Danish strategy: solutions to balance 80% Wind and PV power systems

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Member of the IEA-PVPS Task 1

- More than 30 years of experience with PV technology, including consultancy, development, and operation of solar energy systems.

- IEA-PVPS work is supported by:

Danish Energy Agency

Denmark generel information

Population 5.96 mil.

Area 43.094 km²

Electricity consumption 36 TWh/year

1,419 islands, 443 of them have a name, 75 of them are inhabited

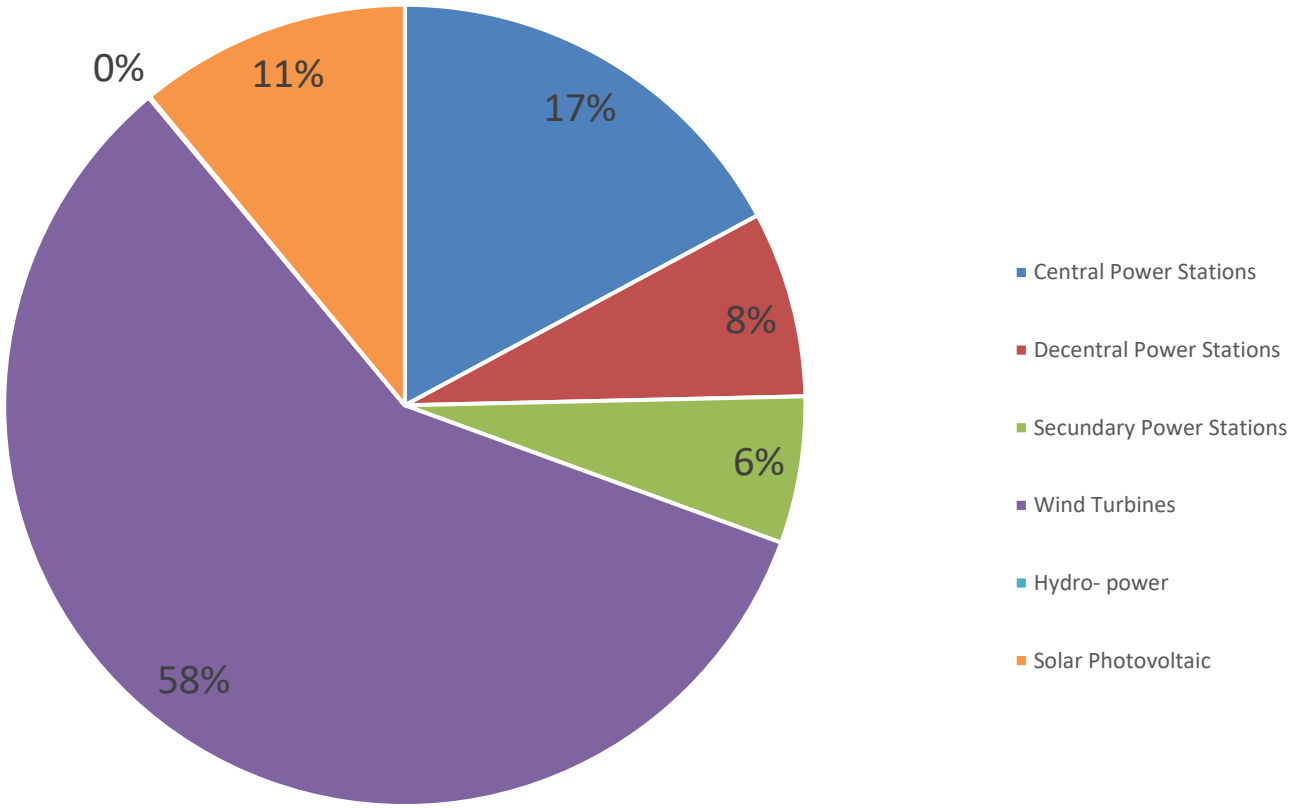
When did the RE transition start in Denmark?

Gedsermøllen, 200 kW, 1957
Source; Elmuseet

Small hydropower plants were established in the late 1800 centuries.

Solar in Brædstrup, 6 kWp, 1993

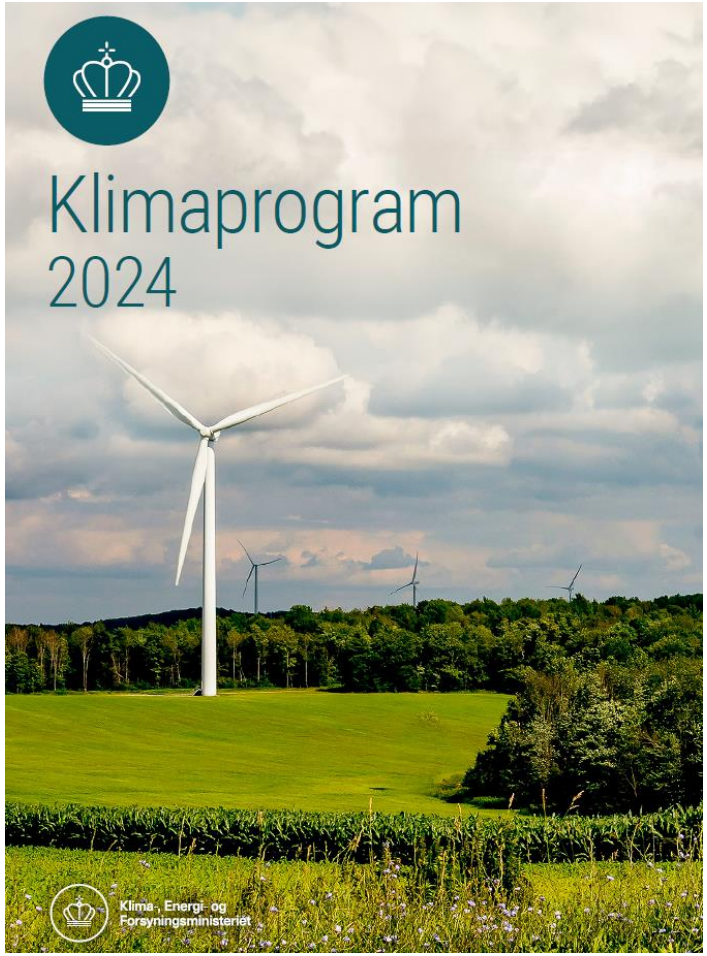
Electricity energyproduction mix 2023



Klimaprogram 2024

The Danish Government has presented a climate program named Klimaprogram 2024, outlining initiatives and concert actions to achieve Denmark's 2030 target of a 70% reduction in greenhouse gas emissions.

The plan introduces a series of critical measures to help the country stay on course towards reaching its climate goals.



Key political drivers

- The national climate program highlights Denmark's multi-faceted strategy to meet its 2030 climate goals.
- The program includes:
  - The implementation of a high CO2 tax for industries starts in 2025, with full enforcement by 2030.
  - An increase in the diesel tax and significant financial support for the green transition of the transport sector.
  - Investments in CCS technologies to capture and store CO2 from power plants, with the potential to significantly reduce emissions from heavy industries.
  - A substantial push to phase out oil and gas heating systems by 2035, supported by DKK 1 billion allocated to helping households switch to district heating or other renewable sources.

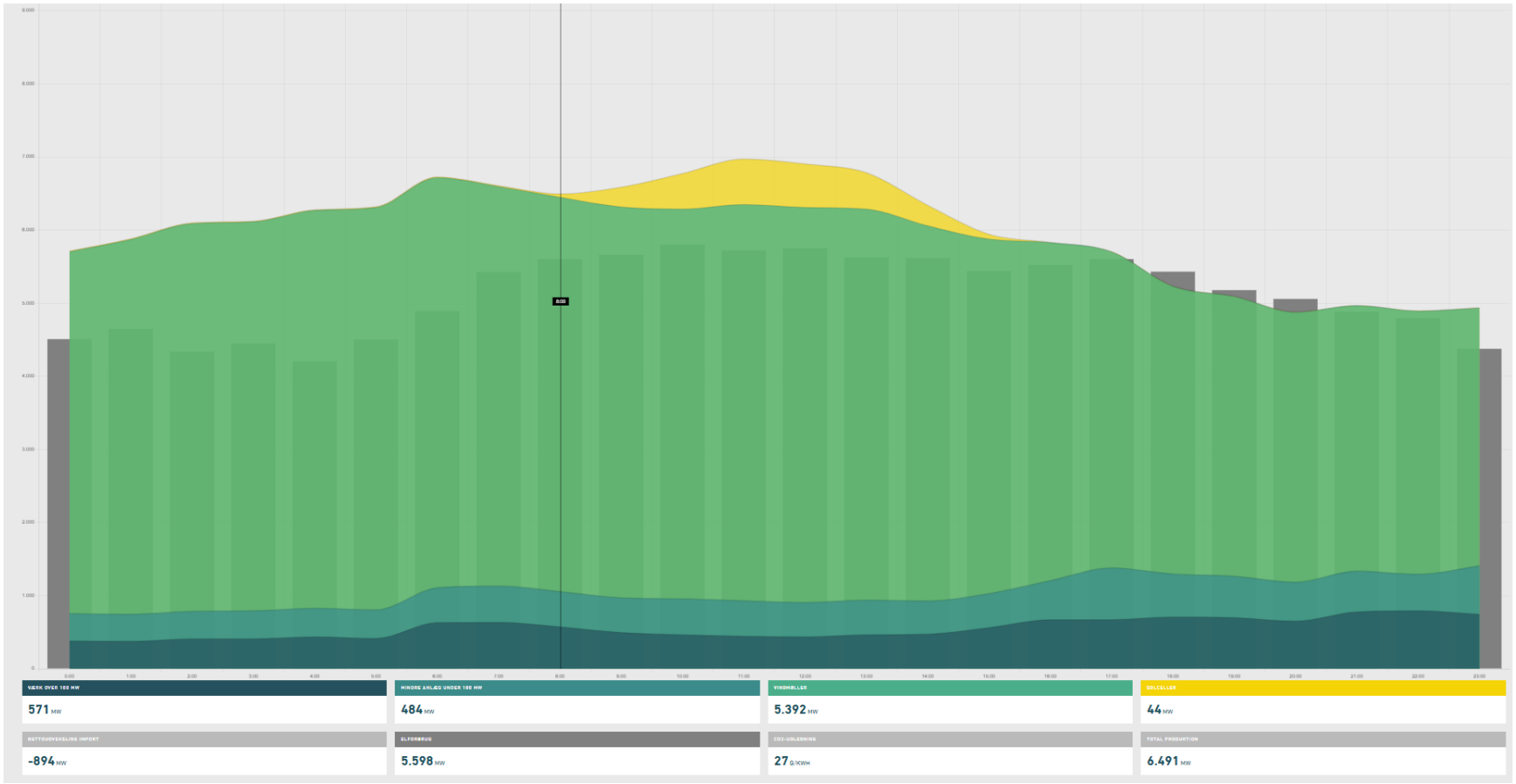
Climate goals for 2035, 2040 and 2050

- The According to Denmark's Climate Law, the 2035 target will be set by 2025, reflecting a new reality where the energy sector is mainly green. The focus shifts towards decarbonizing other sectors, notably transport and agriculture.

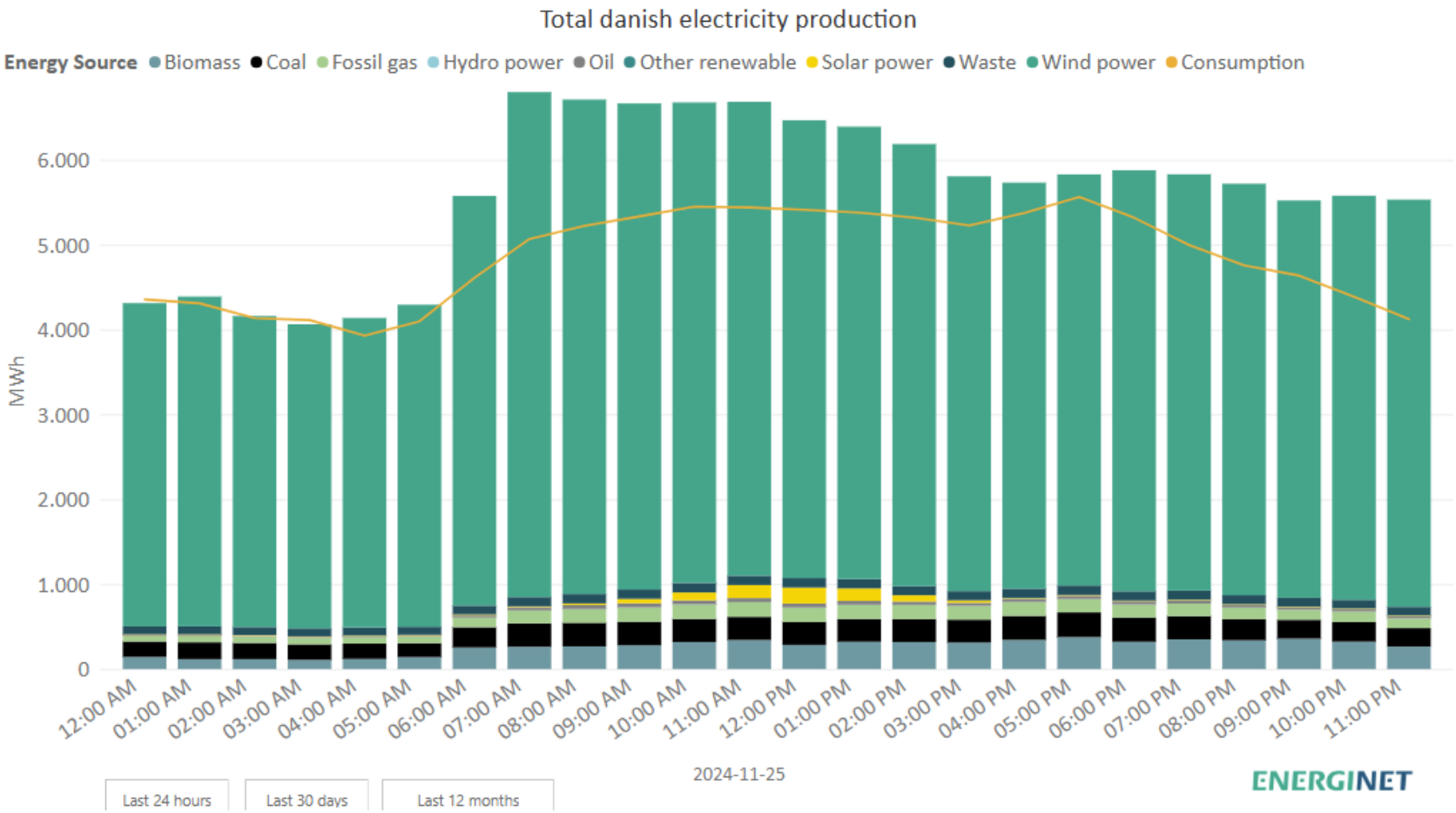
- Denmark support the EU climate goal of at least a 90% reduction by 2040, aligning with broader European efforts to combat climate change and reduce emissions across sectors.

- The goal until now has been a 100% reduction in 2050.

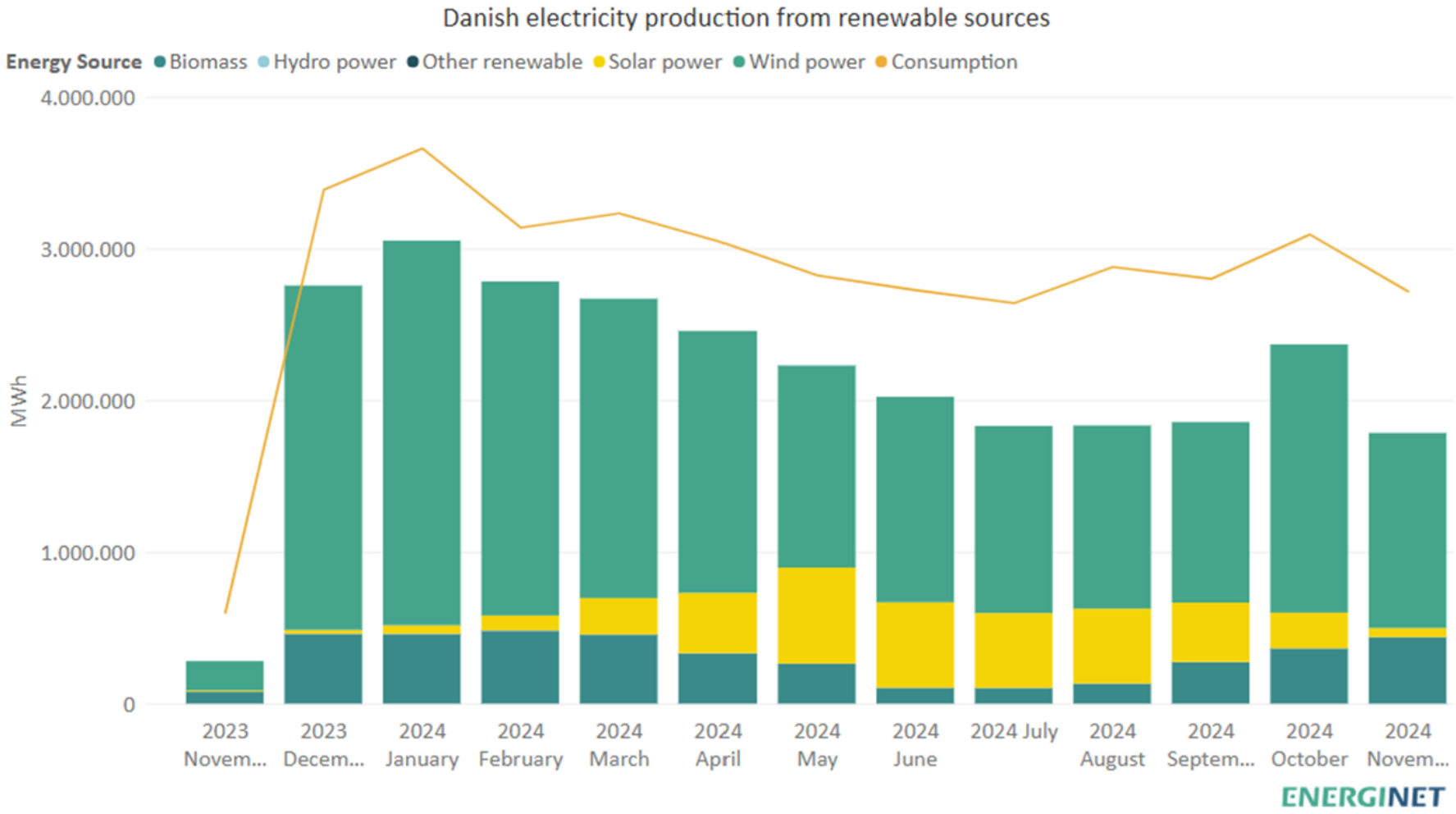
Electricity mix 26.11.2024



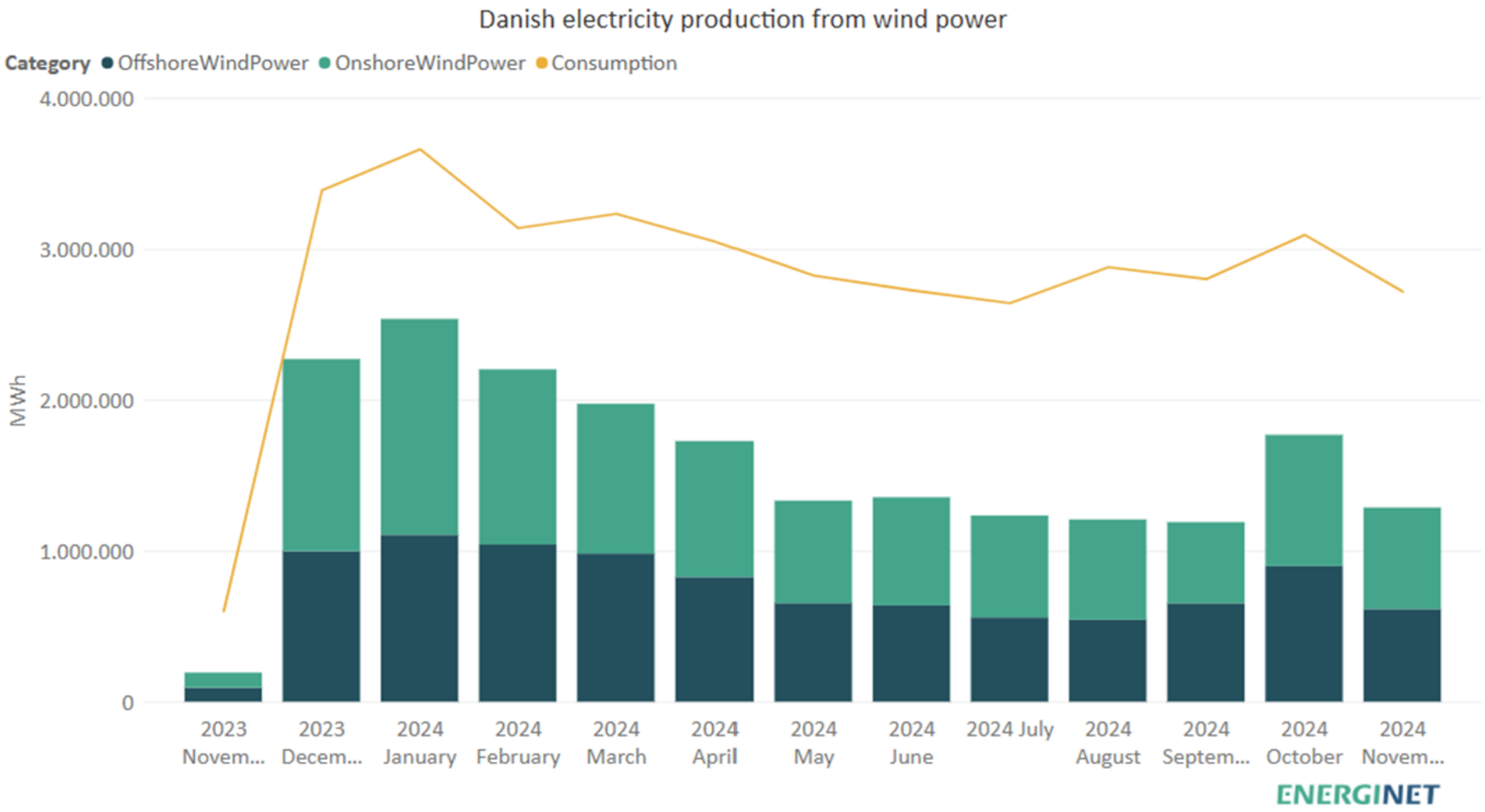
Total production



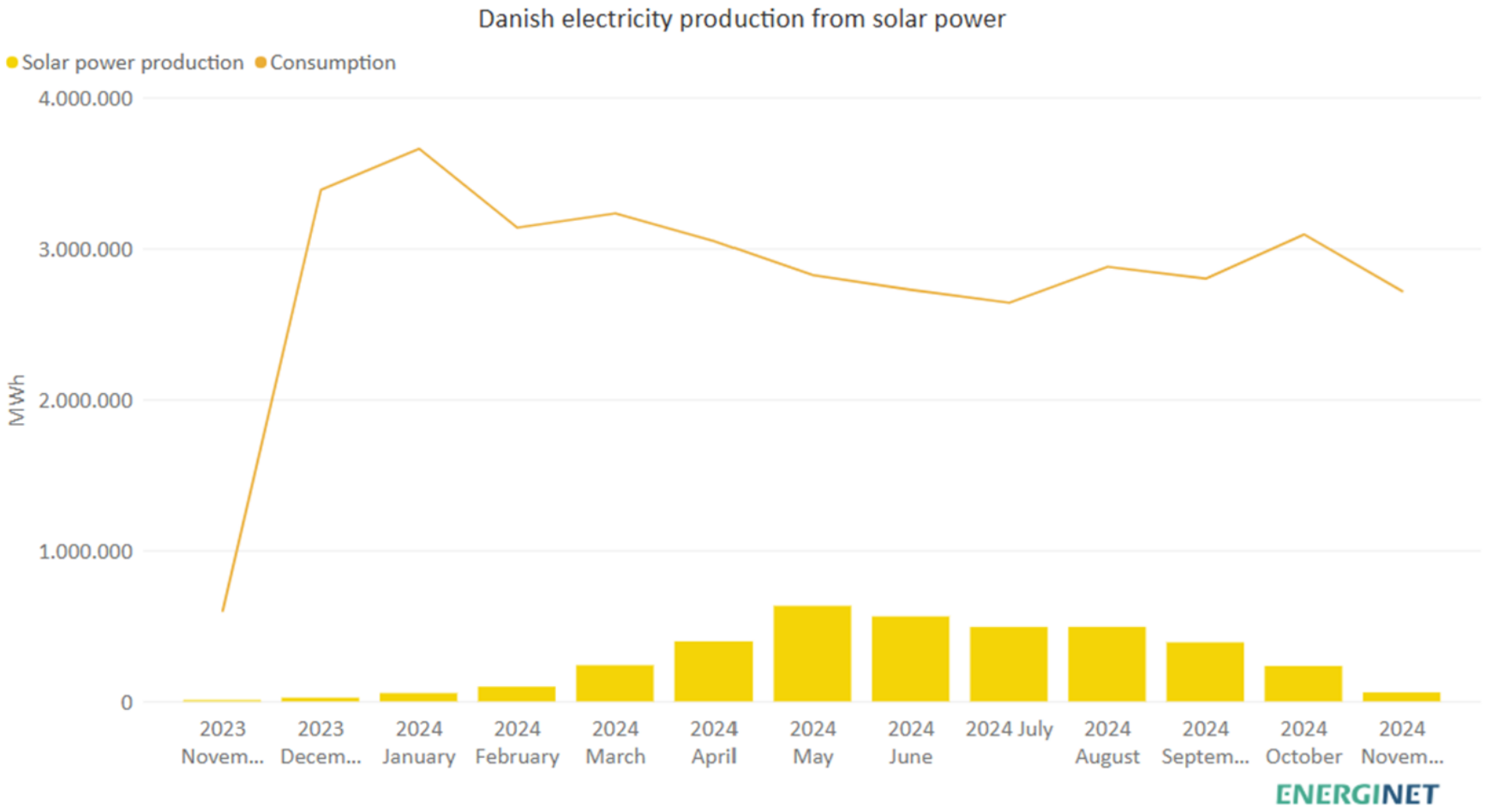
Renewable energy sources



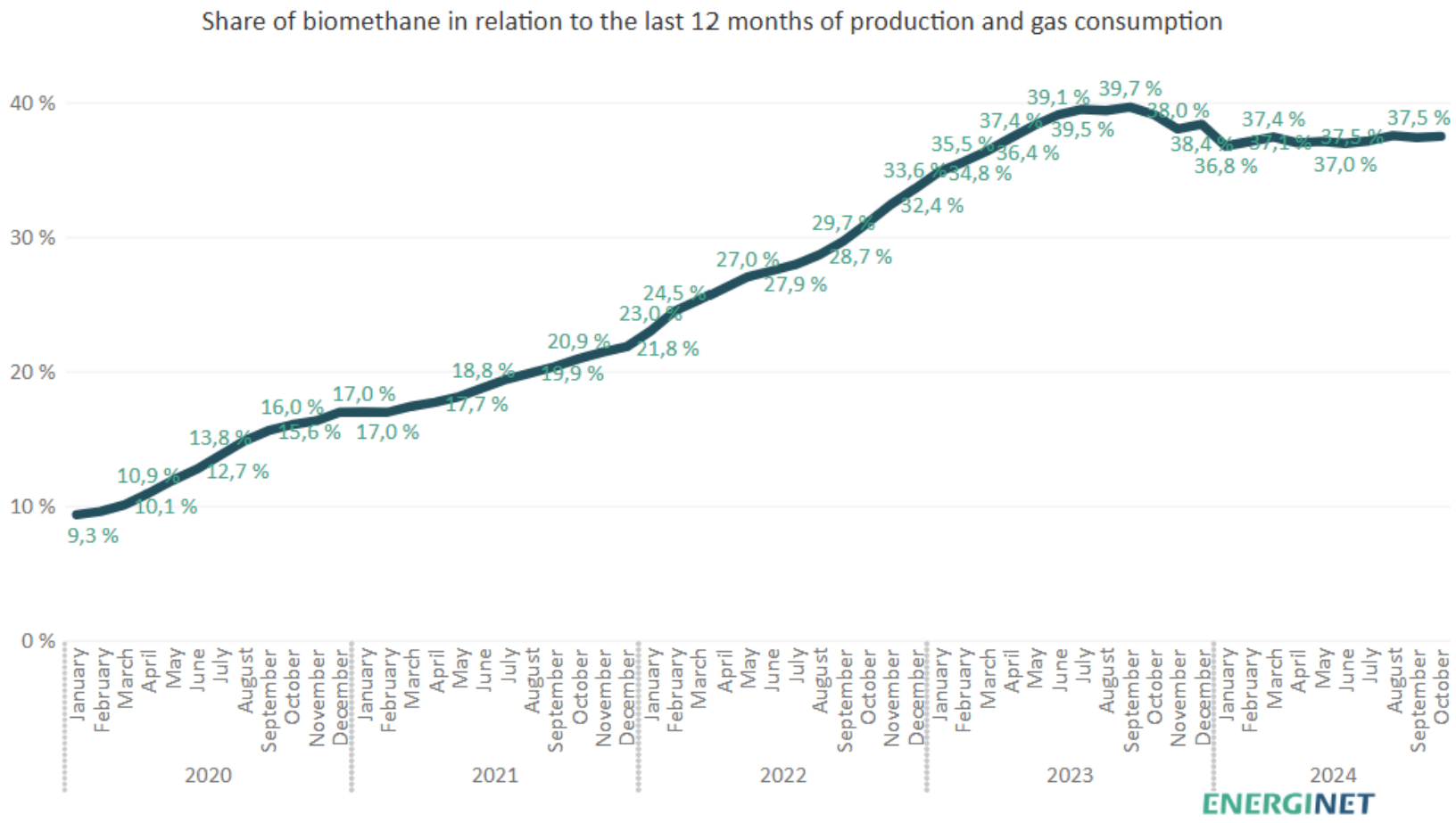
Renewable energy sources



Renewable energy sources



Biomethane production



The Danish Government's 2024 solar strategy

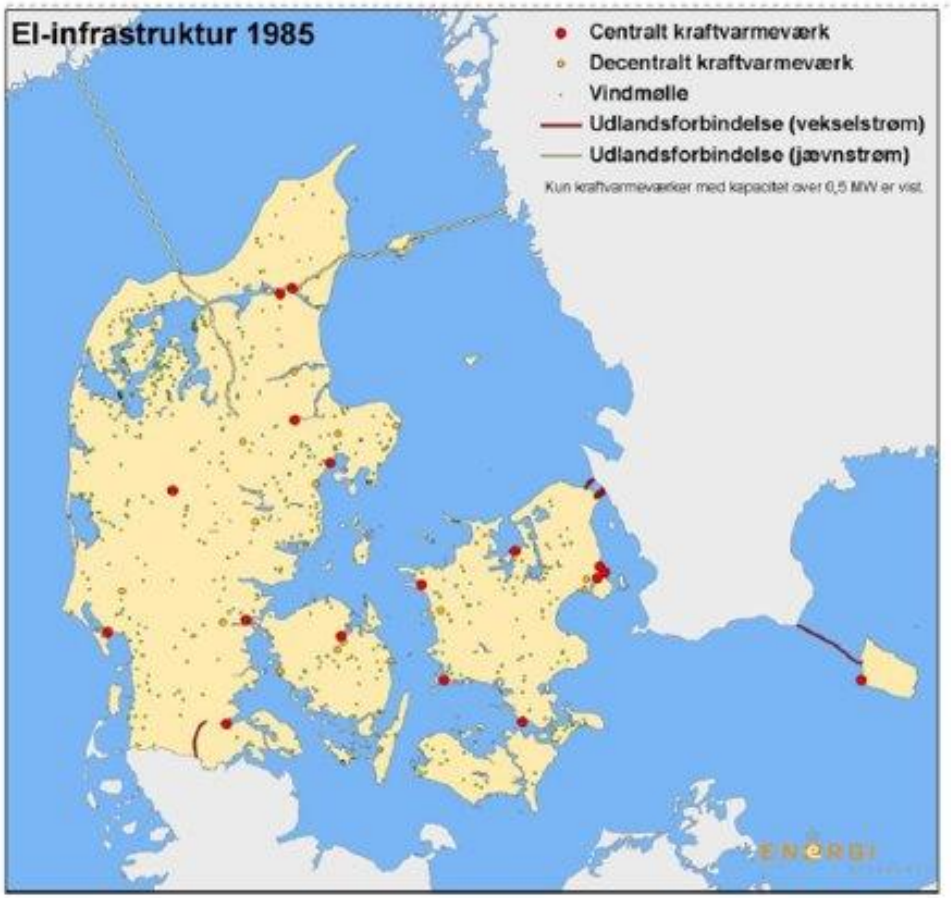
The Government's new solar strategy generally emphasises the following overall focus areas:

- Speeding up the green transition
- Solar cells in the open countryside
- Roof-mounted solar cells (on the roof areas of commercial properties)
- Solar cells on the roofs of public buildings
- Small energy communities

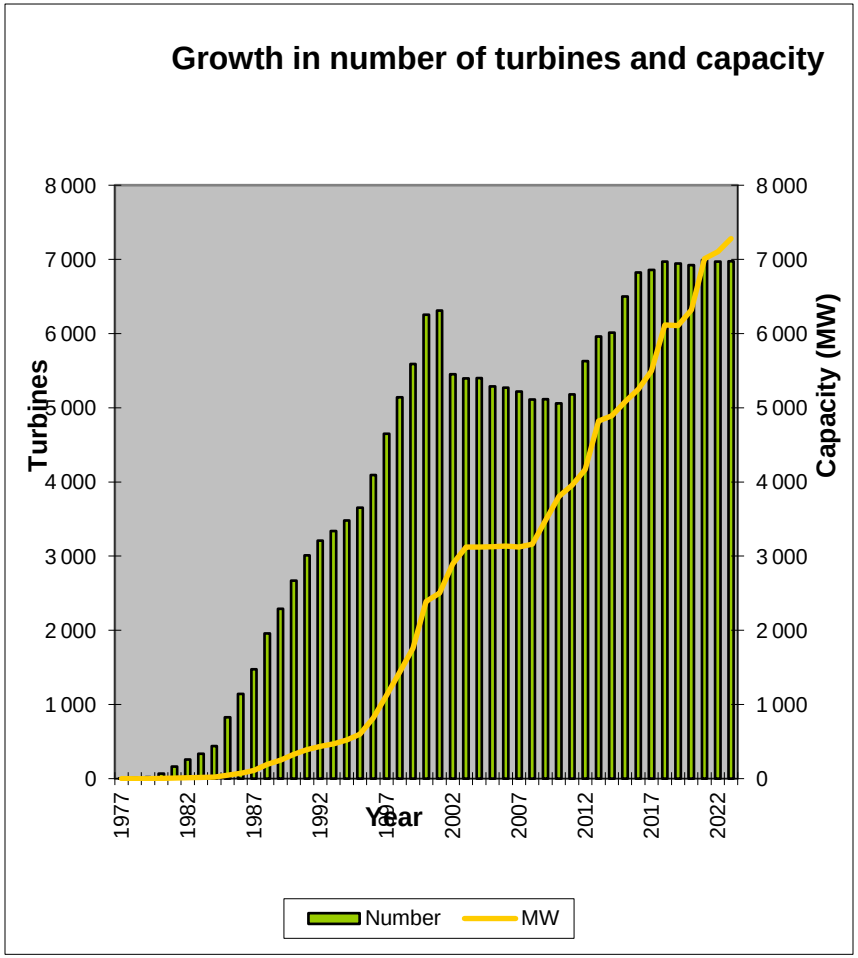
- Framework conditions that enable a quadrupling of electricity production from renewable energy on land by 2030:
- The quadrupling compared to the starting point in 2022 can be done, for example, by increasing the capacity of solar cells tenfold to approx. 20 GW and doubling the capacity of onshore wind to approx. 8.2 GW

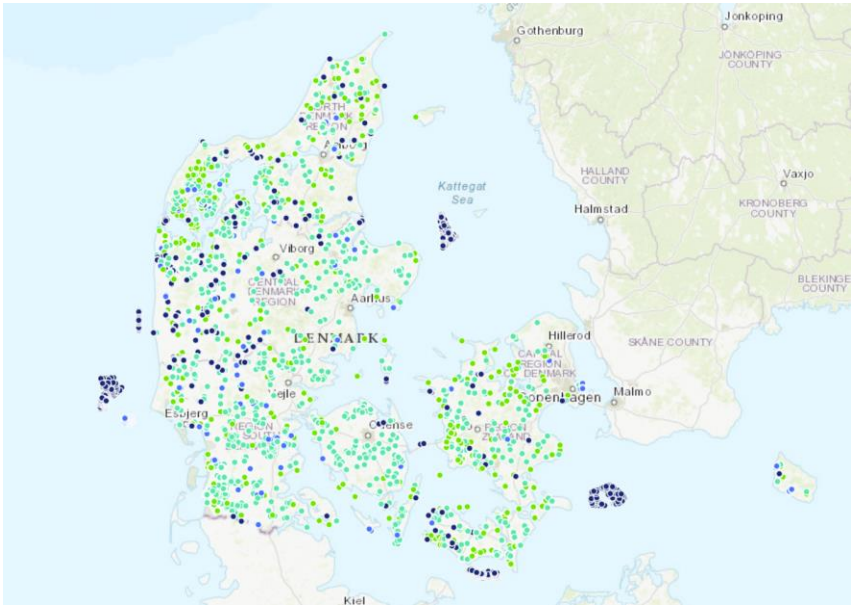
Eletrical infrastructure 1985

- Less that 20 Large scale coal and natural gas fired powerplants.
- Some wind turbines was installed, no solar.



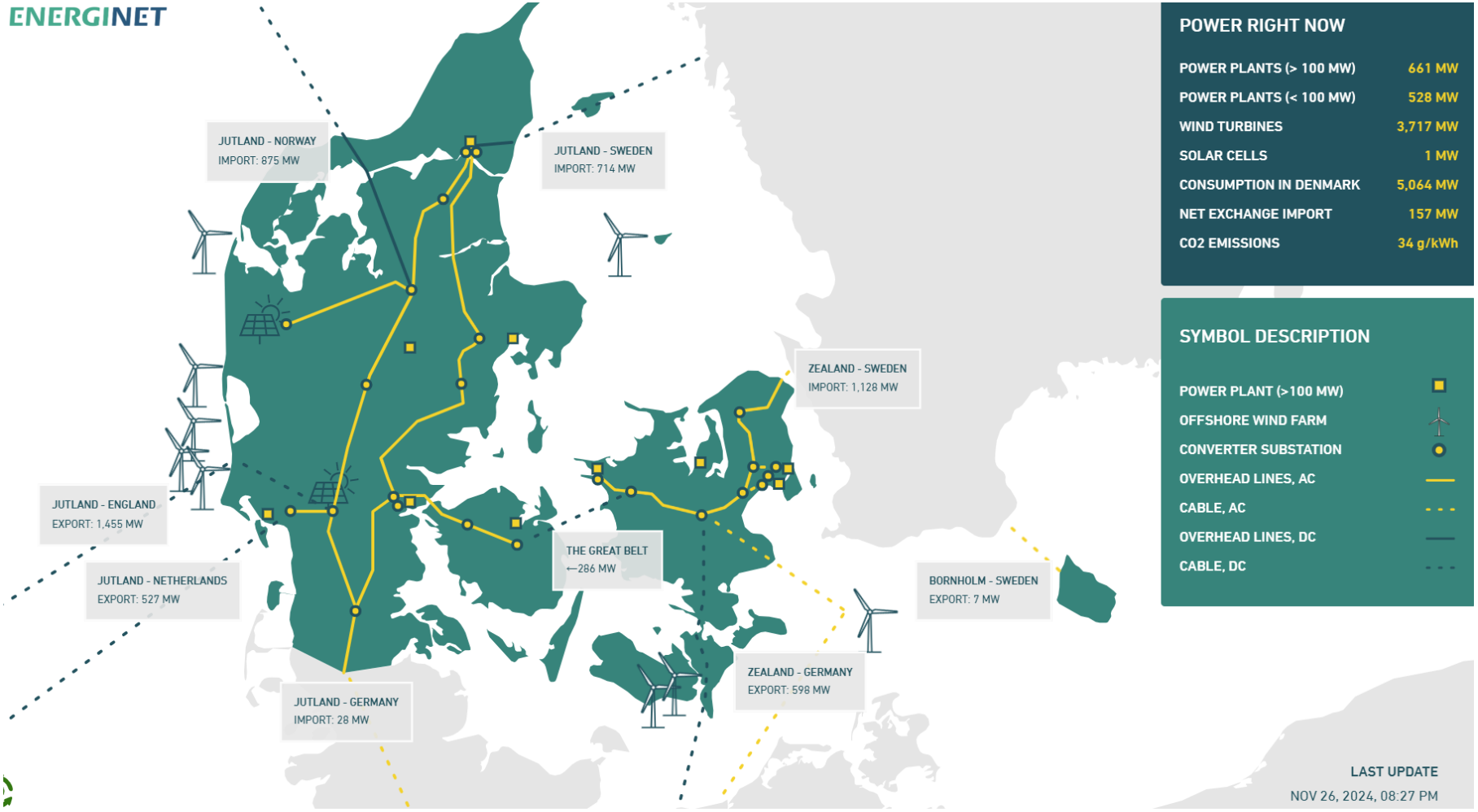
Number of RE plants



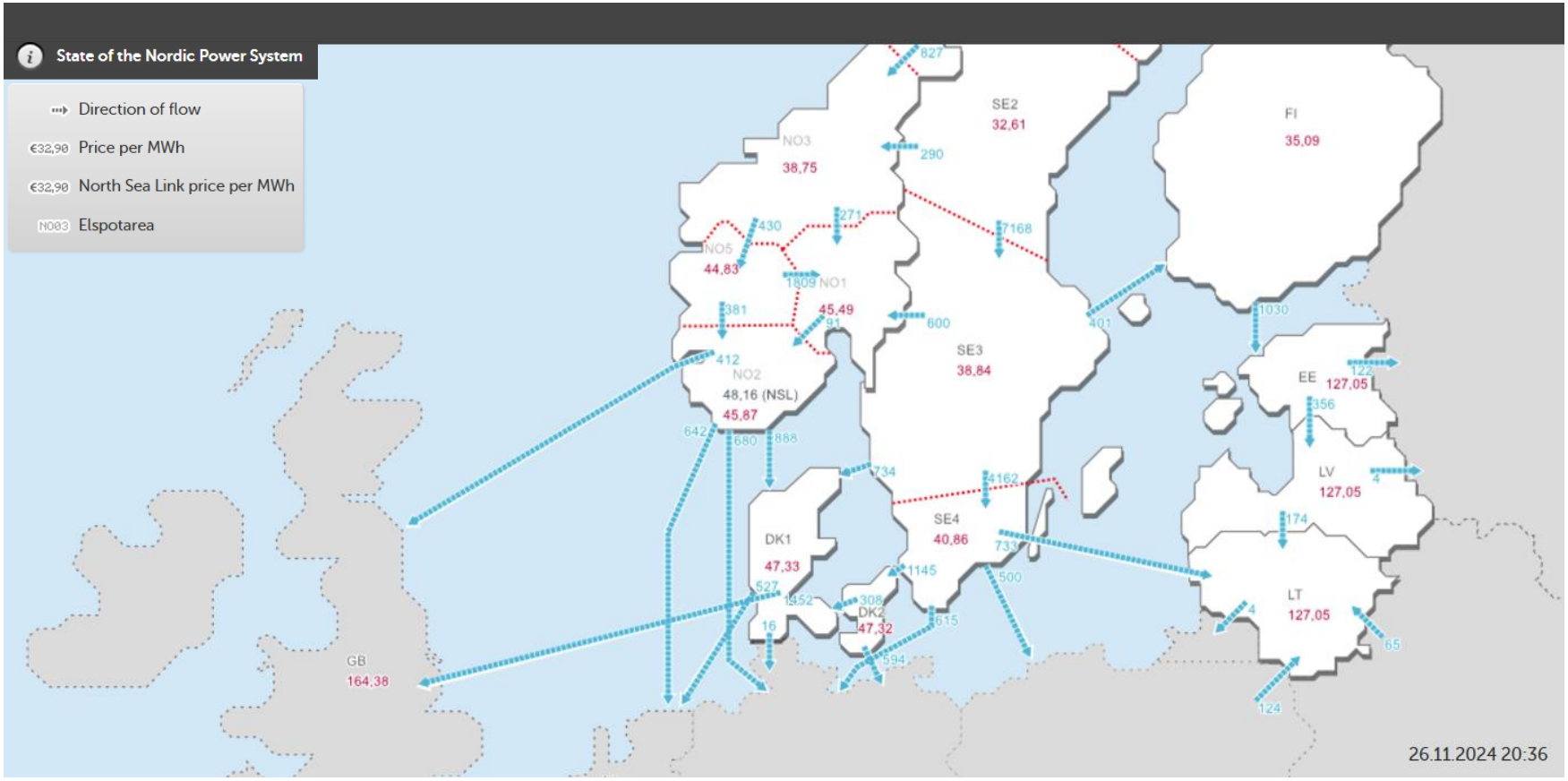


+ 7.000 Wind Turbines
+ 150.000 photovoltaic plants
App. 150 biogas plants
District heating and power plants

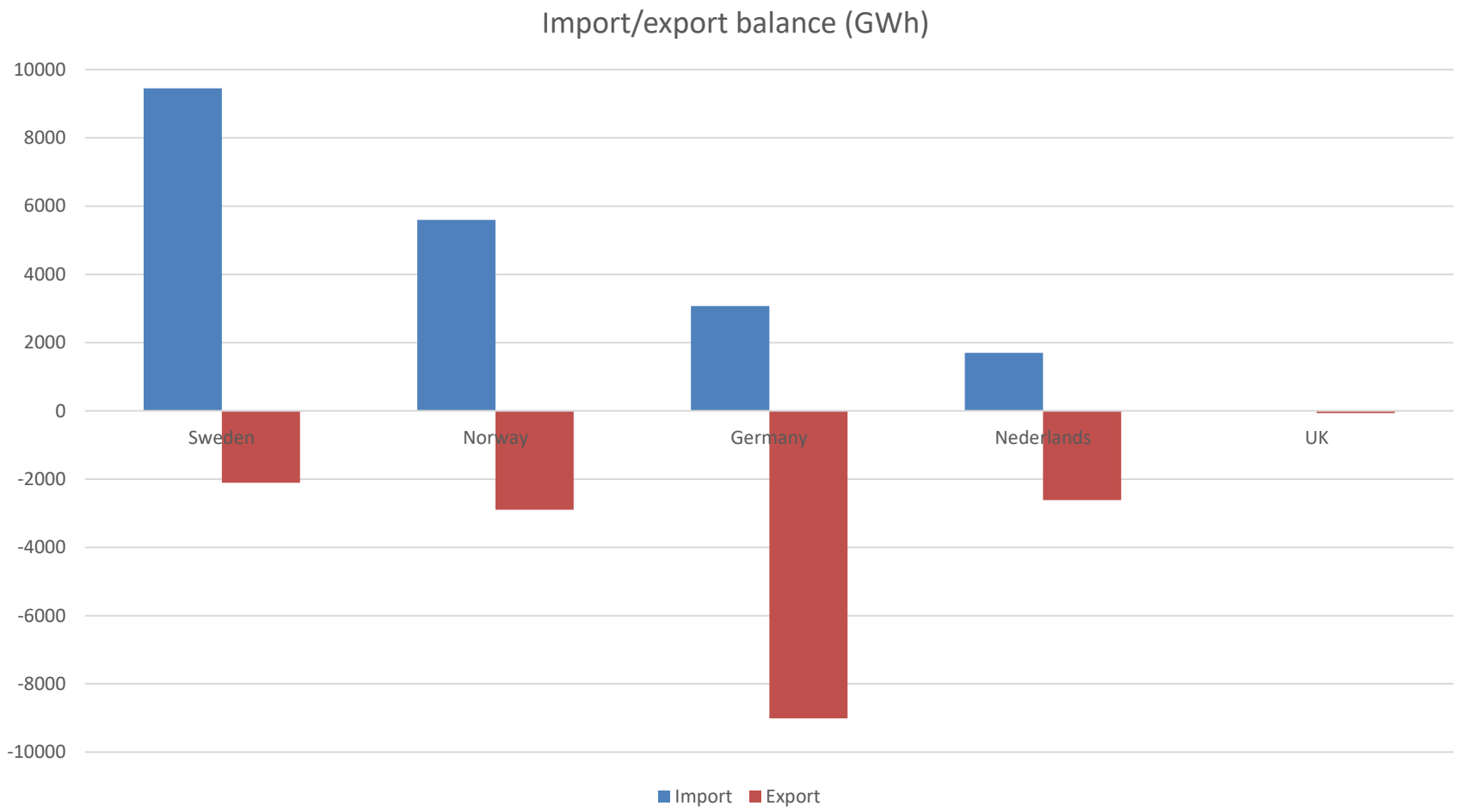
THE ELECTRICAL SYSTEM RIGHT NOW



The Nordic Power System



Electricity import/export balance 2023



Net import 3.133 GWh

WHAT ARE ANCILLARY SERVICES?

Supply / Demand

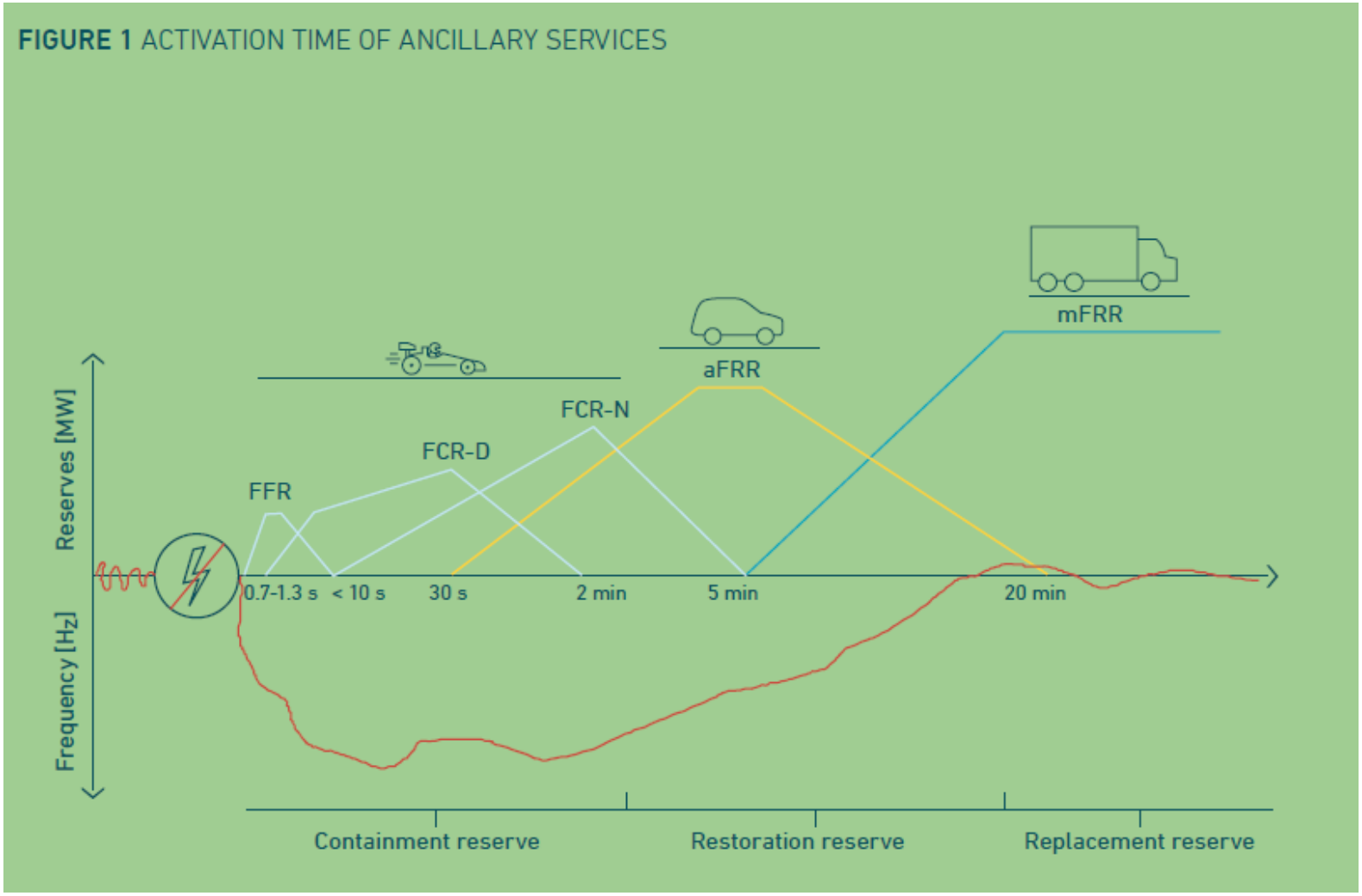
- Ancillary services cover a range of products, which the TSO procures to ensure equilibrium between electricity supply and electricity demand at all times of the day. Ancillary services are used to close gaps resulting from the difficulty of predicting and planning electricity production and consumption without minor deviations. If Energinet does not have access to ancillary services, the electricity system will be overloaded and, in a worst-case scenario, damaged

Source: Energinet

Types of ancillary services?

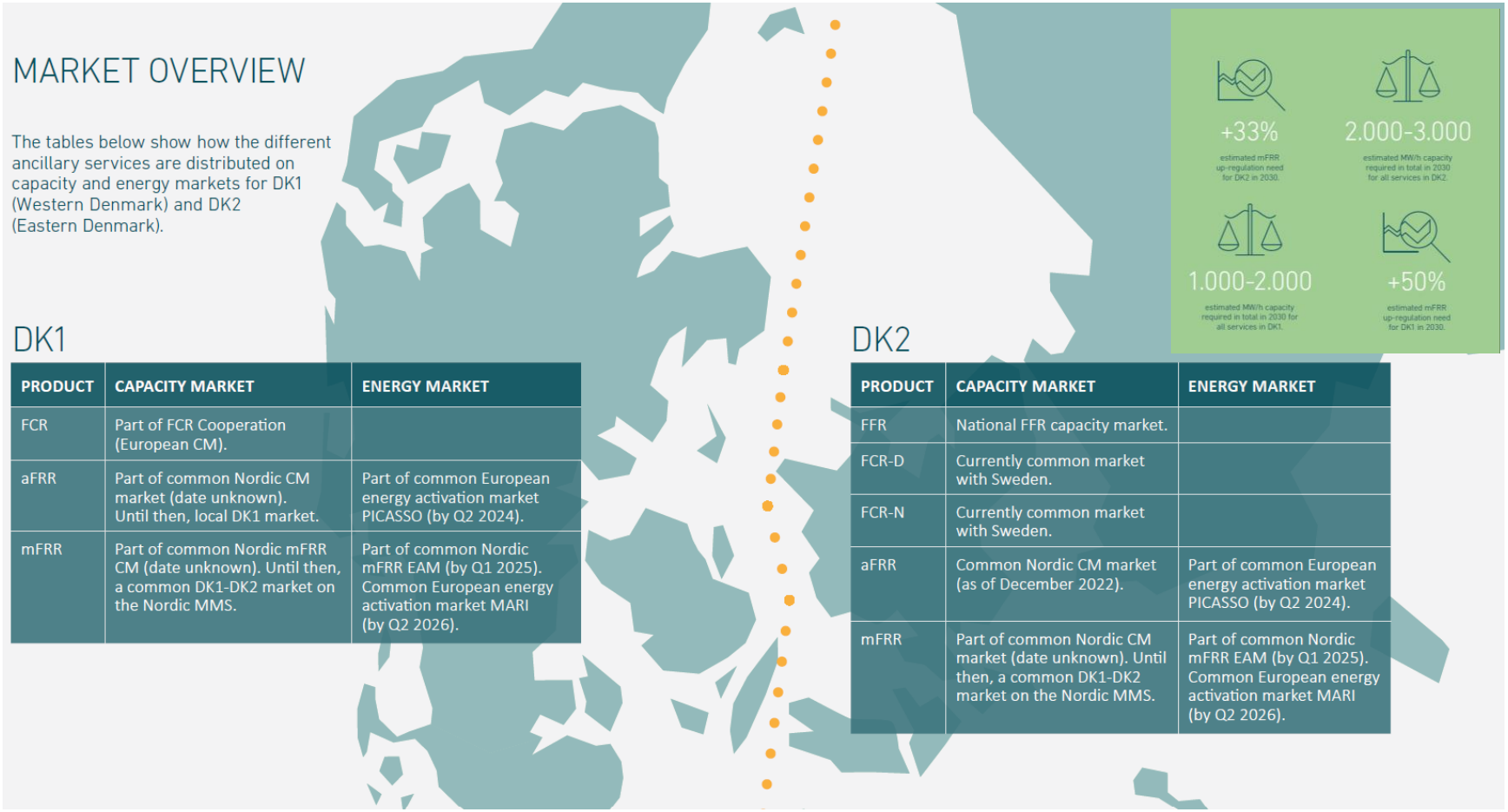
- Frequency response
- Reactive power
- Voltage management
- Interia
- Reserve power
- Black start
- Flexible consumption

Types of ancillary services (bidding)



Source: Energinet

Ancillary services needs by 2030



DK1

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FCR	Part of FCR Cooperation (European CM).	
aFRR	Part of common Nordic CM market (date unknown). Until then, local DK1 market.	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic mFRR CM (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).

DK2

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FFR	National FFR capacity market.	
FCR-D	Currently common market with Sweden.	
FCR-N	Currently common market with Sweden.	
aFRR	Common Nordic CM market (as of December 2022).	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic CM market (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).

Source: Energinet

BESS + PV + wind

- Denmark's largest battery is installed on the Island Bornholm. Capacity at 30 (MW) and 43 MWh.

Source: Ewii

METHODOLOGY FOR PREDICTED IMBALANCES

FIGURE 17 SOLAR AND WIND IMBALANCES IN DIFFERENT SIMULATION AND CLIMATE YEARS FOR DK1

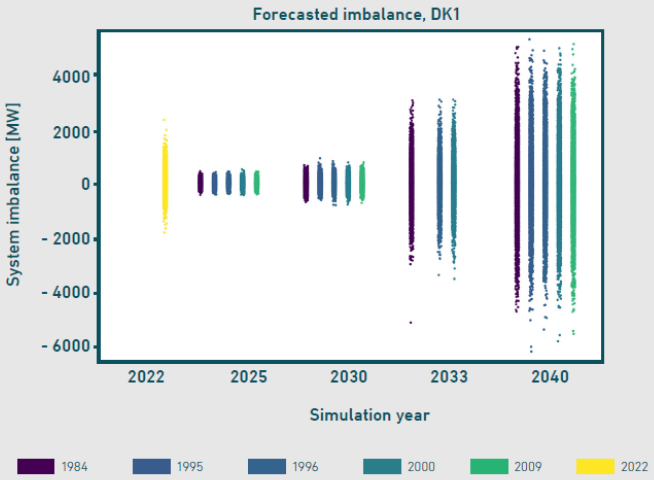
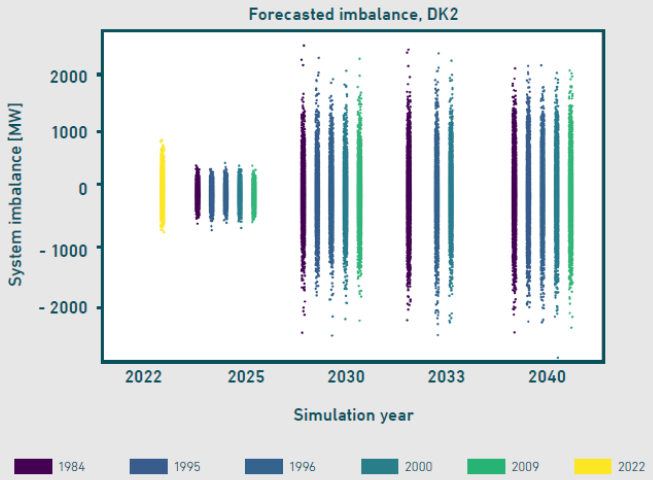


FIGURE 18 SOLAR AND WIND IMBALANCE IN DIFFERENT SIMULATION AND CLIMATE YEARS FOR DK2



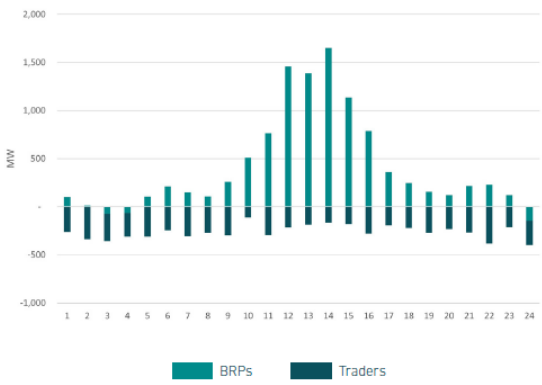
The two graphs show the simulated hourly imbalances on the y-axis with the respective years on the x-axis, differentiated by various climate years represented by different colours. These simulations incorporate forecast errors derived from a Monte Carlo simulation.

Source: Energinet

Missed oppertunities

In the last year, the energy system has experienced new challenging scenarios due to extreme weather situations and the introduction of a higher share of wind and solar energy. This has resulted in periods with both very high and negative electricity prices. These scenarios are difficult to foresee, and it can be relatively expensive to cause imbalances in these periods. Examples below show two situations from the previous year: One characterized by a massive down-regulation need and another with a massive up-regulation need.

FIGURE 42 IMBALANCES FROM MARKET PARTICIPANTS IN DK1 ON 10 APRIL 2023*

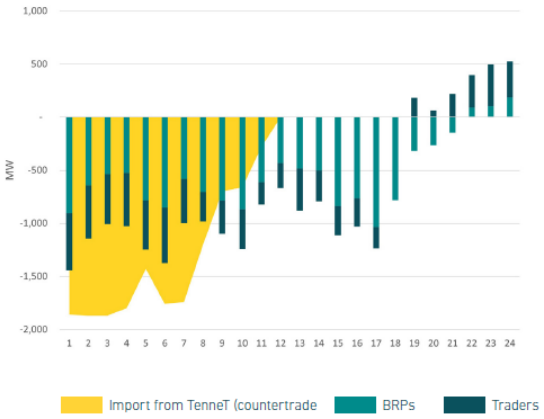


Example 1:
Down-regulation need for balancing was at a record-high at 1,500 MW in DK1 with all-time lowest down-regulation price at –16,391 DKK/MWh. At the time, adjacent bidding zones had similar issues.

Reasons for down-regulation need:

- ½ was caused by more wind production than anticipated.
- ¼ was caused by more solar production than anticipated.
- ¼ was caused by procurement in the intraday market without knowledge of the situation in DK1.

FIGURE 43 I MBALANCES FROM MARKET PARTIFICPANTS IN DK1 ON 10 MAY 2023*



Example 2:
High up-regulation (moderate) need of 650 MW in the late afternoon. The most noticeable point was the record-high up-regulation price of 35,000 DKK/MWh.

Reason for the high price:

- DK1 had very little remaining import capacity on Skagerrak and Kontiskan, which was partly used for the imbalances. Great Belt was in full import.

*"Negative: Up-regulation need, Positive: Down-regulation need."

Source: Energinet

Thank you for your attention

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