Electricity in Denmark 2020

25% of the Electricity Consumption in Denmark in 2020 was imported

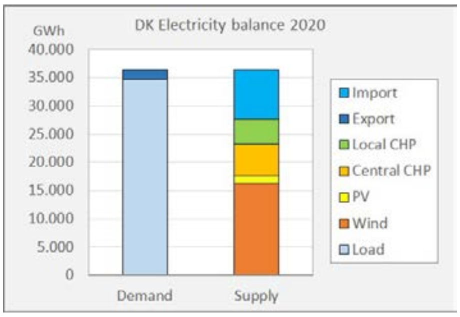

Fig. 1 - Danish electricity balance 2020

Fig. 2 - Balance of market values 2020

Wind energy made up 47% of the Danish gross electricity consumption or 45% of the total balance. Electricity import accounted for 25% of the supply volume (fig. 1) and 33% of the total market value (fig. 2).

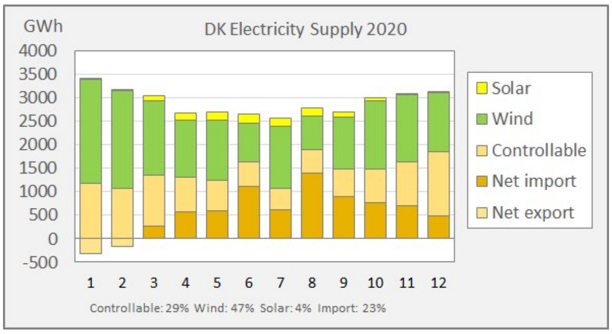

Fig. 3 - Electricity supply by month in 2020

Large volumes of import and export are consequences of the large share of wind energy and the missing flexibility in the Danish power system. A fourth of the electricity consumption in 2020 was import, but due to the stressed international markets, imported electricity made up a third of the economic volume or more than € 300 million (fig. 3).

The controllable (or dispatchable) production (central and local CHP) in Denmark depends on heat demand. It is replaced by import during the summer season when the heat demand is low and most thermal power plants are out of service for maintenance (fig. 4).

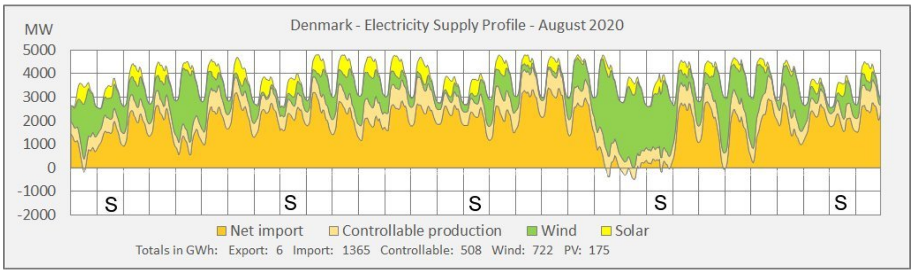

Fig. 4 – Poor wind in August 2020 in Denmark (and Sweden) (more charts on http://pfbach.dk/)

The following maximum and minimum hourly values were found for 2020:

			Max	Date	Hour	Min	Date	Hour
Gross load	DK	MWh	6.466	03.12.2020	10	1.461	22.12.2020	3
Wind	DK	MWh	8.039	25.10.2020	1	9	08.08.2020	10
Dispatchable	DK	MWh	3.603	22.01.2020	18	0	31.12.2020	24
PV	DK	MWh	996	15.06.2020	12	0	01.01.2020	1
Net export	DK	MWh	3.448	25.10.2020	2	-3.408	19.08.2020	7
Spot price	DKW	€/MWh	200	21.09.2020	18	-59	13.09.2020	12
Spot price	DKE	€/MWh	254	30.11.2020	8	-43	13.04.2020	13

Table 1 - Extremes DK 2020

The average spot market values indicate unusual Danish market conditions in 2010 (fig. 5). The import and export prices were never before that unfavourable from a Danish point of view. It may be an exceptional case, but it demonstrates the Danish vulnerability due to lack of dispatchable production capacity. Some years ago, when the oil prices were at the top, it was claimed that wind energy had become cheaper than any potential production capacity. This case demonstrates that the combined properties of the fleet of production facilities is decisive for the economic result.

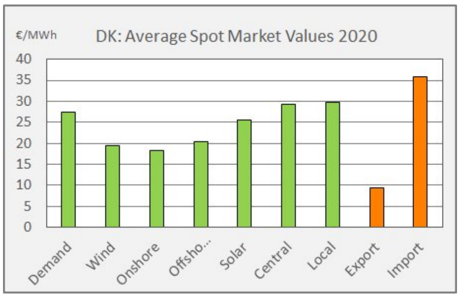

Fig. 5 - Import was the most expensive electricity source in 2020

Collapse of the Nordic Electricity Market – A Foretaste of the Future?

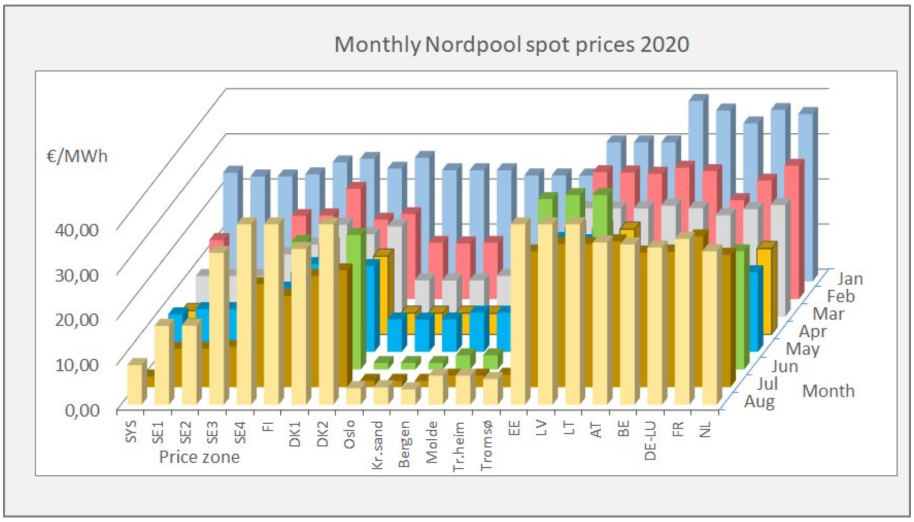

Fig. 6 - Nordpool: Average electricity spot prices January to August 2020

The spot price profile was quite normal in January 2020. The Nordic price zones had average prices between €31 and €36 per MWh. The three Baltic States and the recorded continental countries had prices between €40 and €50 per MWh.

The six Norwegian price zones from Oslo to Tromsø experienced spot prices falling to nearly nothing during the following months.

The Swedish spot prices developed differently with low prices for the two northernmost price zones, (SE1 and SE2) and rather high prices for the southern price zones, (SE3 and SE4). Swedish media reported about the electricity crisis during 2020.

The crisis was caused by an unexpected combination of long-term and short-term trends.

The most important long-term trend is Sweden's closure of nuclear power plants in the southern part of Sweden combined with the installation of wind farms in the northern part of Sweden. The consequence is an increasing transfer of electricity from north to south beyond the capacity of the transmission grid. Norway's increasing export of electricity to the continent creates an electricity transit from Finland to Norway. The combined result of these changes was frequent congestions in the Swedish grid in 2010.

The short-term trends in 2010 were sub-see cable faults, maintenance works in the transmission grids and full hydro reservoirs in Norway.

The limited transfer capabilities limited the electricity export from Norway and caused the decrease of market prices in Norway (fig. 1). There is no shortage of energy, but of transmission capacity.

The question is if this was an extreme combination or a foretaste of a future with increasing occurrence of similar conditions.

Volatile Spot Market and Decreasing CHP Production

Spot Price variations from year to year:
The spot price level for a year can be calculated as a plain average. An average market value is found by weighting spot prices with electricity demand variations.

Fig. 7 demonstrates the considerable variations from year to year. In spite of the stressed market conditions, the average demand value was the second lowest since 2010.

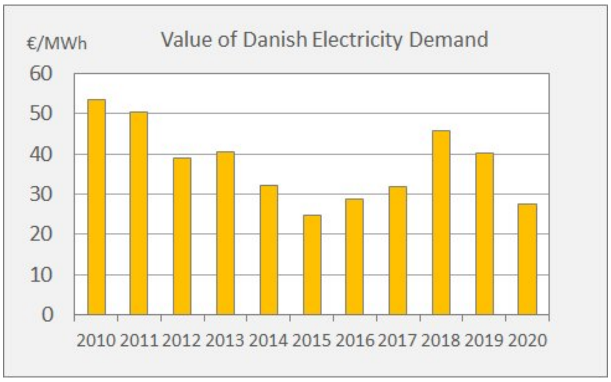

Fig. 7 – Large variations from year to year

Spot price variations in 2020:
The duration curves in fig. 8 reflect the spot price volatilities in 2020. Values above € 100 per MWh and below € -50 per MWh are disregarded.

The differences between countries in the first example show the economic "voltage differences" driving electricity from Norway to Germany via all available channels. The congested interconnectors cause the price differences as economic "resistors".

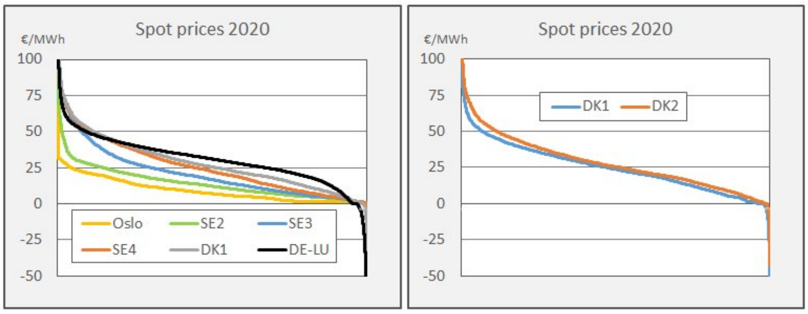

Fig. 8 - The duration curves show large variations during the year and between countries

The spot prices in the six Norwegian price zones are nearly identical with the Nordpool system prices. The two Danish price zones have identical spot prices close to the German price level in most hours. Three of the four Swedish price zones form different price levels on a main road from Norway to Germany (fig. 8).

Fig. 8 does not support the idea of a large transit from Finland to Norway, but it does support the impression that the transmission capacity of the grids is far from sufficient.

Poor value of overflow:
Market values are compared in fig. 8 by setting the value of demand to 100%.

Fig. 9 shows 2020 as different from the previous years. The value of overflow electricity was only 34% of the demand value, while the cost of import was 131%.

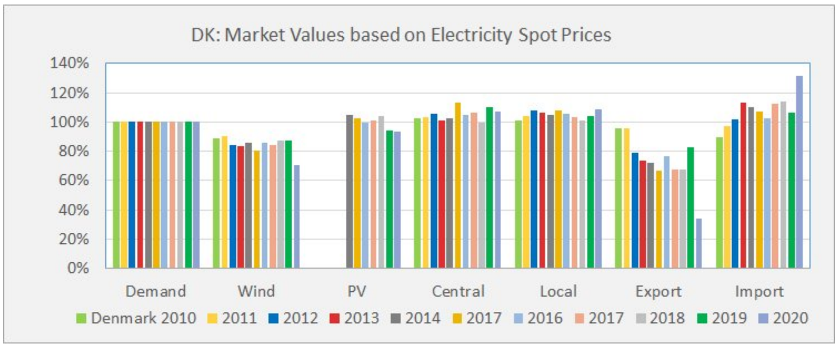

Fig. 9 – Poor opportunities for international balancing support in 2020

Even the value of wind energy was remarkably lower than in previous years.

Decreasing CHP Output:
The decrease in thermal electricity production in Denmark has continued in 2020 (fig. 10). Import was probably cheaper than condensing production, and even CHP electricity is becoming less competitive. The decreasing CHP production is a dilemma because the CHP systems are the most important domestic sources of flexibility for wind power integration.

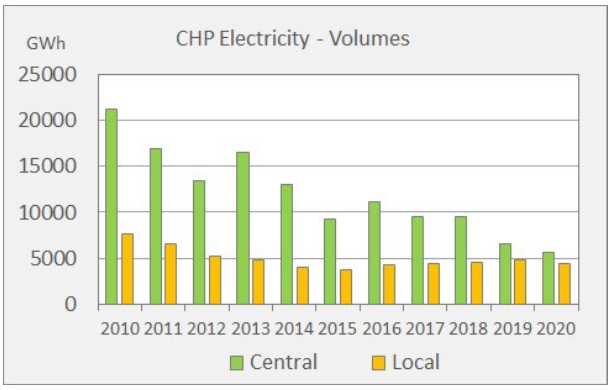

Fig. 10 - From 29 TWh in 2010 to 10 TWh in 2020

Exchanges and Congestion Income

Denmark exchanges electricity with Norway, Sweden, Germany and the Netherlands. The Danish net import from Norway and Sweden in 2020 was 10.9 TWh. The net export to Germany was 3.1 TWh and to the Netherlands 1.1 TWh (fig. 11). The resulting Danish net import was 6.7 TWh.

In 2019, the import from Norway was only 3.4 TWh, and the export to Norway 3.3 TWh. The difference between the two years reflects variations in the hydro systems. The Skagerrak link exports electricity from Norway, when the inflow of water is high as in 2020. In 2019, the link was operated as a pumped-storage unit.

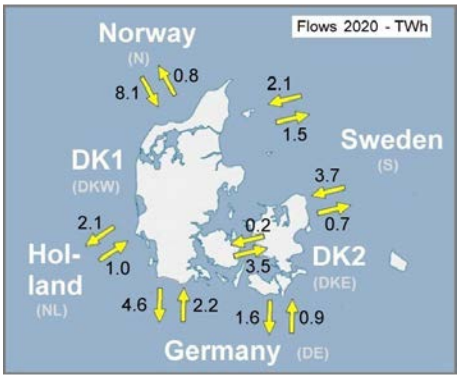

Fig. 11 - Denmark's net import was 5.8 TWh in 2019

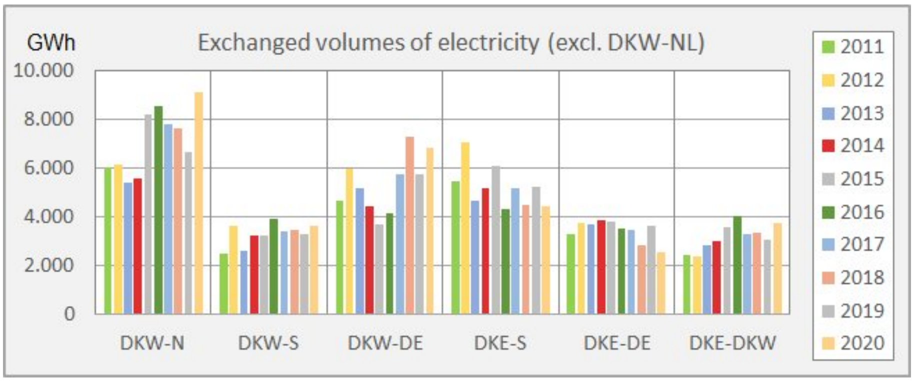

Fig. 12 - Total exchanges (both directions)

The HVDC link to Norway was reinforced in 2015 from 1000 MW to 1700 MW technical capacity (fig. 12). The exchange increased correspondingly.

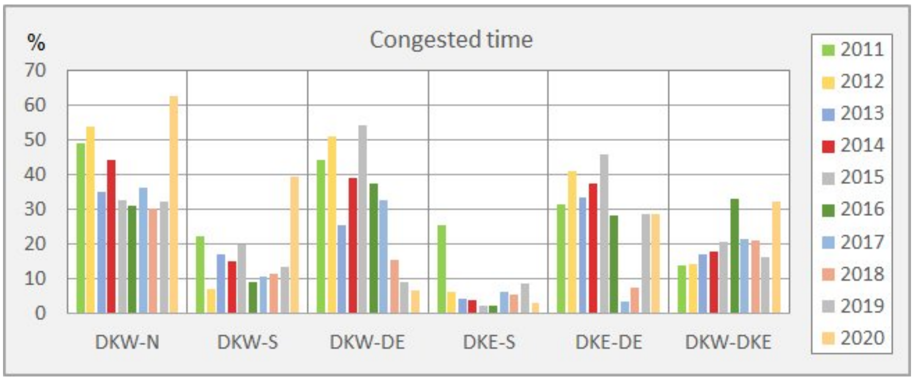

Fig. 13 - Most congestion at the borders to Norway and Germany

An interconnector is congested when the demand for transfer exceeds the available capacity

Fig. 13 shows the time with congestion for each link and each year. A low share of congested hours suggests that the interconnector capacity is too large, while a high share might suggest that the capacity is too small.

The electricity flows change from year to year. The future electricity balances in Europe are uncertain. This must be considered in the planning of future interconnections. On the other hand, unforeseen events usually increase the need for international trade. Unforeseen

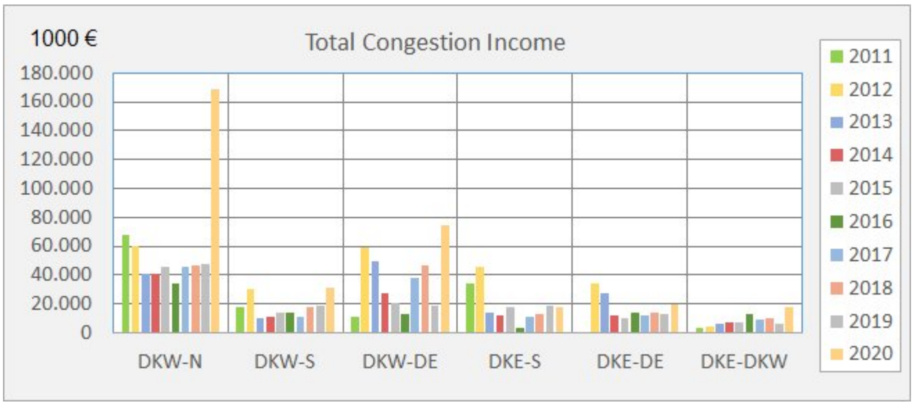

Fig. 14 – 2020 was an unusual year, which made the Skagerrak link very profitable

events do happen. Therefore, it has been claimed that there has not yet been reason to regret investments in stronger interconnections.

Trade across a congested border causes different market prices and a surplus of money. The surplus is the congestion income (or bottleneck fee), which is usually shared between the grid owners (fig. 14).

Congestion income is exchange multiplied by price difference. Thus, there will be no income if either exchange or price difference is zero.

The congestion income is an important income for the grid owners.

The congestion income per MWh transferred is an indicator of the importance of a link and of the need for additional capacity (fig. 15). There are normally only small spot price differences between the two Danish price zones. The average congestion incomes from the Great Belt Link are correspondingly low in spite of a fair utilization.

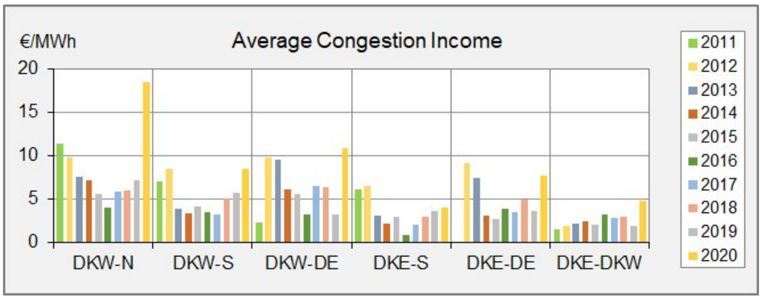

Fig. 15 - The owners of a link share the congestion income.

Export of Danish Wind Power Limited by Sweden and Germany

The transmission system operators (the TSOs) define the commercial capacity of a link. It can be much lower than the technical capacity.

The commercial interconnector capacities are reduced when

- the link itself has a technical limitation and when
- there is a risk of grid overloads or power failures in the adjoining grids.

In some cases, TSOs reduce the capacity in order to protect local commercial interests or to maximize their own profit. Such reasons are less acceptable, but undetectable, because only the TSOs have the capacity to analyse the technical limits of the grids.

The Skagerrak link (DK1-N) had a rather poor performance in 2020. I did not find the reasons on Energinet's homepage. The link has four poles. The availabilities in 2020 were only 72% from Norway to Denmark and 68% in the opposite direction. The steps on the duration curves (fig. 16) indicate technical reasons such as cable faults.

The Konti-Skan link (DK1-S) has two poles. The availabilities are 71% from Sweden to Denmark and 88% in the opposite direction. The smooth shape of the duration curve from Denmark to Sweden suggests limitations in adjoining grids.

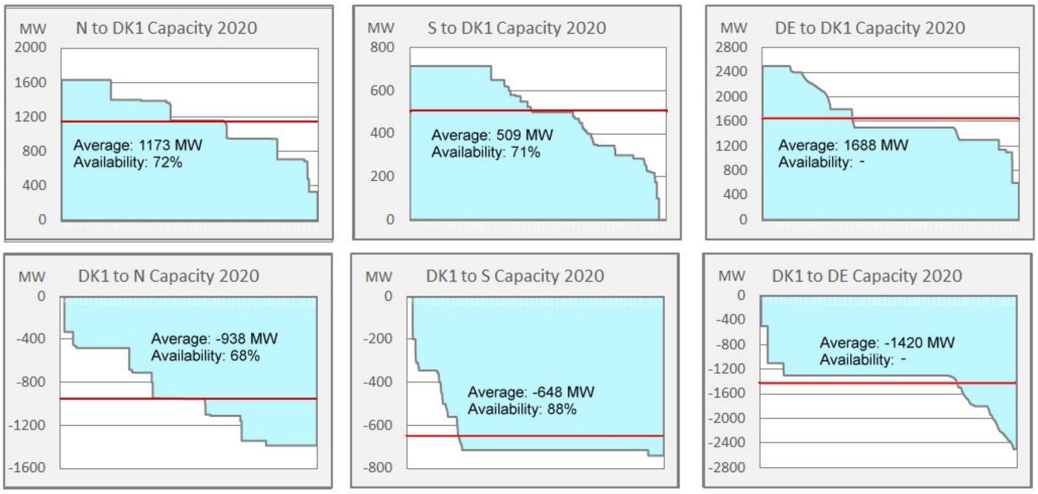

Fig. 16 - Available capacities for DK1 in 2020 - Duration curves – Export capacity < 0

The AC[1] interconnection to Germany has been reinforced during 2020. Two 220 kV lines to Flensburg from Kassø and Aabenraa in Denmark have been replaced by a 400 kV line from Kassø to Hamburg. Calculating average availabilities makes less sense, when the cross-border capacity has changes during the year.

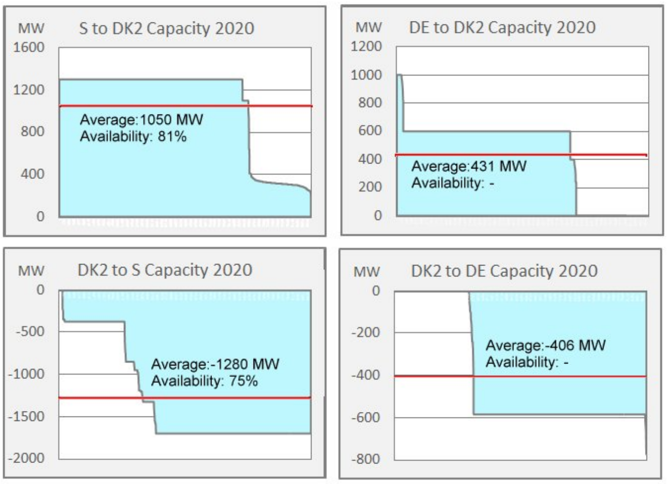

Fig. 17 - Available capacities for DK2 in 2020 - Duration curves – Export capacity < 0

Fig. 17 shows duration curves for DK2 (East Denmark).

The AC interconnection with Sweden has reduced the export capacity for 38% of the hours. The average capacity is 75% of the maximum capacity.

The reduced export capacity towards Sweden and Germany has caused some concern in Denmark. Denmark expects to install new wind power capacity in spite of the limited capacity of domestic facilities for utilizing the overflow of wind energy. Exchange with neighbouring countries is by far the most important Danish means to absorb wind power variations. The barriers for export to Germany and Sweden call for alternative solutions for utilizing Danish wind power peaks.

Negative Spot Prices Spreading from Germany

There are conflicting trends in the German "Energiewende" (energy transition). On one hand, there is a steady growth in the use of renewable energy for electricity production. On the other hand, the use of lignite as power station fuel continues.

The most important renewable sources in Germany are wind and photovoltaics (PV). Other important renewables are hydropower and bio fuels. The share of wind energy was about

[1] AC: Alternating Current contrary to DC or Direct Current

23% and PV about 9%. The corresponding Danish figures are 47% and 3%. Nevertheless, Germany seems to have more difficulties from wind power than Denmark.

Spot Prices	Period	Nordpool						
	01-01-2020	SYSTEM	DK1	DK2	DE	NO2	SE3	SE4
	31-12-2020							
Average	€/MWh	10,92	24,97	28,40	30,46	9,28	21,19	25,86
Minimum	€/MWh	-0,93	-58,80	-42,66	-83,94	-1,73	-1,73	-1,96
Maximum	€/MWh	51,13	200,04	254,44	200,04	99,92	254,44	254,44
St.Dev.	€/MWh	8,25	17,43	19,72	17,50	8,26	19,29	20,20
Negative	Hours	3	192	89	298	5	9	10

Table 2 - Spot prices for Denmark and its neighbours in 2020 (DE is Germany)

The year 2020 was different. Was it a coincidence or a trend? Here follows the same table for the previous year:

Spot Prices	Period	Nordpool						
	01-01-2019	SYSTEM	DK1	DK2	DE	NO2	SE3	SE4
	31-03-2019							
Average	€/MWh	46,88	42,23	43,75	40,90	48,02	46,49	46,89
Minimum	€/MWh	29,90	-48,29	-48,29	-48,93	37,12	2,90	2,90
Maximum	€/MWh	84,97	109,45	109,45	121,46	109,45	109,45	109,45
St.Dev.	€/MWh	7,61	17,00	16,73	18,95	8,52	10,74	11,11
Negative	Hours	0	75	66	89	0	0	0

Table 3 - Spot prices 2019

Some essential differences from 2019 to 2020:

- Lower spot prices due to the Norwegian energy surplus in 2020
- Hours with negative spot prices in 2020, even in Norway and Sweden.
- Hours with negative spot prices in Germany increased from 89 to 298.
- Price volatility (or standard deviation) nearly doubled in southern Sweden (SE3 and SE4).

There is no doubt that stronger transmission grids could stabilize the spot price markets.

It is a main problem in Germany that most of the wind power is concentrated in the northern part of the country. It is much faster to build wind turbines than to reinforce the grids. It is another problem that Germany is only one price zone (together with Luxembourg). The result of these two problems is that the volatile German electricity market rubs off onto the Danish markets, and that most Danish wind power peaks cannot be exported to Germany.

Denmark depends on exchange of wind power variations. The alternative is curtailment of wind energy and load shedding. There are limitations on export to Sweden and Germany. There is still Norway left, but it is understandable that the Danish TSO, Energinet works hard to establish interconnections to new markets, i.e. the Netherlands and England.