The Market Value of Fluctuating Renewables

What drives the market value of electricity from fluctuating renewables sources (fRES) such as wind and solar power?

Lion Hirth, Vattenfall*

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*The findings, interpretations, and conclusions expressed herein are those of the author and do not necessarily reflect the views of Vattenfall.
Contact: Lion Hirth, Vattenfall Europe AG, Chausseestraße 23, 10115 Berlin. lion.hirth@vattenfall.com.

Motivation

When will wind and solar power be competitive on the (wholesale) market?

- → cost development
- → revenue development

Two properties of fRES matter for market income

fRES depend on fluctuating primary energy sources (non-dispatchable)

Uncertainty

- when day-ahead markets close, uncertainty about generation remains
- imbalances have to be closed at intraday or imbalance markets

Imbalance Costs

- costs of forecast errors
- ~ 10% of spot market revenues (today)

Fixed Generation Profile

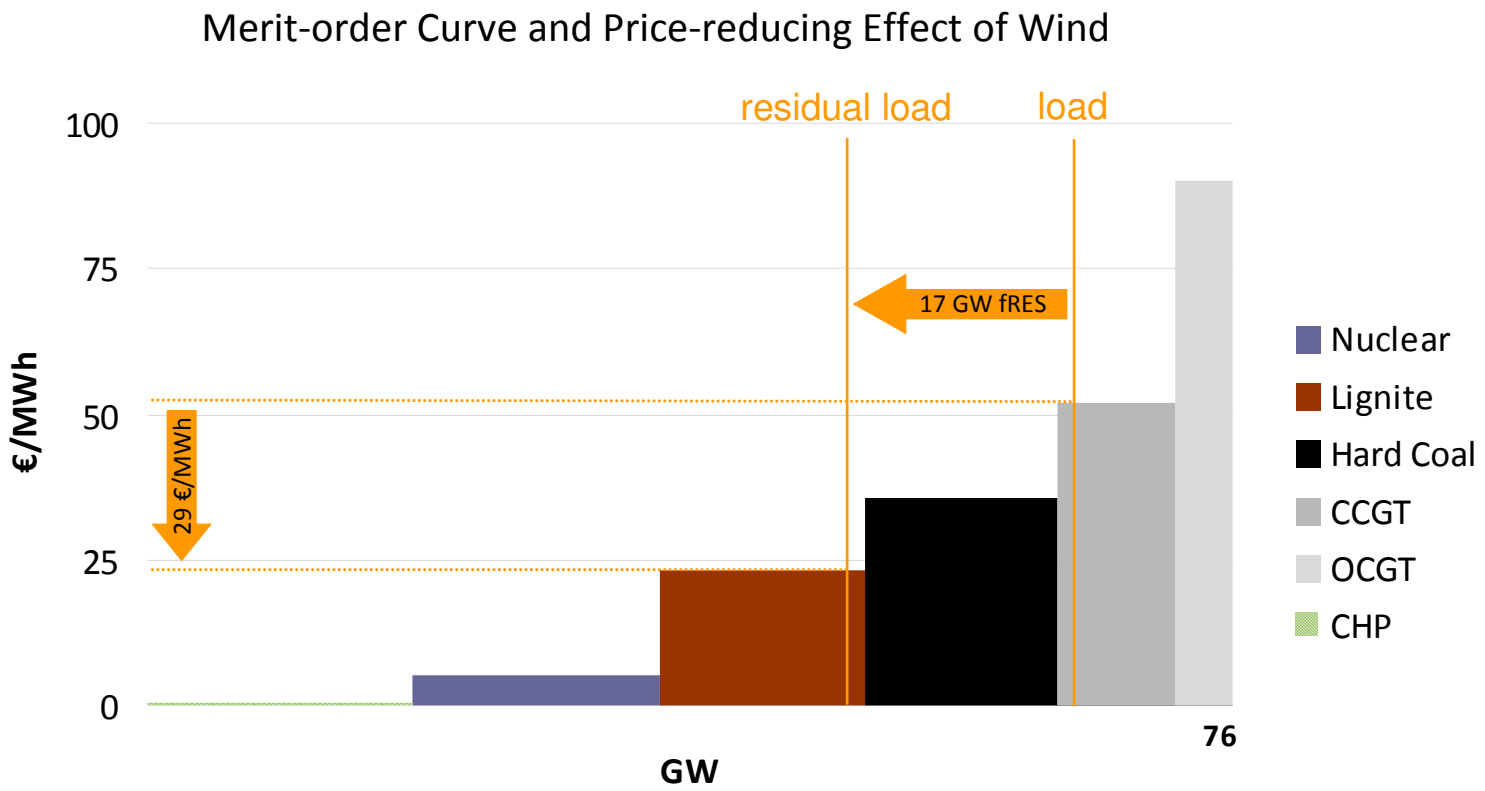
- electricity price is different in every hour
- whenever it is windy / sunny electricity price is lowered

Profile Costs

- costs of fixed generation profile
- ~ 10% of spot market revenues (today)

→ to understand competitiveness of fRES, it is *not* sufficient to compare levelized costs of electricity to the average electricity price (base price)

The Mechanics of Price Setting



Size of the price drop during windy hours is a function of:

- installed wind capacity
- shape of the merit-order curve (“steepness”)
- intertemporal flexibility (e.g. hydro reservoirs)

Stylized merit-order of Germany 2010 at 20 €/t CO2; bidding price including run-through discount; only dispatchable technologies; weighted with average availability

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Market Data: Status Quo

Onshore Wind in Germany			
	Base price (€/MWh)	Ave Revenue (€/MWh)	Value factor (1)
2007	38	33	.88
2008	66	59	.90
2009	39	35	.91
2010	44	42	.94
Average	47	42	.91

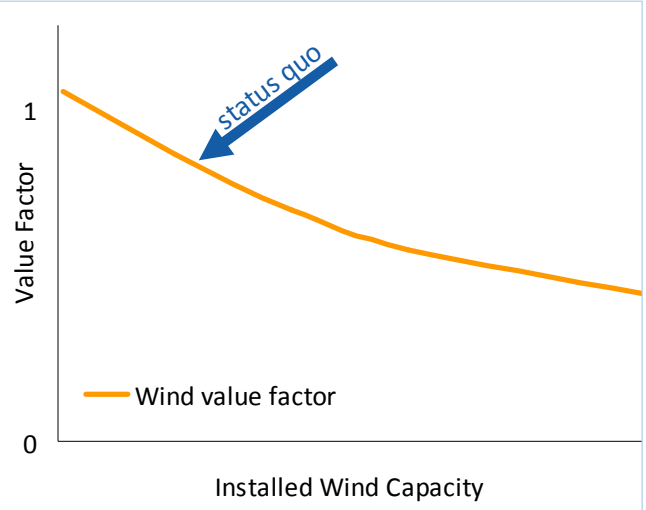
Solar in Germany			
	Base price (€/MWh)	Ave Revenue (€/MWh)	Value factor (1)
-			
2008	66	82	1.25
2009	39	44	1.14
2010	44	49	1.11
Average	50	58	1.17

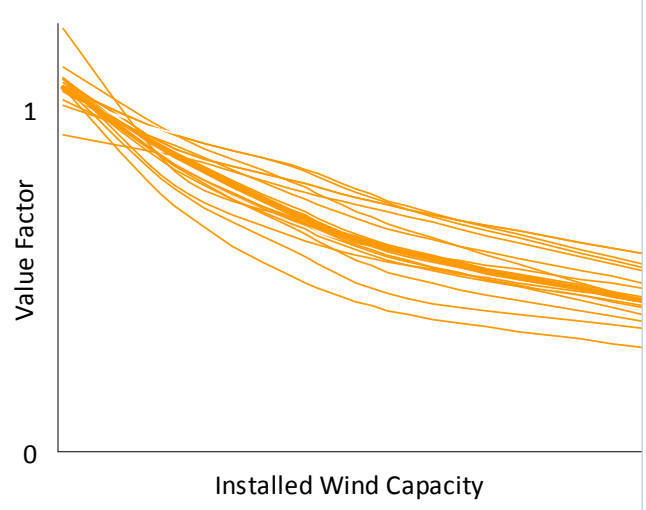
Wind earned 9% less than the average electricity price.

Solar earned 17% more.

Future development

1. Value factor curve
   - from market data value factors for the current state of the electricity system can be calculated
   - we are interested in the future development of profile costs
   - particularly, we are interested in the relationship between profile costs and installed capacity
2. Understand Drivers
   - many parameters potentially influence profile costs (by influencing the shape of the merit-order curve and intertemporal flexibility)
   - we want to identify and quantify drivers
   - CO_2 price, fuel prices, power plant stack, interconnector development, capacity markets, electricity storage, generation flexibility, nuclear phase-out
- time series are too short for econometrics → model





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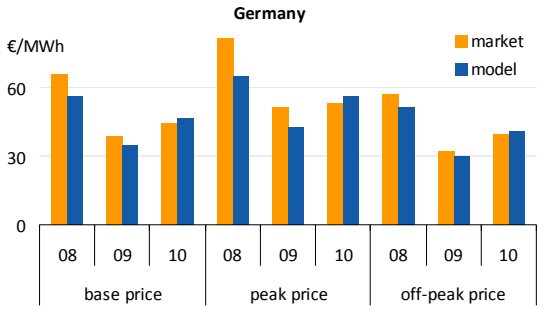
The numerical model

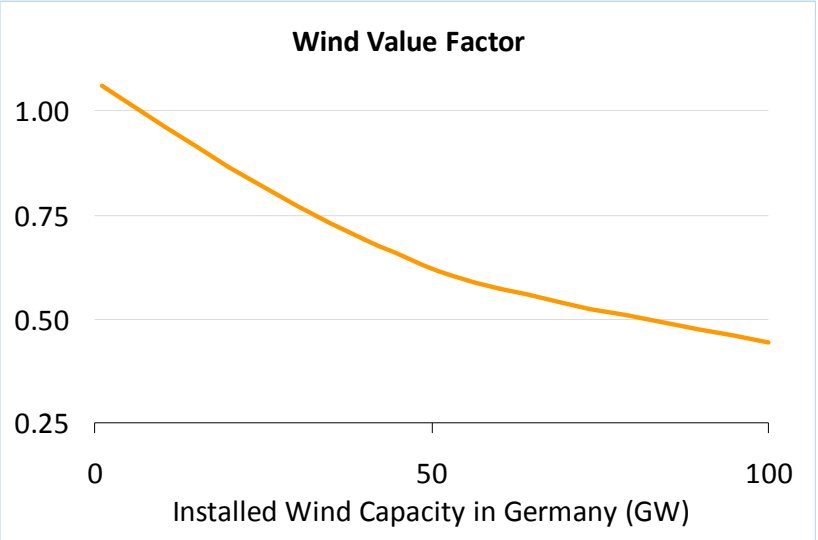
- stylized electricity market model
  - ten technologies (wind, solar, eight dispatchable, pump hydro)
  - perfect competition
  - electricity price is set by variable cost of marginal plant
  - no load flow, NTCs between market areas
- integrated dispatch and investment
  - hourly time steps for a full year
  - existing plant stack, storage and interconnectors
  - endogenous (dis-)investments in generation
  - investments in storage and interconnectors
- parameterization of key inflexibilities
  - CHP must-run
  - start-up costs
  - ancillary services
- back-tested to market prices

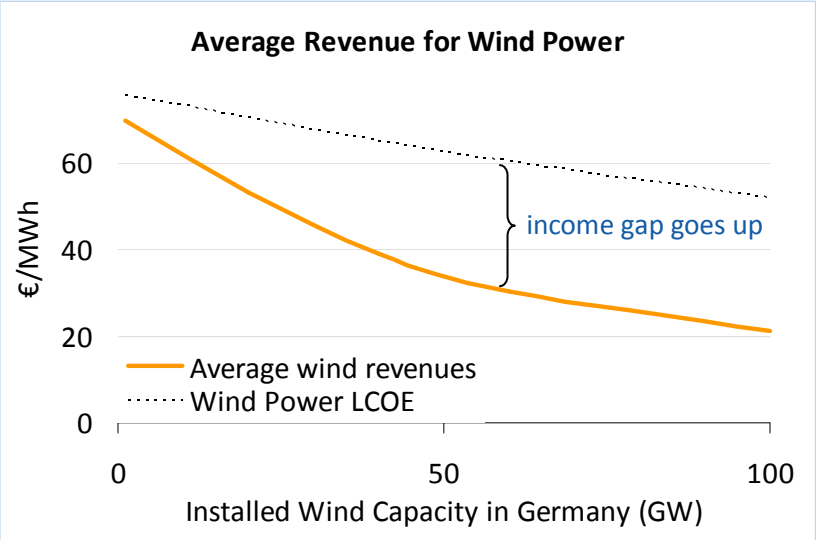


Wind Value factors in Germany		
	model	market
2008	0.93	0.90
2009	0.95	0.91
2010	0.94	0.94

Results

- Main run
  - installed wind capacity is increased from zero to 100 GW (equivalent to 41% of consumption)
  - all other parameters are at long-term “best guess” levels and are not changed
- market value depends strongly on amount of installed capacity
  - value factor drops from 1.1 to 0.4
  - → the value factor curve is (steeply) downward sloping
  - average revenue drops from 70 €/MWh to 21 €/MWh
- compare to costs of onshore wind
  - learning rate of 5% per doubling of global installed capacity
  - assumption: global capacity doubles twice as quickly as German
  - revenues fall quicker than costs
- → it will be tough for wind power to become competitive (under these conditions)





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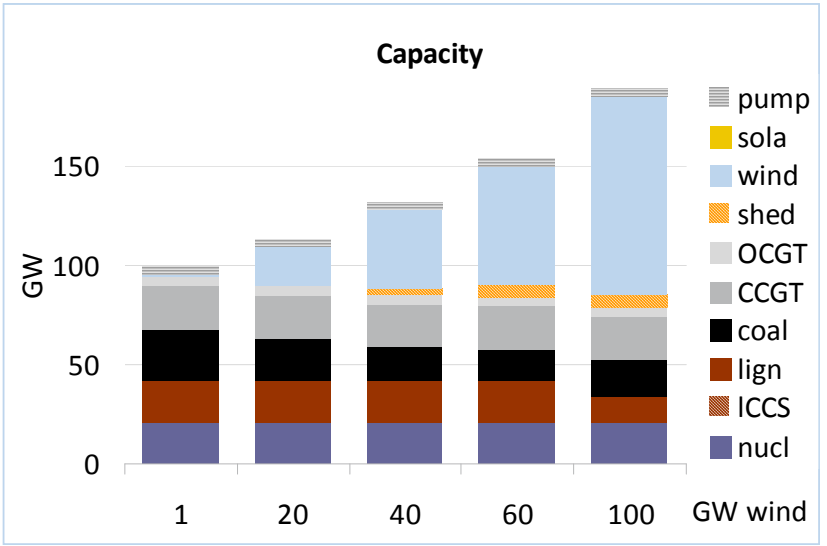
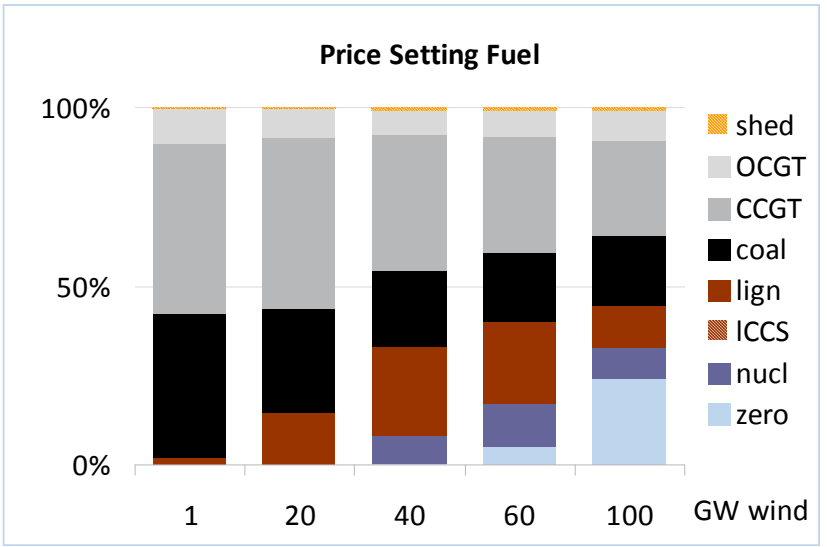
Results II

- Capacity development
  - total dispatchable capacity is reduced from 94 GW to 79 GW (decommissioning of hard coal and lignite)
  - revenues from pump hydro storage double, but still too low to trigger investment
  - existing nuclear remain profitable
- Price setter
  - price drops to zero in 500h (80GW) and 2000h (100GW)
  - curtailment remains limited: 10% of wind energy at 100GW





there are no negative prices in the model

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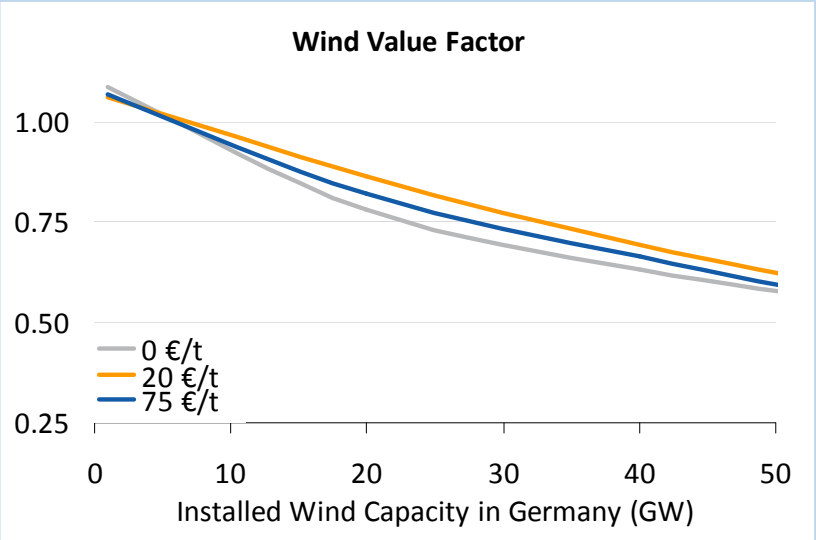
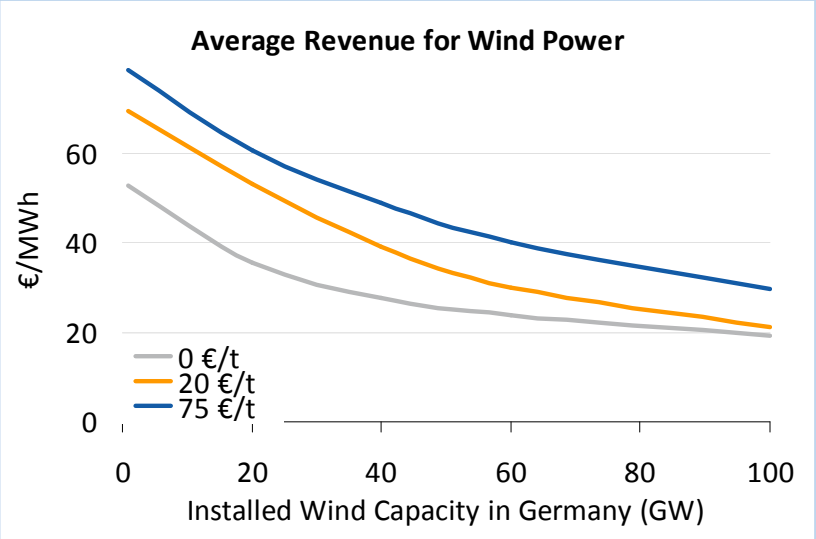
The effect of CO_2 pricing

- higher CO_2 prices…
  - … increase the base price and thereby increase wind revenues
  - … but can *decrease* the value factor (sometimes)
  - because higher CO_2 prices induce investments in nuclear or CCS, which increases the steepness of the merit-order curve, leading to low prices in windy hours
- effects of parameter changes can counter-intuitive
  - direct effect: higher CO_2 price → higher variable cost → higher electricity price and flatter merit-order curve → higher revenues for wind power
  - indirect effects triggered by investments





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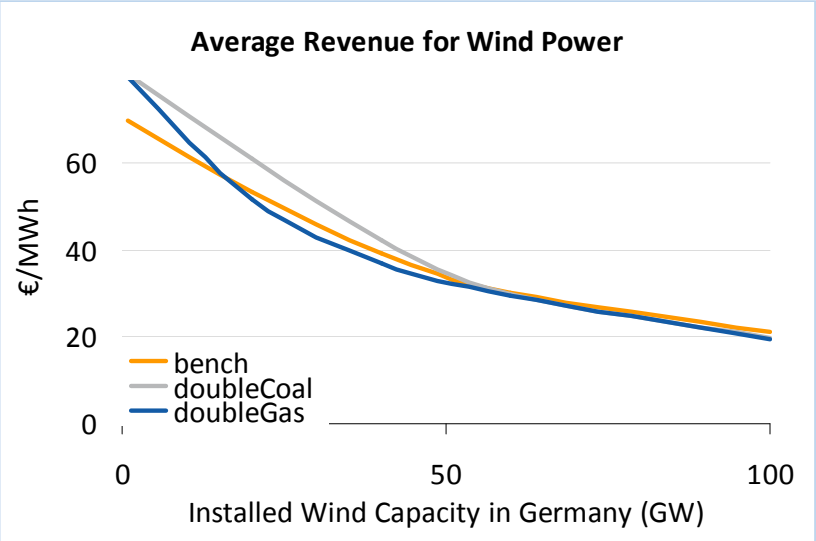
The effect of higher fuel prices

- Do higher prices increase the revenues for wind power?
  → not necessarily
- higher coal price
  - direct effect: higher electricity price when coal is price setter (+)
  - merit-order flatter (+)
  - investments in gas (+)
  - investments in lignite (-)
  - → overall: increases wind revenues
- higher gas price
  - direct effect: higher electricity price when gas is price setter (+)
  - merit-order steeper (-)
  - investments in coal and lignite (-)
  - → overall: non-monotonic effect; *decreases wind revenues sometimes*



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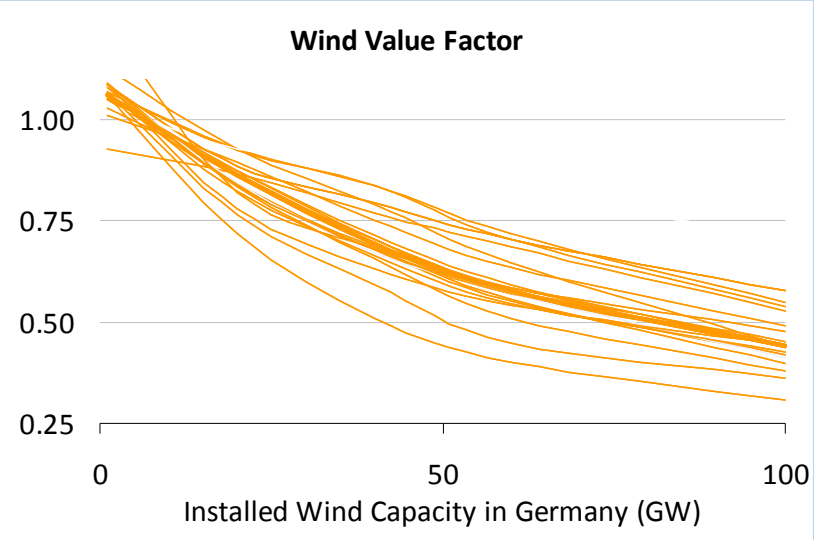
More effects

What affects wind revenues?	
Parameter change	**Effect on wind revenues**
Higher CO_2 price	↑ (+10 €/MWh at increase of 55 €/t CO_2)
Higher gas price	↓(-2 €/MWh at double gas price)
Higher coal price	↑ (up to +8 €/MWh at double coal price)
More interconnector capacity	↓ / → (-1 €/MWh at double IC capacity)
More storage capacity	↑ / → (+1 €/MWh at double IC capacity)
Spatial distribution of wind capacity	↓ (up to -13 €/MWh if all wind power was in Ger)
More flexible CHP plants	↑ (up to +14 €/MWh with entirely flexible CHP)
Capacity markets	↑ (+3 €/MWh at 150 €/MWh cut-off price)



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Take home

1. **Don’t compare levelized costs of renewables to the average electricity price!**
   (You can’t ignore profile and imbalance costs.)

2. **The revenue of wind power drops significantly as more capacity is installed.**
   (The wind value factor drops from 1.1 to 0.4 [0.3;0.7] as the wind power market share grows to 40%.)

3. **It will be harder for renewables to become competitive than many studies suggest.**
   (50% to 150% times harder than base price comparisons indicate.)

4. **Changes in the electricity system can have unexpected effects.**
   (Higher gas prices or more interconnection capacity might reduce wind revenues, for example.)

5. **Increasing the flexibility of the electricity system is key to make fRES competitive.**
   (Anything from storage, interconnectors, flexible CHP, flexible providers of ancillary services, …)

lion.hirth@vattenfall.com