Getting Rid of Wind Energy in Europe

Recently, I heard two representatives of the wind power industry argue for more grid capacity for export of Danish wind energy. In 2009 the CEPOS report, "Wind Energy – The Case of Denmark"[1] assumed that parts of the increasing wind energy production was exported. This caused an indignant academic criticism[2].

Since then, the share of wind energy has doubled, and it has been clearly demonstrated that there is a high correlation between Danish wind power output and Danish exchange of electricity with the neighbouring countries. The intentions of developing flexible electricity demand for absorbing the wind power variations did not yet materialize.

Wind energy has become a Danish speciality. The cost of wind energy has fallen considerably. This development encourages the installation of more wind power. New interconnections to the Netherlands (CobraCable) and to Great Britain (Viking Link) are expected to absorb the future Danish wind power peaks.

Large amounts of wind power are being installed in other European countries. This note is an attempt to describe how the present European grids and markets distribute the wind energy.

The average electricity flows in 2016

The large interconnectors move electricity from country to country. A country can have both import and export, even within the same hour (transit). Germany has a central location in Europe. Fig. 1 shows resulting exchanges for borders and countries around Germany in 2016.

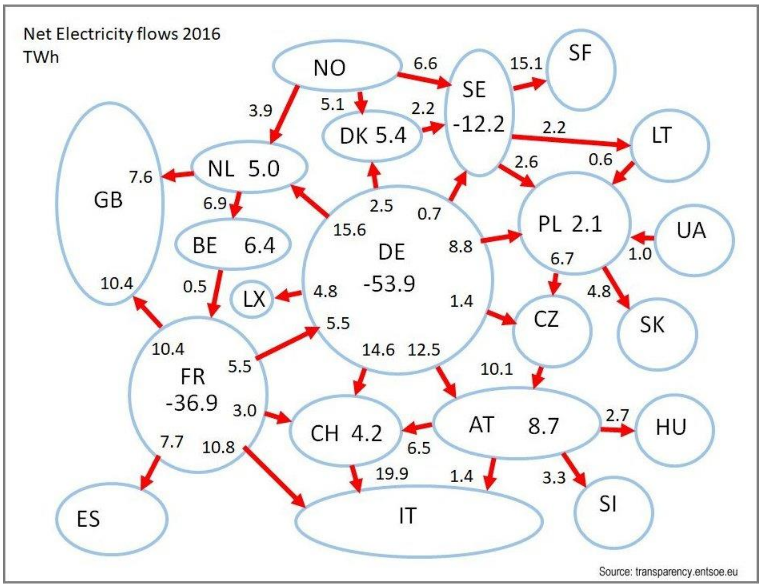

Fig. 1 - Net balances and exchanges in 2016 for Germany and surrounding countries

The total balance, shown for certain countries, is positive for import and negative for export. Germany is the largest exporter of electricity. The net export in 2016 was 53.9 TWh. Denmark's net import was 5.4 TWh.

France was the second largest electricity exporter in Europe in 2016. Germany and France form at block with about 10% surplus of electrical energy. This surplus is conveyed to other European countries. Safe operation of the highly meshed European AC power grid is a complicated matter. Due to the variability of wind and solar power, the grids are often operated close to the security limits.

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[1] http://pfbach.dk/firma_pfb/cepos_wind_energy.pdf
[2] http://pfbach.dk/firma_pfb/ceesa_danish_wind_power.pdf

Wind power curtailment is regularly necessary for relieving the pressure on the grids. It is known in Germany as *redispatch*. The cost of redispatch has been rapidly increasing since 2013 (fig. 2). The redispatch cost is still small compared with the total support for renewable energy in Germany, but the question is if the trend lasts.

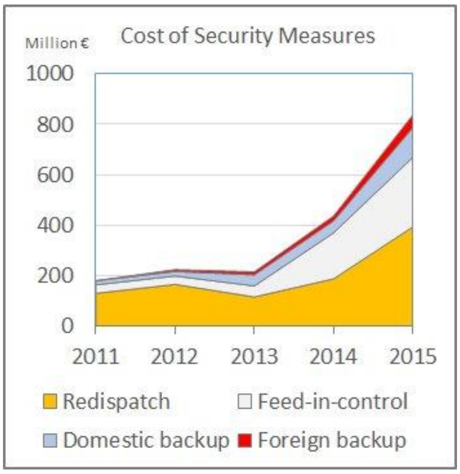


Fig. 2 - Growing German cost of security measures

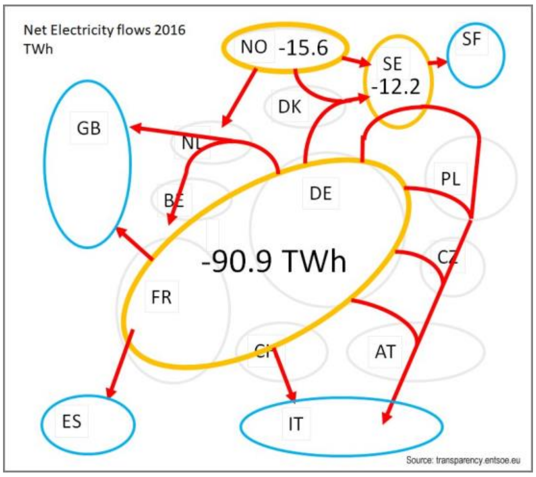


Fig. 3 - Transport corridors in west and east

Fig. 1 may look confusing. Fig. 3 is a simplification with the purpose of showing the main transport corridors. Germany and France is the dominating supply block. Norway and Sweden is another supply block. The demand regions are Italy, Great Britain, Spain and Finland.

Most German wind power is concentrated in the northern states. During high wind periods, this leads to heavy flows in both internal German grids and in the two corridors west and east of Germany.

The flow in the western corridor is controlled by a phase shifting transformer at the German Dutch border. This seems to keep the transit through Belgium at a low level. The TSOs in Poland and the Czech Republic do not want to invest in stronger grids for the transit of German wind energy. Therefore, the first of four phase shifting transformers at the German Polish border has been commissioned.

Denmark is a small player in this game. Fig. 3 seems to suggest Denmark to send surplus wind power to Sweden. Such additional transit is not welcome in Sweden. Import from Denmark was curtailed in more than 1000 hours in 2016. An analysis of the flows during the storm "Urd" in December 2016 identifies bottlenecks in the Nordic grids[3]. Those, who would like to study the European electricity flows in 2016 in more detail, can download hourly time series of all exchanges, used in this note, from http://pfbach.dk/.

The results mentioned above seem to justify the interest of the Danish TSO in new links to the Netherlands and to Great Britain.

[3] http://pfbach.dk/firma_pfb/references/pfb_bottlenecks_duing_storm_urd_2017_01_07.pdf

New transmission corridors in Germany for export of wind energy

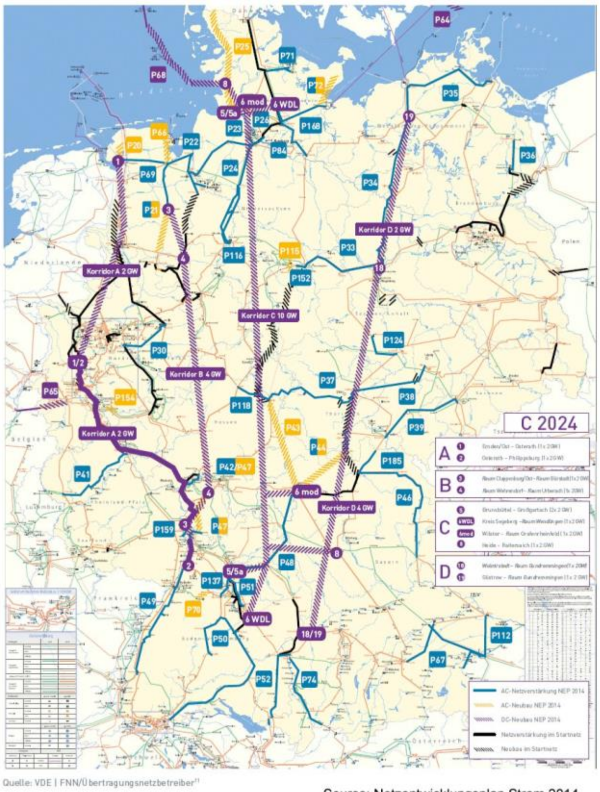
Germany has planned to reinforce its internal grids in order to be able to move the increasing surplus of electricity from north to south and to limit the future cost of security measures (fig. 4). The construction works have started. It remains to be seen when the new large transmission facilities can be commissioned.

The popular explanation is that the new transmission capacity is needed for the electricity supply of the industrial centres in southern Germany.

The flows, identified in this note, suggest wider purposes. The electricity supply for the industries in southern Germany is not a real problem. The problem is to distribute the wind power surplus to other countries in Europe. It takes a larger "classic" electricity demand to absorb the variations from wind and solar power.

It is a matter of bookkeeping if German wind energy, which is consumed in other countries, benefits the energy transition (die Energiewende).

A transmission system must be able to handle extreme and rare conditions. The flows can vary from day to day depending on maintenance works and forced outages of power plants. The planning is based on statistical methods.



Source: Netzentwicklungsplan Strom 2014

Fig. 4 - The new German transmission corridors

The typical result is a low average utilization of the grid. Some elements will be fully loaded in an optimally designed grid. Congestions can move around depending on the operational situation. This is always carefully monitored and the dispatch of production must be adjusted correspondingly.

When a large amount of fluctuating production with a low capacity factor is added to the system, the transmission capacity must be reinforced disproportionately in order to limit the congestion problems. The average utilization of the grid will be correspondingly lower.

Another purpose of the grid reinforcements in Germany is to avoid splitting the country up into price zones. Low market prices in northern Germany and higher prices in southern Germany will not be politically acceptable. A stronger grid reduces the need for countertrade and redispatch.

It was also Sweden's intentions in the 1990s to maintain a single price zone, but the Swedish grid is not yet strong enough for preventing congestion problems. It is a question if it is common sense to build a transmission system that strong.

The increasing German export of electricity

From a Danish point of view, there is good reason to look closer at the development in our neighbouring countries. The German Energiewende will influence Denmark's opportunities.

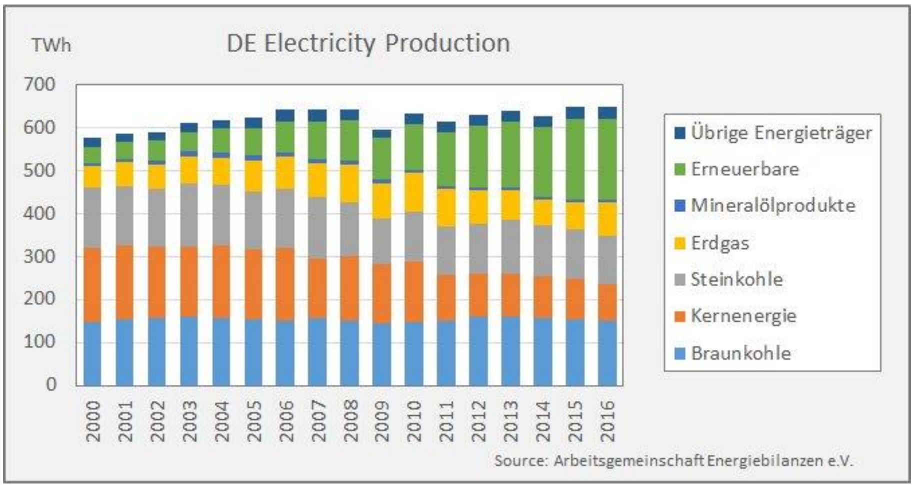


Fig. 5 - Growth in German renewable electricity from 3% in 2000 to 30% in 2016

The largest renewable sources are wind (12%), biomass (7%) and photovoltaic (6%). The renewable energy more than outweighs the reduced nuclear production (from 28% to 13%).

The changing energy balance is remarkable. The electricity export has increased to more than 50 TWh (10% of consumption) since 2000.

This development may have different reasons.

New subsidized renewable energy adds to the supply. Previous investments in thermal power plants are sunk money. The electricity production continues as long as the market can pay the variable costs.

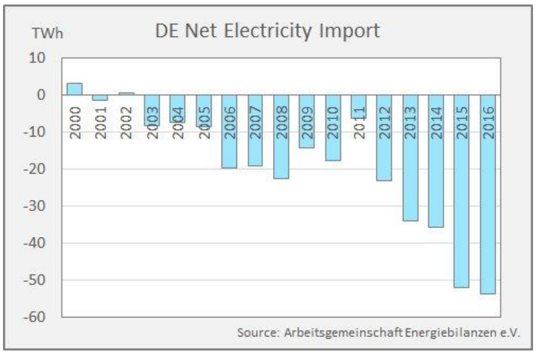


Fig. 6 – Electricity export has increased from nothing to more than 50 TWh since 2000.

The capacity credit of wind and solar power is very low. It takes some dispatchable backup capacity to maintain normal security of supply. When power plant owners want to close down operations, decommission can, depending on location, be prevented, if the plant is considered to be indispensable as backup capacity.

The result is an oversupply of electrical energy, increasing export and declining electricity prices in the spot market.

It takes a better understanding of the reasons to predict how long the growth in electricity export from Germany will continue, but there is no doubt that an increasing export will have a considerable impact on the European electricity markets, particularly for Denmark.

Norwegian flexibility

Norway was the pioneer in developing electricity markets. The hydro system with large water reservoirs has the flexibility, which most other nations have lost, but it also has the challenge that the inflow of water can vary considerably from year to year (fig. 7). Before the market introduction (with the new energy law in 1991), it was Norwegian security policy to have surplus of energy in 9 years out of 10. Surplus of water could be spilled or used for export of electricity at low prices.

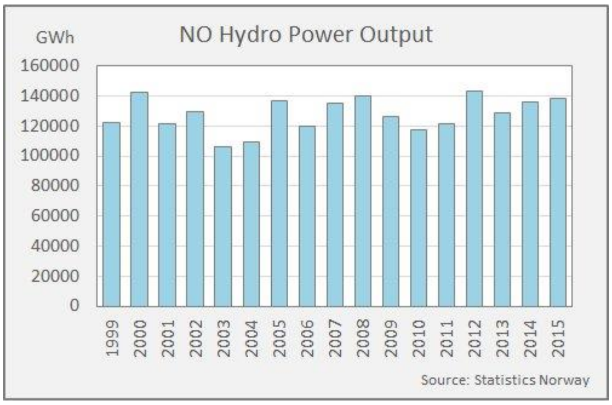


Fig. 7 - Different inflow of water from year to year in Norway

A competitive market was supposed to reduce investments and lead to a more balanced energy market.

12 of the 19 years in fig. 8 are export years. The average exchange for the 19 years was about 6 TWh export. Fig. 8 does not suggest any increasing or decreasing trend.

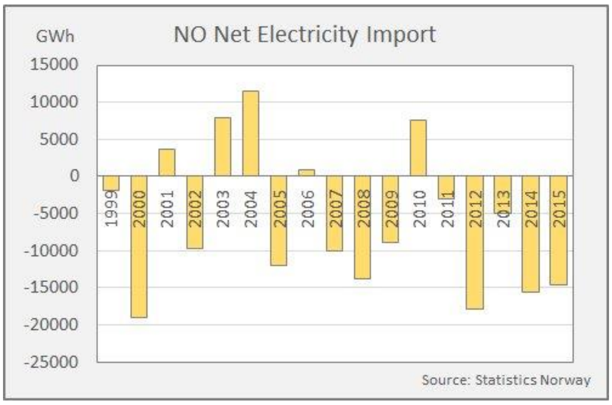


Fig. 8 - Energy surplus 12 years out of 19

There seems not to be reason to expect different Norwegian energy balances in the future apart from the hydrological variations.

Fig. 9 shows the weekly hydro storage levels since 2006 and the slightly declining market prices for electricity.

The Norwegian gross consumption of electricity was 130 TWh in 2015. The total storage capacity is 82 TWh.

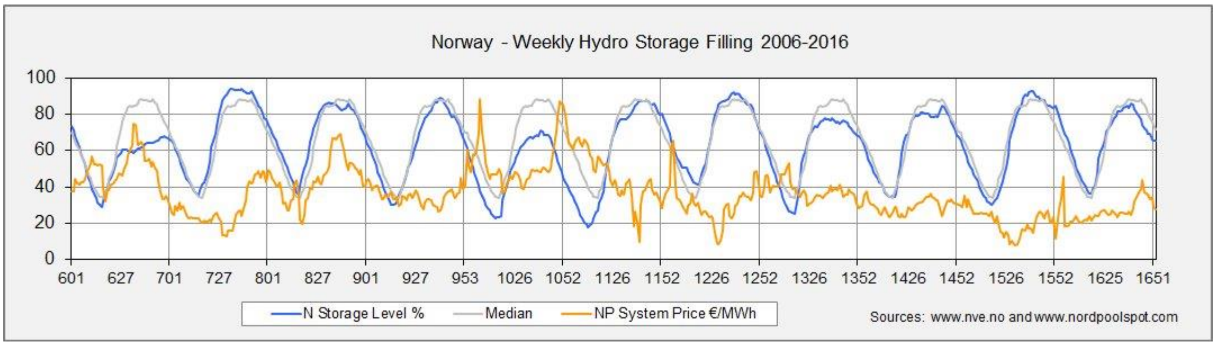


Fig. 9 - Rather normal hydrological conditions the last few years, but decreasing market prices.

2006 and 2010 were dry years. Fig. 8 confirms that exchange of electricity was used for bringing the storage level (fig. 9) back to the median profile.

Declining market value of wind energy

Hourly spot market prices are used for an estimation of market values. In most hours, Danish spot prices are set in either Germany or in the other Nordic countries. One possibility is to calculate a plain average of a year's spot prices. In this note, *weighted average prices* are used for quantifying the values of different profiles, such as load, wind energy and solar energy. Denmark has two Nordpool price zones. The calculations are based on data for both price zones. 2016 was a poor wind year and therefore maybe less typical (fig. 10).

Since 2010, the Danish share of wind energy has doubled from about 20% to about 40%. In the same period, the relative market values of different energy profiles have changed (fig. 11).

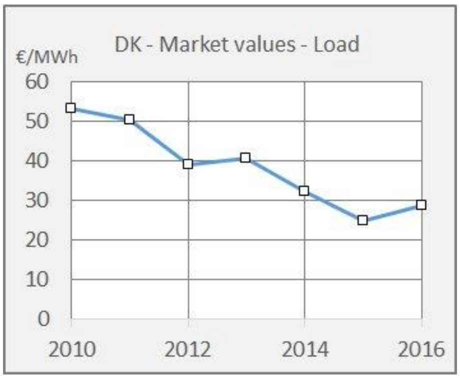


Fig. 10 - Declining spot price level since 2010

Fig. 11 - Low market values of wind and export profiles

The reference in fig. 11 is the load value. The relative market values for dispatchable power is between 100% and 110%.

The market value of Danish wind energy seems to have stabilized between 80% and 85%. The market value of Danish electricity export is still declining.

DE	Energy	Value	Value
2016	TWh	Mill. €	€/MWh
Load	481,1	14536	30,22
Wind	77,0	1927	25,03
Solar	34,5	924	26,83
Exchange	-53,9	-1491	27,65
Net import	0,6	18	30,67
Net export	54,5	1509	27,68

Table 1 - German market values 2016

DK	Energy	Value	Value
2016	TWh	Mill. €	€/MWh
Load	34,0	973	28,65
Wind	12,8	314	24,55
Solar	0,7	21	28,47
Exchange	5,1	176	34,51
Net import	7,0	215	30,70
Net export	1,9	39	20,05

Table 2 - Danish market values 2016

German and Danish market values can be compared in the tables 1 and 2.

Net import and net export are defined as national net exchanges, hour by hour.

The differences in load values may be the result of influence from the other Nordic countries. Germany exports about 10% of the electricity production at prices, which are 8% lower than the market value of the load. Import has practically the same market value in Germany and Denmark. The market value of Danish export is 30% lower than the market value of load.

Flexible demand for wind energy is still missing

Declining spot prices indicate an oversupply situation. Oversupply seem to be a natural condition for power systems with high shares of fluctuating production (wind and PV) and with sufficient backup capacity for maintaining usual security of supply level.

Wind and solar energy displaces thermal production due to the low variable costs. The thermal units cannot survive only by filling the gaps in wind and solar power production. Declining market prices will force thermal units to close down.

When the share of wind energy exceeds about 40% of the electricity demand, overflow will be an urgent problem. The present solutions are export or curtailment.

New transmission systems can move electricity, but they do not produce or demand electrical energy. The large transmission projects can relieve problems in the short term, but they are not the solution.

Grandiose ideas on flexible demand have been discussed for at least 20 years. New technologies for storing or converting electricity have been outlined, but nothing was made in essential scale so far.

Enthusiastic supporters of renewable energy have succeeded in the installation of a large capacity of fluctuating and non-controllable production without worrying about the proper utilization of the fluctuating energy output.

The great idea was to replace fossil and nuclear energy by renewable energy sources, but the demand side has not been prepared for such transition.

A balanced development of fluctuating supply and flexible demand is necessary for a stabilization of the European electricity markets. Until then it is most likely that the development from the recent years will continue. This means more surplus energy, declining market prices, more congested grids, more curtailment of renewable sources and increasing electricity prices at consumer levels.