

Statistical Survey 2008

1. General

The purpose of the study is to analyze the impact of wind power on market prices and to discuss its possible influence on power system economy in Denmark.

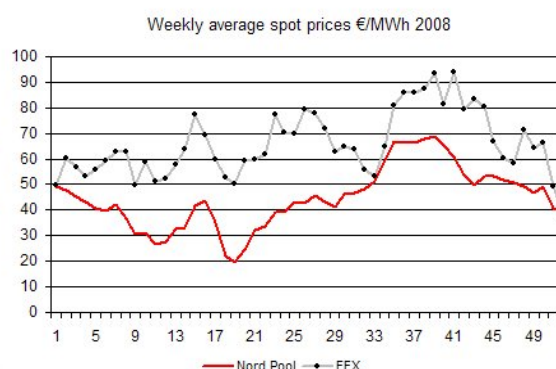
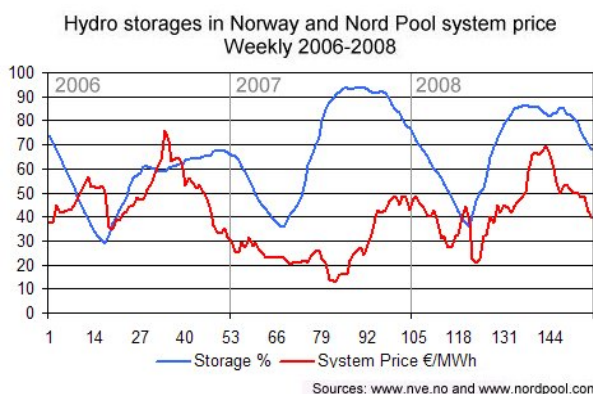
The study is made by Paul-Frederik Bach for Renewable Energy Foundation in London.

The purpose of the survey is to screen a set of data on hourly market and operational conditions in order to identify characteristics for further analysis. The data are extracted from the Energinet.dk web site unless other sources are specified.

Abbreviations:

EEX	European Energy Exchange	DKE	Denmark East	DE	Germany
NP	Nord Pool	N	Norway		
DKW	Denmark West	S	Sweden		

2. Neighbouring countries in 2008



The weekly spot prices seem to have encouraged a southbound transit from the Nordic area most of the year.

The NorNED interconnection between Norway and Netherlands was taken in normal operation in May 2008. The export from Norway to Netherlands may have contributed to higher spot prices and lower storages levels than in 2007. The export to Netherlands was 3 TWh in 2008. The total export from Norway was 11 TWh in 2008.

3. Main characteristics of Danish power systems in 2008

3.1. Annual key figures

The following table is based on market data from Energinet.dk:

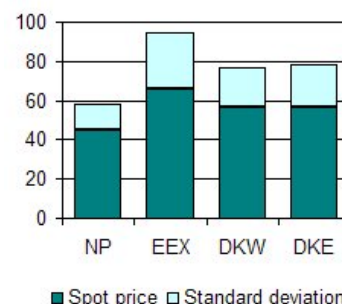
	Demand MWh	Net exchange		Wind generation MWh	% of demand	Wind energy export		
		Export MWh	Import MWh			MWh	Hours	% of wind generation
West	21.619.685	2.682.452	1.655.208	5.191.701	24,0	2.203.872	4.998	42,4
East	14.482.611	585.248	3.066.726	1.785.197	12,3	374.736	2.213	21,0
Denmark	36.102.296			6.976.898	19,3			

The net exchange has been calculated hour by hour as a total of all exchange from each of the two Danish systems. In this context the *wind energy export* has been defined for each system and for each hour as the smaller value of generated wind energy and net export.

The average market conditions are summarized in this table:

	Area price	St.Dev.		Spot price	St.Dev.
	€/MWh	€/MWh		€/MWh	€/MWh
DK West	56,33	20,22	NP	44,61	13,71
DK East	56,52	21,91	EEX	65,68	28,66

Average spot prices €/MWh 2008

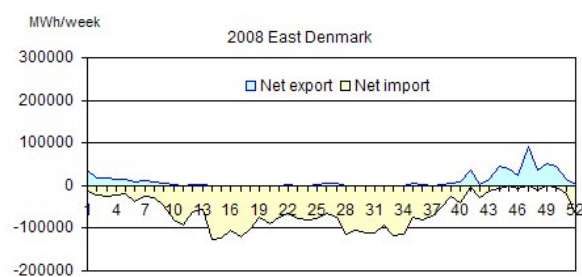
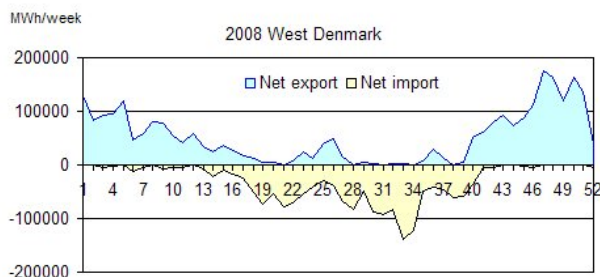


The standard deviation is an indicator of the price volatility. EEX has a higher volatility than Nord Pool. Both Danish areas are in between.

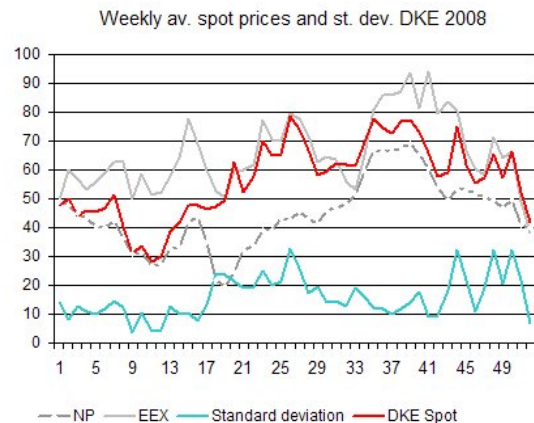
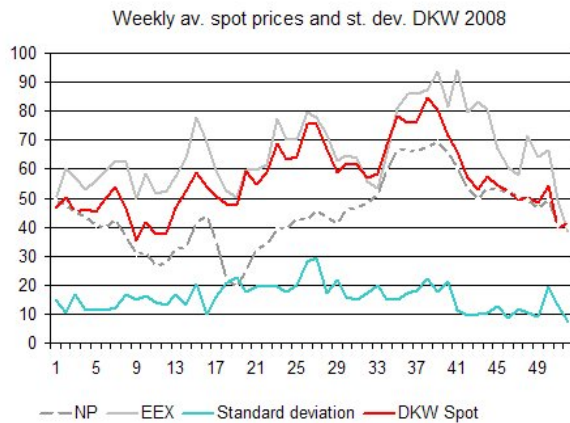
The magnitude of the overflow problem due to Danish wind power can be indicated in a table with number of hours with spot prices equal zero and balancing prices downwards equal to or below zero. When the price of balancing (or regulating) power is below 0 the system operator must pay for export of energy. Nord Pool is currently preparing the handling of negative spot prices.

No of hours	Spot price = 0	Spot price >100	Bal. price <= 0	Bal. price >100
	DK West	28	193	80
DK East	9	225	25	552
Nord Pool	0	2		
EEX	35	888		

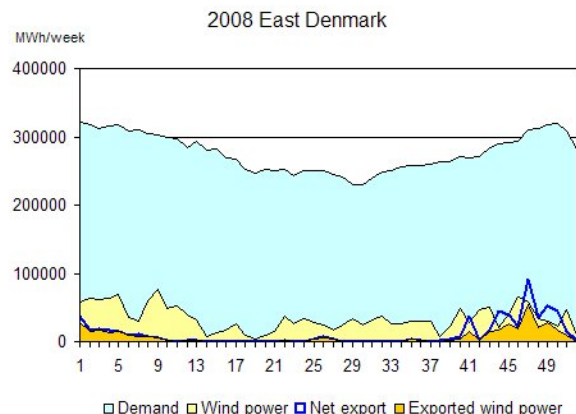
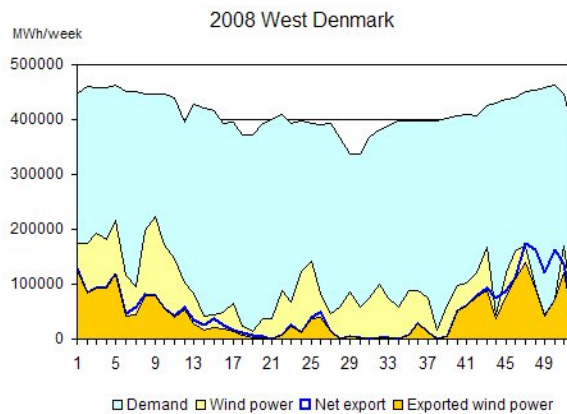
3.2. Weekly averages



The diagram shows that surplus of energy during cold periods is characteristic of the Danish power systems, probably due to CHP (combined heat and power).

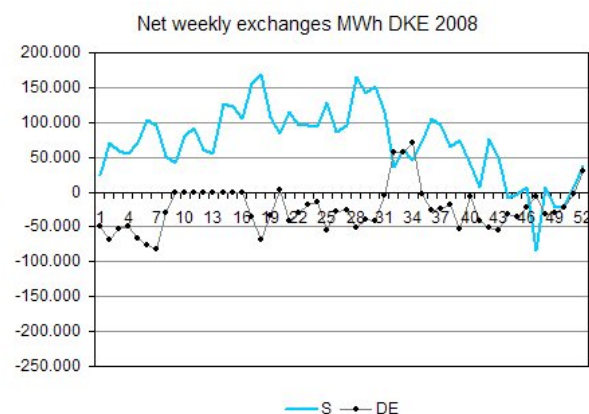
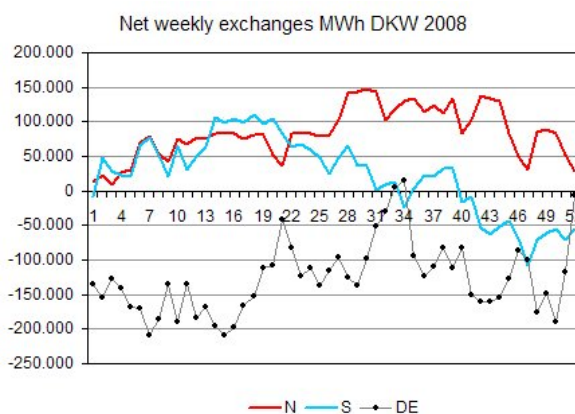


During transit periods congestion on one of the interconnectors is common. The spot prices of the two Danish systems follow either Nord Pool or EEX depending on which interconnector is congested. The diagram shows that during the weeks 20 to 32 both Danish systems joined the German price level in order to compete on energy from Norway.



Following the definition in 3.1 the wind energy is divided into an export share (the light brown area) and a share used locally (the light yellow area). The dark blue curve is the net electricity export. There seems to be some correlation between wind energy and net export.

Net weekly exchanges have been calculated for each border in order to verify the transit directions suggested above from the spot prices.



3.3. Operational Incidents

The Energinet.dk Annual Report 2008 is not yet available.

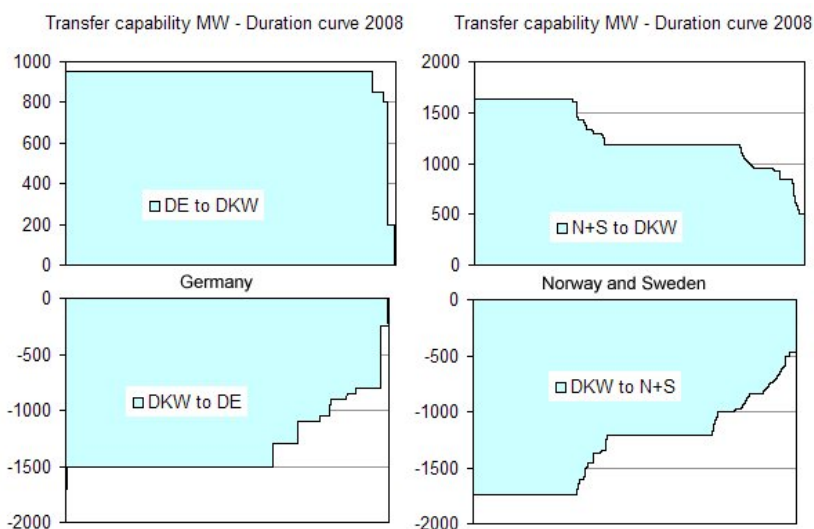
3.4. Interconnector Capacity

The electricity market is the modern tool for optimization of power system operation across national borders. Sufficient transport capacity is a decisive factor to both a reasonable system security and an efficient market service.

The trading capacity on the 400 kV AC interconnection between West Denmark and Germany depends on stability limits of the interconnected AC networks.

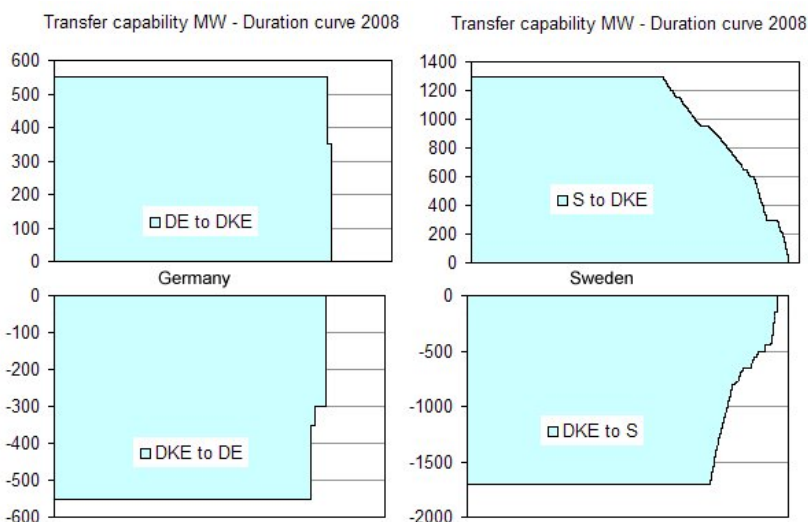
The duration curve shows how the transfer capability from Denmark to Germany has been more or less reduced nearly half of the time in 2008.

The HVDC links to Norway and Sweden still suffered from severe hardware faults during 2008. The 500 MW Skagerrak 3 link was back in operation in July 2008 after severe transformer faults.



The Kontek HVDC link between Denmark East and Germany was unavailable in March and April and again a couple of weeks in June.

The capacity reductions on the AC interconnection between Denmark East and Sweden reflect the Swedish congestion policy. The Nordic system operators are using different methods for the handling of internal bottlenecks. Norway is divided into areas with different area prices in case of congestion. It is a Swedish policy to maintain the same spot price for all parts of Sweden. Therefore internal bottlenecks are transferred into reduced trading capacity on interconnectors.



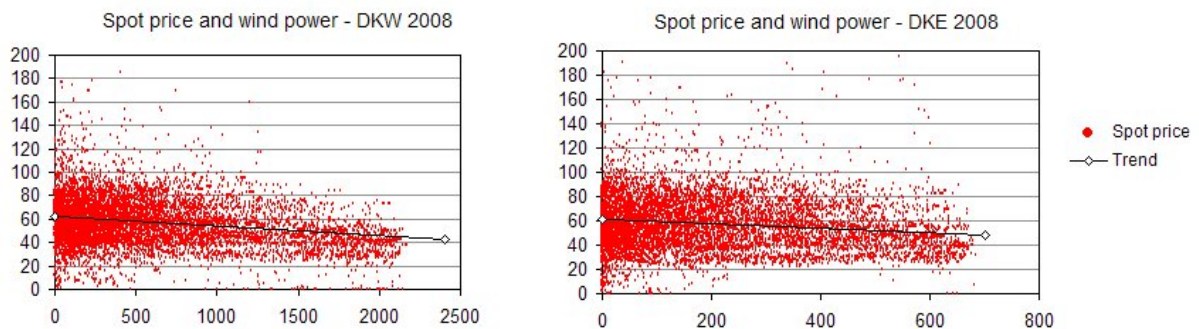
The interconnections can help smoothing spot price oscillations due to intermittent generation (particularly wind power), if there is capacity available for this purpose.

4. Wind Power and Spot Markets

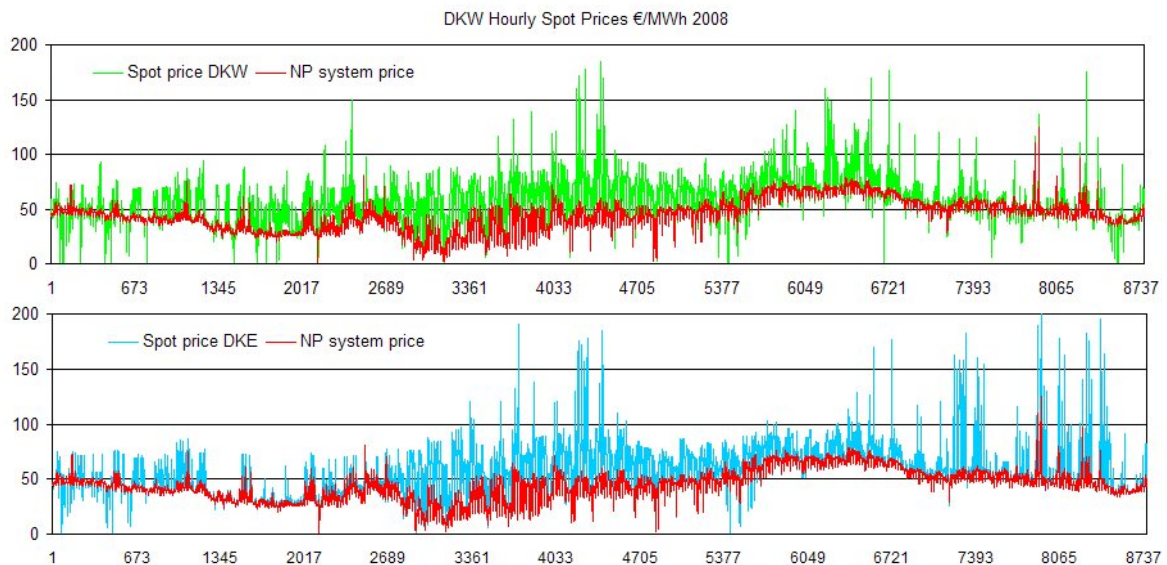
Wind power has an impact on market prices in two ways:

- increasing wind generation may cause reduced prices
- the volatility of wind power may cause price volatility

The following diagram shows local spot prices and wind power for the entire year 2006.



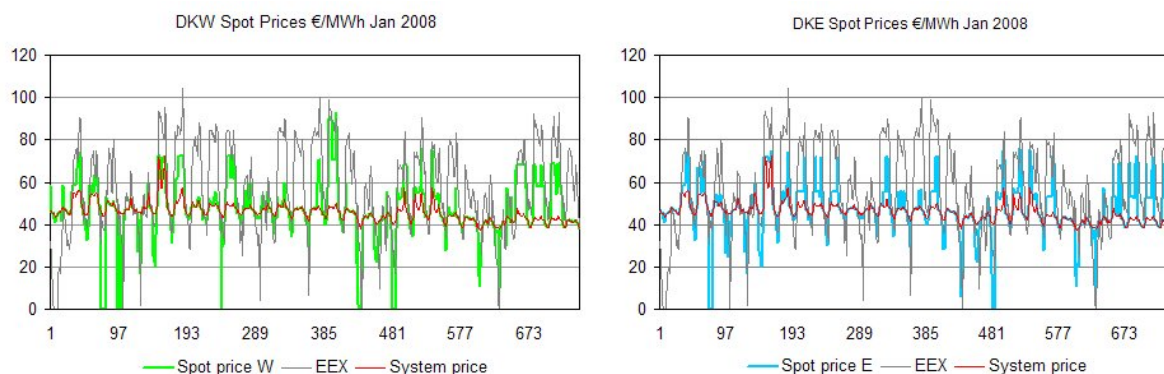
The average trend is obvious, but the dispersion is considerable and several other factors have an impact on market prices. A view on the hourly spot prices reveals some characteristic periods.



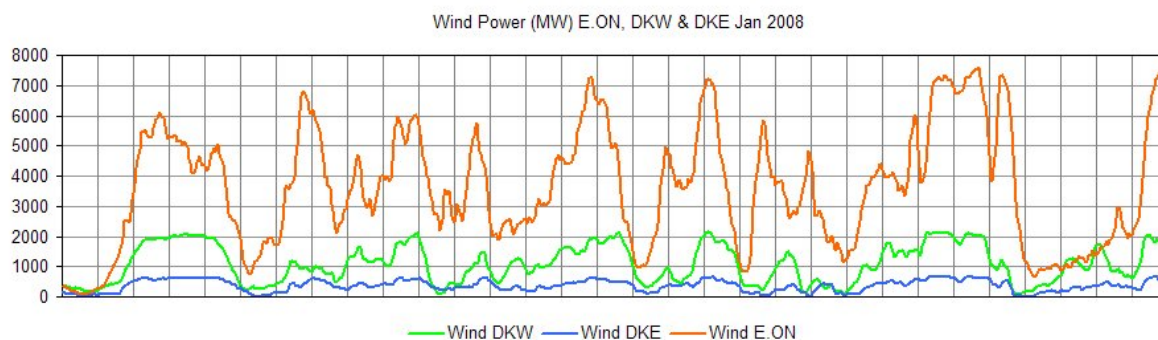
Some price volatility can be observed in the Nord Pool spot prices in May and June. Price patterns are similar in DKW and DKE in 2008. Two diagrams were necessary in order to identify differences. There has been very little overflow in 2008, but periods with moderate price spikes. Causes and relations will be demonstrated in examples.

4.1. January 2008: Congestion and overflow

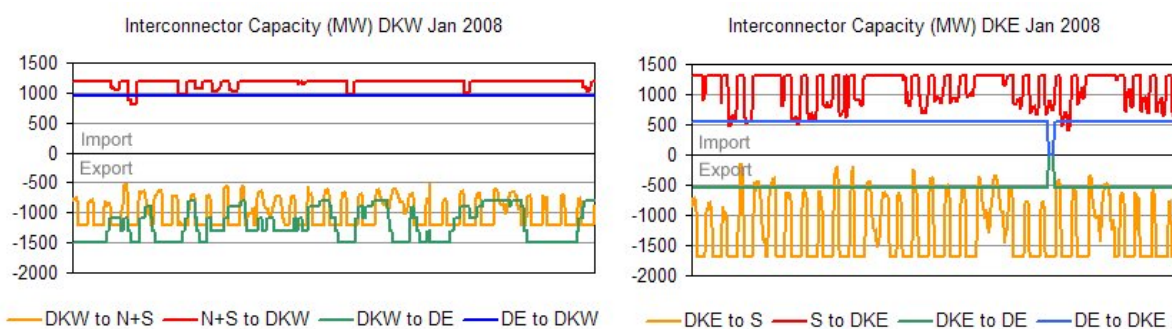
The zero prices on the previous diagram have drawn our attention to the first days of 2008. The following diagram shows the spot prices in January:



The wind power image for January 2008 shows a nearly perfect synchronization of wind power output in Germany and Denmark:

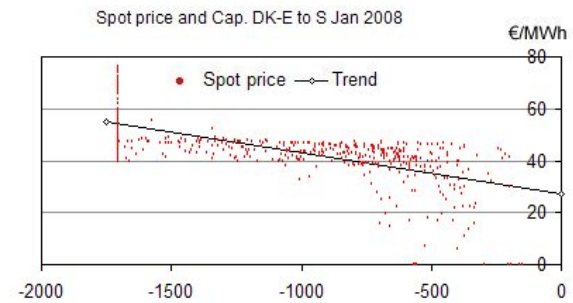
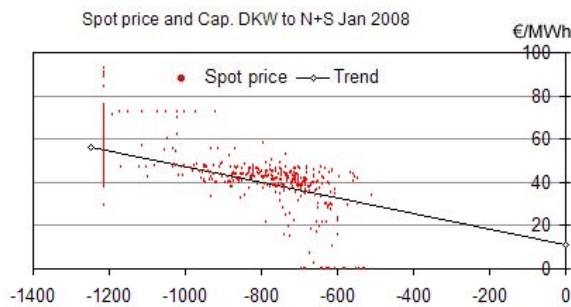


One reason for the energy overflow in Denmark is that the export capability towards Norway and Sweden has been reduced every night the first 10 weeks of 2008, particularly to DKE:



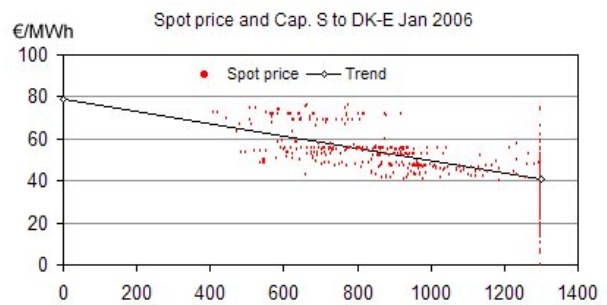
The spot prices have been determined by the combination of wind power, export capacity, import capacity and other circumstances. The correlation between spot prices and wind power is weak (DKW: -0.32 and DKE: -0.12).

The best correlation was found with the export capability towards Norway and Sweden (DKW: -0.63 and DKE: -0.67):

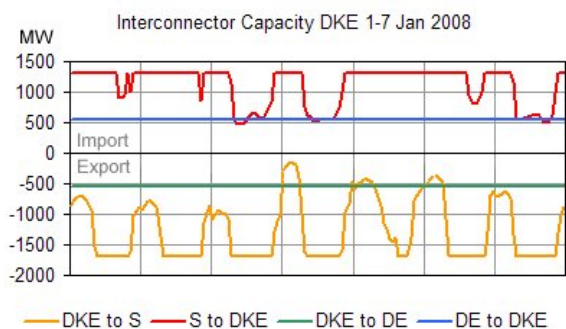
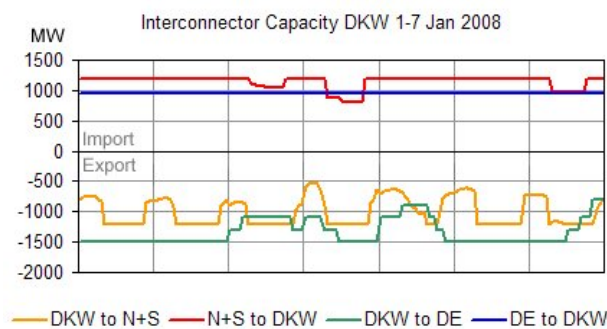


Obviously reduced export capability means reduced spot prices, but if spot prices are related to import capability, grid reductions seem to give increasing prices (correlation DKE: -0.65).

This contradiction can be explained, if we take a closer look at the first 7 days.

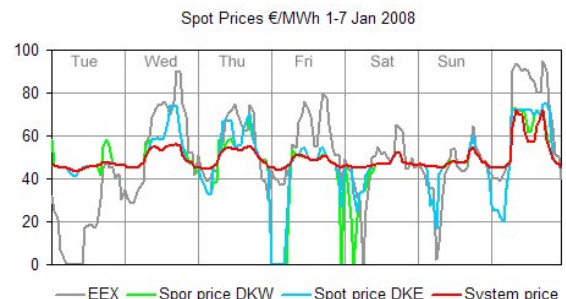


4.2. 1st to 7th January 2008: Wind Power Surplus



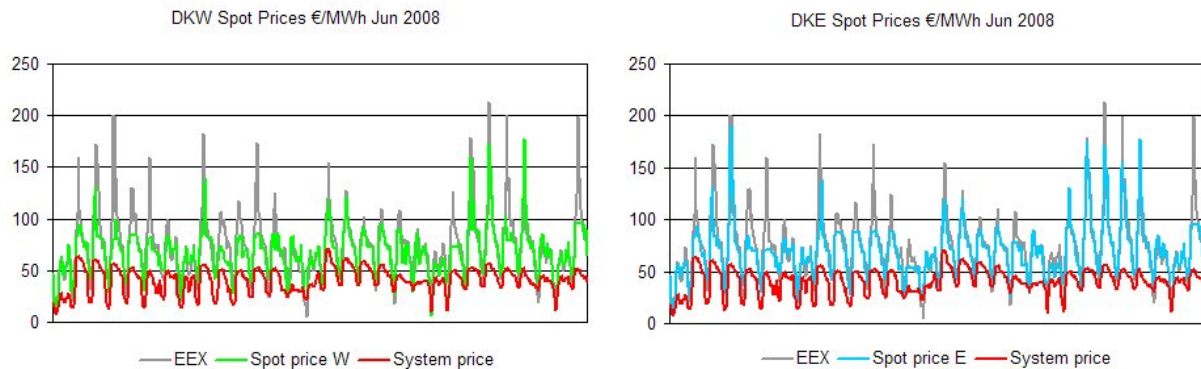
The DKE diagram to the right shows that export limitations occur during nights and import limitation during days. Export limitations may create energy surplus and reduced spot prices, while import limitations may create energy shortage and increased prices. However, attempts to analyze day and night separately did not give more convincing correlations.

The DKW and DKE spot prices are similar during the first week and difficult to separate in the diagram. The reason for zero prices in Germany on the first day is not known. The waves of wind energy in Denmark and Germany seem to be well synchronized (see diagram in 4.1), but there is no direct correspondence between wind power and spot prices. But the Danish spot prices seem to respond to the export limitations Friday and Saturday.

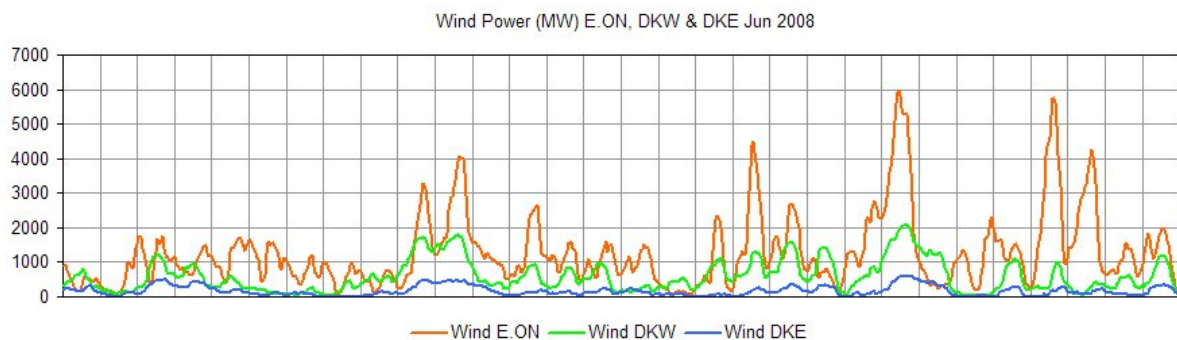


4.3. June 2008: Price Volatility and Spikes

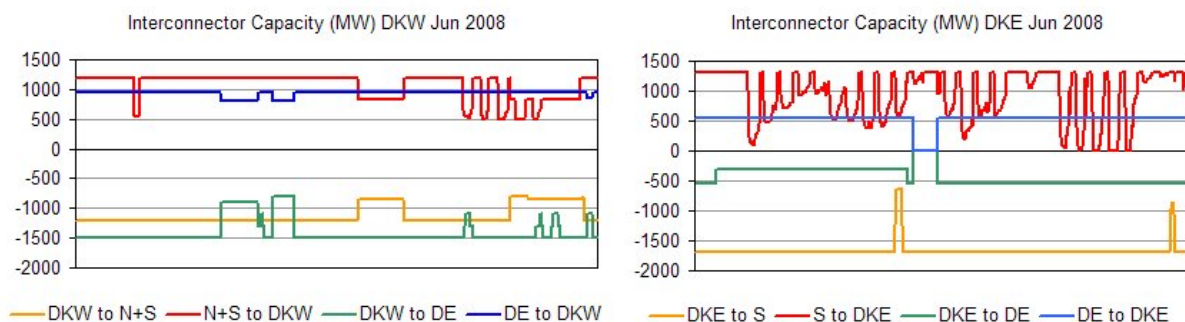
In June 2008 even the Nord Pool spot price has some volatility:



This is probably due to closer relations between the Nordic market and the Continent after commission of the NorNED interconnection in May 2008. From a Danish point of view we shall search for explanations in the wind power pattern and the transfer capability to the neighboring countries:



There is a low level of wind energy in June 2008 and the peaks are remarkably simultaneous in Germany and Denmark.



Wind power and transfer capabilities do not offer simple explanations to the spot price variations. Generally low wind energy output, transmission bottlenecks and market expectations of low precipitation in Norway and Sweden may have contributed to a higher price level in Norway and Sweden and Danish prices at the German level.

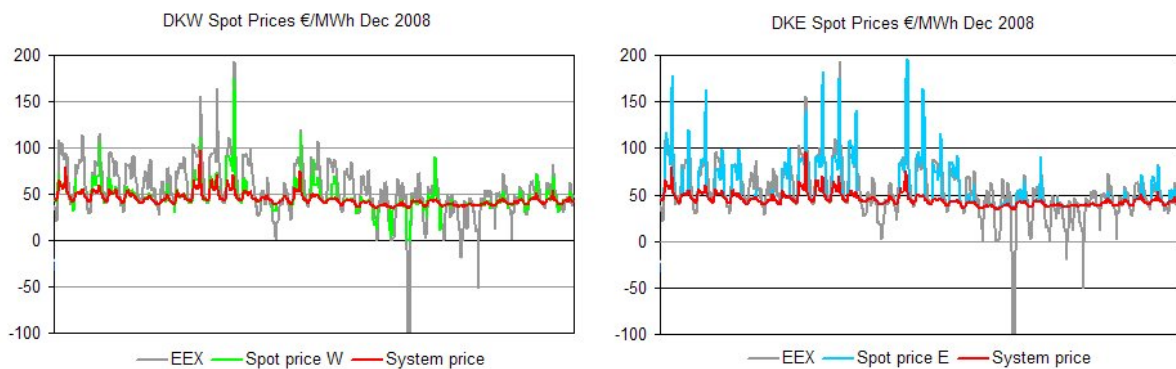
The Energinet.dk Market Report June 2008 adds the following comment:

Imports to Eastern Denmark through the Øresund Link were limited for most of the month. Due to Svenska Kraftnät's management of internal congestion Eastern Danish imports from Sweden were low and contributed rising prices in Eastern Denmark, forcing the East Danish consumers to continue paying too high spot prices.

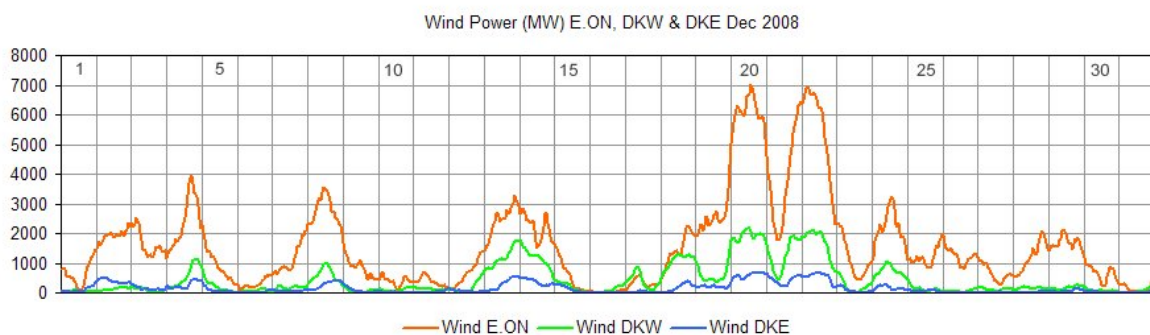
Southbound direction through the Kontek Link (the interconnection between Zealand and Germany) was limited during the period 2-13 June due to inspection and maintenance on the German side, and the link was shut down on 14-15 June for the testing of a new operational planning system in Eastern Denmark.

4.4. December 2008: Negative EEX spot prices

In December 2008 negative EEX spot prices have occurred:

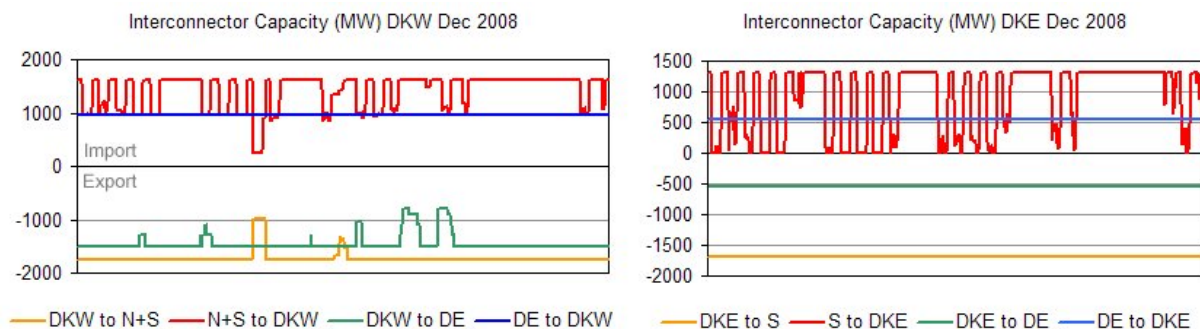


The wind power generation in December:

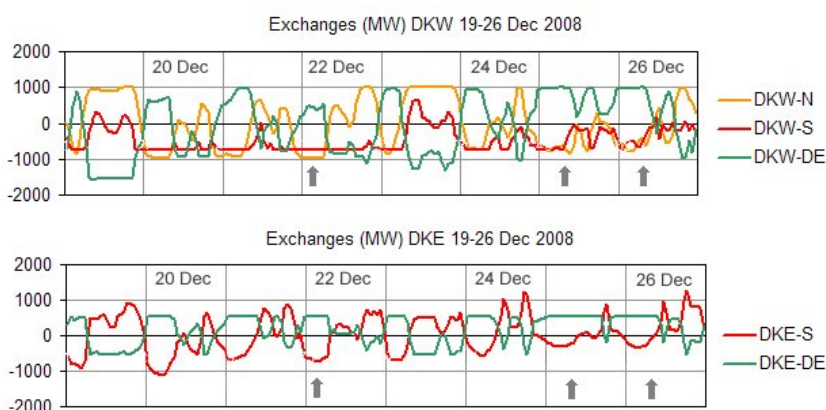


Apart from the twin towers the wind energy level is low in December 2008. The image shows the usual synchronism between wind power in Germany and Denmark.

The export capacity from East Denmark to Sweden has been reduced to zero during a large part of December, but not simultaneously with the negative spot prices in Germany on 22nd, 25th and 26th December. The limitations explain the price spikes in Denmark.



The negative spot prices in Germany occurred on 22nd December (0:00 to 6:00), 25th December (6:00 to 7:00) and 26th December (6:00 to 7:00).



During these periods (and several others) there has been northward transit with import from Germany to Denmark up to the import capacity limits.

5. Regulating Power

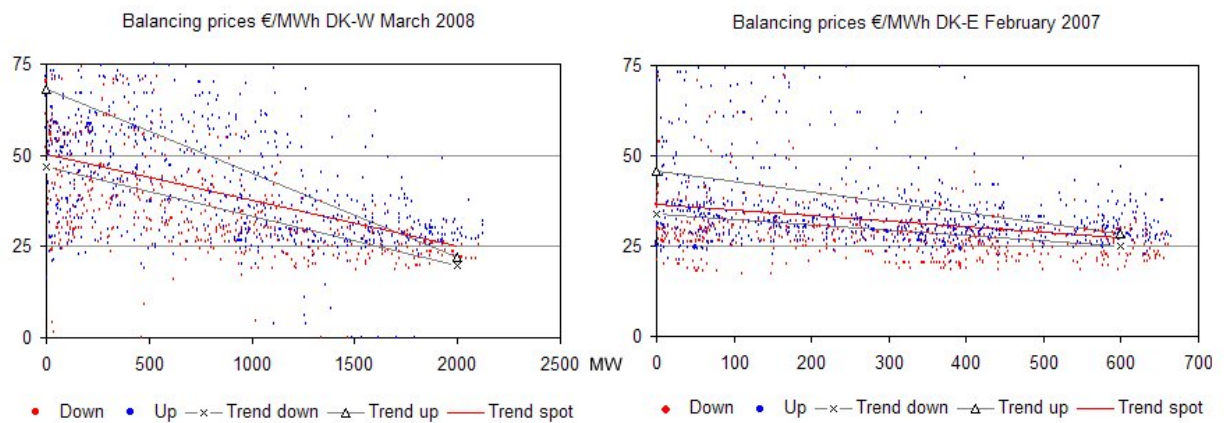
Nord Pool Spot is a wholesale market for both buyers and sellers. Nord Pool Spot has gate closure for the following day at noon. Therefore the spot prices are based on expectations 24 to 36 hours before real time, and day-ahead wind power forecasts are very inaccurate.

The Nord Pool ELBAS market offers market players access to intra-day trade until 1 hour before delivery.

The Nordic system operators use the Nordic regulating power market for real time balancing. Market players are bidding in advance, and the system operators can activate the bids when needed. In Denmark there are different prices for regulating upwards and downwards.

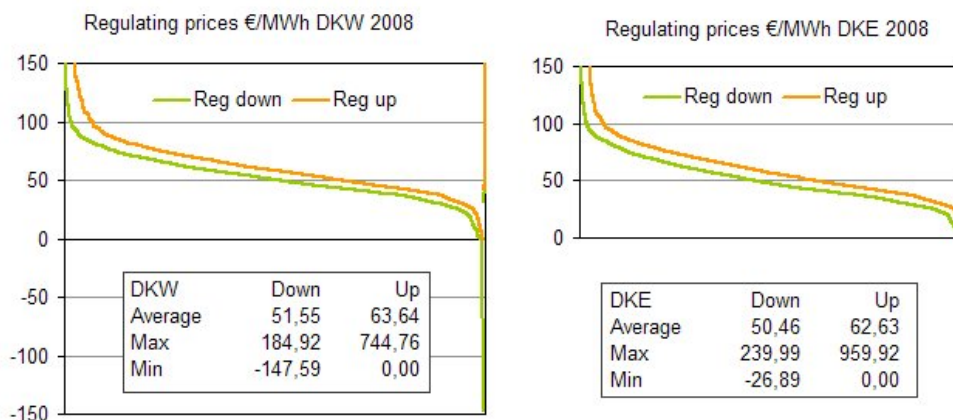
Prices and quantities depend very much on the situation. Spot and regulation prices as function of wind power March 2008 are shown on the diagram below (Upwards regulation: blue dots. Downwards regulation: red dots). Dots below 0 and above 75 €/MWh are not shown. The correlation coefficients show how far the relations are from linearity (1 or -1 are perfect linearity):

Correlation March 2008	Spot price	Reg. up	Reg. down
West Denmark	-0.48	-0.34	-0.55
East Denmark	-0.32	-0.28	-0.34



In this case the trends for DKW have higher slopes than the DKE trends for DKE indicating a higher share of wind power. The trends are not typical, but may be different from month to month.

Dispersed regulating prices are a first warning of unsatisfactory market stability.



Different rules apply for balancing within Nordel and UCTE. This is probably the reason why the need for purchasing regulating power is higher in West Denmark than in East Denmark. Negative prices for regulating power occurred 80 hours in West Denmark and 25 hours in East Denmark. This is considerably less than the 194 and 53 hours in 2007.

6. Economic Key Figures

The Nord Pool Annual Report 2008 is not yet available.

The Energinet.dk Annual Report 2008 is not yet available.

7. Wind energy trading

One of the important traders of wind energy in Denmark is "Vindenergi Danmark Amba", which is a cooperative of owners of wind power plants, who must sell wind energy commercially. The web site, www.vindenergi.dk, presents the following trading statistics for 2008 (with my translations):

2008	Jan	Feb	Mar	April	May	June
West Denmark						
Installed capacity, MW	560	584	610	620	627	646
Production, GWh	186,2	157,4	145,0	52,6	42,9	114,3
Clearing price, øre/kWh	33,3	30,4	25,5	39,2	41,7	51,3
Balancing cost., øre/kWh	1,1	0,5	2,4	5,8	8,3	1,2
East Denmark						
Installed capacity, MW	116	121	129	123	138	145
Production, GWh	36,9	29,2	31,1	10,0	9,1	20,4
Clearing price, øre/kWh	33,4	28,5	22,5	36,4	42,0	56,8
Balancing cost., øre/kWh	2,7	1,6	0,7	5,7	3,6	3,2
Total						
Installed capacity, MW	677	705	739	743	765	791
Production, GWh ,	223,1	186,5	176,1	62,6	52,0	134,6
	July	Aug	Sep	Oct	Nov	Dec
West Denmark						
Installed capacity, MW	667	697	714			
Production, GWh	69,5	92,7	57,1			
Clearing price, øre/kWh	51,5	47,1	57,0			
Balancing cost., øre/kWh	3,0	2,1	3,3			
East Denmark						
Installed capacity, MW	151	156	160			
Production, GWh	17,6	24,0	32,2			
Clearing price, øre/kWh	50,1	48,6	57,1			
Balancing cost., øre/kWh	3,1	2,7	2,3			
Total						
Installed capacity, MW	818	854	873			
Production, GWh	87,1	116,7	89,3			

