System-friendly renewables

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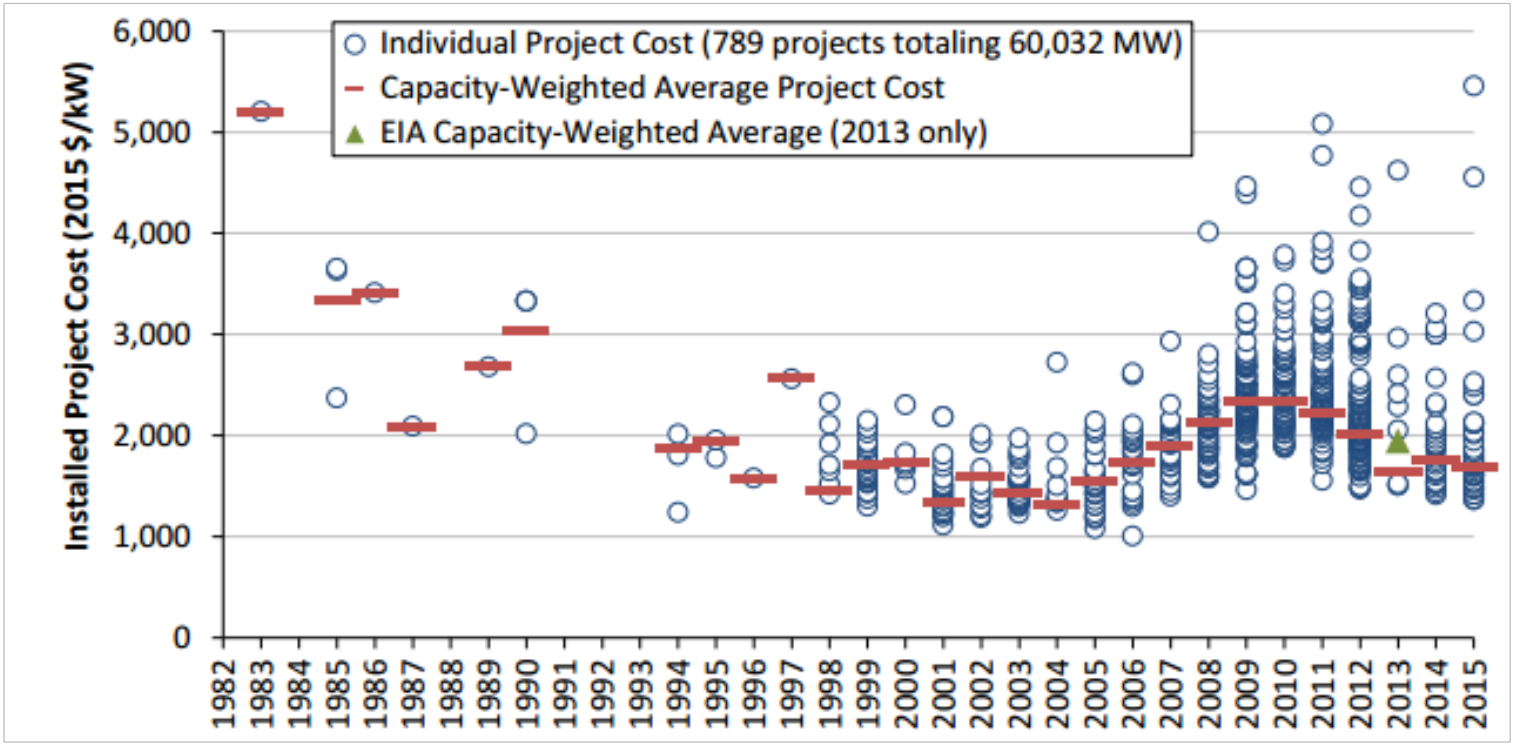
neon neue energieökonomik

Wind and solar costs continue to fall

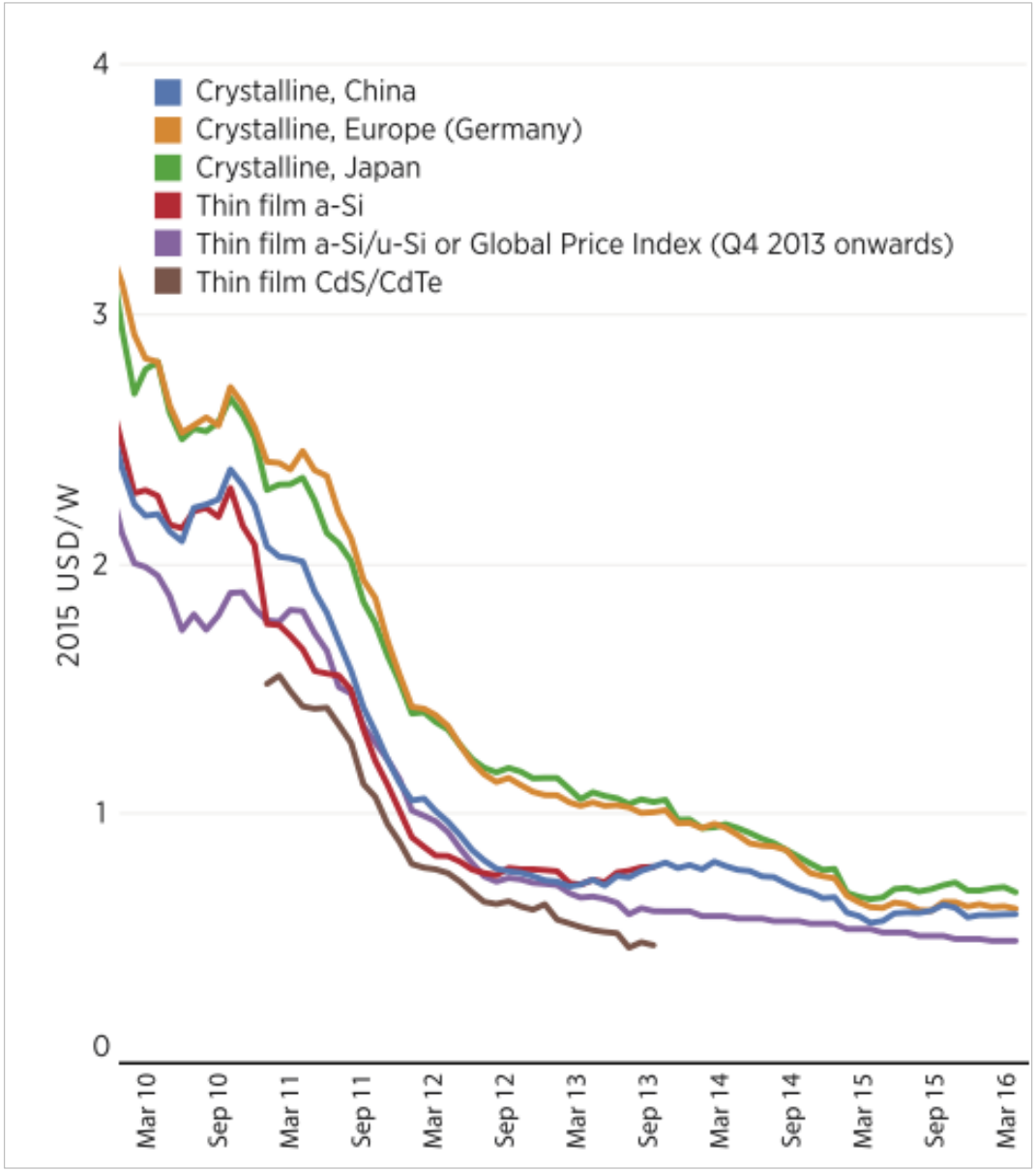
- Significant further drops in generation costs (LEC) of wind and solar power on a global scale
- Four main drivers
  - Reduced equipment cost ($/MW)
  - Reduced O&M cost ($/MWh)
  - Reduced capital cost (WACC)
  - Increased capacity factors (MWh/MW)
- PPAs and auction results need to be interpreted with care – they often include explicit and implicit subsidies
- Nevertheless, very low bids by renewable energy investors in many auctions worldwide

Wind power in the United States



DOE (2016): Wind power market report

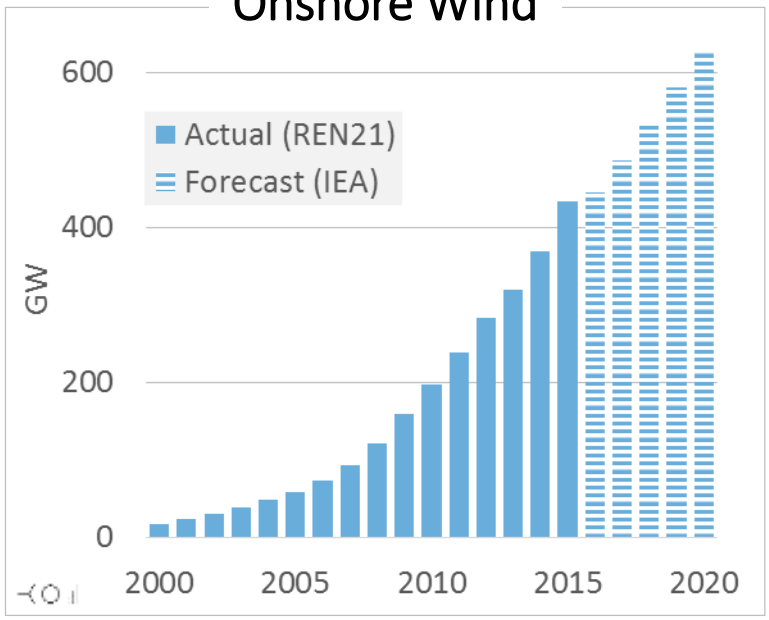
Solar PV module prices



IRENA (2016): Solar and wind cost reduction potential

Global wind and solar capacity

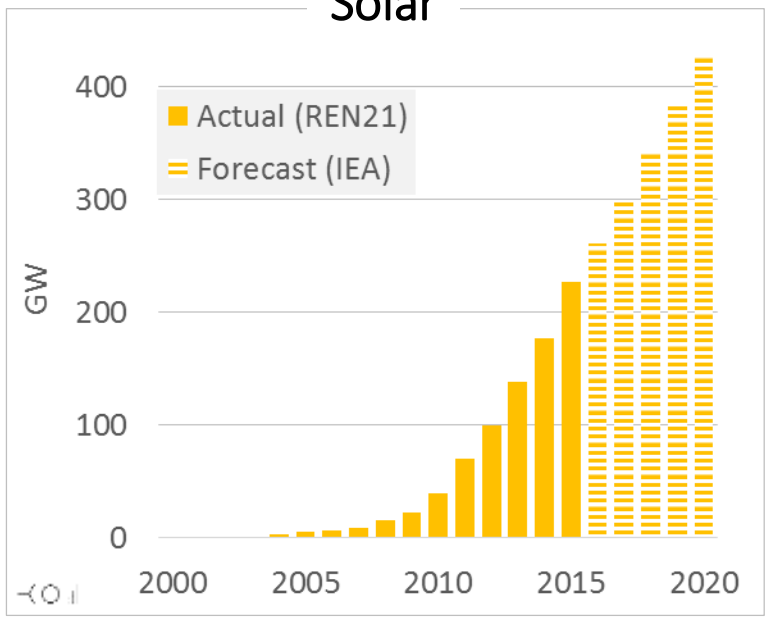
Onshore Wind



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

More than 400 GW of wind power capacity is installed worldwide.

Solar

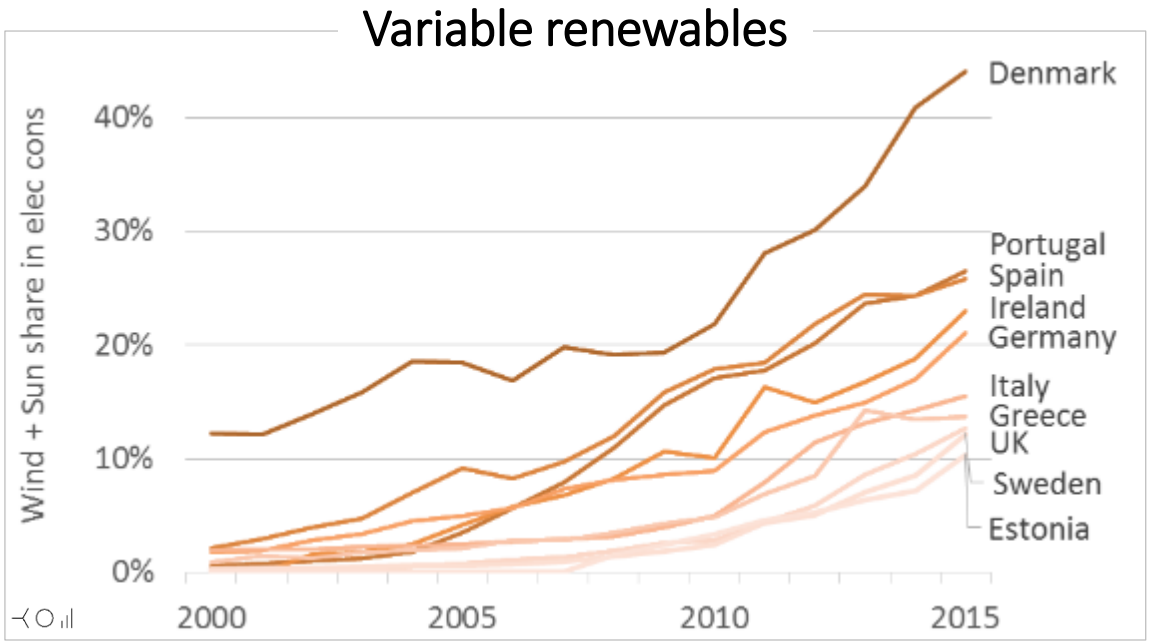


Neon analysis. Based on data from BMWi, AG Energiebilanzen, BDEW, BWE, BSW, IEA.

More than 200 GW of solar power is installed worldwide.

market data

Wind and solar deliver >10% in ten IEA countries



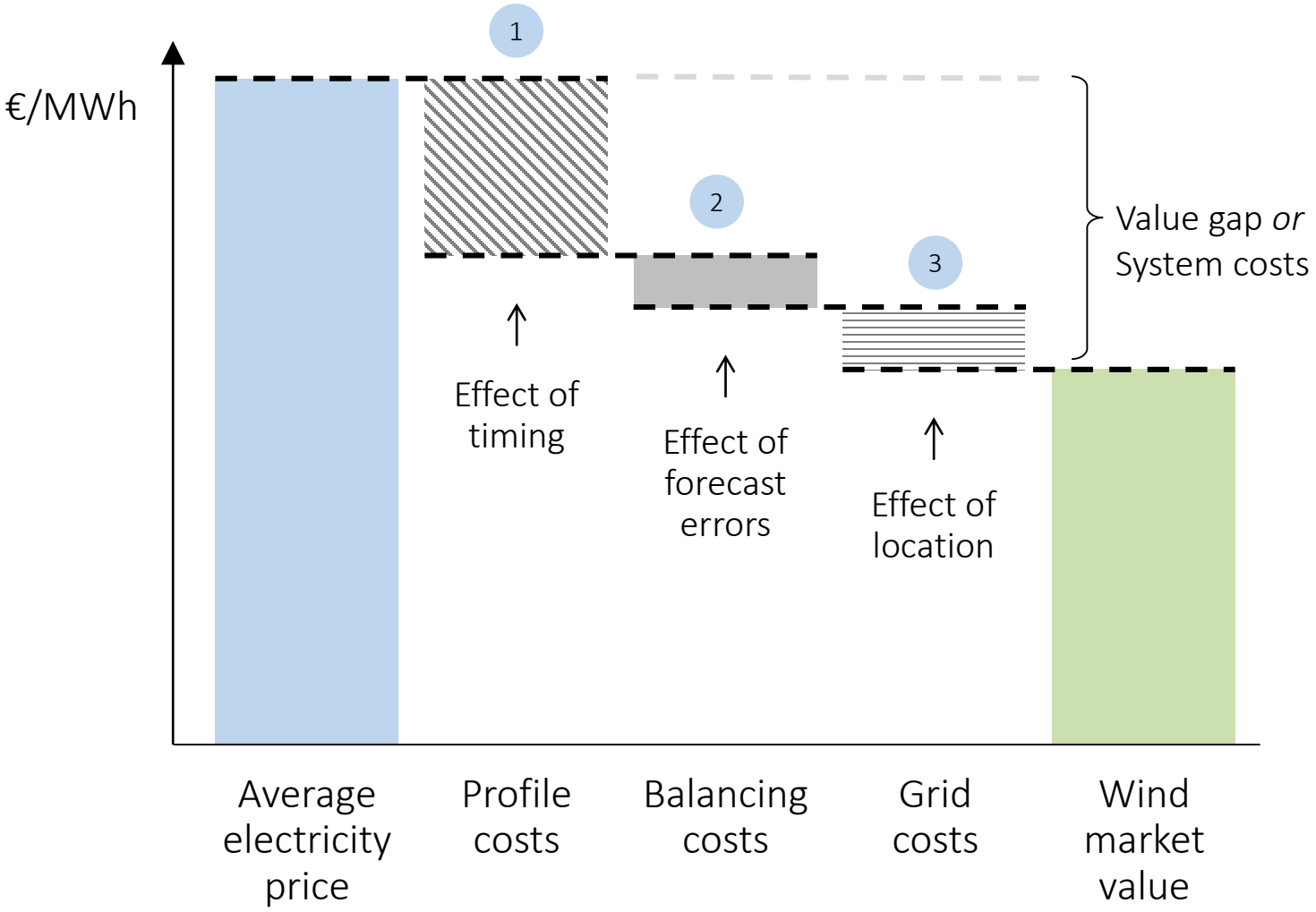
Neon analysis. Based on data from BMWi, AG Energiebilanzen, BDEW, BWE, BSW, IEA. Data for 2015 runs until 07/2015.

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.

The wind and solar value drop

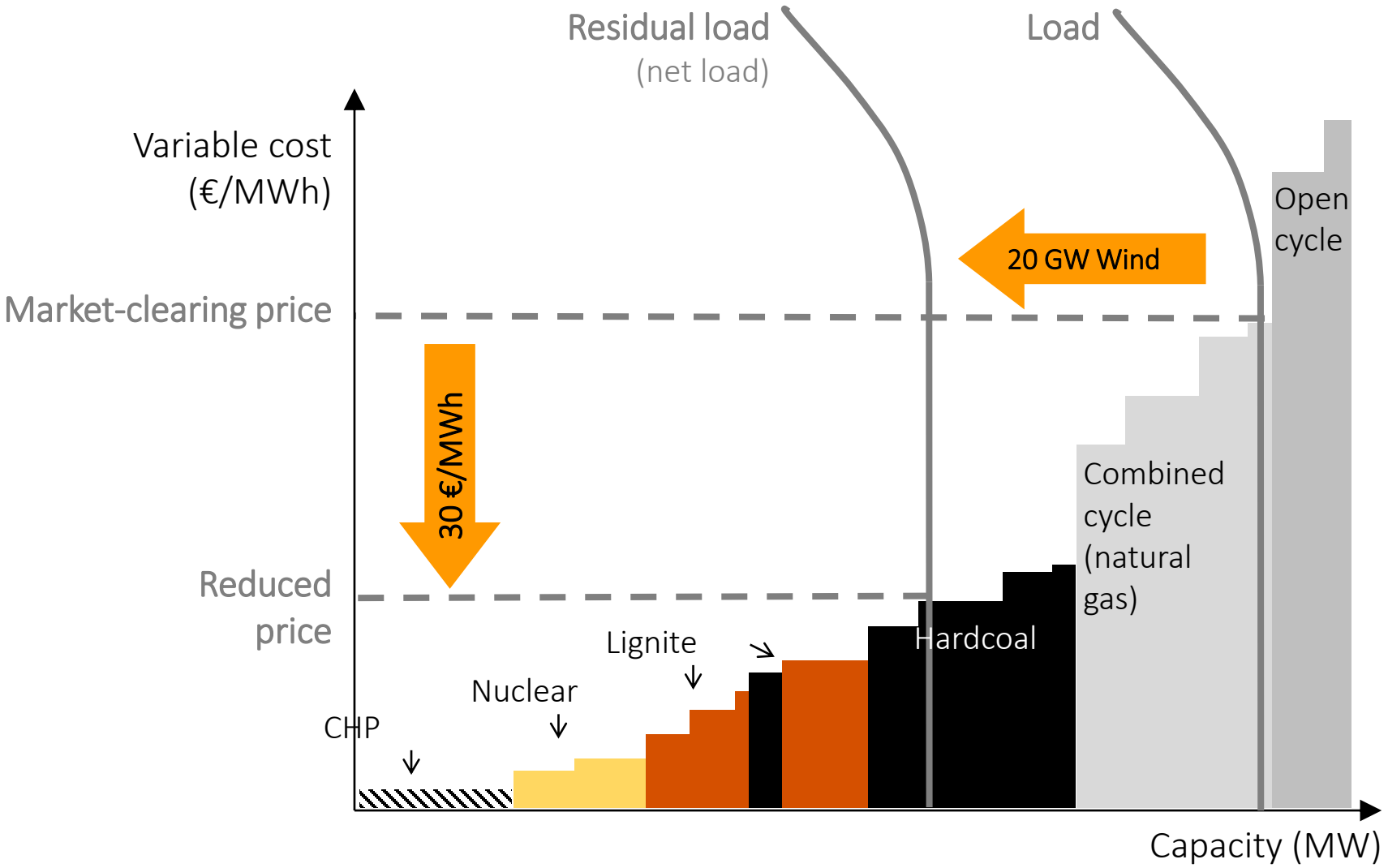
illustrative

The market value of wind power



illustrative

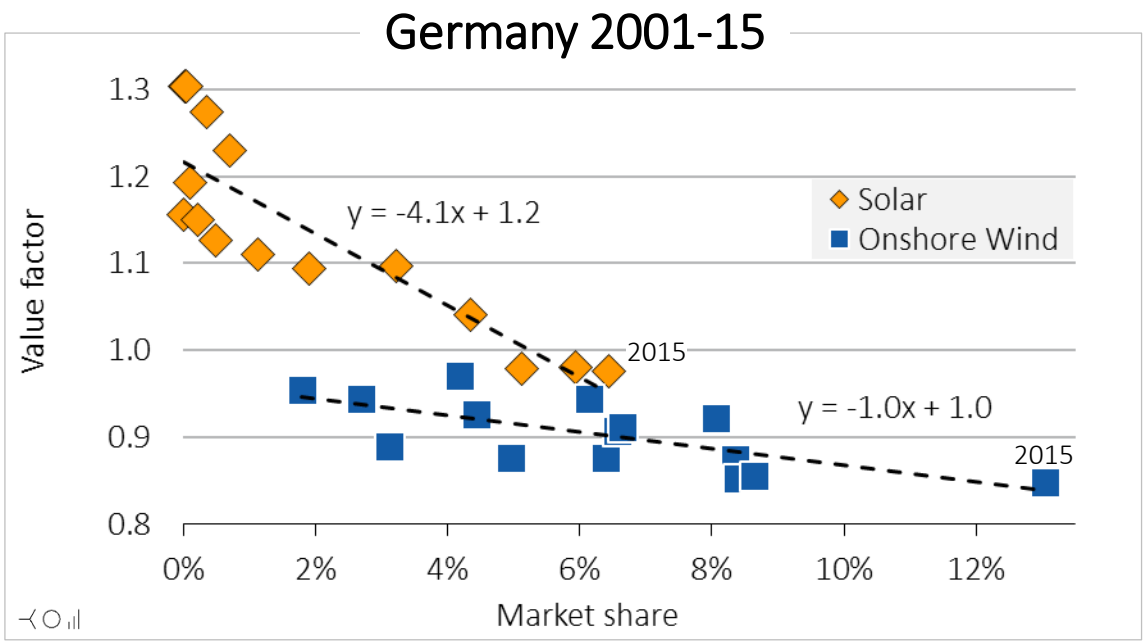
The mechanics behind the value drop



Market value of wind and solar power

Value Factor =
Market value / base price

Each dot is one year



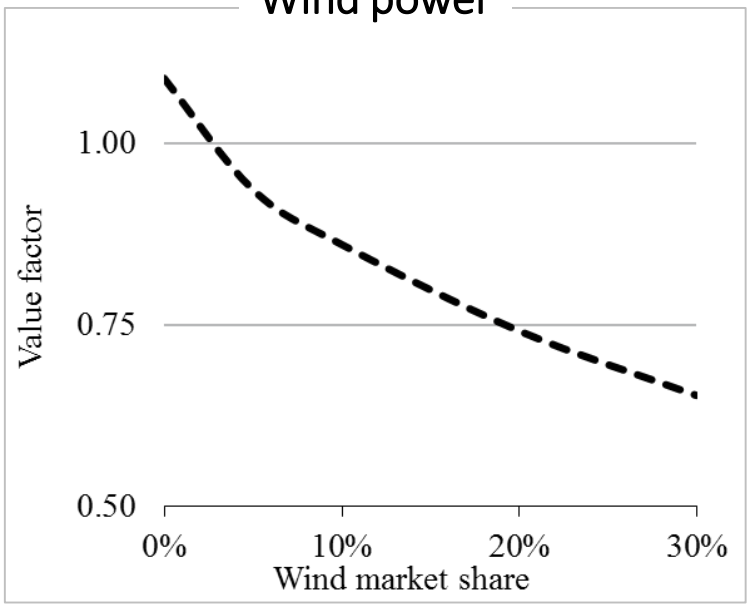
→ ?

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 value drop continues: model results

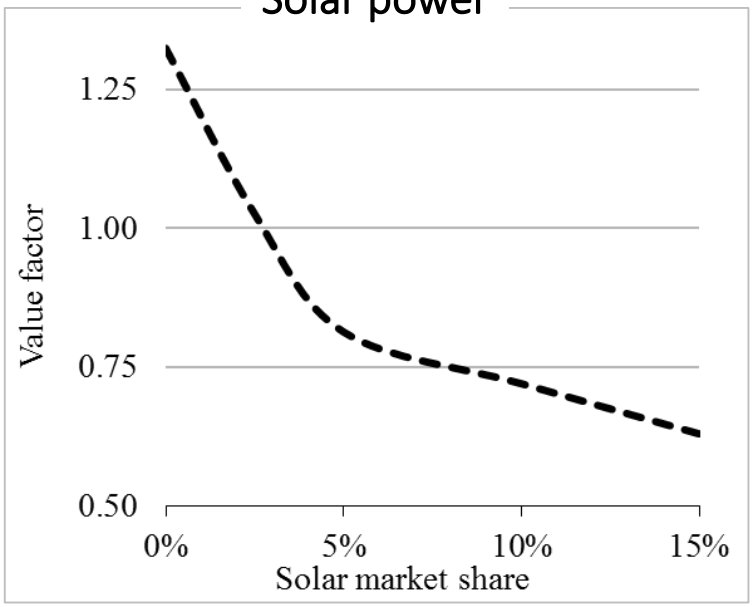
Wind power



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).

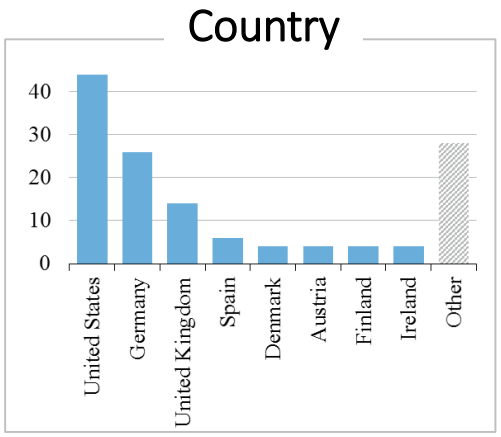
Solar power

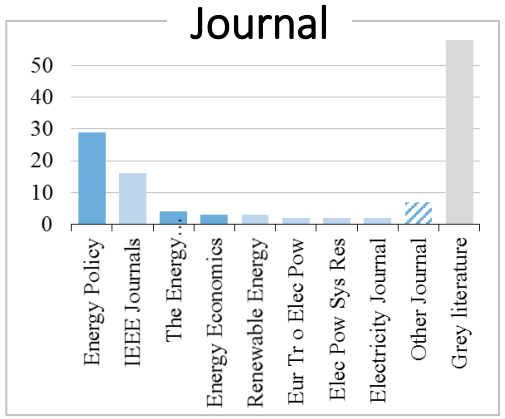


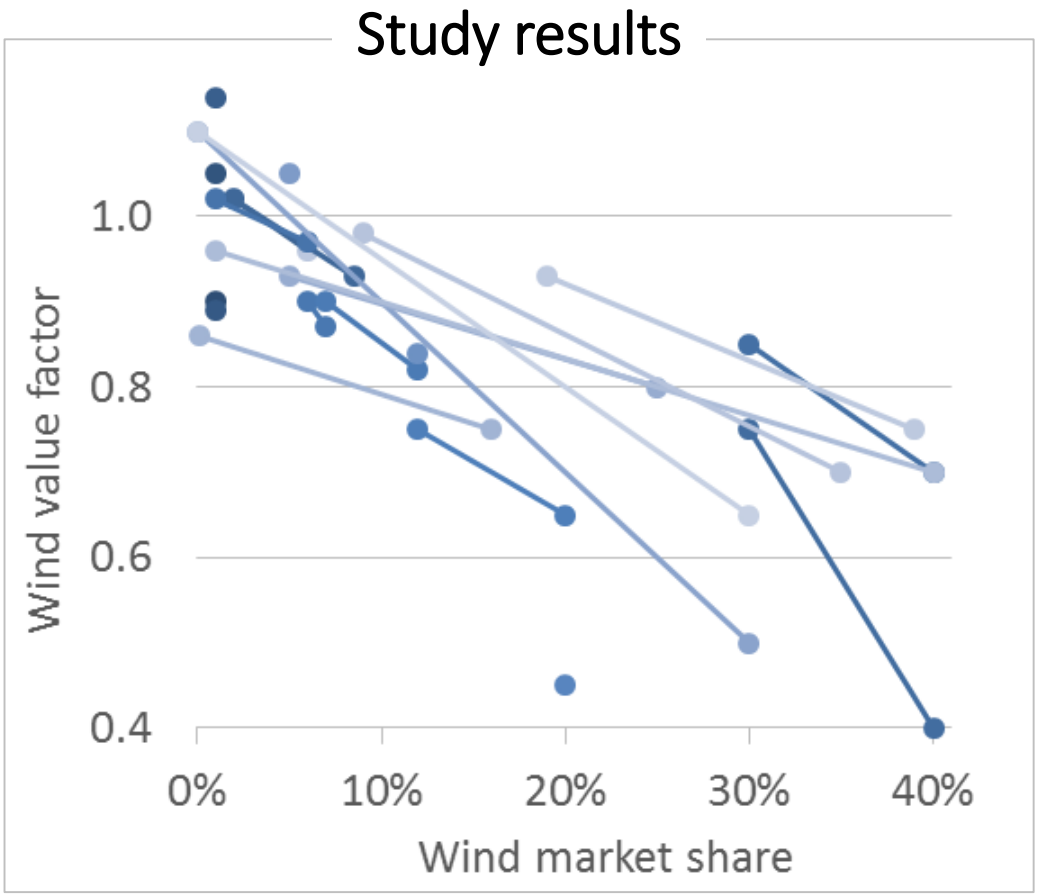
Updated from Hirth (2013): Market value

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).

We reviewed 100+ studies







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

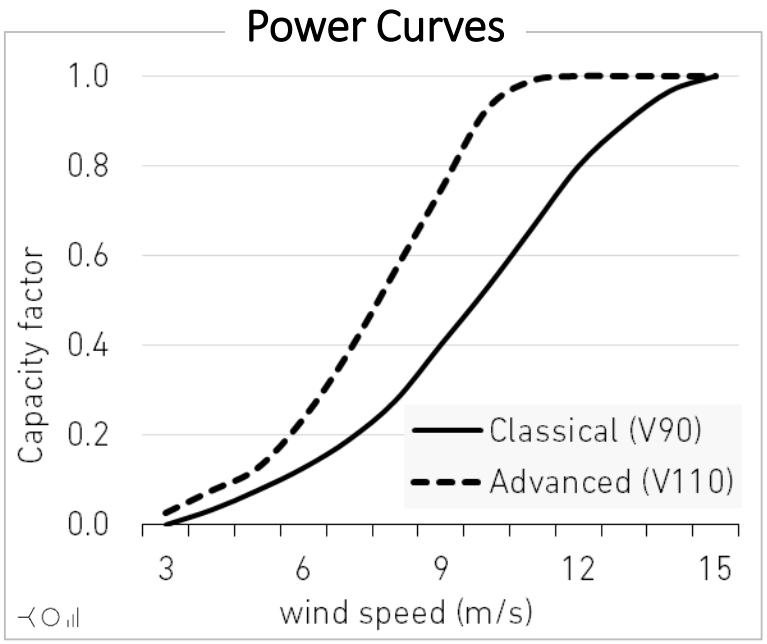
- Demand response / price elasticity
- Electricity storage
- Long-distance interconnection
- Reservoir hydro power
- Reduce thermal must-run (CHP, ancillary services)
- Shifting the thermal generation mix from capital-intensive base load towards low-capex mid and peak load plants
- Spot and balancing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

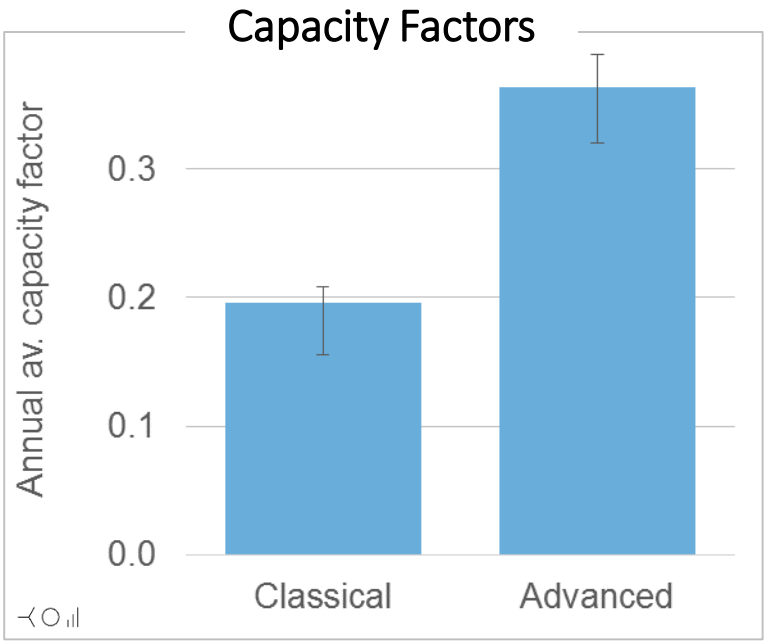
System-friendly VRE

- Optimized geographic allocation of VRE generators (e.g., geographic smoothing)
- Diversification of VRE mix (e.g., wind vs. solar)
- East-west oriented solar modules with higher capacity factors
- Low wind speed turbines with higher capacity factors

System-friendly renewables

Advanced wind turbines are *very* different



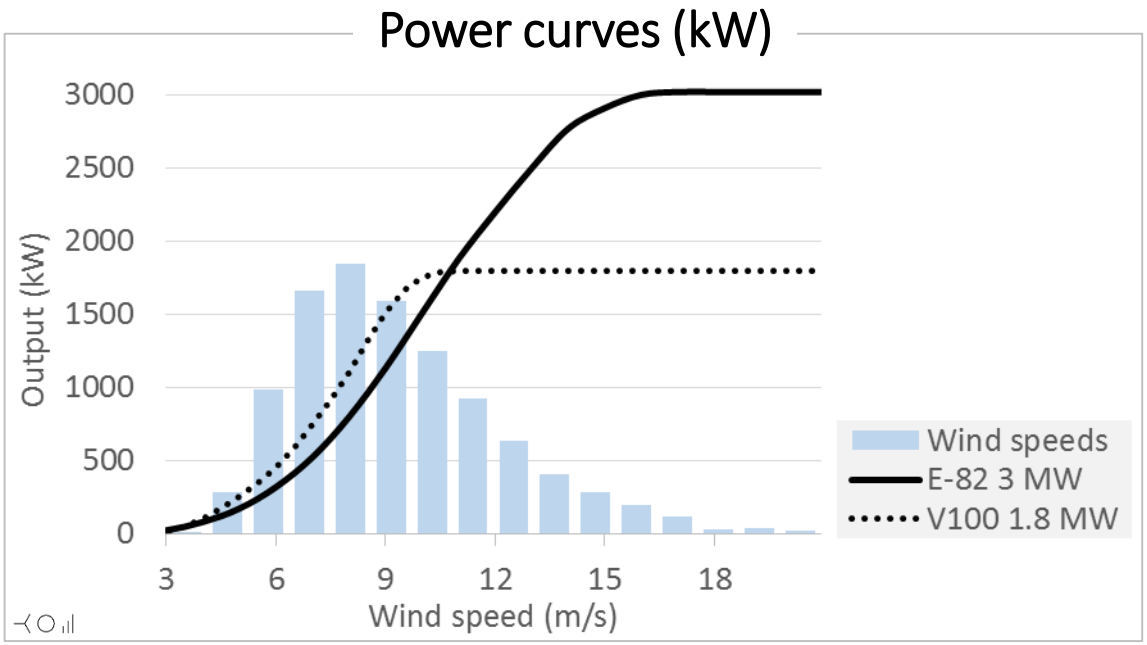


Neon analysis.

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.

Two turbines with same energy yield

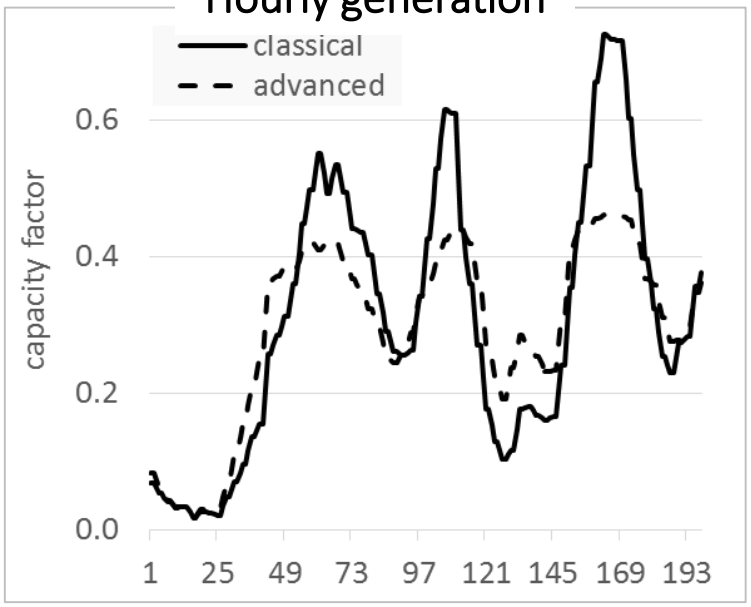


Neon analysis.

The Enercon E-82 (3 MW) and the Vestas V100 (1.8 MW) have roughly the same annual generation, but very different power curves.

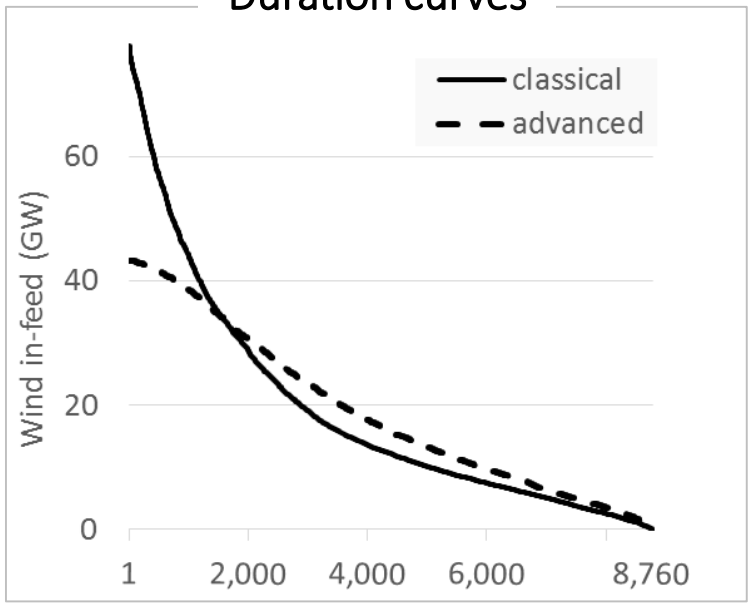
Much *smoother* generation profile

Hourly generation



Less fluctuations of output...

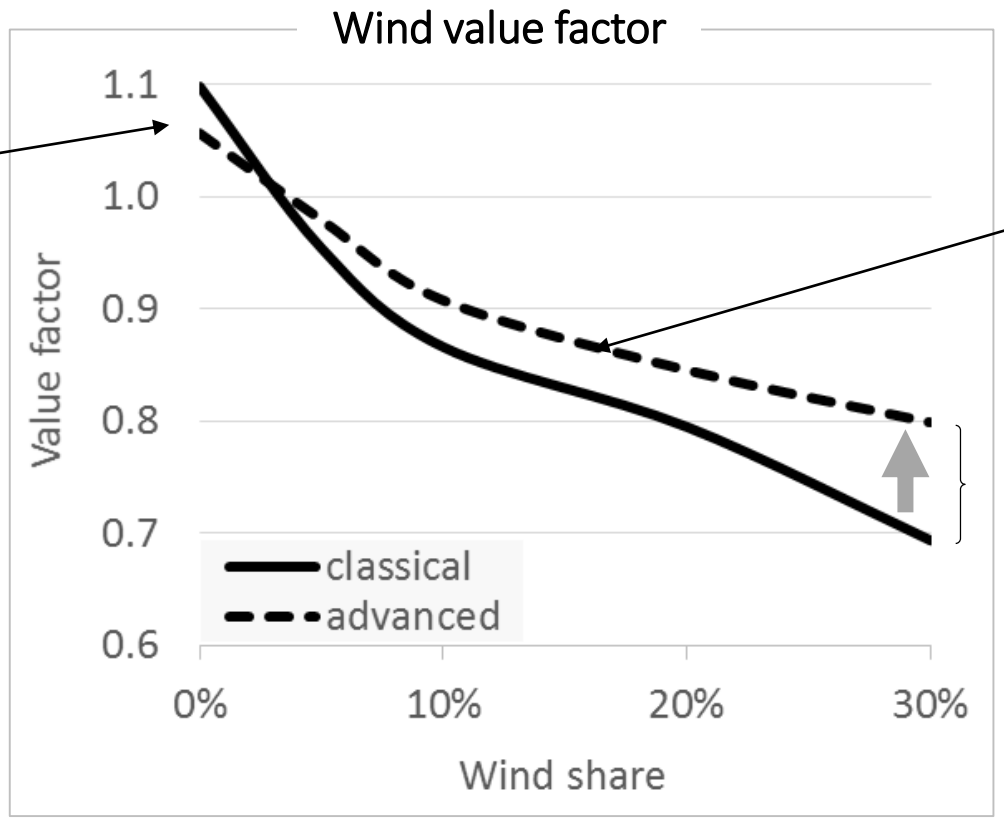
Duration curves



... 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



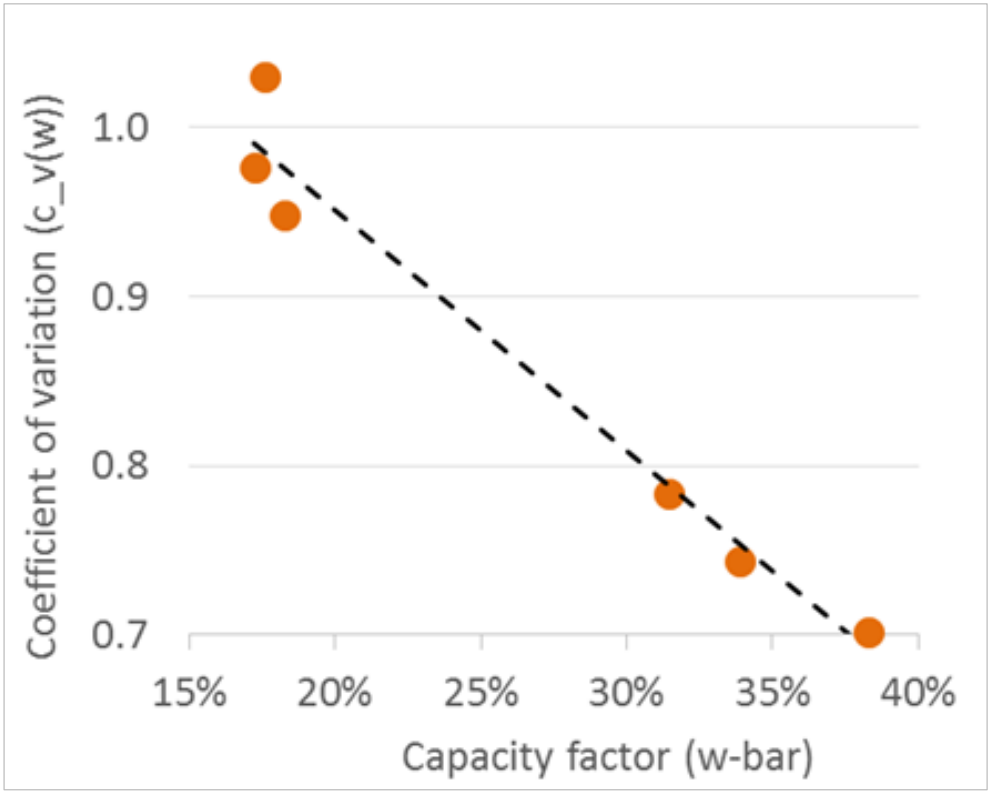
Delta becomes significant at 15% penetration

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).

Analytical results back support this finding

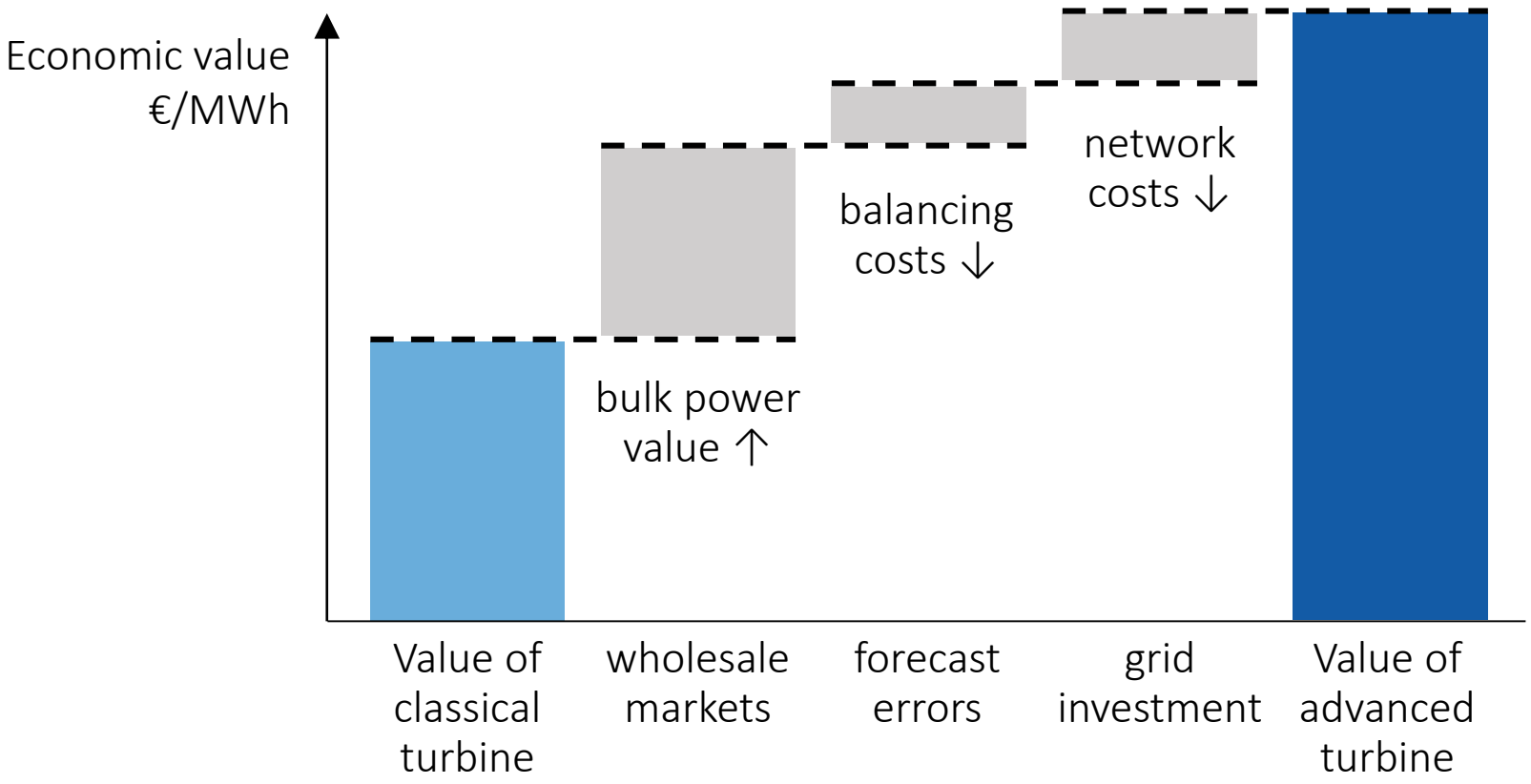


Hirth & Radebach (2016)

Analytical mode: slope of value drop depends on variation of output – which is highly correlated with capacity factors.

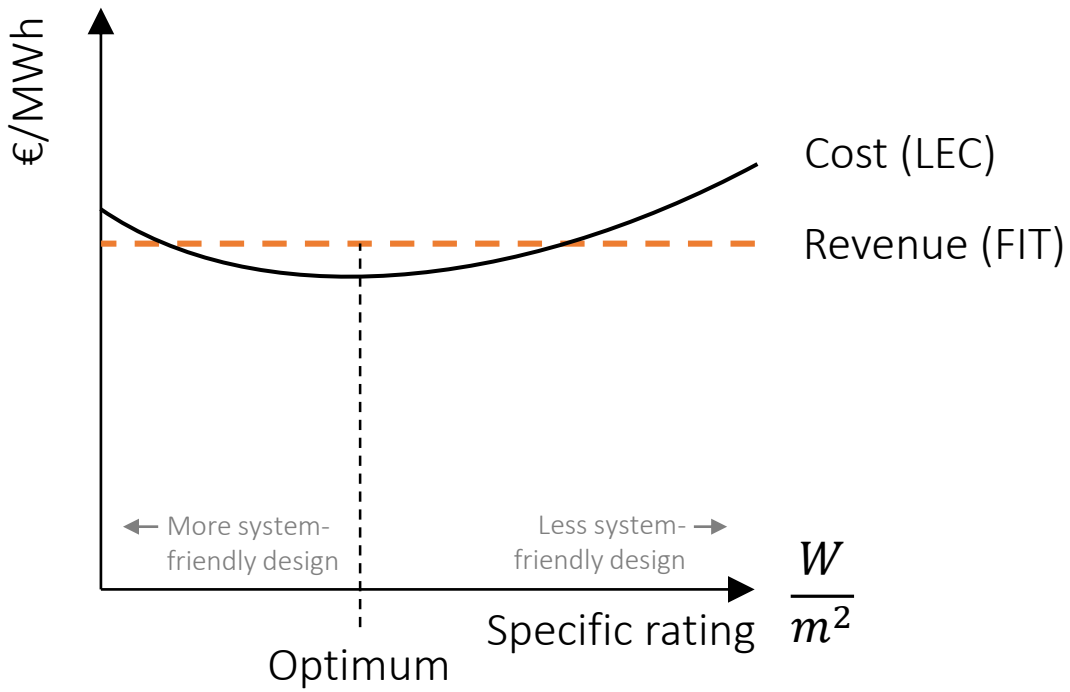
illustrative

Advanced turbine design: possibly *multiple benefits*



Cost-benefit analysis under FIT

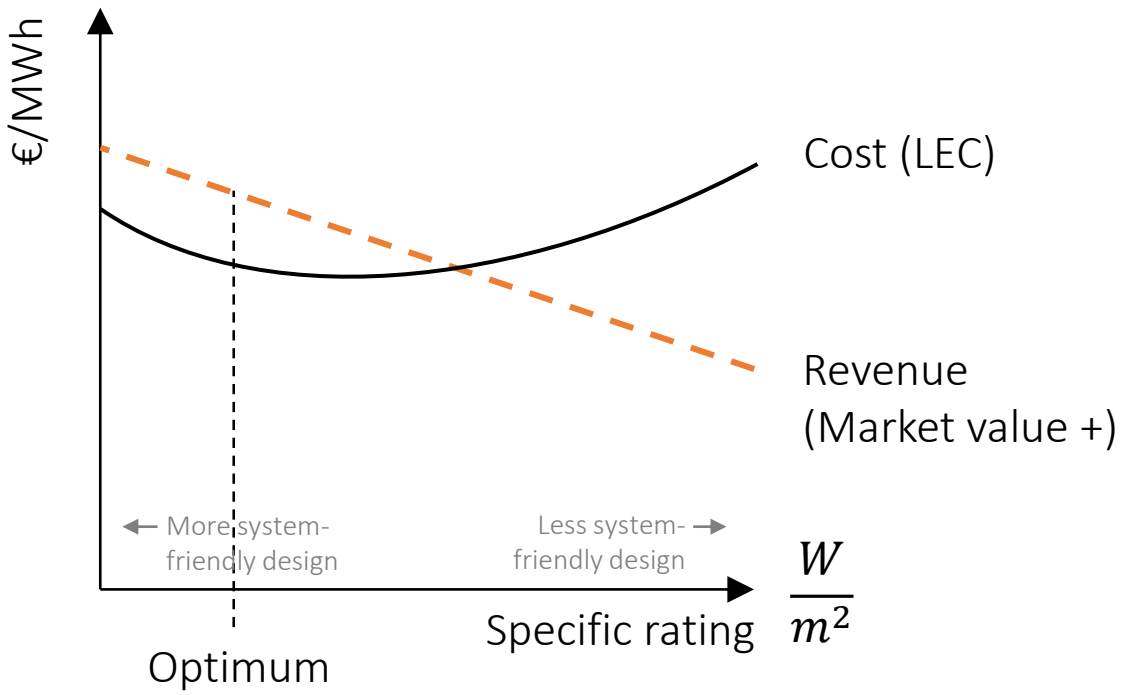
illustrative



- Under FITs, the benefits of system-friendly turbine design are not internalized
- They are invisible to investors
- Traditionally, project developers and manufacturers minimized generation costs
- This optimization leads to a certain optimal specific rating

Cost-benefit analysis under FIP / certificate scheme

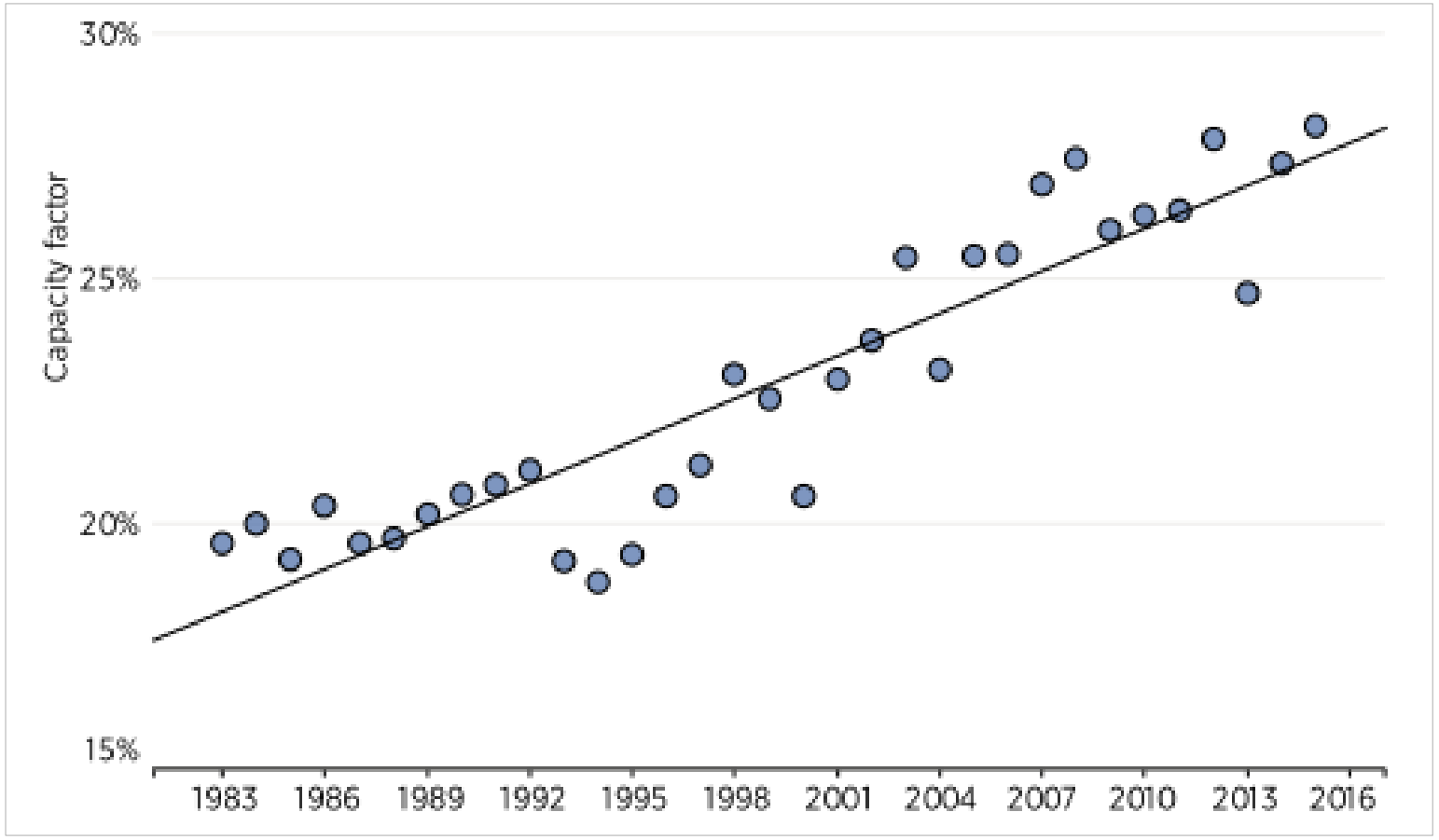
illustrative



- Without support schemes, or with FIP or certificates, (some) benefits are internalized
- Investors face a new optimization problem
- The new optimal design is moved to the left (more system friendly)
- The new optimum is a question of both costs and benefits of building turbines with lower specific rating

Recent developments in wind power capacity factors

Global average capacity factor for onshore wind additions



IRENA (2016): The power to change. Cost reduction potential

U.S. wind power capacity factors

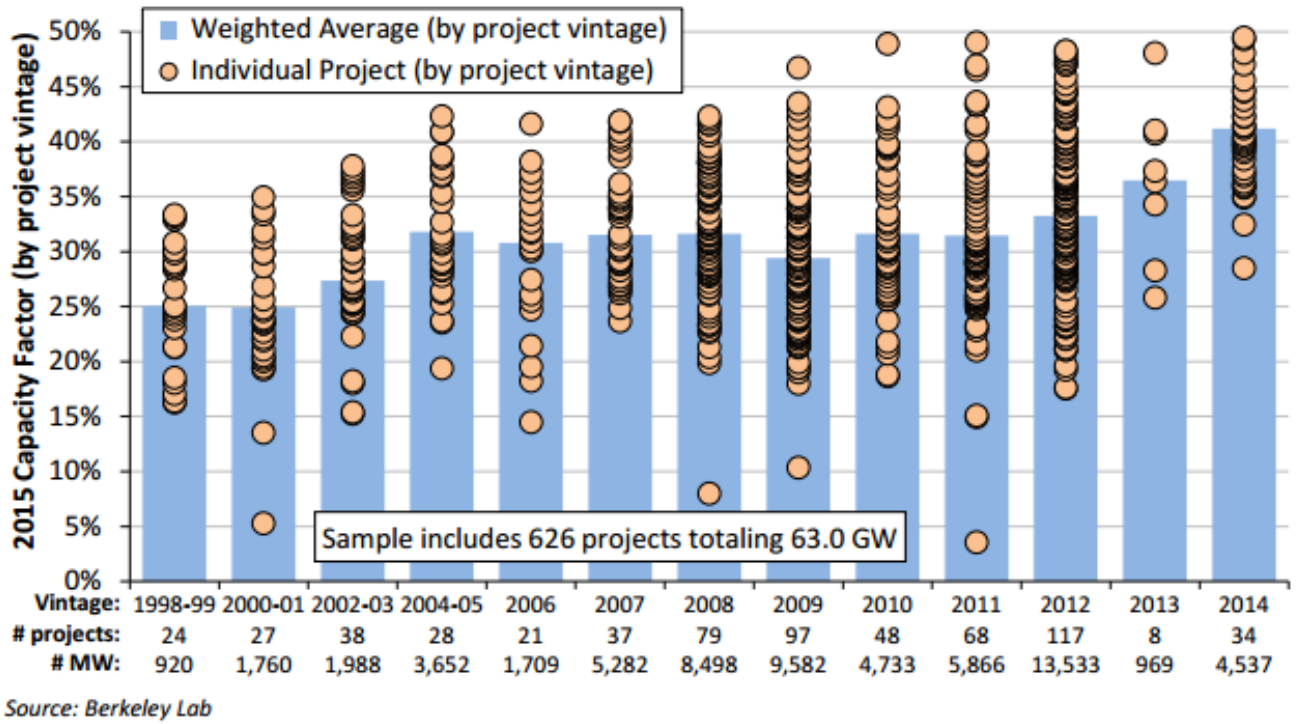


Figure 32. Calendar year 2015 capacity factors by project vintage

DOE (2015): Wind technologies market report

U.S. wind power capacity factors by resource quality

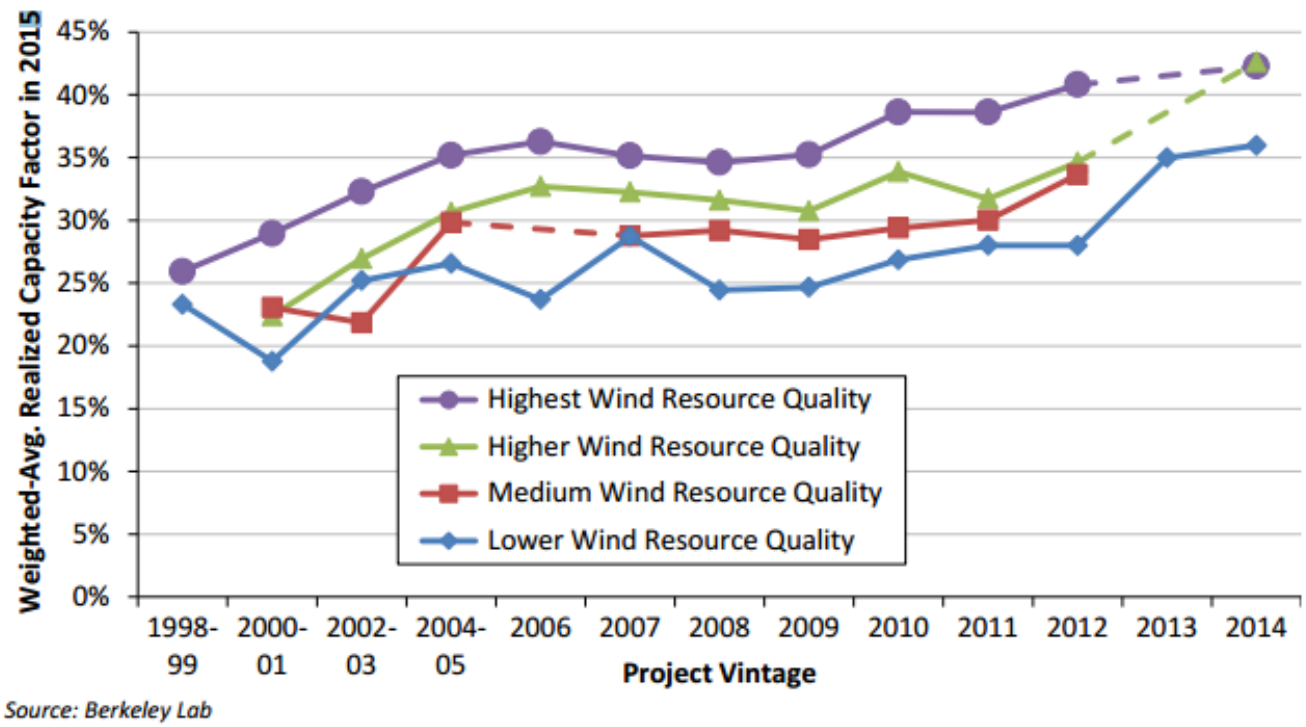
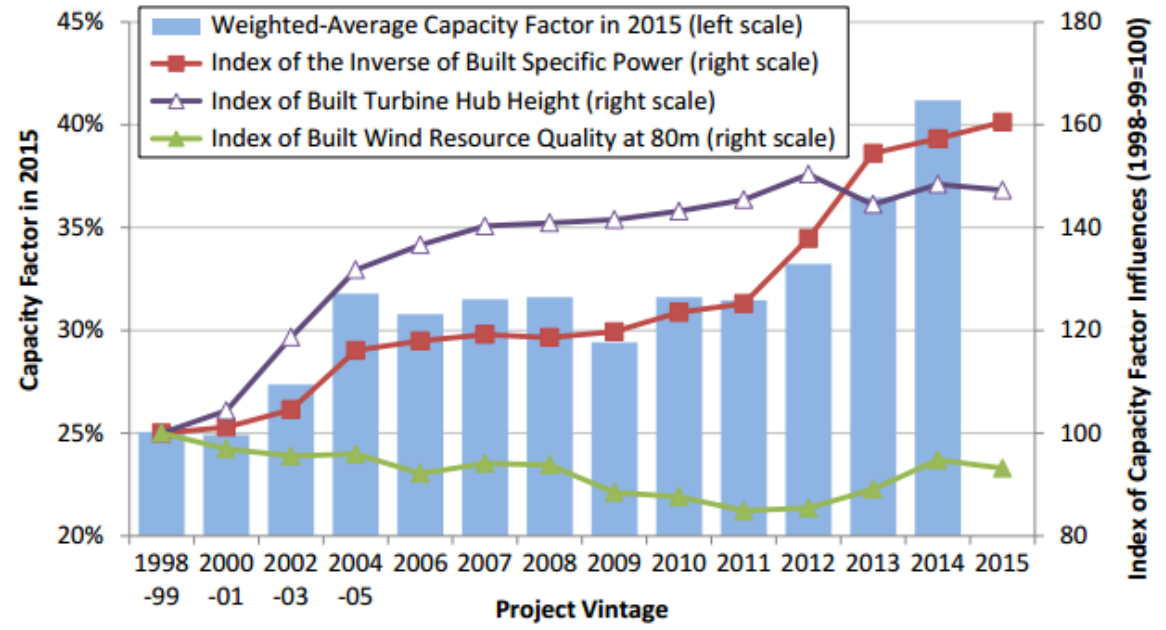


Figure 35. Calendar year 2015 capacity factors by project vintage and wind resource quality

DOE (2015): Wind technologies market report

Decomposing the capacity factor increase



Note: In order to have all three indices be directionally consistent with their influence on capacity factor, this figure indexes the inverse of specific power (i.e., a decline in specific power causes the index to increase rather than decrease).

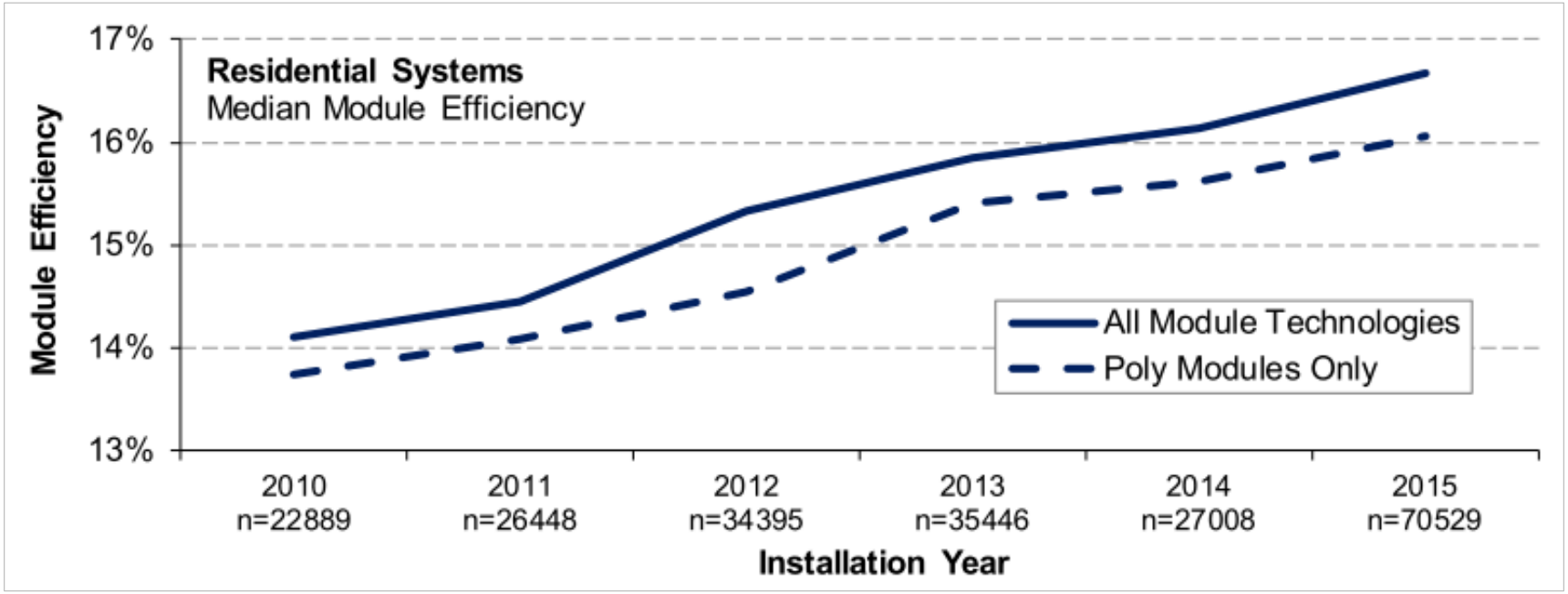
Source: Berkeley Lab

Figure 33. 2015 capacity factors and various drivers by project vintage

DOE (2015): Wind technologies market report

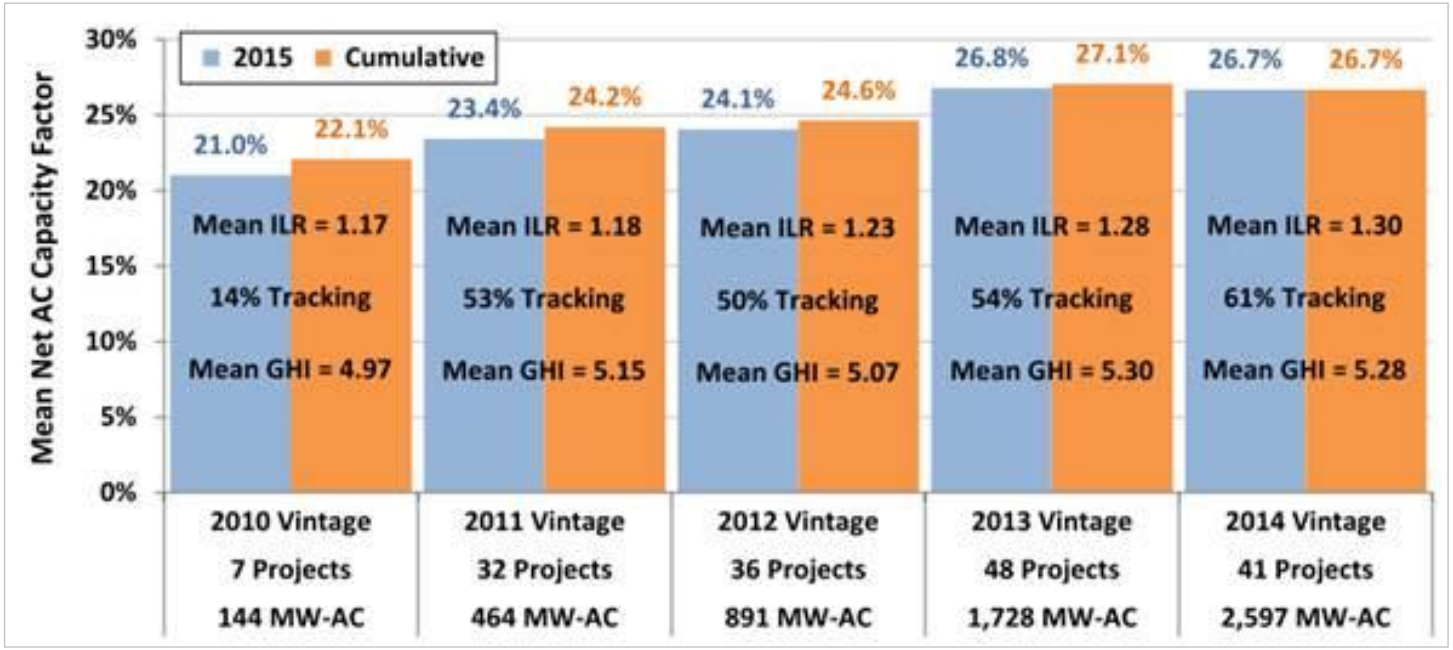
Recent developments in solar power capacity factors

Solar PV conversion efficiency (U.S.)



LBNL (2016): Tracking the sun

Utility-scale solar PV capacity factors (U.S.)



LBNL (2016): Utility-scale solar

Market Value	Hirth, Lion (2013): "The Market Value of Variable Renewables: The effect of solar wind power variability on their relative price", *Energy Economics* 38, 218-236, doi: 10.1016/j.eneco.2013.02.004.
Market Value of Solar	Hirth, Lion (2015): "The Market Value of Solar Power: Is Photovoltaics Cost-Competitive?", *IET Renewable Power Generation* 9(1), 37-45, doi:10.1049/iet-rpg.2014.0101.
System-friendly wind	Hirth, Lion & Simon Müller (2016): "System-friendly Wind Power", *Energy Economics* 56, 51-63, doi:10.1016/j.eneco.2016.02.016.
Market Value Analytically	Hirth, Lion & Alexander Radebach (2016): "The Market Value of Wind and Solar Power: an Analytical Approach", *USAEE Working Paper* 16-241.
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System-friendly renewables

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