Denmark's Inflexible Power System

Danish companies specialize in climate-friendly technologies, and Danes like to describe their country as a forerunner in the climate field. Wind energy now covers over half of the country's electricity consumption.

This result is not only due to advanced Danish methods, but also to flexible resources in Denmark's neighboring countries and to the international electricity market, which makes it possible to share resources internationally. The current power system in Denmark could not be operated safely without massive support from abroad.

Too little traditional power for self-sufficiency

Fig. 1 shows, as an example, the operating pattern for week 37 in 2024. No two weeks are the same.

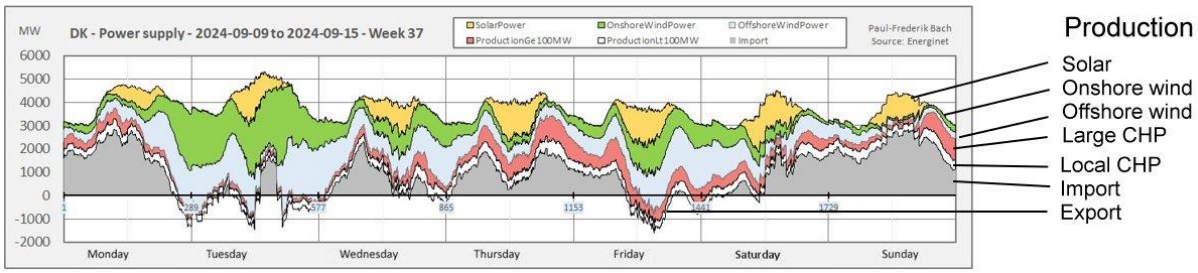


Fig. 1 – Denmark, week 37 of 2024. Exchanges reflect wind variations

Week 37 had strong winds on Tuesday and weak winds on Thursday and Sunday. The grey areas (import) reflect periods with low winds.

Production is determined by the electricity market. You can trade in both the day-ahead market (spot market), the intraday market and the regulating power market.

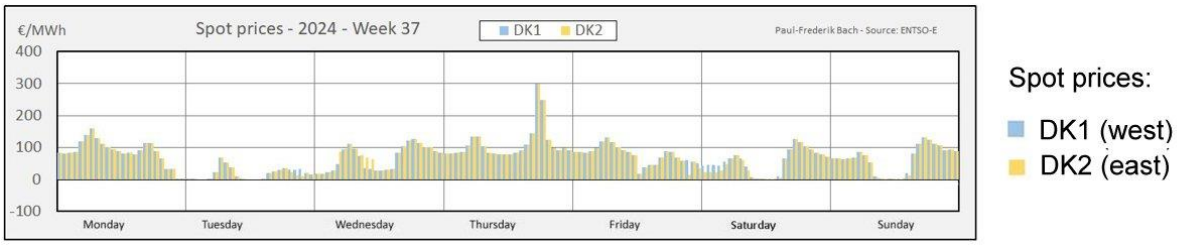


Fig. 2 - Spot prices are strongly influenced by conditions in neighboring countries.

Total wind and solar generation vary between approx. 280 MW and approx. 5800 MW. The low spot prices on Tuesday reflect the strong winds (Fig. 2). Offshore wind contributes to the down-regulation[1] during one of the zero price periods. The offshore turbines may be able to make money from providing the downregulation. Society pays for the balance, but must do without the clean energy.

[1] When balancing the electricity system, the term **up-regulation** is used when more production (or reduced consumption) is desired, and **down-regulation** when less production (or more consumption) is desired.

The combined heat and power units (CHP) increased production by more than 1300 MW from Monday to Wednesday.

Electric water heaters and heat pumps in district heating systems are important consumers of excess electricity. Their highest consumption in week 37 was 572 MW on Tuesday.

Overall, the Danish upregulation in week 37 is made up of approx. 1350 MW CHP, while the downregulation is made up of approx. 1000 MW offshore wind and up to 572 MW power-to-heat. The upregulation lacks approx. 2700 MW, if Denmark were to have been self-sufficient in electricity in week 37.

The summer week in fig. 3 had changing winds and some sun. The largest production of solar power was 3057 MW on Monday and the largest export 1607 MW on Saturday. Power-to-heat consumed up to 350 MW this week. On Sunday, most operators of offshore wind chose to temporarily stop production.

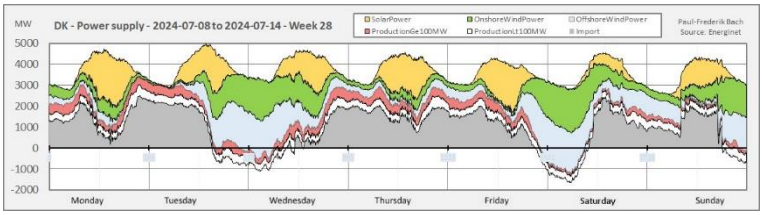


Fig. 3 - A summer week 2024 with offshore wind cut off Sunday

The dark November week in fig. 4 is an example that Denmark may need to manage almost without electricity from wind and sun for a week. Without almost 50% imports, it would have been necessary to cut back on electricity supplies.

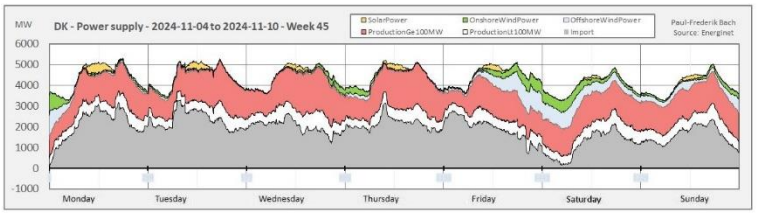


Fig. 4 - A November week in 2024 with high pressure weather and practically no electricity from wind or sun

Solar power is now causing zero-prices in the electricity market

Market prices for electricity fluctuate up and down as in fig. 2 often so that low prices follow strong winds.

When large production of wind power coincides with low market prices, it has the effect that the average value of wind energy becomes lower than the value of controlled production. Measured in relation to traditional consumption, wind energy in Denmark is down to around 80%. On the other hand, controlled production approaches 120%.

Solar energy has a special history because it is always produced in the middle of the day, when the price is usually high. Therefore, solar energy in Denmark had a value of around 100% for a long time.

The total capacity of solar power in Europe is growing steadily, but the capacity now appears to have reached a critical point, with excess production causing very low mid-day market prices. Therefore, the average value of solar energy has fallen to the same level as wind energy.

Germany has by far the largest capacity of solar power in Europe and also the largest growth (Fig. 5). In the first three quarters of 2024, 11 GW of new capacity has been installed, indicating the same growth as the previous year.

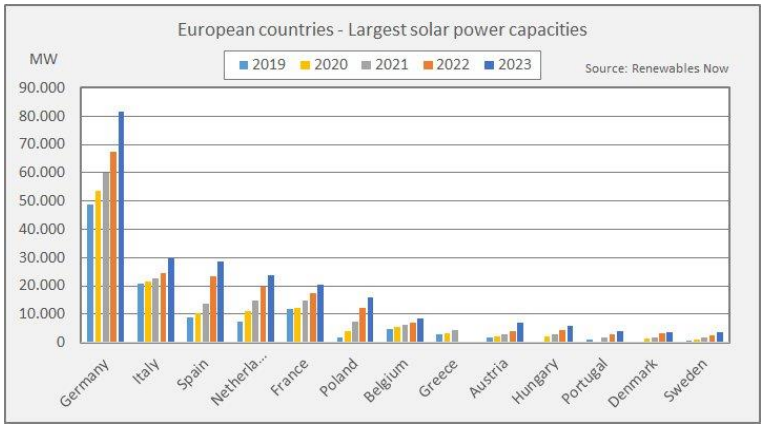


Fig. 5 - The German growth in 2023 has the same order of magnitude as for the next three countries combined. The Danish part of this game is nearly invisible.

The electricity market is divided into price zones. Norway, Sweden, Denmark and Italy have several price zones in each country, while Germany has only one. Due to its size, Germany has a strong influence on the electricity market, also in neighboring countries.

The changes can be read in terms of the number of hours with negative prices in the individual price zones.

To include 2024, fig. 6 and 7 are limited to the first 3 quarters of the year. Germany is included in both fig. 6 and 7.

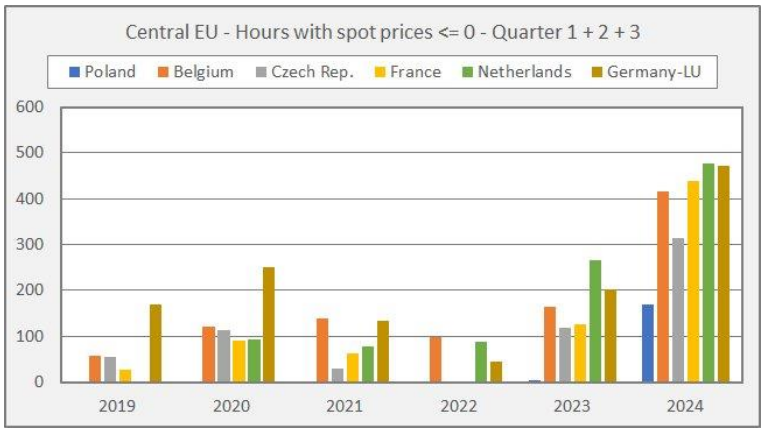


Fig. 6 - Germany has long experienced spot prices of zero and below

Less income

Fig. 6 and 7 indicate a significant change since 2022. It is uncertain how the development will continue, but more hours with zero prices mean less income for both solar and wind producers.

This uncertainty may be the reason why Danish developers of solar and wind power plants are currently hesitating, so that development seems to be at a standstill. This also applies to the development and installation of the facilities which will convert surplus production of electricity into hydrogen and other fuels.

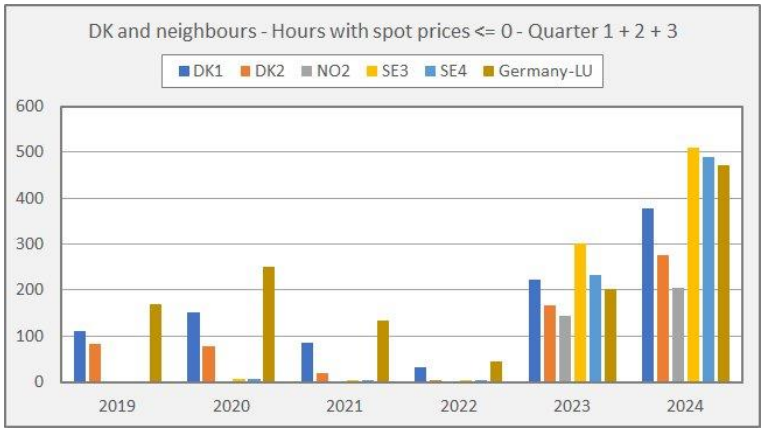


Fig. 7 - Most Nordic price zones experienced only a few hours of zero prices before 2023

The uncertainty may be temporary, but it probably means delays in the next few years' expansion plans.

The Danish ambitions

The development of Danish infrastructure for electricity supply no longer aims to supply the Danes with electricity in a way that is cheap, safe and clean. Now the main issue is the green transition, which must reach certain goals in certain years.

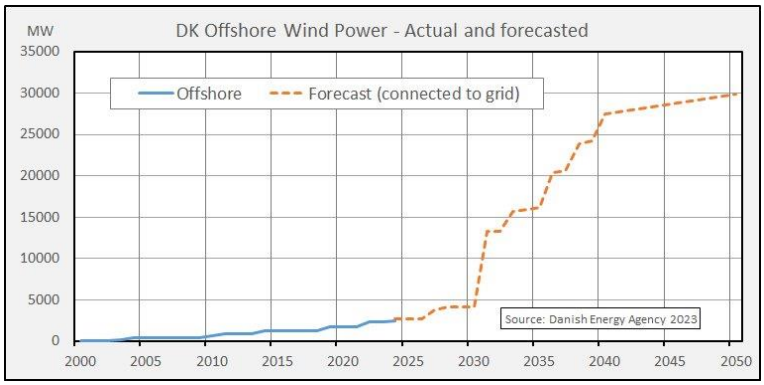


Fig. 8 - Delays have put off the big leap until the early 2030s

In this connection, Danish energy politicians want to demonstrate a leading Danish role by producing far more electricity than the Danes need. Electricity must become an export commodity and it must drive new industries for the production of carbon-free fuels.

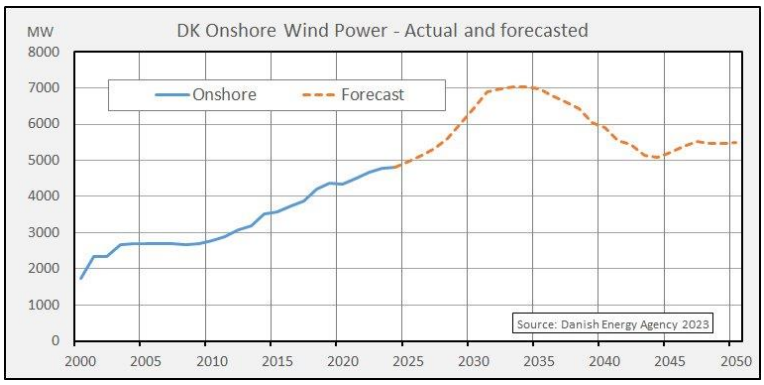
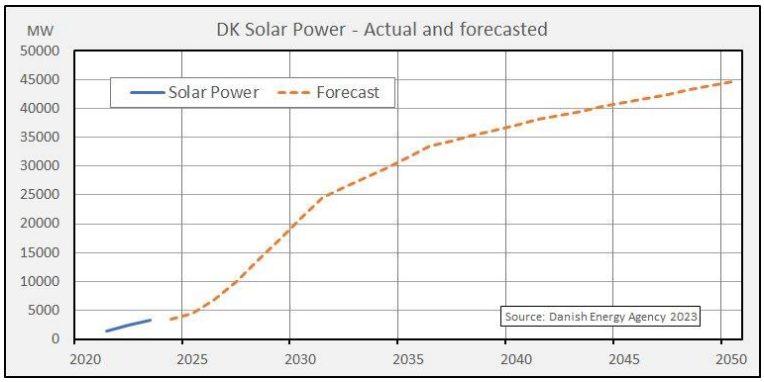


Fig. 9 - We do not know why onshore capacity must decrease from 2035

The ambitions are made concrete in the annual "Analysis requirements for Energinet" from the Danish Energy Agency. The intention is to dictate the data that the Danish system operator, Energinet, must use in its analyses.

Until 2030, the Danish wind power capacity is assumed to be increased by approx. 3 GW. In the same period, the solar power capacity is assumed to have increased by about 17 GW. This is around three times Denmark's maximum electricity consumption.



Such a development will face many challenges. An expansion of the Danish transmission system in 6 years to handle around 20 GW new generation looks impossible due to lack of manpower, bottlenecks at the suppliers and lengthy approvals. Building a large transmission line can take a decade or more. New electricity consumption in the form of Power-To-X is facing technical and financial challenges.

The Danish power system must be adjusted to international reality

With the introduction of fluctuating electricity production in large quantities, it was intended that the lack of controllability should be offset by flexible consumption, but the introduction

of flexible consumption in Denmark was far from sufficient. Instead, the balancing work has moved abroad.

The growing number of hours of overproduction throughout Europe shows that the Danish solution will not be sustainable in the long run. It will be necessary to reduce the production of solar and wind power when the market shows a lack of demand. Growing periods of low prices and downregulation will reduce the projects' income and expected profitability.

The developers of Danish solar projects have become cautious, and a number of new projects are being postponed. In this way, market forces can contribute to preventing excessively large imbalances.

Time will tell if lack of production capacity becomes problematic. This will lead to a need for additional dispatchable backup production.

For many years, Denmark has seen an advantage in having strong interconnections to other countries. On the one hand, this has given Denmark the opportunity to get other countries to offset the fluctuations in solar and wind power, but on the other hand, electricity prices in Denmark have been governed by electricity markets in neighboring countries, especially Germany.

The problem is that Germany will not divide the country's electricity market into price areas. This exposes Denmark, Norway and Sweden to the high prices set by the high demand of electricity in southern Germany.

Electricity consumers in Norway and Sweden have been dissatisfied with this because they have experienced sharply rising electricity prices in recent years. In order to weaken this unfortunate influence, Norway and Sweden have postponed the establishment of new interconnections, such as the Hansa Bridge from Sweden to Germany.

Denmark has long benefited from being able to draw on foreign resources. The question is whether increasing international tensions and uncertainty on the electricity markets have made the time ripe for establishing Danish reserves to increase the resilience of the local energy systems.