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# Addressing Market Issues in Electrical Power Systems with Large Shares of Variable Renewable Energy

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IEA Wind Task 25

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# Maximising value of Variable Renewable Energy (VRE) in markets

Minimising curtailment

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

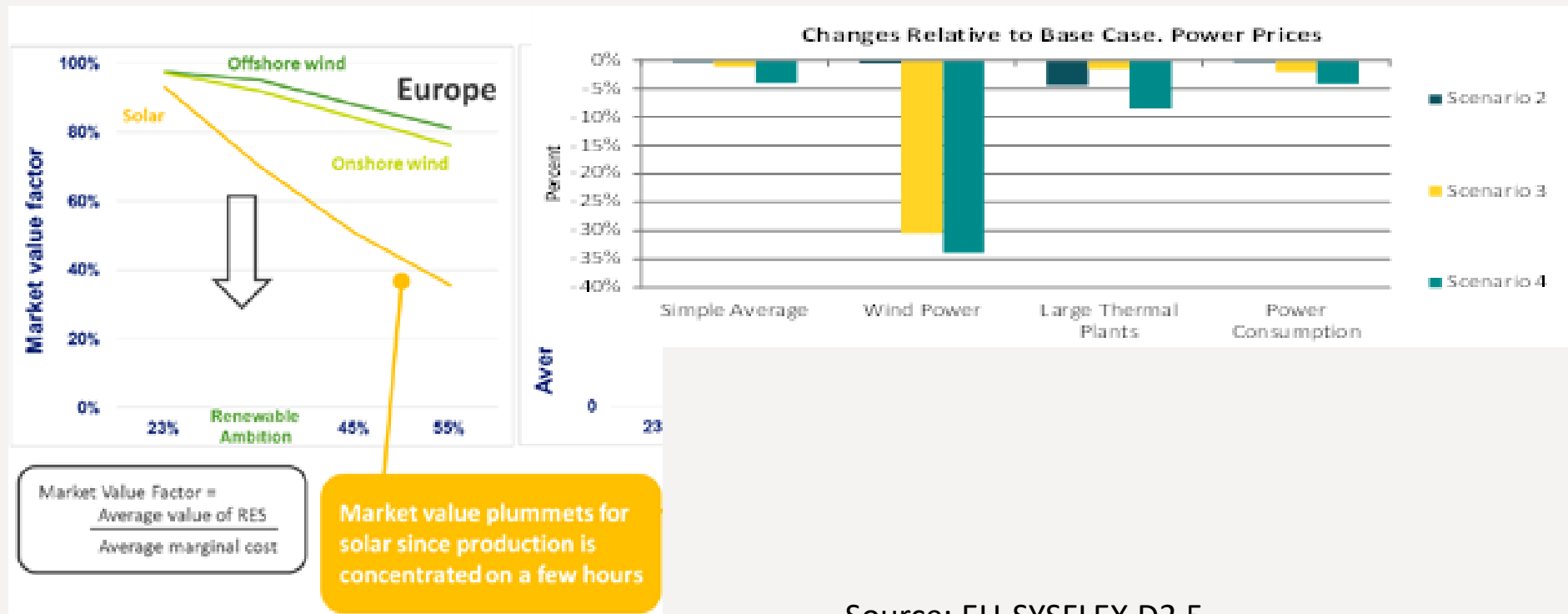
- Flexible thermal
- Storage
- Flexible demand (EVs, heat, industry..)
- Hydrogen and P2X

# 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 of demand-side management
- Geographic integration of different market segments
  - Harmonisation of pan-European markets
  - Co-ordination of emerging local energy markets

# Flexibility will increase value of wind energy in markets

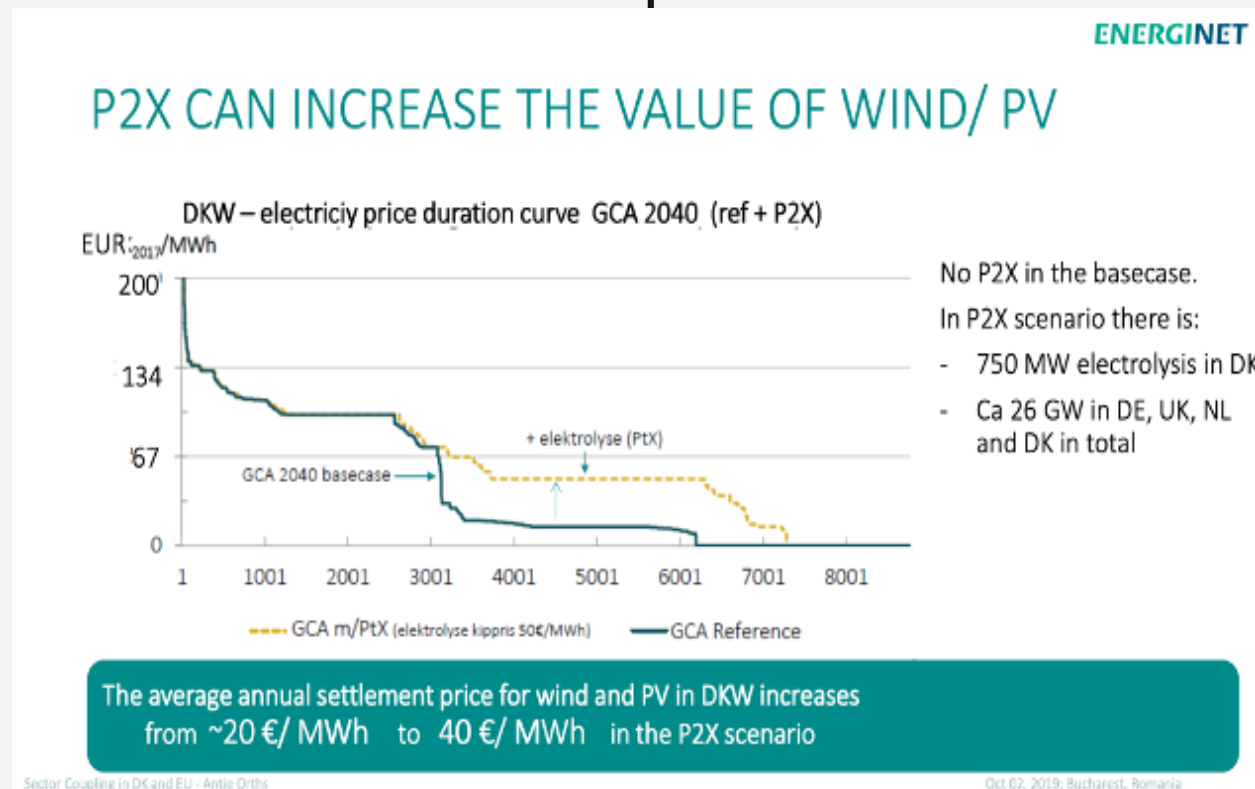
“Profile losses” of wind and solar are lower when other generation and loads operate more flexibly, according to wind and solar availability



Source: EU-SYSFLEX D2.5

# 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

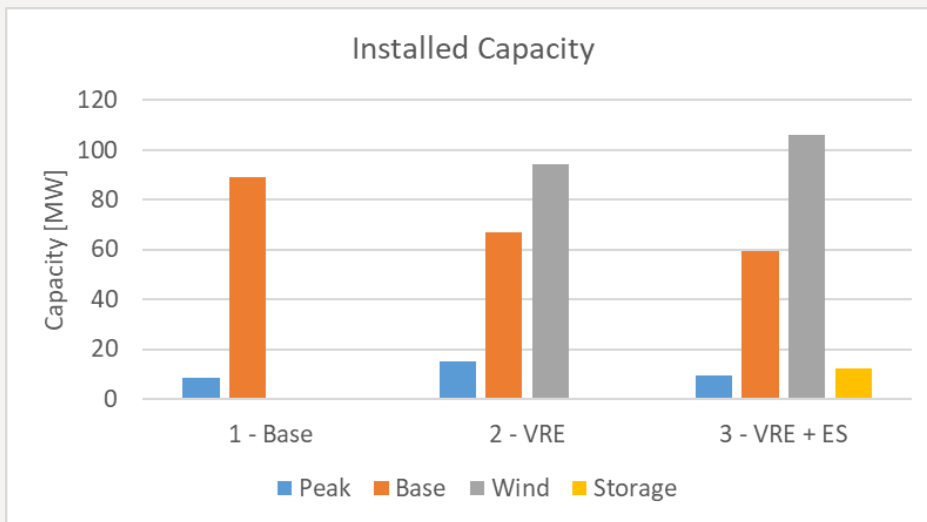


Source: ENERGINET.DK

# Flexibility will increase value of wind energy in markets

Storage and flexible demand creates new price segments which increases profitability of wind energy

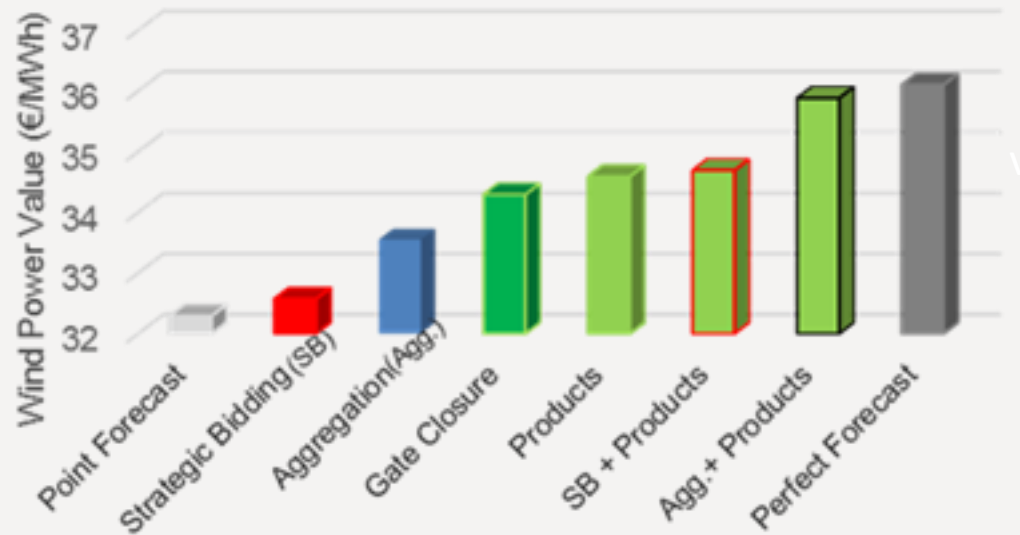
→ Lead to more installed wind power in competitive markets



Source: Korpås, Botterud 2020

# 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).

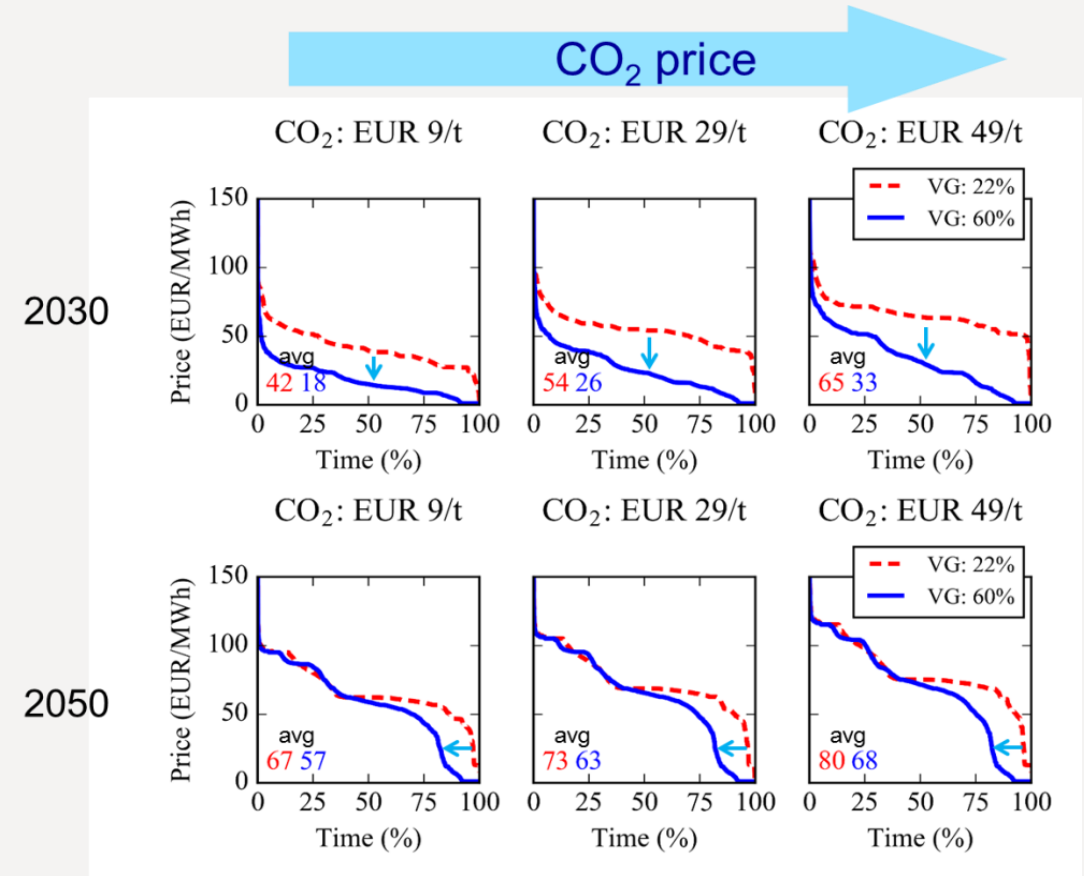
# Revenue sufficiency

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<sub>2</sub> pricing
- Scarcity pricing



Source: 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.



**Til Kristan Vrana**  
**SINTEF**

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TCP Task 25

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# THANK YOU.

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## Questions?

# 100% RES markets: Some questions I/II

## How to design markets that are attractive for investments in 100% RES?

- Small-scale (behind the meter) and large-scale (RES-farms)
- PPAs, revenues from spot or a combination

## How to design markets for investing in Flexibility

- Storage, clean thermal, flexible energy sector coupling
- Small-scale flex, aggregated flex and large-scale flex
- Flexibility as part of RES-products, or separate objects?

## What is the future role of the energy markets (DA, ID..)?

- Will RES energy be sold in the market or only through PPAs? Future volumes traded? Will the energy markets create investment signals for RES and Flex?
- Will the demand side be the dominating price-setter?

## How to price energy and flexibility according to grid availability

- Nodal pricing? Hybrid nodal/zonal? Local zonal? Offshore zones? What are the alternatives for pricing RES and Flex in constrained d-grids?

## What is the market value of electricity for different uses?

- Pricing of flexible demand and storage of electricity
- How can demand side participate in all markets (short to long term, power and energy)?

# 100% RES markets: Some questions II/II

## Short-term pricing of energy and ancillary services

- Do they cover investment costs?

## Treating of uncertainty – What is the role of forecasting in 100% RES markets?

- Short-term (weather, electricity demand)
- Long-term (fuel prices, electrification grade, CO2-prices)

## Does local markets and Flex markets that facilitate economic efficiency?

- Price takers, Good information, No entry barriers, Free flow of goods, Rational participants, No externalities

## Pricing of stored energy in systems without thermal generation

- Opportunity costs, market value of stored energy

## Central planning vs free market

- Role of regulators, governments: Market-based or regulated reliability handling?
- Capacity reserves: How much does the Avg Cost of Electricity increase, compared to EOM?