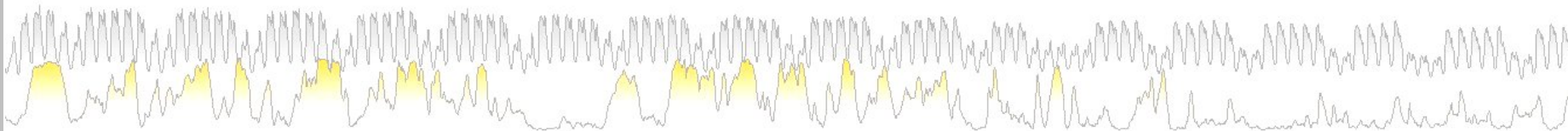


The Effects of Wind Power on Spot Prices

A Study for the Renewable Energy Foundation

by

Paul-Frederik Bach



About the Study

- Danish wind energy equals 20% of Danish electricity consumption
 - Widespread assumption: Denmark made a perfect wind power integration
 - Question: Could the recipe be replicated in the UK?
 - Renewable Energy Foundation in London commissioned an analysis of the power system and the electricity market in Denmark
- Intended method:
 - Regression analyses of wind power, electricity demand, interconnection capacities and spot prices in Denmark
 - ...but correlations are weak
 - ...because the data are related in a complex pattern
 - More pragmatic methods had to be chosen
- Main observation:
 - German and Danish electricity markets are closely related
 - The two countries have together absorbed 7% wind energy
 - Germany, Denmark and (from 2008) the Netherlands are competing for balancing resources in Norway and Sweden

Collecting and Organising Data

- Mainly market data from www.energinet.dk
- Data from www.eon-netz.com added during the study
- Data and preliminary observations presented in Data Surveys 2006, 2007 and 2008

2006: A dry year
2007: A wet year
2008: A transit year
(due to shortage
in Germany)

Abbreviations:

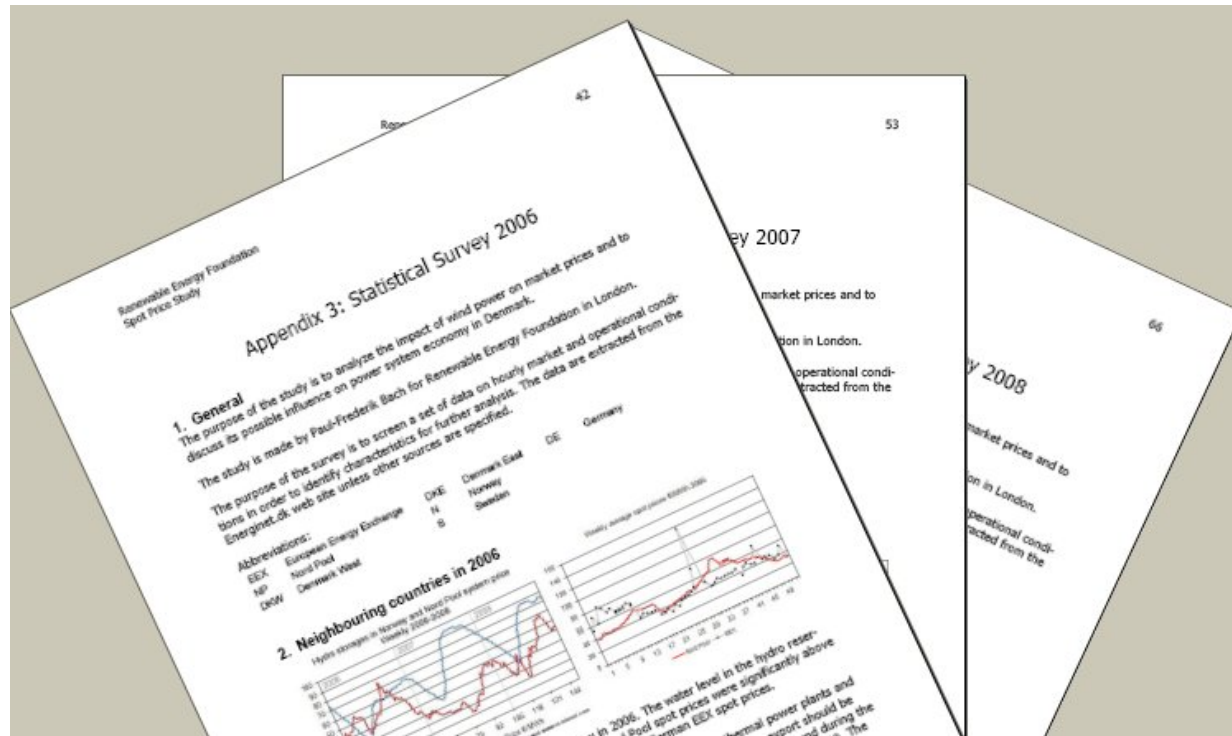
NP: Nord Pool

EEX: European Energy
Exchange

DKW: West Denmark

DKE: East Denmark

DE: Germany



Spreadsheet sample

	A	B	C	D	E	F	G	H	I
1									
2	2006	Sources: http://www.energinet.dk/en/menu/Market/Download+of+Market+Data/Download+of+Market+Data.htm						and http://www.eon-netz.c	
3			Elspot Price, EUR/MWh						
4	Date	Hour	DK-West	DK-East	System price	DE European Energy Exchange	DK-West to Germany	Germany to DK-West	DK-West to Nordic coun
5	01-01-2006	1	33,88	33,88	33,82	32,10	-1200,0	800,0	-1
6	01-01-2006	2	33,43	33,43	33,38	30,07	-1200,0	800,0	-1
7	01-01-2006	3	32,10	32,10	32,68	27,94	-1200,0	800,0	-1
8	01-01-2006	4	18,61	29,56	31,88	21,71	-1200,0	800,0	-1
9	01-01-2006	5	2,97	29,10	31,25	8,24	-1200,0	800,0	-1
10	01-01-2006	6	0,29	29,47	31,54	1,13	-1200,0	800,0	-1
11	01-01-2006	7	0,18	27,53	31,49	0,00	-1200,0	800,0	-1
12	01-01-2006	8	0,32	26,29	31,42	0,00	-1200,0	800,0	-1
13	01-01-2006	9	0,24	26,90	31,22	0,00	-1200,0	800,0	-1
14	01-01-2006	10	6,40						-1
15	01-01-2006	11	23,63						-1
16	01-01-2006	12	32,56						-1
17	01-01-2006	13	32,96						-1
18	01-01-2006	14	32,87						-1
19	01-01-2006	15	32,91						-1
20	01-01-2006	16	33,34						-1
21	01-01-2006	17	34,41						-1
22	01-01-2006	18	47,20						-1
23	01-01-2006	19	43,22						-1
24	01-01-2006	20	35,24						-1
25	01-01-2006	21	34,66						-1
26	01-01-2006	22	34,47	34,47	34,46	34,93	-1200,0	800,0	-1
27	01-01-2006	23	37,52	33,93	34,19	41,92	-1200,0	800,0	-1
28	01-01-2006	24	32,25	32,25	33,22	32,40	-1200,0	800,0	-1

Including:

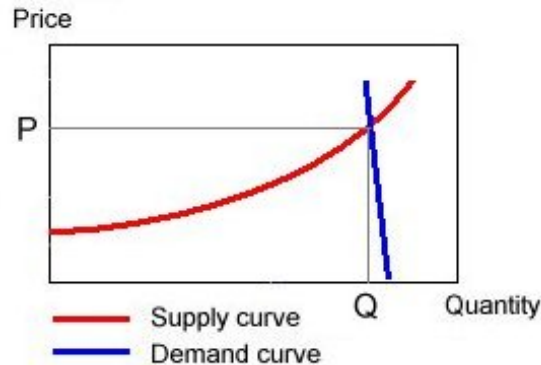
- Elspot Price, EUR/MWh
- Capacity on transmission lines, MWh/h
- Physical exchange on transmission lines, MWh/h
- Production and consumption, MWh/h
- Real-time market, EUR/MWh
- Additional data incl. wind power in the E.ON control area



Understanding the system requires **both market data and physical data**
 The selection of data deserves discussion prior to future studies

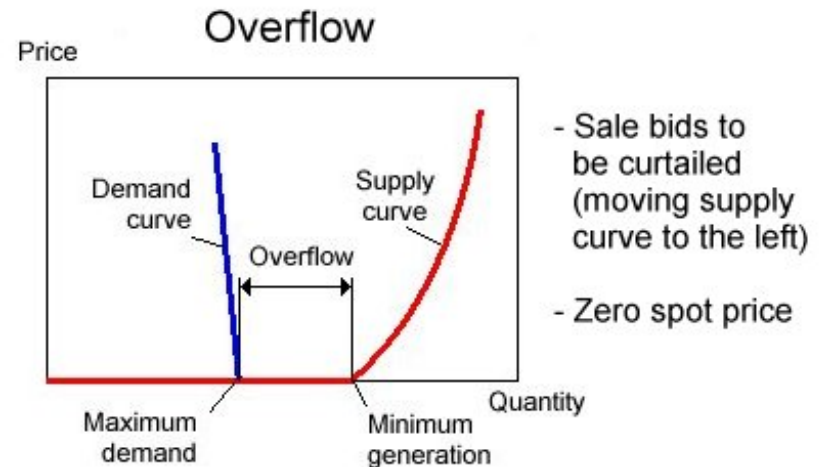
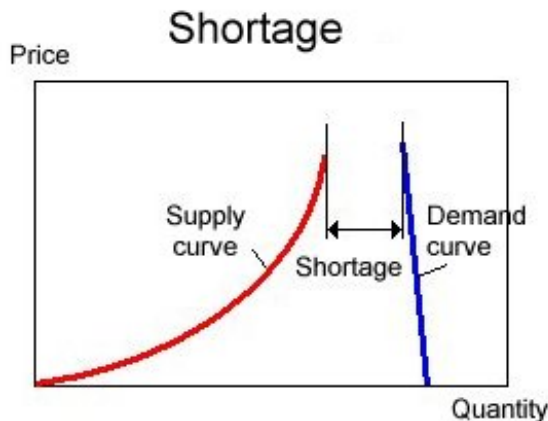
Use of the spot price as a Canary in a Coal Mine

Finding a fair spot price requires an intersection between a supply curve and a demand curve



Nord Pool and EEX use daily bids from market participants for creation of demand and supply curves

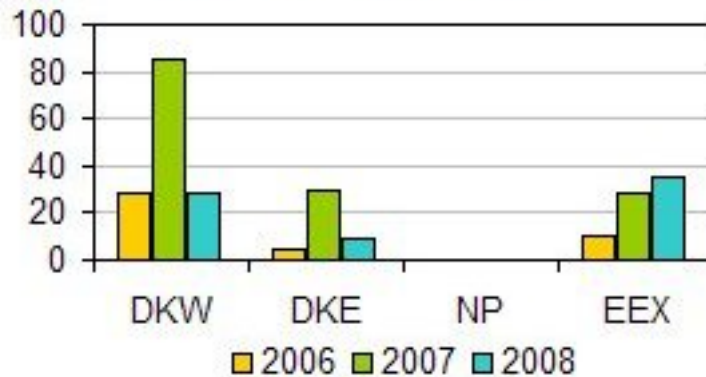
- No intersection
- Purchase bids to be curtailed (moving demand curve to the left)
- Maximum spot price



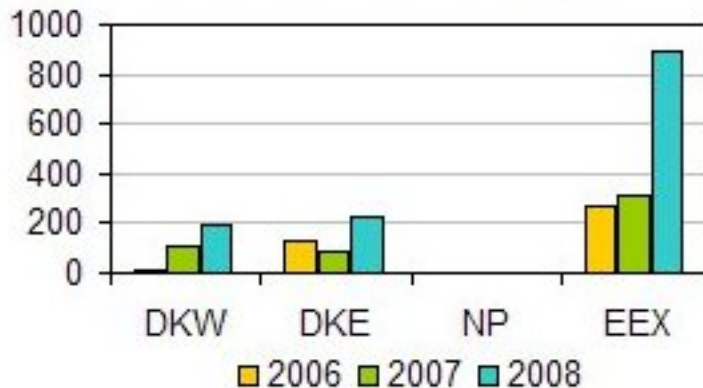
Extreme spot prices indicate imbalances between demand and supply

Spot Prices Indicating the Level of Market Service

No of hours: Zero Spot Price



No of hours: Spot Price > 100 €/MWh



Number of hours with surplus of power

Zero prices indicate poor market service because sale bids have been curtailed

Nord Pool Spot will introduce a negative price floor (-200 €/MWh) as from 1 October 2009

Number of hours with shortage of power

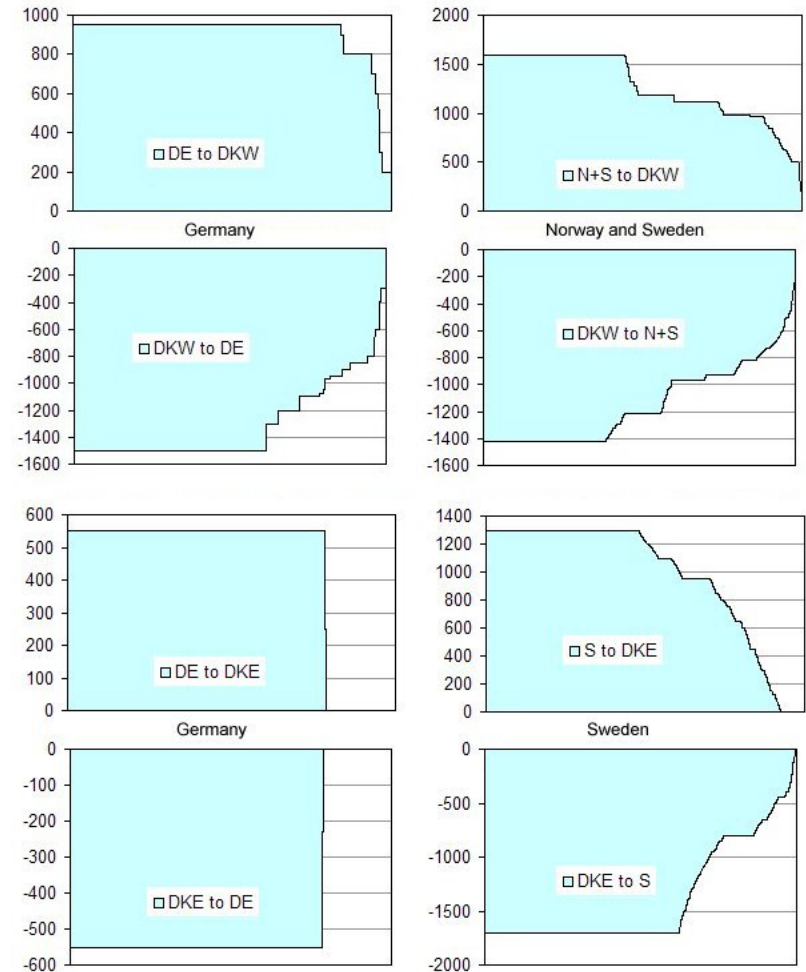
Purchase bids may have been curtailed.
Upper limit subject to discussion

- A reasonable level of market service observed for 2006-2008

Bottlenecks and congestion policy

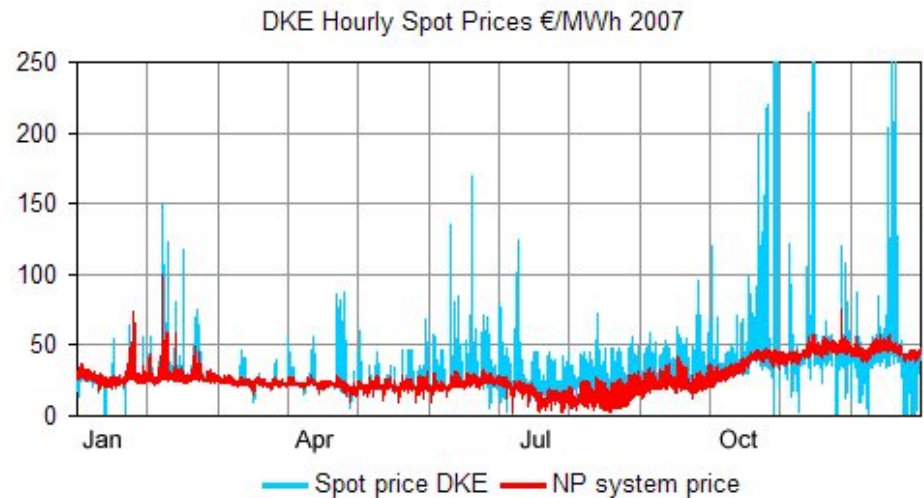
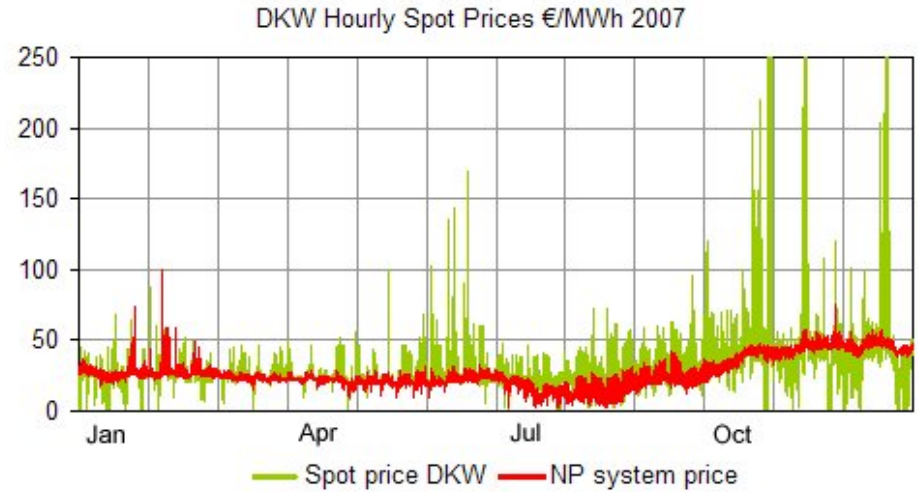
- The available capacity of interconnectors is far below nominal values
- The reasons can be technical (such as cable faults) or operational (internal bottlenecks within a price area)
- A system operator can remove internal congestion problems by defining bottlenecks at the national borders
- Temporary reductions of transfer capabilities are significant barriers for efficient utilization of wind energy
- This fact seems to be ignored in most studies on wind power integration

Transfer capabilities MW - Duration curves 2007

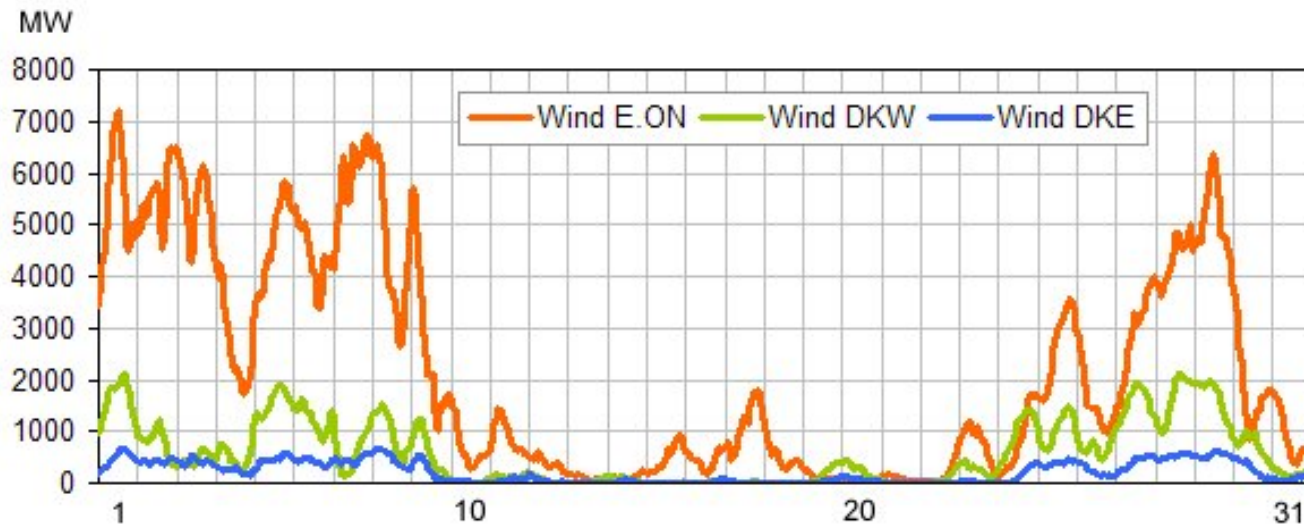


The Simple Approach: Observing Spot Price Volatility

- Danish spot prices are more volatile than the Nord Pool system price
- There is no simple relationship between wind power and spot prices
 - Extreme prices are created by combinations of unfavourable conditions
- Spot price time series can help identifying problematic periods
- December 2007 has been selected as an instructive case

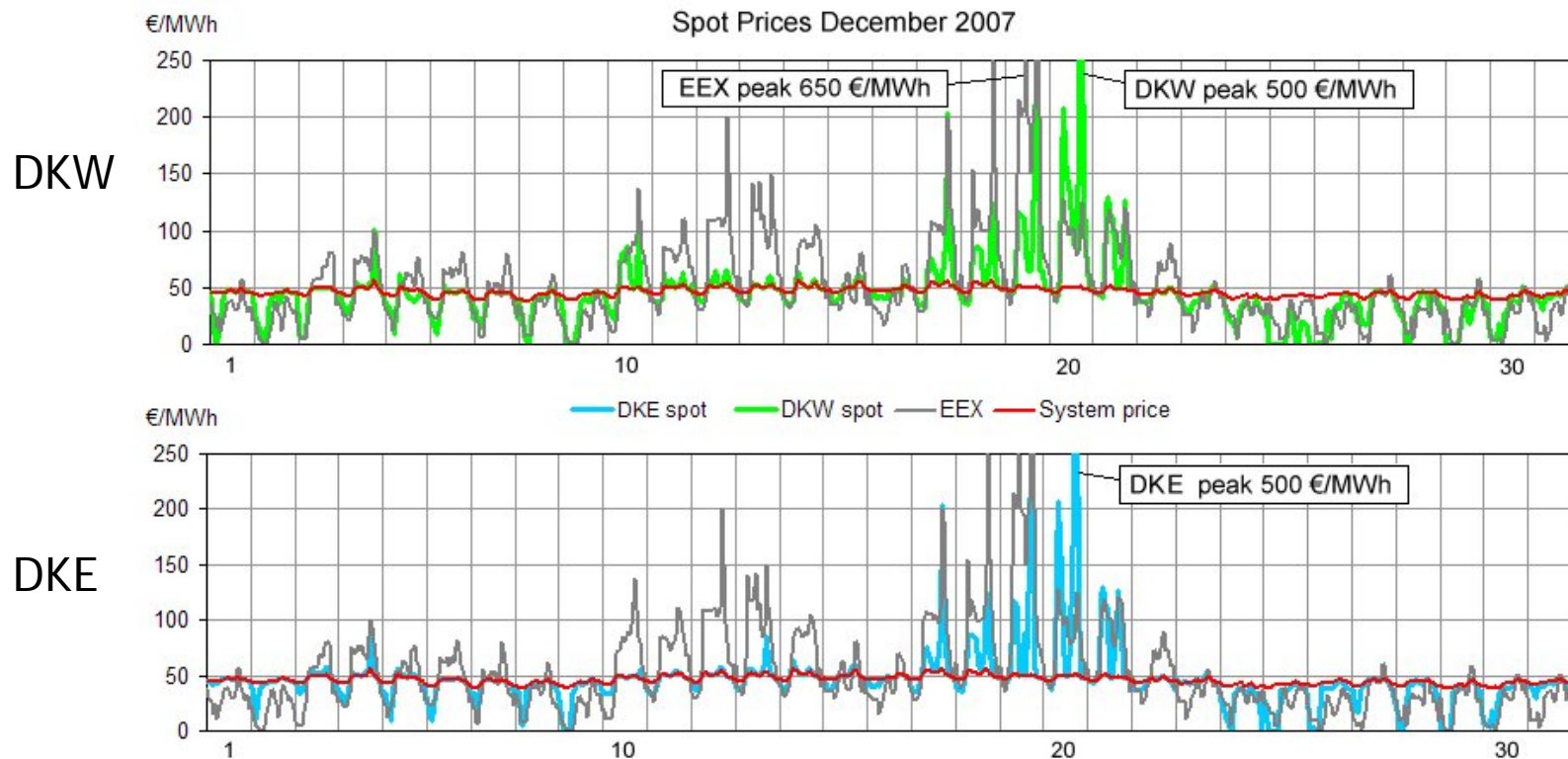


Contrasts in December 2007



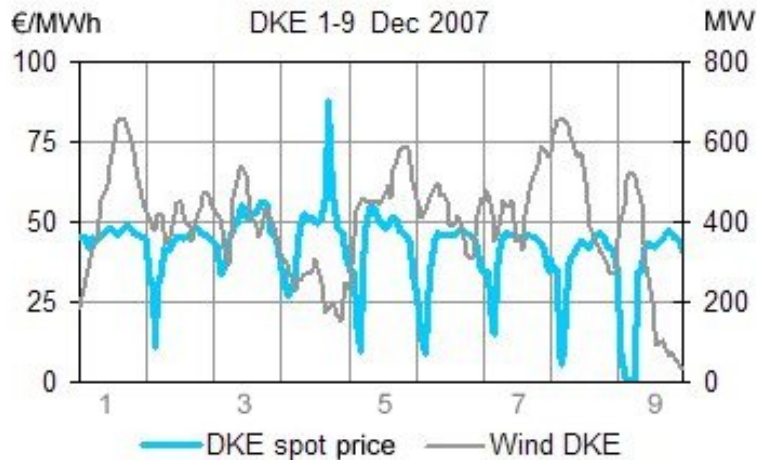
- Characteristics:
 - Synchronism between wind power in Germany and Denmark
 - High wind power output the first 9 days
 - Two consecutive calm weeks
 - High wind power output combined with low electricity demand at the end of the month

Spot Prices Reflecting Wind Power

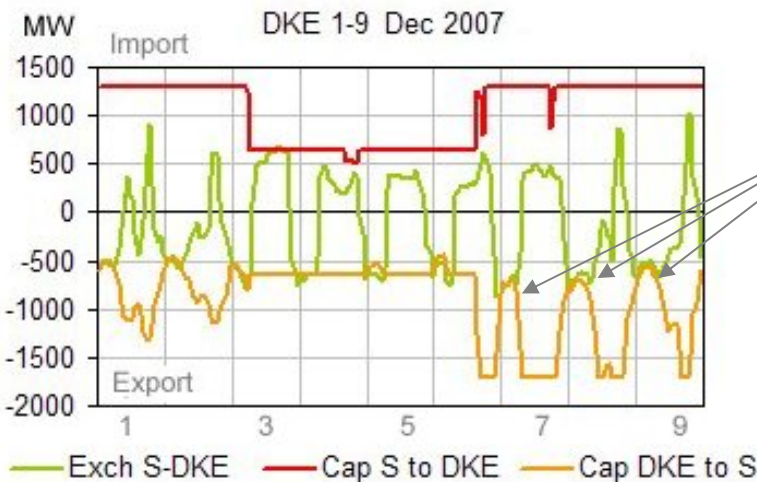


- Low or zero spot prices during the high wind periods
- High German spot prices during both calm weeks
- High Danish spot prices during the second calm week

Export Limited by Bottlenecks (DKE) 1-9 December

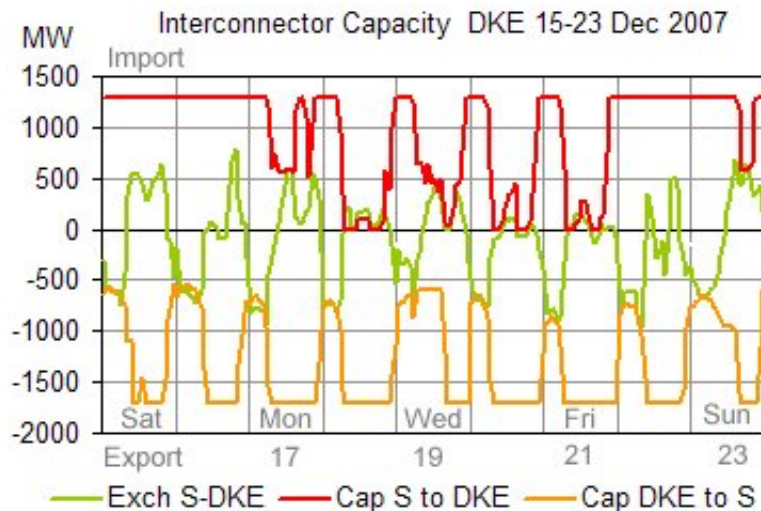
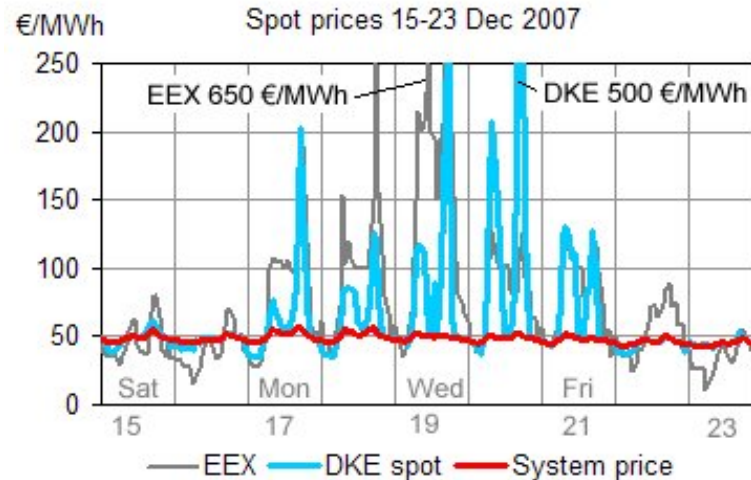


- Low spot prices observed during several nights
- Spot price peak on a single day with low wind power output



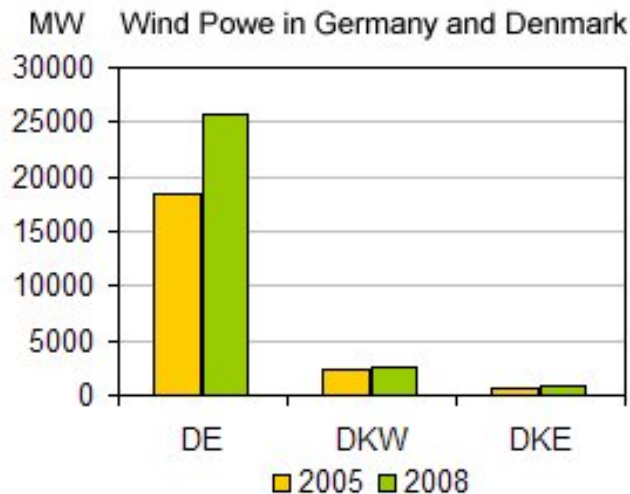
- Temporary export limits when there is a need for export
- When transfer capability is needed less than half the nominal capacity is available
- Extreme prices created by a combination of wind and bottlenecks

Import Limited by Bottlenecks (DKE) 15-23 December



- Shortage of power in Germany and Denmark
- The peak prices are ceilings
 - No demand supply equilibrium
- Import limits temporarily reduced to zero
- A narrow gap is left for exchanges
- The reductions
 - prevent normal market functions
 - isolate Denmark from the Nordic market
 - explain the relations between German and Danish electricity markets

Wind Power in Germany and Denmark



- Germany has much more wind power than Denmark
- ...and a higher growth

- 4 control areas in Germany
- Wind energy 2008:
 - 40.2 TWh (www.bdew.de)
 - Penetration at transmission level: 6.5 %
- Only data for the E.ON control area downloaded for the study



Source: EUROENERGIE AG

Monitoring Markets and Power Systems?

- The spot prices in Germany and Denmark are more volatile than the Nord Pool system price
 - The volatility depends on several factors, including competition, daily load variations, wind power and interconnector capacity
 - A high volatility seems to indicate a vulnerable electricity market
 - The number of hours with extreme spot prices indicates the quality of market service
- Practical experience is decisive in power system design
 - The Danish power systems are being changed into new unprecedented structures
 - Shortage of resources in the European power systems may occur as unexpected as a financial crisis
- Monitoring the performance of electricity markets and power systems might be helpful for early warning and guidance on necessary adjustments

Conclusions

- It has been demonstrated how the German and Danish electricity markets respond to 7% wind energy
- A successful implementation of 20% wind energy has not yet been demonstrated
- Efficient international electricity markets and a strong European electricity transmission network will be among the conditions for a successful integration of an increasing share of wind power
- Better and larger international studies of market and power system response to wind power can pave the way for the integration process
 - However, access to data is heterogeneous from country to country and in some cases publicly available data are distributed and incomplete
- The European TSOs are recommended to develop and publish harmonized market and power system data and performance reports
 - with market data from Energinet.dk as a suitable model

Congestion policy

- 6 bidding areas (or price areas)
- Transfer capability between bidding areas allocated by Nord Pool
- In spite of significant internal bottlenecks Sweden insisted so far on having only one spot price
- This is possible by transferring internal Swedish bottlenecks to capacity reductions at the national borders
- The alternative is dividing Sweden into price areas
- In April 2009 The EU Commission has opened "proceedings against Swedish electricity Transmission System Operator concerning limiting interconnector capacity for electricity exports"

