FLEXIBILITY THROUGHOUT THE CLEAN ENERGY TRANSITIONS

An overview of how flexibility is provided today and tomorrow in systems with high shares of VRE to ensure electricity security

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Social Mission: A renewable energy system with a high level of security of supply and at an affordable price.

- Balances the Danish electricity system consisting of two synchronous areas (DK1 in Continental Europe and DK2 in the Nordic area) connected through HVDC (600 MW).
- Owns and operates ~7,000 km transmission lines in Denmark.
- Connected to Sweden, Norway, Germany, the Netherlands and soon UK.
GREEN ENERGY FOR A BETTER WORLD
Energinet creates the foundation in Denmark for a safe and efficient green transition

2030
100 % green electricity
70 % CO$_2$ reduction (compared to 1990)

Energinet creates the foundation, the providers create the solutions
What is the challenge in a 100% RE based electricity system?
- How is the electricity markets part of the solution?
The decreased predictability of the consumption and production in the operational hour creates larger imbalances and hence an increased demand for balancing reserves. So do internal bottlenecks if they are to be handled with flexibility.
BALANCING REQUIREMENTS ➔ BUSINESS OPPORTUNITIES

RESPONSE TIME
How quickly the unit is able to turn up or down its consumption or production?

TIMEPERIOD
How long should the unit be able to provide the service?

SIZE
How much can the unit deliver during the period?

BUSINESS OPPORTUNITIES

+ + =
ANCILLARY SERVICE : TECHNOLOGY

The technologies that provides the different services today. Wind power is expected to provide FCR soon.
CHALLENGES IN A 100% RENEWABLE ELECTRICITY SYSTEM

Wind and PV in DK in 2020 (ca.)
- Onshore wind: 4.325 MW
- Offshore wind: 1.700 MW
- PV: 1.025 MW
- Total: 7.050 MW

Wind and PV in DK in 2030
Cf. AF2019
- Onshore wind: 4.600 MW
- Offshore wind: 4.900 MW
- PV: 4.900 MW
- Total: 14.400 MW

Wind and PV in DK in 2030 (+10 GW)
Cf. AF2019 + 5 GW offshore wind og 5 GW PV
- Onshore wind: 4.600 MW
- Offshore wind: 9.900 MW
- PV: 9.900 MW
- Total: 24.400 MW

Wind+PV share: ca. 55 pct.
Wind+PV share: ca. 90 pct. (excl. PtX)
Wind+PV share: ca. 150 pct. (excl. PtX)
**BALANCE BETWEEN RENEWABLES AND CONSUMPTION**

- Balancing of the electricity grid becomes increasingly difficult as the renewables capacity is increasing.

- Short term storage and infrastructure optimization is needed with batteries and EVs.

- Additional flexible demand, i.e. electrolysis, heat pumps, industrial heating / cooling, data centers, etc. is needed.

- Electrolysis is the key to enable more renewables!
The need for balancing is rising with the share of renewable energy.

Wind production and imbalances (Hourly values)

System imbalance [MW]

Wind share of production [%]

Partly cloudy weather can be tricky to forecast
CAPACITY RESERVES FROM RENEWABLES AND FLEXIBLE DEMAND

**Assumptions:** Forecasting precision and tools have high enough quality to meet firmness requirements.

**Result:** Increased liquidity and better utilization of existing resources.

**Method:** Precision of forecasting must be proven based on at least 3 months of historical data.

Renewables & Flexible demand will be allowed to bid in capacity equal to the 10% quantile of a probabilistic forecast, to ensure that the capacity is available.

The rest can be bid into the energy markets, day-ahead and intra-day from the 10% quantile and up.

At times with the largest uncertainties the spread is larger, and hence the capacity that can be bid is reduced (to maintain firmness)
RAPID INCREASE IN PTX-PROJECTS

Publicly announced electrolysis capacity from PtX projects/visions for 2030 has increased since January 2020 from 40 MW to app. 7000 MW.

Increase in announced electrolysis capacity in 2025 og 2030 from PtX projects/visions

<table>
<thead>
<tr>
<th>Announced capacity (MW)</th>
<th>In operation in 2025</th>
<th>In operation in 2030</th>
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<tbody>
<tr>
<td>Primo 2019</td>
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<tr>
<td>Primo 2020</td>
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<tr>
<td>Primo 2021</td>
<td>400</td>
<td>3.000</td>
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<tr>
<td>Primo 2022</td>
<td>2.500</td>
<td>6.900</td>
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In operation in 2025

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In operation in 2030

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Kilde: https://brintbranchen.dk/danske-brintprojekter/ og offentliggjorte PtX-projekter i danske medier.
LCOH BASED ON MODEL FOR 2021 - BASE SCENARIO WITH/WITHOUT RESERVES

H₂ production cost - DK1 2021

- Reserves (income)
- CAPEX (H₂ storage)
- CAPEX (Grid)
- CAPEX (electrolysis)
- Cost of tariffs
- Cost of electricity
- Hydrogen production cost

Weighted average electricity price and capacity factor for the electrolysis plant with reserves

- Weighted electricity price
- Capacity factor electrolysis (second y-axis)
QUESTIONS?