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HOW TO PLAY THE GAME AS THE BRIDGE BETWEEN TWO EUROPEAN POWER MARKETS - THE CASE OF WESTERN DENMARK

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How to play the game as the bridge between two European power markets – the case of Western Denmark

By

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Abstract

In this paper we set out to investigate the price and quantity fluctuations in Western Denmark, which took place during the winter season 2002-2003. This was a period, which exhibited critical supply conditions in the Nordic area due to a shortage of hydropower. On average, the market in Western Denmark helped to ease the situation by large net exports. However, a more detailed investigation reveals anomalies in market behaviour that do not fit well into this overall positive description of the situation. Several explanations of the anomalies are offered. These may work separately or act in concert. In particular, we look at the large capacity of volatile wind power; the role of the guaranteed fixed prices and the design and functioning of the special auction system of transmission capacity in the interface between Western Denmark and Germany.

Keywords: electricity trade, market power, wind power

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1. Introduction

This paper deals with Western Denmark that was integrated in the Nordic power market in 1999. Western Denmark has several features that are rather special as compared to its neighbours and that make it an interesting case for economic research. In particular, the area of Western Denmark

- constitutes a link between the now well integrated Nordic power market and the power markets of Germany and continental Europe
- has a significant amount of wind power capacity that makes a strong influence on the real time power provision
- has one dominant supplier, ELSAM, that occasionally can exercise market power
- has a part of the power provision (wind power and power from local CHP plants) exempt from competitive pricing through guaranteed fixed prices
- shows large price fluctuations as well as trade patterns that at times run counter to what is expected considering the price development in the neighbouring areas

In this paper we set out to investigate the price and quantity fluctuations in Western Denmark during the winter season 2002-2003 that was a period with critical supply conditions in the Nordic area due to a shortage of hydropower (see Bye et.al., 2003). On average the market in Western Denmark helped to ease the situation by large net exports. However, a more detailed investigation reveals anomalies of market behaviour that do not fit well into this overall positive description of the situation. Several explanations of the anomalies are offered. These may work separately or act in concert. In particular we look at: the exercise of market power and gaming of the dominant power generator; the role of the large capacity of volatile wind power; the role of the guaranteed fixed prices and the design and functioning of the special auction system of transmission capacity in the interface between Western Denmark and Germany.

In the next section of the paper a description of the power market in Western Denmark and its position between the Nordic and the German market is provided. In the third section we analyse the overall pattern of production, prices and trade during the winter season 2002-2003. The fourth and the fifth section are devoted to the analysis of the anomalies that were observed during this season and to the possible explanations of these phenomena. In the sixth section the observed pattern of prices, production and trade is compared to scenarios of perfect competition and market power as

derived by a mathematical model developed for the power market in the Nordic countries and Northern Germany.

2. The power market

Western Denmark (DK-West) is a small system (about 20TWh annually) between the large hydro systems in Norway and Sweden and the large thermal system in Northern Germany.

The system is unique because of the large amount of wind power and local CHP (see Figure 1). Due to large exports that activated otherwise idle central capacity and to relatively low wind speeds the share of these technologies was lower than expected during the winter season 2002-03.

It is only the central production that is exposed to market conditions whereas wind power and local CHP have priority access to sell all power they produce to prices that are fixed by government. Wind turbines will produce according to wind speed whereas local CHP will produce according to a price schedule with three levels (peak, high and low load). As the local CHPs are back-pressure units with hot water storage the owners prefer to produce during hours defined as peak or high (during the day on weekdays) and supply from the storage tank during low load hours (during nights and weekends). To satisfy heat demand during the coldest months it is necessary to increase electricity generation in periods with the low tariff.

All central generation stems from a single producer (Elsam). A large share of the supply comes from extraction-condensing plant (mainly coal-fired) that is obliged to serve a market for district heating (approx. 1,000 MW per hour). Some of the central plants have storages for hot water. The marginal plant that was activated during the dry winter period is typically a condensing coal-fired plant.

Western Denmark is connected to Germany, Norway and Sweden by relatively strong transmission links (see Figure 1). Due to transmission constraints in the connected areas the rated capacity is not always available.

2.1. Western Denmark and the Nord Pool market system

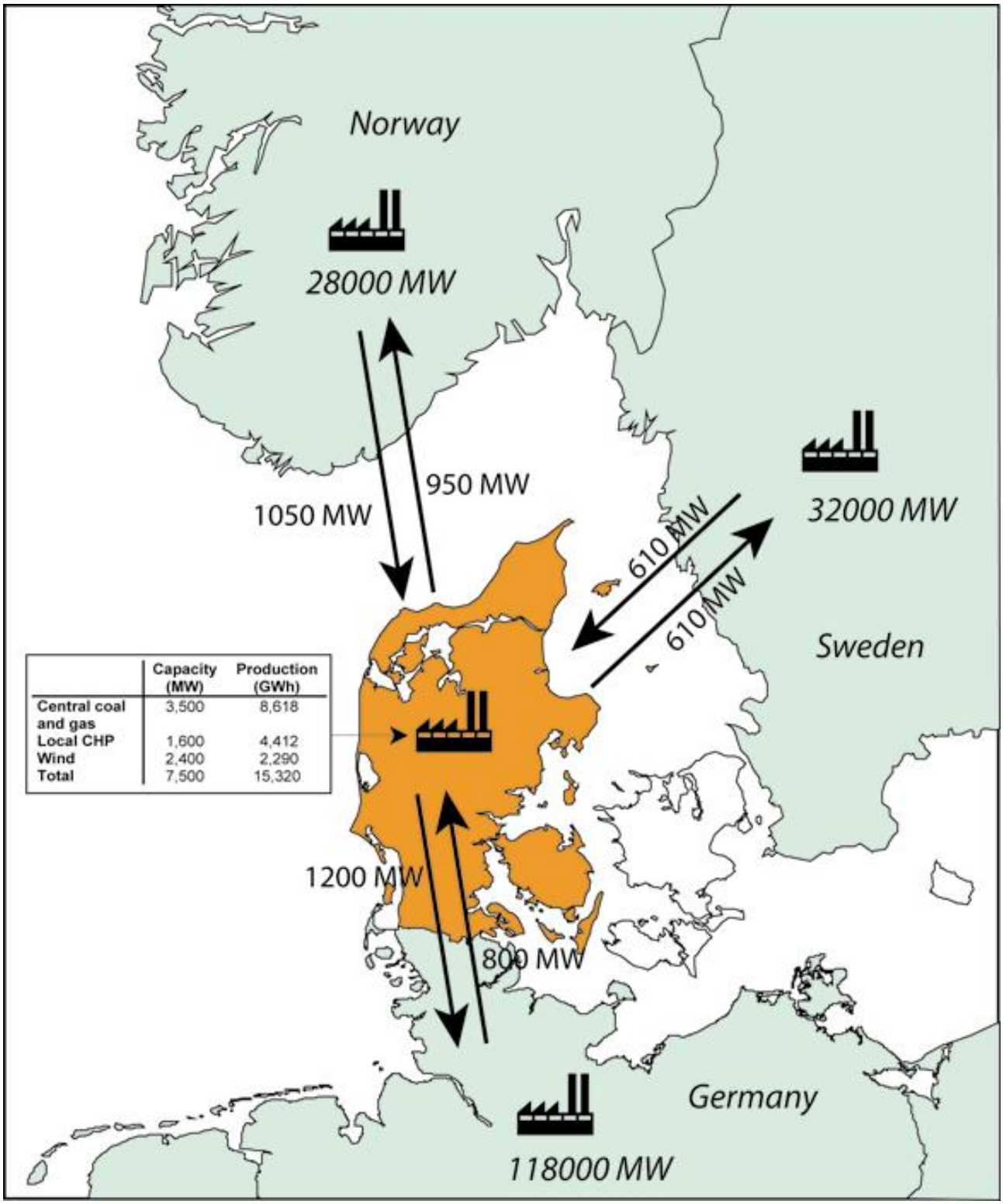
After liberalisation that took place during the 90'ies the Nordic market has become integrated by a common power pool (Nord Pool). Supply and demand bids are delivered each day at noon for each of the 24 hours of the following day beginning at midnight and a spot price, the so-called system price, is determined for each of these hours. This is the most important reference price for the Nordic electricity market. In case of transmission constraints different area prices are quoted. In such cases Western Denmark can be a separate price area. The transmission lines between Western Denmark and Norway/Sweden are operated by Nord Pool. There are no direct costs incurred by transmitting power over these lines. Nord Pool's spot market accounts for a significant share of trade in Western Denmark and amounts to about 50% of sales and purchases.

The power not traded on Nord Pool's spot market is handled by bilateral contracts. These usually are settled with a reference to the spot price. There are additional markets for so-called regulating power as well as for hedging (forward markets and contract for differences between system price and area price).

As 55% of generation in the Nordic area comes from hydropower precipitation and water filling of the large reservoirs in Norway and Sweden is very important for market conditions. A year with much precipitation (i.e. a wet year) will usually have low prices and a year with little precipitation (i.e. a dry year) will have high prices. The demand side in Norway and Sweden is dominated by a large metallurgical industry and by much electric heating. The supply and demand conditions in Norway and Sweden determine a price pattern that is relatively constant over the day and week but varies between the summer and winter season. This pattern and its underlying dynamics of supply and demand is very different from that in Western Denmark where demand is fluctuating much more over the day and week and supply is influenced by heat demand and the variations of wind power[4].

[4] See Nordic Competition Authorities (2003) for a general description of the Nordic power market.

Figure 1. The power market in Western Denmark



2.2. Western Denmark and the German power market

The connection to Germany is operated in a different way. The two system operators on each side of the border (Eltra in Denmark and EON Netz in Germany) arrange annual, monthly and daily auctions (see www.eonnetz-eltra-auctions.org/). Power companies wanting to transmit power can reserve capacity on either or all of these auctions by paying the relevant auction price. The procedure for allocating capacity is as follows:

Annual auction:

- Capacity for the whole calendar year is auctioned.
- Separate auctions for each direction.
- Bids for capacity are accepted according to decreasing price.
- The lowest accepted bid price constitutes the auction price valid for all accepted bids.
- If the total quantity bid is less than capacity the auction price is zero.
- "Use it or lose it" conditions apply.

The monthly auction is based on the same general conditions as for the annual auction

The daily auction:

- The day before real time companies with accepted annual/monthly capacity announce how much capacity they will use. Surplus capacity is auctioned off for each hour the following day.
- Otherwise, the auction is based on the same general conditions as for the annual auction.
- Additional payment for real time transport applies both on the German and Danish side of the border.
- Comprises capacity additional to annual capacity that is only available for parts of the year.

A power pool EEX is operated for the German market. However, it covers much less of electricity trade than Nord Pool. The tradition in Germany is bilateral contracts for longer periods. This is presumably also predominant for the Danish-German trade. A tariff, 1 Euro/MWh, was paid for transmitting over the line during the winter season 2002-2003.

The German market is characterized by a thermal system (coal condensing and nuclear power) on the supply side and a demand that varies considerably over the day and week. The price pattern accordingly displays the typical variations of a thermal system with much larger variations over the day and week than what is common in the hydropower dominated Nordic system.

3. Western Denmark during the dry winter season 2002-03

The year 2002 started and continued over the summer as a year with more than normal precipitation. To avoid water spilling and to make room for expected autumn water inflow the hydropower generators increased production and exports from Norway and Sweden. From mid-September to the end of October that is usually a very rainy period precipitation more or less stopped. As the water fillings were low the supply situation came under pressure at the time the increasing winter demand set in. This development created the dry winter season in 2002-2003.

It was feared that the Nordic market would not be able to handle the situation with tight supply and that things could go out of control with price spikes and brown- and blackouts as in California a few years earlier (see Borenstein and Bushnell, 1999; and Borenstein, Bushnell and Wolak, 2002). For a period prices went up to a very high level (see Figure 2) but not by more than could be expected from the underlying conditions of supply and demand. Several reports analysing the winter season 2002-2003 came to the conclusion that the Nordic market overall behaved as a well-functioning market (see Nordel, 2003; and Bye et.al., 2003). In the report by Bye et.al. allegations put forward of misuse of market power by the large Norwegian generators were refuted (see also Amundsen and Bergman, 2002).

The German market has its own dynamics and is usually not influenced by the conditions on the Nordic market. The winter 2002-2003 was normal in Germany with generally much lower prices than those at the Nordic market. The German average spot price was even lower than in the previous winter season (190 DKK/MWh compared to 202 DKK/MWh in 2001-2002).

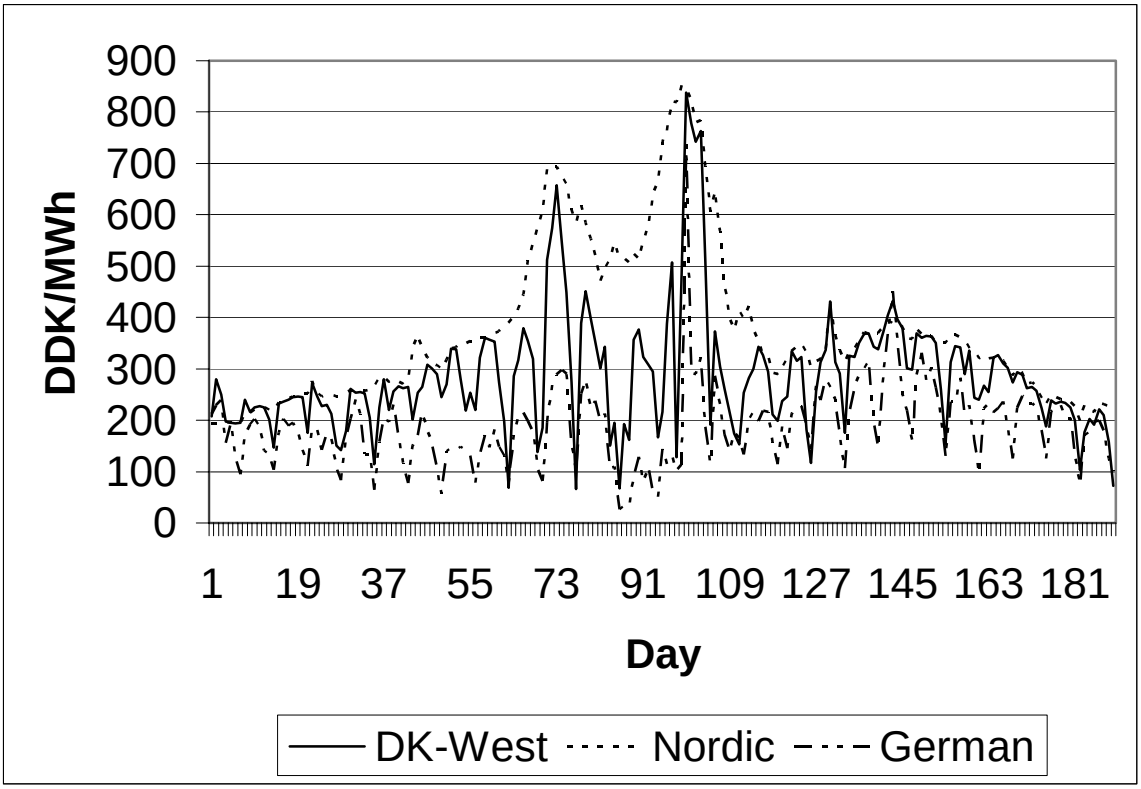
On average the Western Danish market during the winter season 2002-03 behaved according to what would be expected from a normally functioning market:

- The spot price in Western Denmark was intermediate to the German and the Nordic spot price most of the time (the average German price was 190 DKK, the average price in Western Denmark 286 DKK and the average Nordic price 377 DKK).
- The dominating trade direction was South-North (the average trade was 205 MWh/h from Germany to Western Denmark totalling 0.9 TWh for the whole season; from Western Denmark to Norway and Sweden it was 1.021 MWh/h totalling 4.6 TWh for the whole season).
- The power producer in Western Denmark activated coal-fired reserve plants and increased production by 12.2% compared to the former normal winter season of 2001-2002. Total production was 15.3 TWh, consumption was 11.6 TWh thus creating a surplus of 3.7 TWh that together with the net import from Germany was exported to Norway and Sweden[5].

This average picture, however, covers over large variations during the winter season. The Nordic system price started moving upwards during October and November and then increased dramatically to very high levels in December and January. It declined somewhat during February and early March to reach a more normal level (200 DKK/MWh) by the end of March.

[5] All figures are calculated from the hourly market data published by the TSO Eltra in Western Denmark, see www.eltra.dk/show.asp?id=14843.

Figure 2. Daily average price (week 40/2002 – week 14/2003)



3.1. Prices

The *seasonal* price variation is as expected more pronounced for the northern part of the Nord Pool area than for Western Denmark and Germany. The explanation is the combination of hydropower with a consumption pattern in Norway and Sweden that is dominated by large metallurgic industries and electric heating. Figure 2 also shows that the Nordic system price is relatively constant over the week in the Nordic system whereas the price varies much more in the two thermal systems.

In Table 2 spot prices are ranked for each hour in the three market areas for the winter season 2002-2003. The typical rank order was as expected a high Nordic price, a Danish price in the middle and a lower German price. The second largest rank order is a Danish price equal to the system price and a lower German price. The third largest category is a high Nordic price, a lower German price and a very low Danish price. Explanations of these differences will be suggested below.

Table 1. Ranking of spot prices

Rank order of prices	Number of hours with combination	%
Pn>Pwd>Pg	2480	54.73
Pn=Pwd>Pg	837	18.47
Pn>Pg>Pwd	526	11.61
Pwd>Pn>Pg	320	7.06
Pg>Pwd>Pn	141	3.11
Pg>Pn=Pwd	114	2.52
Pg>Pn>Pwd	70	1.54
Pwd>Pg>Pn	43	0.95
Total number of hours	4531	100.00

Pn = Nordic System Price; Pwd = spot price in Western Denmark; Pg = German EEX price – daily auction price

3.2. Trade

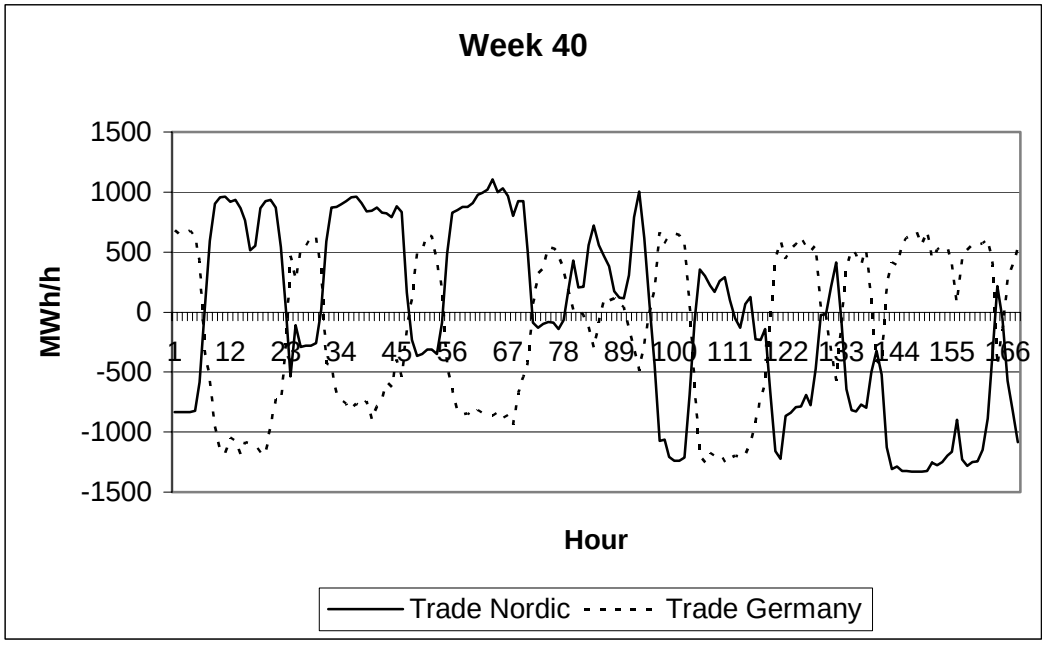
Trade during the winter season of 2002-2003 appears to be determined by price differences as it should be in a normally functioning market:

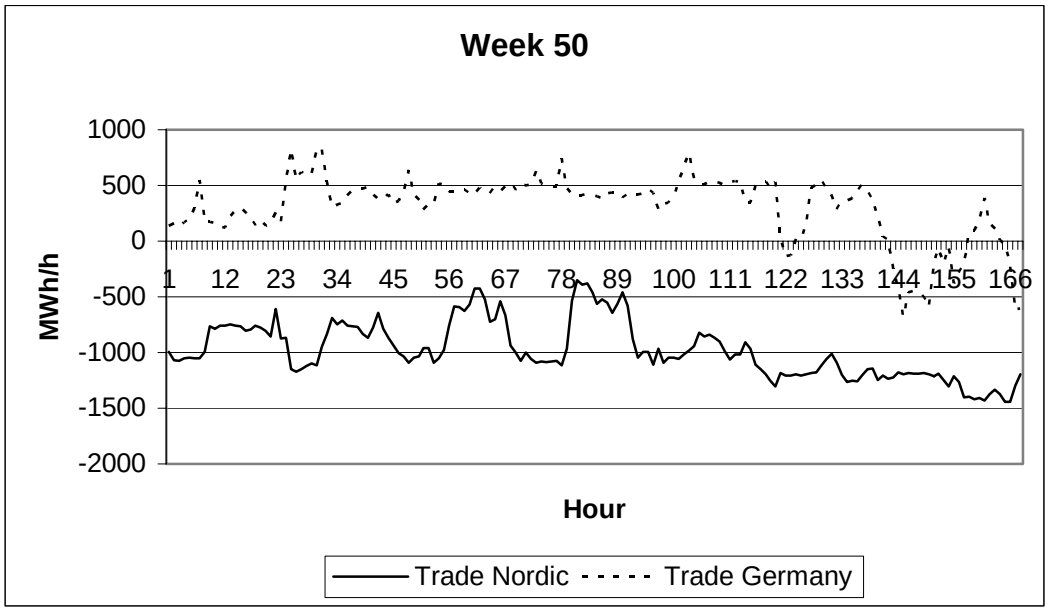
- In October (as represented by week 40 in Figure 3) and to a lesser degree in November, February and March the direction of trade varied according to the following pattern:
    - Imports from Norway and Sweden and exports to Germany during the day on weekdays.
    - Exports to Norway and Sweden and imports from Germany during weekday nights and weekends.
- This is the trade pattern that should be expected under normal conditions for the interaction between a hydro and a thermal system. During the day on weekdays expensive peak load

capacity in the thermal system is substituted by cheap hydropower. During the night and weekends with low demand the cheap surplus from base load capacity is exported to the hydro system where it substitutes water from the reservoirs.

- During December and January (as represented by week 50 in Figure 3) the trade direction was unilaterally South-North during most hours. This is as expected as there were high seasonal demand and a very tight supply due to the shortage of water in Norway and Sweden

Figure 3. Trade in week 40 and 50, 2002





3.3. Production and consumption

Consumption in Western Denmark is high during the day on weekdays and low during nights and weekends. There is a moderate seasonal trend with higher consumption in the cold and dark months. Demand is in general inelastic with respect to the spot price as it only accounts for a small part of the total price due to net tariffs, high consumer taxes and payments to prioritised production. This phenomenon can be illustrated by a comparison of prices and consumption for week 50 in 2002 and 2003. The average spot price in Western Denmark was two times as high in 2002 (439 DKK/MWh as compared with 216 DKK/MWh) whereas average consumption was approximately the same (2,779 MW in 2002 as compared with 2,644 MW in 2003).

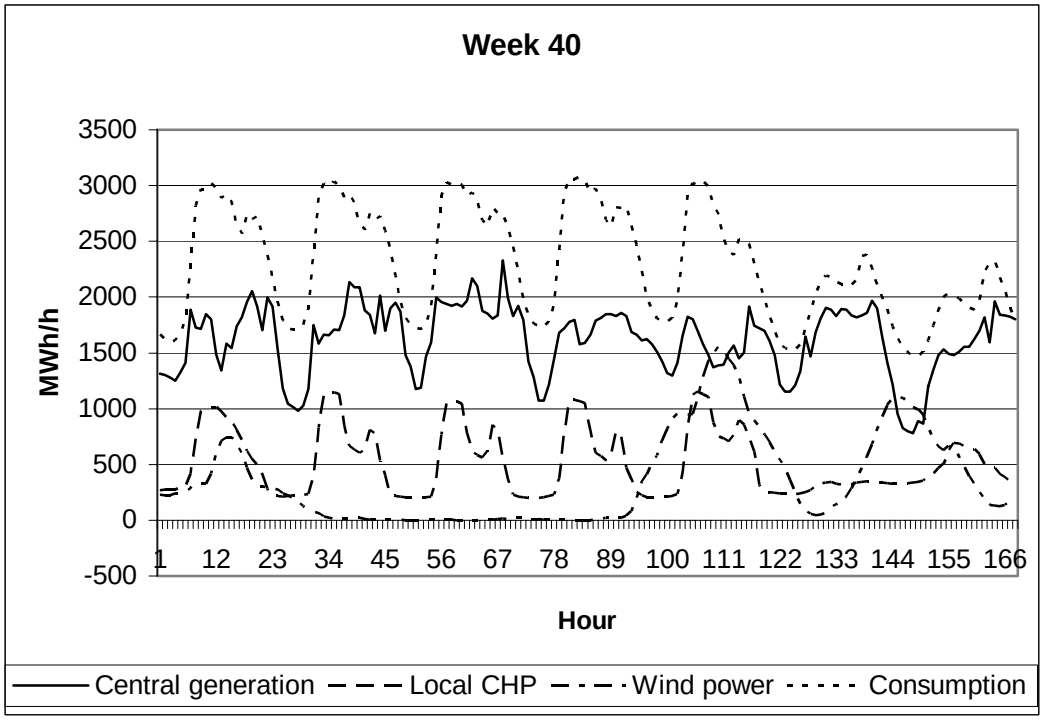
Figure 4 shows consumption and generation for week 40 and 50 in 2002. Variation of central generation follows the variations of consumption most of the time. Only when there is much wind power this pattern is broken and central generation decreases relatively to consumption. This phenomenon will be discussed in the following sections.

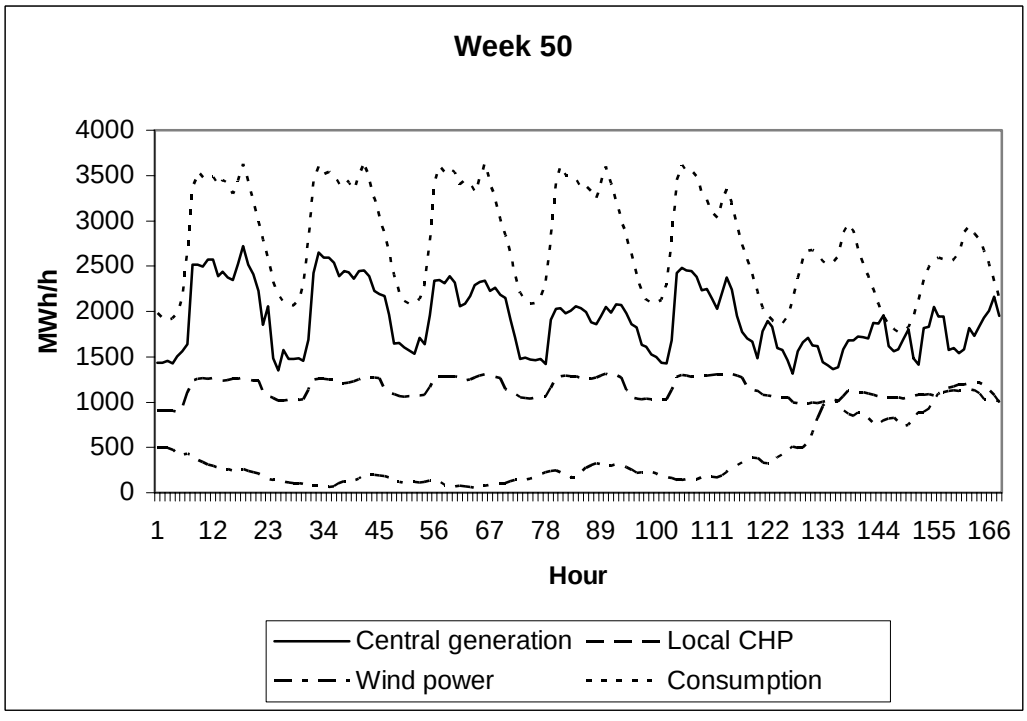
Local CHP follows as mentioned above a daily and weekly pattern according to a politically determined price scheme for each hour of the year (three levels with peak and high prices during the day and low prices during the nights and weekends). The production level increases for low price

hours during the cold period in December-February. The underlying price scheme follows the Danish consumption pattern but not the Nordic pattern.

Wind power is stochastic and can occasionally be very high when consumption is low and *vice versa*. In certain hours with low demand and much wind there is enough wind power to satisfy all consumption in Western Denmark.

Figure 4. Generation and consumption in week 40 and 50, 2002





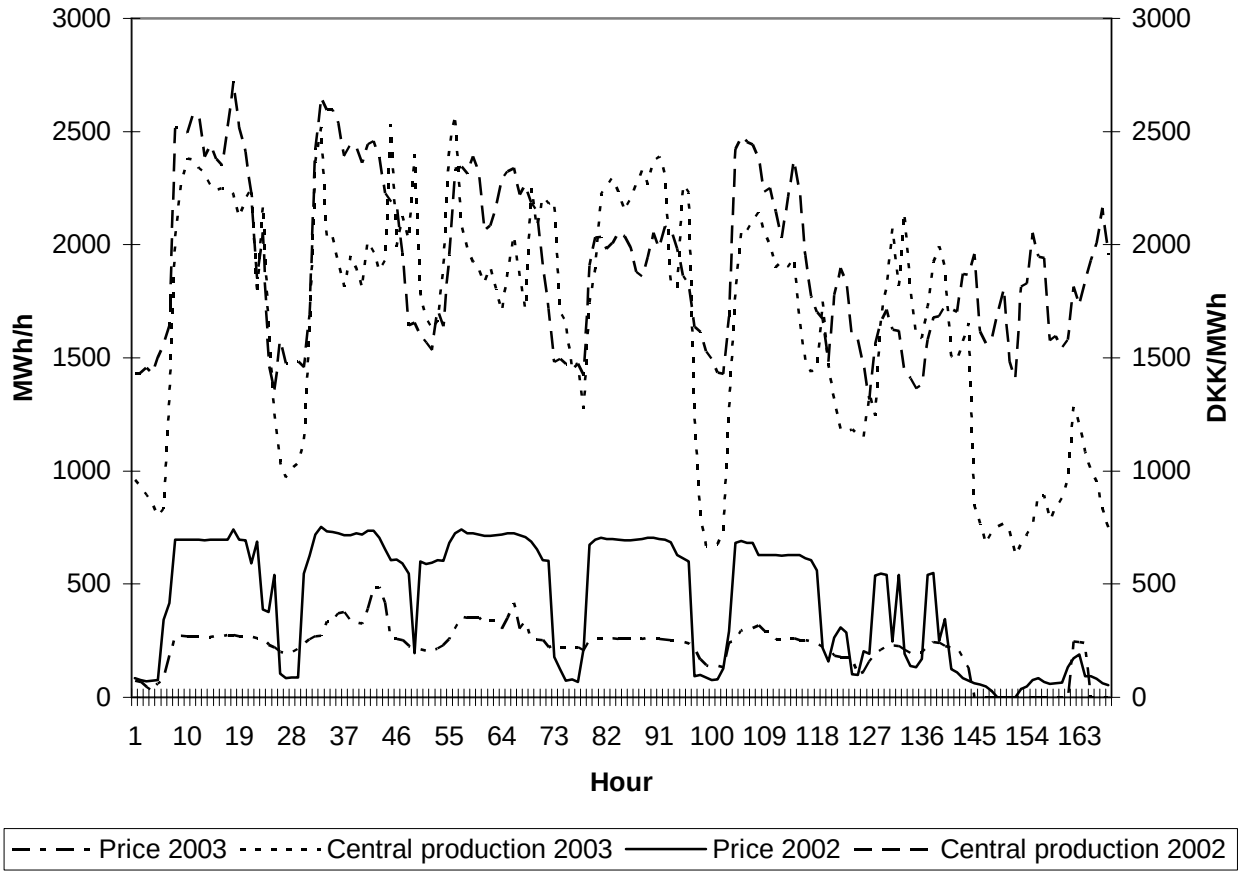
4. Identification of anomalies

The Nordic electricity market managed to handle the very tight supply conditions during the winter season 2002-2003 without serious problems and misuse of market power in the two major countries Norway and Sweden. On average the outcome of the market in Western Denmark helped to ease the situation by large net exports. However, a more detailed investigation reveals market behaviour in Western Denmark that does not fit well into this overall positive description of the situation. In this section deviations from what would be expected at a well-functioning market are identified, while some explanations of these deviations are suggested in the following sections.

1. High prices. It follows from Table 2 that during quite many hours (26%) the spot price in Western Denmark was higher than or equal to the high Nordic spot price. In most hours it was below the Nordic price but often not very far below. In 25% of the hours the Danish price was less than 25 DKK/MWh lower than the Nordic price but more than 100 DKK/MWh higher than the German spot price. It may surprise that it was possible for the Danish producer to get so close to the (mostly) high Nordic price in so many hours. Does the price actually reflect the underlying marginal cost of the supply curve for the dominant producer?

The problem is illustrated in Figure 5 where prices and central production in Western Denmark are compared for week 50 in 2002 and 2003. Electricity generation during the day on weekdays is more or less at the same level whereas prices are three to four times as high in 2002.

Figure 5. Prices and central generation in week 50, 2002 and 2003



2. Idle transmission capacity. When the supply situation in Norway and Sweden is very tight the export from Western Denmark should be maximal. This was not always the case during the winter season 2002-2003. During December and January, when the supply situation in Norway and Sweden was particularly tight, more than 100 MW transmission capacity was idle during 25% of the hours and more than 200 MW capacity was idle during 13% of the hours. Hence, there are clear indications that export and import activities in Western Denmark were not always compatible with a well functioning integrated Nordic power market.

3. Transmission in the wrong direction. Furthermore, during the winter period it also happened that trade went against the direction that was expected according to the price differentials existing at that time. This phenomenon occurred only for trade between Western Denmark and Germany where the Danish price was highest most of the time (see Table 2). During 14% of the hours with Danish prices higher than German prices trade went from Denmark to Germany contrary to what one

should expect. Due to Nord Pool's area price system the same could not happen for the trade with Norway and Sweden.

4. The market collapses. During some hours Danish prices dropped to zero and it became necessary to rationing supply, as even a zero price would not clear the market. These were hours with much wind power and a lot of co-generation necessary to satisfy heat demand – typically nights and weekends during the cold period in December and January.

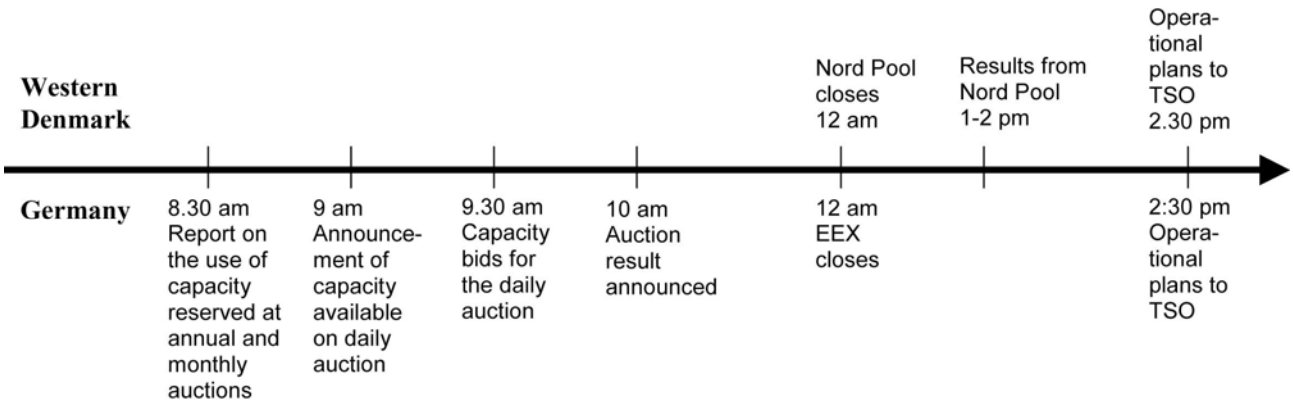
5. Possible reasons for the observed deviations from the expected pattern

The previous section clearly indicates that market behaviour of Western Denmark during the winter season of 2002-2003 was not totally in line with what one should expect from a well functioning power market. In the following two main reasons for this are suggested.

5.1 *Uncertainty and incomplete information*

The deviations from what one should expect from a competitively functioning power market could in part be attributed to stochastic events and incomplete information, i.e. decisions under uncertainty that ex post turn out to run counter to what they should have been if the true state of nature were known with certainty. This could for instance be the case for power transport in "the wrong direction". While power flows freely within the Nordic power market thus equalising area prices (as long as transmission capacity is unconstrained), the same is not true for transmission over the German border. The auctioning system on the Danish-German border implies that import and export decisions be made prior to the closing hour for the German (EEX) and the Nordic power pools (See Fig. 6). Thus, the decision makers have to act on incomplete information with respect to wind conditions, EEX and Nord Pool prices, transmission constraints etc. Strange price and trade movements may thus result. Nevertheless, as will be expanded upon below, exercise of market power in the Western Denmark price area seems to be an at least as probable explanation of the observed deviations as unlucky decisions under uncertainty or bad management.

Figure 6. Daily timetable for the Danish, Nordic and German power markets



5.2. Market power

As mentioned above the power company Elsam is the dominating producer in the Western Denmark price area, possessing some 50 percent of total production capacity. The potential market power indicated by this capacity share must, however, be qualified according to several factors that indeed suggest an even stronger market position than indicated by the mere capacity share.

The exercise of market power is helped by the fact that the daily demand and supply conditions one day ahead are very predictable. Further, as demand is very inelastic Elsam can predict consumption with great precision and so is the case with respect to the supply from Elsam's Danish "competitors", the local gas-fired CHPs. These companies generate so-called "prioritised electric power", i.e. they are guaranteed to sell all their production according to a three-levelled fixed price schedule (see above) and, therefore, cannot be considered as direct competitors to Elsam. The local gas-fired CHPs, thus, produce in a very predictable way and are in this respect comparable to a fringe of competitive producers. However, unlike a competitive fringe the local gas-fired CHPs do not react to price variations and for instance will not expand electricity generation as the market price (the Western Denmark area price) increases. Potentially this gives Elsam a larger amount of market power than what is indicated by its mere capacity share.

Wind power is also prioritised but the amount supplied the following day is not as predictable as supply from the local CHPs. Wind power is delivered to the market as the wind blows. Hence, wind power is supplied to the market seemingly without any strategic decisions made by the owners (thus implying an extremely low price elasticity of supply). However, it could be argued that it is not

wind speeds realised the following day that matters but the predictions made by the market actors. Prioritised wind power is purchased and sold at Nord Pool by the TSO in Western Denmark, Eltra, at the market price. If Elsam assumes that it has the same model for forecasting wind speeds as Eltra it can predict the amount offered on Nord Pool for the following day and thereby its impact on the market outcome.

With respect to power exchange with the neighbouring countries Elsam will know the expected flow crossing the Danish-German transmission link (at 10 am, see Figure 6) before it decides its bids on Nord Pool (at 12 am) and the German spot market (at 12 am). It will also possess good information on the expected supply situation in Norway and Sweden.

In short, Elsam may potentially determine the area price by acting on the residual demand function and raise the price without triggering increased supply from other local producers. However, the possible choice of market strategy by Elsam is not unconstrained. One constraining factor in this respect is the size of total demand and the size of total supply coming from wind power and local gas-fired CHP. During day hours in the winter season (with net exports to the other Nordic countries), demand is sufficiently high to give Elsam a strong position for exercising market power. In this situation power from the other producers is supplied in a very predictable manner as explained above and there is a large amount of residual demand that Elsam may satisfy at high prices.

At other times (e.g. during the nights and weekends) demand falls a lot and Elsam's position is weakened as generation from local CHPs and wind power becomes sufficient to supply the market. In addition, Elsam is not totally at liberty of restricting power generation during such periods. The reason for this is that Elsam has an obligation of delivering hot water to the heat market in the larger cities that necessitates a corresponding amount of power generation. This is probably the reason why Elsam sometimes is not able to keep high prices. Therefore, at times of slack domestic demand the area price of Western Denmark may drop to zero, even with a sizable export to the neighbouring regions.

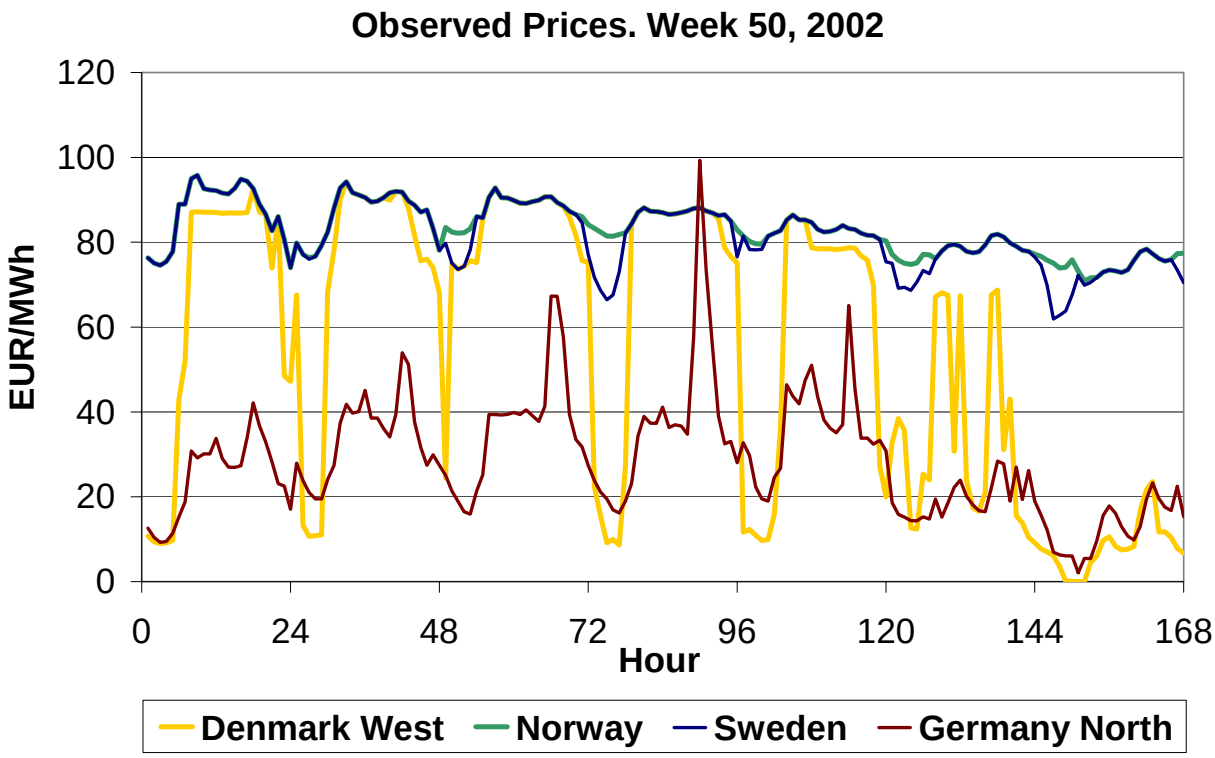
Elsam is also constrained by the operational inflexibility of central generation that makes it very expensive to change the load from hour to hour and in particular when it becomes necessary to start or stop a coal-fired plant.

Finally, Elsam's potential for exercising market power is constrained by imports from the other Nordic countries and Northern Germany. If supply tends to be scarce in the Western Denmark price area power will be exported from its neighbouring areas. Due to the Nord Pool system this is more or less automatic for power stemming from the other Nordic countries. Still transmission capacity puts a constraint as to how much power may flow from these areas. As the capacity becomes constraining a situation of higher prices in the Western Denmark price area may be sustained. As already observed the power flow from Germany is, however, not automatic and Elsam may in fact play a role in restricting the imports from Germany even though the price level in Germany may be far below the price level of Western Denmark.

The strategy of a producer attempting to exercise market power will be different according to the direction of the price difference. When prices are expected to be lower in Norway and Sweden than in Denmark it pays to fill the transmission lines to reach the constraint, which will cause a separate price area with a high Danish price. Higher German prices will of course help to achieve this purpose but even with a lower price it can be profitable to export some power to Germany thus "emptying" the Danish market. When prices are expected to be higher in Norway and Sweden the opposite will be the case, i.e. it pays to keep the transmission lines open to avoid a separate price area and to get the high system price. Selling power on the German market can help to achieve this outcome and again be profitable even when prices are lower here than in Denmark.

An example could be week 50 in 2002 (see Figure 7) when the Nordic price was extremely high. It shows how the Western Denmark price tracked this price in the neighbouring regions very closely in periods when Elsam had a strong position of market power (i.e. day time hours during the winter season). The interesting observation is that the high price of Western Denmark could have been avoided by importing a lot more from Germany (most of the time import was 500 MWh/h or below, cf. Figure 3, i.e. a sizable amount of free import capacity was available). This analysis will be continued in the next section.

Figure 7. Observed prices week 50, 2002



6. Model analysis of market power for two selected weeks

The TSO in Western Denmark, Eltra, has developed a simulation model for studying prices, production, demand and exchange in the power market called *MARS* (MARket Simulation, see Eltra, 2003). The model can be applied to the analysis of market power. The model comprises the Nordic countries (Nord Pool area) and Northern Germany. It is designed for studying the interaction between hydro-, thermal-, nuclear, and wind-power. It calculates a piecewise linear supply function for each plant and calculates a supply function equilibrium. In doing so it takes account of capacity constraints in generation and transmission. Demand is price sensitive (Cobb-Douglas function). The model calculates a competitive solution (maximizes social surplus) as well as a Nash equilibrium (using mark-ups on supply functions) for the case of market power.

The model calculates supply function equilibria for six price areas determining prices, generation, demand and trade for each hour for each price area.

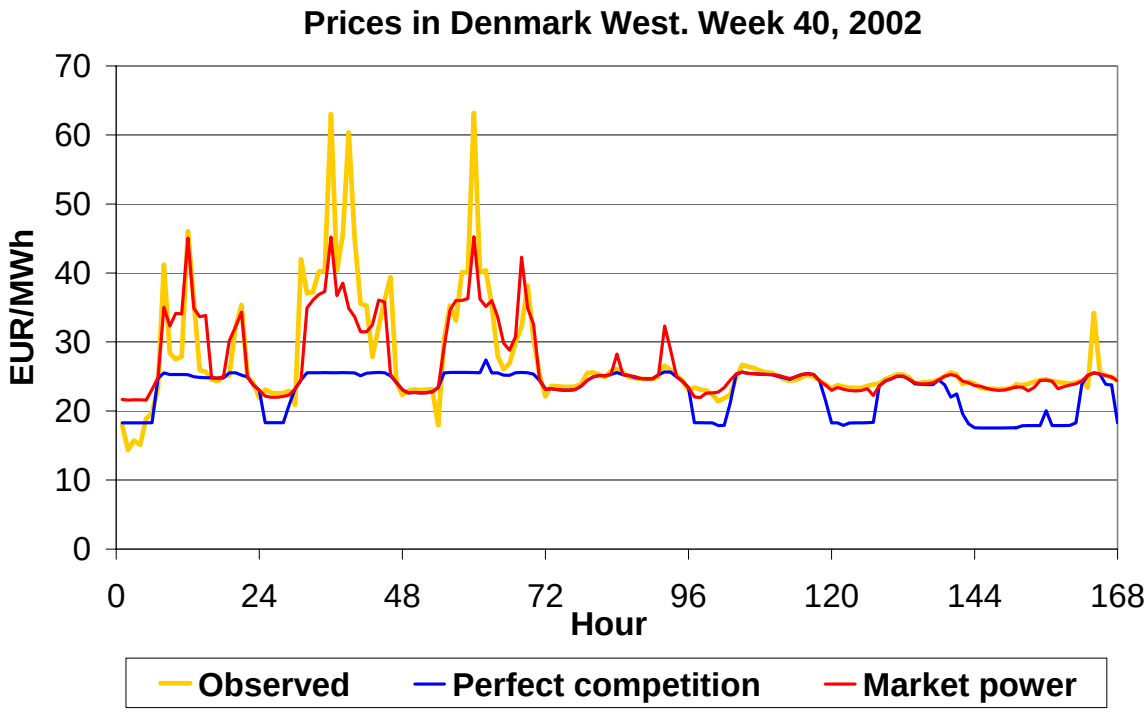
In this paper, the model has been applied to two selected weeks during the winter season of 2002-2003:

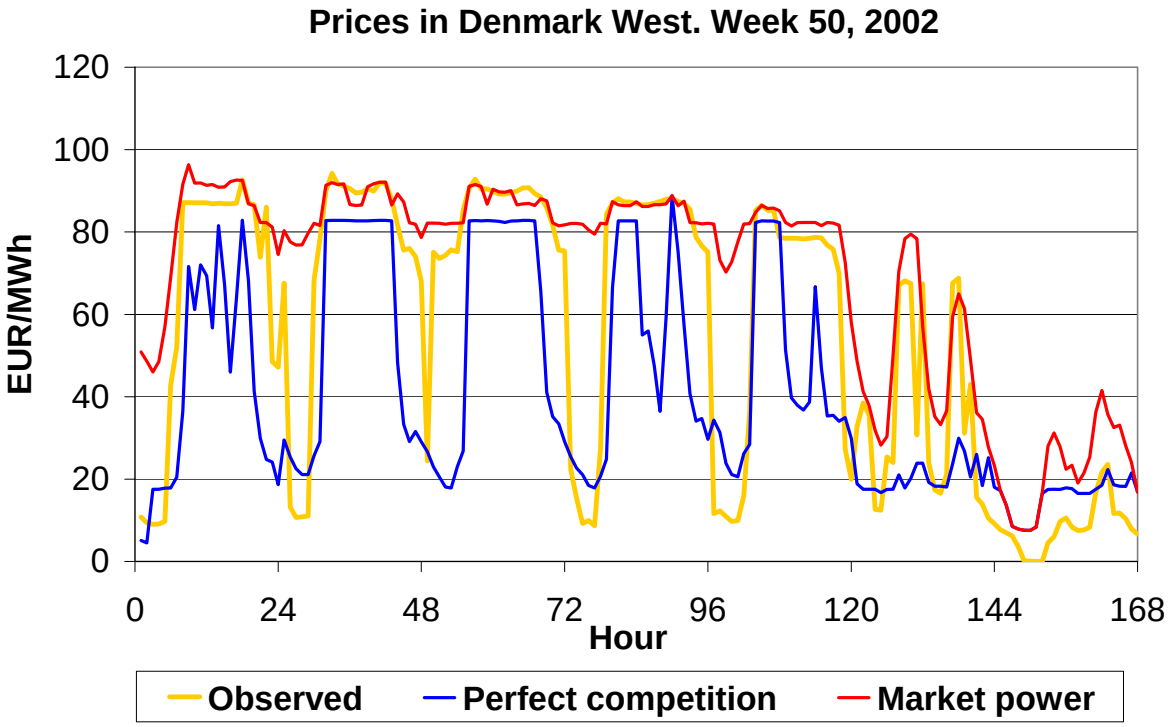
- Week 40 as representing a close to normal week in early October.
- Week 50 in December as representing a week from the critical period with tight supply and very high prices.

For the two selected weeks equilibria for perfect competition and market power were calculated for Western Denmark and compared with the observed data with respect to the following indicators: prices, central generation and trade. The specific assumptions for this exercise of the model can be seen in Appendix 1.

As the model simulations only consider a very limited period of time the results can primarily be used to illustrate possible market mechanisms and do not constitute a full description of the market conditions in the winter of 2002/2003.

Figure 8. Calculated and observed prices for week 40 and 50, 2002



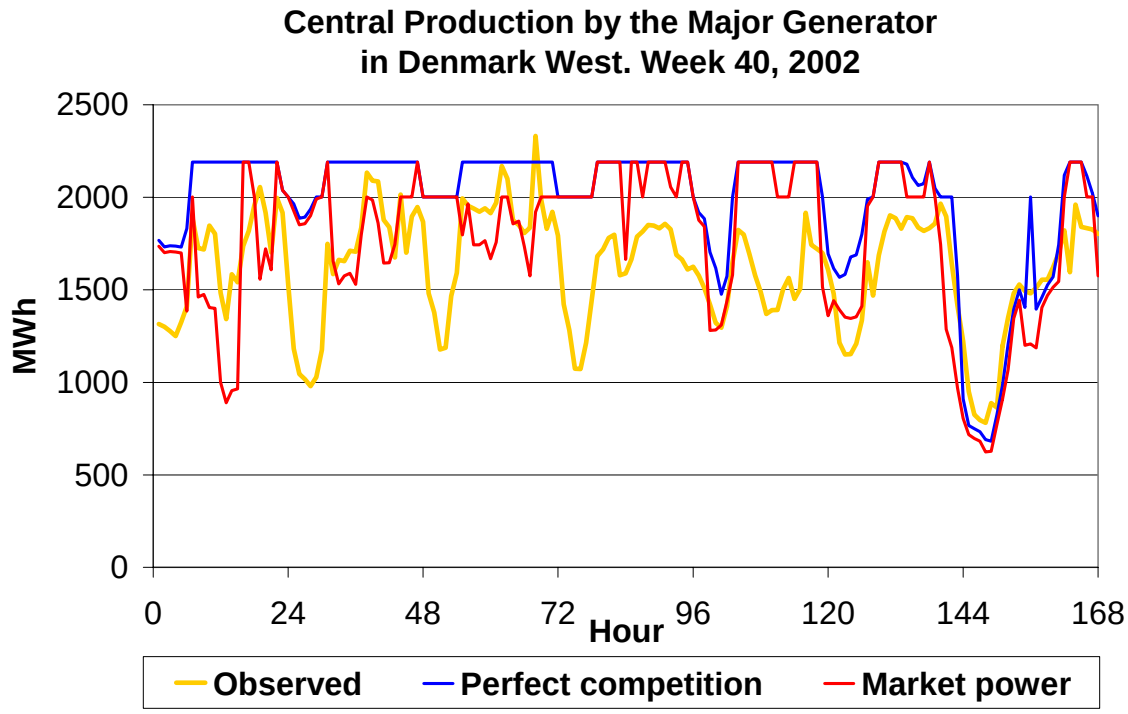


From the simulation of perfect competition in week 40, 2002 (Figure 8), it is obvious that perfect competition does not describe the observed market outcome. A better fit is obtained when simulating market power. In this scenario prices in Denmark West are raised to the high daytime price level in Germany on Monday, Tuesday and Wednesday. For the market power scenario, the model thus traces observed prices rather closely (except for a few price spikes). During the rest of the week (night hours and weekend) the market power scenario gives a Danish price that follows the Nordic price that except for a few day hours on Thursday and Friday is higher than the German price.

In week 50, 2002, the Nordic system price was very high. Simulation of perfect competition in Denmark West results in prices similar to those actually observed: very high prices in day hours and low prices at night and during the weekend (the market power scenario also simulates the first but not the last). Although the prices are not the same, the tendency is clear. The reason for the high

prices is lack of production capacity in Denmark West, not high marginal costs. Low production capacity relative to demand causes a suspension of the congestion between Denmark West and Sweden and thereby equalises the prices in the two areas. It may be questioned whether the lack of production capacity as determined in the model actually did occur in Denmark West in week 50.

Figure 9. Calculated and observed central production in week 40 and 50, 2002



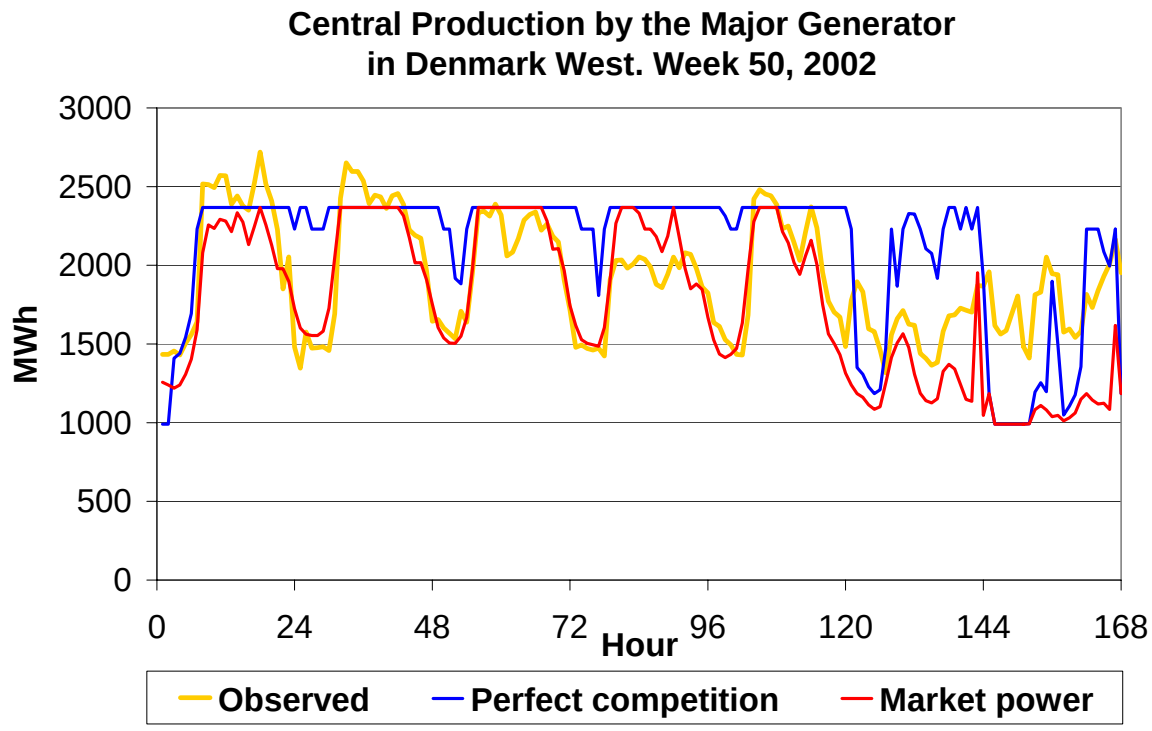
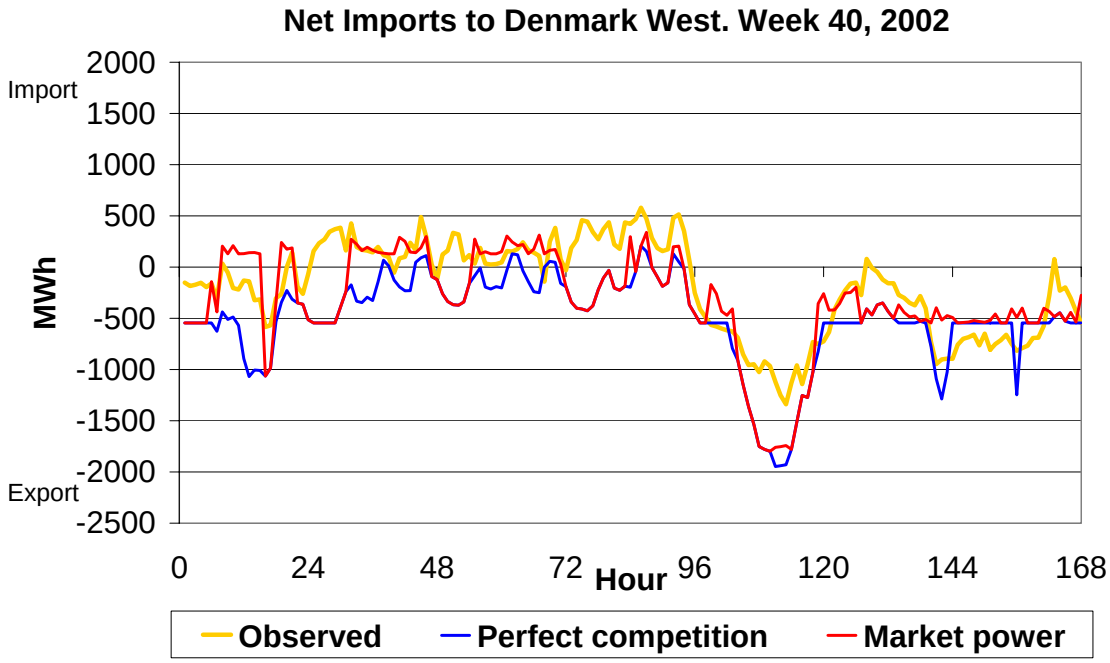
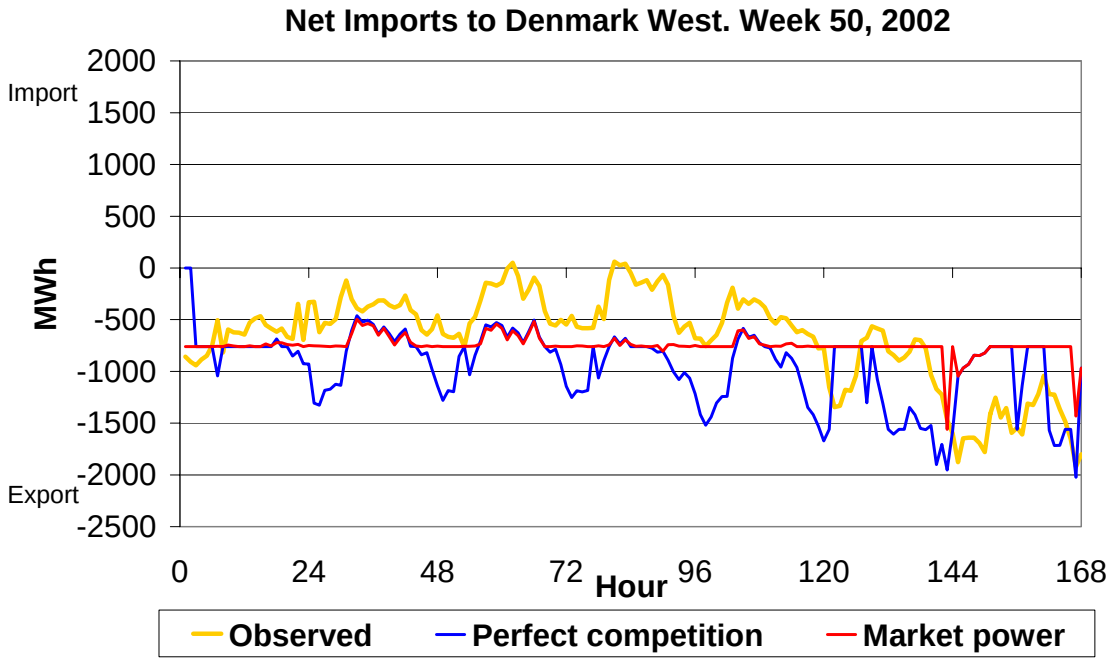


Figure 9 showing the dominant generator's supply during the two selected weeks doesn't substantiate the price picture. During week 40 the observed electricity generation deviates from the generation calculated in the two scenarios - in many hours it is below the outcome calculated for the market power scenario. Observed central generation fits quite well with the market power scenario during week 50 (except for Sunday). However, prices were closer to the perfect competition scenario. These deviations should be analysed in relation to the power exchanges with the neighbouring countries in Figure 10.

Figure 10. Observed and calculated net exchanges in week 40 and 50, 2002





Week 40 was a week with a "normal" exchange pattern for Western Denmark (see Figure 3) – exports to Germany and imports from Norway and Sweden during the day and imports from Germany and exports to Norway and Sweden during the night and weekend. The result is a relatively small net exchange. The observed exchange data do not fit very well with any of the two calculated scenarios, which reflect the deviations of the calculated central generation (see above). In hours when central electricity generation is considerably below the scenario predictions net imports are higher than in the scenarios, i.e. it is a consequence of the balancing of demand, production and net exchange in the model calculations. The calculated demand is very close to observed demand in both scenarios.

Week 50 was a week with a very tight supply situation in Norway and Sweden. The trade direction was South-North with net exports in most hours (see Figure 3). This is also the outcome of the two scenarios with more export under perfect competition than under market power. However, the amount of exports in both scenarios is considerably higher than the observed amount (except for Sunday). A part of the explanation of these deviations can be higher observed than calculated consumption – the price elasticity assumed in the model is too high (numerically). To balance this net exports are lower.

7. Concluding remarks

The winter season 2002-2003 was special for the power market in Northern Europe due to the unexpected low rainfalls in Norway and Sweden. In general the liberalized market managed to handle the difficult situation and avoid disruption of supply and other emergencies. Western Denmark served as a bridge between the large hydro system in Norway and Sweden and the large thermal system in Northern Germany and was crucial during the period for securing extra supplies to the Nordic market. On average the Western Danish market behaved according to what would be expected from a normally functioning market during the strained situation. Electricity generation from central coal-fired plants was increased and exported to Norway and Sweden together with extra imports from Germany in order to ease the supply constraints there.

However, there were deviations from this description of market behaviour in Western Denmark: prices were most of the time much closer to the high Nordic price than to the low German price; sometimes there was idle transmission capacity or transmission went in the wrong direction; at

other times the market in Western Denmark collapsed and prices went to zero making it necessary to rationing supply.

Several explanations of such anomalies are discussed in the paper. One is uncertainty and incomplete information: the precise wind speeds, spot prices, transmission constraints and demand are not known when the generators decide their bids on the power pools. An alternative explanation is the exercise of market power by the dominant producer that possesses about 50 per cent of total generation capacity. The power market in Western Denmark has several unique features and it is argued in the paper that some of these contribute significantly to decrease uncertainty for the dominant generator. Most of the electricity not supplied by this generator comes from local CHP that because of guaranteed fixed prices does not react to market signals and thus is very predictable. Even the market impact of wind power, the amount of which sometimes is quite large, can be predicted with some certainty.

The hypothesis of market power is further investigated by model analysis of two selected weeks, one representing the period with normal supply conditions and one representing the period with very tight supply conditions. There is no simple conclusion from this analysis that partly fits the observed behaviour and partly not. The prices in the normal week correspond best to the market power scenario whereas the prices in the tight week corresponds best to the perfect market scenario.

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Appendix 1. Assumptions for the calculations using the MARS model

Parameter	Description
Consumption	Metered hourly values
Demand model	Average price: EUR 25 per MWh Demand elasticity: -0.1
Production	Wind power, local CHP units, central CHP units and central condensing units. The local CHP units are not integrated into the market. Metered hourly production from wind turbines and local CHP units is given as input to the model. Production at the central units is endogenous. The capacities of the central units are average values taking maintenance and risk of breakdown into account.
Exchange capacity	Assessed capacities from hourly registrations. The capacities are kept constant during each simulated week because of model limitation.
Point access tariff	EUR 1.25 per MWh for exchanges with Germany North and EUR 0.125 per MWh elsewhere.
Boundaries	In Norway as in Germany the model gets a complete match of the historical prices. In Sweden, however, weekly average prices are used as water values.

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