

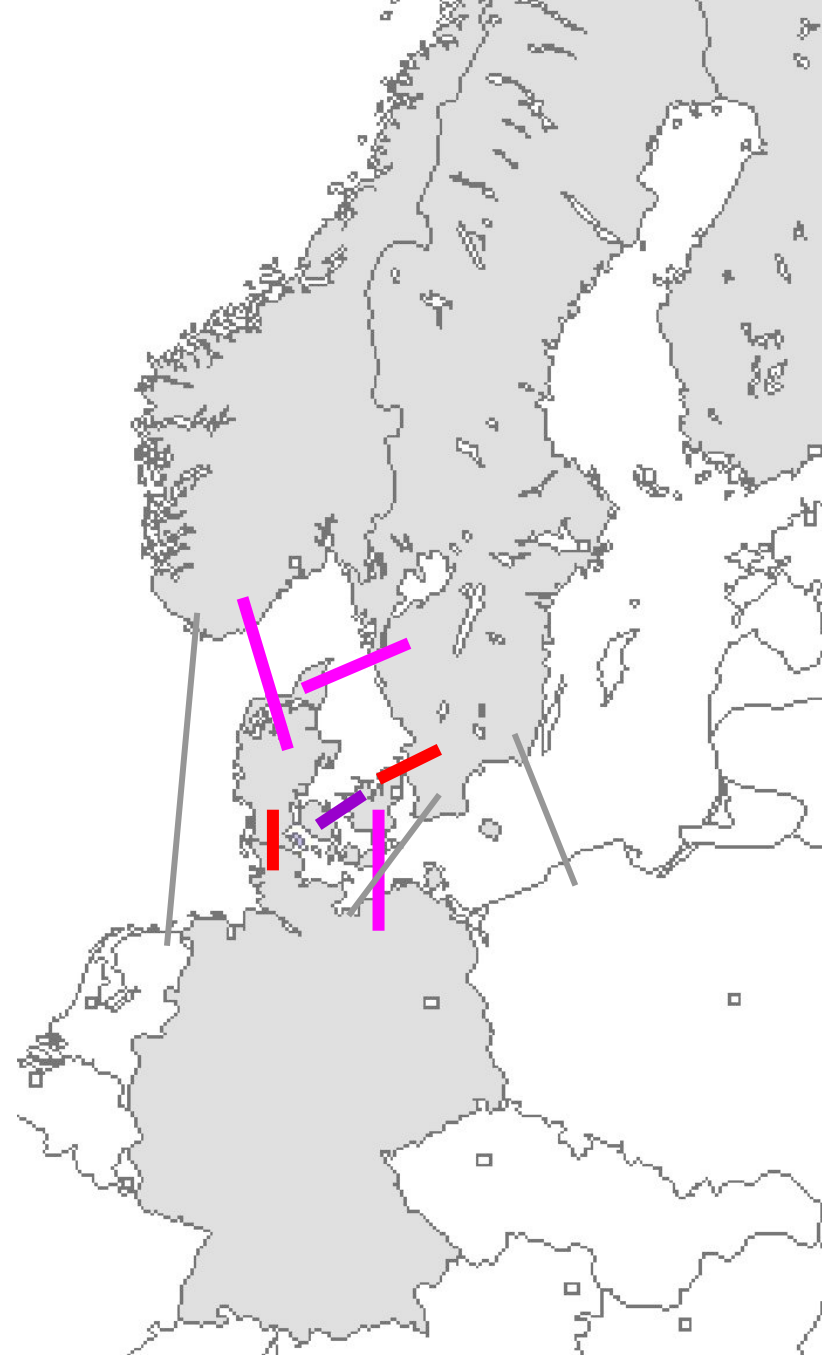
The Effects of Wind Power on Spot Prices

A Statistical Study of the German and
Danish Electricity Markets 2006-2008

by
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for
Renewable Energy Foundation,
London

1. About the study
2. Three different years
3. Other factors influencing spot price
4. Wind power in Germany and Denmark
5. Wind power and spot prices
6. Conclusions



1. About the study

The Spot Price Study

- Question:
 - How does wind power influence spot prices?
- Original purpose:
 - Analyze correlation between wind power, electricity demand, interconnection capacities and spot prices in Denmark
- Findings:
 - Weak correlations between wind power and spot prices
 - because other factors are decisive
 - More significant correlations between
 - spot prices in Denmark and Germany and
 - wind power in Denmark and Germany
 - Denmark and Germany seem to share resources of balancing power
 - ...and behave like one electricity market
 - 7 % wind energy integrated in Denmark and Germany

1. About the study

Method

- Collecting data
 - Mainly market data from www.energinet.dk
 - Data surveys 2006, 2007 and 2008 prepared
 - Data from www.eon-netz.com added during the study
 - All data are available as 3 spreadsheets on the CD
- Analyses
 - Plots of related data and linear regression
 - Diagrams with time series
 - Simple examination of selected periods
 - Spot price spikes
 - Zero spot prices
 - Calm periods
- Some key words:
 - Market performance and **Market Design**
 - Transfer capability and **Grid Planning**
 - Bottlenecks and **Congestion Management**

Abbreviations:

NP: Nord Pool

EEX: European Energy
Exchange

DKW: West Denmark

DKE: East Denmark

DE: Germany

1. About the study

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

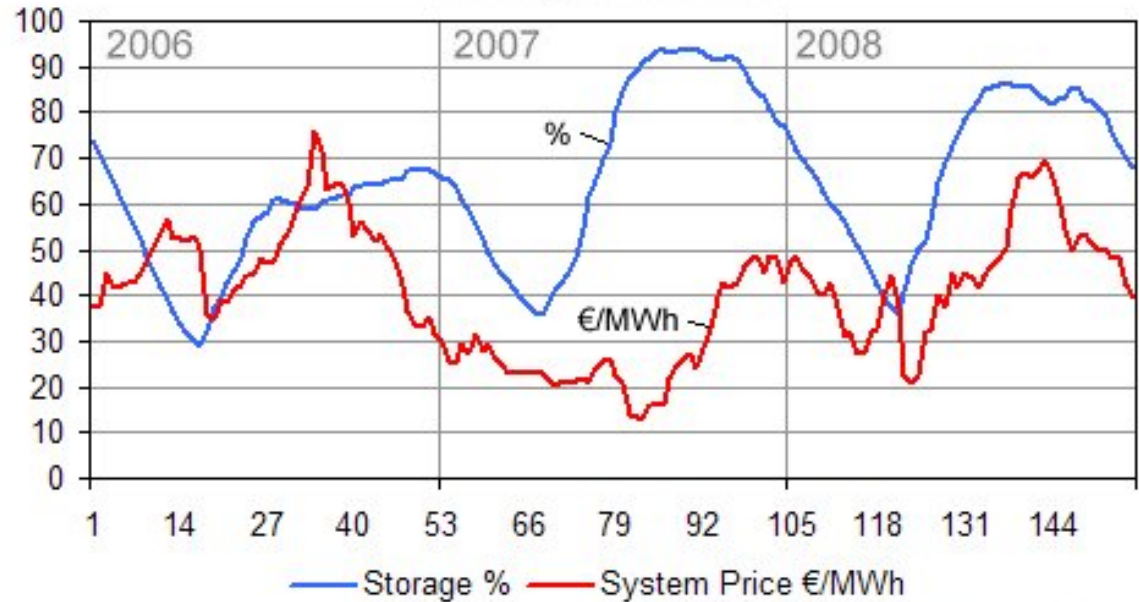
The selection of data deserves discussion prior to future studies

2. Three different years

Three very different years

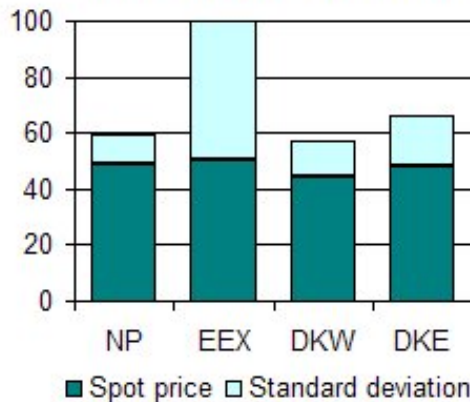
- 2006: Shortage of water
- 2007: Surplus of water
- 2008: The NorNed interconnection added

Hydro storages in Norway and Nord Pool system price Weekly 2006-2008

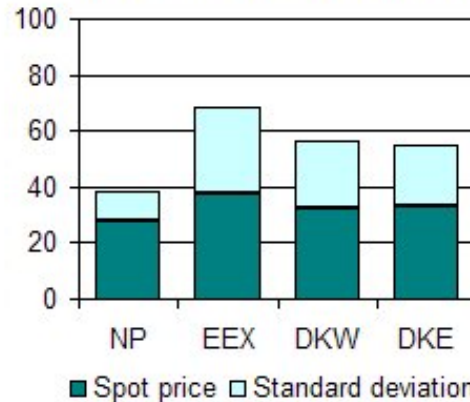


Sources: www.nve.no and www.nordpool.com

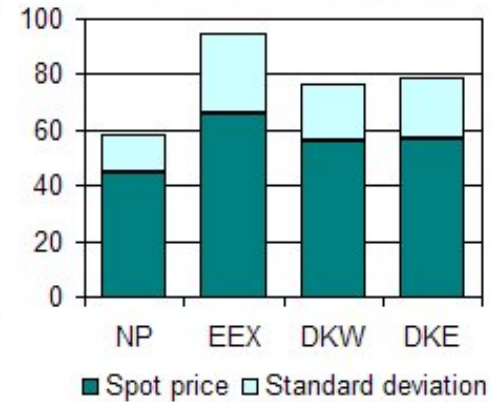
Average spot prices €/MWh 2006



Average spot prices €/MWh 2007

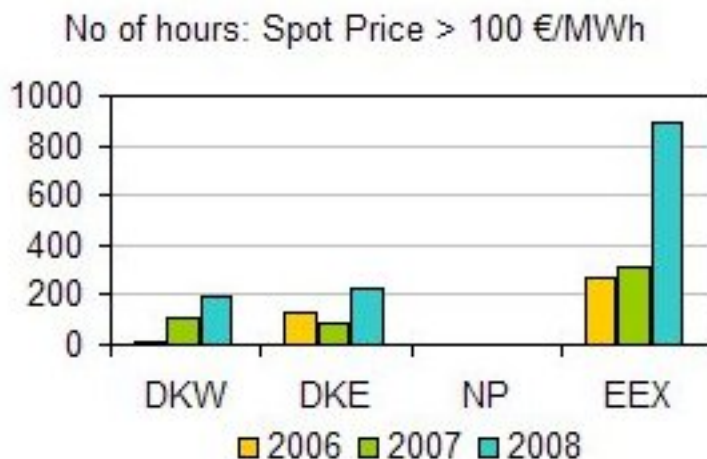
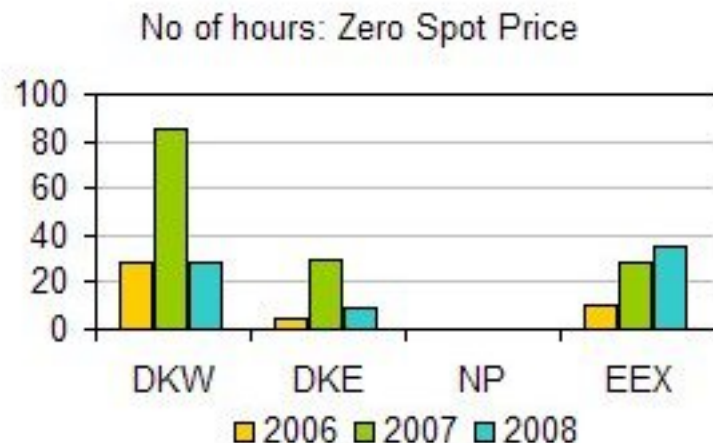


Average spot prices €/MWh 2008



2. Three different years

Extreme spot prices



- A reasonable level of market service 2006-2008
- A yardstick for quality of market service?

No of hours with surplus of power

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

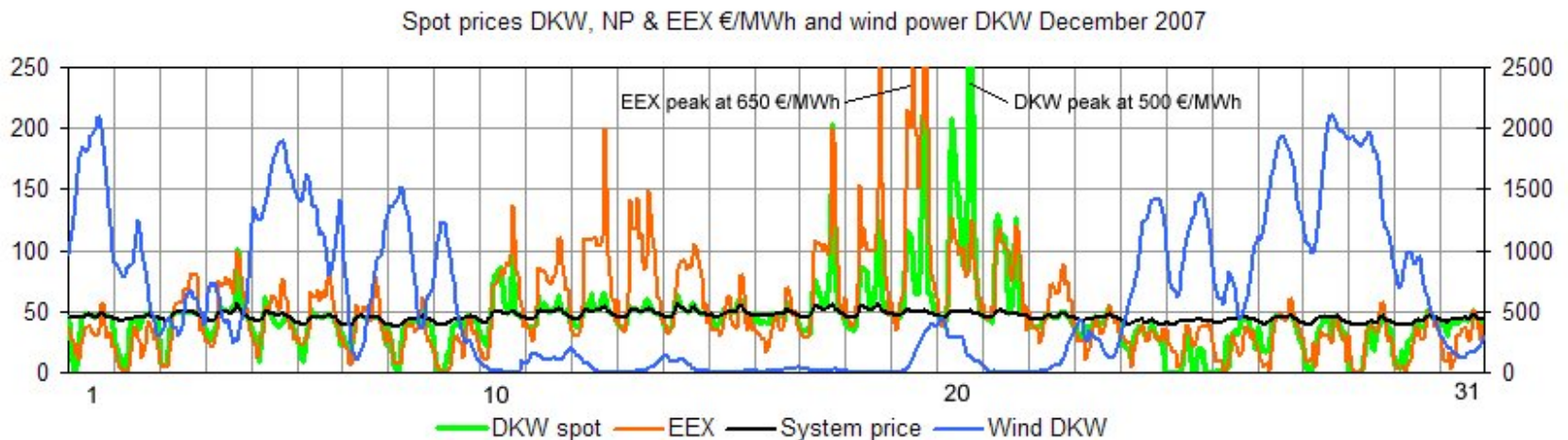
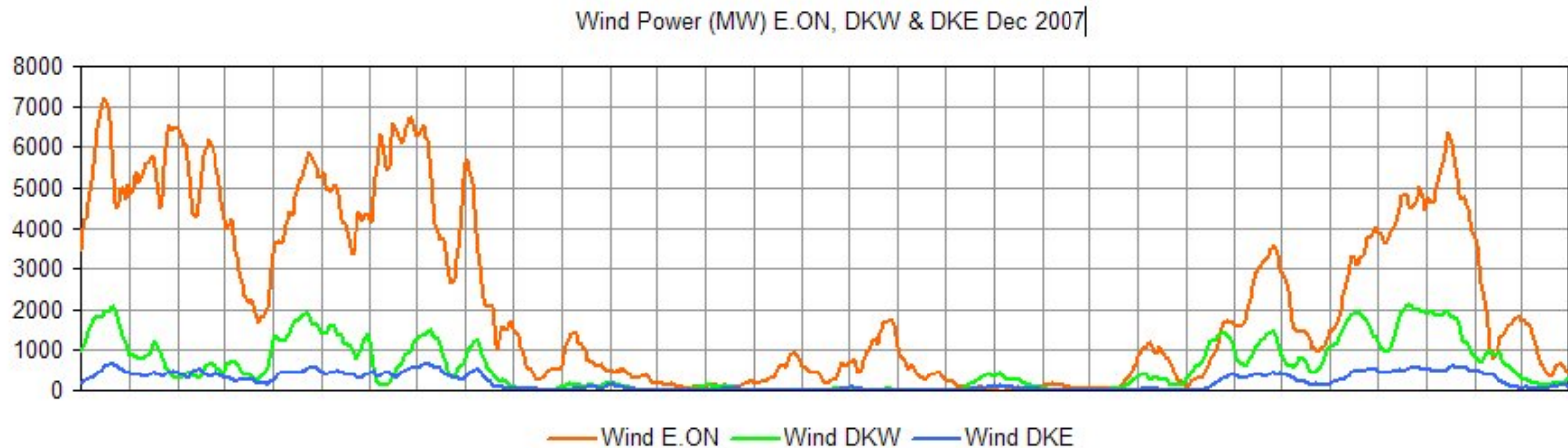
Nord Pool will introduce negative spot prices later this year

No of hours with shortage of power

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

2. Three different years

Calm Weeks in December 2007



Why were Danish spot price profiles different for the two weeks?

3. Other factors influencing spot price

Factors influencing spot price

- besides wind power

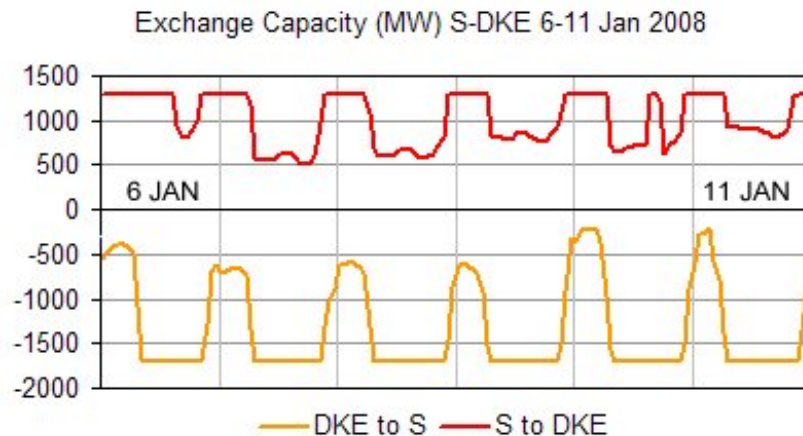
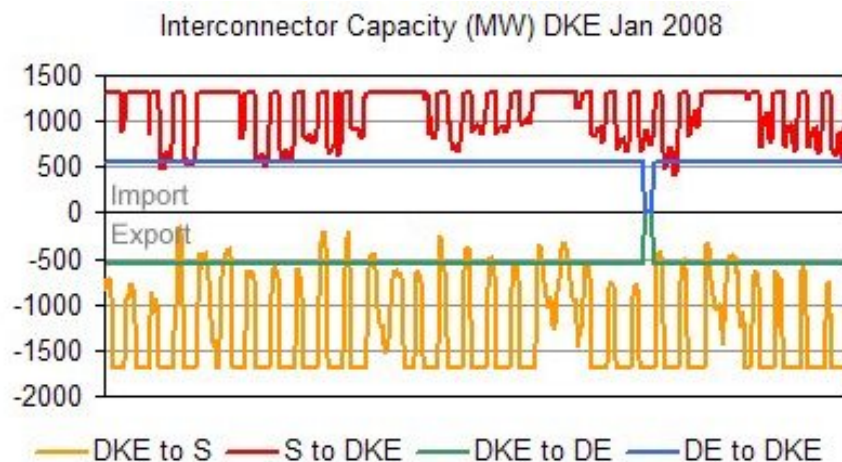
- Daily load variations
- Transfer capabilities
- Congestion policies
- Bidding policies and market power

- The upcoming battle:
 - Forces destabilizing the market
 - ...such as uncontrollable generation (wind) and abuse of market power
 - Possible measures for stabilizing the market
 - ...such as grid reinforcement, more flexible generation and price sensitive demand
 - It will take good planning and coordination and to find a fair balance

3. Other factors influencing spot price

Daily reductions of transfer capabilities

...always when capacity is most needed



- Import reductions predominantly during daytime
 - ...when the thermal systems demand more power
- Export reductions predominantly during nights
 - ...when there is a surplus of power in the thermal systems
- Such “targeted” reductions are more important than average availability figures would suggest
 - ...and they are ignored in most studies

3. Other factors influencing spot price

Possible reasons for reduced transmission capacity

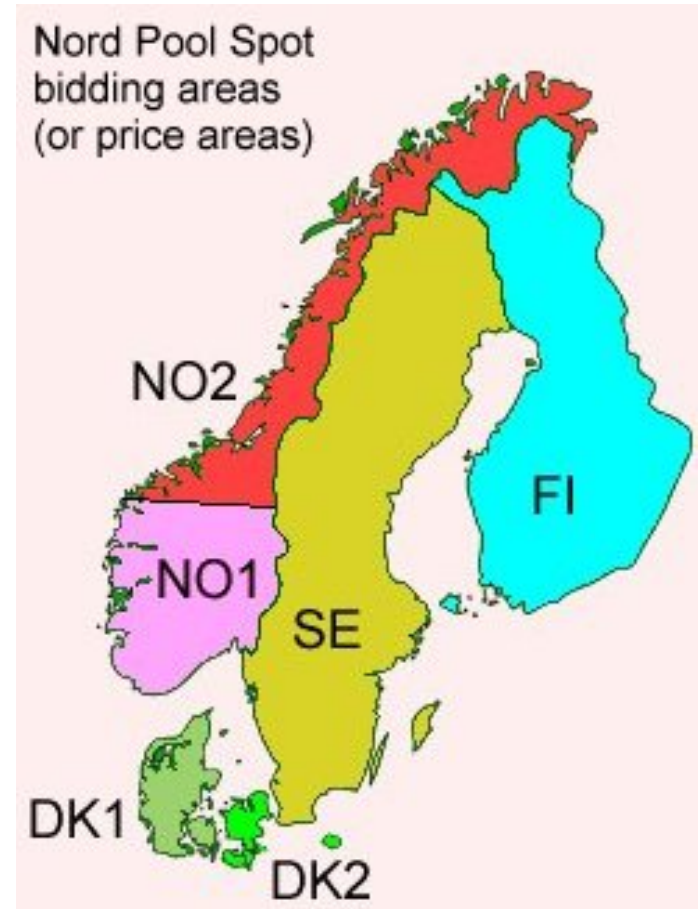
- Network stability limits
 - It is difficult to determine stability limits
 - ...like walking along the edge of a cliff
 - For security reasons conservative estimates are common
- Compensation for internal bottlenecks
- Protection of national commercial interests
- Collect congestion charges (depending on market arrangements)

The screenshot shows the top section of the Europa Press releases website. At the top left is the European Union flag and the word "Europa" in a stylized font. The main heading is "Press releases RAPID" in large blue letters. To the right is a globe with a language dropdown menu set to "English (en)". Below the heading is a navigation bar with icons for "Login", "Register", "Documentation", and "About". Underneath is a secondary navigation bar with buttons for "Search", "RSS", "Midday Express", and "Recent Press Releases", along with a search input field containing the text "Select a topic". The main content area begins with the text "MEMO/09/191" and "Brussels, 23rd April 2009". The primary headline is "Antitrust: Commission opens proceedings against Swedish electricity Transmission System Operator concerning limiting interconnector capacity for electricity exports" in orange text.

3. Other factors influencing spot price

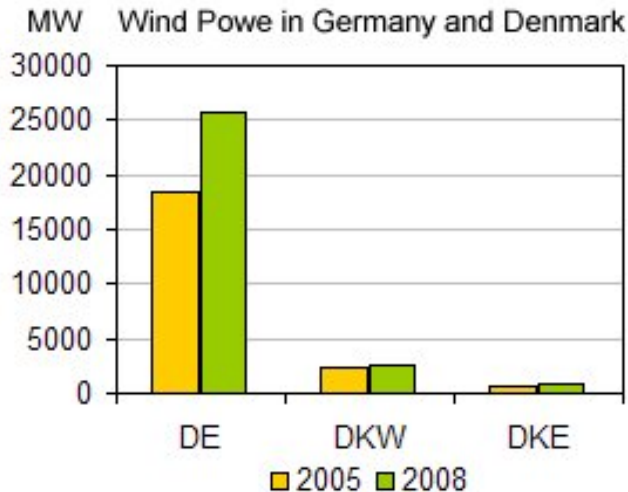
Congestion policy

- 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



4. Wind Power in Germany and Denmark

Wind Power in Germany and Denmark



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

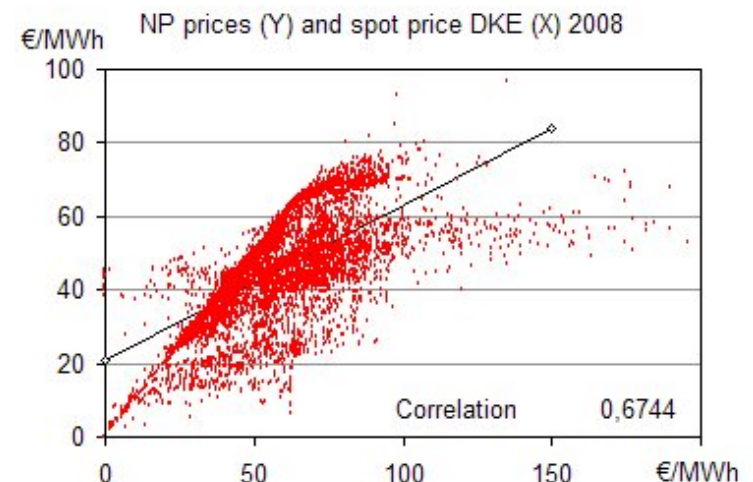
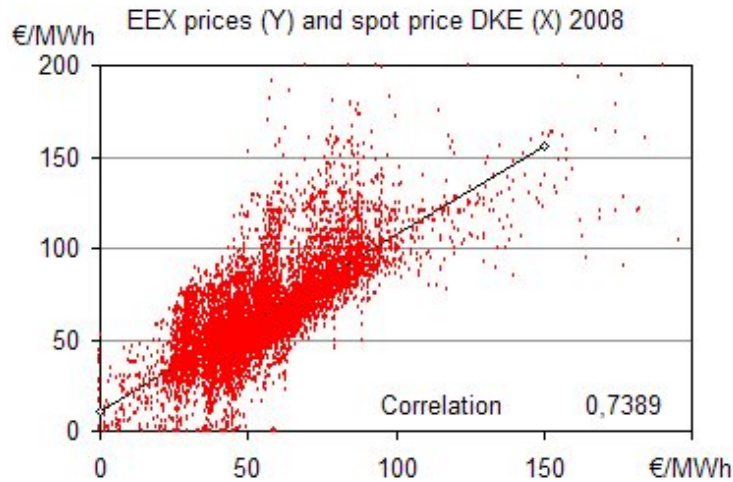
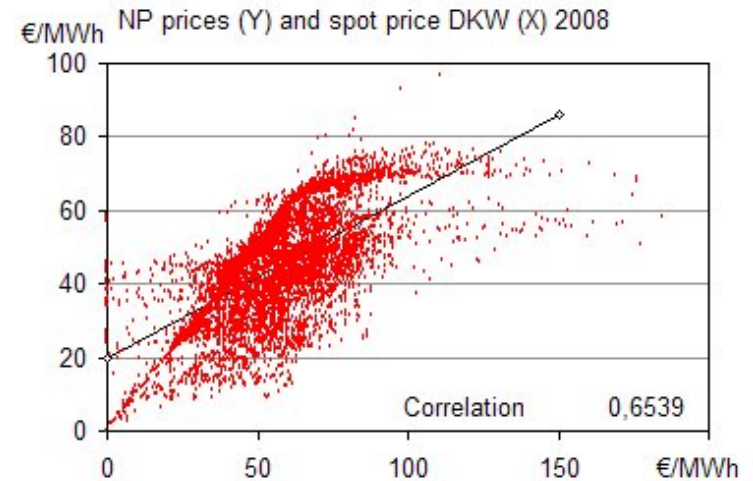
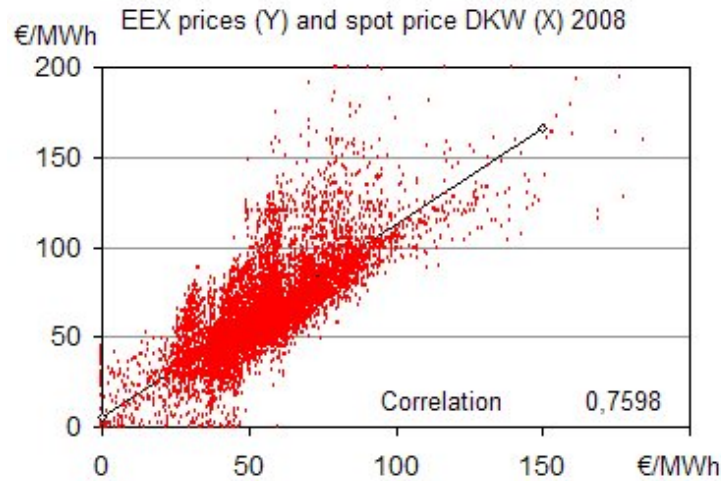
- 4 control areas in Germany
- Wind energy 2008:
 - 40.2 TWh (www.bdew.de)
 - Penetration at transmission level: 6.5 %
- Only data for the E.ON control area downloaded for the study



Source: EUROENERGIE AG

4. Wind Power in Germany and Denmark

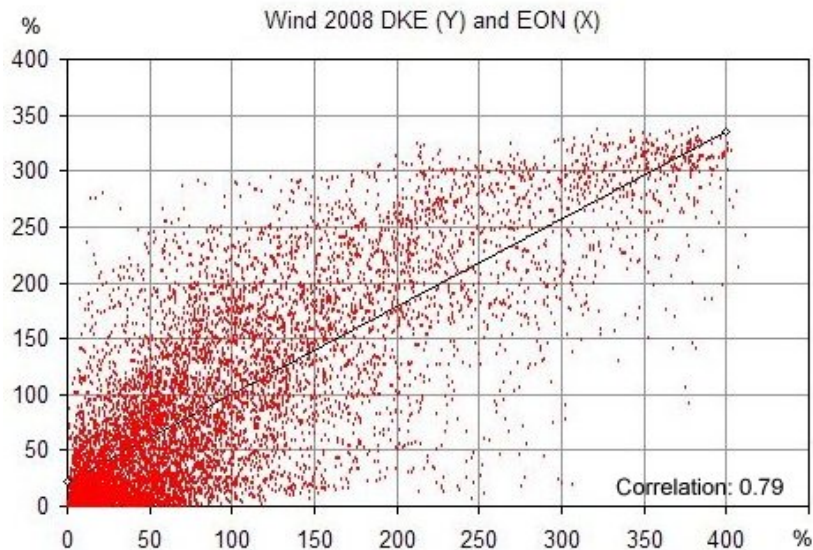
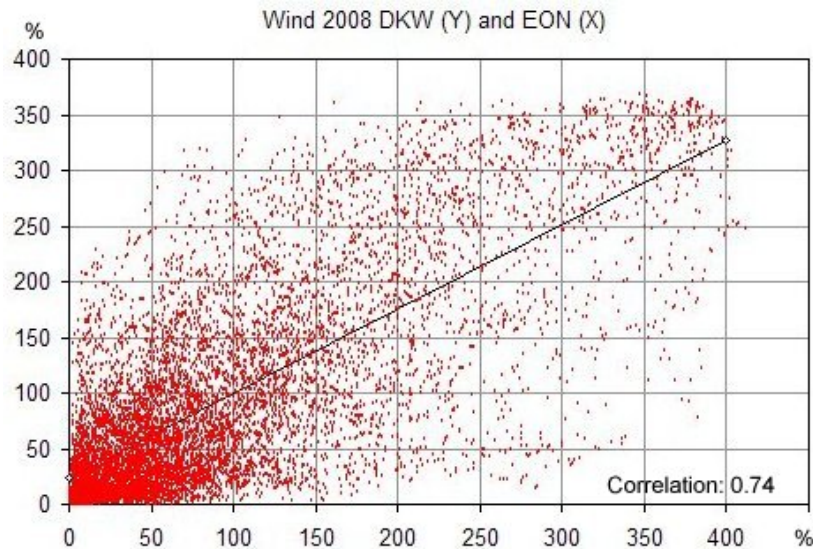
Spot prices 2008: Denmark, Germany and Nord Pool



Danish spot prices are closer related to German than to Nordic market

4. Wind Power in Germany and Denmark

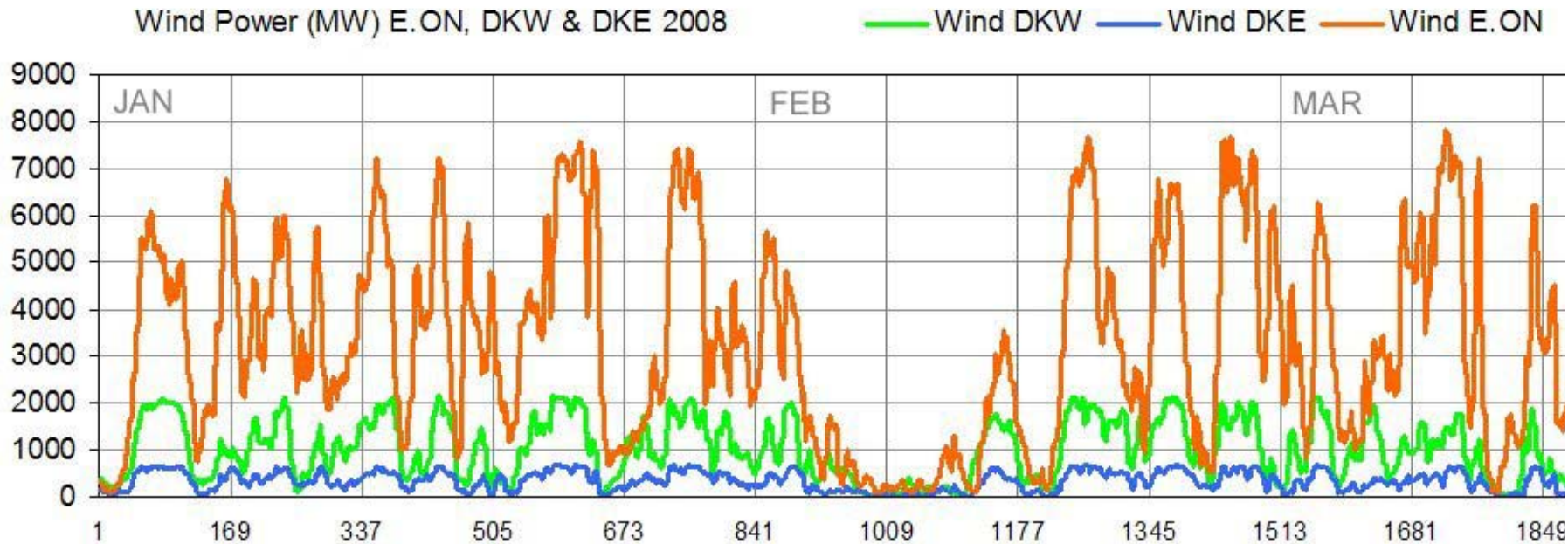
Wind Power 2008 in Denmark and Germany



- Per cent of annual average
- Correlation:
 - DKW-DE: 0.74
 - DKE-DE: 0.79
- Interpretation:
 - High correlations?
 - Good smoothing effect?
- Is the bottle half full or half empty?
- Lower correlation (and better smoothing) between DK and NL

4. Wind Power in Germany and Denmark

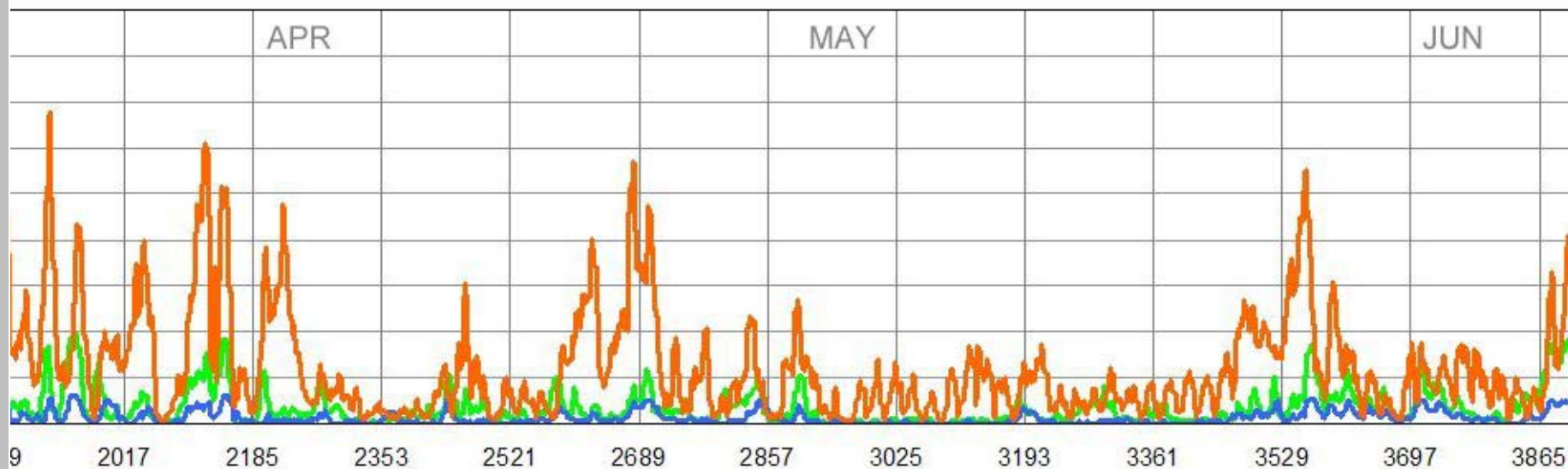
Wind Power Time Series 2008



Peaks and calms seem to be simultaneous during the winter

4. Wind Power in Germany and Denmark

Wind Power Time Series 2008



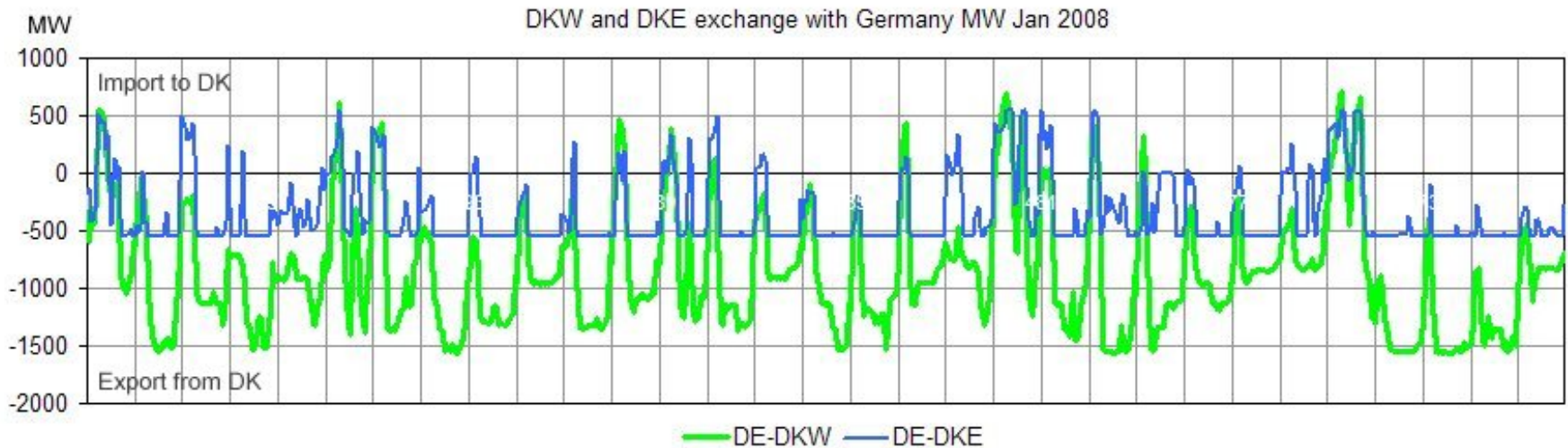
Low wind power output in both countries in April and May

No convincing smoothing effect observed...

4. Wind Power in Germany and Denmark

Exchange of Power

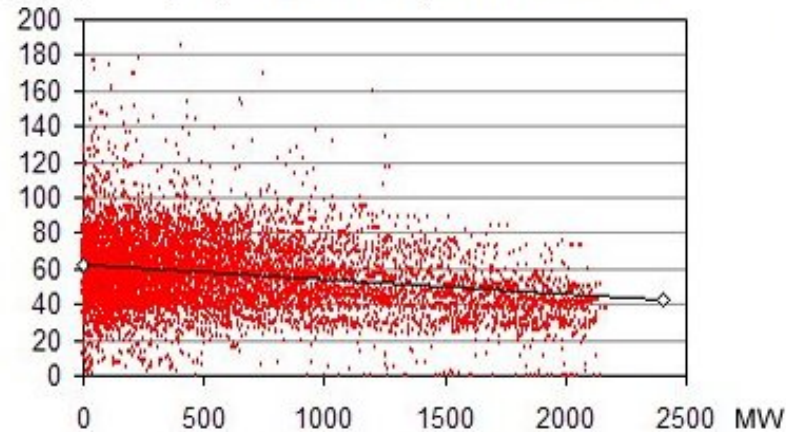
- No market coupling between Nord Pool and EEX
 - ...but explicit auctions of transmission capacity
- Nevertheless a dynamic operational pattern



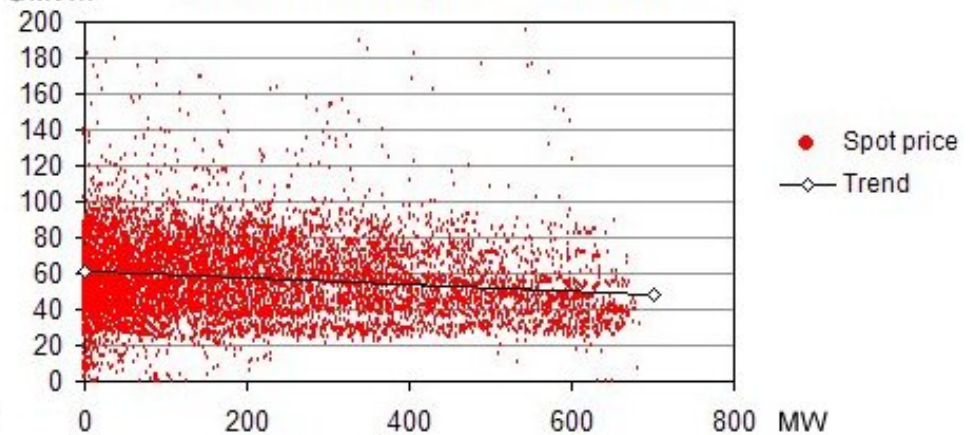
- Southward energy transport
- Surplus of power in the thermal systems during nights
- Bottleneck between DKE and Germany

Wind Power and Spot Prices

€/MWh Spot price and wind power - DKW 2008

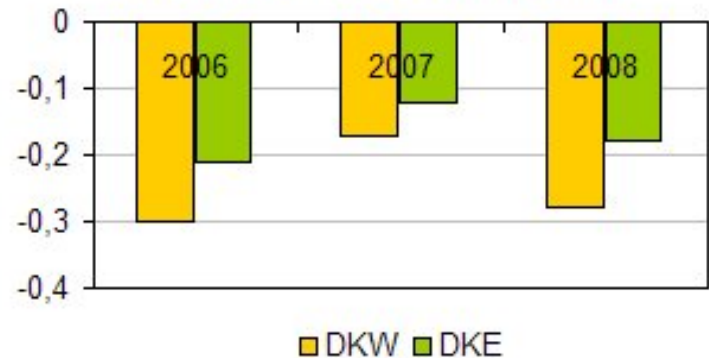


€/MWh Spot price and wind power - DKE 2008

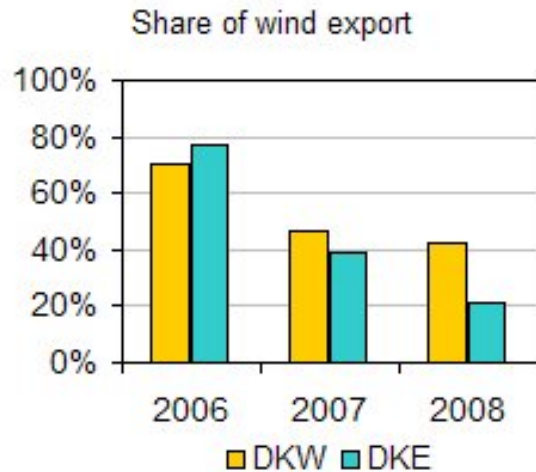


- Low correlations (-0.1 to -0.3)
- Usually low negative slope of trend lines

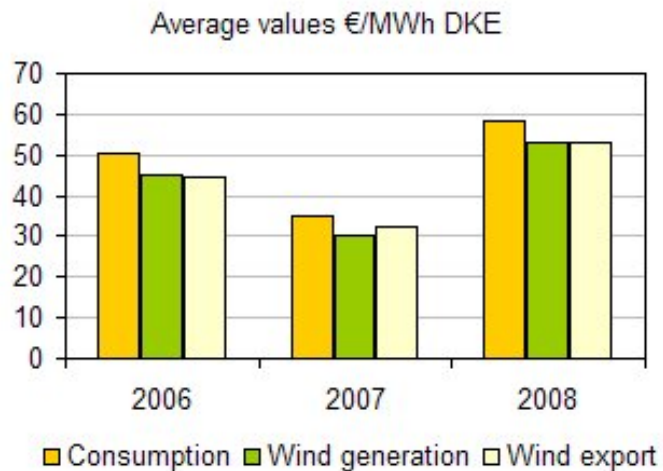
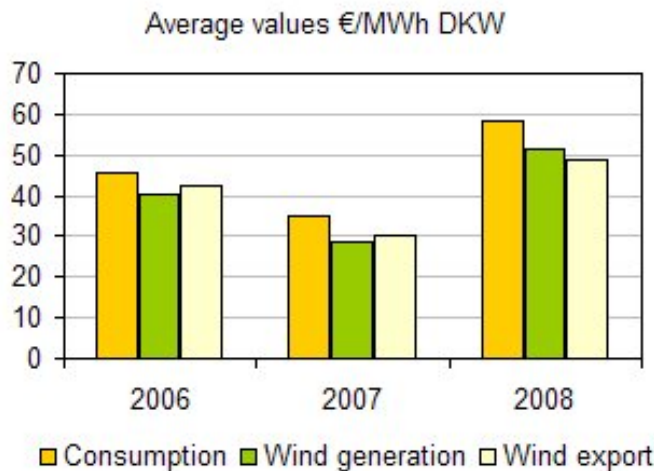
Correlation Spot price vs. Wind power



Fair average prices of exported wind energy



- Consumption, wind generation and wind export have different profiles
- Wind generation has a lower value than consumption
- ...but the spot market has offered fair prices for exported wind power



Results

- The Danish wind power integration
 - No special measures implemented
 - Denmark and Germany seem to share the same balancing resources
 - The interconnectors and the international market systems are decisive
 - Germany and Denmark have together integrated 7% wind energy
 - There is a long way to go to 25% and 50%
- Market performance and system operation
 - Acceptable results observed for the years 2006, 2007 and 2008
 - Market problems seem to be results of grid capacity reductions
 - Spot price volatility is not necessarily a problem
 - ...but it may disturb the confidence of the market players
- The battle between destabilizing forces and stabilizing measures
 - Monitoring market performance can help finding a fair balance
 - Overinvestment is also a risk
 - Stabilizing measures may include grid reinforcement, more flexible generation and price sensitive demand