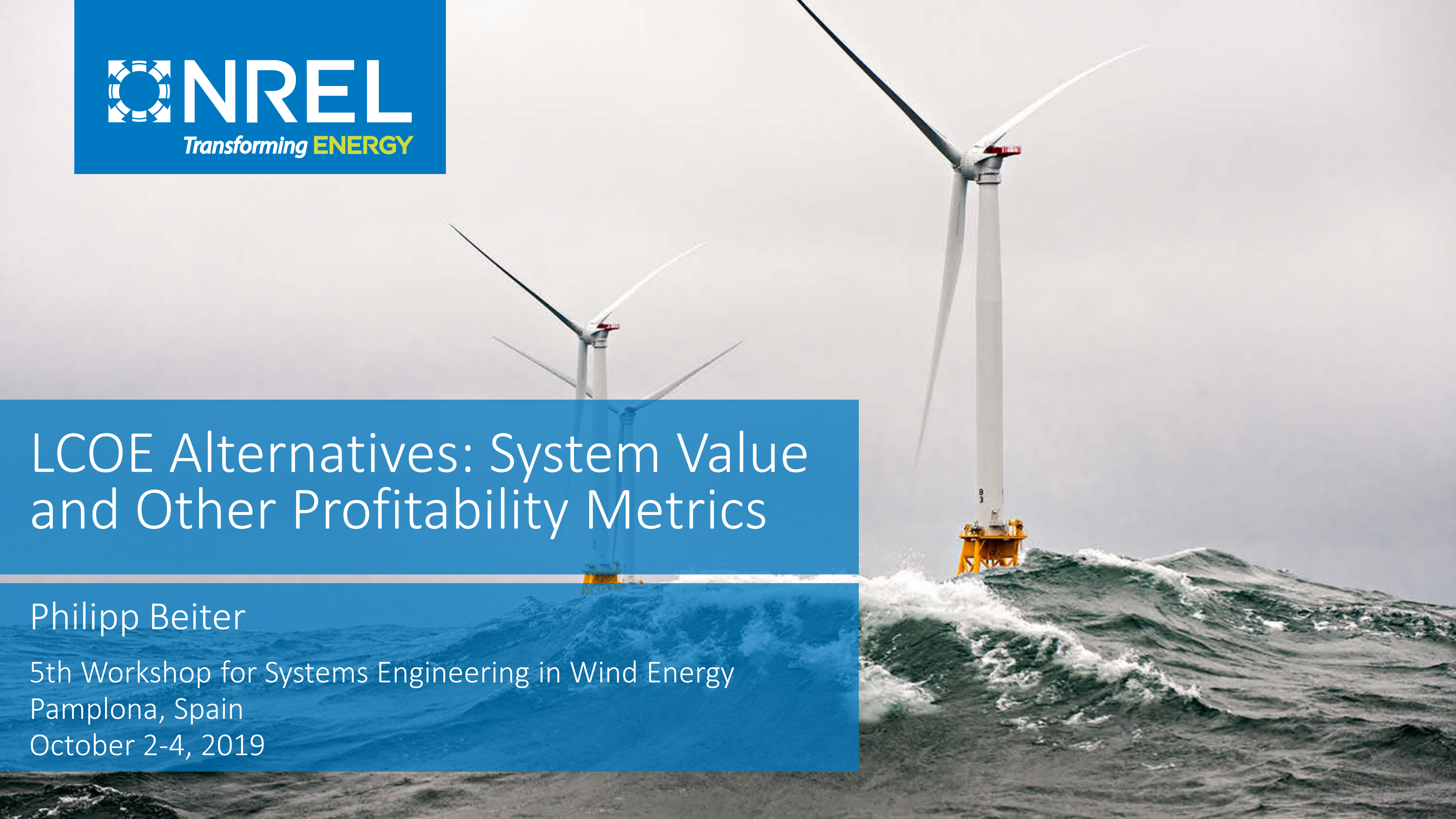

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LCOE Alternatives: System Value and Other Profitability Metrics

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LCOE is a commonly used metric to assess generation technologies

Criteria

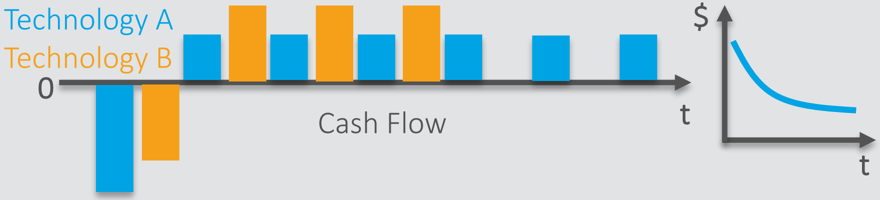
Simple and **measurable**

$$LCOE\left(\frac{\$}{MWh}\right) = \frac{\sum_{t=0}^{T} \frac{CapEx_t + O\&M_t + F_t}{(1+\text{Discount Rate})^t}}{\sum_{t=1}^{T} \frac{AEP_t}{(1+\text{Discount Rate})^t}}$$

Average revenue per unit of electricity that would be required to recover the costs of constructing and operating a generating plant during an assumed financial life

Use Case

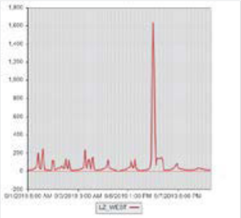
Comparison between
different cash flow profiles and **over time**



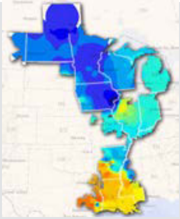
Limitations

Does <u>not</u> capture the ***location*** and ***time*** **value** of the generated ***energy*** **and** ***other services***

Real-time electricity price variation in MISO (9/1/2019)



Temporal



Spatial

Day-Ahead

Intra-Day

Real-Time

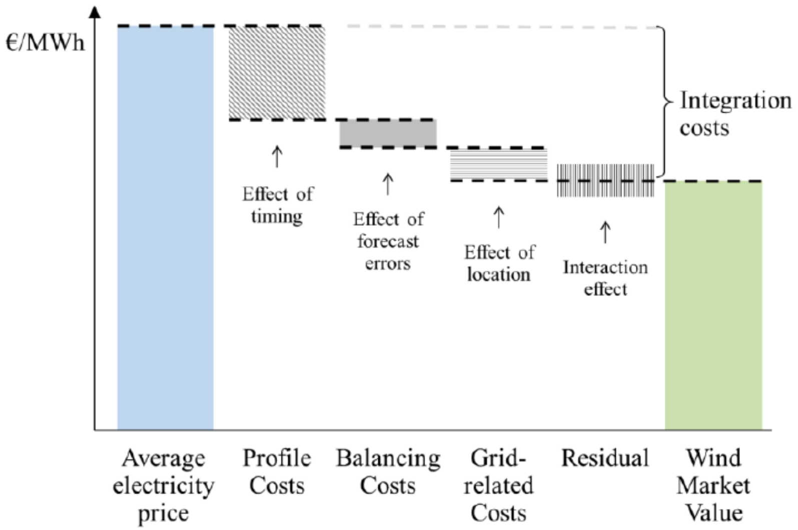
Market

Sources: https://api.misoenergy.org/MISORTWD/lmpcontourmap.html (left image); http://www.energyonline.com/Data/GenericData.aspx?DataId=4&ERCOT___Real-time_Price (right image)

What is Power System Value?

Bulk Power System Value has two different interpretations (in a competitive market):

- ***Marginal economic value***: *Incremental (system) cost savings from adding one MWh of wind power*
- ***Electricity Price***: *Specific revenue ($/MWh) that an investor earns from selling the output on power markets (e.g., "wind-weighted" electricity price)*



Source: Hirth, Ueckerdt and Edenhofer (2015); Hirth (2013)

Wind value is impacted by the technology's properties and the heterogenous commodity characteristics of electricity

- **Profile Costs**: *Variable* wind supply
  → Electricity price differs between hours
- **Balancing Costs**: *Uncertain* wind supply
  → Electricity price differs between contract and delivery time
- **Grid-related Costs**: *Locational* transmission constraints
  → Electricity price differs between locations

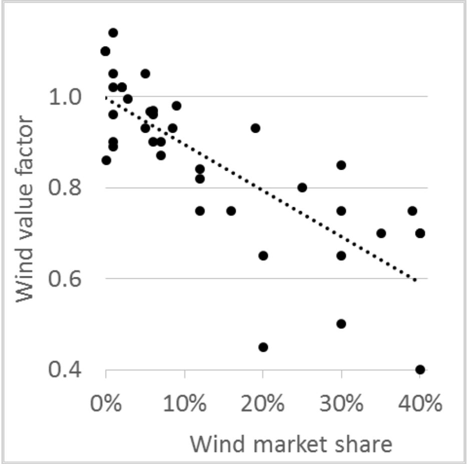
Alternative System Value and Profitability Metrics

Metric	Expression	Units	Examples
Levelized Value of Electricity	Value / Energy	\$/MWh	U.S. Energy Information Administration (EIA) *Levelized Avoided Cost (EIA)*
Net Value of Electricity	(Value-Cost)/Energy	\$/MWh	International Energy Agency (IEA) *Value-Adjusted LCOE (IEA)*
Net Value of Capacity	(Value-Cost)/Capacity	\$/kW-yr	Lawrence Berkley National Laboratory (LBNL) *Marginal Economic Value (Factor)*
System LCOE	(Cost – Value)/Energy + Benchmark Price[a]	\$/MWh	Bloomberg New Energy Finance (BNEF) *Realized Power Prices*
System Profitability	f(Value/Cost) Value/Cost (Benefit-cost ratio) Value/Cost – 1 (Return on investment) 1 – Cost/Value (System Profit Margin)	Unitless	National Renewable Energy Laboratory (NREL) *System Profitability* Hirth (2013) *System Value (Factor)*

[a] Various benchmark prices have been suggested in the literature, including the annual average of hourly marginal electricity prices or an average price in a no-renewables system (e.g., "flat-block" power).

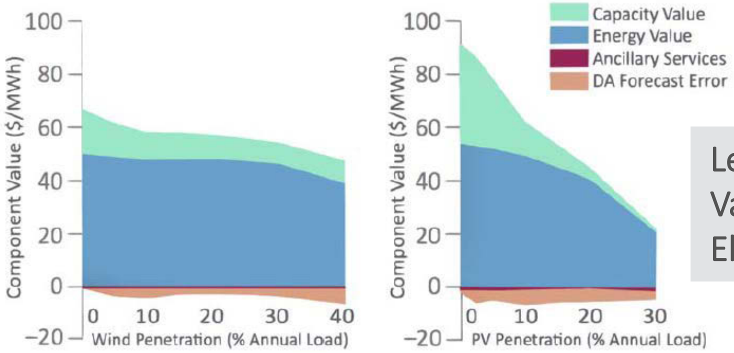
Source: Adapted from Mai, Mowers and Eurek (2019 forthcoming)

Alternative System Value and Profitability Metrics



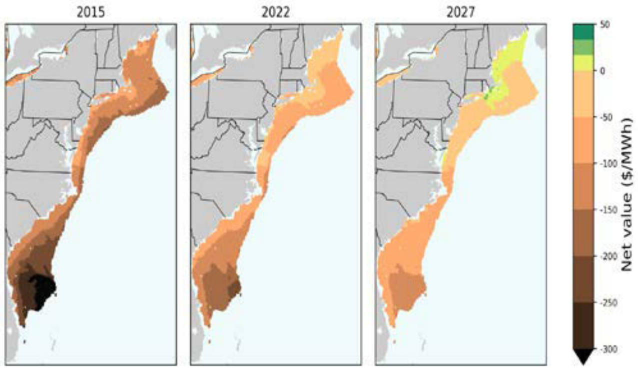
Hirth et al. (2015)

Value Factor:
Ratio of the hourly wind-weighted average wholesale electricity price and its time-weighted average.



Mills and Wiser (2012)

Levelized Value of Electricity



Beiter et al. (2017)

Net Value of Electricity

How Can These Metrics Inform Wind Systems Engineering?

Commonly Used

- Max(Energy Production)
- Min(Mass)
- Min(LCOE)
- Etc.

Are these feasible?

- Max(System value) = f(cost, energy value, capacity value, ancillary services value, etc.)
- Max(Tax incentives) = f(capacity factor, curtailment, O&M strategy, etc.)
- Etc.

Trade-offs

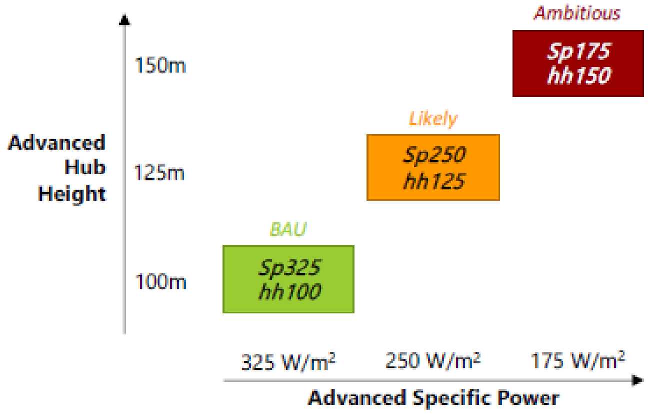
- Validity
- Robustness
- Comprehensiveness
- Simplicity
- Data availability

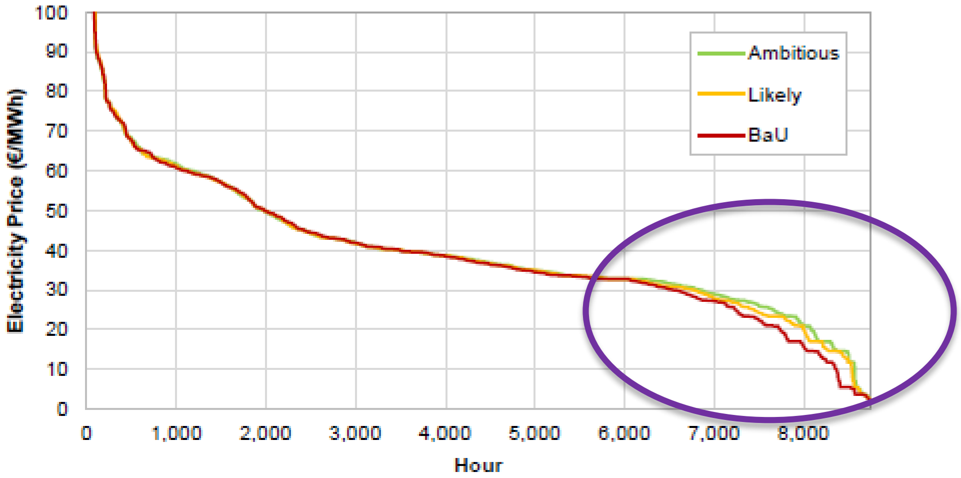
One metric not inherently better than another, depends on *purpose* and *data availability*

An Application of Alternative System Value Metrics to Specific Power Considerations

- Lower Specific Power (Low Wind Speed) Turbines:
  - Produce at Lower Wind speed (i.e., Higher Annual Full Load Hours)
  - Less Volatile Production

- Does this production profile coincide with favorable electricity market prices?



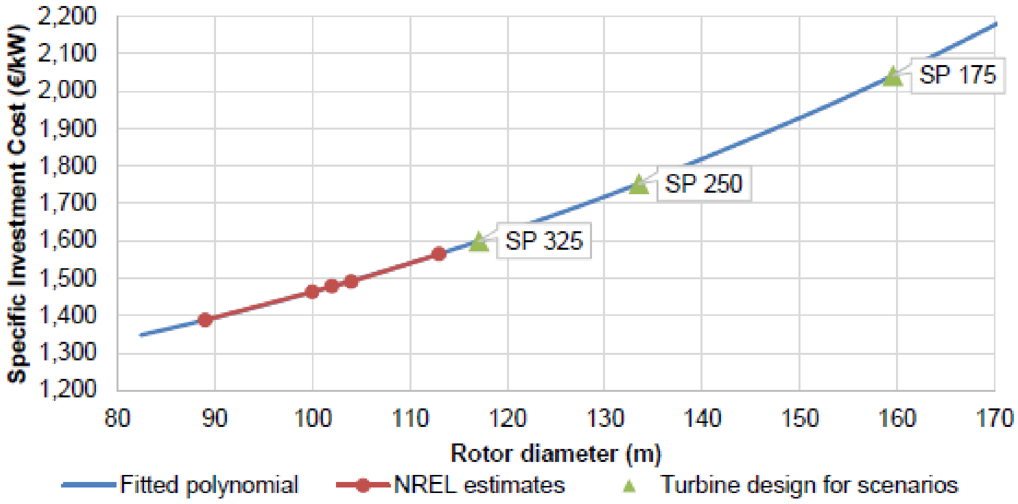


Price duration curve for the DE-NW region in 2030

Source: Dalla Riva et al. (2017)

An Application of Alternative System Value Metrics to Specific Power Considerations

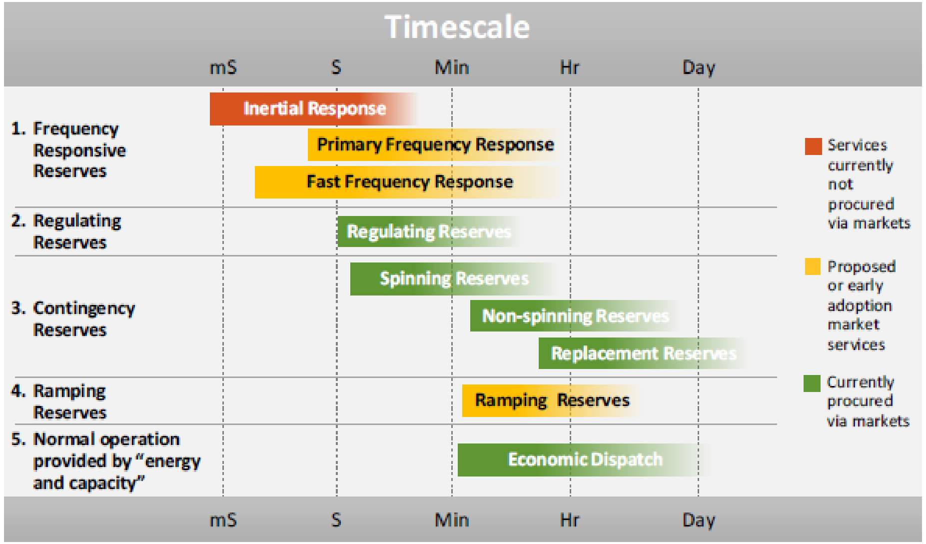
- If revenue is higher, what are the cost trade-offs?



- How does uncertainty (in energy production, electricity prices, costs) play into this evaluation?

Source: Dalla Riva et al. (2017)

Can Wind Power Provide Grid Services in a Future Power System?



Wind Technology		
Technical Capability	**Provision Currently**	**Definitions**
Y	N/A	Services that act to slow and arrest the change in frequency via rapid and automatic responses that change the output from generators providing these services
Y	Limited	
Y	Limited	
Y	Limited	Rapid response by generators used to help restore system frequency
Y	Limited	Reserves used to address power plant or transmission line failures by increasing output from generators
Y	No	
Maybe	No	
Y	Limited	An emerging and evolving reserve product that is used to address "slower" variations in net load
Y	Y	

Source: Denholm, Sun and Mai (2019)

Thank you.

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References

References

Beiter, Philipp, Walter Musial, Levi Kilcher, Michael Maness, and Aaron Smith. 2017. "An Assessment of the Economic Potential of Offshore Wind in the United States from 2015 to 2030." NREL/TP-6A20-67675. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy17osti/67675.pdf.

Dalla Riva, A., J. Hethey, A. Vitina. 2017. "Impacts of Wind Turbine Technology on the System Value of Wind in Europe" IEA Wind TCP Task 26. https://www.nrel.gov/docs/fy18osti/70337.pdf

Denholm, P., Y. Sun, T. Mai. 2019. "An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind." NREL/TP-6A20-72578. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy19osti/72578.pdf.

Hirth, Lion, Falko Ueckerdt & Ottmar Edenhofer (2015): "Integration Costs Revisited – An economic framework of wind and solar variability", Renewable Energy 74, 925–939.
doi:10.1016/j.renene.2014.08.065.

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.

Mai, T., M. Mowers, K. Eurek. 2019 forthcoming. "Competitiveness Metrics for Electricity System Technologies" (Technical Report). National Renewable Energy Laboratory (NREL).

Mills, A., R. Wiser. 2012. "Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Study for California." Lawrence Berkeley National Laboratory (LBNL). https://emp.lbl.gov/sites/all/files/lbnl-5445e.pdf.