Centre for Intelligent Electricity Distribution

Norwegian Research Centre on Wind Energy

Task 25: Design and operation of Energy Systems with Large Amounts of Variable Generation

Addressing Market Issues in Electric Power Systems with Large Amounts of Offshore and Onshore Wind Power –

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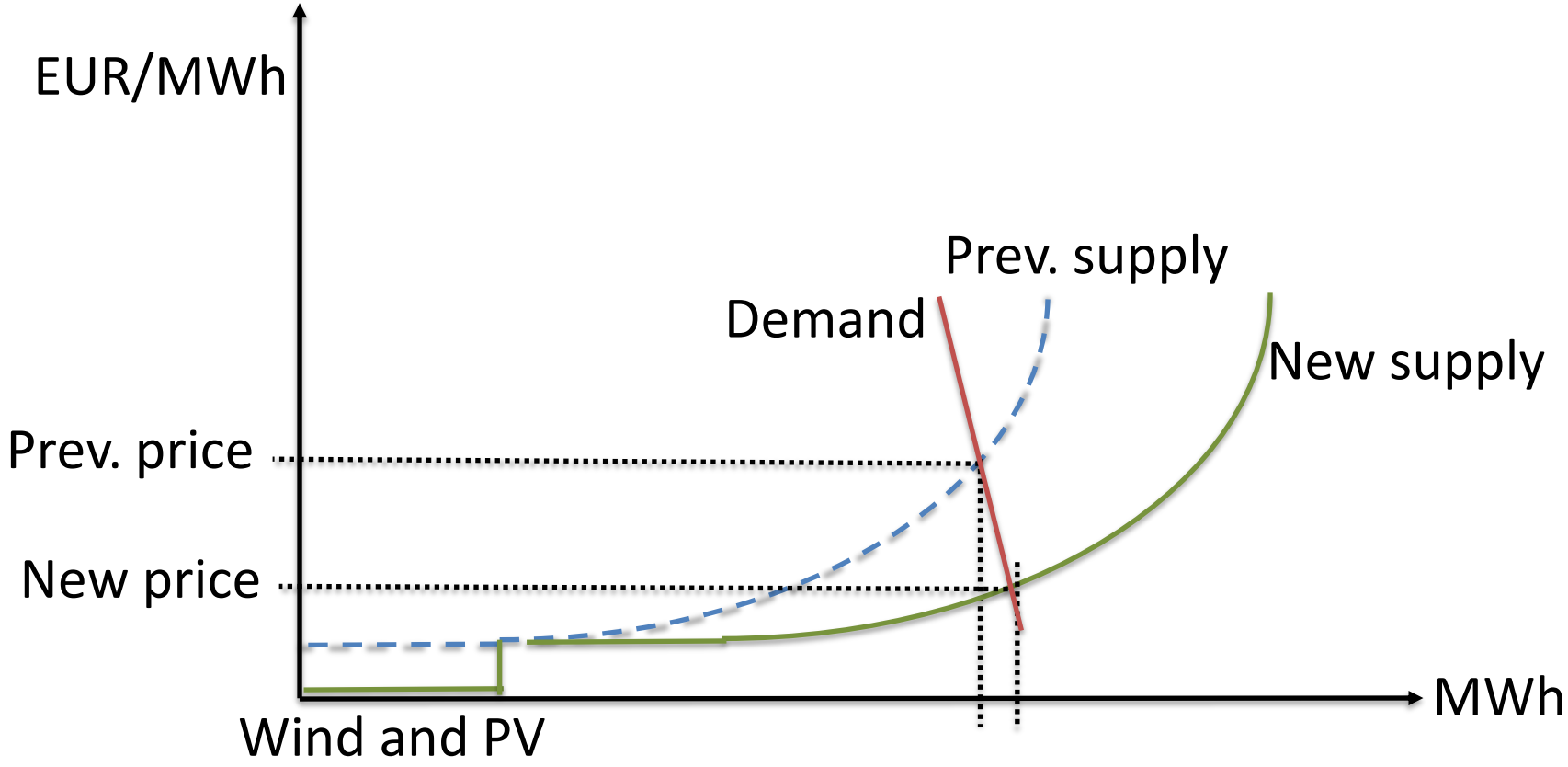
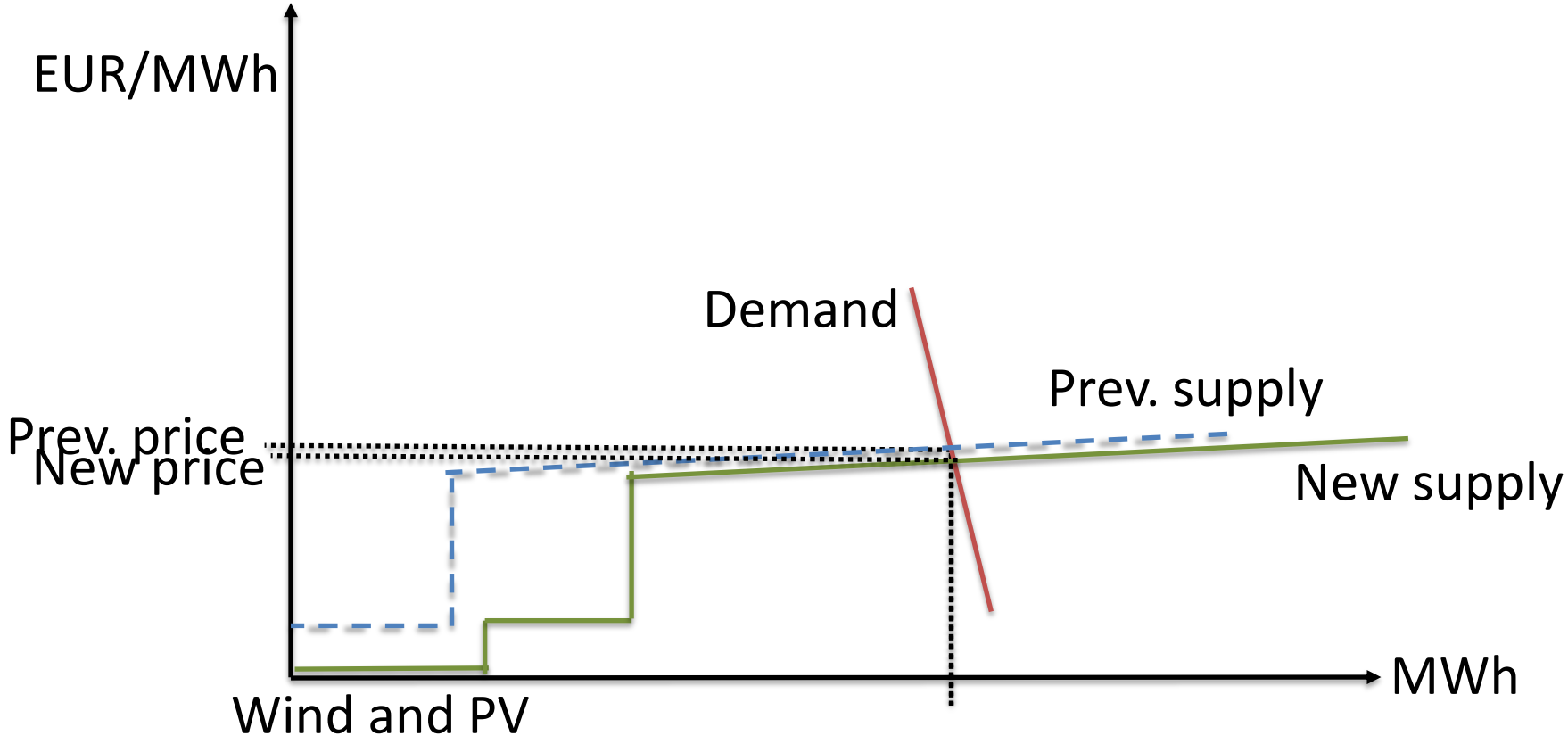
Deepwind Conference. Jan. 19. 2023

NTNU SINTEF

Wind and solar PV push the price downwards (zero marginal cost)



But impact of wind and PV depend on the supply curve



Maximising value of Variable Renewable Energy (VRE) in markets

- Minimising curtailment: Geographical smooting, diversification
- Using wind and solar power for system services
- Adapting operational practices to high shares of VRE
  - Grid planning and operation
  - market design
- Using existing and new flexible resources
    - Flexible thermal
    - Storage
    - Flexible demand (EVs, heat, industry..)
    - Hydrogen and P2X

Challenges in markets with high levels of VRE

- Merit order effect and missing money problem
- Integration of new smaller and variable assets to energy and ancillary services markets
- Design of an effective carbon emissions market
- Capturing of full value of (distributed) flexibility resources
- Marginal pricing of storage and demand-side management
- Geographic integration of different market segments
  - Harmonisation of pan-European markets
  - Co-ordination of emerging local energy markets

Diversification
LCoE-centric wind energy

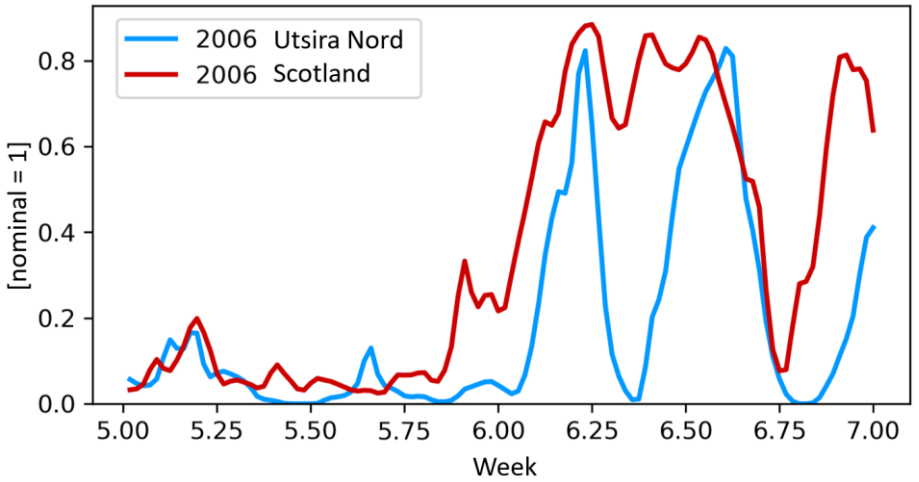
- Challenging to match demand and *weather-driven* supply
- Levelised Cost of Energy (LCoE)
  - LCoE ≠ 42
  - it is not the answer to all questions
- Turbine design: Large similarity of turbines
- Wind park placement: "everything" around the North Sea
- Decreasing LCoE
- Increasing aggregated wind power output variability (correlation)

-> even more challenging to match demand and supply

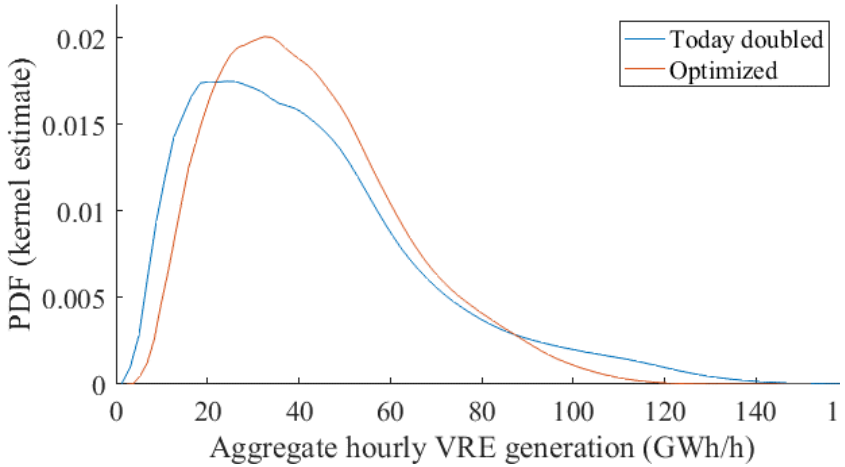
-> increasing electricity price variability

Solution = Diversification

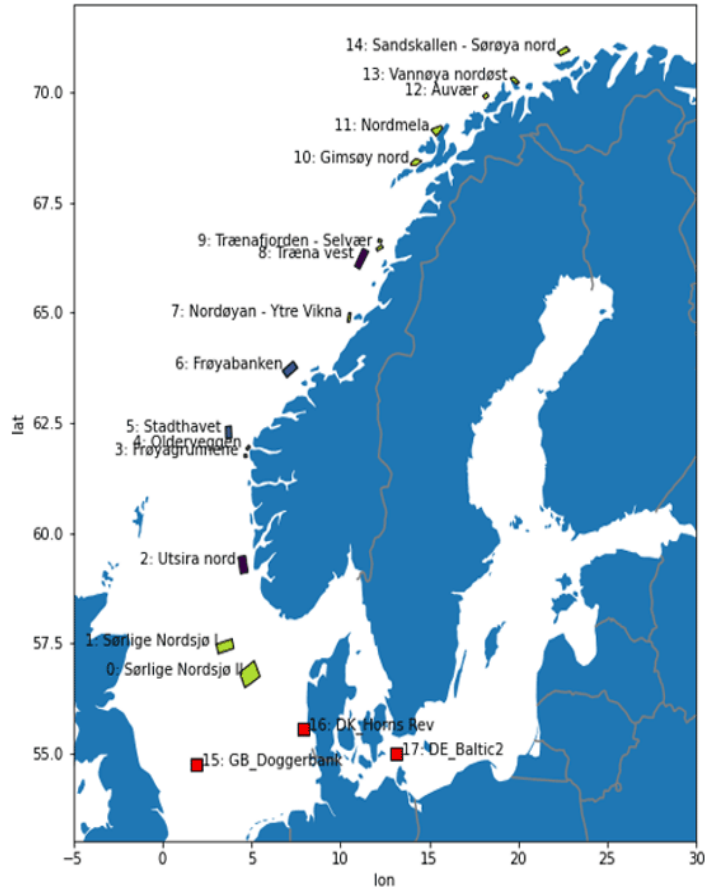
Diversification
Wind park placement



- Wind power needs to be dispersed
- Distributing it around the North Sea is not good enough
- LCoE does not drive this

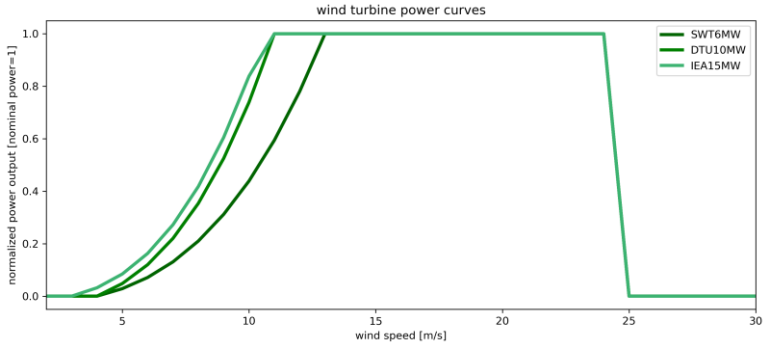


Matti Koivisto et al.: Minimizing Variance in Variable Renewable Energy Generation in Northern Europe



More information on correlation on potential Norwegian wind park locations:
Harald G. Svendsen, "30 GW Offshore wind in Norway – wind power correlations and smoothing effects", This session (4A)

Diversification
Wind turbine design



- Rotor generator pair defines the power cu
  - Older turbines large generator
  - Newer turbines large rotor
- Mix beneficial for reducing variability
- New design will become dominant

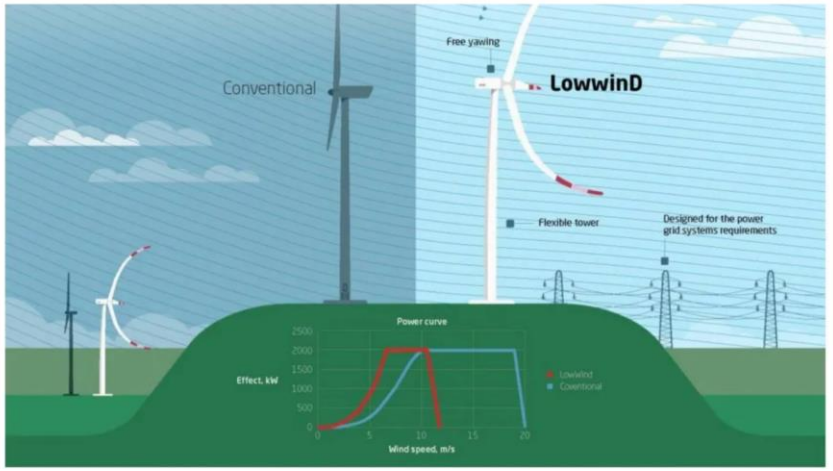


Illustration: DTU Vindenergi

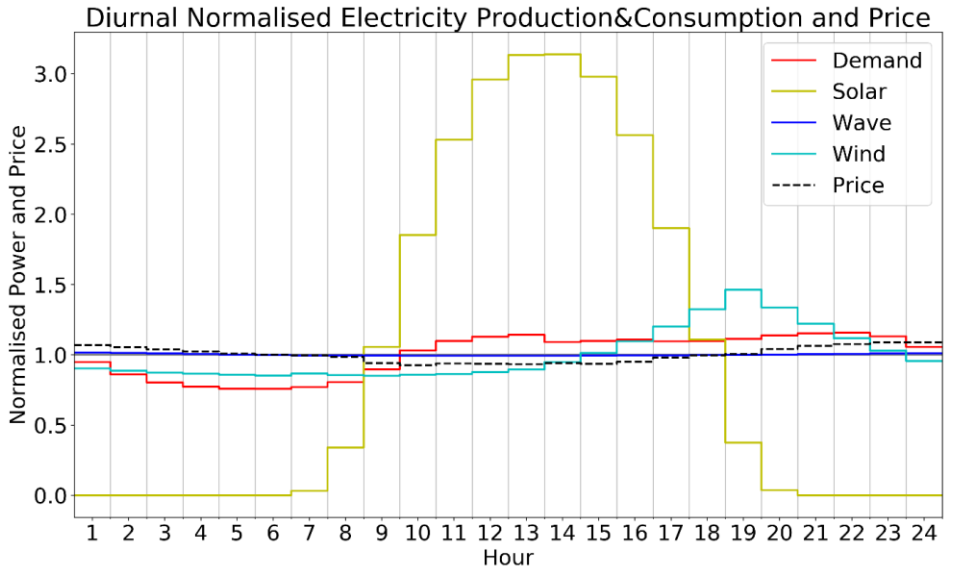
Picture: DTU Vindenergi

New project proposal under development: GigaWind

Topic: brinding a more detailed pepresentation of wind power into power system optimisation models.

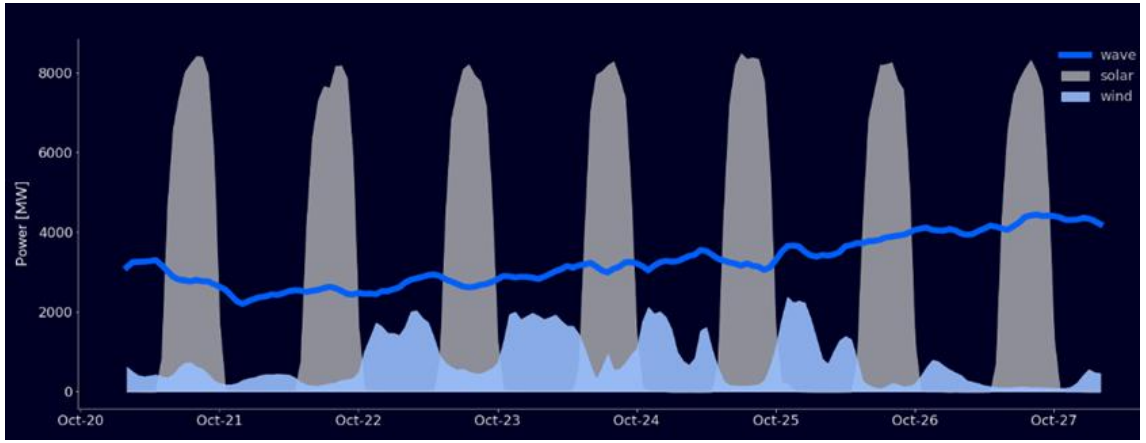
Picture: Makani Power

Diversification
Wave power



- Wave power has higher LCoE than wind & solar ☹
- But if LCoE ≠ 42 (not the answer to all questions)...
  - shows different variability
  - potentially more stable output

    -> Maybe other sources like wave power will find their role ☺



Credit: CorPower Ocean, https://corpowerocean.com/wave-energy/

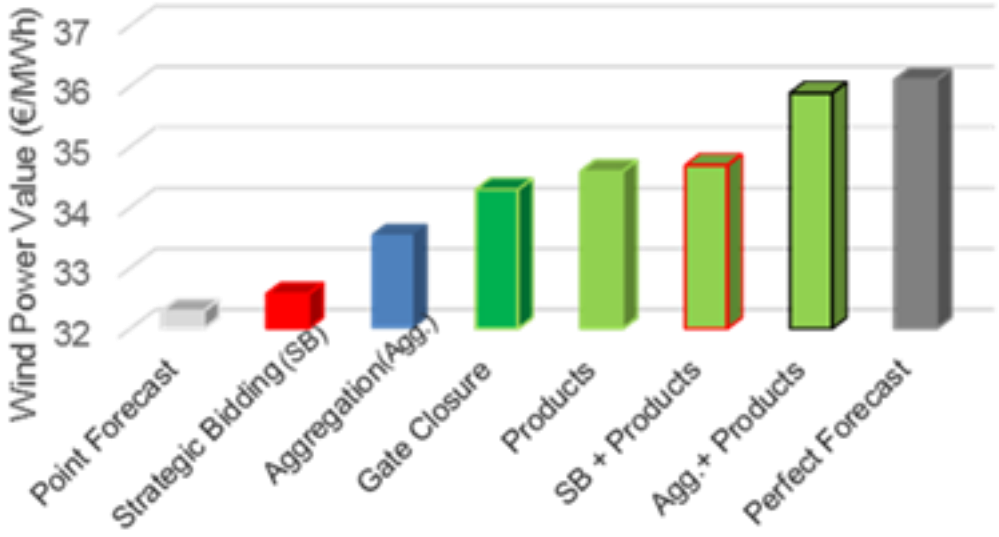
Esbjerg declaration: Industry sees wave energy as 'natural partner' to offshore wind and solar

The representatives of ocean energy associations have called both the Danish and Dutch governments and parliaments to also integrate wave energy in the energy strategy for the North Sea region by setting both national and regional deployment targets.

https://www.offshore-energy.biz/esbjerg-declaration-industry-sees-wave-energy-as-natural-partner-to-offshore-wind-and-solar/

Market design to enable grid support services income to wind

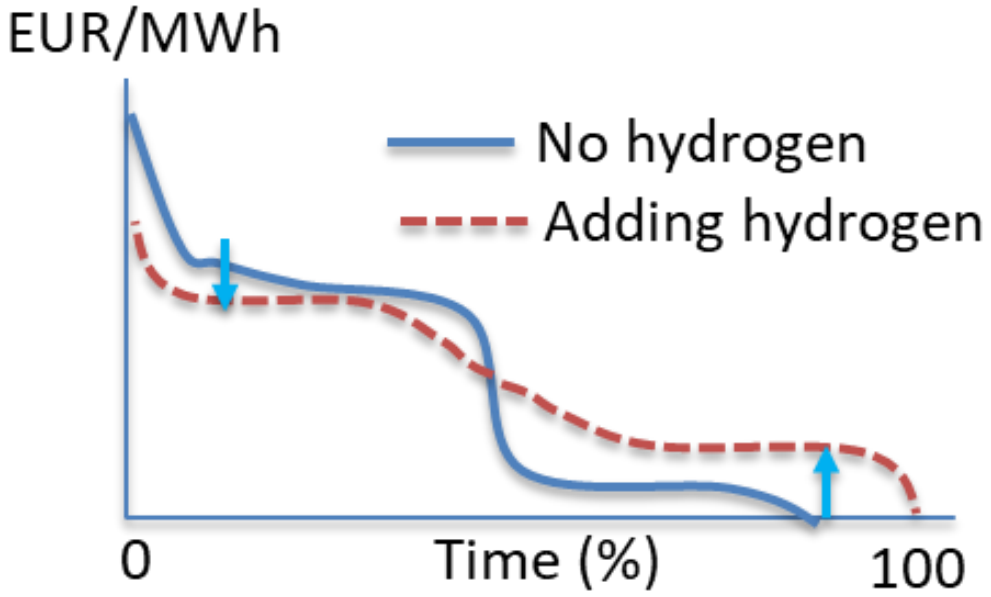
- Possibility to bid close to delivery (for example, hour ahead); smaller amounts of MW; only down-reg
- Local flexibility markets – DSO/TSO coordination



(Source: Algarvio & Knorr, 2017).

Flexibility will increase value of wind energy in markets

- New demand from decarbonisation and power to X, can be utilised especially during times of surplus wind and solar and revive close-to-zero market prices



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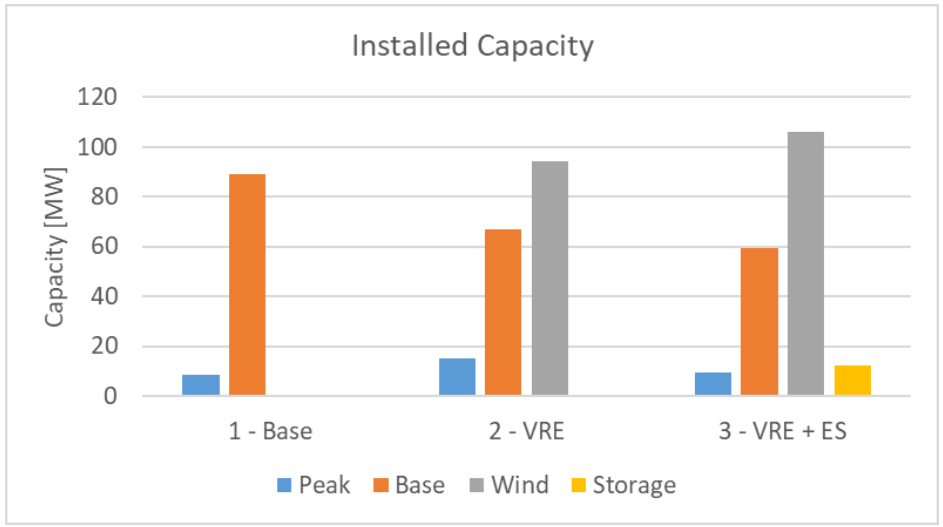
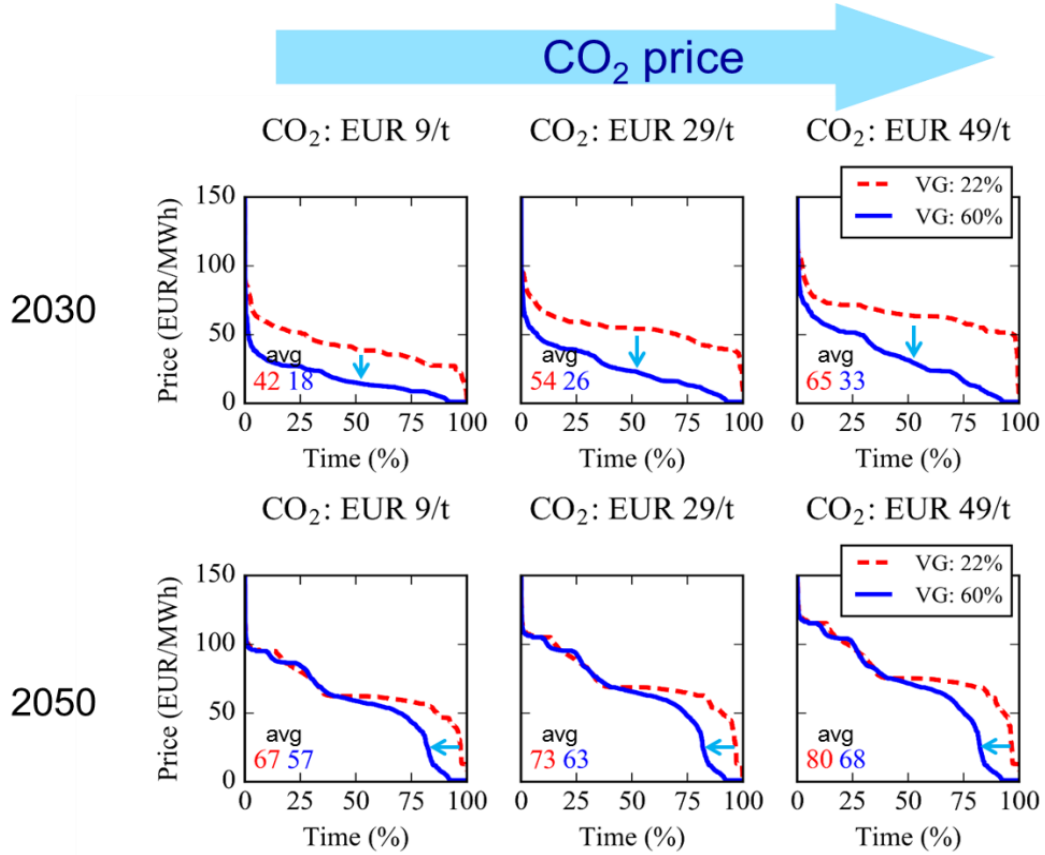


Source: Korpås and Botterud, 2020

Revenue sufficiency

- Ideal energy-only markets can in theory recover costs
  - Also valid for systems with thermal generation, energy storage and VRE under certain conditions (Source: Korpås, Botterud 2020)
- Ways to improve cost recovery:
  - CO_2 pricing
  - Scarcity pricing



(Figure: VTT)

Markets with high shares of VRE: Summary of findings

- Price impacts of VRE is smoothed by building more transmission and diversify technology
- Demand forecasting and flexibility estimation and becomes increasingly important for markets
  - Due to electrification of transport, heat, and industry
- Low-price periods can be utilized by storage, electrolysis and P2X
  - Long-term market impacts of these storage and demand types must be better understood
- Cost recovery in markets with very high shares of VRE is challenging
  - May call for alternative pricing methods and targeted instruments to ensure system adequacy
- Importance of a range of system services grows significantly
  - Impacting the revenue streams between energy, system services and capacity.