRE – provide 21% of electricity demand.

50% of globally added capacity is renewable

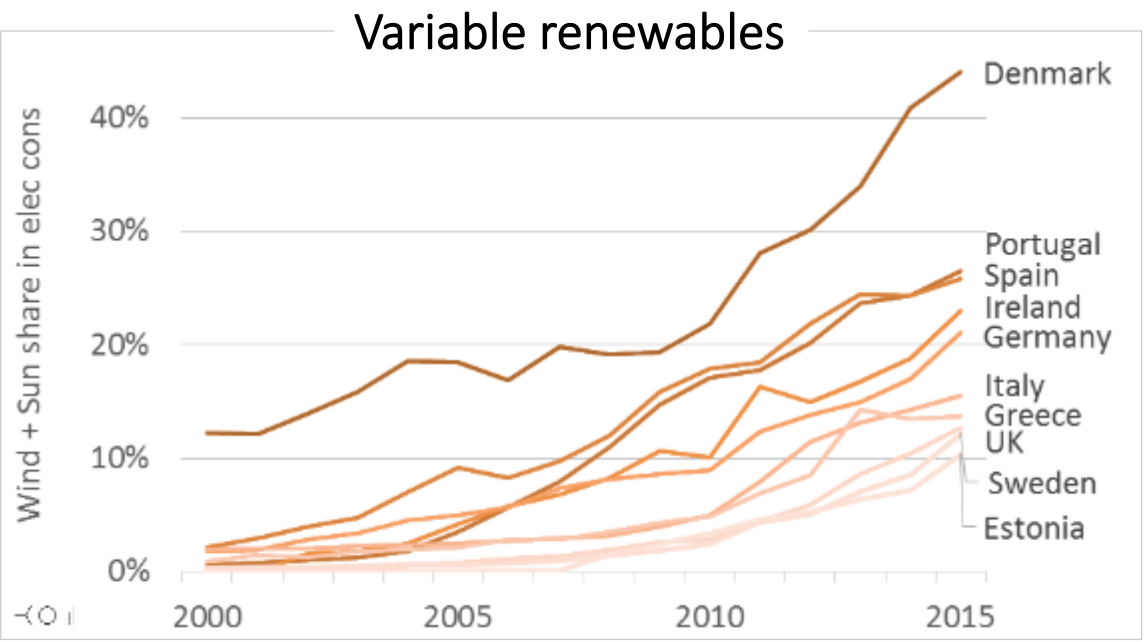
Global power generation additions



Source: IEA (2015): WEO special report

In 2014, almost half of all new power generation capacity globally was based on renewables – of which wind and solar power captured the lion's share of 70%.

Wind and solar on the rise



Neon analysis. Based on data from BMWi, AG Energiebilanzen, BDEW, BWE, BSW, IEA. Data for 2015 runs until 07/2015.

In ten out of 33 IEA member countries, wind and solar power supply more than 10% of electricity demand. On the Iberian Peninsula, they provide more than a quarter of electricity.

What is the *economic value* of wind-based electricity – today and at high penetration?

1. Market data

Value factor: the relative price of wind power

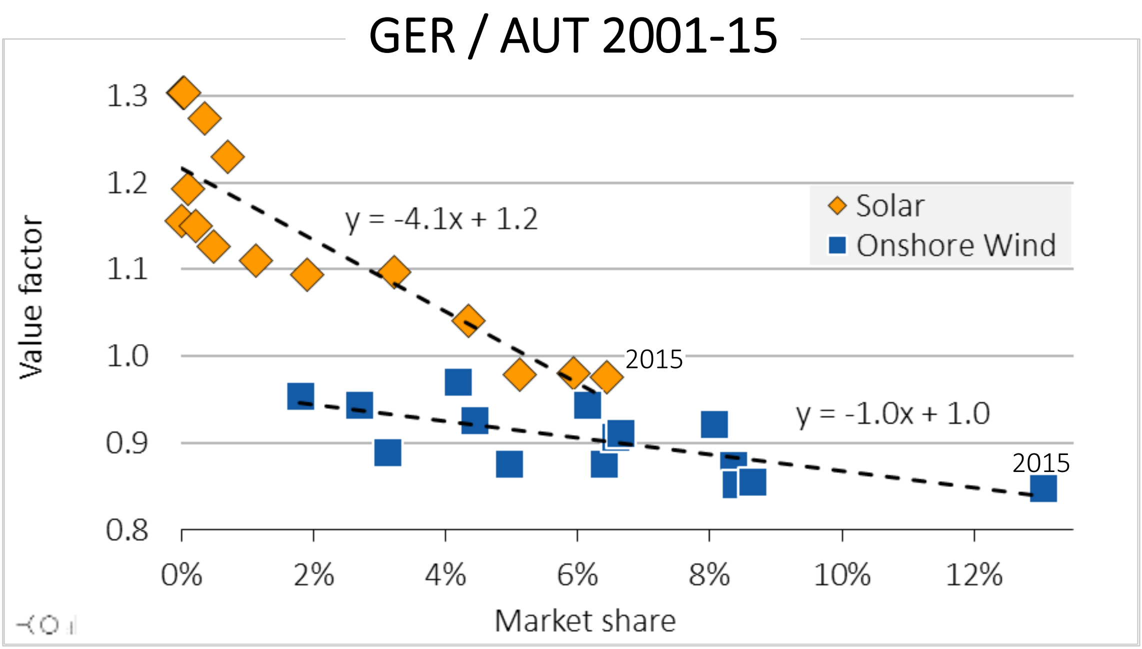
Wind in Germany / Austria			
	Base price (€/MWh)	Wind Revenue (€/MWh)	Value Factor (1)
2001	23.1	22.7	0.96
…	…	…	…
2015	32	27	0.85

↑ Simple average of all hours of the year

↑ Wind-weighted average

↑ Ratio of these two

Market value of wind and solar power



→ ?

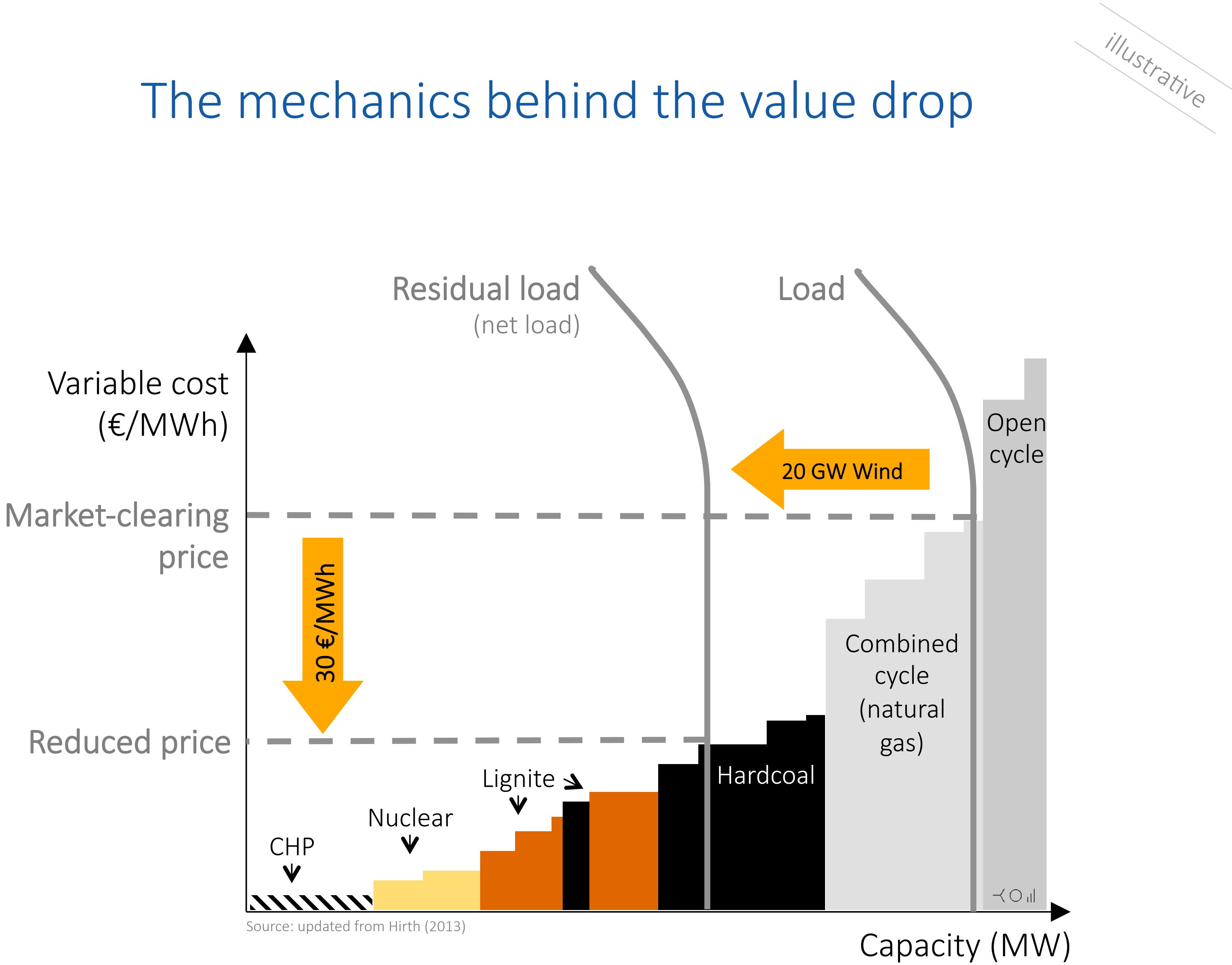
Value Factor =
Market value / base price

Each dot is one year

Updated from Hirth (2013).:Market value

The relative value of electricity from wind and solar power is reduced as their market share grows. This has been called the “cannibalization effect”, or: diminishing returns.

The mechanics behind the value drop

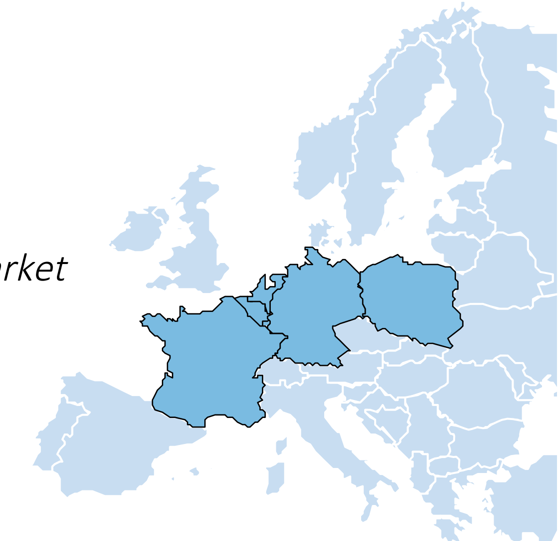


Source: updated from Hirth (2013)

2. Model results

The Electricity Market Model EMMA

Numerical partial-equilibrium model of the European interconnected power market



Objective: minimize system costs

- Capital costs
- Fuel and CO2 costs
- Fixed and variable O&M costs
- ... of power plants, storage, interconnectors

Decision variables

- Hourly dispatch
- Yearly investment
- ... of plants, storage, interco's

Constraints

- Energy balance
- Capacity constraints
- Volume constraints of storage
- Balancing reserve requirement
- CHP generation
- (No unit commitment, no load flow)

Resolution

- Temporal: hours
- Spatial: bidding areas (countries)
- Technologies: eleven plant types

Input data

- Wind, solar and load data of the same year
- Existing plant stack

Equilibrium

- Short-/mid-/long-term model (= dispatch / capacity expansion / greenfield)
- Equilibrium ("one year") rather than a transition path ("up to 2030")

Economic assumptions

- Price-inelastic demand
- No market power
- Carbon price

Implementation

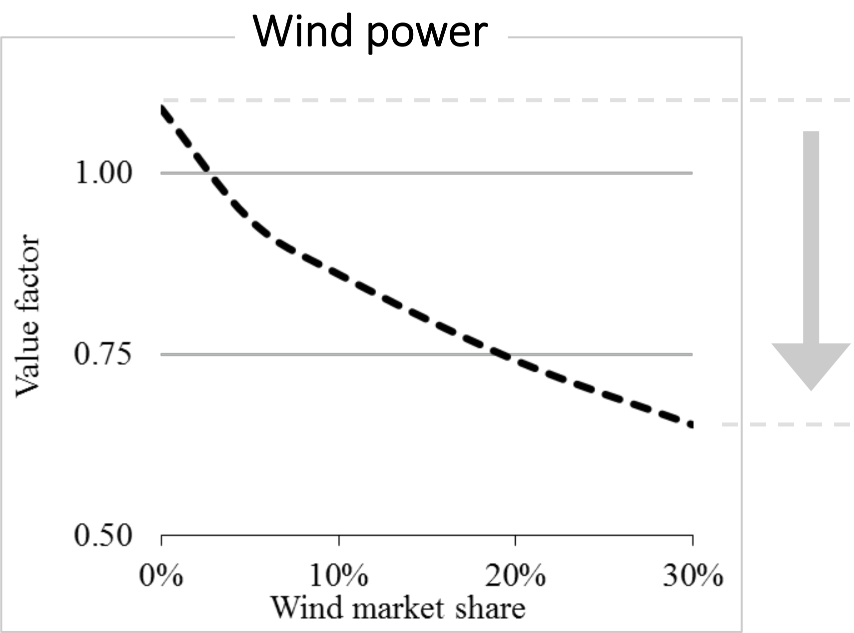
- Linear program
- GAMS / cplex

Applications

- Four peer-reviewer articles
- Various consulting projects
- Copenhagen Economics

Open source

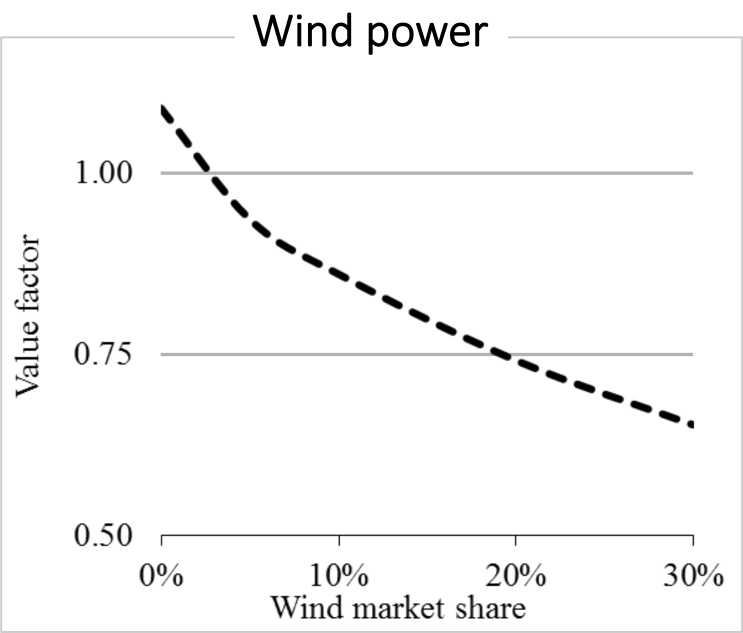
The value drop continues: model results



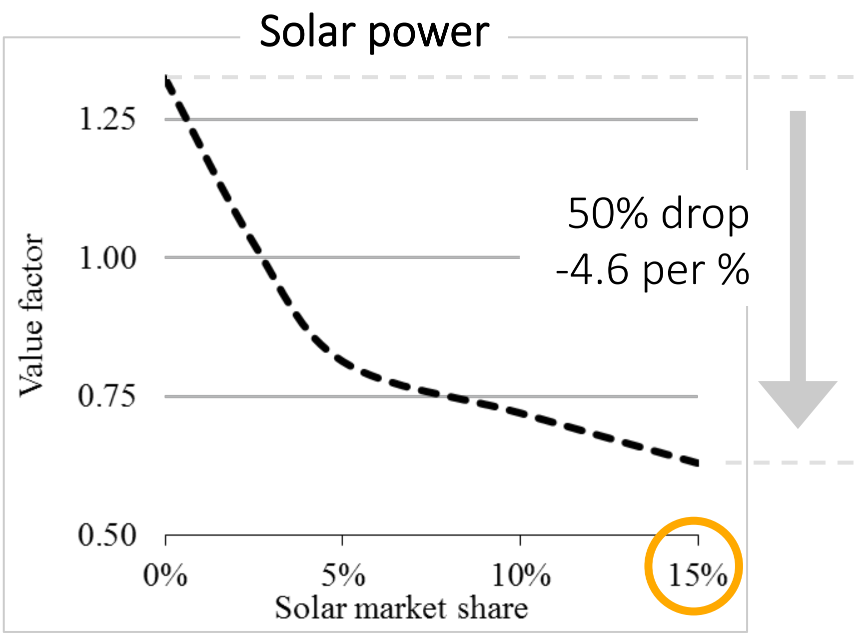
Updated from Hirth (2013): Market value

The value factor of wind power decreases from ~1.1 at low penetration to ~0.65 at 30% market share (1.5 points per point market share).

The value drop continues: model results



Updated from Hirth (2013): Market value

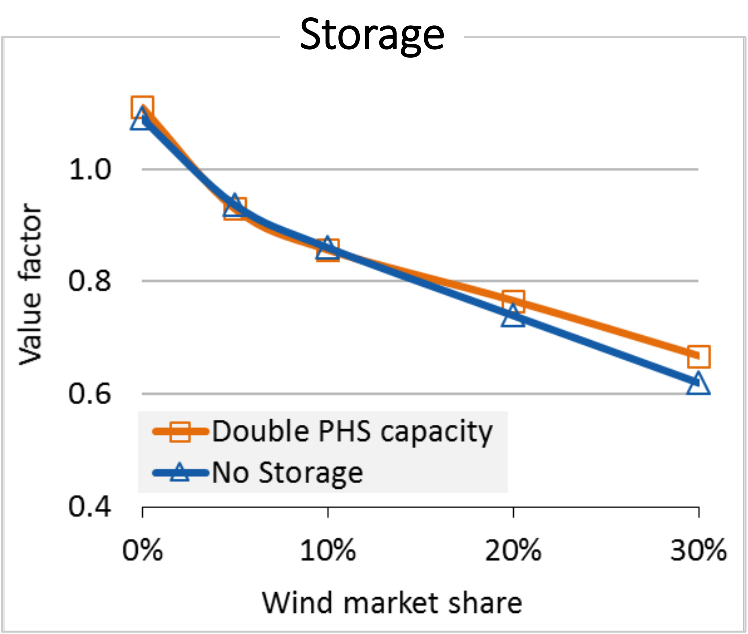


Updated from Hirth (2013): Market value

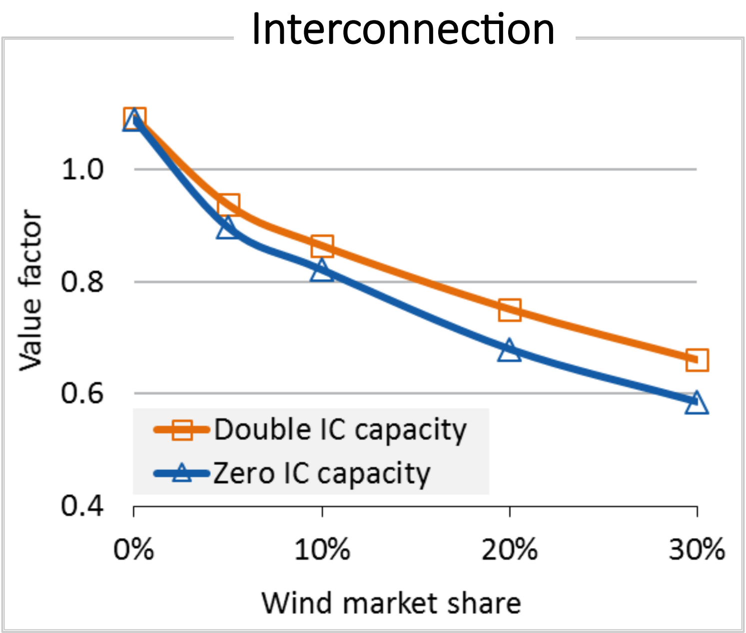
The value factor of wind power decreases from ~1.1 at low penetration to ~0.65 at 30% market share (1.5 points per point market share).

The value factor of solar power decreases from ~ 1.3 at low penetration to ~ 0.6 at 15% market share: (4.6 points per point market share).

Storage and transmission help … but not much



Updated from Hirth (2013): Market value



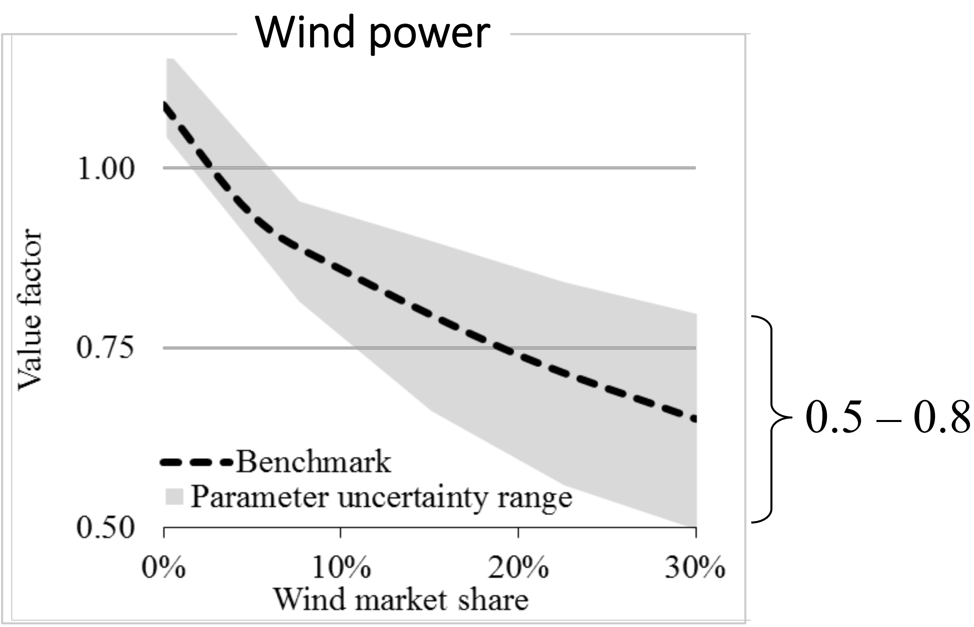
Updated from Hirth (2013): Market value

Doubling existing pump hydro storage capacity has a positive, but minor, impact on the value of wind power. The impact is larger for solar.

Doubling European interconnector capacity has a moderate positive.

The value drop continues: model results

model results



Updated from Hirth (2013): Market value

The wind value factor falls to 0.5 to 0.8 at 30% penetration.

CO_2 price between 0 – 100 €/t, Flexible ancillary services provision, Zero / double interconnector capacity, Flexible CHP plants, Zero / double storage capacity, Double fuel price, ...

The value drop jeopardized...

... profitability

... phase-out of support schemes

... decarbonization of the power system

... renewables targets

... which is bad news for ...

... investors in renewables

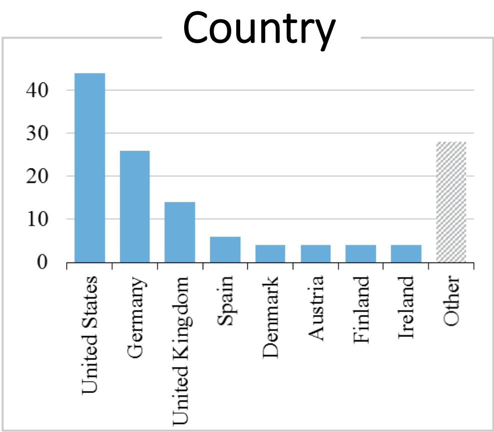
... finance ministers

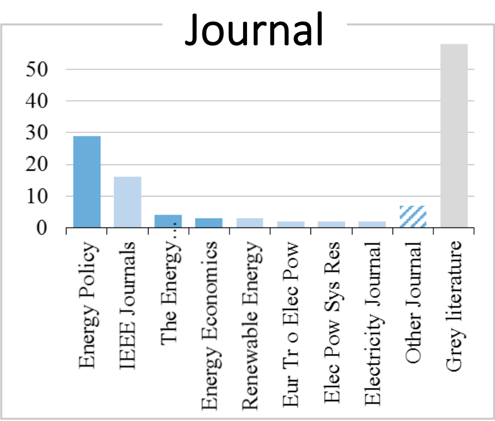
... the climate

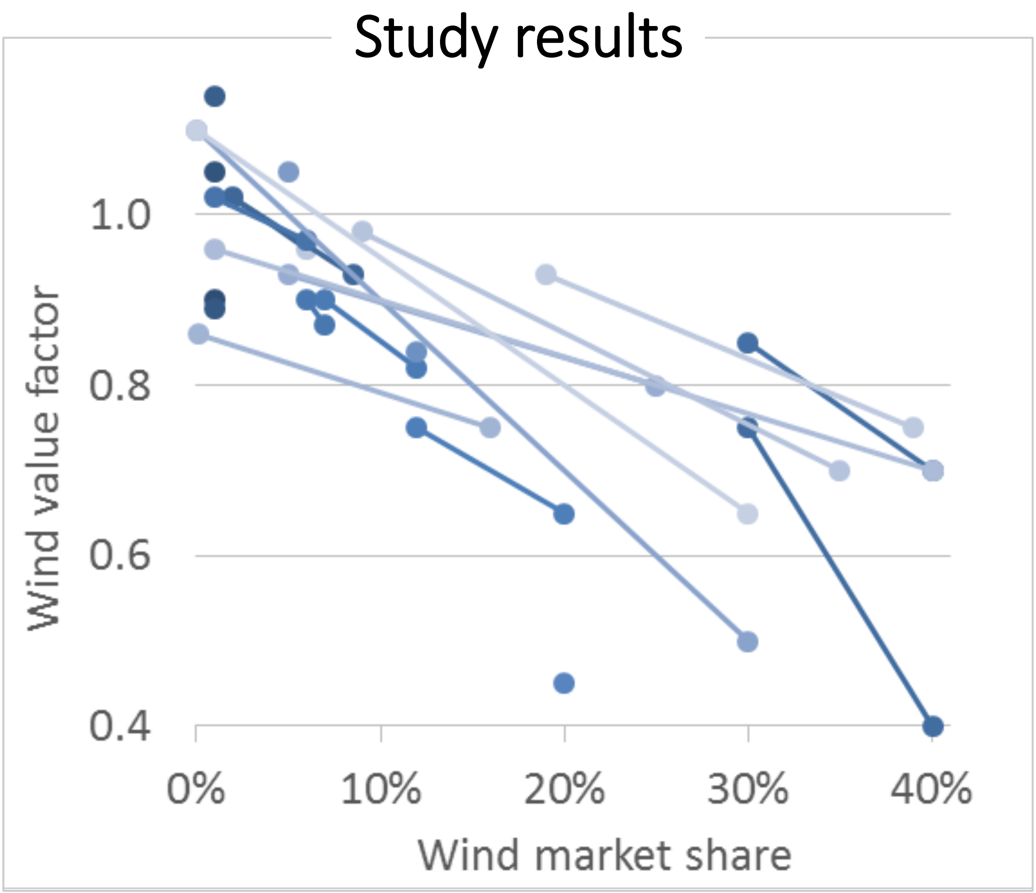
... the renewable industry

3. Literature review

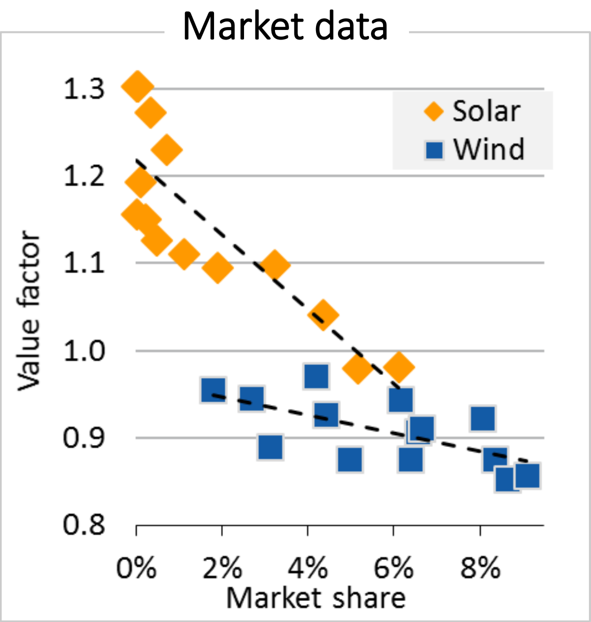
We reviewed 100+ studies

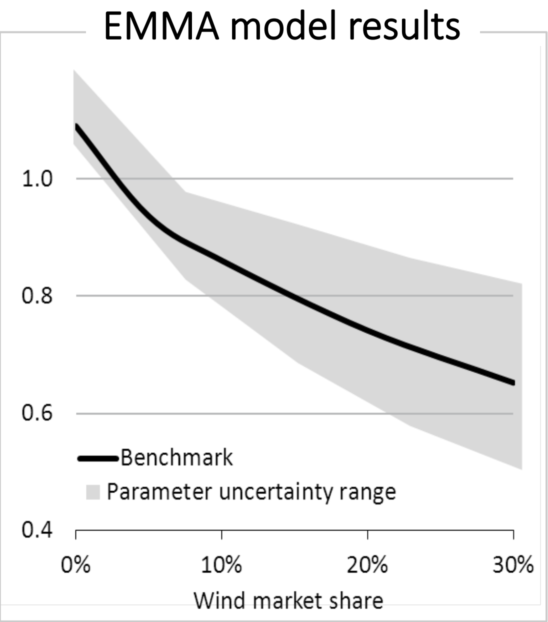


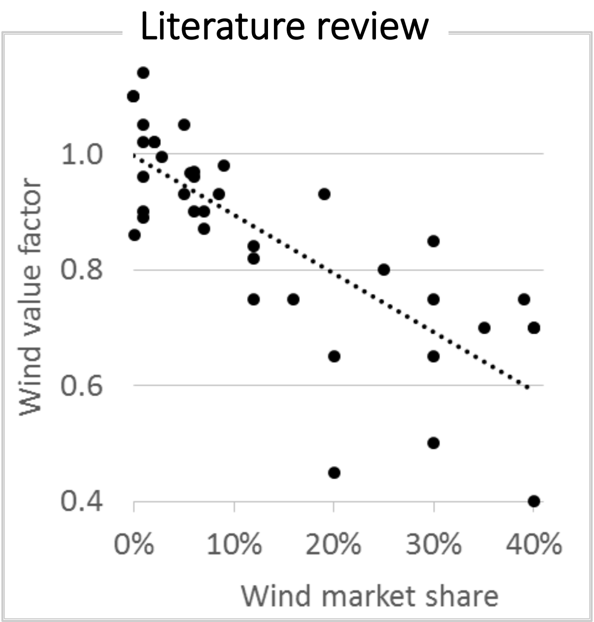




Different methodologies – robust finding: value drops







Updated from Hirth (2013): Market value and Hirth (2015): Market value solar

At 30% penetration, the value factor of wind falls to 0.5 – 0.8 of the base price. In Germany, it has already fallen from 0.96 to 0.86 as penetration increased from 2% to 8%. The value drop jeopardizes power system decarbonization and transformation.

Summing up: Market value

Low value of wind and solar power at high penetration

- Compared to value of other generators
- Compared to today's value of wind and solar power

Value drop is large

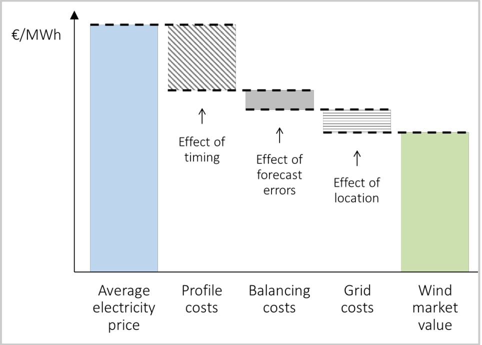
- ~40% value drop for wind
- In other words: a massive shift in relative prices
- Drop is at least twice as steep for solar as for wind

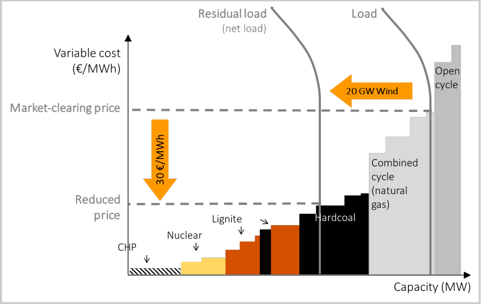
Robust results

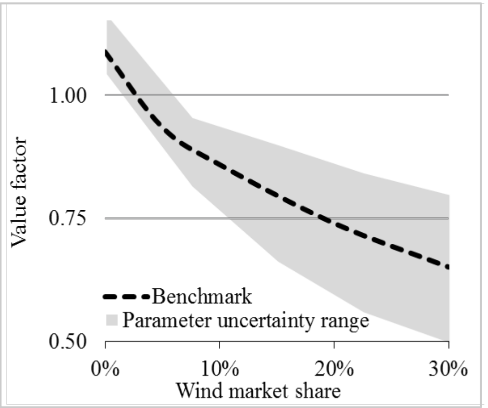
- w.r.t. parameter uncertainty
- w.r.t. model uncertainty

Profitability in questions

- Difficult to archive profitability at high penetration rate
- Puts into question ambitious renewables targets without subsidies







Mitigating the value drop: integration options

There exist a wide range of options to integrated VRE into power systems that help mitigating the value drop ("integration options" or "mitigation measures").

VRE-friendly system

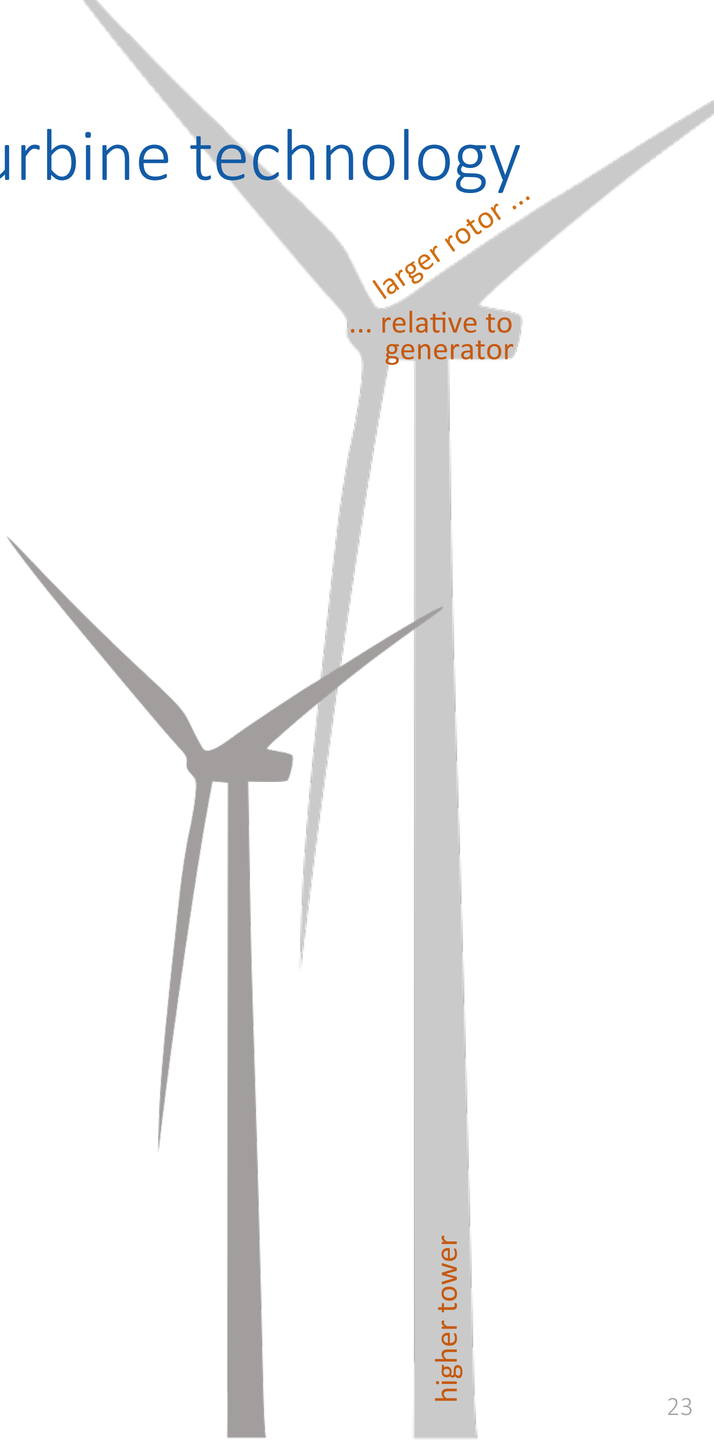
- Demand response / price elasticity
- Electricity storage
- Long-distance interconnection
- Reduce thermal must-run (CHP, ancillary services)
- Shifting the thermal generation mix from capital-intensive base load towards low-capex mid and peak load plants
- Spot and balancing market design
- Reservoir hydro power

System-friendly VRE

- Optimized geographic allocation of VRE generators
- Diversification of VRE mix
- East-west oriented solar modules with higher capacity factors
- Low wind speed turbines with higher capacity factors

4. System-friendly wind power

The *silent revolution*: new wind turbine technology



Wind turbine technology has changed dramatically during the past years…

- higher towers
- lower specific rating (W/m²)
- → increased capacity factors
- "advanced wind turbines"

… with potentially large effect on power systems and markets.

- higher capacity credit
- reduced grid expansion requirements
- impact on optimal thermal mix
- reduced storage & flexibility requirements
- less forecast errors
- *higher market value*

The *silent revolution*: new wind turbine technology

market data

Wind turbine technology has changed dramatically during the past years...

- higher towers
- lower specific rating (W/m²)
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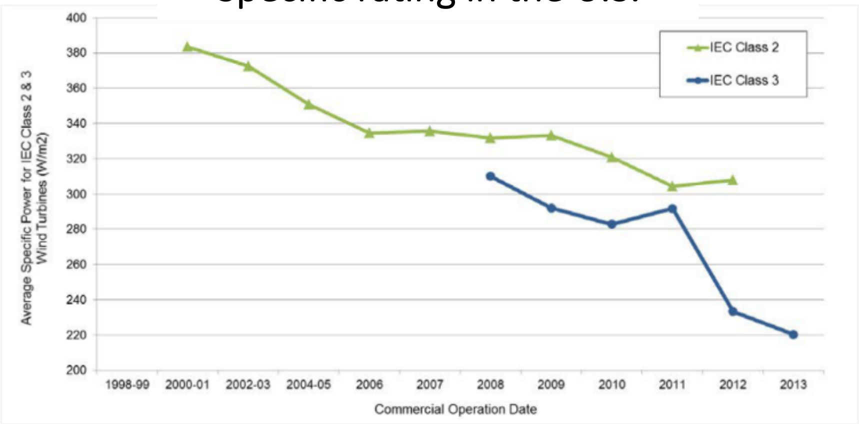
- "advanced wind turbines"

Specific rating in the U.S.

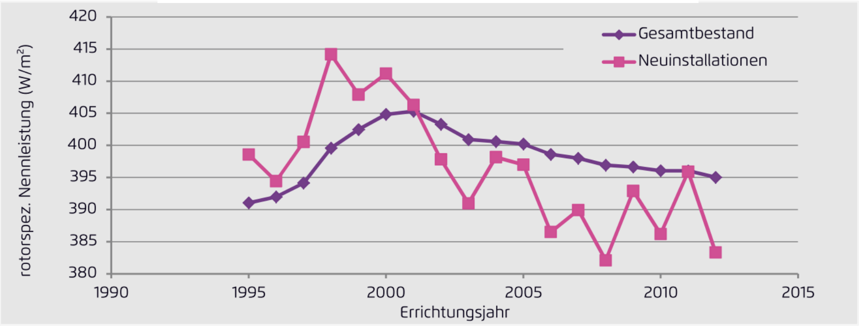


Wiser & Bolinger (2014)

... with potentially large effect on power systems and markets.

- higher capacity credit
- reduced grid expansion requirements
- impact on optimal thermal mix
- reduced storage & flexibility requirements
- less forecast errors
- *higher market value*

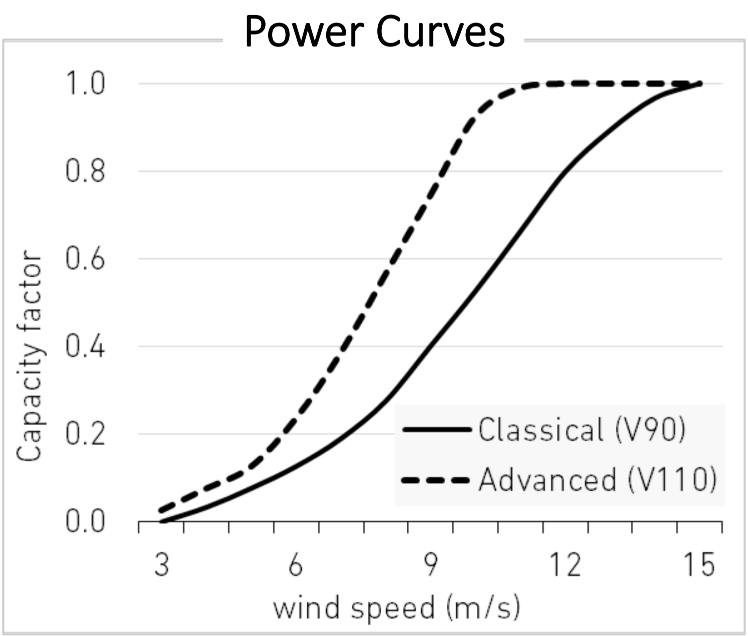
Specific rating in Germany



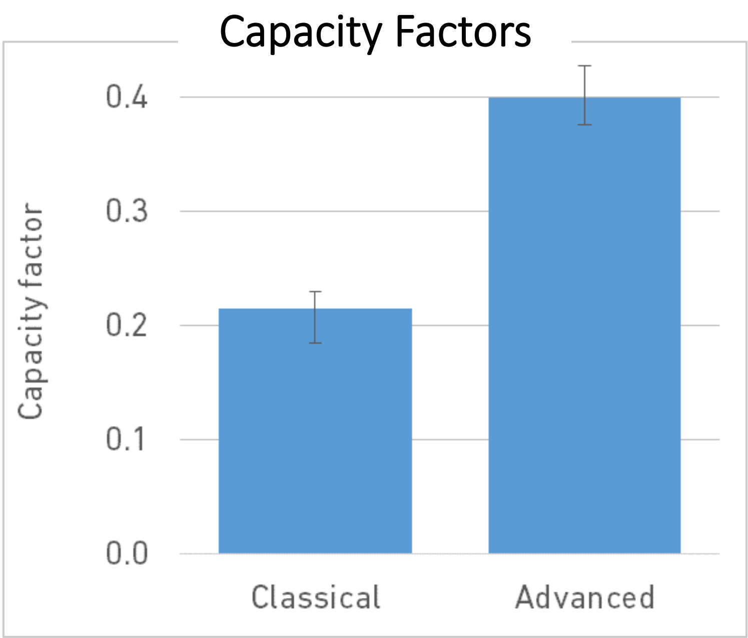
Fraunhofer IWES (2013)

Advanced wind turbines are *very* different

model results

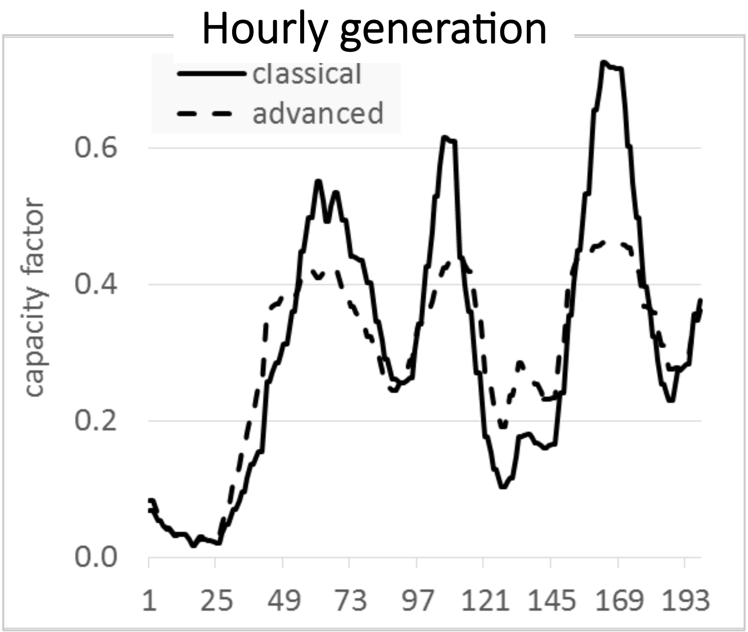


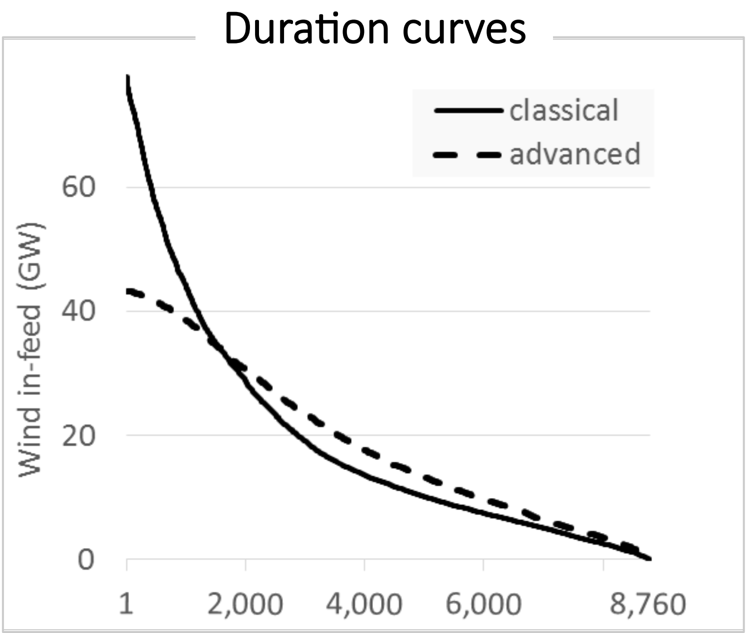
At intermediate wind speeds (8-10 m/s), advanced turbines generate much more electricity than classical turbines.



Advanced turbines can have twice the capacity factor of classical turbines.

Much *smoother* generation profile



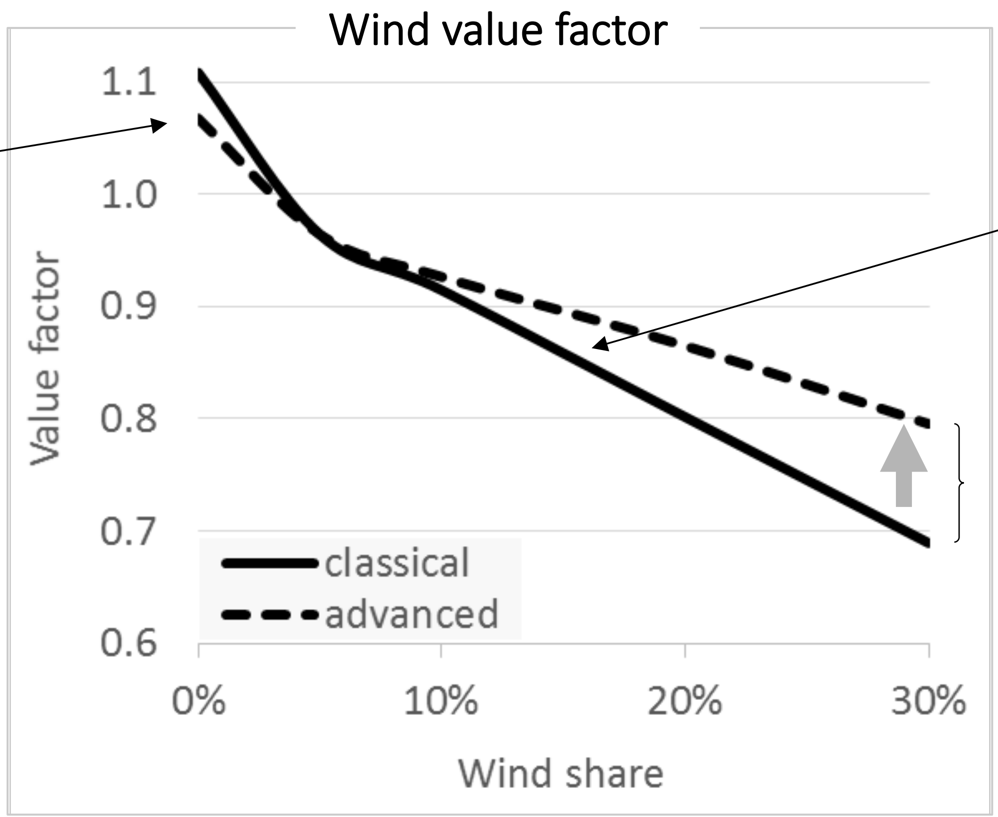


Less fluctuations of output...

... and more evenly distribution. (Both figures assume the yearly amount of electricity generated.)

Major result: market value strongly increases

Classical turbines: stronger seasonal correlation with load



Delta becomes significant at 15% penetration

11 percentage-points (15%): large delta at high penetration

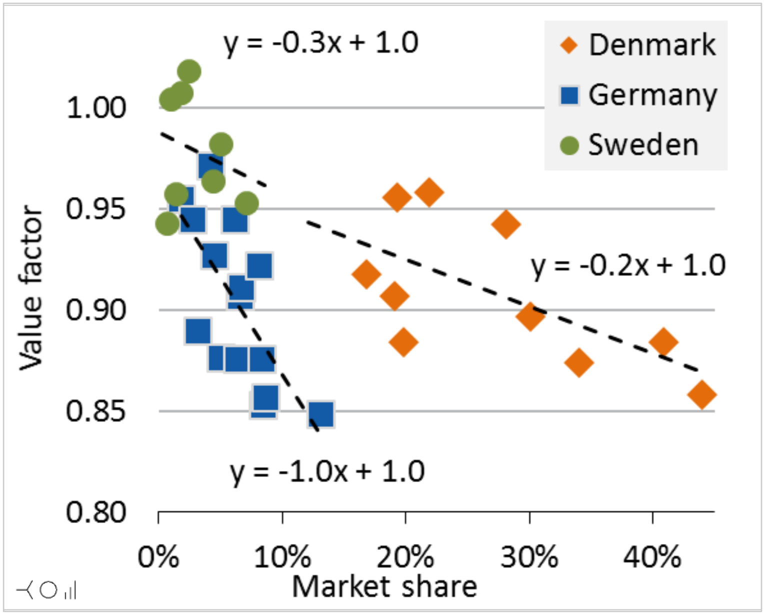
Penetration (always) in energy terms

Land-based wind power from system-friendly turbines is 15% more valuable than wind power from classical turbines (at 30% penetration).

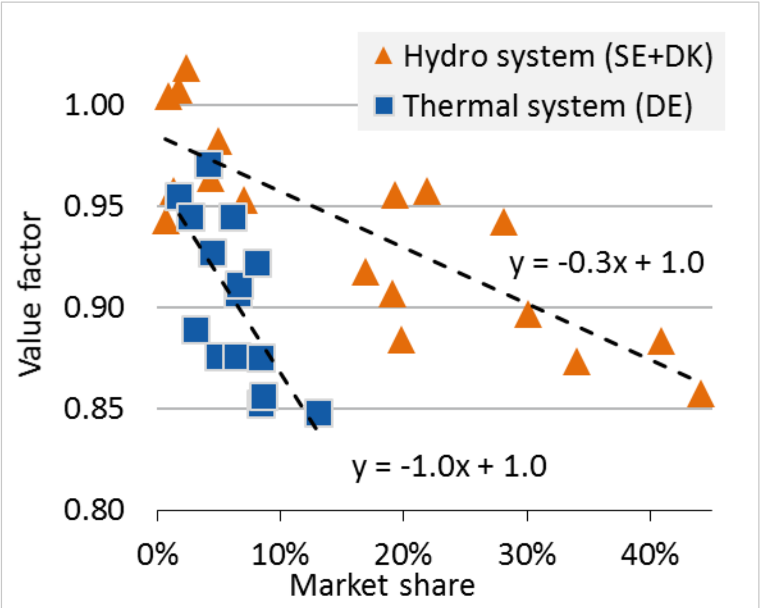
6. Flexible hydro power

market data

Empirical value factors



Neon analysis.



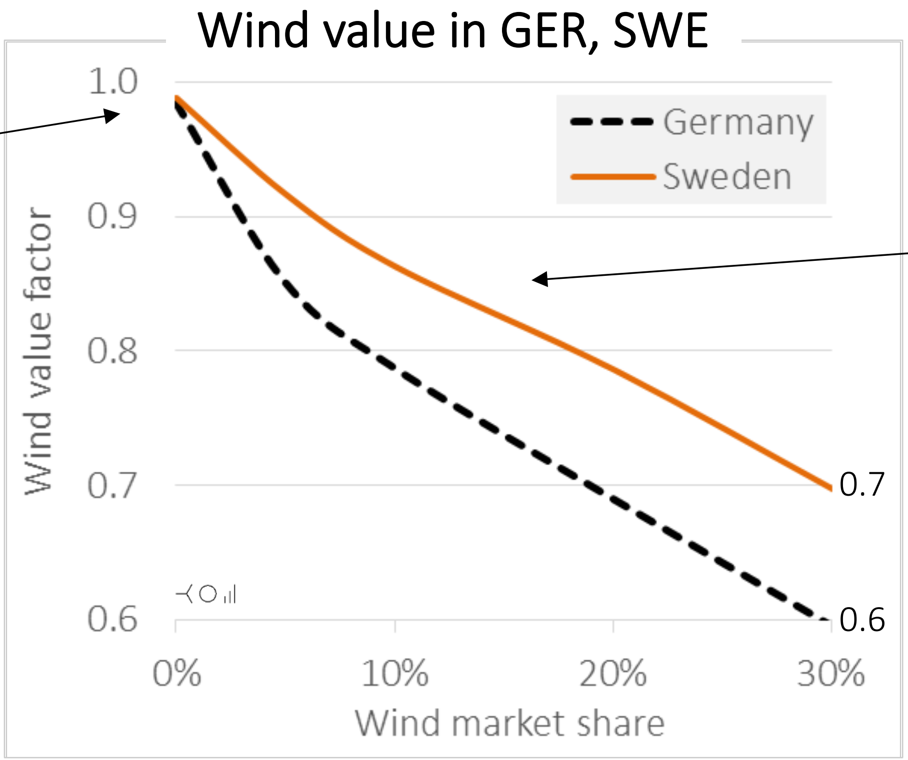
In Sweden and Denmark, value factors have been much mores table than in GER.

Grouped together, SE+DK value factors decline at a third the rate than in GER.

Wind value factor: Sweden vs. Germany

model results

Value factor around unity in both countries



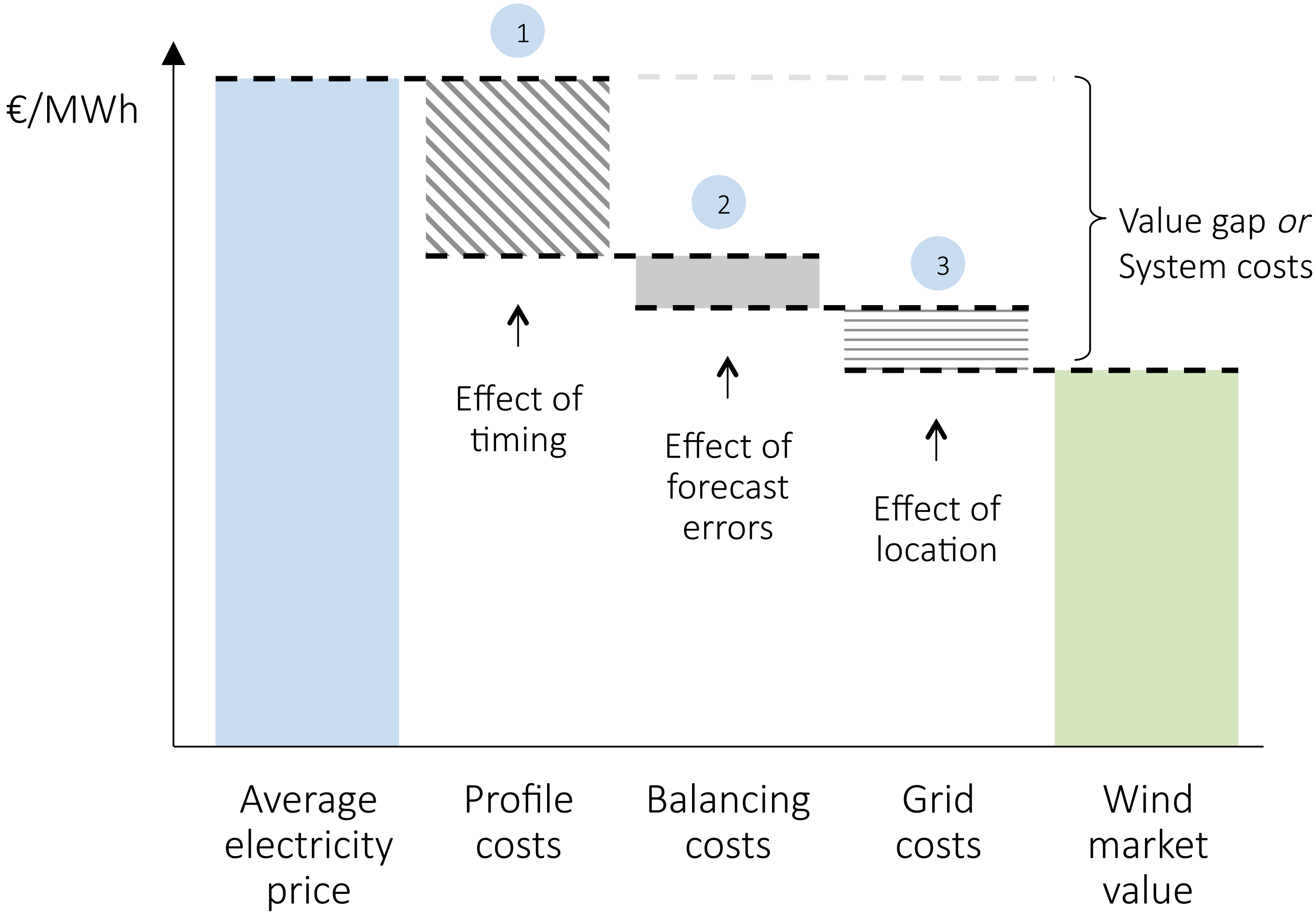
Market value more stable in Sweden

Ten points difference at 30% market share (=17% higher value) – recall: upper bound

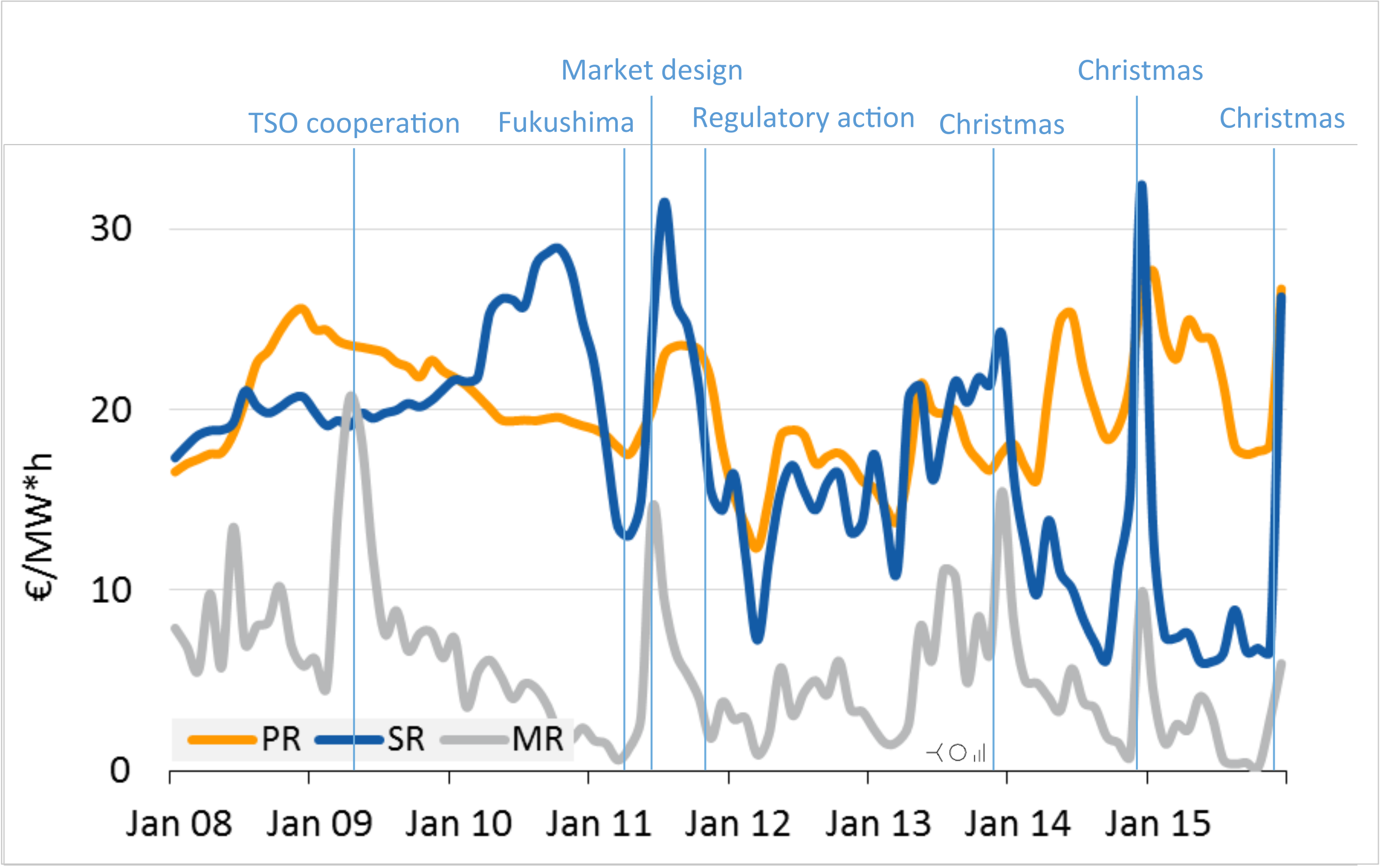
The market value of wind power drops in both regions, but faster in Germany.

5. Balancing

Market value of wind power – a holistic perspective



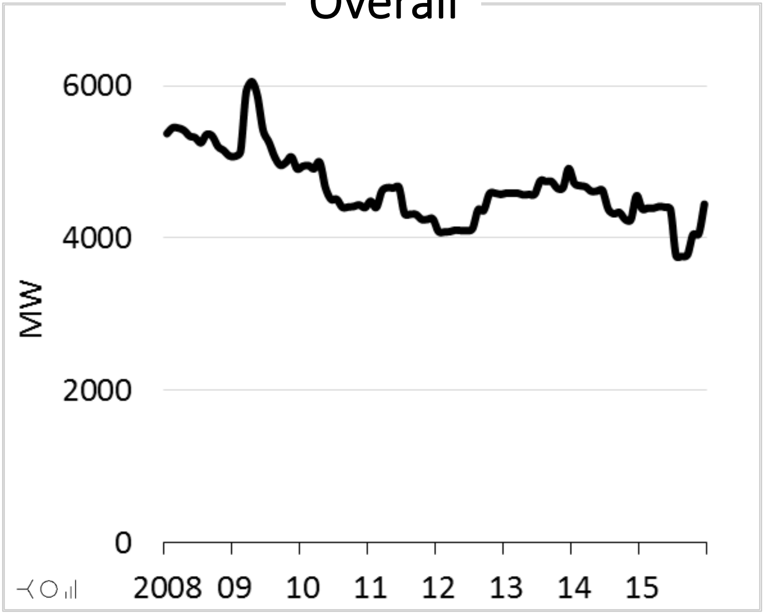
Balancing power prices remain volatile



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Monthly volume-weighted averages of all products (peak / off-peak, negative / positive) per segment.

Balancing reserves are decreasing

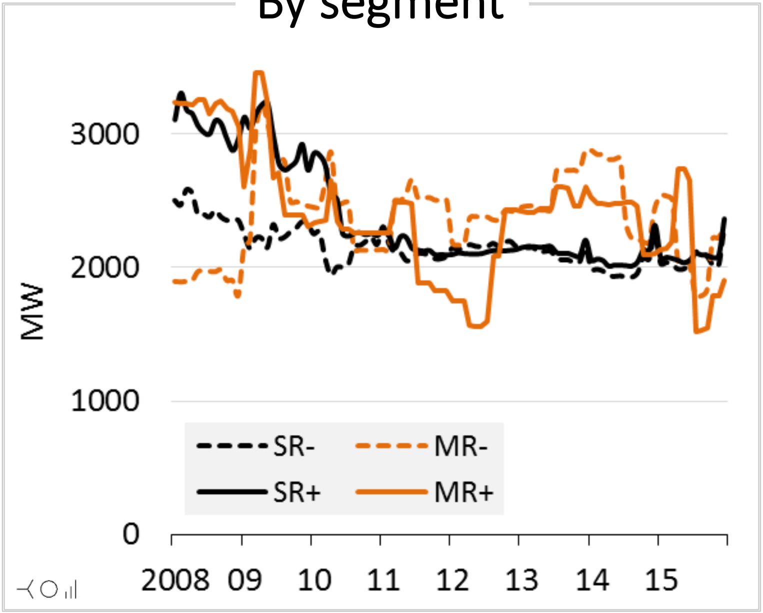
Overall



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only. Secondary and tertiary only.

Despite seasonality, the trend is clear: less and less balancing reserve is needed.

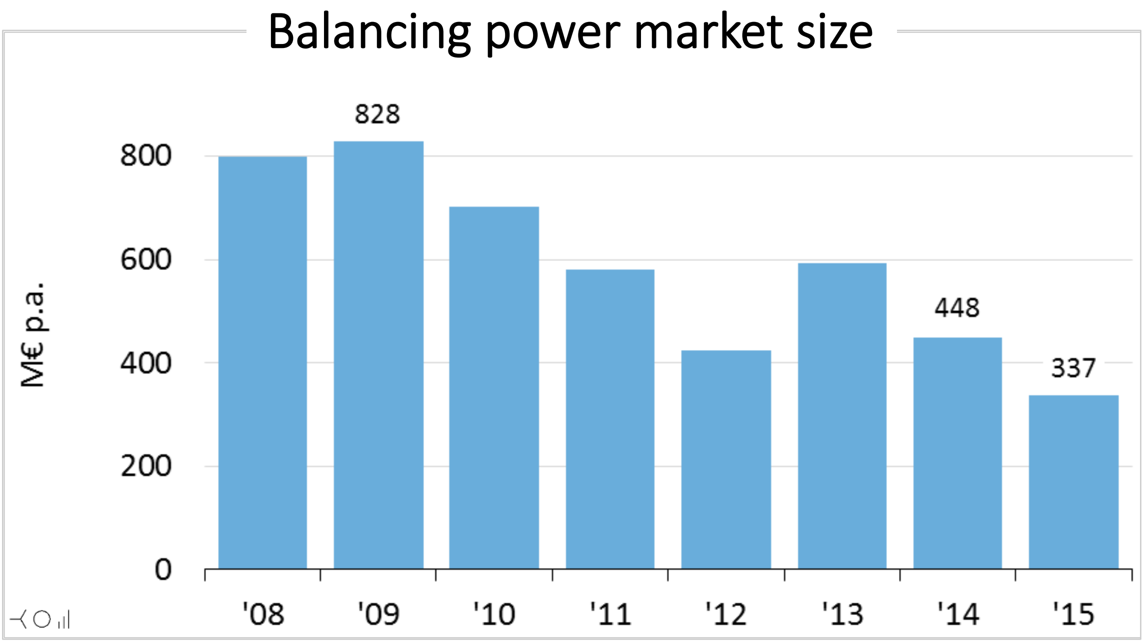
By segment



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

Procured volumes decline across product types.

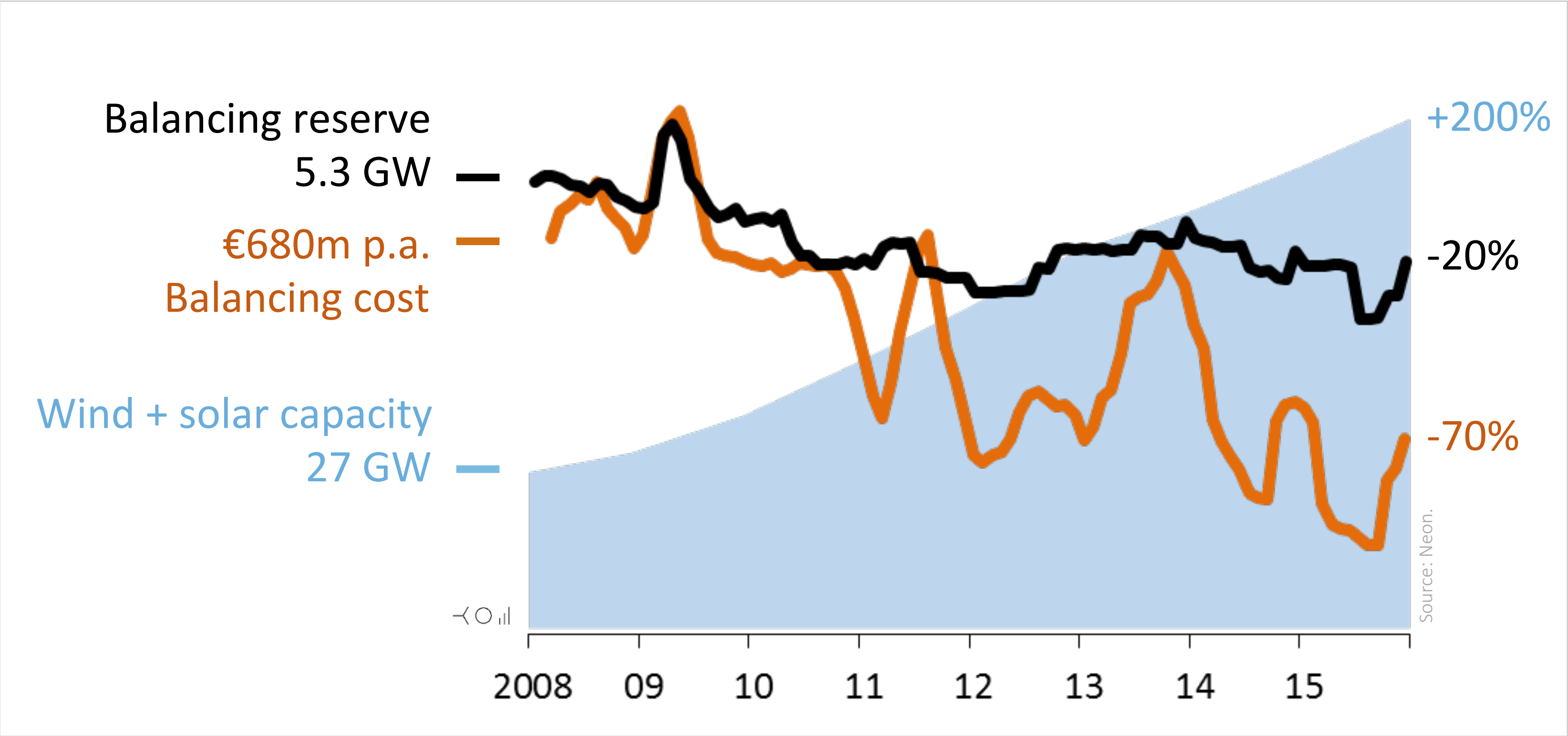
The German balancing market is shrinking



Neon analysis. Based on data from Bundesnetzagentur, Regelleistung.net, TSO websites. Power (capacity) payments only.

In 2015, the market for balancing power contracted further. Revenues totaled to € 340m, 60% less than in 2009 and 25% less than in 2014.

The German Balancing Paradox



Since 2008, installed wind and solar capacity tripled. At the same time, balancing power reserves *decreased* by 20% - and procurement costs by 70%!

Conclusions

Conclusions

The market value of wind power: declining

- At 30% penetration, one MWh generated by wind turbines is worth 20%-50% less than one MWh from a base load power station (at low penetration, its value is higher)
- This reflects the "system costs" of wind and solar power

Mitigating the value drop

- Wind-friendly power systems, particular hydroelectricity (also storage, transmission)
- System-friendly wind power

The role of policy and market design

- The value loss is *not* caused by a "flawed" design of power markets, but a fundamental economic effect
- Policies and markets should be designed to signal scarcity – on wholesale, balancing, and other markets

Neon: relevant project references

Neon is a Berlin-based boutique consulting firm for energy economics, headed by Lion Hirth. We combine expertise on economic theory with advanced modeling capabilities and extensive industry experience. Neon specializes in five areas:

1. Market value of wind and solar power
2. (Whole) system costs
3. Balancing power
4. Market design
5. Power market modeling

System-friendly wind and solar power (IEA). Model-based study for the International Energy Agency, Paris. Neon assessed the market and system benefits of low-wind speed wind turbines and east- and west-oriented PV based on its power market model EMMA. 2014-16. The study is published in *Energy Economics*. More

Integration costs (Agora Energiewende). Literature-based study for Agora Energiewende, Berlin. Neon advised Agora and helped implementing workshops in Berlin and Paris. 2015. The report has been published by Agora. More

Whole system costs (DECC). Neon advised the UK Department of Energy and Climate Change in a project on whole system costs of wind and solar power. 2015.

Open Power System Data (BMWi). Construction of an open platform for European power system data for the German Ministry of Economic Affairs an Energy. Neon coordinates a team of three research institutes. 2015-17. More

Electricity market design (IEA-RETD). Assessment of long-term wholesale and retail power market design under very high shares of variable renewables. Neon partnered with FTI CL Energy for this project. 2015-16. More

Model development (Vattenfall). Neon supported Vattenfall in model development. 2015.

Wind market value in the Nordic region (Energiforsk). Model-based assessment of the market value of wind power in the hydro-dominated power system of the Nordic region. Neon design the study, developed the model, and wrote the report. 2016.

Reasons for the Nordic price drop (Swedish Energy). Swedish wholesale power prices declined by two thirds 2010-15. Neon conducted a model-based assessment of the reasons for this price drop. 2016.

Power market trainings. Neon trained staff at IRENA, ERRA, Vattenfall, JRC, UFZ, Swedenergy, Clean Air Task Force, IG Windkraft in topics such as power markets, energy economics, and electricity policy. More

Studies and publications

Economics of Electricity	Hirth, Lion, Falko Ueckerdt & Ottmar Edenhofer (2016): "Why Wind is not Coal: On the Economics of Electricity", *The Energy Journal* (forthcoming). www.feem.it/getpage.aspx?id=6308
Integration Costs	Hirth, Lion, Falko Ueckerdt & Ottmar Edenhofer (2015): "Integration Costs Revisited – An economic framework of wind and solar variability", *Renewable Energy* 74, 925–939. http://dx.doi.org/10.1016/j.renene.2014.08.065
Market Value	Hirth, Lion (2013): "The Market Value of Variable Renewables", *Energy Economics* 38, 218-236. http://dx.doi.org/10.1016/j.eneco.2013.02.004
Optimal Share	Hirth, Lion (2015): "The Optimal Share of Variable Renewables", *The Energy Journal* 36(1), 127-162. http://dx.doi.org/10.5547/01956574.36.1.5
System LCOE	Ueckerdt, Falko, Lion Hirth, Gunnar Luderer & Ottmar Edenhofer (2013): "System LCOE: What are the costs of variable renewables?", *Energy* 63, 61-75. http://dx.doi.org/10.1016/j.energy.2013.10.072
Market Value of Solar	Hirth, Lion (2015): "The market value of solar photovoltaics: Is solar power cost-competitive?", *IET Renewable Power Generation 9(1), 37-45*. http://dx.doi.org/10.1049/iet-rpg.2014.0101
Balancing Power	Hirth, Lion & Inka Ziegenhagen (2015): "Balancing power and variable renewables: Three links", *Renewable & Sustainable Energy Reviews* 50, 1035-1051. http://dx.doi.org/10.1016/j.rser.2015.04.180
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