



Cost and value of wind power - Implications of wind turbine design

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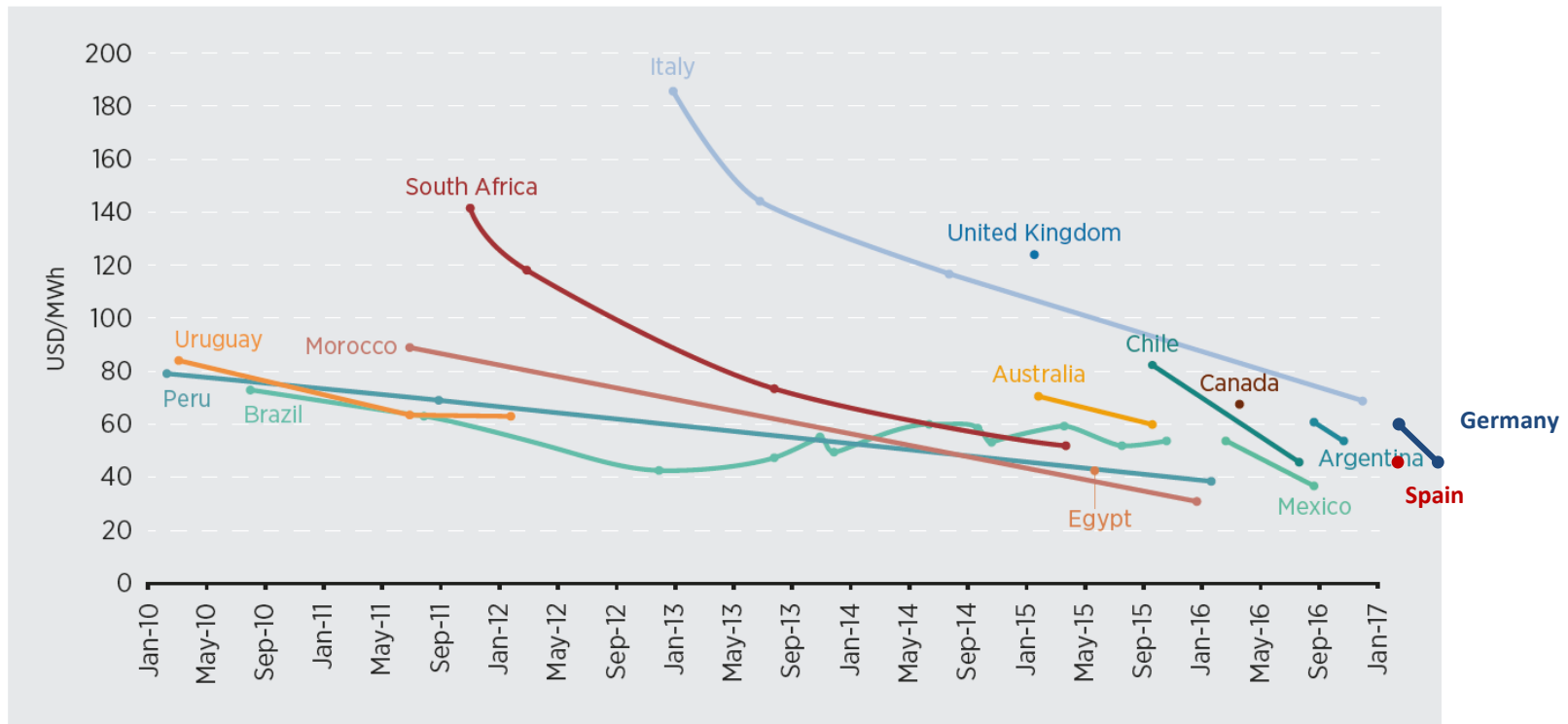
**4th Workshop on Systems Engineering for Wind Energy,
RISØ
September 13, 2017**

Agenda

- Trends in wind turbine technology and cost
- The importance of market integration
- Outlook for the value of wind power

Where are we today?

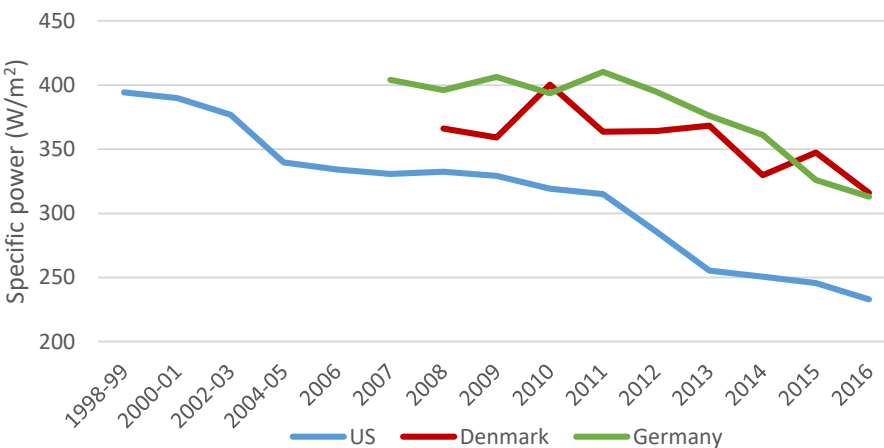
- Auction results can provide some insight in cost development in recent years
 - Compare with caution due to wide range of resource quality and regulation regimes



Source: RENEWABLE ENERGY AUCTIONS – analysing 2016, IRENA 2017. Added information for Germany (BMWi) and Spain.

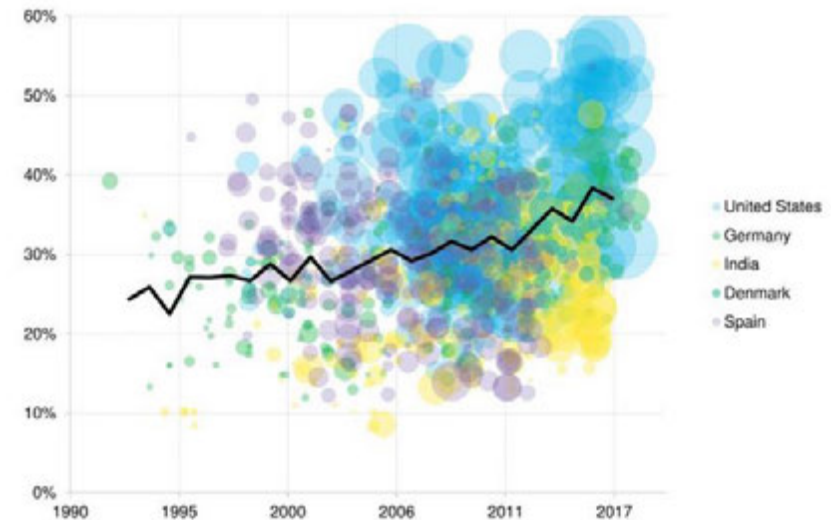
Trends in Wind Turbine Technology

- Increasing capacity factors
 - Better rotor design
 - Larger rotors
 - Higher hub heights

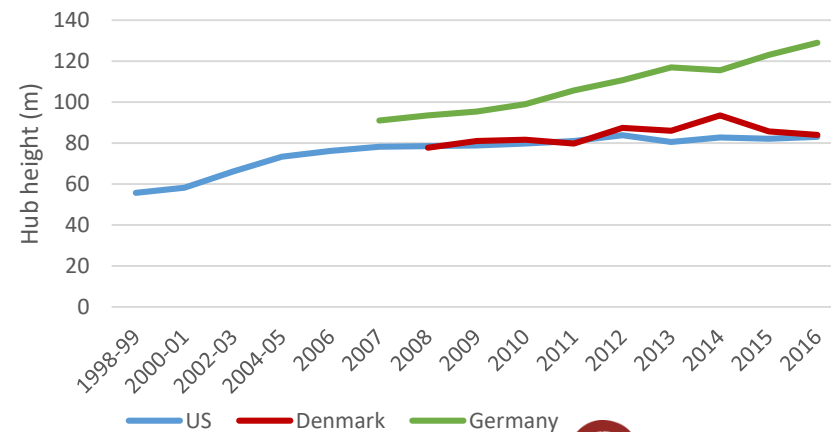


4 Data sources: IEA Wind Task 26 collaboration, US DEO Wind Technologies Market Report 2016, Deutsche WindGuard, Stamdataregister for vindmøller

Improving onshore wind capacity factors



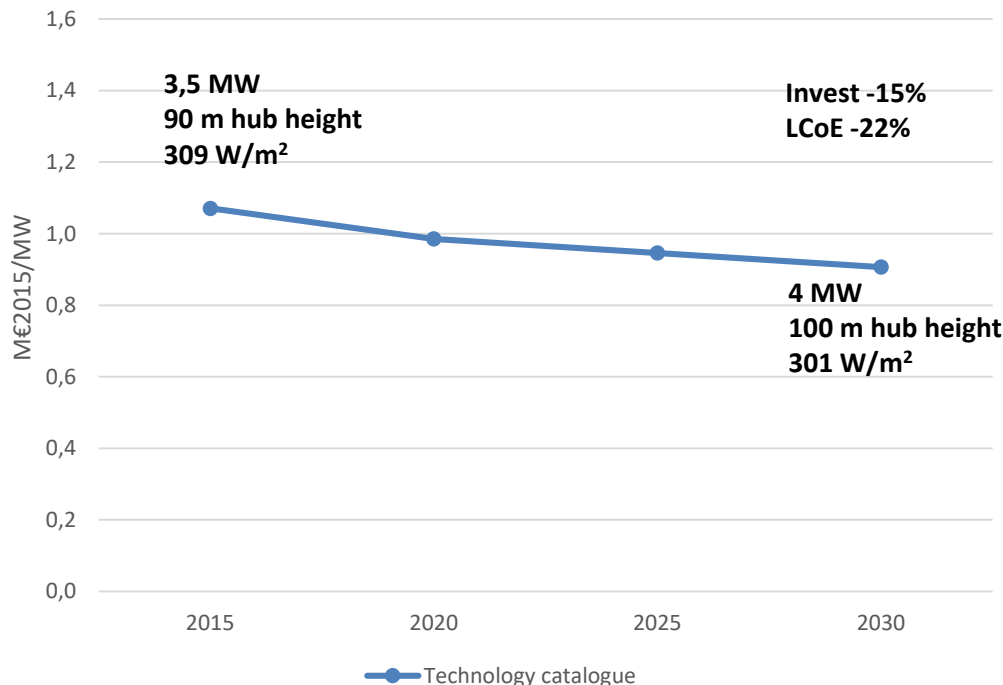
Source: Bloomberg New Energy Finance



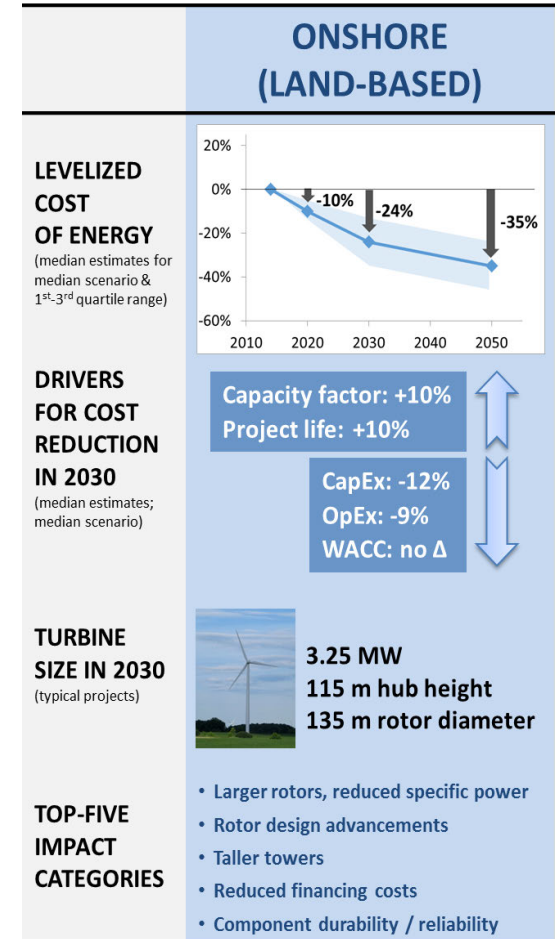
Trends in turbine cost

- Future cost reductions of LCoE largely depend on turbine design parameters
- Optimal turbine choice depend on ressource quality and market integration

Investment cost onshore wind - Denmark



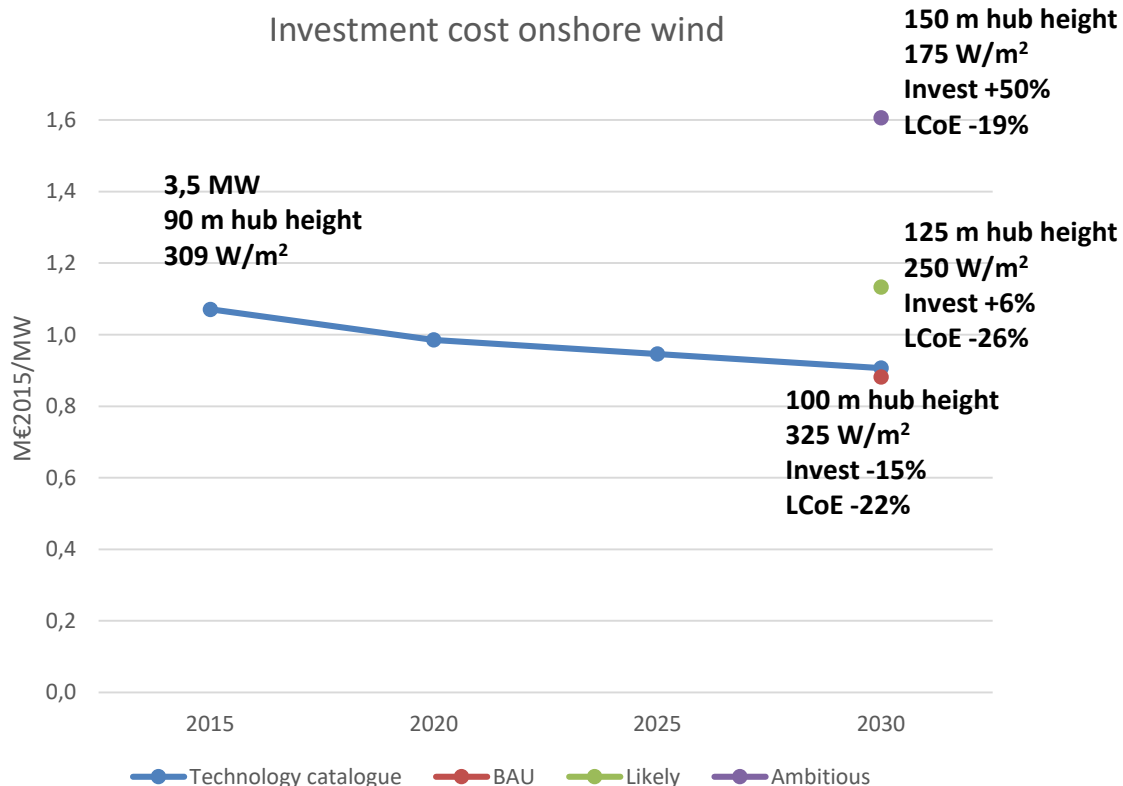
Source: Technology Data for Energy Plants, Danish Energy Agency and Energinet.dk August 2016



Source: Forecasting Wind Energy Costs and Cost Drivers: The Views of the World's Leading Experts, Ryan Wiser, Karen Jenni, Joachim Seel, Erin Baker, Maureen Hand, Eric Lantz, Aaron Smith, June 2016

Trends in turbine cost

- Future cost reductions of LCoE largely depend on turbine design parameters
- Optimal turbine choice depend on ressource quality and market integration



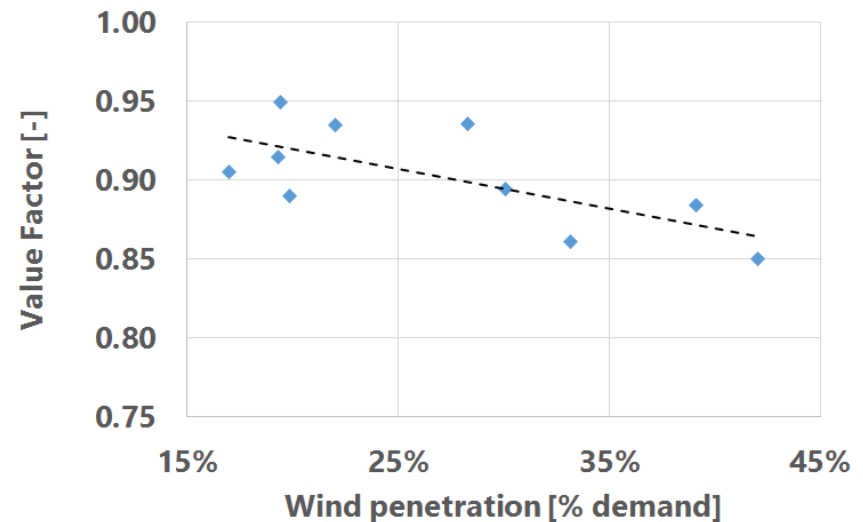
LCoE estimates for Northwestern Germany

- Estimates for effect of hub height and rotor size are based on *extrapolation* from data from NREL (specific power) and Deutsche WindGuard (hub height)
 - More likely to over- than underestimate additional investment

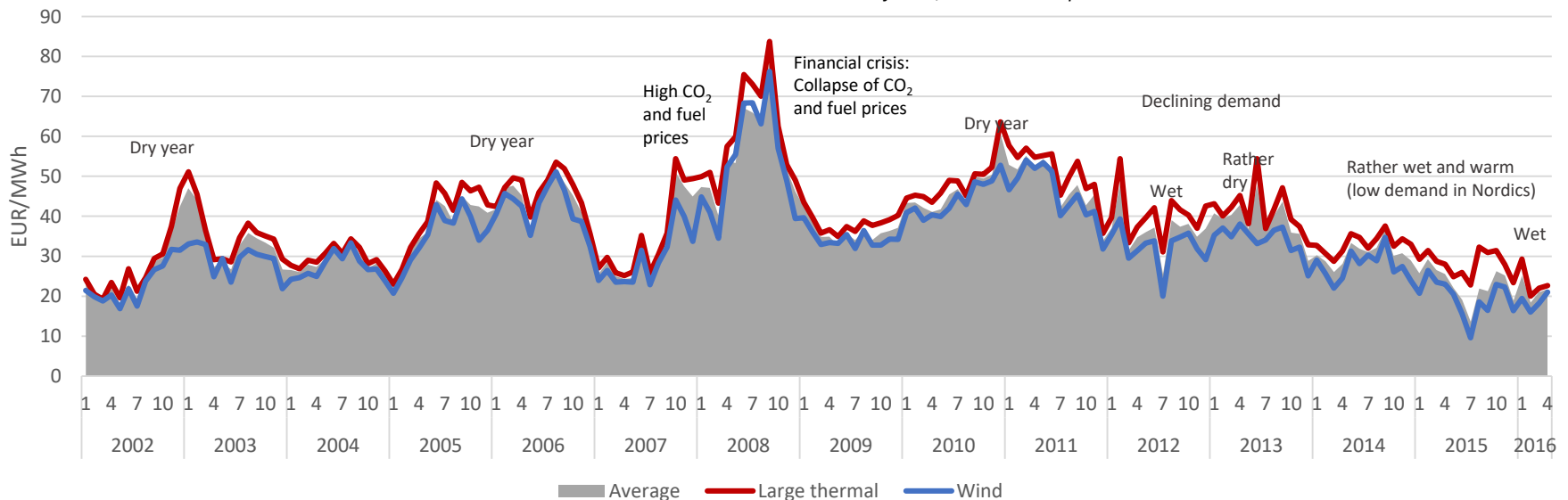
Market integration and the value of wind

- Power prices vary significantly
 - By year and hour

$$\text{Market value} = \frac{\text{Total wind revenues}}{\text{Potential wind generation}} [\text{€/MWh}]$$



Value factor, onshore wind power Western Denmark



Power prices Western Denmark, Datasource: Energinet.dk, nominal prices

IEA Wind Task 26 WP4 – The value of wind*

- System analysis at a European level of the value of wind in the power system
- Power system modelling using the Balmorel model

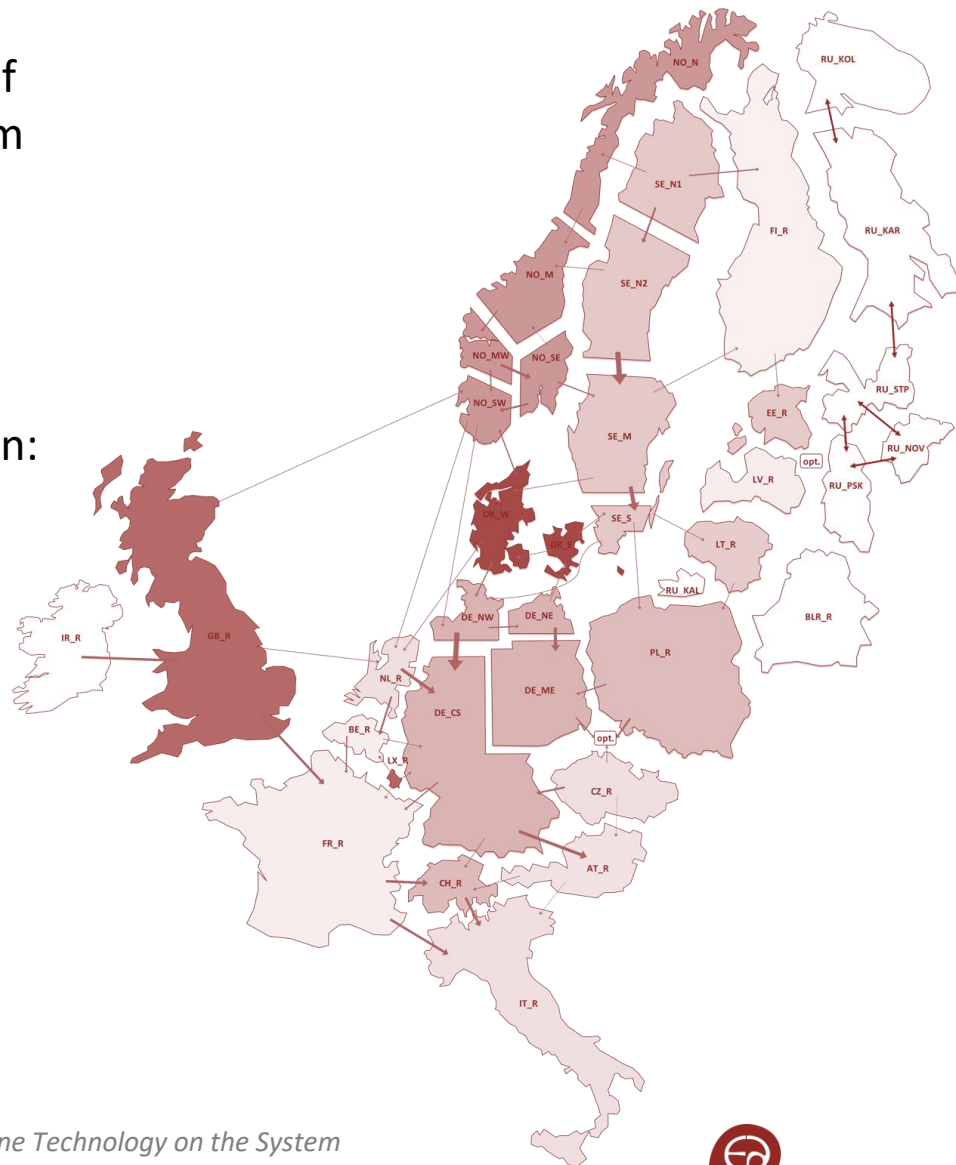
Focus

Impact of onshore wind turbine design on:

- **System operation**
- **System cost**
- **Market value of wind power**

Scenarios for technology development

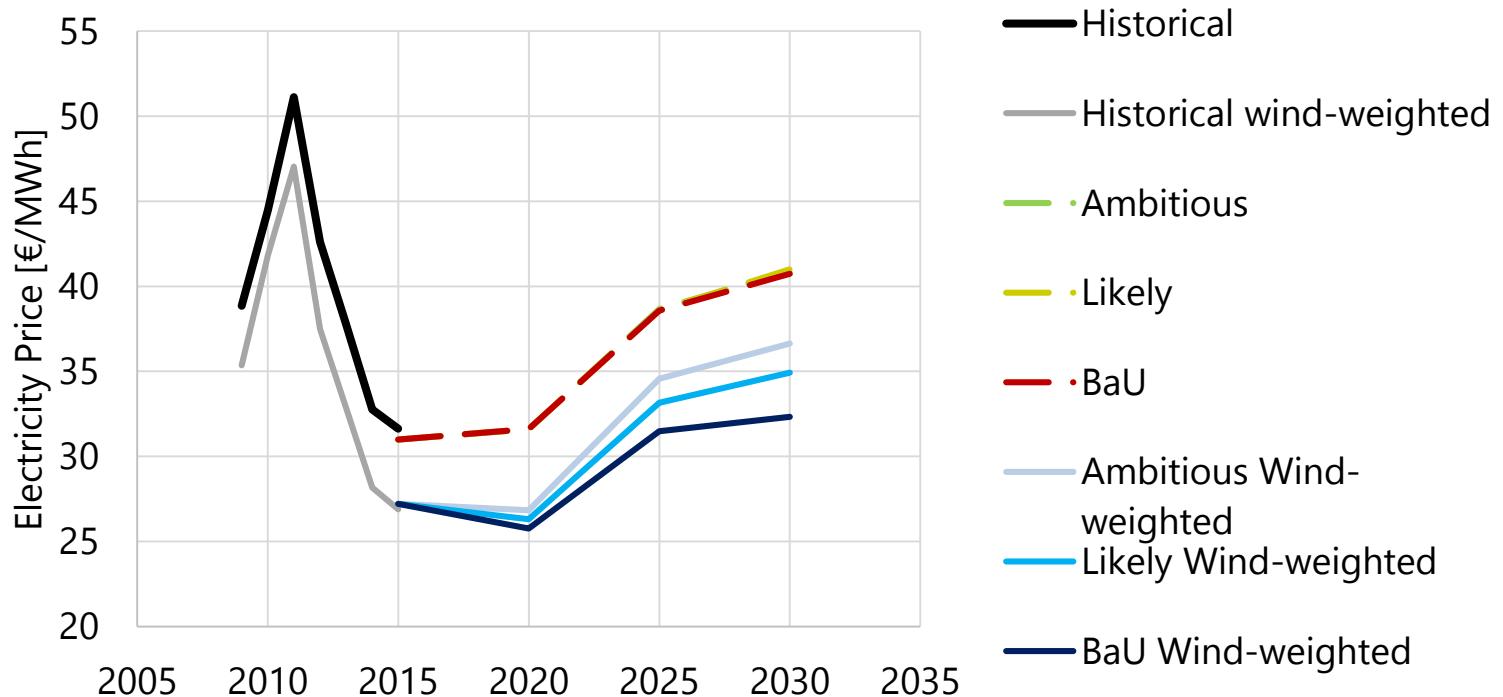
	Specific power (W/m ²)	Hub height (m)
BAU	325	100
Likely	250	125
Ambitious	175	150



*A. Dalla Riva, J. Hethey, and A. Vitiņa, "Impacts of Wind Turbine Technology on the System

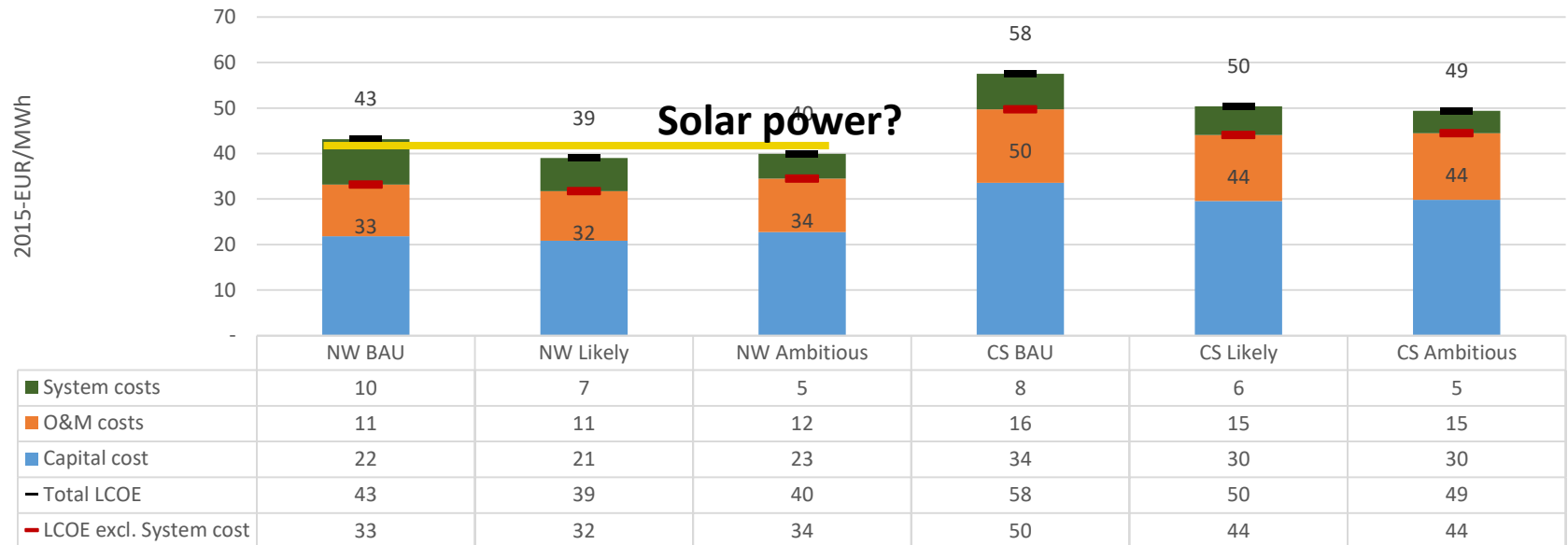
Market value and price evolution

- The average wholesale electricity price is not very different across scenarios
- The evolution of Market value is largely dependent on the technology choice



Levelized Cost of Energy

Result: Levelised Cost of Energy



Technology cost based on own estimates. 4% real interest rate, 30 year lifetime, calculation year 2030.

NW = Northwest Germany; CS = Central/southern Germany

Sources: DEA Technology Catalogue, NREL, Deutsche WindGuard,

System cost account for 11-22%

Full load hours

Technology	Northern Germany	Southern Germany
BAU	2.407	1.566
Likely	3.244	2.284
Ambitious	4.203	3.206



Thank you

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