

# Electricity in Denmark 2017

## The Danish Electricity Balance 2017

DK 2017	Demand	Supply
Load	34.021	0
Wind	0	14.779
PV	0	789
Central CHP	0	9.516
Local CHP	0	4.373
Export	2.322	0
Import	0	6.886
Total	36.343	36.343

Table 1 – Danish electricity balance 2017 (GWh)

Wind energy made 43% of the gross electricity consumption or 41% of the total balance. The trading opportunities in the international electricity markets made the high share of wind energy possible.

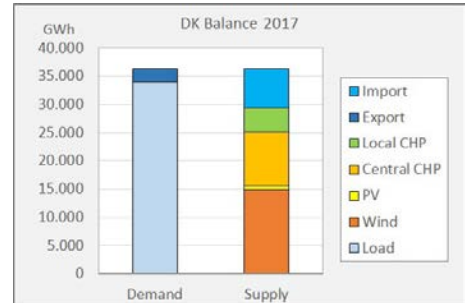


Fig. 1 - Danish electricity balance 2017

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. 2).

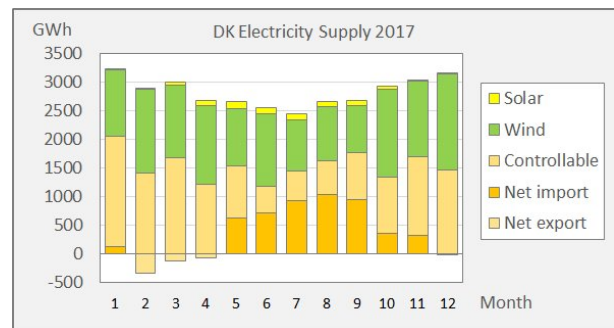


Fig. 2 - Seasonal variations

The increasing dependence on imported electricity seems to have been without problems, so far. Import was 40% of the demand in July 2017 (fig. 3).

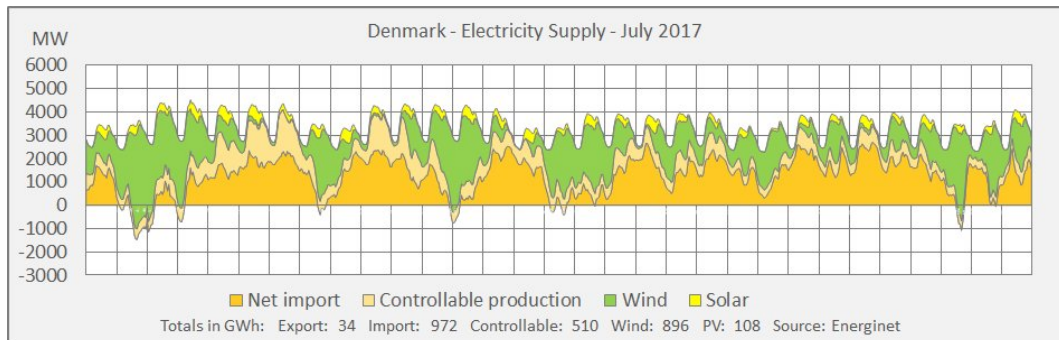


Fig. 3 – Import was the main source of electricity in July 2017 (more charts on <http://pfbach.dk/>)

Wind power can change within a few days from more than demand to nearly nothing. The minimum wind power output on 7 July was 4 MW.

The following maximum hourly values were found for 2017:

- Domestic load: 6108 MW on 21 November
- Net import: 3339 MW on 11 August
- Net export: 2823 MW on 28 February
- Controllable production: 4530 MW on 9 February
- Wind power: 4812 MW on 11 January
- Solar power: 673 MW on 1 June

## Stabilized trends in Spot Prices and CHP Production

### Broken Spot Price Trend:

The spot market value of demand is used as the average spot price of the year in fig. 4. The spot prices dropped by 50% from 2010 to 2015. Since 2015, the spot prices suggest a light increasing trend.

Shrinking European capacity reserves have been mentioned as possible reasons of the change. If this is the case, the market seems to work as intended.

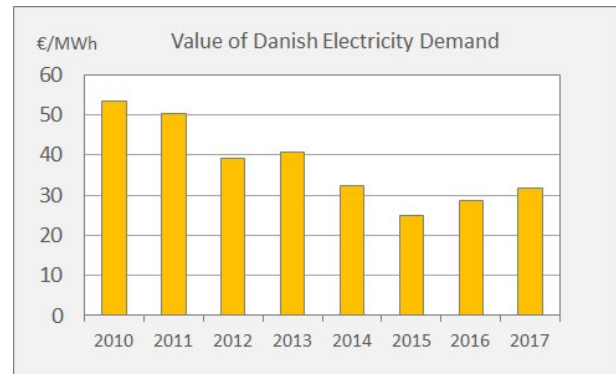


Fig. 4 – Apparently a new trend in spot prices

### Different Market values:

Market values are compared in fig. 5 by setting the value of demand to 100%. There are remarkable differences between the value of wind and solar energy and between export and import.

The import prices have been moderate so far. This may explain the decreasing thermal electricity production in Denmark.

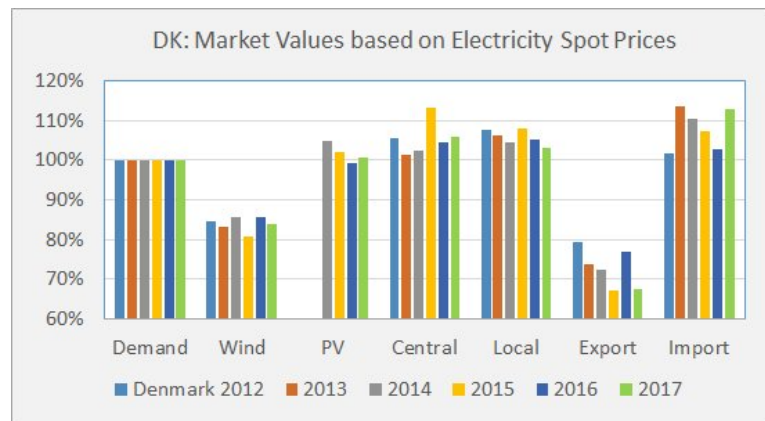


Fig. 5 - Increasing gap between import and export prices

### CHP Output stabilized:

The combined heat and power production (CHP) may decrease further in the next few years, because the support for local CHP systems is expected to stop in 2018, and because the replacement of coal by biofuels may lead to more local heat production without electricity and correspondingly less electricity production on the large CHP units.

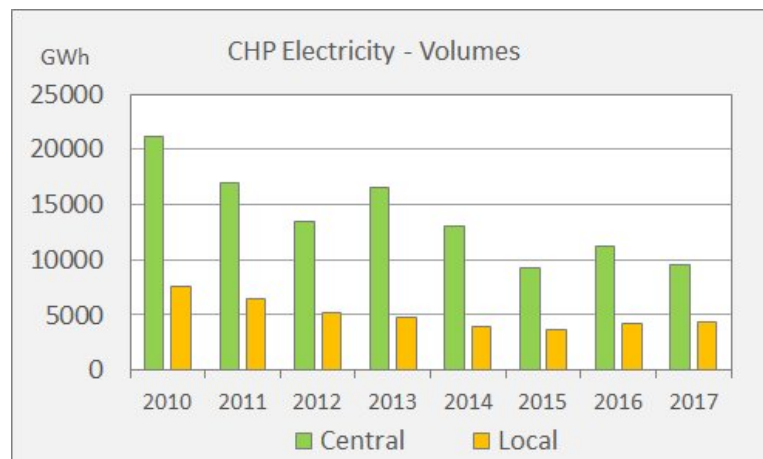


Fig. 6 - From 29 TWh in 2010 to 14 TWh in 2017

This is a dilemma because the CHP systems are the most important domestic sources of flexibility for wind power integration.

## Exchanges and Congestion Income

Denmark exchanges electricity with Norway, Sweden and Germany.

Denmark imported 5.9 TWh from Norway and Sweden in 2017 and exported 1.3 TWh to Germany (fig. 7). The Danish net import was 4.6 TWh and the main flow direction was from north to south.

The total transit from Norway and Sweden to Germany was 2.5 TWh. Transit in the opposite direction was 1.9 TWh.

The exchange between DK1 and DK2 was mainly from west to east.

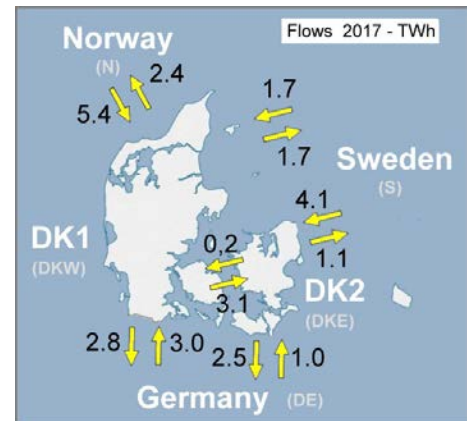


Fig. 7 - Danish electricity exchanges 2017

The HVDC link to Norway was reinforced in 2015 from 1000 MW to 1700 MW technical capacity (fig. 8). The exchange increased correspondingly.

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

Fig. 9 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. For some links and some years, congestion has occurred for about 50% of the hours.

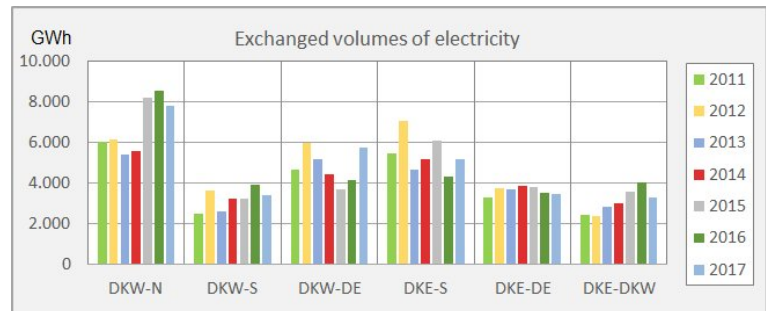


Fig. 8 - Total exchange in both directions 2011-2017

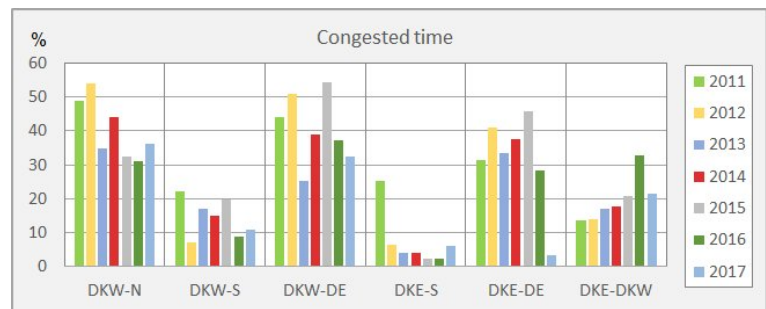


Fig. 9 - Most demand for trade in the north-south direction

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 events 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. 10).

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

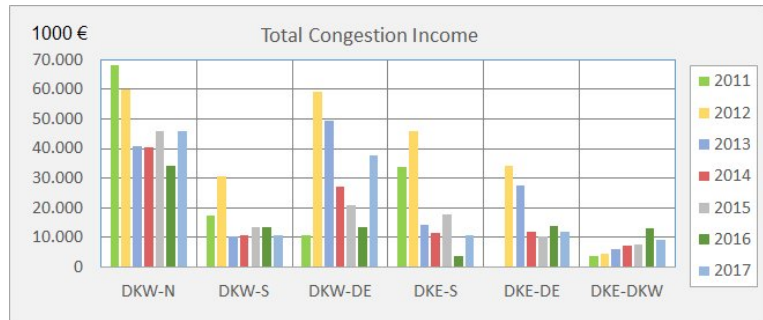


Fig. 10 - The owners of a link share the congestion income.

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. 11).

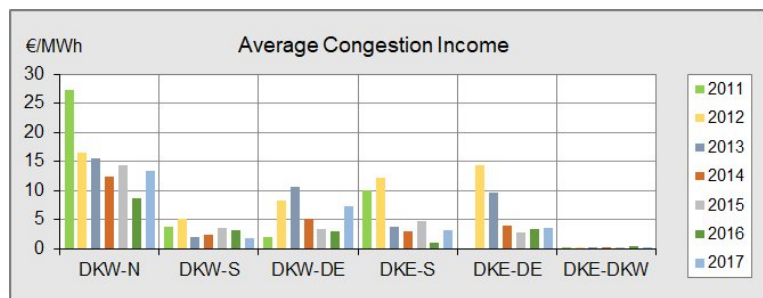


Fig. 11 – The most important links have a high congestion income per MWh transferred

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.

### Capacity Limitations Cause Concern in Denmark

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

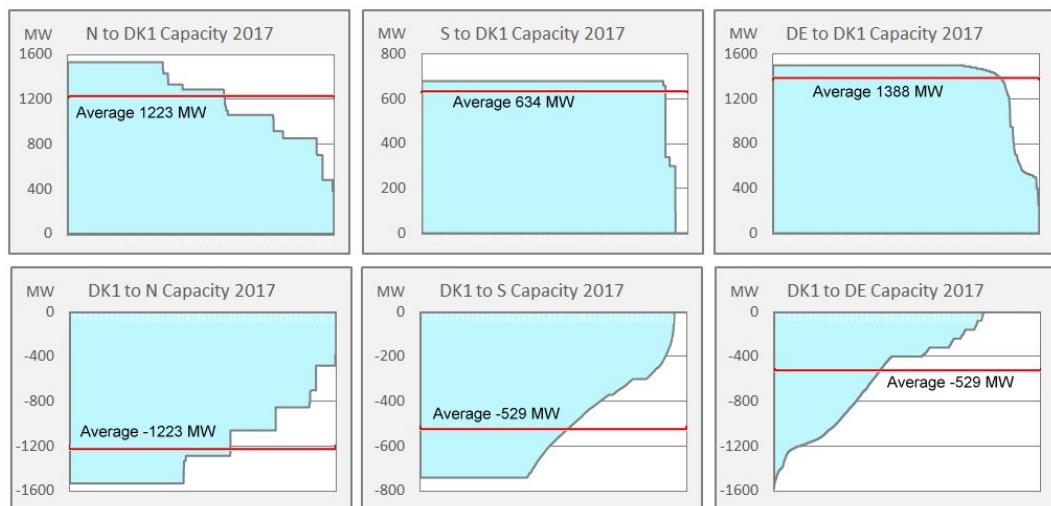


Fig. 12 - Available capacities for DK1 in 2017 - Duration curves – Export capacity < 0

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.

Fig. 12 demonstrates some characteristics for the interconnections for DK1 (or DKW).

The capacity limits for the Skagerrak link (DK1-N) seem to be technical reductions for the interconnector itself. There have been cable failures, and the reductions are symmetrical for the two directions. The link has four poles. At least one pole has been available every hour of the year.

The Konti-Skan link (DK1-S) has two poles. The link has been completely unavailable for about 400 hours in 2017. The reductions are asymmetrical. The average capacity for export from Denmark is 529 MW or 71% of the full capacity.

The AC<sup>1</sup> interconnection to Germany is even more asymmetrical. The average export capacity from Denmark is only 33% of the maximum capacity, and export was completely blocked for 1860 hours or 20% of the year. The reason is congestion in internal German grid.

Fig. 13 shows duration curves for DK2 (East Denmark).

The AC interconnection with Sweden has reduced the export capacity for more than half of the hours. The average capacity is about 71% 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.

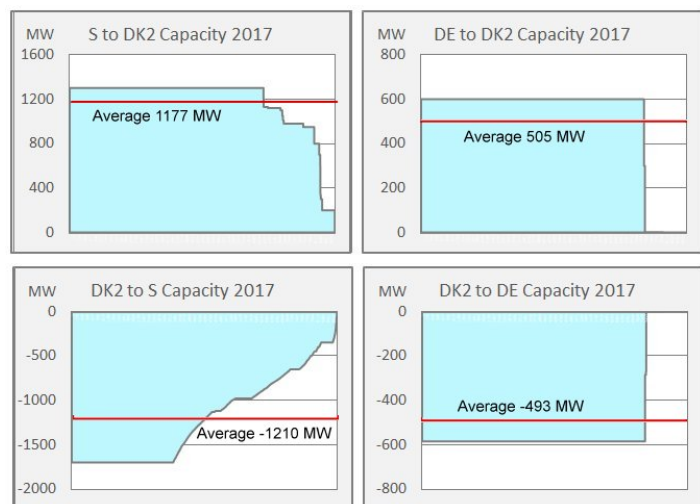


Fig. 13 - Available capacities for DK2 in 2017 - Duration curves – Export capacity < 0

### Bottleneck in Swedish Grid Prevents Danish Export

Capacity reductions on the links to Sweden are barriers to Danish export of wind energy. The reasons for such reductions for Nordic interconnectors must be reported to Nordpool. Therefore, it is possible to identify the declared reasons, hour by hour.

The tables 2 and 3 show the five most frequent reasons for Danish export reductions in 2017 on the Konti-Skan (DK1-SE3) and Øresund (DK2-SE4) interconnections.

<sup>1</sup> AD: Alternating Current contrary to DC or Direct Current



DK1 > SE3			
Code	Hours	Reason	Location
1010	4044	Normal capacity (100 MW tolerance)	No bottleneck causing reduction
1624	3608	Stability	The West coast corridor in Sweden (SE3)
1434	363	Planned outage	Sweden (SE4)
1125	275	Planned outage on cross-border connection	The Konti-Skan interconnection (SE3-DK1)
1425	144	Planned outage	The Konti-Skan interconnection (SE3-DK1)

Table 2 - Frequent conditions for export to Sweden in 2017 on the Konti-Skan link

DK2 > SE4			
Code	Hours	Reason	Location
1010	3547	Normal capacity (100 MW tolerance)	No bottleneck causing reduction
1624	3491	Stability	The West coast corridor in Sweden (SE3)
1126	1422	Planned outage on cross-border connection	The Øresund interconnection (SE4-DK2)
1433	108	Planned outage	Sweden (SE4)
2524	62	Thermal limitation	The West coast corridor in Sweden (SE3)

Table 3 - Frequent conditions for export to Sweden in 2017 on the Øresund interconnection

The west coast corridor forms a bottleneck within price zone SE3 in Sweden. This bottleneck has limited the capacity for Danish export about 40% of the hours in 2017.

Import from Denmark can together with production from the nuclear power station, Ringhals cause high loads in the transmission grid west of Lake Vänaren. By limiting import from Denmark, the Swedish TSO moves an internal bottleneck to the national border.



Fig. 14 - Sweden's west coast corridor

This is a technical trade barrier, which should normally lead to a redesign of the price zone structure, but EU's GD Competition accepted in negotiations about 8 years ago a temporary exception. In return, Svenska Kraftnät promised to build a 400 kV line Lindome-Stenkullen, which was ready for operation in 2012 (fig. 14).

However, the congestion problems continued. A new 400 kV line Stenkullen-Skogssäter is planned for commissioning in 2021. It remains to be seen if the conditions for export from Denmark to Sweden will improve after 2021.

The true nature of the interrelation between spot prices and available export capacity from DK1 to SE3 is uncertain.

## 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 result is that the German targets for CO<sub>2</sub> emission in 2020 seem to be unattainable.

The most important renewable sources are wind and photovoltaics (PV). Other important renewables are hydropower and bio fuels. The share of wind energy was about 21% and PV

about 7%. The corresponding Danish figures are 43% and 2%. Nevertheless, Germany seems to have more difficulties from wind power than Denmark.

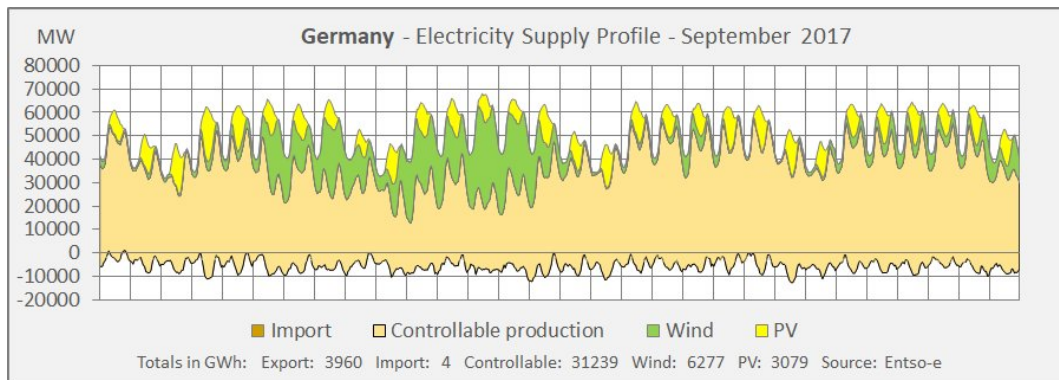


Fig. 15 - Germany, September 2017

The chart from September 2017 shows high wind power output in the first half of the month and practically no wind power in the other half. It also demonstrates why solar power has a more valuable profile than wind power.

The German spot prices reveal some of the problems (table 4).

Spot Prices	Period	Nordpool						
	01-01-2017	SYSTEM	DK1	DK2	DE	NO2	SE3	SE4
	31-12-2017							
Average	€/MWh	29,41	30,09	31,97	34,20	28,83	31,24	32,18
Minimum	€/MWh	5,00	-50,04	-50,04	-83,04	2,97	1,70	1,70
Maximum	€/MWh	127,32	120,01	120,01	163,52	114,70	130,05	130,05
St.Dev.	€/MWh	5,18	10,67	10,98	17,65	4,63	7,97	8,95
Negative	Hours	0	84	58	147	0	0	0

Table 4 - Spot prices for Denmark and its neighbours (DE is Germany)

Germany had negative spot prices in 147 hours in 2017. The two Danish price zones have 84 and 58 hours with negative prices. Norway and Sweden did not have negative spot prices at all. The standard deviation is an indicator of the price volatility. It was nearly 18 €/MWh in Germany and less than 5 €/MWh in southern Norway (NO2).

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 and Austria). 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. The correlation (R) between Danish wind power and the export capacity (DK1 to DE) is 0.48.

Denmark depends on exports of wind power variations. The alternative is curtailment of wind energy. 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.