Onshore vs. Offshore Wind Power

Wind power is supposed to become the dominant source of electricity in Denmark. The plans include both onshore and offshore wind turbines. It is claimed that both are necessary for fulfilling the climate targets.

It is a municipal duty to identify suitable locations for the installation of large wind turbines. The Danish population is about to find the density of onshore wind turbines disturbing and the resistance against new onshore wind parks is increasing.

An offshore wind turbine costs largely 50% more than an onshore, and it produces about 50% more. These figures suggest a kind of balance. **However, other less noticed differences are in favour of offshore wind.**

Market values in 2020

Data for 2020 have been chosen for a comparison between Danish sources of RES[1] electricity.

DK 2020	GWh	Max MW	Min MW	Duration hours	Load factor
Consumption	35.277	6.466	1.461	5.456	62%
Offshore wind	6.601	1.639	0	4.027	46%
Onshore wind	9.744	3.909	2	2.493	28%
Solar panels	1.248	990	0	1.261	14%

Fig. 1 - Danish sources of RES electricity in 2020

The Danish production of RES electricity made up 50% of the electricity consumption (fig. 1). The duration hours[2] suggest that the productivity was 62% higher for offshore wind than for onshore wind.

A kWh is not just a kWh. The market values per kWh of offshore wind, onshore wind and solar power are different.

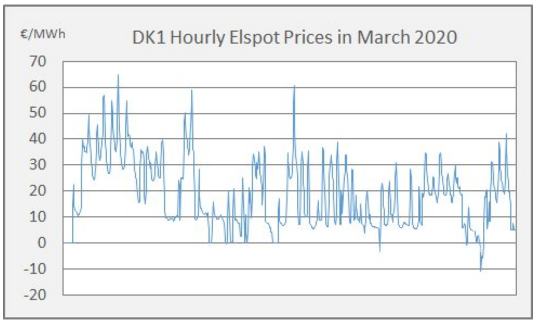

Fig. 2 - Spot price variations in West Denmark

The fluctuating wind power causes corresponding fluctuations in the hourly prices in the spot market. Fig. 2 shows the price variations in West Denmark in March 2020.

Controllable energy sources have a better **market value** than fluctuating energy sources. We can find the market value by multiplying production and price for each hour. The result is a weighted average.

Fig. 3 shows the market values of Danish electricity demand, production and exchange in 2020.

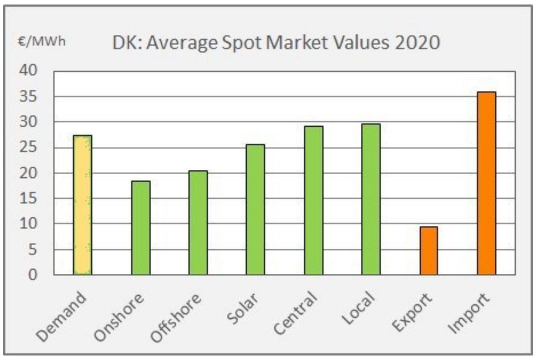

Fig. 3 – Large differences in market values

Offshore wind energy is worth 11% more than onshore wind energy. Solar energy has a 26% higher market value per MWh than offshore wind energy though it has a much lower productivity

---

[1] RES: Renewable energy sources
[2] Duration hours: consumption divided by peak load. Load factor: average load divided by peak load

(load factor) than wind power. The explanation of this paradox is that solar power has a high positive correlation with the market prices while the corresponding correlation for wind power is negative.

An economic comparison between onshore and offshore wind power should include **both the 62 % difference in productivity and the 11 % difference in market values.**

It depends on cost estimates for each specific case if these differences outweigh the additional cost of offshore wind turbines.

Fig. 3 also demonstrates that export of overflow electricity can be a bad bargain. For each MWh stored abroad in 2020, Denmark could only buy 0.26 MWh back, which is a poor storage efficiency.

These results are based on market conditions in 2020. Other years are different. Anyhow, with more wind power and less dispatchable power in Denmark and its neighbouring countries, even larger variations of spot market prices must be anticipated.

The essential difference

We can compare production profiles of onshore and offshore wind for one year by sorting the hourly production from the largest to the smallest value. The result is called a **duration curve**. The curves for onshore and offshore are adjusted to include one TWh each (fig. 4).

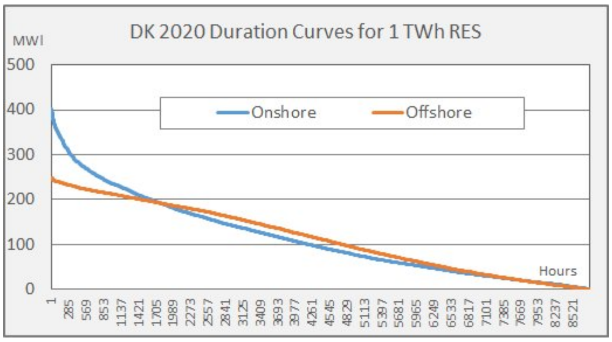

Fig. 4 - Large differences for high values

The duration curves show that neither onshore nor offshore wind can contribute to the electricity supply during calm periods while onshore wind causes more electricity overflow than offshore wind during windy periods.

Each of the two areas between the curves surrounds 6.8% of the annual production.

More overflow and more shortage of power from onshore wind

The typical electricity demand is quite inelastic to price variations. Electricity consumers did not yet learn to adjust the electricity consumptions to the current supply. New ways to more flexible electricity demand have been investigated for decades, but so far with poor results.

The Danish Energy Agency (DEA) has published a “Market Model 3.0”. The use of electricity is supposed to increase significantly, but with new types of demand, which will accept frequent reductions and low annual load factors.

The report from DEA recognizes that the neighbouring countries are about to reduce their controllable capacity and that Denmark therefore cannot continue to rely on foreign balancing services.

This sets the Danish challenges into relief. The total demand for electricity must be limited to remaining controllable capacity during calm periods, while waste of energy seems to be unavoidable during windy periods.

A simple calculation can illustrate the challenges and quantify the problems. The calculation is based on time series for electricity consumption, onshore wind, offshore wind and solar power in 2020.

DEA has published a set of recommended data for energy analyses for the period until 2040 (AF20). Based on AF20 we have assumed the following data for 2040:

- Total Danish consumption: 70 TWh
- Wind energy: 72 TWh
- Solar panels: 9 GW, 12 TWh
- Dispatchable backup: 3 GW
- Power to X (PtX): 3 GW

It makes an annual average energy production exceeding consumption by 14 TWh.

The total balance has been calculated hour by hour for one year. The results have been sorted into a duration curve. Two cases have been analysed. The first case has 100% offshore wind energy. For comparison, a second case has 50/50 per cent onshore and offshore wind energy.

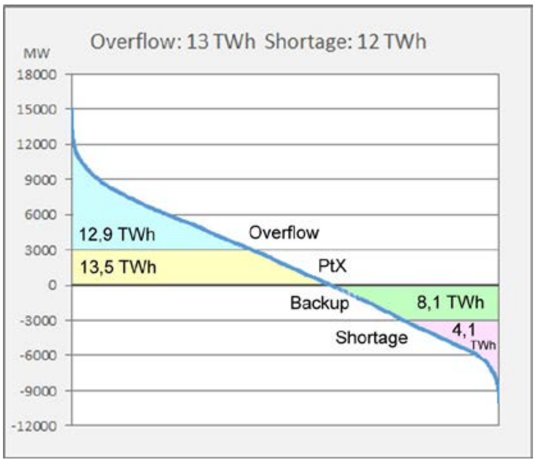

Fig. 5 - DK 2040 with 100% offshore wind

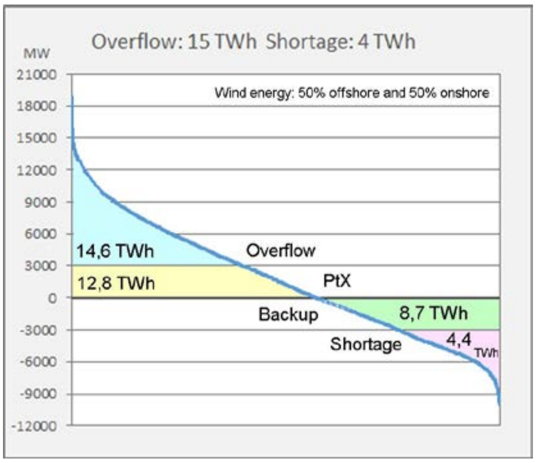

Fig. 6 - DK 2040 50/50% onshore/offshore wind

The balancing tools in this simplified case are 3 GW PtX and 3 GW backup capacity. Fig. 5 shows that they can only absorb a modest share of the imbalances. There will remain 40% of the hours with electricity overflow and 24% with shortage. In fig. 6, onshore wind has caused slightly more overflow and more shortage, but the basic challenges are the same.

The dilemma is that additional PtX and additional backup capacity will have low utilizations and consequently poor economy. Regardless of the choice of new market arrangements, **wasted energy and irregular electricity supply from fluctuating power will cause an additional cost**.

The question is if the shortage of supply and the overflow of energy can be absorbed by new routines before 2040. **Will enterprises and end-users accept the new conditions as reasonable energy services?**

The calculations in this note are not predictions, but examples, but overflow and shortage will anyhow be larger if we assume that 50% of the wind energy is from onshore wind turbines (fig. 6). The disadvantages of onshore wind will grow with increasing share of wind power in Europe.

The hidden cost of onshore wind power

This note suggests that the transition from traditional controllable production of electricity into wind and solar power will cause additional overflow and increased shortage of electricity.

The overflow can be wasted, exported or utilized for new purposes. The overflow has only few duration hours and therefore a poor value.

In comparison with offshore wind, onshore wind has some external costs such as noise, disturbed landscapes, additional overflow and supply reductions.

External costs are a matter of judgement and can be set to fit any purpose. It is beyond the scope of this note to assess external costs, but it can be argued that all disadvantages and additional costs of onshore wind turbines should be considered in setting a balance between onshore and offshore wind power,