POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

System LCOE: What are the costs of variable renewables?

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http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2200572

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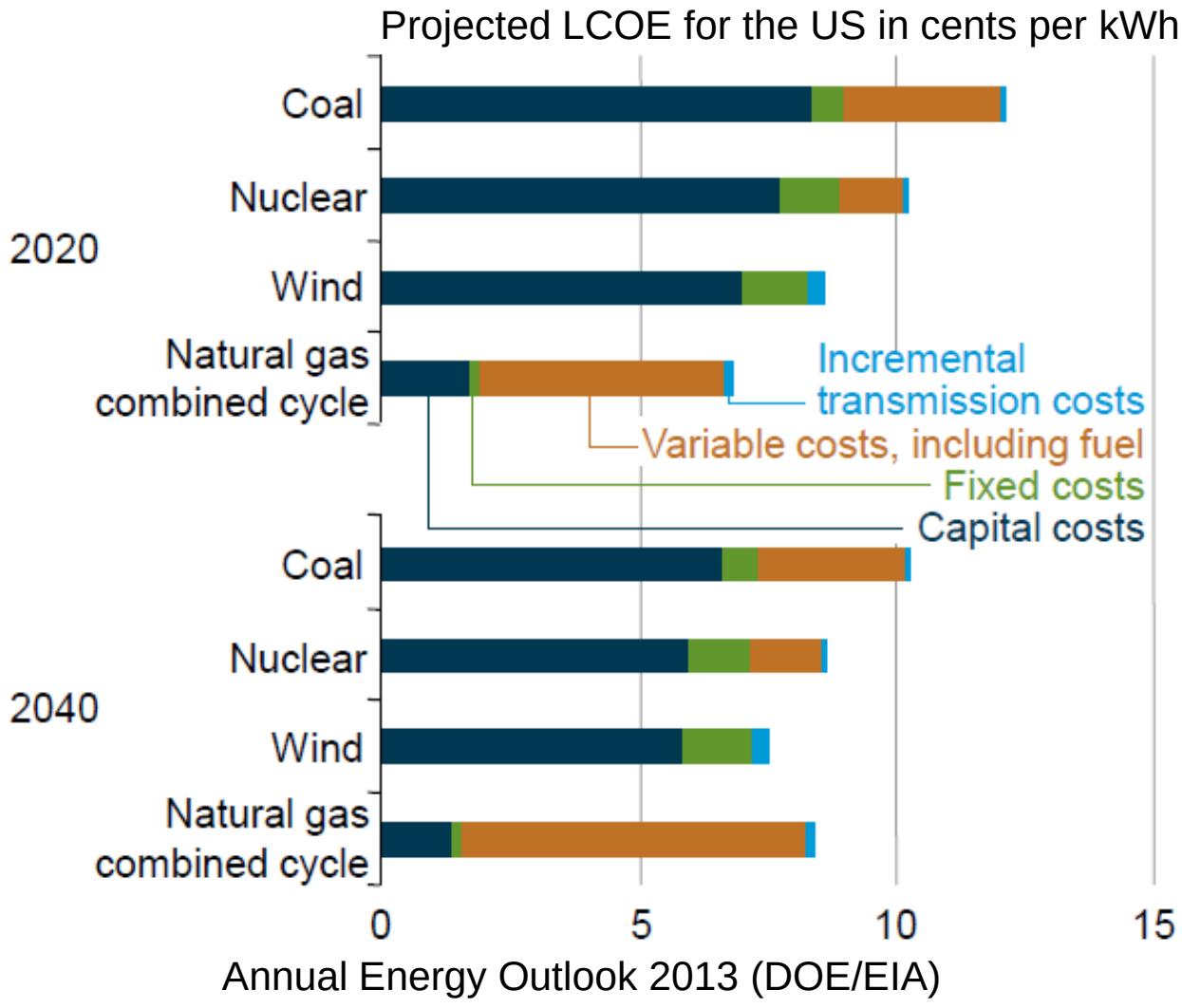
What are the costs of variable renewables?

Levelized costs of electricity (LCOE) are the full life-cycle costs (fixed and variable) of a technology per generation unit



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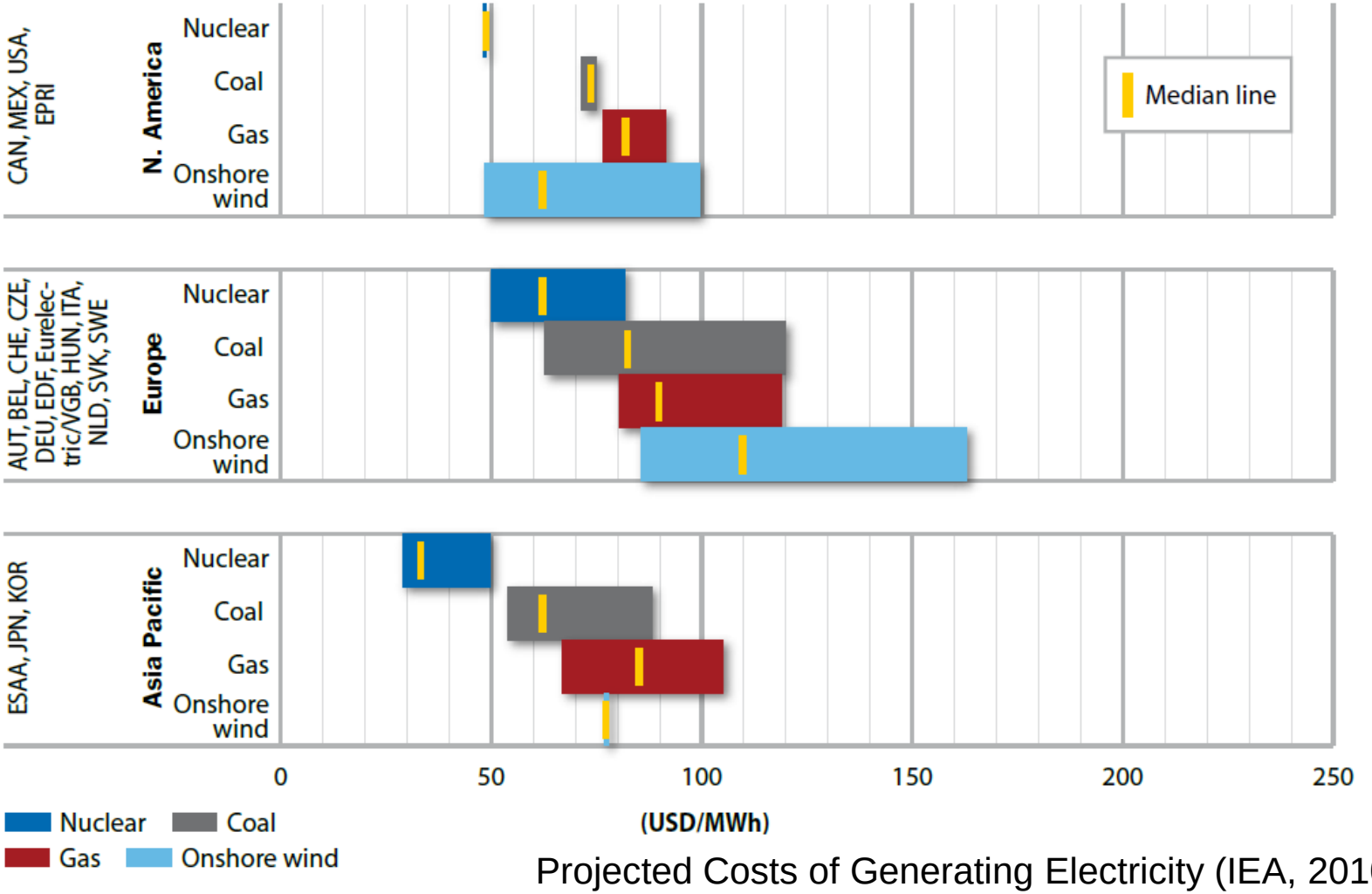
LCOE for plants commissioned in 2015 at 5% discount rate



Projected Costs of Generating Electricity (IEA, 2010)

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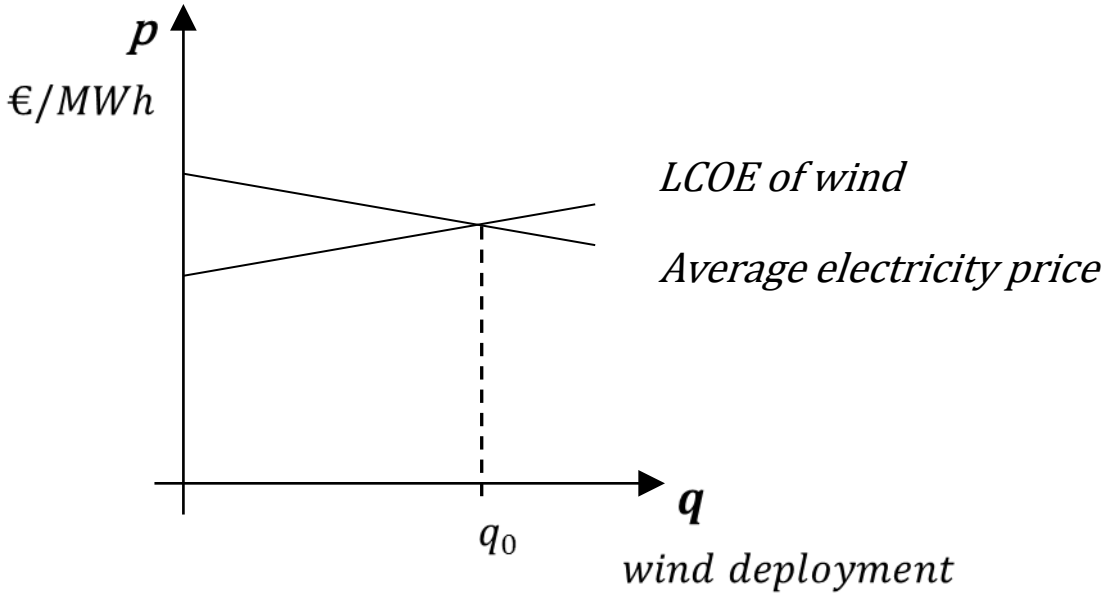
When will wind power be competitive? (investor)

→ ~~„As soon as wind LCOE will be fallen below those of conventional plants!“~~

or equivalently

→ ~~„When LCOE are equal to the average electricity price!“~~

What is the optimal amount of wind? (modeler/policy maker)



However, this is all wrong!

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→ ~~„As soon as wind LCOE will be fallen below those of conventional plants!“~~

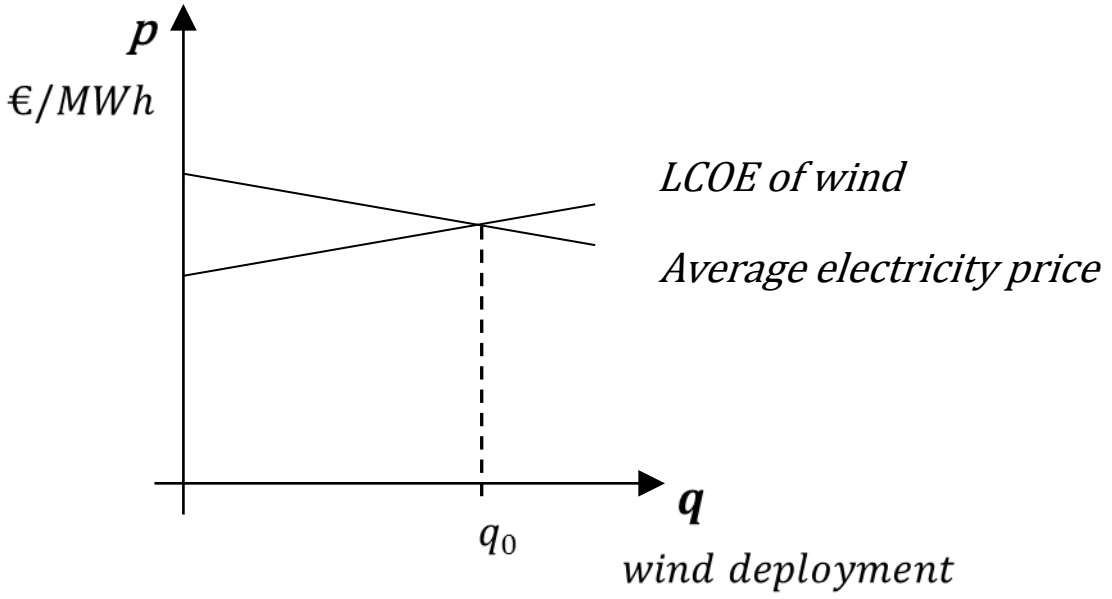
→ **Don‘t compare LCOE of different technologies!**

or equivalently

→ ~~„When LCOE are equal to the average electricity price!“~~

→ **Don‘t compare generation costs with the average price!**

What is the optimal amount of wind? (modeler/policy maker)



However, this is all wrong!

Electricity is a unique commodity

Demand is variable, storage is costly	Demand is uncertain. Ramping of plants is costly	Transmission is costly
↓	↓	↓
The value (price) of electricity varies over **time**	Short-term **balancing** is costly	The value of electricity varies between **locations**
Electricity is a **heterogeneous** good over time	**Heterogeneous** w.r.t. lead-time between contract and delivery	**Heterogeneous** across space

→ Generation of different technologies is no perfect substitute, e.g. „nuclear power“ is not „wind power“

→ Do not compare LCOE

Variable renewables make electricity even more unique

Output is **fluctuating**	Output is **uncertain**	Bound to **certain locations**
• Wind speeds and solar radiation vary over time • Thus its value depends on <u>when</u> it is produced	• Winds and radiation is uncertain day-ahead • <u>Forecast errors</u> are costly	• Resource quality varies geographically • Thus its value depends on <u>where</u> it is generated
↓	↓	↓
„Profile costs“	**„Balancing costs“**	**„Grid-related costs“**

Integration costs

(are neglected in LCOE comparison)

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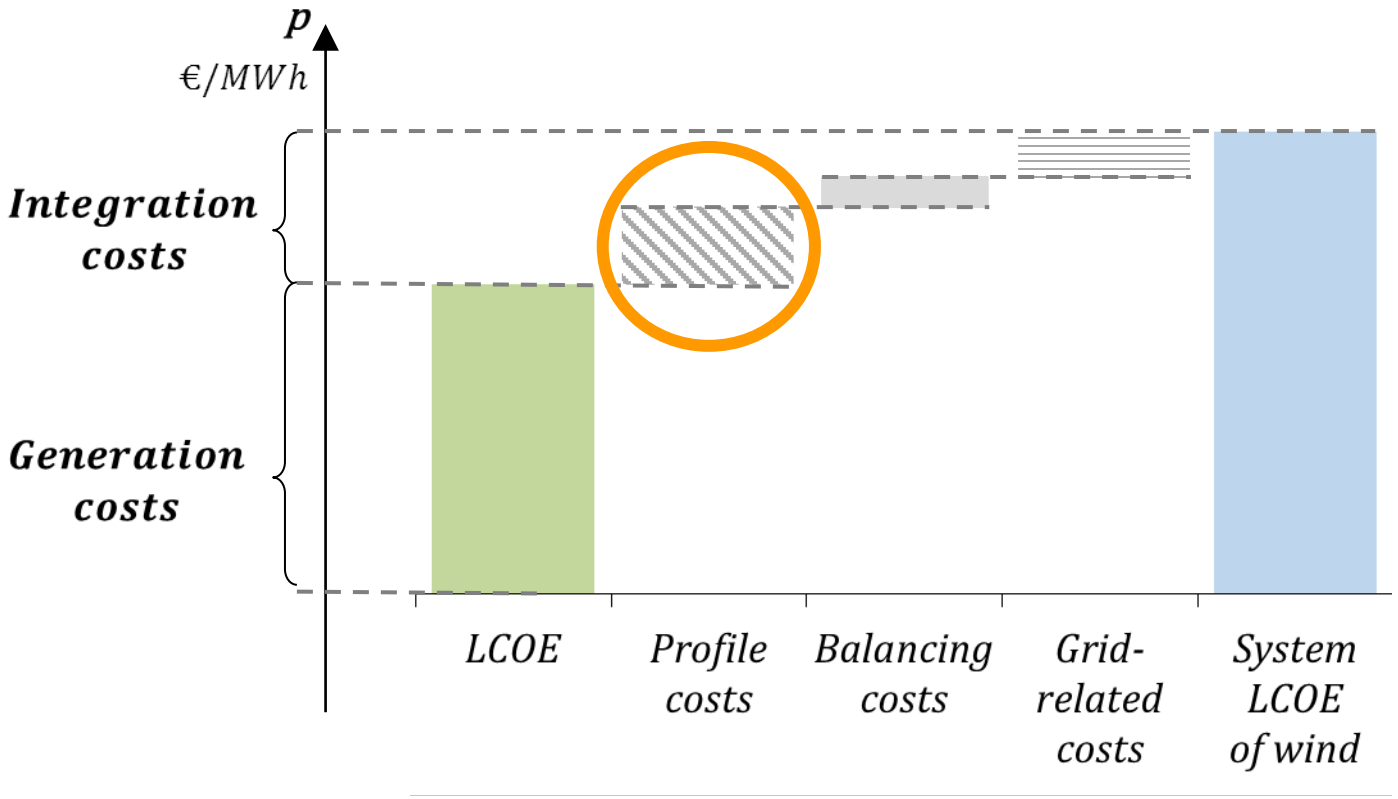
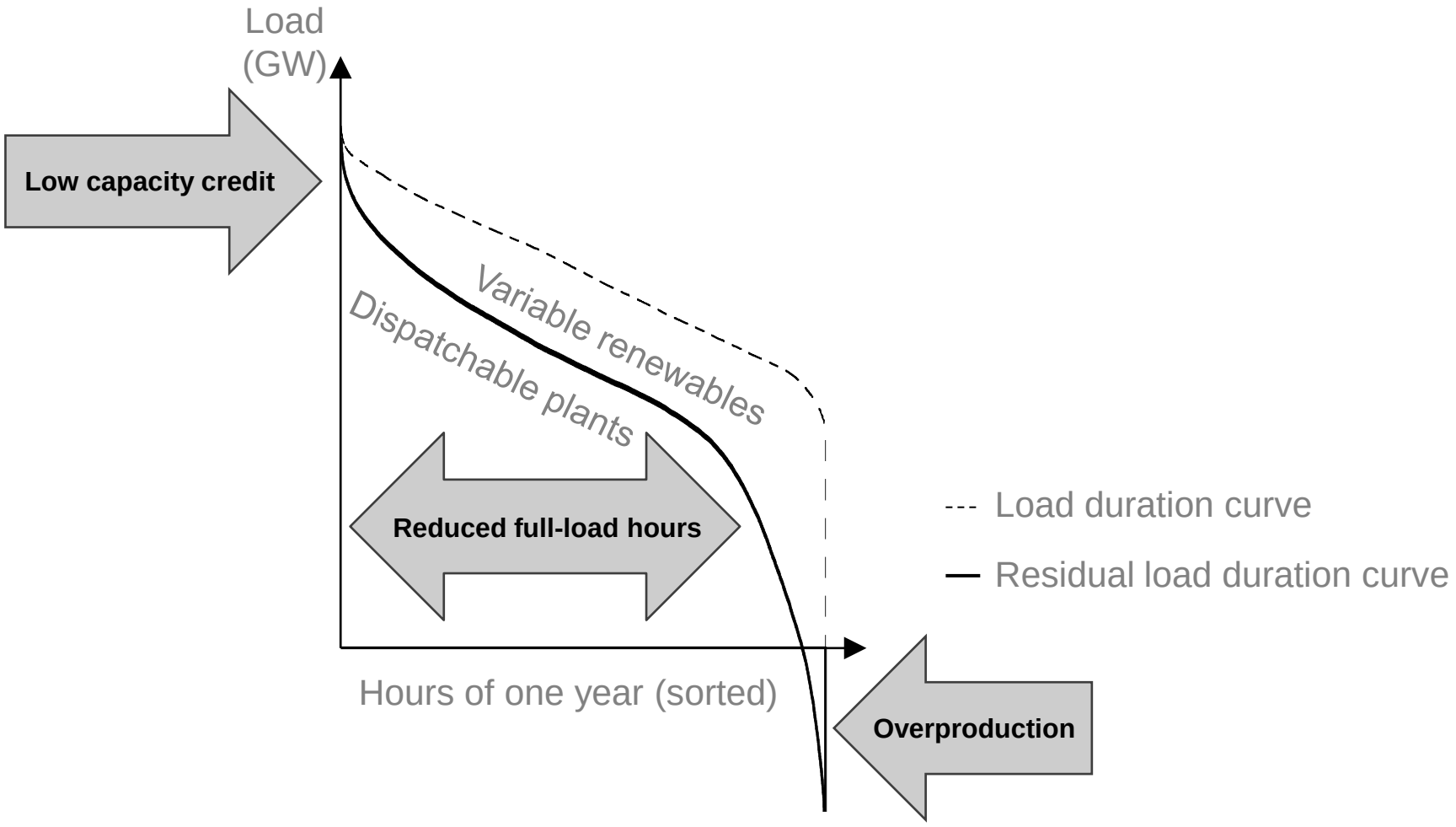
System LCOE are defined as the sum of generation and integration costs



Profile costs: Residual load duration curve shows challenges



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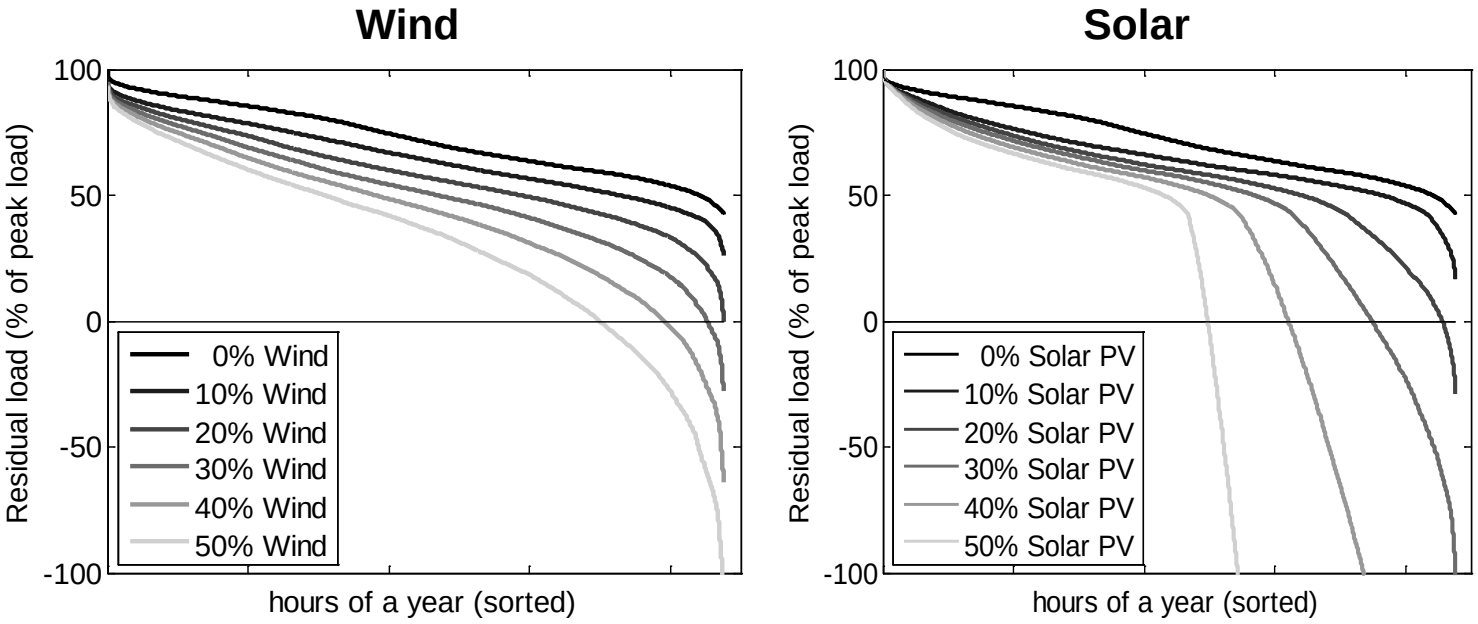
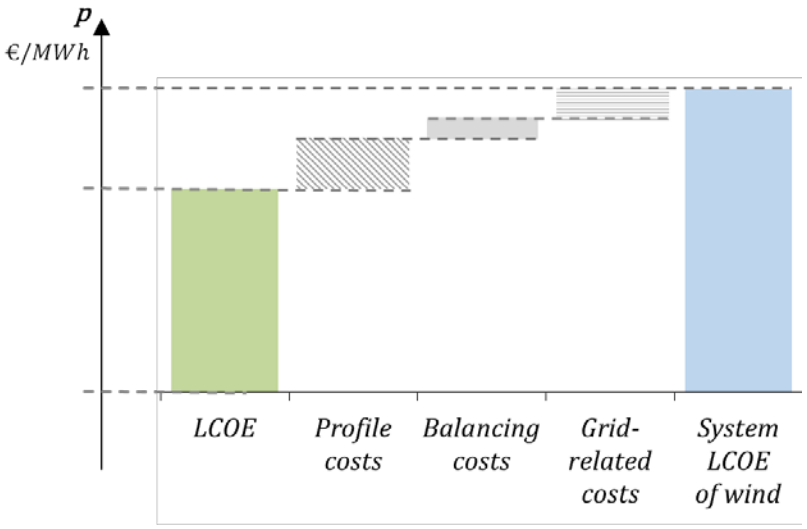


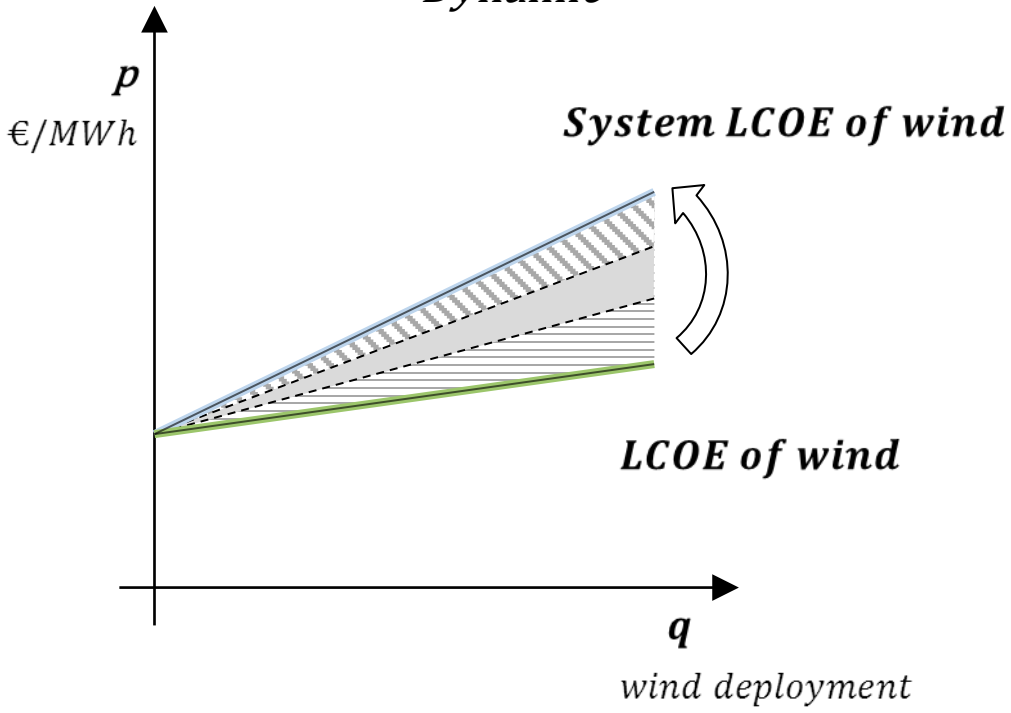
German data

System LCOE are defined as the sum of generation and integration costs

Static

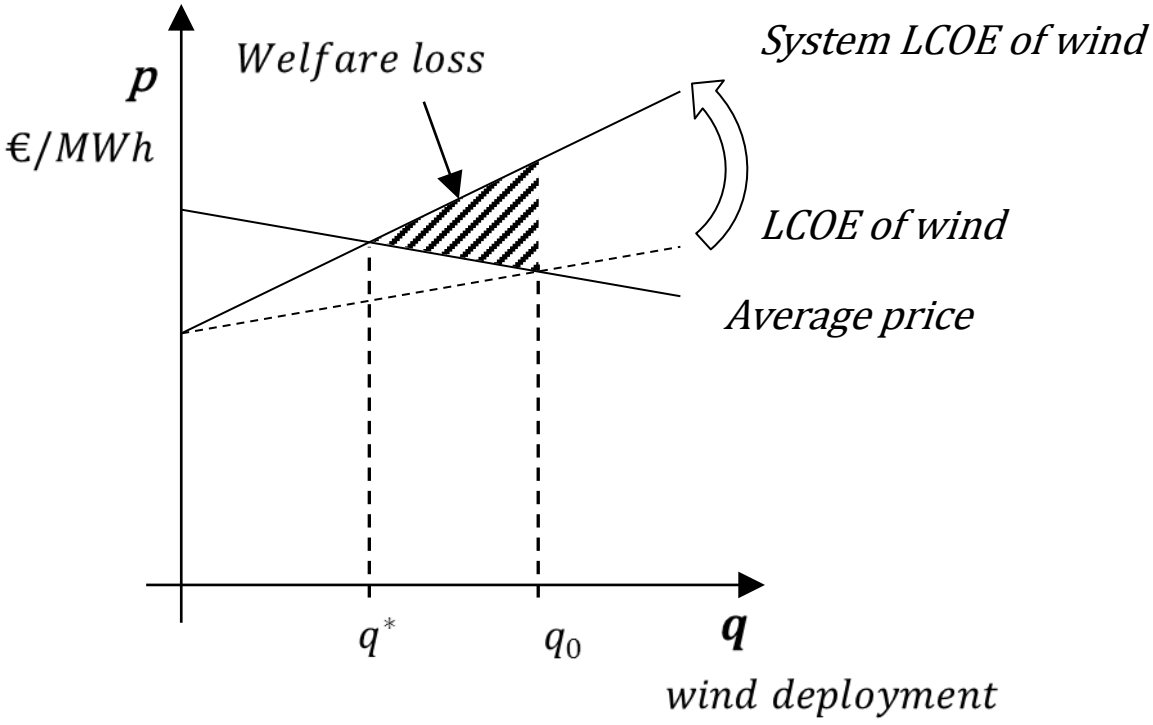


Dynamic



When will wind power be competitive? (investor)

What is the optimal amount of wind? (modeler/policy maker)



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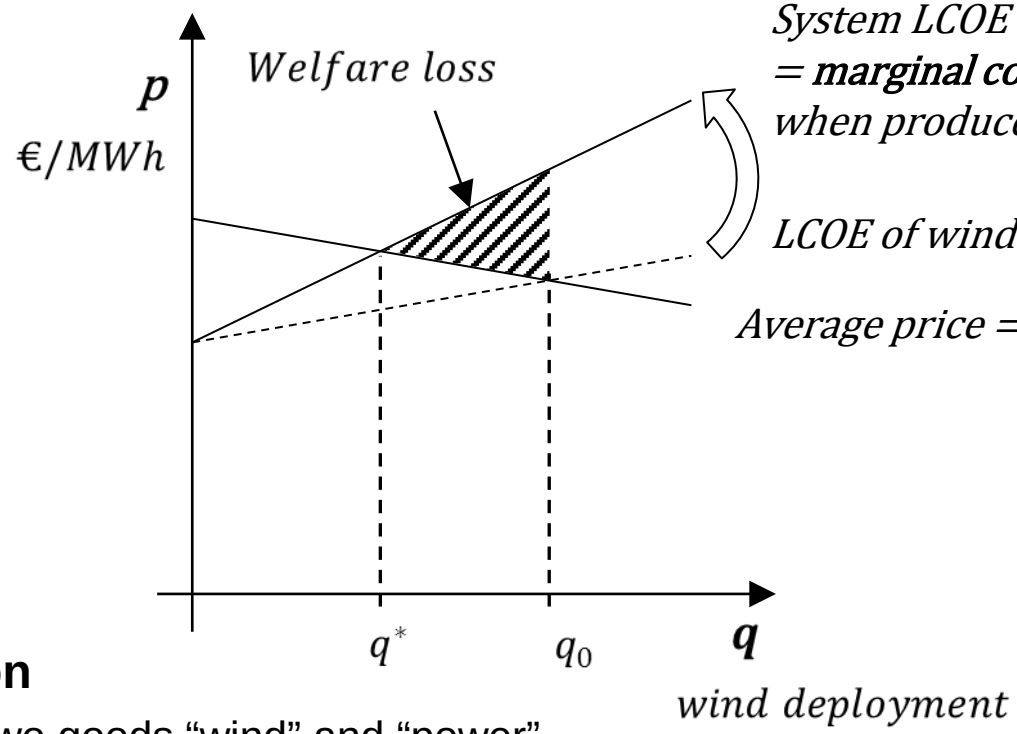
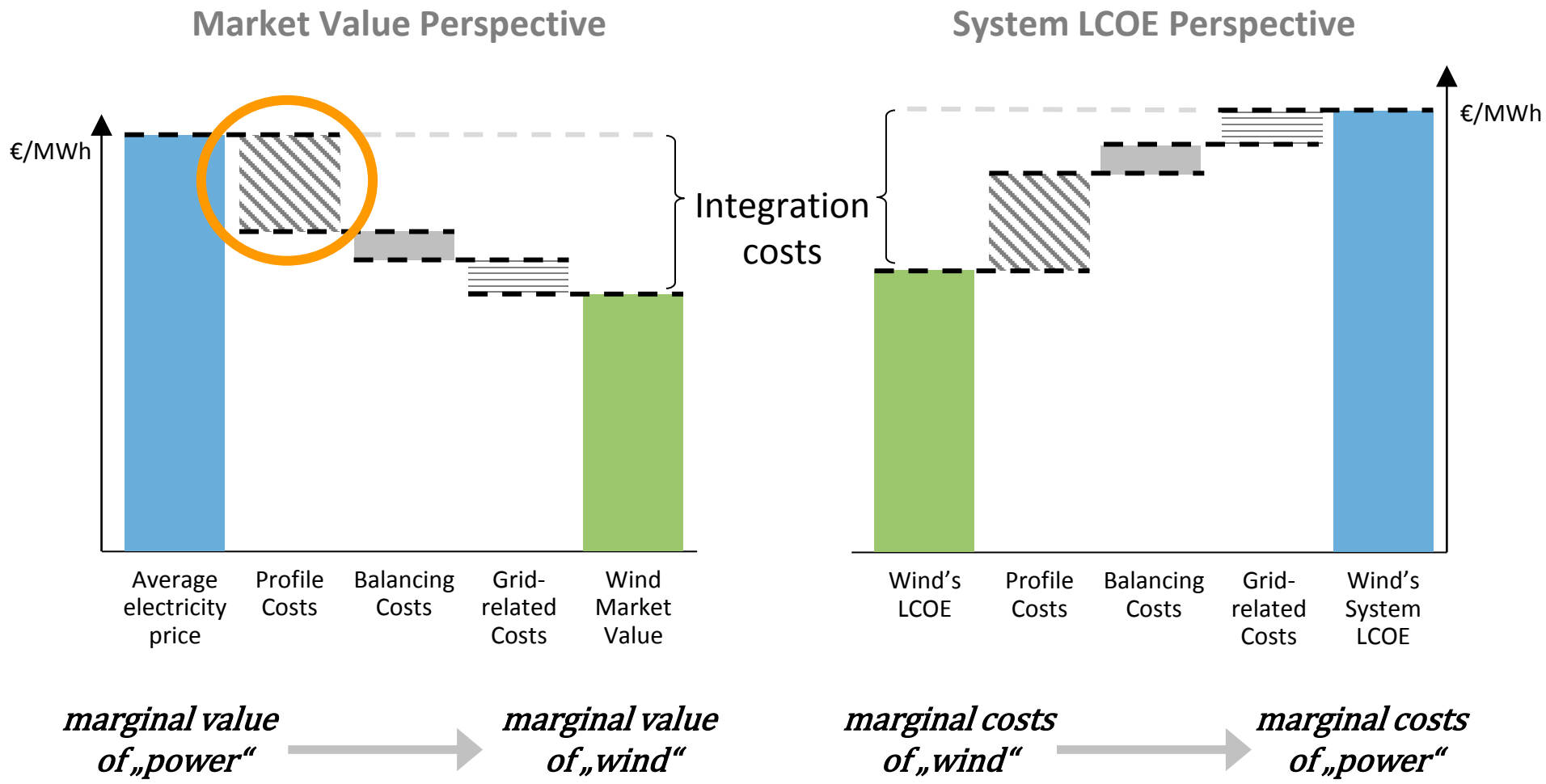


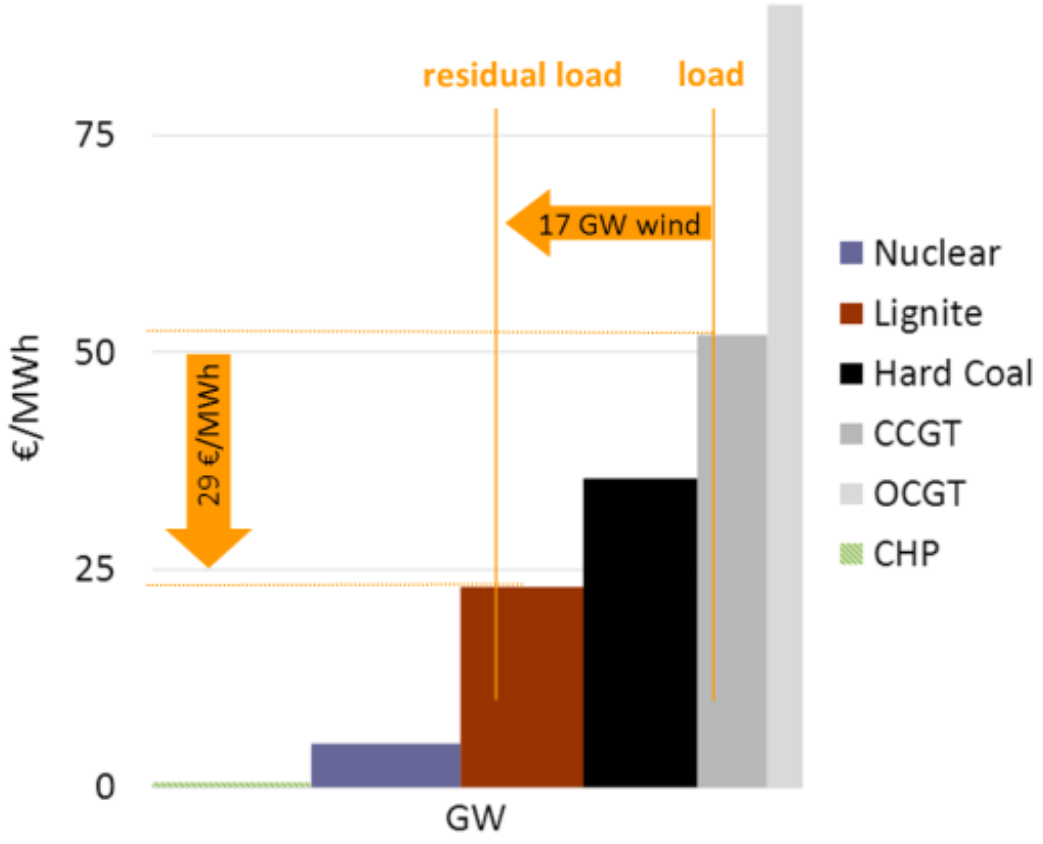
Interpretation

- There are two goods “wind” and “power”
- „Power“ is perfectly matching load
- Additional costs needed to transform „wind“ into „power“ → integration costs
- The total costs to cover load with „wind“ are System LCOE

Two perspectives, one framework: System LCOE and market value



Profile Costs: The “Cannibalization” Effect



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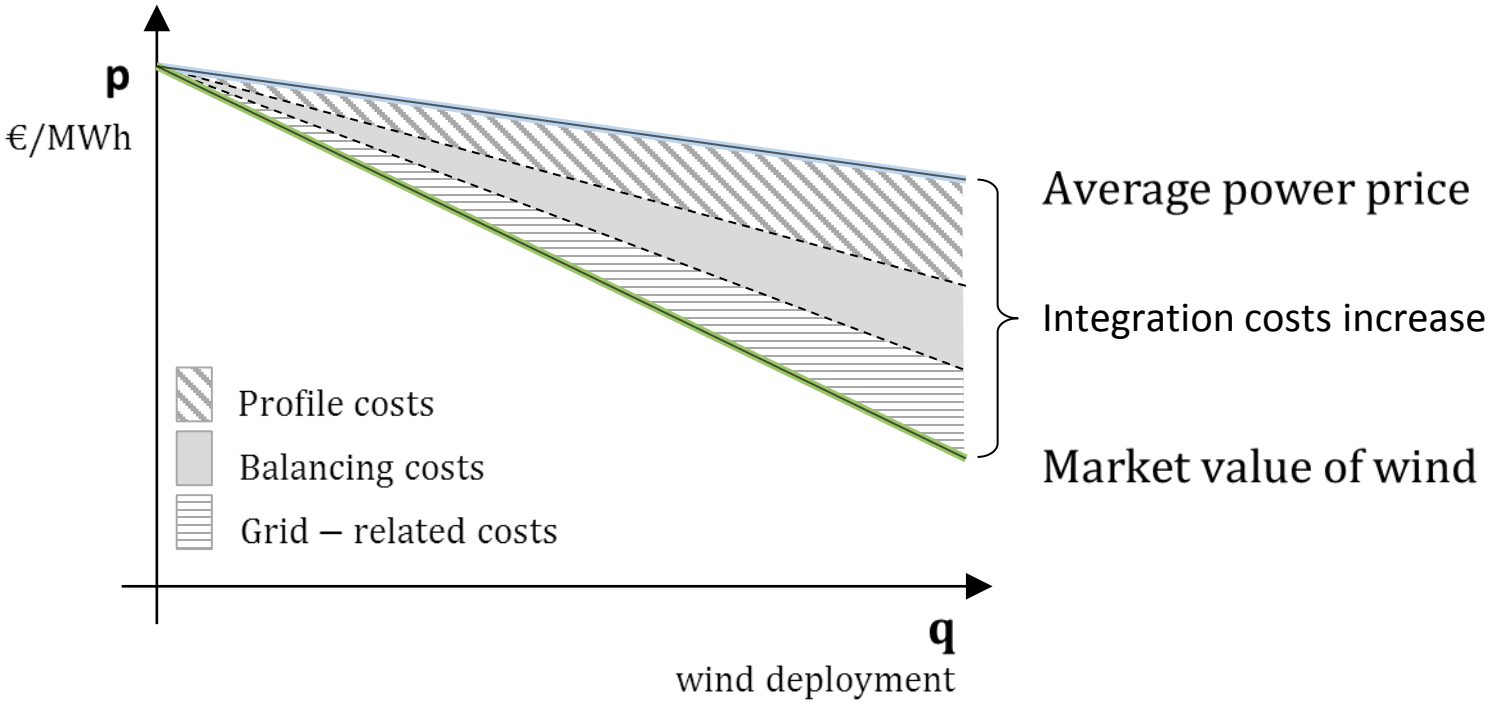
Market value of wind decreases with increasing share



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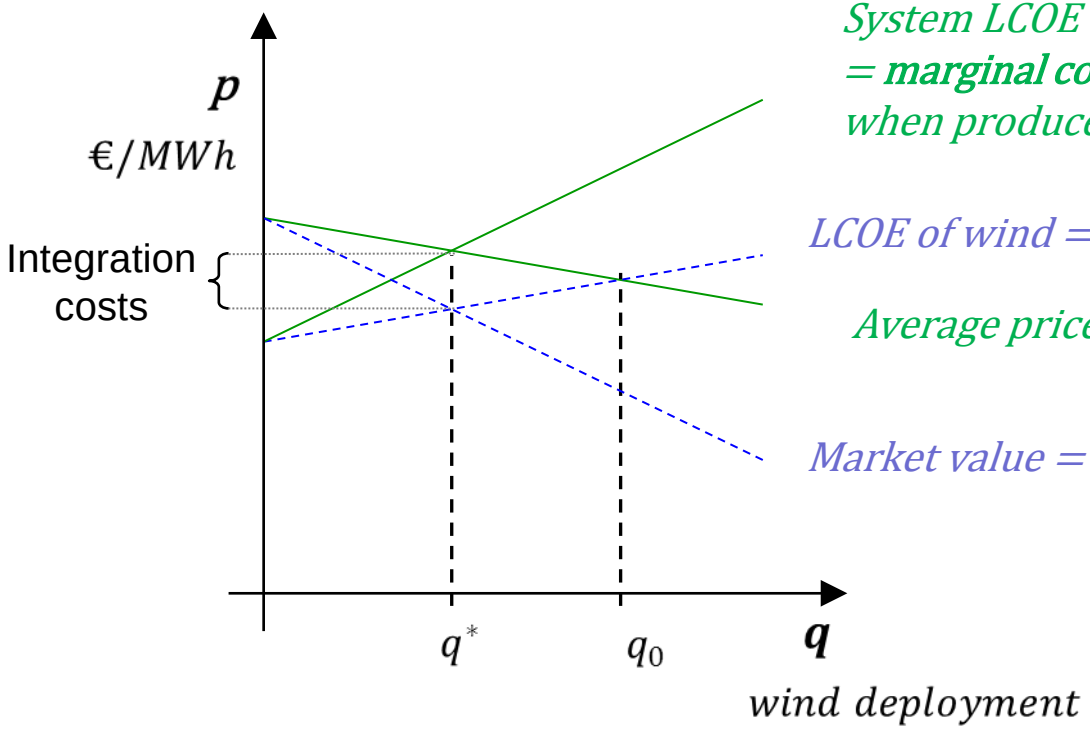


System LCOE of wind
*= **marginal costs of „power“***
when produced from wind plant

*LCOE of wind = **marginal costs of „wind“***

*Average price = **marginal value of „power“***

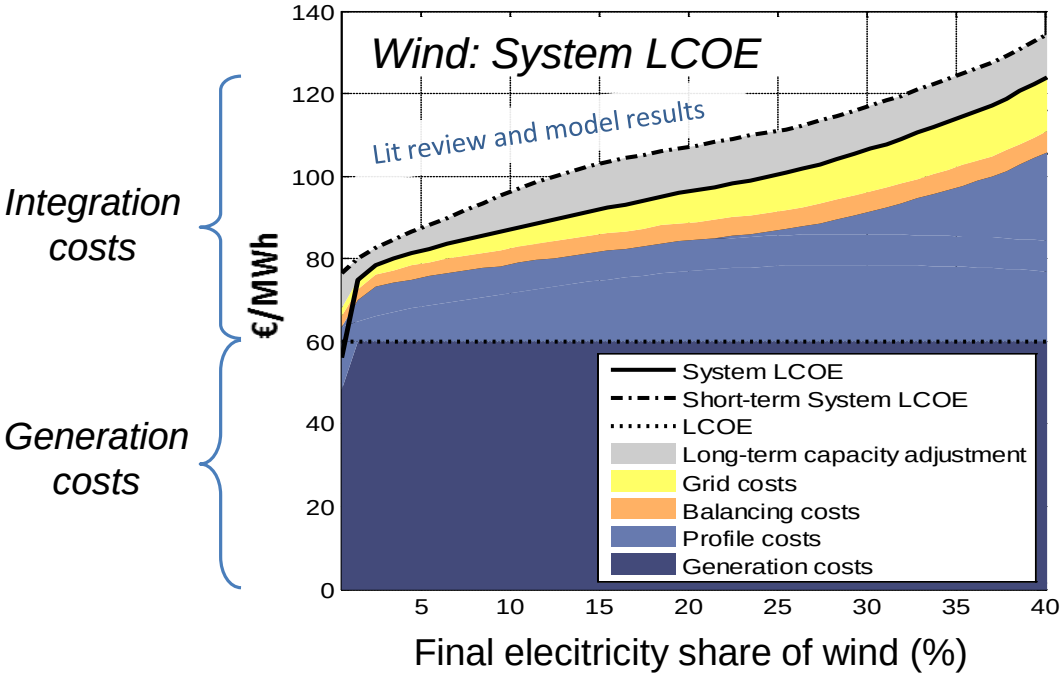
*Market value = **marginal value of „wind“***

Reference system (good)

"*power*"

"***wind***"

System LCOE – magnitude and shape



- From literature: Grid and balancing costs (Holttinen et al. 2011; Gross et al. 2006; Hirth 2012a, dena 2010)
- From a simple model: profile costs.
- Parameterized from German data, representative for thermal systems in Europe
- Caveats that increase integration costs
  - No import/export
  - No demand elasticity
  - No storage
  - Power sector only

- Integration costs of wind power can be in the same range as generation costs at moderate shares (~20%)
- A significant driver of integration costs are profile costs, especially the reduced utilization of capital-intensive thermal plants.

→ Integration costs can become an economic barrier to deploying VRE at high shares.

→ An economic evaluation of wind and solar power must not neglect integration costs.

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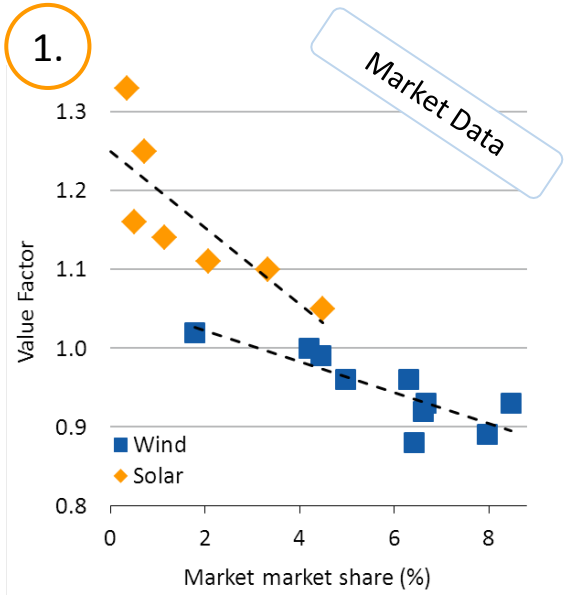
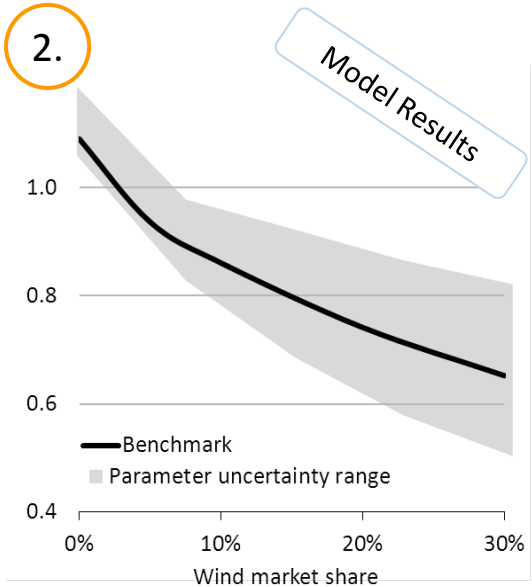
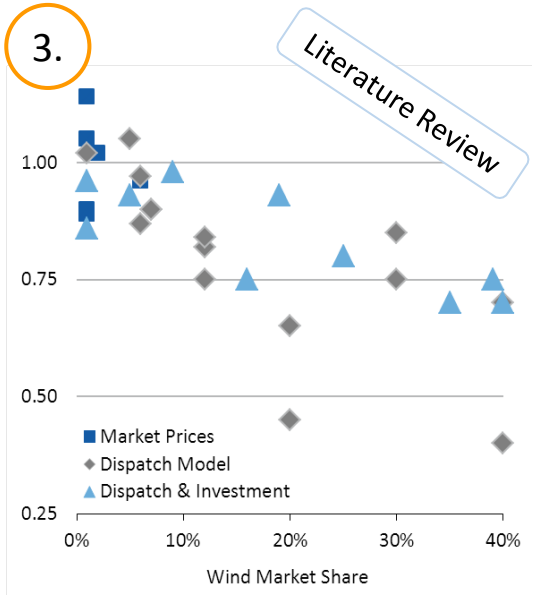
The market value (here value factor) reduces: Market Data, Model Results, Literature Review







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 1.02 to 0.89 as penetration increased from 2% to 8%.

Hirth, Lion (2013): "The Market Value of Variable Renewables", Energy Economics 38, 218-236.

Conclusions

1. We show that LCOE are a flawed indicator to evaluate power technologies
2. We propose a better metric ‘System LCOE’
3. We present a framework of System LCOE and market value and link it to welfare theory
4. Integration costs of wind power can be in the same range as generation costs at moderate shares (~20%)
5. A significant driver of integration costs are profile costs, especially the reduced utilization of capital-intensive thermal plants.
6. Integration costs can become an economic barrier to deploying VRE at high shares.
7. An economic evaluation of wind and solar power must not neglect integration costs.