Dispatchable power from wind:

The case of baseload Hybrid Power Plants.

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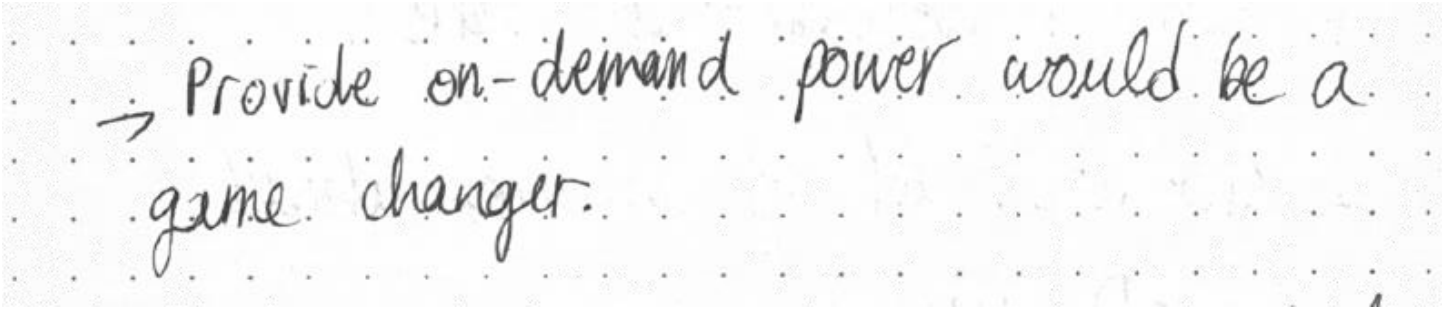

Notes from IEA Task 50 WP2 discussions

Dispatchable power from wind …

"Dispatchability defines the ability for the operator to control a sizable share of the power output."[1]

Goal: design a *dispatchable* hybrid power plant

Problem: the design problem for dispatchability is not clear

[1] Suchet, D., Jeantet, A., Elghozi, T., & Jehl, Z. (2020). Defining and Quantifying Intermittency in the Power Sector. Energies, 13(13), 3366. https://doi.org/10.3390/en13133366

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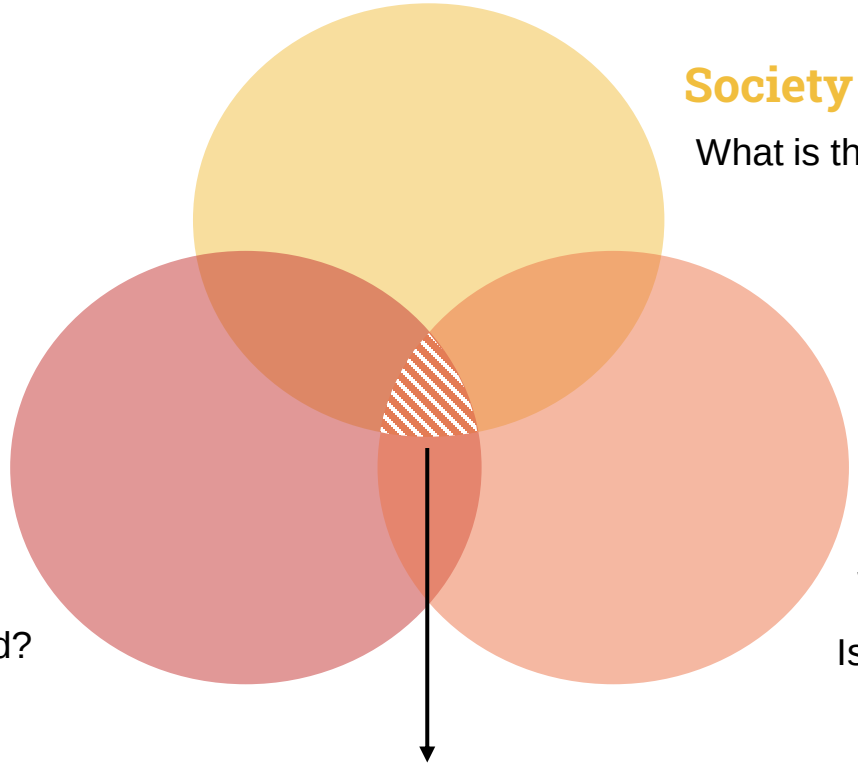
… with a systems engineering approach



Society

What is the societal need?

Technology

Is it technically feasible?

Does it work as intended?

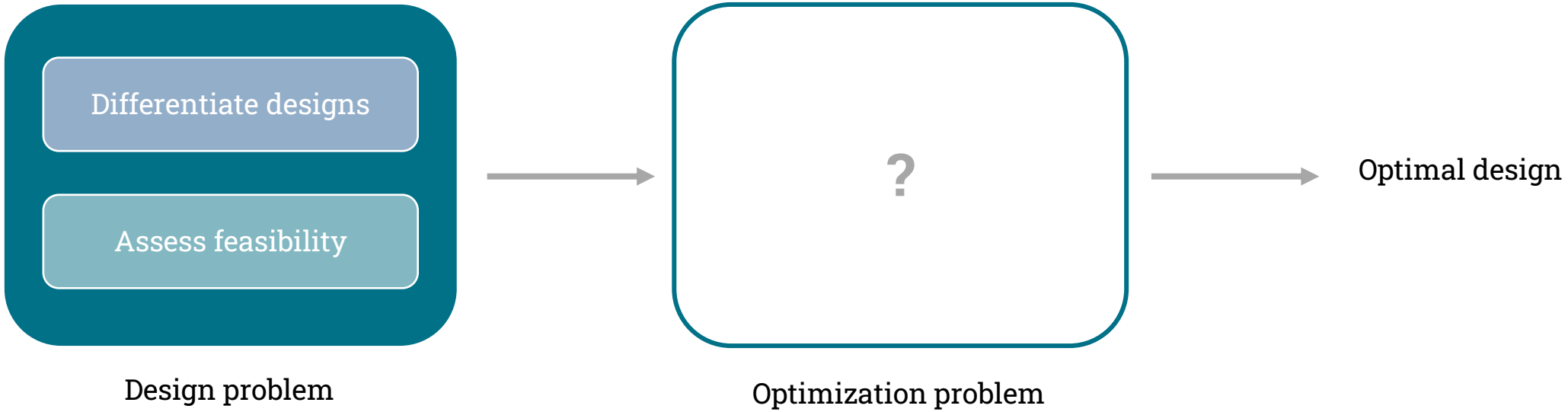
Economy

What is the economic value?

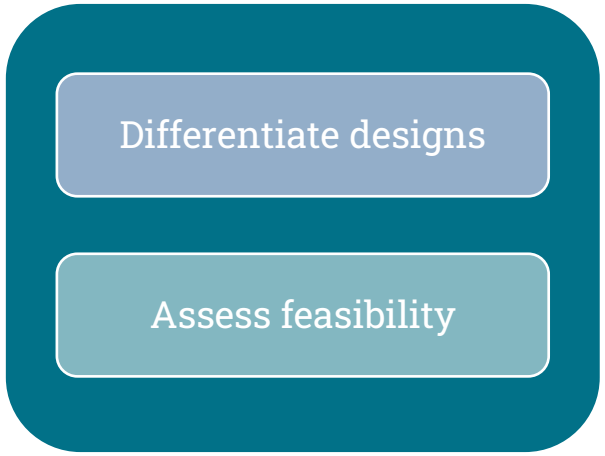
Is it financially viable?

All aspects are important for defining the design problem

The need for a clear design problem



The need for a clear design problem



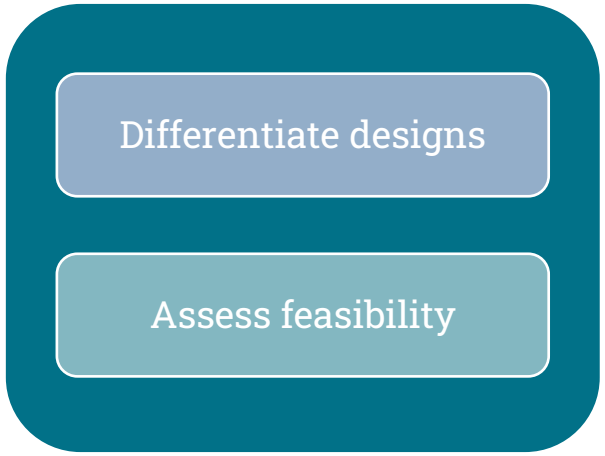
Design problem

Example: Wind turbine design

- Societal goal of increasing the share of wind energy in the generation mix → Reduce the cost of the technology
- Certification standards

→ All aspects are clear!

The need for a clear design problem



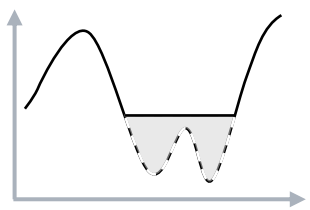
Design problem

Dispatchable HPPs:

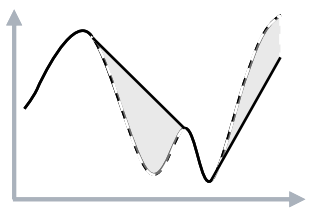
- Societal goal of producing electricity when needed: flexible electricity production

→ What does that mean exactly?

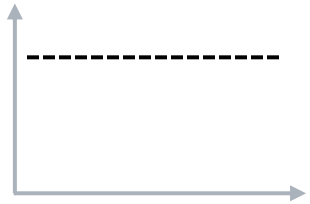
→ What are the technical requirements?



Minimum power?



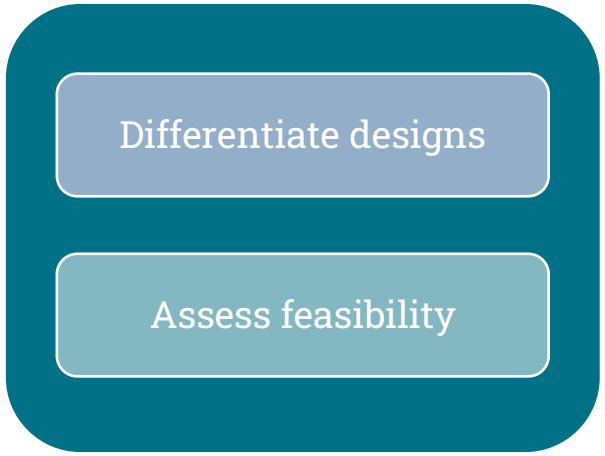
Reduce up/down ramps?



Energy capacity?

Matching demand? *All the time or at specific hours?* *etc.*

The need for a clear design problem



Design problem

Dispatchable HPPs:

- Added value: increase revenues on the electricity markets

→ Problem: no economic incentives for dispatchability

"There is a general consensus that profits from energy arbitrage are insufficient for achieving capital cost recovery." [1]

"*When the battery costs are taken into account, the IRR drops compared to the wind-only case. […] there is no added incentive for a wind farm developer to deploy storage for arbitrage […]."* [2]

[1] Heredia, F. J., Cuadrado, M. D., & Corchero, C. (2018). On optimal participation in the electricity markets of wind power plants with battery energy storage systems. Computers and Operations Research, 96. https://doi.org/10.1016/j.cor.2018.03.004
[2] Mehta, M. K., Van Holthoon, G. J., Von Terzi, D. A., & Zaaijer, M. B. (2021). Technical and economic value of utility-scale wind-storage hybrid power plants. Proceedings of Hybrid Power Systems Workshop, 2021.

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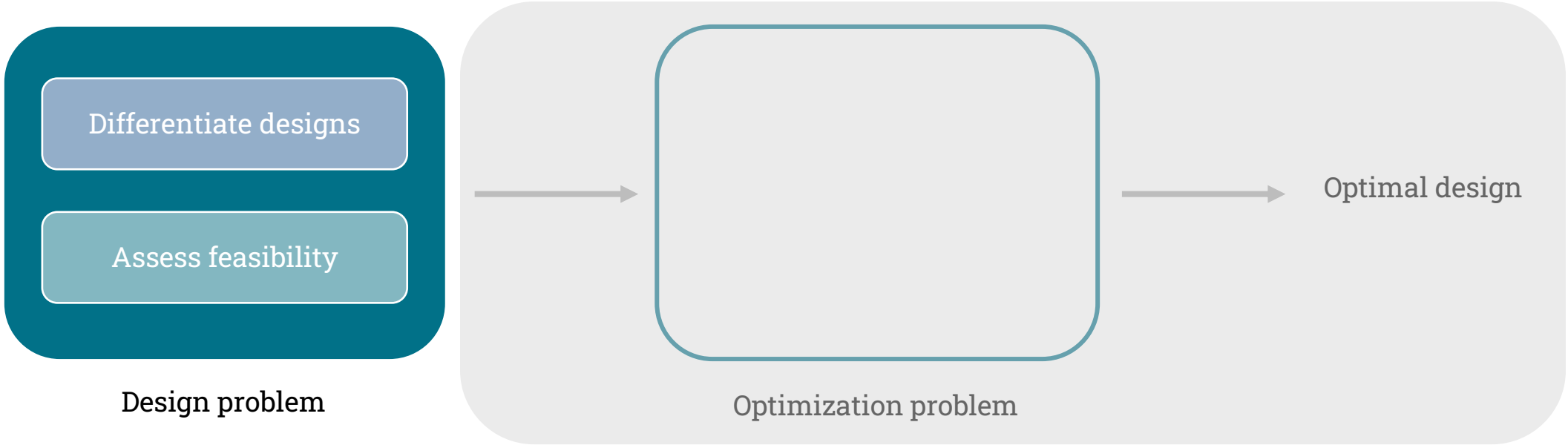
The need for a clear design problem

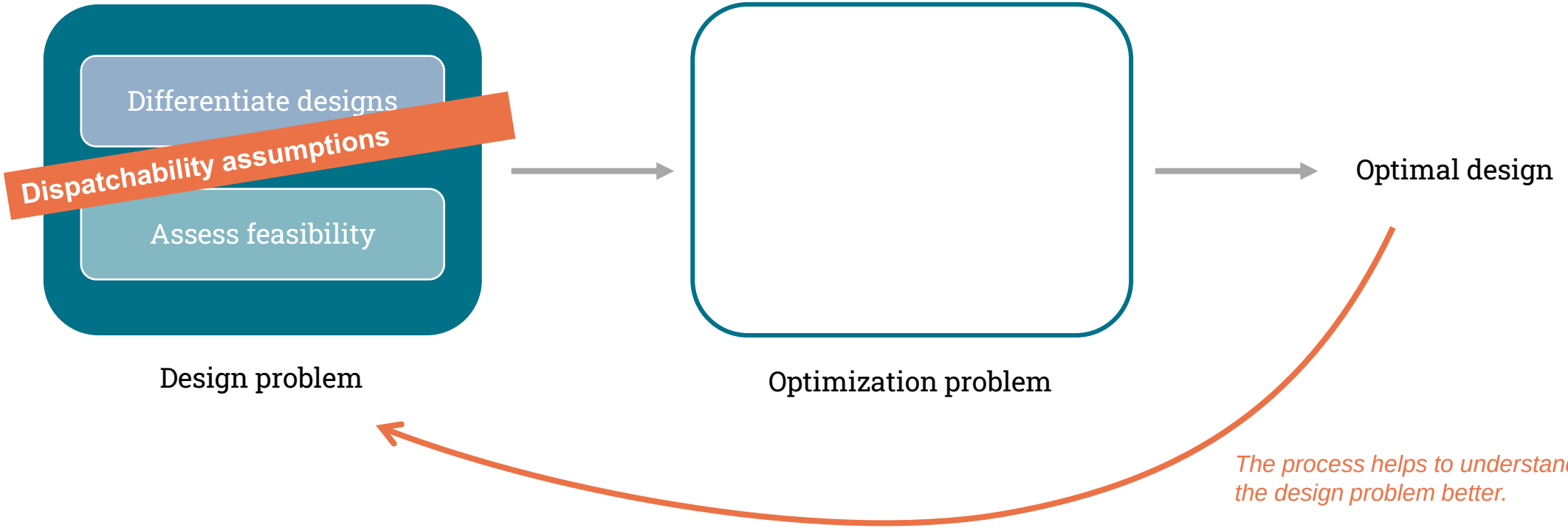
Dispatchable HPPs:



→ Unclear! ←

What is the relevance of the optimal design then?

Design for dispatchability: a work-around

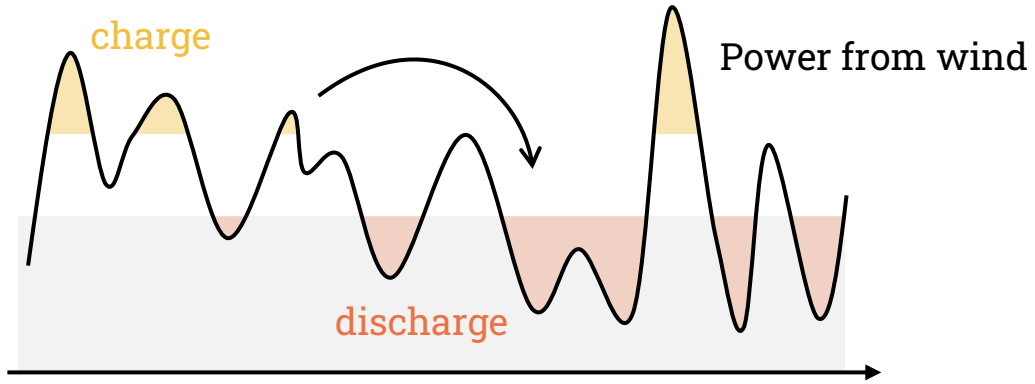


Baseload HPPs

Dispatchability assumptions

Baseload HPPs:

- Produce a baseload power 99% of the time
- Increase revenues using arbitrage



Design: *what would be the storage sizing and cost?*

Operation: *can the baseload power be provided reliably?*

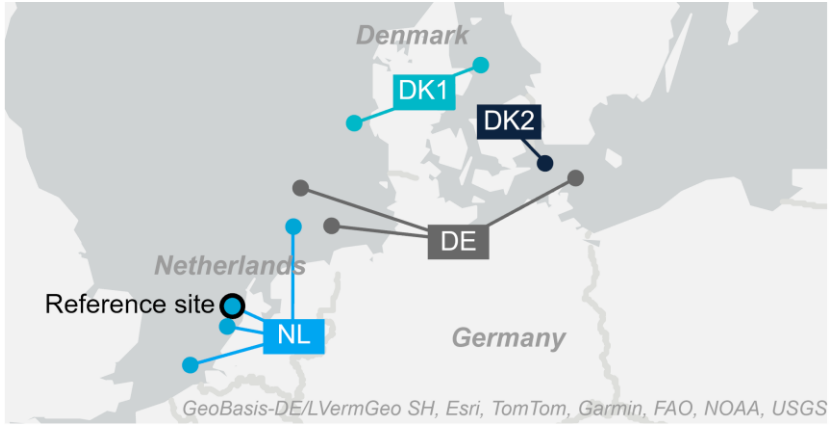
Baseload HPPs - Design

Objective: minimize the *cost of baseload* $c(\boldsymbol{x}) = \mathrm{NPV}_{\mathrm{Wind}} - \mathrm{NPV}_{\mathrm{Wind+Storage+Baseload}}(\boldsymbol{x})$

Constraint: ensure the power production is above a baseload level 99% of the time

Design variables: Power and energy capacity of the storage + dispatch schedule

→ Integrated design optimization problem



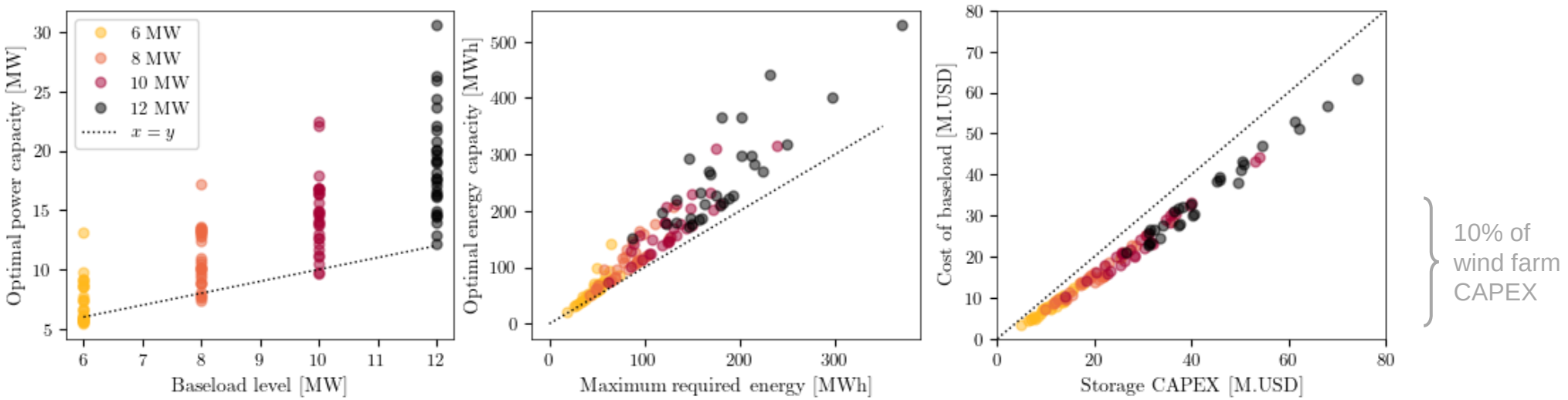
Comparison over **10 sites:**

- 100 MW wind farm
- 1 year of operation (2019)

Wind data: renewables.ninja

Electricity prices: ENTSO-E transparency platform

Baseload HPPs - Design



10% of wind farm CAPEX

→ Power and energy capacity are site dependent
→ No “size-fits-all”

→ The cost of baseload is driven by the storage CAPEX and not compensated by arbitrage

Further analysis in Iori, J., Zaaijer, M., Terzi, D. von, & Watson, S. (2024). Design drivers for the storage system of baseload hybrid power plants. IET Conference Proceedings, 245-250(5). https://doi.org/10.1049/icp.2024.1844

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Baseload HPPs - Operation

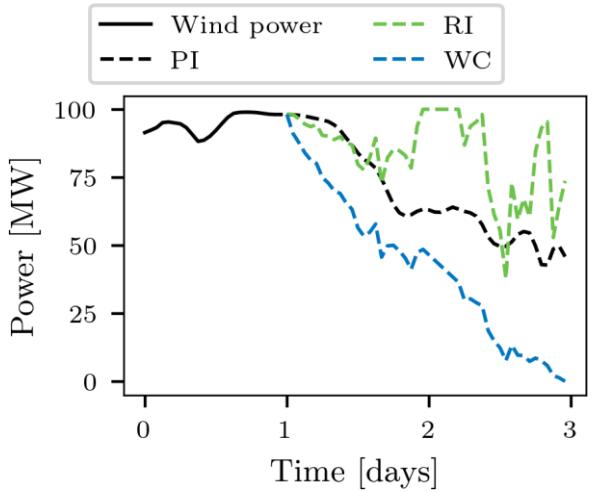
The value of baseload production lies in its **reliability**.

Problem: the storage dispatch is based on (imperfect) forecast

→ What is the reliability of the baseload production considering forecast errors?

Method: online optimization for revenue maximization under baseload constraint, considering:

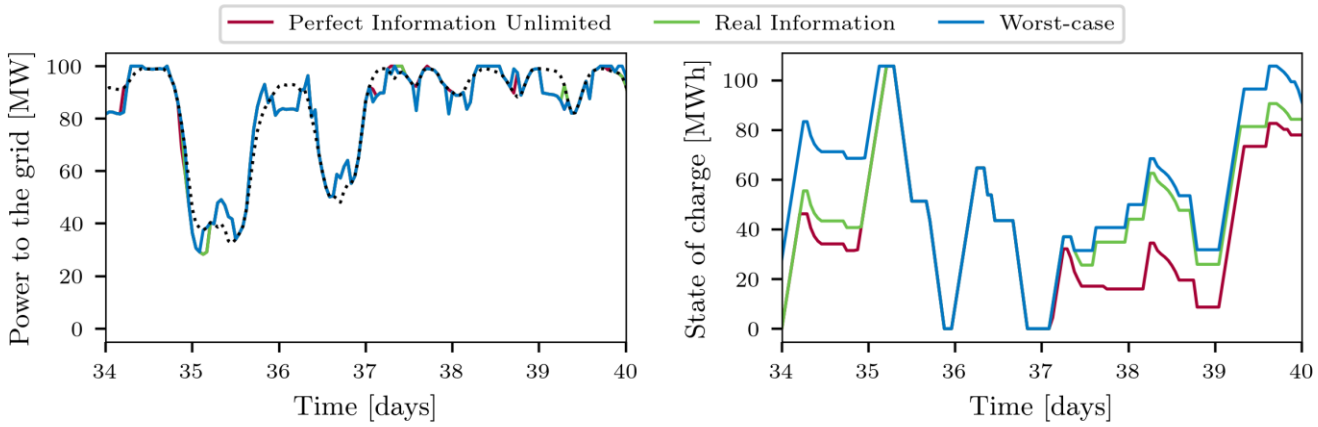
- A point-forecast (RI)
- A worst-case forecast (WC)

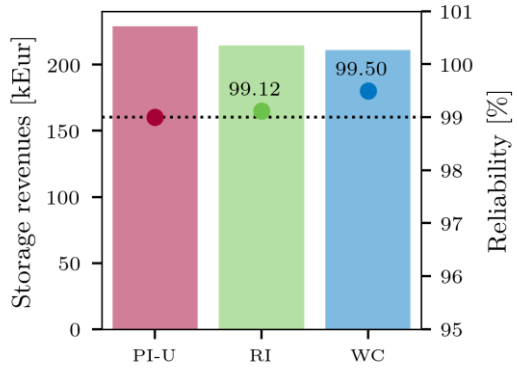


Assumptions: perfect information on prices, market structure neglected

Baseload HPPs - Operation

For one site





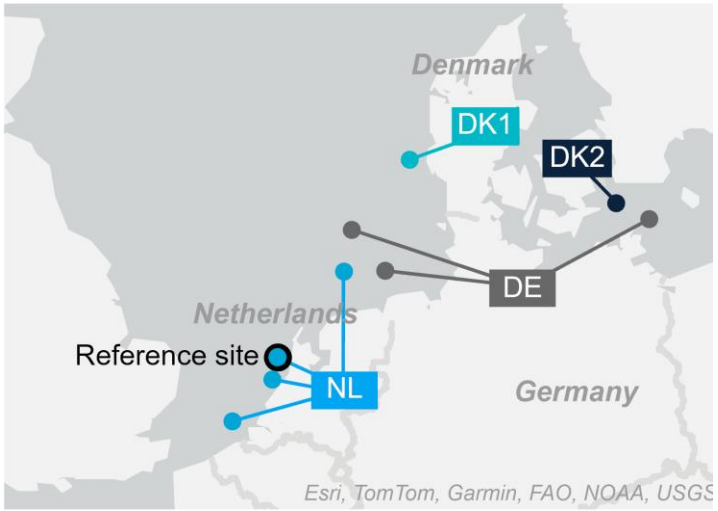
→ The storage schedule is more conservative with WC

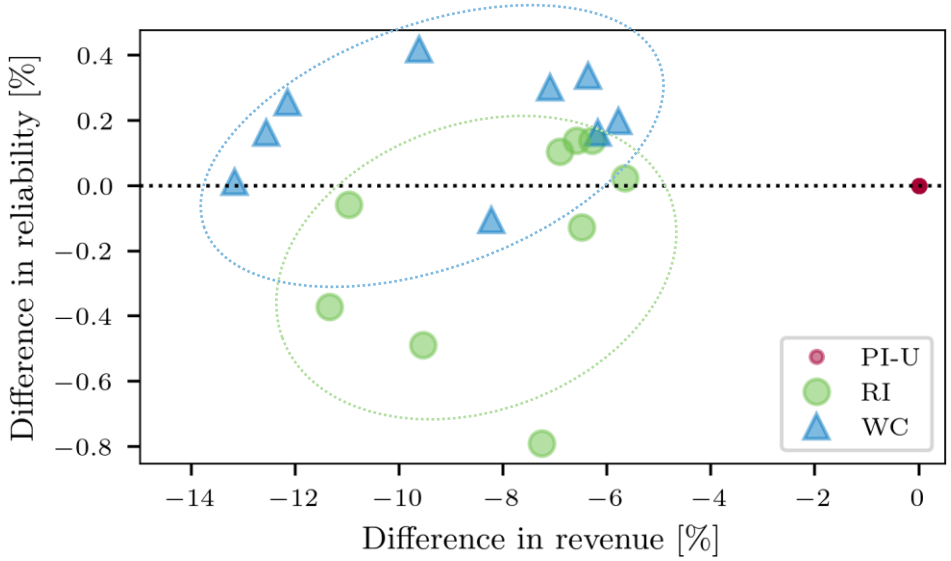
→ The target reliability can be reached

Upcoming presentation at WindEurope: Iori, J., Zaaijer, M., Kreeft J., von Terzi, D., & Watson, S.: Reliable operation of wind-storage systems for baseload power production.

Baseload HPPs - Operation

For 10 sites in Northern Europe:





→ Trade-off between reliability and revenues

Upcoming presentation at WindEurope: Iori, J., Zaaijer, M., Kreeft J., von Terzi, D., & Watson, S.: Reliable operation of wind-storage systems for baseload power production

Conclusion

- Design for dispatchability does not make much sense without clarity on the design problem
- We need to explore:
  - → Technical requirements
  - → Policies and regulations
  - → Financial incentives

- Baseload power plants…
  - → … are expensive!
  - → … are reliable despite forecast errors.

Questions?

Feel free to contact me at **j.iori@tudelft.nl**

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This presentation is based on discussions with my colleagues and collaborators Michiel Zaaijer, Dominic von Terzi, Simon Watson, Jasper Kreeft, Sebastian Perez-Moreno, PJ Stanley and Maria Kalogera.

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