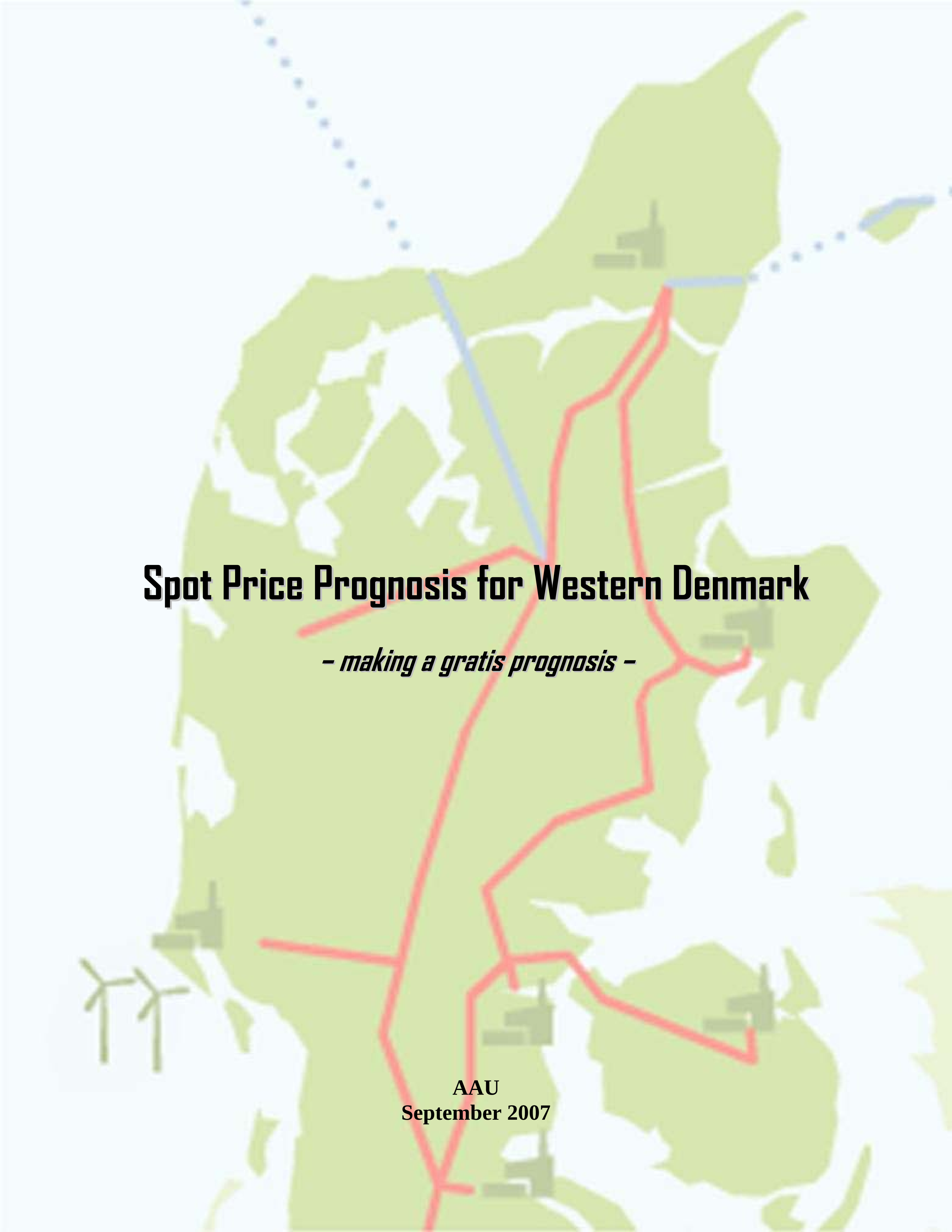

Spot Price Prognosis for Western Denmark

– making a gratis prognosis –

AAU
September 2007

Front page background image taken from ww.Energinet.dk

Spot Price Prognosis for Western Denmark

– making a gratis prognosis –

AAU
Environmental Planning and Management
September 2007

Supervisor: Anders N. Andersen

Student: Constantin Iulian Laza

Table of Content

1 Introduction

This section contains a general introduction to the report, framing the field of interest and the scope of the problem area to be analyzed further. The main question is proposed in the context of a free market and competition. The chapter includes a definition of the research question and the associated sub-questions to be answered during the course of the report.

1.1 Background

Electricity market in Europe is undergoing changes aimed towards security of the energy resources and market deregulation. In the wake of this, Nord Pool market shows signs of growing beyond the boarders of the Nordic Countries, with better integration of Germany in the near future, building of new interconnections, such as the one with Netherlands.

Denmark, as one of the Nordic Countries participates on the Nord Pool, having an increasing share of power traded through it. As a front runner in Europe, in regards to developing its renewable energy infrastructure Denmark has large wind turbines farms from which a large portion are in the Western Denmark. They constitute an influential factor on the power market, especially in Western Denmark. Beside wind based power production Denmark, has a large pool of CHP producers participating on the electricity market. However, still the largest dependable contribution comes from central power plants, which use coal, and in a smaller degree natural gas in CHP units.

All producers in Denmark participate on a free spot market, competing and thus creating the need for improvement in production strategies and market participation strategies. Small and medium CHP units have an important role on the spot market, because of their flexibility.

1.2 Problem Formulation and Related Research Questions

To be able to participate profitably on the electrical Spot Market players need a production strategy that follows the fluctuations in the spot prices hour by hour and take advantage of the most profitable production hours. Producing companies and consumers participate on the spot market at the moment either directly, Vattenfall, DONG Energy, industrial consumers, etc.; or indirectly through representing companies. It can be argued that the latter companies lack the financial power to participate effectively. From initial studies the prognosis bears responsibility with regards to increasing costs for competitive access to the power Spot Market.

At the moment, prognoses are made by participating companies using data acquired contra cost and data obtained free of charge, usually from authorities and companies such as Transmission System Operators or Nord Pool.

What if the there is a way to reduce, or even eliminate the cost related with making a good prognosis? A prognosis that is affordable to everyone would surely help small companies to have a better opportunity in a direct participation on the spot market and reduce their spending. It can be argued that this might help in opening the Spot Market even further stimulating competition.

In the light of these considerations, the problem formulation is defined by the project main question:

Is it possible to make a good prognosis for the electricity spot prices in Western Denmark, using free available data from internet sources?

To clarify this formulation additional questions are raised and answered through out the present report. They are as follow:

What is a good prognosis?

This question clarifies what constitutes a good prognosis and sets up a reference point in order to be able to judge the project's results. This question is treated in detail in section **5.2**

What can be considered free available data?

It treats the availability of the data required to calculate the prognosis and makes distinction in the importance of relevant variables. In larger sense it makes the distinction between usable data and data excluded from the calculation. This is treated in detail though out several sections further on (section **5.2**, **6.1**).

What is the time frame of the prognosis?

This is a complementary question aimed at presenting the prognoses extend. For the project purpose only one day ahead prognosis is sufficient. However it is considered that a more practical prognosis is required to fully answer the main question in practical terms. A seven day prognosis is preferable in practice to a one day prognosis. This is due to the fact that all producers are using the prognosis to plan their production and participation on the spot market at least several days ahead. This issue is treated into detail in section **4.2**.

To help answer the project main question a series of research questions will be treated through out the present report. They are grouped in three sections not necessarily in the order in which they will be answered, as follows.

To understand the background in which the prognosis are used a relatively detailed image of the studied market is presented and its inner workings with emphasis on the aspect of interest, the Electricity Spot Market. From the main question it is clear the studied market is one that includes the Western Denmark; therefore the focus of the questions is on this region.

- Who are the major stakeholders?
- What energy aspects define the region?
- How are the spot prices reached?
- What influences the spot price?

Next a method to calculate a prognosis is needed; together with this, limits are set up for the prognosis and the depth of the investigation undertaken. Prognosis and the beneficiaries of it are discussed using following questions:

- How are the existing prognosis made?
- What calculation method is used to reach a usable prognosis?

- What uses has a prognosis?
- Is prognosis needed?
- How accurate are the existing prognosis?
- Who uses prognosis?
- What degree of accuracy is required in a usable prognosis?
- What is the time frame for a usable prognosis?

The term of ***usable prognosis*** is used often as focus of the questions; this refers to prognosis that can be used effectively in participating on the spot market and so, scheduling the electricity production.

Finally questions are used to provide a satisfactory image of future developments related with the subject at hand, prognosis.

- What influence will a better integration of price areas have on the prognosis?
- Is the model developed practical?

In the following section the motivation and the base support for the main question are given, further enforcing the validity of the problem raised through this question.

1.3 Why and What for

It felt necessary to argument further towards acceptance and understanding of the project main question from the previous section. This is done using five questions as presented in this section.

Why is this topic of interest?

At this time no model for calculating spot market prices as prognosis using the same limitation as the one presented through out the present report is available freely or commercially to the knowledge of the author. Further, from initial estimations most of the data required to make a viable calculation model for spot prices needs to be bought, making relatively difficult to develop a mathematical model that uses it in its algorithm. The main assumption is that the involvement of the commercial data in obtaining a prognosis can mean high prices for the end user. What if a fairly accurate prognosis can be made using freely available data, such as consumption forecast from ***Energinet.dk*** or spot prices in previous days from ***Nord Pool***? This, of course, could result in a prognosis that has a lower requirements to obtain and thus cheaper that a prognosis obtained by using bought data. For this reason it would be a commercial advantage to any user interested in obtaining this prognosis as it will reduce the costs involved with participating on the spot market.

What is the Background on the previous solutions, if any?

The access to any solutions similar with the one sought through this research project are restricted. This is due to the usage of the data resulted from it, which is a commercial one by power plants interested to participate on the spot market. It is understandable that companies providing these data are going to protect their financial interests and not make the mathematical model used available. From investigations into this matter no such model, as the one proposed by the present report, has been developed.

What is the background on potential solutions?

The project seeks to improve a mathematical model which calculates a series of numbers representing the spot price for one day or several days, in each hour of the day. The starting model is taken as a simple average calculation of the spot price for one day using data from previous three days and excluding any other external variable such as climatic conditions or fuel prices. The final mathematical model includes also external variables and is looking to improve the results from the starting model. As a further refinement of the model it is sought to compare its results with the data from a company that provides prognosis for spot market prices and the actual data from the market.

What will be presented in this paper, present report?

In the report the theoretical framework is presented in the support of the mathematical model developed. Further, a detailed analysis of the variables that can be used or are used in this model is made. The mathematical model is described in detail and resulting data is presented in support of it. Data resulted from the model (time series of the spot prices-prognosis) are analyzed against any similar data available. Alternative models are discussed and conclusions are drawn aiming at the improvements made in accurately making a cheap prognosis.

Who needs the prognosis?

The prognosis is now an integral part of the production strategy a power plant uses to maximize its profits from participating in the spot market. It can be said that any company that participates on the spot market as producer wants a prognosis that gives a fairly accurate estimation of the upcoming prices in order to schedule its production so it sells in the most profitable hours - when the difference between the spot price and the marginal cost of production is higher than in other hours.

The model developed is aimed at medium and small producers, CHP plants in particular, for the simple reason that the case study used in developing the model is such a plant (***Hvide Sande Fjernvarme***).

2 Theories and Methods

This section provides the reader with a theoretical outline of the project within a given structure. The report structure and its limitations are provided, while the theory for data collection and research design is elaborated.

2.1 Report Structure

Following the questions raised in previous sections and keeping in mind the main question the report is structured in several sections interconnected to support each other.

Following an introduction into the theme of the project the report has a multithread progression where theoretical and empirical investigations are carried simultaneously. The theoretical and empirical analyses are most of the time intertwined to support each other points.

The structure of the report as presented in **Figure 2.1** shows the main sections of the report and is explained further in the next paragraphs.

Electricity Market in Western Denmark, this section is dedicated to set up a background and the limitations for the prognosis. It looks into the electricity market workings and aspects regarding the processes associated with the electricity spot market.

Prognosis Theory and Tools, this section treated in two chapters is divided in three topics: *Importance of Prognosis*, *Relevant Variables* and *Prognosis Approach*. It is aimed at clarifying the prognosis not only from the point of view of user but also from the methodological perspective. It sets both the theoretical and empirical support and limitations for the development of the prognosis model.

Data Collection is an empirical analysis of the data available and collected as annex to the report. It is both used for developing the prognosis model and as test bed for the prognosis model results.

Prognosis Model is the section where the model for calculating the prognosis is made and verified. It represents the result of the analysis in the previous sections and the core of the report.

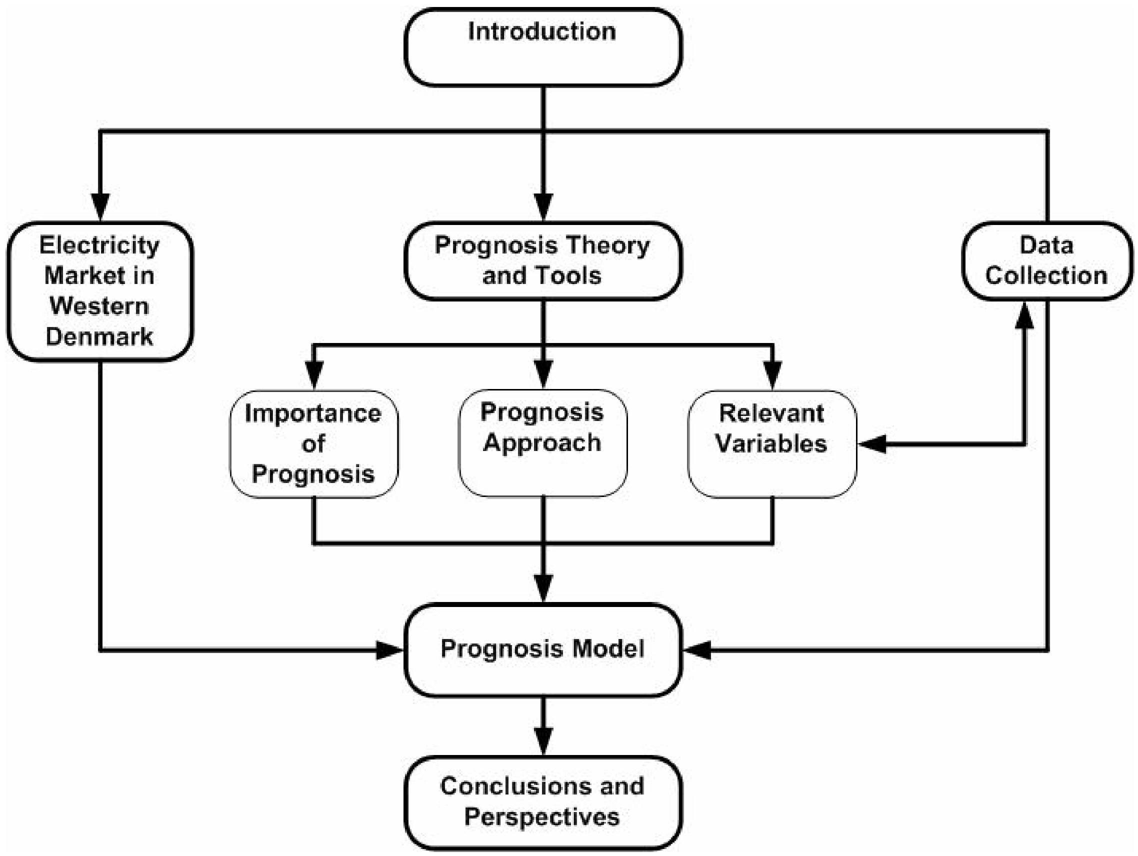

Figure 2.1 Report Structure Diagram

2.2 Project Limitations

Although most of the investigation is carried out in an empirical fashion, the report itself concentrates on the theoretical aspects of the subject at hand.

The Data collected are no earlier than May 2006; data before this are not reliable, according to Søren Rygaard from Nordjysk Elhande. The most recent data used in the model is no later than August 2007, although later data might be brought to attention upon report defense. September 2007 constitutes a crossing point for the energy market in Western Denmark, specifically the way the trading takes place between Western Denmark and Germany. The implicit auction for the daily cross-border capacity allocation will be implemented. This means the present report does not take in consideration this change; in effect the model developed might not be valid for the new way the market works (Nord Pool Spot 2007, Press Releases).

The report concentrates in its analysis on the Western Denmark price area, although limited considerations are given regarding the surrounding areas. It has been chosen to concentrate on a single price area because of the complexity such a model will imply. Further, it is presumed that the number of influences needed to be taken in account will be less than it would be if the model is for all the price areas.

Another reason to restrain the investigation to the region is the wind turbine power contribution. This represents a topic of interest in the context of sustainable energy because of the direction Denmark takes in its energy policy is towards a better integration and expansion of the renewable.

The goal of the project is to prove or dismiss the main question on the basis of a developed model for the calculation of prognosis. The prognosis itself is restrained to one day. However, considerations regarding a more extensive prognosis, 7 days, are made to give a more practical weight to the project conclusions.

The prognosis limits to the spot price alone and considers variables related directly with it and, in smaller measure, factors that influence these variables.

2.3 Research Methodology

In order to ensure the scientific validity of the present report from its problem formulation to its conclusion, a methodological Research Design has been set up specifying how the problem formulation is sought to be answered.

2.3.1 Research Design

The point of departure for the methodological framework of the report is given by the *study's questions*; which is given with the problem formulation. In this report the problem formulation is explorative in nature and it can be argued that it allows for an empirical analysis of the Electricity Spot Market in Western Denmark but is not limited to it.

The *study's proposition*; is expressed implicitly in the problem formulation. It looks to develop a prognosis model that allows the calculation of a good prognosis with minimum investment.

The *unit of analysis*; it designates what needs to be analyzed; this is clear from the problem formulation, although it can be argued that is implicit through the timeframe set up.

To make clear the *logic linking the data to the propositions* and the *criteria for interpreting findings* an analysis of the data collected is carried out.

2.3.2 Data Collection and Theory

The data collection is set up as an initial and continuous effort during the project investigation. The data are gathered from different authorized resources and where is possible crossed referenced. Bulk of the data collected comes from Nord Pool and Nord Pool Spot, but Energinet.dk has a significant contribution as well, being the Transmission System Operator and the owner of the transmission grid (electrical lines above 150 kV) in Denmark and co-owner of the infrastructure connecting Denmark with Nordic Countries, and with Germany.

This investigational effort does not limit to simply gathering the data directly available but also through interviews with market actors, such as Nordjysk Elhandel (energy trader and prognosis provider), Nord Pool Power Exchange and Vattenfall (electricity producer).

Table 2.1 Interviews details

Interviewed/Company	Medium	Subject of Discussion/Interview
Kenneth Rotvig Dupont *Sales Manager for Nord Pool Spot*	Phone	Working of the Nord Pool Spot, how spot price is reached, interconnection handling
Ole Knop *Production Planning for Vattenfall*	Phone	Working of Central Power Plants, how is Vattenfall participating in Elspot
Søren Rygaard and **Morten** *Nordjysk Elhande*	Direct	How prognosis are made by Nordjysk Elhande, what influences the spot prices, general workings of the electrical spot market

The first part of the project is an exploratory one, and in the report is split into three major sections *Electricity Market in Western Denmark*, *Prognosis Theory and Tools* and *Data Collection*. These exploratory sections gather and filter the data necessary in developing the prognosis model upon which the project conclusions are drawn.

Electricity Market in Western Denmark gives the theoretical and empirical tools to pursue an investigation into the spot market and its workings. It provides the base knowledge of how the market works and what might influence the prognosis. Important insight into this market is given by Kenneth Rotvig Dupont, allowing for a clear and critical analysis. This section clarifies external and internal influences on the Western Denmark energy market in general and on the spot prices in particular.

Prognosis Theory and Tools gives the tools necessary in making the prognosis. For this purpose it looks at methods in use for making prognosis and theory relating with making prognosis. Also it is looked at how these prognoses are used and by whom to set up the limits for the prognosis, in this sense it is valid to enquire upon the precision a user needs for the obtained prognosis. This section clarifies even further the variables involved and differentiates between them in order to allow selection of the most relevant variables to be used in the model.

Data Collection is a process that is continuous through out the project. The section in the report concentrates on assessing the data collected and in coordination with the previous section selects the relevant variables. It makes the distinction between usable data and data to be ignored. In this way provides the means to produce a model.

It can be concluded that the first section describes and investigates the market and the way spot prices are reached, the second section clarifies variables and provides the algorithm to calculate the prognosis and the third section provides the input for the model. While the last sections provide the results in the form of a prognosis model, the resulting series using the data provided in the third section and based on these a conclusion answering the main question of the project.

3 Western Denmark Electricity Market

In this section a detailed description Electricity Market in Western Denmark is presented. It describes the work of the Nord Pool exchange for trading electrical power and concentrates on Nord Pool Spot (Elspot). The chapter also deals with the electrical infrastructure that makes the trading system possible.

The Danish electricity market is an integral part of the free Nordic electricity market which, since January 2003, became fully liberalized. Resulting that the transmission grid is independent from electricity generation and thus all market players have equal opportunity to use it. From the total amount of electricity produced in Denmark, 60% to 90% is traded through Nord Pool exchange. The rest is traded through independent bilateral contracts.

Market trade is done through Nord Pool exchange, which sustains the trade between market players. Nord Pool exchange consists of two market places for electricity trading, Elspot and Elbas. Trade on Elspot takes place in Denmark, Norway, Sweden, Finland and Germany, while trade on Elbas takes place in Sweden, Finland and Eastern Denmark, and since April 2007 also Western Denmark.

The difference between these 2 markets is the way the trading takes place. While the prices on Elspot are set up some hours before the generation and it is given a production schedule for 24 hours, the prices for Elbas are decided one hour before the generation for one hour of production. This makes Elbas better suited for plants with short starting and stopping times.

The Western and Eastern parts of Denmark are not physically connected through a power line and thus are separated and can not physically exchange power. The Western Denmark is the Jutland peninsula and Fyn Island. (Energinet.dk 2007)

3.1 Market Organization

The electricity generated by the specific producers is transmitted via transmissions and/or distribution grids to the costumers. The grids can be circumvented by domestic generators such as wind turbines or solar cells.

The Transmission Grid is co-owned and managed by Transmission System Operators (TSOs) and Transmission Companies, while the Distribution Grid is owned and managed by Grid Companies.

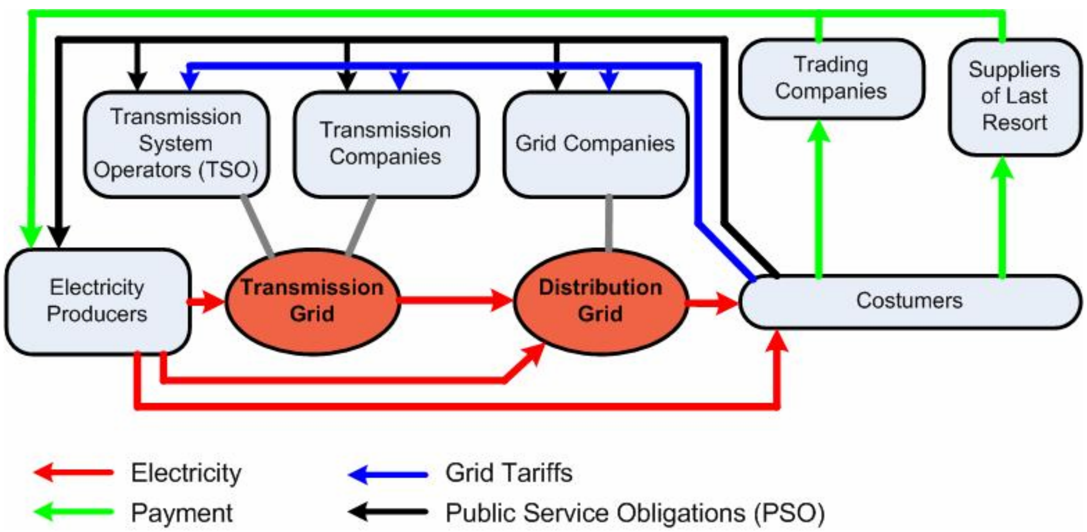

Figure 3.1 Electricity Market Structure (ENS 2007, Electricity Market Structure)

While the trading companies trade electricity on a strictly commercial basis, some are obligated to supply electricity to costumers who do not elect to choose their own supplier at reasonable terms.

Three payments flows are noticeable, as presented in **Figure 3.1**:

Trading on the electricity market, marked as simply 'Payment'; here the costumers acquires power from trading companies or supplier of last resort through Nord Pool.

"Grid tariffs; *Users of the services of the grid (i.e. transport of electricity), pay the collective supply companies for the costs related to running the grids. Grid- and transmission companies have costs related to maintenance of the grid. Transmission system operators have costs related to running the grids.*

PSO (Public Service Obligations*) are compulsory services designed to satisfy public interests in the electricity sector. They include i.e. security of supply and subsidies for environmentally-friendly electricity. The collective supply companies (transmission system operators, transmission companies and grid companies) have to fulfill these obligations and the costs are passed on to the costumer."* (ENS 2007, Electricity Market Structure)

This is valid for each trading area/price area, link between them is provided through means of interconnections by the TSOs.

3.1.1 Price Areas

Geographically the Nord Pool Spot Electricity Market (Elspot) is organized in 9 Price Areas including Kontek area. For each Price Area a price for electricity traded is calculated through bid and offer. Although most of the areas are determined by geographical and geopolitical features, such as separating seas and state board, some are technically created to cope with internal bottlenecks. Here Norway is a good example being split in 3 Price Areas.

Figure 3.2 Elspot Prices illustrating the Price Areas (Nord Pool Spot 2007)

Each area has its own hourly spot price calculated by Nord Pool after receiving the offers and demands for power from the producers and grid companies.

The areas are linked together through interconnections, which allow the transfer of power between them.

3.1.2 Interconnections

Physical structures between price areas are known as interconnections, or bottlenecks because they behave as such in the electrical grid, limiting the flow of electricity, usually having limited capacity. One such structure is the transmission cable Konti Skan between Western Part of Denmark (DK1) and Sweden (SE), with a transmission capacity of 500 MW export and 620 MW import (DK1 to SE) (Nord Pool 2007, UMMs).

They provide the means to transport electricity between price areas. However they are limited, most likely because population meets their development with resistance.

The interconnections represent the central infrastructure in the Nord Pool, around which the trading system is set.

Participants in the power market which are separated by interconnections can not trade physical capacity or buy capacity on the interconnection because the entire capacity of the interconnection is given to the power exchange. This is to ensure a fair and efficient use of it. The participants in the same Price Area can deal directly without any restrictions. As seen in **Figure 3.2** the difference in prices between areas can vary greatly, one of the main reasons being the limitations of the interconnection between price areas.

The main characteristic of an interconnection is its capacity or Total Transfer Capacity (TTC). This is through design and is subjected to several influences and limitations. By design the capacity from one area to another can vary, as shown in the previous example of interconnection between Western Denmark and Sweden.

Influences and limitation for an interconnection

To ensure the security of transmission a part from TTC is reserved as Transmission Reliability Margin or TRM. This is subject in general to three influences, as listed by Nordel:

1. Unintended deviations of physical flows during operations due to physical functioning of load-frequency regulation;

2. Emergency exchanges between TSOs to cope with unexpected unbalanced situations in real time; and

3. Inaccuracies, e.g. in data collection and measurements.

In the Nordic countries only the first is present in practice, determining a TRM for each connection as shown in **Table 3.1**. An important exception is represented by High Voltage Direct Current interconnections, or HVDC, where TRM is not used.

Table 3.1 The distribution of the TRM on the interconnection in Nordic countries (Nordel 2007, Transfer Capacity)

Sweden – Southern Norway	150 MW
Sweden – Northern Norway	50 MW
Sweden – Finland	100 MW
Sweden – Eastern Denmark	50 MW
Sweden – Western Denmark (HVDC)	0 MW
Southern Norway – Northern Norway	50 MW
Southern Norway – Western Denmark (HVDC)	0 MW

The trade capacity available at any one point on the interconnection, or the Net Transfer Capacity (NTC) is the remaining capacity, (NTC = TTC – TRM). This is the capacity that is used in day to day trading on the spot market.

After the spot trading [1] the remaining capacity is used by Elbas and the regulation power market. This capacity is the Available Transfer Capacity (ATC).

The TSOs on both sides calculates the TTC using the computed network models. If the values differ the lower one is chosen as TTC.

Another limitation is presented by the ramping rule. This refers at how much the flow on the interconnection is allowed to change between 2 hours, at the moment this is set to 600 MW. For example the difference between the flow at 12:00 and the flow at 11:00 can

[1] Elspot trading

not be greater than 600 MW. If at 11:00 the flow was 1500 MW, at 12:00 this can't be higher than 1500 ± 600 MW.

Other limitations on the interconnection are provided by repairs or modernizations, and are published by Nord Pool.

An important interconnection is between Germany and Denmark. This is probably the most discussed interconnection at the moment, being the focus of the market coupling between Denmark and Germany. When referred here to the interconnection both the interconnection between Germany and Western Denmark and Germany and Eastern Denmark are considered.

Market Coupling

Market coupling as defined by Nord Pool is the process where two or more power exchanges cooperate in order to ensure the full utilization of the available capacity between them in each hour of operation.

The coupling between Denmark and Germany was scheduled towards the end of 2007 and aimed at improving the trade across border by introducing an implicit auction. The **implicit auction** is when the interconnection capacity is made available to spot market mechanism. Resulting prices are reflecting thus not only the cost of energy in the bid area, but also the price of congestion between them.

Contrary to this, in the **explicit auction**, the interconnection capacity is auction independently from the market places where electricity is trade. In effect to be able to trade across border one must buy the capacity on the interconnection in advance, without knowing with certainty if it will actually sell power to be transferred through this interconnection. This is obviously an inefficient way to conduct trade and thus the need for coupling between the areas (Nord Pool Spot 2007, Market Information).

As stated before the market coupling between Germany and Denmark was schedule late this year, as announced in the beginning of 2007 by the actors involved in the coupling. However, the coupling has been delayed to an unspecified date for the moment. This coupling is the result of the cooperation between the TSOs, Vattenfall Europe Transmission, E.ON Netz, and Energinet.dk, and the two power exchanges EEX and

Nord Pool Spot. It represents an important step towards a better integration of Nord Pool and EEX exchange markets (Nord Pool Spot 2007, Press Releases).

3.2 Electricity Generation

Western Denmark is a special region from the point of electricity generation, as it has a large installed capacity of wind power. At times the production from these turbines exceeds the production from central power plants which in general are the primary producers of electricity.

3.2.1 Central Power Plants

These are high capacity Power Plants using coal and to some extent biomass to produce heat and electricity. They are in number of 15 spread through out Denmark and carry most of the production during high demand. It is argued by some that they are obsolete and an impendent to development of renewable energies. They are owned by DONG or Vattenfal, Danish and Swedish state owned companies respectively although some, such as Vattenfall A/S - Generation Nordic are equipped with the newest technologies reducing their emissions to very low levels.

They participate in the same way as any other producer to the Elspot and are subjected to the same rules. They have a minimum production capacity determined by the heat that needs to be delivered to the district heating or technical considerations, such as minimum capacity for generators. Two out of 6 Central Power Plants in Western Denmark are owned by Vattenfal with the rest being owned by DONG. (Danish Energy Authority, 2007)

3.2.2 Local[2] CHP Plants

These are plants that typically use natural gas, waste, biomass and biogas as fuel to produce heat and electricity. They are about 600 generators of medium and small

[2] ***'Decentral'*** is used instead of ***Local*** by Energinet.dk and Danish Energy Authority

capacity spread through out Denmark. Their cumulated capacity is smaller than the one from central power plants but they are more flexible in their production schedule being able to effectively participate on the spot market. In general they are characterized by having heat storage tanks, which helps as well in participating on the spot market.

3.2.3 Wind Turbines

In July 2007 Western Denmark had more than 75% of the installed wind capacity with 2390 MW of 3134 MW in total. The number of turbines installed was 4060 of 5248 in total, both inland and offshore (Danish Energy Authority, 2007).

In the spot price consideration this might prove to be the most influential variable because of its sheer capacity.

They are offered at zero on the Elspot market. It means that the price of 1 KWh of electricity from Wind Turbines is offered on the Elspot market at 0 EURO. This is done in order to assure that the production is sold and they can produce as long as the wind conditions allow. The Wind Turbines are not stopped unless maintained thus the need to have them producing while they can.

3.3 Elspot

The day-ahead market is named Elspot in the Nordic countries and Kontek in Germany. Its manifestation in Western Denmark is the focus of the present project. This market is managed by Nord Pool Spot organizing the physical trade of electricity between participants: producers, distributors, energy and industrial companies, trading representatives, large consumers and TSOs.

Nord Pool Spot is co-owned in equal shares of 20% by the Nordic TSOs: Statnett SF, Svenska Kraftnät, Fingrid Oyj and Energinet.dk, while the remaining 20% is owned by Nord Pool ASA.

More than 60% of the total consumption in the Nordic countries was traded through Elspot in 2006, amounting to 249.8 TWh, while in Western Denmark it reached 90% of the consumption.

The regulating authority for Nord Pool Spot is Norwegian Water Resource and Energy Directorate (NVE) while the Norwegian Ministry of Petroleum and Energy allows Nord Pool Spot to organize the physical exchange of power with other countries.

(Nord Pool Spot, 2007)

The participants in the Elspot market have to forward bids and offers for the 24 hours ahead (hence the name of day-ahead market) of the actual physical transaction of electricity.

3.3.1 Bidding System for Elspot

The bids are submitted electronically to Nord Pool Spot on bidding forms by all participants for offer and demand. These bids are aggregated in 2 intersecting curves, in each of the 24 hours of the producing day ahead. The intersection point between the offer and demand curves determines the Elspot Price in each hour. In turn this price establishes the trading result for each participant for that hour. (Nord Pool 2007)

The participants can submit three types of bids available on Elspot: Hourly Bid, Block Bid and Flexible Hourly Bid.

Hourly Bid

Each participant selects of price steps in the Hourly Bid individually. The bid may consist of up to 62 price steps in addition to the current ceiling and floor price limits set by Nord Pool Spot.

The simplest bid is a *price- independent bid* for all hours. The participant will receive a schedule of deliveries most of the times equal to the specified volume for all hours, regardless of the price level within the range.

In the case of *price-dependent bids* the Nord Pool will compare the Elspot price for each hour with the participant bid form and establishes the results for that participant. On the bidding form, purchase is shown as positive value; sale is shown as negative value.

Table 3.2 Price-Dependent Bid (Nord Pool Spot, 2007)

Hour/price	0	20	20.1	22	22.1	25	25.1	2000
1								
2								
3	50	50	0	0	-10	-10	-30	-30
4								
Etc.								

Hourly bid is the focus of the report; where for each hour a participant will set a price for its production and decides by consulting the prognosis if the respective hour is profitable.

Block Bid

The Block Bid gives the participant the opportunity to set an "all or nothing" condition for all the hours within the block. The Block Bid is particularly useful in cases where the cost of starting and stopping power production or consumption is high.

Table 3.3 Block Bid Representation (Nord Pool Spot, 2007)

Block hours	Price	Volume
Hour 1-7	24	200
Hour 1-7	20	50
Hour 8-17	19	-50
Hour 8-17	24	-100

A Block Bid must be accepted in its entirety; thus, if accepted, the contract covers all hours and the volume specified in the bid. The Block Bid price is compared with the mean Elspot rice for the hours to which the block period applies; Elspot can only accept a Block Bid if it meets the so-called Block Bid condition:

- If the bid price of a supply-side (selling) block is lower than the average Elspot area price, the Block Bid condition is said to be satisfied.

- If the bid price of a demand side (buying) block is higher than the average Elspot area price, the Block Bid condition is said to be satisfied.

Flexible Hourly Bid

The Flexible Hourly Bid is a sales bid for a single hour with a fixed price and volume. The hour is not specified, but instead the bid will be accepted in the hour with the highest price, given that the price is higher than the limit set in the bid. This type of bid gives companies with power intensive consumption the possibility of selling back power to the spot market by closing down industrial processes for the hour in question. (Nord Pool)

In any case the bids forwarded to Nord Pool are centralized and the resulting intersections for each hour determines the trade price in that hour, price which all the participant buyers will pay and which all the sellers will receive regardless of their initial bid. In this way the higher difference between initial bid and final trade price is obtained by those producers that offer power at 0 EURO/MWh.

3.3.2 Spot Price

Nord Pool collects all the bids and offers for the day ahead no later than 12 o'clock and at 12 its computer network will start calculating the spot price for each hour of the operation in the following day. It does so by matching the bids and offers received from participants at the market.

The calculations are made in the first phase as it were no interconnection in the power network (no bottlenecks). It results a system price which is a financial price and is not the actual trading price. The principle is shown in **Figure 3.3** where for simplification it is taken a simple demand, independent from the offer. This is used as a reference price in determining the price for each Price Area. After the system price is calculated, another calculation is made for each Price Area.

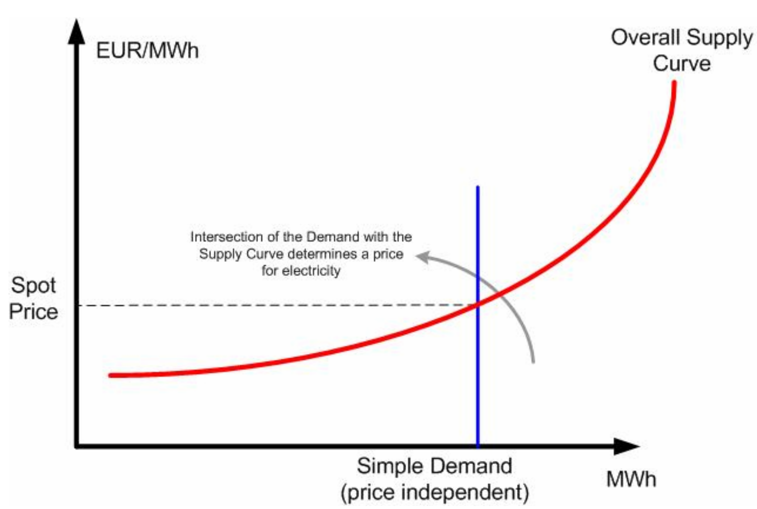

Figure 3.3 Spot Price principle, calculated in each hour

Once the spot price for each Price Area is calculated Nord Pool intervenes using the interconnections between Price Areas as an equilibrating tool, to decrease the price in the high price areas and thus increase the price in the low price areas.

A low price area is defined by comparing the price obtained for it with the system price and ultimately with the price in the neighboring Price Areas. If the price in one area is higher than the price in a neighbor area, Nord Pool will try to decrease the price in that area. The way Nord Pool does that is by buying and selling electricity at the Elspot. It will buy electricity in the lower price area; increasing the demand and thus offsetting the point of intersection with the offer curve, resulting in a higher spot price as shown in **Figure 3.4**. In the same time it will sell electricity in the higher price area, offsetting the offer curve resulting in a lower spot price.

The offsetting of the intersection point is limited by the capacity of the interconnections at any given hour. Taking as example a system of 2 Price Areas the transfer of electricity between them is limited by the capacity of the interconnection. In this way the influence of Nord Pool over the price is limited. Nord Pool can not buy from one area to sell in another more than the interconnection allows. In a theoretical situation where the capacity of the interconnection is limitless, the prices in will be equalized by Nord Pool creating a homogenous market. This theoretical price is the system price described earlier.

The profit resulting in this trade goes to the grid owners. This profit is the difference in price between the higher price area and the lower price area multiplied with the quantity traded. The higher the difference between the prices in the areas is, for the same capacity on interconnection, the higher the profit for the grid owners. This can be viewed as an obstacle in creating a larger capacity of the interconnection and an incentive to artificially create higher prices in some areas. It can be considered as a weakness in a system which was originally made in order to obtaining the lowest price for the end consumer.

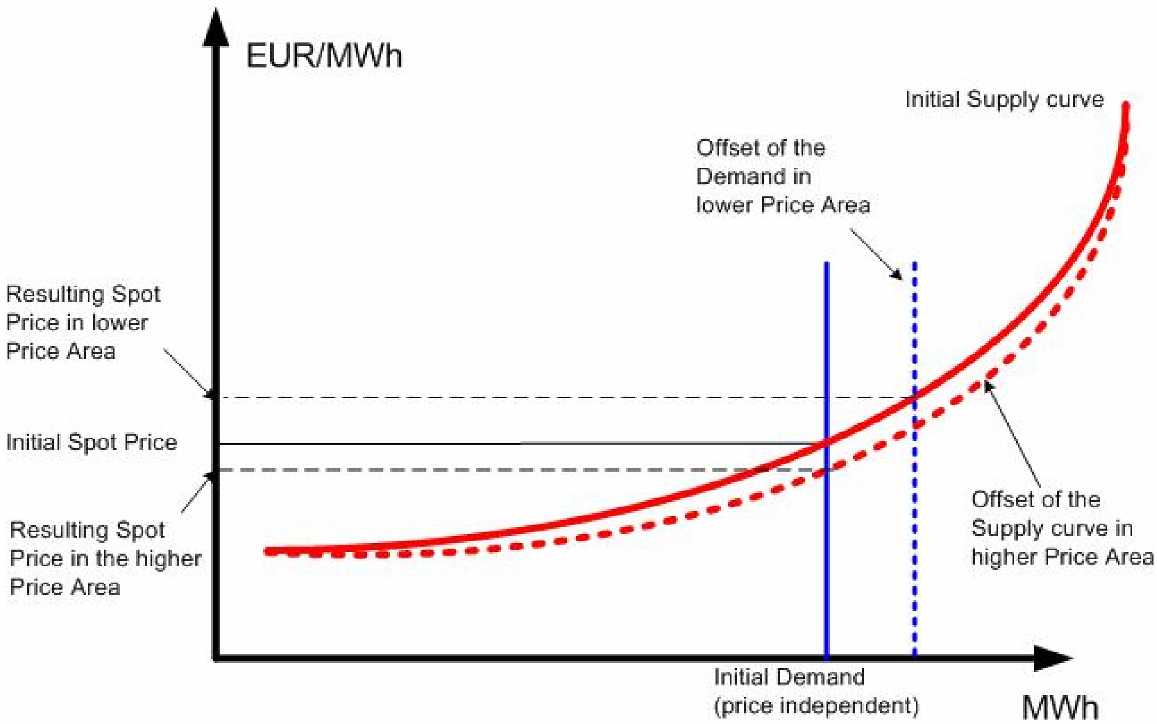

Figure 3.4 Offsets in the Demand and Offer forced by Nord Pool through market participation

This mechanism of equilibrating the prices in neighbor areas can be argued as being also a tool to diminish monopolistic actions in some areas by creating an indirect competition between producers from different Price Areas. However, taking as example the Western Denmark where until July 2006 Elsam owned all of the central power plants, the pressure put by Elsam on the interconnections effectively eliminating the competitions when the limit of the interconnections was reached. The bid strategy Elsam used allowed it to have market power in Western Denmark and was not reflected by the production costs. In effect Elsam could be in control of the interconnection transforming it into a bottleneck or preventing it from becoming one.

A less used method of trading electricity is the bilateral contracts; they are made between a producer and a consumer on the basis of a written contract specifying the amount of power transported from the producer to consumer and the price paid by the consumer.

3.4 Bilateral Contracts

Bilateral Contracts are signed between a producer and a consumer within an price area, meaning that for example a producer in one price area, lets assume Western Denmark can not make a bilateral contract with a consumer in Eastern Denmark. Usually the bilateral contracts are made over long periods, weeks, months and the partners in these contracts are aware of the trading prices on the spot market. It is reasonable to assume that the prices in bilateral contracts follow the prices on the spot market.

The bilateral contracts take place outside the control of Nord Pool and they are using the grid managed by the TSOs.

Giving the numbers forwarded by Nord Pool regarding the trade in Western Denmark, according to which 90% of the power consumption was traded through Elspot, it is safe to assume that the rest of the consumption was traded through bilateral contracts.

Western Denmark power market is influenced in a great degree by the evolution of the wind turbine production. Still, the central production units and in a smaller degree the local CHP play the most important role. Nord Pool plays an important role in regulating the prices and promotes development of new production units through a competitive market.

4 Importance of Prognosis for CHP Plants

In this section the importance of prognosis for CHP plants is discussed focusing on the study case chosen as a typical CHP plant for the Western part of Denmark. Details regarding the strategy used to bid effectively on the spot market are given with emphasis on the practical example of the study case. In the end of the section an analysis of the prognosis's accuracy is made, with regards to its relevance in the production strategy.

A producer that participates on the Elspot needs to have a prognosis of the spot prices in order to schedule its production efficiently. This is done to take advantage of the spot prices variation not only in the day but also from day to day. For example it is sought to have enough thermal reserves to supply district heating and produce electricity in the best hours.

4.1 Study Case

To better understand how a CHP producer participates on the Electrical Spot Market (Elspot), a study case has been chosen. Criteria used are relevance and availability.

Hvide sande CHP plant (HS CHP) is chosen because it represents a typical CHP plant and data were readily available through EMD International A/S in the context of the DESIRE[1] project. Typical CHP plants in Western Denmark are of small and medium capacity using thermal storages.

The thermal storage is an isolated container capable of accumulating heat in the form of heating agent (water), usually above 70 °C. It does so by pumping higher temperature water coming from CHP engines or boilers on top of the container, while the water layer on the lower part acts as a supply of heating agent for the same CHP engines and boilers in a closed loop, as seen in **Figure 4.1**.

[1] www.project-desire.org

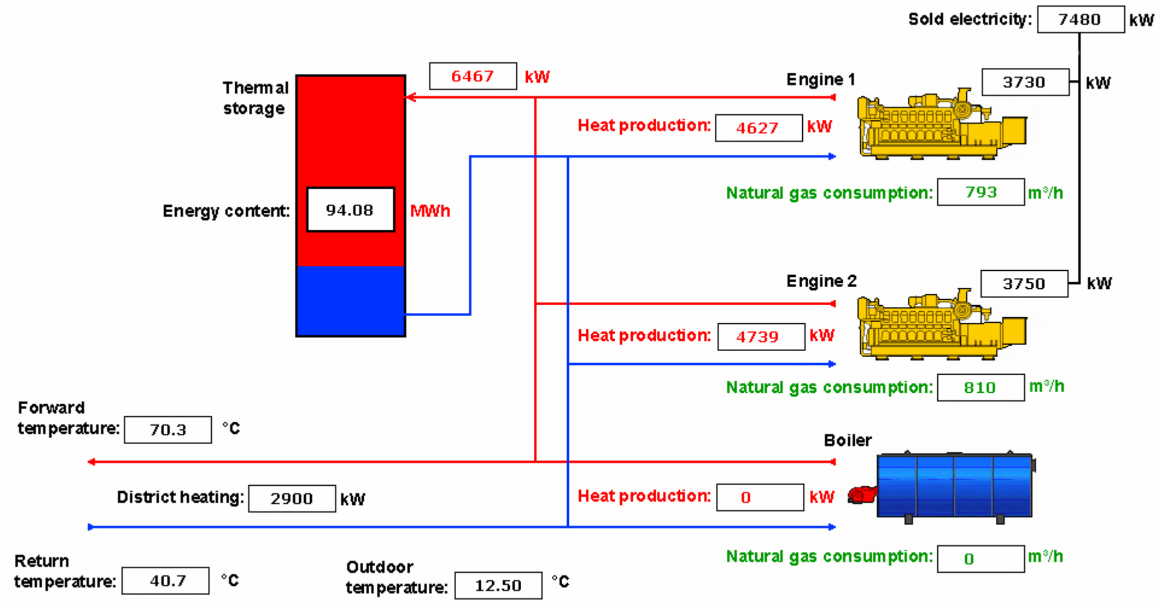

Figure 4.1 HS CHP plant production diagram, 30.08.2007 12:20
(EMD International 2007, Hvide sande CHP plant)

Hvide Sande CHP plant uses two identical natural gas engines with an electrical capacity of 2.77 MW each (40% efficiency) and 4.9 MW heat capacity (52% efficiency). Beside these engines, the plant uses 1 gas boiler with 4 MW capacity and 1 mix natural gas/oil boiler with a capacity of 10 MW. For heat storage a thermal storage tank is used with a volume of 2000 m3, able to store 130 MWh.

During 2006 the plant has delivered 41.1 GWh heat to Hvidesande town and 24.74 GWh of electricity to the grid while using 6.3 millions Nm3 of natural gas. (EMD International 2007, Hvide sande CHP plant)

Until May 2007 DONG Energy has performed the optimal spot market trading. Since then this operation has been performed by Markedskraft[2]. This change represented also a shift in the way the HS CHP participates on the spot market, specifically on how it bids, as discussed further on in section **4.2**.

[2] http://www.markedskraft.com/ontime_front.asp

4.2 Production strategy

The production strategy refers to how a power plant offers electricity on the spot market. In other word is how much and when the producer bids on the spot market taking in consideration related factors. The purpose of the production strategy is to maximize production and in turn profits.

Factors involve in developing a production strategy are: heating needs of the costumer (including the losses on the heating infrastructure), thermal storage capacity, production capabilities (if it has CHP, boilers), producing flexibility (start/stop times), down times (maintenance), work schedule (holydays, small automated CHPs), marginal cost of production and ultimately spot prices prognosis. While most of the other factors can be influenced directly by the producer, the spot prices prognosis is independent and the production strategy must be developed around it, as a central factor.

The production strategies have many approaches, theoretically as many as there are producers; however, the next part of this section talks about two general approaches, while concentrated on the approach representative for the study case, as described in the following paragraphs.

The short term approach to the production strategy is where the strategy evolves from day to day while in the longer term approach the strategy is considered for several days. The later is limited in a great degree by the prognosis for the spot prices and invariably has a great degree of uncertainty, because the accuracy of a prognosis tends to be lower with time, as it is discussed in more detailed in section **5.2.1**

The short term approach is where the producer concentrates its production in the following day, bidding on each favorable hour looking to produce as much as possible. This is a short sighted approach and it can be argued that is incompatible with having a thermal storage. As such, in this section, this is considered a wrong approach and is not treated in more detail, not being related with the stated study case.

The longer term approach is a holistic one, trying to integrate as many of the factors enumerated earlier possible. In this approach the dominating ones can be considered the thermal storage capacity, district heating (how much heating is delivered to town including network losses) and of course the spot price prognosis. The result of such a strategy is shown in **Figure 4.2,** where a six day section of the HS CHP production is taken. This is as a direct result of its bidding on the spot market.

The engines (CHP units) will produce only when the plant has won the right to produce electricity on the spot market, while the boilers will produce only when heating is needed but the plant has not won the right to produce electricity. Ideally the plant will use only the engines to produce heat and electricity and thus cover its bid on the spot market and the district heating demand.

Further, the electricity production over a period of time is limited by the capacity of the thermal storage. This means that the producer will look to produce as much as possible without having to shut down the engines because of overheating. The overheating can occur in the closed system because the thermal agent is acting as a cooling for the engines. So if the engines work continuously, producing more heat than needed for town at one point the thermal agent will not be able to properly cool the engines. Also, it clear that the capacity of the thermal storage is taking in consideration not only the participation on the spot market but also the needs for district heating. This is the purpose of the optimization made before hand when the plant is being built, a tool for that being EnergyPRO developed by EMD International A/S.

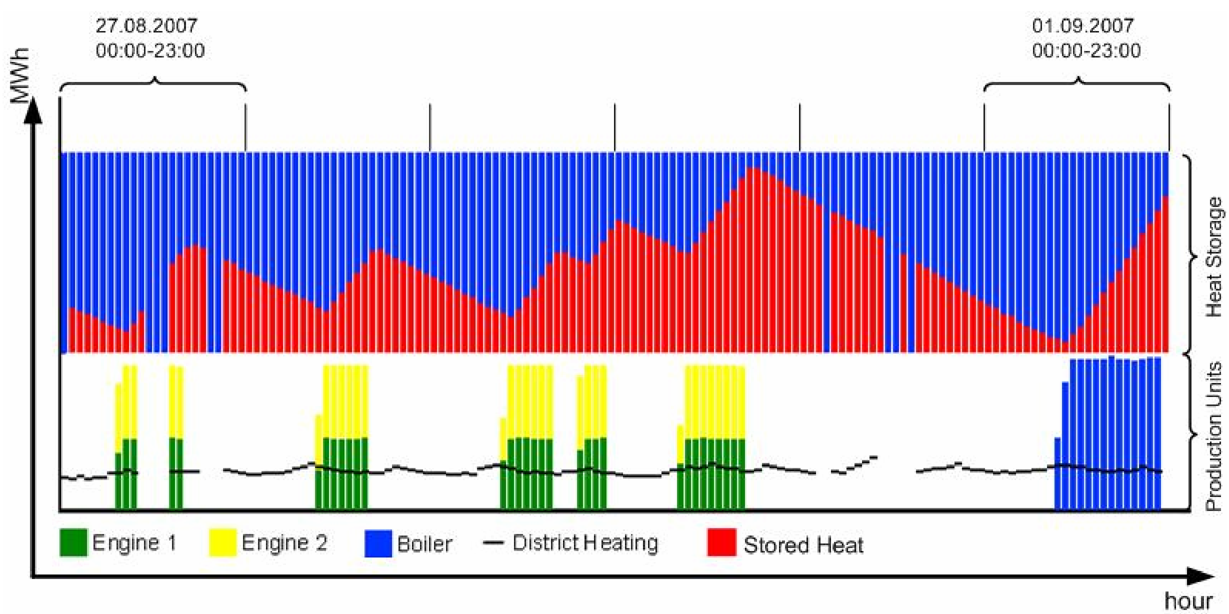

Figure 4.2 HS CHP production strategy results between 27.08 and 01.09.2007 (EMD International 2007, Hvide sande CHP plant)

In **Figure 4.2**, the upper part of the graphic is modified to be more intuitive and show a positive variation of the stored heat. In the original version that part of the graphic is flipped vertically, representing the way the storage tank is working, with hotter thermal agent in the top, as seen in **Figure 4.1**.

Looking at the example given by **Figure 4.2**, it is obvious that the plant has won some of the hours in the first 4 days, allowing not only to cover its bid won on the spot market, but also to cover the district heat demand which seem relatively constant through out the six days period (Monday to Saturday). The lack of production from the engines in the 5th and 6th day shows that the production strategy employed here is not a short term one. It can be argued that the prices were too low for the producer, resulting in no bid on the day. This is dismissed however by the data provided by Nord Pool spot for the days in questions, shown graphically in **Figure 4.3**.

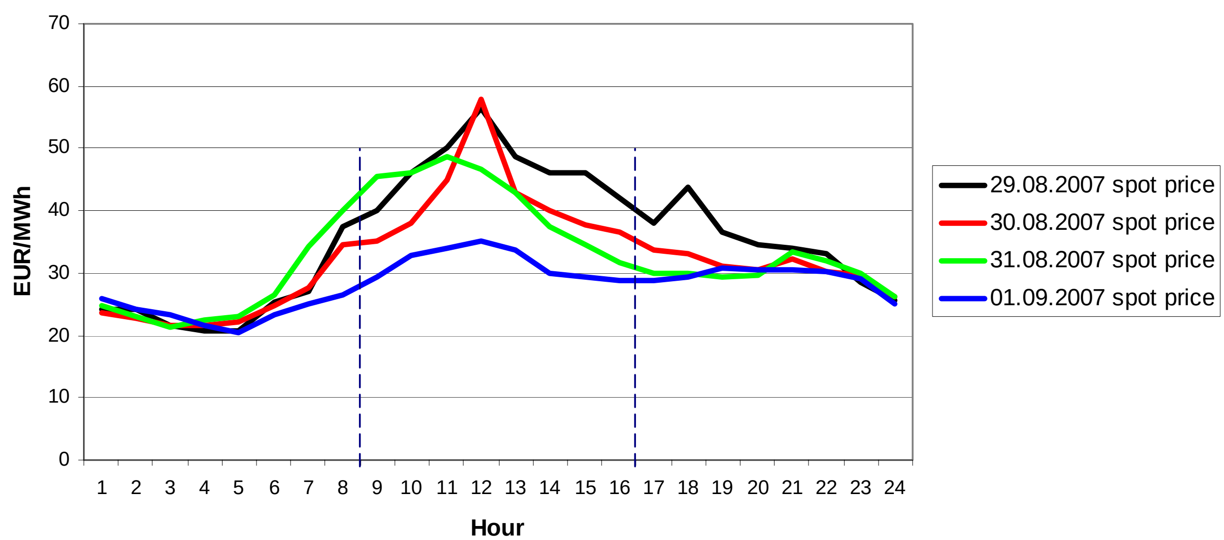

Figure 4.3 Spot Price Variations in Western Denmark between 29.08 and 01.09.2007 (Nord Pool Spot 2007, Area Price)

Although it can be said that in 01.09.2007 the price was too low, it can not be said the same thing about 31.08.2007 where the prices are comparable with the previous day, when the engines produced between 9 and 17 o'clock. If the production strategy was from day to day, the producer would have taken advantage of the higher prices in the 31.08, which in some hours are more profitable than the day before (9 to 12 o'clock).

Overall this gives the example of a bad prognosis which in turns makes the producer to not take advantage of the best hours.

The boilers are started in the 6th day in order to provide district heating and to increase the amount of heat stored in the thermal storage.

It is important to realize that the prognosis has a crucial role in being able to develop a good production strategy over several days. It can even be argued that short term approach to the production strategy can be made without the need for prognosis, as long as the price dependent bidding is used.

The price dependent bidding at spot market is characterized by the fact that the producer will offer its capacity at the marginal cost, using the prognosis to place its bids. The producer offers enough capacity to cover the town heat demand in the form of block bids or hourly bids placed in the times when the prognosis shows an increase in the spot price. The usual result is that the producer wins some of the hours in which bids were made, in the period with good prices, and looses some of hours. The hours won will always have better prices than the marginal cost, while the hours lost have lower prices than the marginal cost. This is a good way to assure that the producer will not win bids where the spot price is below the marginal cost. Also the prognosis plays a lesser role in here, in effect their accuracy having a less impact on what hours are won and the hesitation with which the producer participates on the spot market.

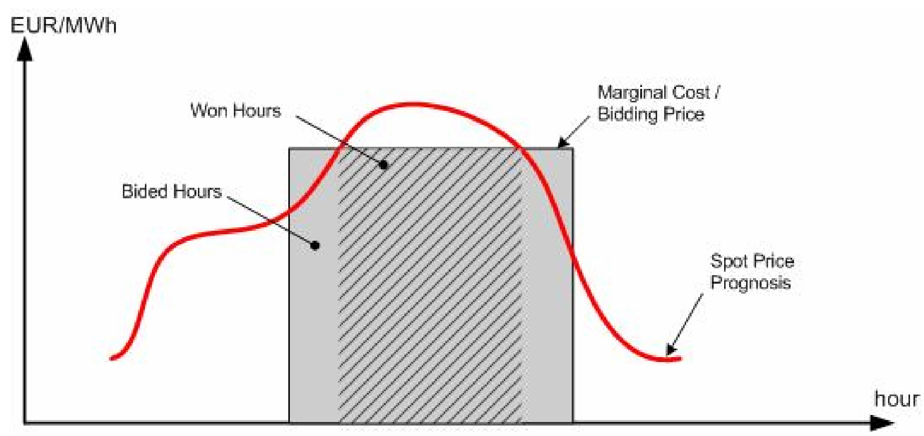

Figure 4.4 The price dependent bidding

The price independent bidding is very dependent on the accuracy of the prognosis. The producer offers its capacity at zero through hourly or block bids in hours where is thought that the spot price will be higher. This type of bidding is used by the HS CHP, where the capacity is offered at zero, and the bidder must choose carefully the hours in which bids are made, because they are all won, regardless of the marginal cost or the price on the spot market. A unique situation is where the spot price is zero; in this case the producers offering at that price get a share of production related perceptual with the initial bid.

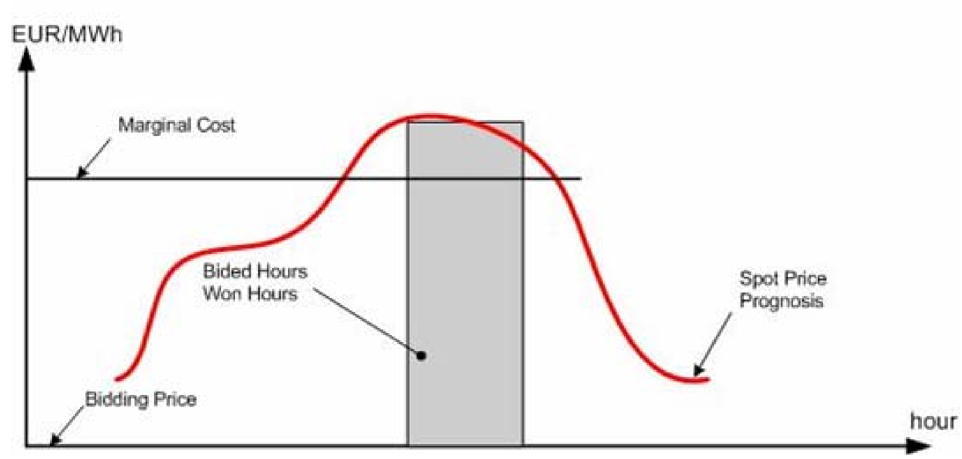

Figure 4.5 The price independent bidding

The optimization of longer term production strategy relies heavily on the prognosis, as the producer tries to take advantage of high spot prices while producing enough heat for district heating. And is not only that is relies on the prognosis but specifically on the accuracy of the prognosis, as it is discussed in the next section.

4.3 Relevance of prognosis Accuracy

This section treats the accuracy of a prognosis from a practical point of view, strictly related with the implications on the production strategy.

The accuracy of a prognosis bears a great degree of influence on the strategy. In this section two important aspects regarding the accuracy are brought up and their relation with the production strategy.

Accuracy detail, this refers to the periods or the pacing that characterizes a prognosis. A prognosis can have a minimum of 1 hour pace, and it referred to this as maximum accuracy detail. In other words a prognosis used for spot market has maximum degree of detail when its pacing is 1 hour. The pacing of a prognosis can be increased at the leisure of the provider and the user. For example one might be interested in the average price over several hours as it is sought to participate with a block bid.

For the subject at hand one hour pacing prognosis is considered as a typical prognosis.

A producer is interested in offering/bidding when the difference between the marginal costs and the spot price is noticeable.

Two main characteristics are used when considering a prognosis: When the prices are favorable and for how long.

The positive prognosis level; represents the positive difference between the prognosis price and the marginal cost. The difference between levels of prognosis is made arbitrary by the user considering in how many hours is sought to have a production. This shows when the prices are favorable.

The duration of the positive prognosis level; represents the duration for a certain prognosis level. This characteristic is represented by a start hour and an end hour. This shows for how long are the prices favorable.

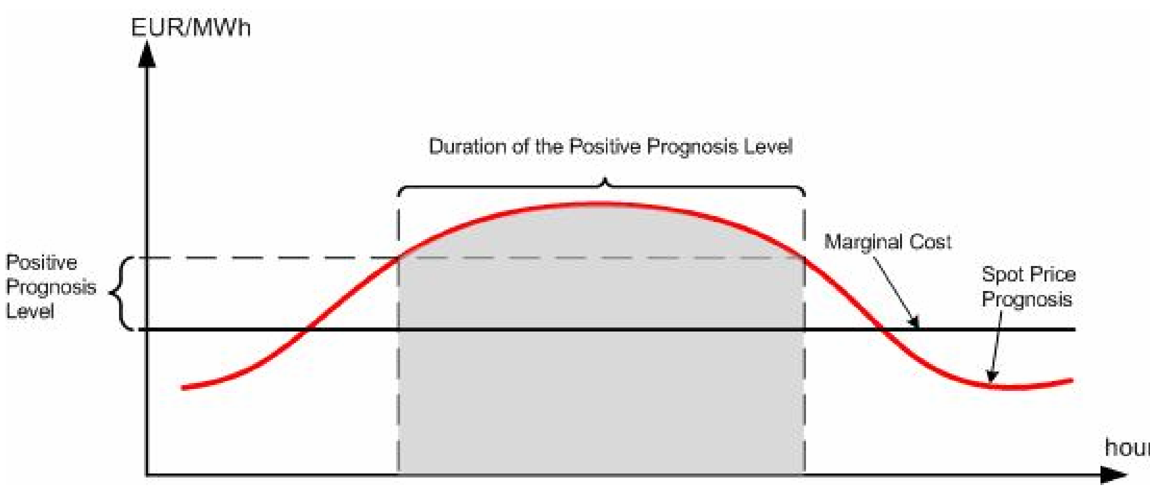

Figure 4.6 Prognosis level and duration representation

Although a more accurate prognosis is sought, the most important characteristic used are when the prices are right and for how long. One must differentiate and choose between various positive prognosis levels as they vary over time. It seems more profitable to bid when encountering higher levels, where the difference between the marginal cost and the prognosis is the largest comparing with the others.

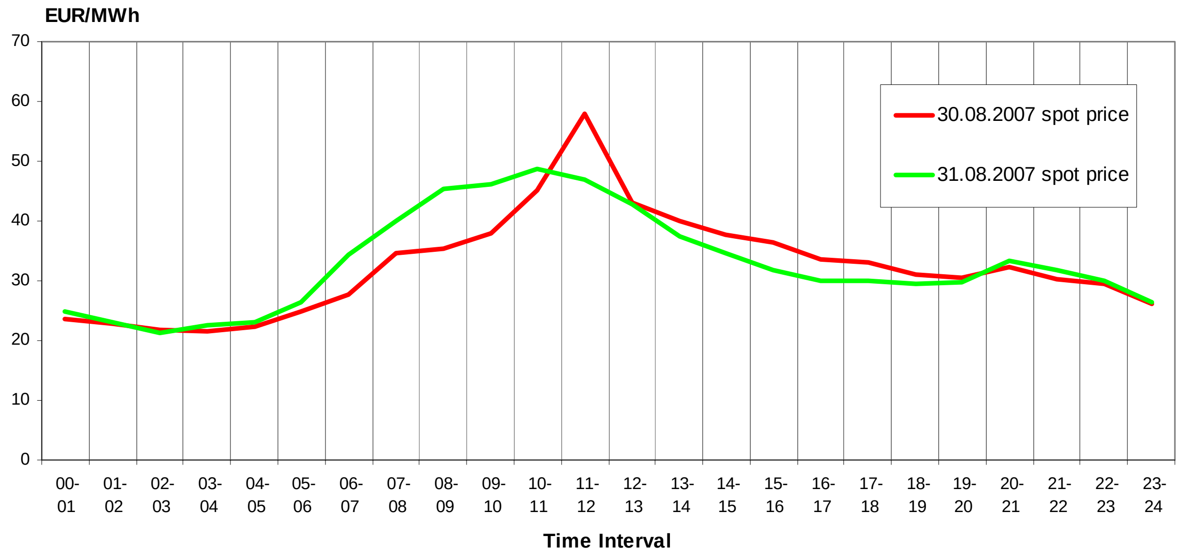

Figure 4.7 Two days spot prices in Western Denmark, extracted from Figure 4.3

The accuracy of the prognosis has an evident influence in the example represented through out **Figure 4.2, 4.3 and 4.7**, where the poor accuracy of the prognosis determines the loss of better biding hours over worst. It is clear when comparing the 9th hour, or more precise the 9-10 interval in the 30th and 31st of August 2007. In that case the production is registered in the 30th even though the better price is in the 31st. One conclusion can be that a better, more accurate prognosis would have prevented the bidding on a period with lesser price.

The accuracy of a prognosis can make the difference between a good production strategy and a bad one. Between a strategy where the typical CHP plant maximizing its profits and a strategy where production is lost and opportunities for better profit are missed.

It can be argued that beside the accuracy of a prognosis its degree of detail ensures the development of a good production strategy. Looking at technical restriction such as stopping/starting times one can say that the degree of detail takes less priority because a producer will try to win production over several hours and thus reduce the productions costs. The running costs of an engine grow with the number of starts within a period. For example the costs for running an engine that needs to be started five times in a day will be higher than for an engine that is started just one time.

An accurate prognosis does not require necessarily great detail to be used within a good production strategy. Further, from the practical point of view, an average prognosis over several hours with a good accuracy might be considered of better use than a detailed (determined for each hour) prognosis with a very good accuracy. This is because a detailed prognosis will generally require more detailed data than an average prognosis and most likely increase its costs and time to obtain.

The prognosis plays a central role in assuring that the producers 'goes' for better hours in a day or over several days. Beside production factors as capacity, district heating needs, the prognosis increases the chances one can have in winning production time when participating on the spot market. It practically makes a difference between profitable CHP plants and less profitable CHP plants, or even bankrupt CHP plants. The accuracy of a prognosis differentiates even further the degrees of profitability and is one of the main characteristics of a prognosis, which has direct impact on the production strategy.

5 Prognosis Tools and Theory

In this section prognosis is discussed as a tool to improve energy production. A description of an existing prognosis is given, insisting on the relevant variables used. Further on, the factors that define a prognosis from the qualitative point of view are analyzed linking them with the main question, prognosis results and usage. In the last part of the section the approaches towards making a prognosis are investigated with emphasis on the approach used within the present report.

5.1 Existing Prognosis

This section looks at the spot price prognosis model developed by Nordjysk Elhandel (NE), for Western Denmark (Jylland/Fyn). The model has been presented by representatives of the company through out a meeting in July 2007.

The company is a player on the trade market and has balancing responsibilities for power production. Besides being a supplier and in charge with power production, the company has its own spot price prognosis model to help it and its partners participate on the spot market. In the next paragraphs a summary of the information provided by the company representatives is given.

First off, the price drivers in Western Denmark used in the prognosis by NE are:

Marginal Cost (MC) for the coal used in the Central power plants is calculated using the coal prices. The coal prices vary from the source of the coal, and in NE case the reference price is taken from API #2[1] index market, for Western Denmark. As for Eastern

[1] API #2 and API #4 are market on which coal is sold

Denmark API #4 market is used. This is an important variable as the central power plants have most of their production based on burning coal.

Wind (W), according to NE, it is hard to predict. However, weather forecasts are bought from specialized companies. Forecast up to 21 days can be acquired from **Vejr 2** (www.vejr2.dk). Wind production plays a dominant role in offsetting the spot prices in Western Denmark as detailed in section 6.2.

Production capacity (PC) refers to the power plants above 100 MW available for production. It is published by Nord Pool through its web page.

Transmission capacity (TC) refers to the capacity available on the interconnections between the price areas. It is also published by Nord Pool. Both production and transmission capacities are published for 8 days, 3 weeks and 12 months. Production capacity is also published for 3 years.

Load (L), or the expected consumption is published by the Danish TSO, on its web page, for the day ahead.

District heating (DH) is taken as equal with the one registered in the previous week, as it has a tendency to change gradually, it represents the production from local plants.

System Price (SP) is the price calculated for the Nord Pool Spot with disregard for grid bottlenecks (interconnections). These are bought by NE.

EEX price (EEX), the price prognosis in the EEX market, Kontek is bought as well and they represent the price on the German market.

Forced production (FP) is the electricity production of the local and central CHP units due to heat production. This is indicated as being hard to predict. It has been chosen by NE to reduce this to zero in their calculations.

As it can be seen that, although many of the price drivers (variables) used are obtainable free of cost, arguable the most important price drivers: wind, system price and EEX price are obtained contra cost.

The prognosis is made on maximum 7 days basis, but the most common format is a 5 day prognosis. According to NE, the deviation from the actual price tends to aggravate for farther away days. For example it is expected that the absolute error between the real spot price and the prognosis price will be higher in the 5^{th} day than the absolute error in the 1^{st} day of prognosis.

The prognosis performed by NE uses a comparative approach in which the central production is an indicator for choosing between the prices promoted by existing official prognosis, EEX and System price, and the marginal cost for the central plants production.

If the production from central power plants is relatively low, the lowest of the prices will be used. While, if the production from central power plants is relatively high, the higher of the prices will be used, as exemplified in the following cases:

Case 1:

If Central production = low, then Price = Min (System price, EEX price, MC)

Case 2:

If Central production = high, then Price = Max (System price, EEX price, MC)

The Central Production is calculated from formula:

$$L = W + DH + FP + CP - NX$$

Where CP is the central production and NX is the net export, while as previously noted, FP = 0. The resulting Central Production (CP):

$$CP = L - W - DH + NX$$

5.2 Prognosis Factors

Three main factors are very important when talking about prognosis: *accuracy*, *availability* and *affordability*.

The main question concentrates on ameliorating two of them, the availability and the affordability. Availability, through the relatively accessible calculation algorithm with few variables and straight forward result and affordability by using free available data instead of having to pay for data used as variables.

Although it is not sought to improve the accuracy of an existing prognosis, the prognosis model is meant to have a fairly acceptable accuracy, and thus be usable or able to be improve so it can be used in practical bidding.

5.2.1 Accuracy

Accuracy of prognosis refers to how close to the measured data is the calculated prognosis before hand. It is determined not only by the method used to calculate it (see section **5.3**) but also by the accuracy of the available data, or input, this is discussed further in a following section (**6.1**).

As previously discussed the accuracy of the prognosis bears a great importance determining the producers bidding strategy. In particular the risks one can take when using a price independent bid, as clearly seen in the example of the SH CHP plant. In that example, because of poor accuracy of the prognosis the producer didn't bid in the most profitable hours/day.

5.2.2 Availability

Another factor that determines the quality of a prognosis is its availability. First the availability in terms of time, it can be said that a prognosis is perfectly available if it can be used in the spot market bidding. In practical terms it also refers to the time frame of the prognosis, in other words, for how many days in advance is the prognosis calculated.

A prognosis can be available for one day ahead or for few days ahead, usually 5-7 days. This gives the producer a wider range of choices when it comes to participating on the market. It has more bidding hours to choose from, and more important, more price peaks, as opposed to one day ahead prognosis where only 24 hours are available and mostly one price peak. In a prognosis, such as the one given as example in section **5.1** it bears importance on the production strategy influencing if the producer can adopt a long term or a short term strategy.

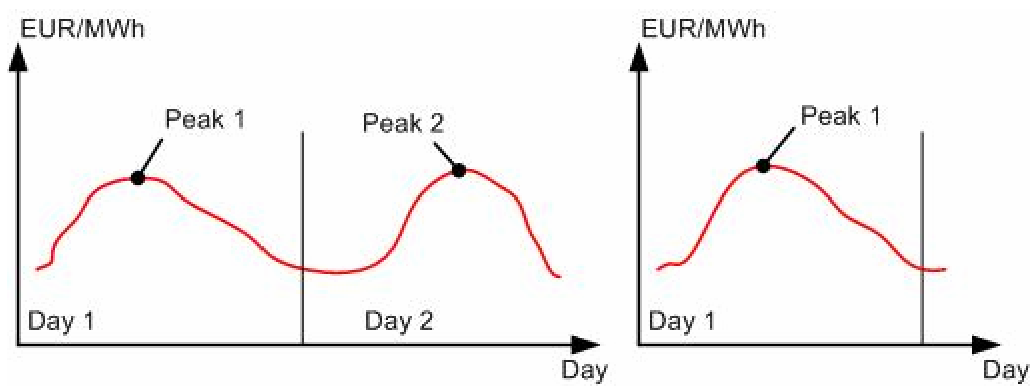

Figure 5.1 Difference in bidding options between one day ahead prognosis and several days ahead prognosis

Availability has little to no importance in a theoretical context; its real value is given by practical necessities as one tries to win production in hours with good spot price.

5.2.3 Affordability

Affordability is one of the factors on which the main question concentrates. A prognosis is more affordable if the costs involve with it are lower. The present report's prognosis model tries to eliminate the major costs involve with obtaining a prognosis. These costs are concentrated in the data acquired, such as some of the price drivers in a previous section example.

Subject of affordability is not that much related with how much is the producer willing to pay but with the amount of finance needed to calculate such a prognosis. Less data needed determines a more affordable prognosis as does the increase in the data that is freely available through internet.

So, what makes a good prognosis?

It can be said that a good prognosis is a prognosis that can be used as a bid premise. And, looking from the point of view of a producer one can say that a relatively accurate prognosis, available in time for at least one day and obtainable at low costs is a usable prognosis.

5.3 Prognosis Approach

Prognosis approach or the method to calculate a prognosis refers to how one develops and calculates a prognosis.

When looking to develop a prognosis one tries to look at the patterns in the variation of quantities such as power produced, power consumed, wind production, etc. A calculation algorithm emerges from the existing patterns and by changing one of the variables the result of the algorithm changes, representing a prognosis.

It can be accepted that with the increase of variable number the result of the prognosis will approach the real value. However, many variables are hard to predict and their variation does not necessarily follow a recognizable pattern. Also the variable itself depends on other factors either controllable or out of human control.

In other words to approach a perfect prognosis when it comes to a spot price, first, perfect prognosis for all the influencing factors must be developed and the factors that influence those. In this line of thinking one might take a very long time before a result, and at the end the development of the market is in such a way that the initial presumption are valid no more.

So, a realist approach to the problem is needed, one that eliminated minor influences and one that does not necessarily aims for a very good prognosis, but one good enough to be usable.

Prognosis such as the one developed by NE makes use not only of the most recent available data but also of years of experience in the market working. This type of prognosis uses a holistic approach to the problem, trying to include as many relevant variables as possible and the developer is willing to pay for many of the data required.

For the present report however, such an approach is out of the question by the limitations of the project premise. All data that needs to be bought to produce a usable prognosis is excluded from the start by the main question, it limiting the data to the one freely available from internet sources.

In turn, it is accepted that excluding data such as system price prognosis, EEX prognosis, wind forecast the prognosis is limited both in attainable accuracy and time span.

In the present report case a more statistical approach is required in order to cope with lack of data, predict the future development following patterns and their interconnections in the historical data such as spot prices, consumption, power production, etc.

It was chosen to follow a statistical approach when it comes to calculating the prognosis. This relies in past data acquired and involves the finding of a mathematical formula that will approximately generate the historical patterns in a time series (Hossein Arsham 1994, Box-Jenkins).

6 Data Collection and Relevance

In this section the collection of data is discussed and the sources used. Here is given a list of the sources used to collect the data used in the prognosis model In the first part the emphasis is put on the accuracy and availability of it in the context of timeline used to calculate the prognosis. The last part of this section concentrates on the defining and analyzing the relevant variables differentiating the variables to be used in the prognosis calculation mode.

In the line with the proposed main question, free available data from internet sources, is defined and limited throughout the next paragraphs.

Free available data from internet sources:

This is data in the form of time series, simple series or individual numbers that can be acquired via legal means, free of charge, from releasing authorities and companies through their sites or through e-mails.

The releasing authorities:

Energinet.dk

It is the Danish Transmission System Operator in charge of the transmission grid in Denmark. It offers through direct download: consumption prognosis, production and consumption history, transmission history over the interconnections

Although these data are thought to be the most trustworthy they have one major drawback when talking about real time prognosis after the present report model: The most recent data available can go back as far as 23 days, but most of the data is from 17 days. However an ftp link is available from where up to date data can be downloaded, but its nature makes it hard to use for the present report. Instead assumptions are made as if the link is easily available. It offers a comprehensive history of data dating as back as 2005.

Nord Pool Spot is the power exchange where the spot auction takes place; its site provides time series for spot prices, production, consumption and exchange for all Nord Pool countries.

Table 6.1 Data sources

Data	Source
	Energinet.dk
Load/Consumption prognosis	http://www.energinet.dk/en/menu/Market/Trading/Electricity+-+Consumption+forecasts/Electricity+-+Consumption+forecasts.htm
Wind prognosis	*To be announced*
Primary Production history	http://www.energinet.dk/en/menu/Market/Download+of+Market+Data/Download+of+Market+Data.htm
Local Production history	
Wind Production history	
	Nord Pool Spot
Power production history	http://www.nordpoolspot.com/reports/production/
Consumption history	http://www.nordpoolspot.com/reports/consumption/
Power traded history	http://www.nordpoolspot.com/reports/volumes/
Spot Prices history	http://www.nordpoolspot.com/reports/areaprice/

Load/Consumption prognosis is a time series representing the expected consumption. It is fairly accurate with relatively small difference when compared with actual consumption.

Wind prognosis should give the expected production from wind turbines. This is a feature yet to be introduced, but has a great impact on the prognosis modeling, and because of this it is mentioned.

Primary production, local production and wind production history is the recorded data in form of time series for the power production from central power plants, local power plant and wind turbines.

Power production history is the recorded data in form of time series showing the total power production.

Consumption history is the recorded data in form of time series showing the total consumption.

Power trade history is the recorded data in form of time series showing the power traded on Elspot.

Spot Price history is the recorded data in form of time series showing the spot price for a specified Elspot area.

6.1 Data Accuracy and Availability

The smaller the difference between actual measured quantities and presented quantities in reports and series sheet the greater the accuracy. Although in general there are no differences between these two, when more than one source are available errors can occur.

Throughout this section the data collected and analyzed is considered with accent on the actual data used in the model, e.g. freely available time series from internet resources.

Gathering and comparing data needed to develop a calculation model for the spot prices, 2 main problems were encounter. One problem translates into the difference between series of data representing the same measured quantities.

This raises *the problem of data accuracy*, as the data from two sources measuring the same quantity seems contradictory.

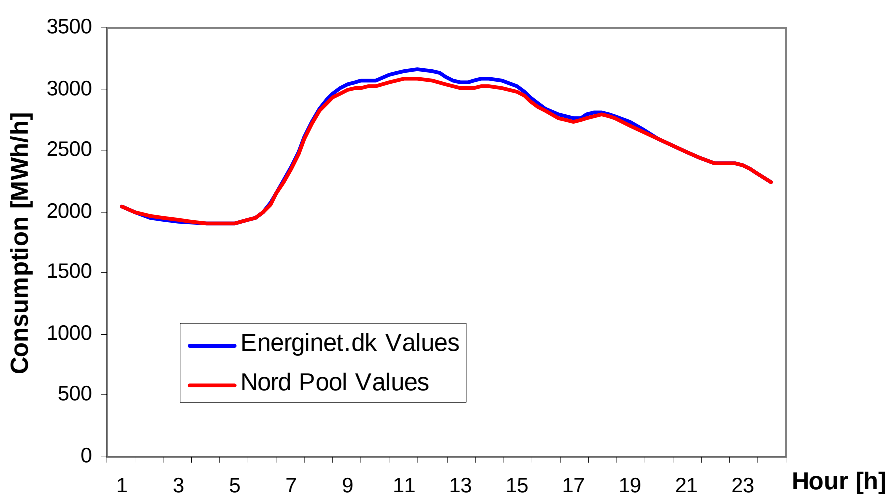

Figure 6.1 Discrepancy in data available from Nord Pool Spot and Energinet.dk observed on the 7th of July, 2007

When gathering the data for the electricity consumption 2 sources where consulted. First source is Energinet.dk and the second is Nord Pool. Although Nord Pool cites

Energinet.dk as source a systematic difference error between the data was noticed. In a measured interval 7-28.06.2007 the maximum absolute error calculated was 211 MWh while the average was 27 MWh.

It was chosen to consult Nord Pool as well because the data for the previous two weeks from the moment of data gathering are not available from Energinet.dk, while Nord Pool Spot has that data. It is worth mentioning that Nord Pool Spot cites Energinet.dk as the source for the data provided, which brings up the question: Why Energinet.dk is not publishing its data directly?

Which source should be used? From the point of view of the model it simply does not matter which series are used and can be argued that the difference between the values is overall minor. However, if the model should be used in day to day prognosis, in other words, used to actually bid on the spot market, the data available from Energinet.dk are preferable as they give a more recent development of the market through their ftp link.

The other problem when it comes to data collection is its availability. As seen in previous paragraphs one source although seemingly more trustworthy it might not have the most recent data. Or in the specific case of the Consumption/Load prognosis from Energinet.dk, the data is limited and requires further inquiring.

Availability of the data expresses in what way is the data used for the model and when, in relation with the Target Day.

The **Target Day** is the day for which the prognosis is calculated or the first day for which the prognosis is calculated in case the calculations are made for more than one day. The Target Day is a normal trading day, starting from 00:00 and lasting 24 trading intervals of one hour each.

The timeline in **Figure 6.2** can be used as reference for availability of the data, giving time limitations for the calculation of the prognosis in relation with bidding time and the Target Day.

The Prognosis for Consumption[1] is made available by the Danish TSO, Energinet.dk several hours before the bids must be submitted for the target day.

The Deadline for Bidding is the time at which the bids must be submitted to Nord Pool Spot for the target day.

[1] On the TSO's site (www.Energinet.dk), this is written as "Consumption Forecast"

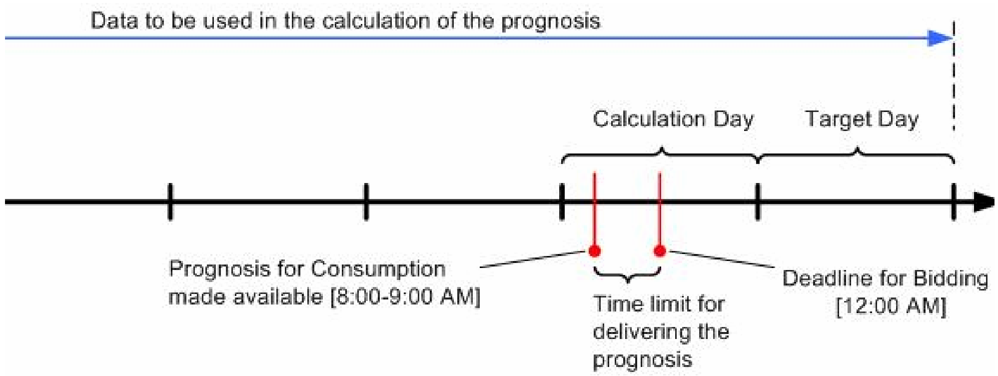

Figure 6.2 Timeline for data availability

The prognosis can be made within a time limit between the time when the prognosis for the consumption is published by the Danish TSO and the Deadline in which the bids are forwarded to Nord Pool Spot.

The **Calculation Day** is the day in which the prognosis is calculated and the producer makes a bid on the spot market based on this prognosis.

Availability of the data collected in relation with the reference timeline

Load (Consumption) prognosis is available in the time limit for delivering the prognosis, but only for Targeted Day and the Calculation Day. Here further inquire is needed to obtain the historical data. However, this bears little to no significance for the prognosis calculation model, as only the data for the Target Day is used.

The data collected from Nord Pool Spot is available in the time limit for delivering the prognosis for 30 days prior and for the Calculation Day.

The data collected from Energinet.dk, aside Load/Consumption prognosis, is available in the Calculation Day for 2 weeks before the Calculation day. This is the most problematic series of data as it was not found a reason why the data is published with such a delay. This delay means that the prognosis model can not take advantage of the most recent data and thus it can be argued its accuracy suffers.

6.2 Relevant Variables

The relevance of a variable is determined by the influence the variable in question has on the spot price variation and not on the prognosis itself.

These variables can be divided in 2 categories:

Market based variables, variables which originates in the market mechanisms: such as interconnection transfer, system price, EEX price, network limitations, market power

External variables, which are beyond the control of the market mechanisms: such as temperature variation, rainfall, wind, fuel price

The relevant variables are chosen using two restrictions:

Availability and affordability restriction

This is given by the project main question, limiting the choice of variables to ones that are freely available from internet sources, as discussed in detail in previous sections. It is chosen as base for the prognosis model the variables available from Nord Pool and Energinet.dk

Influence restriction, this is based on observations conducted on the market price variation, exiting prognosis and discussions with professionals with knowledge in the market workings. It refers to the degree of influence one variable has on the end result of a prognosis. Here the accuracy of data is an implicit variable, which is treated in detail in the previous sections.

In the next sections most important variables considered as relevant are discussed in more detail, with their overall influence on the spot prices.

6.1.1 Demand

The demand or consumption has an important influence as it determines with its increase an increase in spot price. In practical terms, as the demand increases more expensive units need to be used. They are expensive because their marginal costs are higher. The market evolves in such a way that ideally it always be more capacity than demand. However, when approaching the maximum capacity the cost of production increases and thus the marginal cost. In a marginal cost market, as Nord Pool Spot, this means a direct increase in the spot prices.

The demand can be influences by many factors, both linked with the market itself and the external variables, as wind, temperature, humidity, day time and so forth.

Unlike the simplified model used to exemplify some of the variables, the real demand is price dependent and tends to be lower with higher prices.

It can be argued that within the price dependent demand there is an independent demand, as some of the individual household consumers do not participate directly on the market and do not visible change their power consumption to follow a price dependent variation.

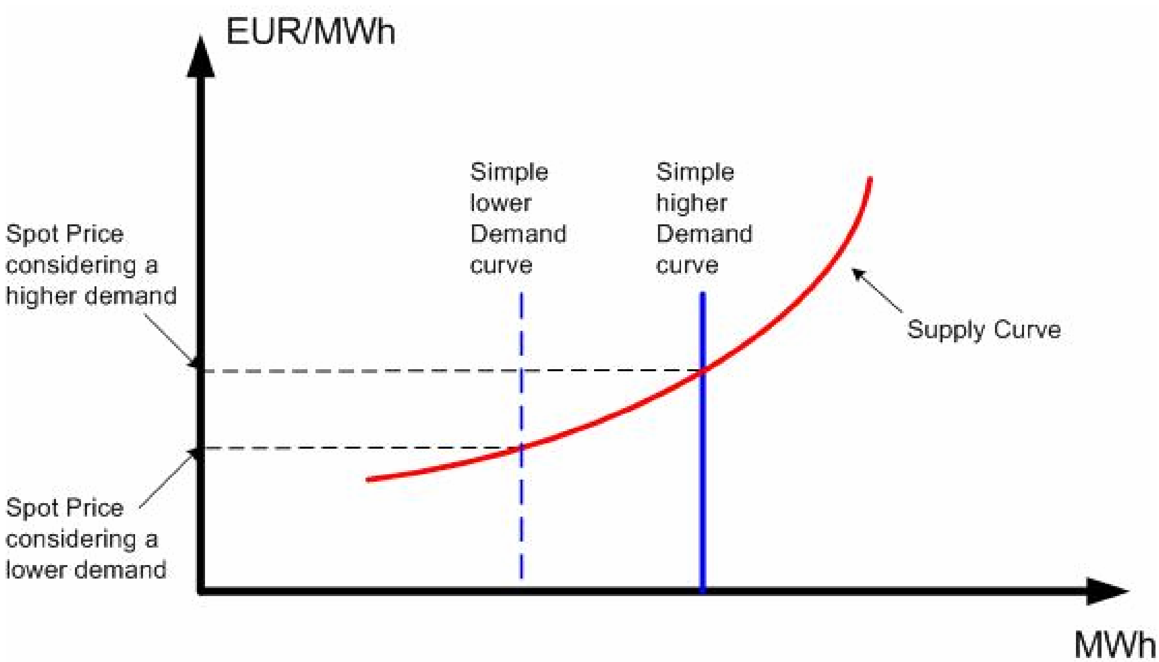

Figure 6.3 Demand influence on spot price, price independent demand

6.1.2 Wind turbines and Protected CHPs Production

It was chosen to put wind and protected production together because of their common influence on the spot prices.

Wind turbines production

Because electricity from wind turbines is offered at 0 EUR/MWh on Elspot, it represents an important variable having direct implication in how much production is needed from local and central power plants.

Wind turbines are influenced by the wind characteristics, and although overall the wind might have positive characteristics, it might happen that these characteristics are not present in the regions where the wind turbines are located. The wind prognosis alone is not sufficient to predict wind turbines production. It is also needed a localization of prognosis to the areas where wind turbines are present. In general meteorological prognoses on long term are unreliable making wind turbine production prognosis a hard task.

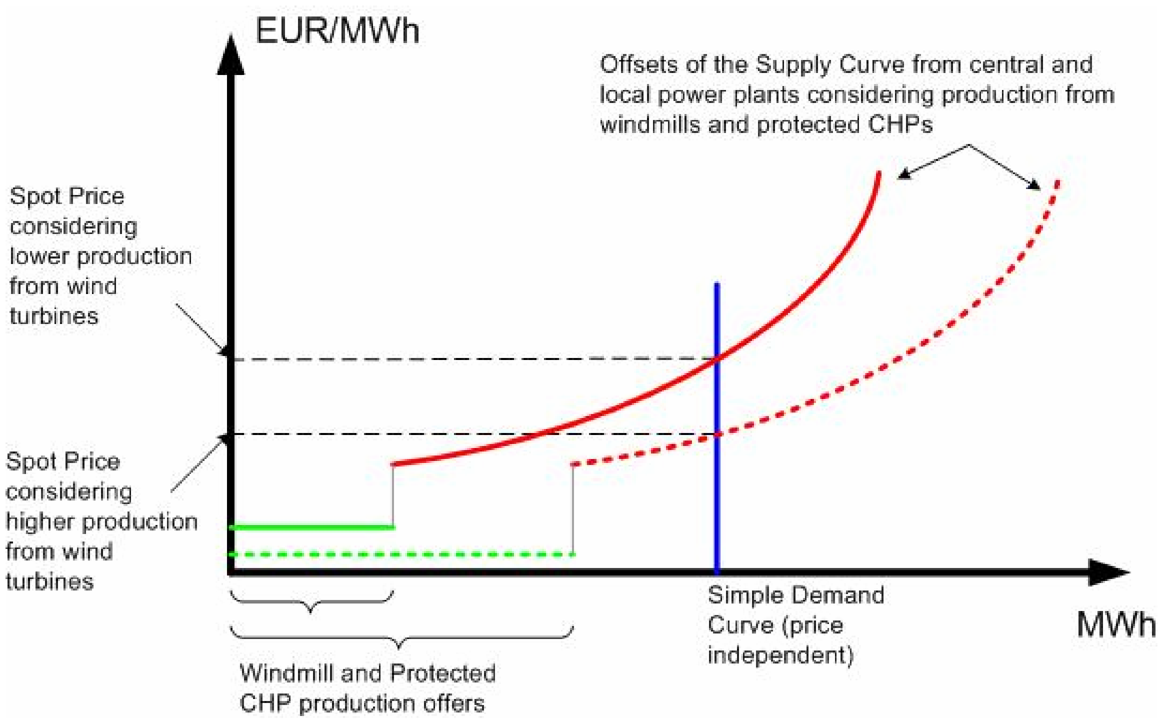

Figure 6.4 Influence of wind turbines and protected CHPs production on the spot price

For **Figure 6.4** the following are assumed as true:

- Central and local production units do not include protected CHP units.
- Demand of electricity is always greater than the offer from wind turbines and protected CHP. In turn this means that the spot price will never be equal with 0.

Protected CHPs Production

Protected CHPs are small and medium CHP units that have a special status within the electricity market. They can produce at any time and be guaranteed the selling of their production on the spot market. These units are offered on the Elspot like the wind turbines, at zero prices to assure the selling of their production.

Both protected CHP production and wind turbines production, being offered at zero, they have the same influence on the production from central and local power plants. As shown in **Figure 6.4** they both offset the offer curve, determining a lower spot price.

6.1.3 Interconnection capacities

Interconnection available capacities, these give the maximum transferable capacity between Elspot areas. They are used by Nord Pool to determine a decrease of price in high price areas and increase in low price areas, as discussed in detail in section **3.1.2**.

Their influence on the spot price in Western Denmark correlates with the prices in the surrounding Elspot areas. They are the main tool used to equilibrate the spot prices on the Nord Pool power market and as such play an decisive role in determining the spot prices.

6.1.4 Human activity

The working schedule and the human common habits determine a variation of spot prices between times in the day. For example the prices at 13:00 will be higher than the prices at 23:00 for the simple reason that at 13:00 human activity is higher and thus the consumption of electricity is greater. This is treated implicitly in the prognosis model.

Also, the seasons vary in temperature and lightning, which can determine drastic changes in human activity, and industries.

6.1.5 Temperatures and climatic conditions

The *temperature* has a direct influence on the demand, lower temperatures meaning that the local and central plants have to produce heat to cover the increasing demand. In turns electricity is produced as well, as most of the units are CHP.

The influence can be considered ambiguous; lower temperatures determines an increase in demand for heat which in turns determines offers of electricity at lower prices, as the plant needs to sell the electricity. Lower temperatures also means increase consumption of electricity through heating units, illumination (as usually low temperature means also poor natural light), people prefer to stay indoors and thus use electrical equipment more.

Rainfall

Rainfall influences the hydro power produced in Norway and Sweden and usually with increase precipitation the cost of electricity decreases in these neighbor region. Being connected with both these region Western Denmark is directly affected through its interconnections.

The variables are present in the prognosis model either implicitly, such as the day time or explicitly, as the demand. For the prognosis model, time series representing the discussed variables are used, such as historical time series for the power production or power exchange in Western Denmark.

Data quality plays and capital role in assuring a good prognosis. Its collection is relatively easy with the development of the communication infrastructure.

7 Spot Market Price Calculation Model

This section is dedicated to put forward a mathematical model for calculating the spot market prices based on discussions in previous sections. In the start of the section assumptions and limitations regarding the model are made in order to facilitate the prognosis approach. The methodology used to make up the model is presented and argued for. A general algorithm for calculating the prognosis is put forward. The section closes with a presentation of the results including a qualitative assessment.

7.1 Model Assumptions, Limitations and Simplifications

1. Marginal costs are constant for all producers. No market power.

Considering the marginal costs constant, power market non existent and all production capacities are offered, it is safe to assume that on a marginal cost market the offer curve will have the same mathematical characteristics from day to day and hour to hour. Therefore the supply curve will maintain its shape for the prognosis day.

This allows using the equations obtained from previous days in specific hours to calculate the prognosis.

2. The model is limited to calculate the spot price prognosis for only bidding day ahead.

3. It is assumed a price independent demand, named simple demand.

4. Wind production is considered as known value.

Its value of it is taken from historical values. This is made in anticipation of the future implementation of a wind production prognosis by the Danish TSO, Energinet.dk, published through its official internet site, (www.energinet.dk)

5. The production from protected CHP units is considered as part of local production and as such it is not defined beyond this.

6. The calculations are made only for workdays.

7. Variables are simplified as follow:

Wind production is noted as W in **Figure 7.1**

The demand (D) used in calculations is the total demand (Dt) without the wind production.

The y-axis represents the spot prices being from historical values or as a prognosis, while x-axis represents the demand at any point.

The values on the y-axis are determined from an equation that involves the x-axis values. While the x-axis values are either historical demand values or forecasted values for the demand.

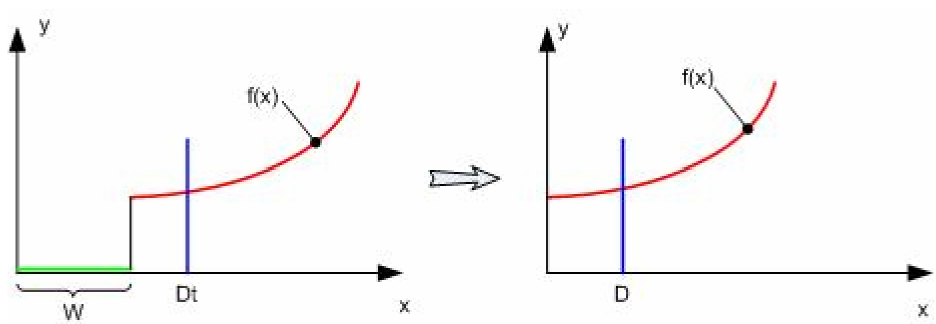

Figure 7.1 Variables Simplifications

Considering previous assumptions for Figure 7.1 the f(x) curve, which is a constant function of x (demand), is offset together with the demand by the variation of the wind production.

The main premise for the calculation is that the f(x) curve will remained unchanged with the variation of wind production. This is not true in reality, knowing the real demand is price dependent.

7.2 Prognosis Methodology and Algorithm

Differentiating between usable and unusable data

This is made through the data collection and the limitations sets through out the present report. This step sets the variables used in the calculation.

Acquiring data

In this step time series from the internet sources are downloaded and organized. Data for 3 weeks or 21 days is downloaded.

Setting up algorithm steps leading to a prognosis result

Microsoft Office Excel is used for the calculations, including its integrated tools.

The data range used is: 6.08.2007-26.08.2007; 3 weeks; starting Monday, ending Sunday.

1. The value for primary and local production is calculated by summing the two, while the consumption (D) is determined by subtracting the wind production from total consumption.

2. Data is centralized for each hour, from a time series spanning on 3 weeks. So, 24 time series are separated for each of the day's interval (hour).

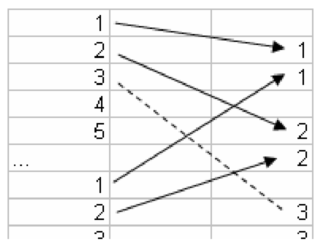

Figure 7.3 Organizing values by hour

3. For each hour a function is determined graphically using the demand (consumption) and the spot price. This is a 2nd degree polynomial function, with the following general form: $F(x) = A \cdot x^2 + B \cdot x + C$, where A, B and C are the equations factors while x is the variable represented by Consumption.

4. The data range used is 6-26.08.2007 only the working days, so a total of 15 points of graphic for each function. The result of this function is compared for each value of consumption to the spot price and the absolute error is calculated as the square root of their difference, as seen in **Figure 7.3**:

Date	Hour	Spot Price	Production	Consumption	Polynom	Absolute Error square
			CL	D	PR	e
	Hour 8	EUR/MWh	MWh	MWh		
6/8/2007	8	25.61	1583.6	2109.4	29.47	14.9
7/8/2007	8	29.75	1591.9	2519.8	29.83	0.0

Figure 7.3 Calculation of the polynomial function

Spot price is taken for the day in question, while the production (CL) is taken as summation between central and local production. Consumption (D) is taken as difference between total consumption and the wind production. Polynom (PR) is the value of the spot price calculated with the determined polynomial function. Absolute Error square (e) is the square power (^2) of the difference between Spot Price and Polynom (PR).

5. The integrated solver is used to recalculate the function factors, A, B and C so the absolute error square is close to zero. The new resulting equation, with the new factors is used to calculate the spot price in each hours, as shown in **Figure 7.4**

Date	Hour	Demand	Prognosed Spot Price	Actual Spot Price	Error	abs Err
		MWh	EUR/MWh	EUR/MWh		
27-08-2007	8	2023.8	29.2	38.7	-9.5	9.5
27-08-2007	9	2158.6	26.3	44.4	-18.2	18.2
27-08-2007	10	2037	32.5	43.5	-11.0	11.0
27-08-2007	11	1939.6	31.3	46.0	-14.7	14.7
27-08-2007	12	1755.1	30.1	47.5	-17.4	17.4

Figure 7.4 Forecasted Spot Price (prognosed spot price)

The demand is calculated as difference between total consumption and wind production in the forecasted day. For more realistic calculations, these should be replaced, by forecasted consumption and forecasted wind production.

7.3 Qualitative Assessment

In the report 2 bases for comparing are used.

First, a simplistic model is used as reference, showing the improvement of the proposed model over a simplistic approach.

Second, the values obtained through the proposed model are compared against the real value, in a historical perspective.

All the data are calculated and compared for the same time frame.

The simplistic model base

Price prognosis is calculated as a simple average of spot prices for Western Denmark in the past 3 days.

This is calculated for each hour, as shown in the following example:

Hour	Day			Prognosis day
	1	2	3	4
0	v01	v02	v03	average(v01,v02,v03)
1	v11	v12	v13	average(v11,v12,v13)
2	v21	v22	v23	average(v21,v22,v23)
3	v31	v32	v33	average(v31,v32,v33)
...				...

Figure 7.5 Simplistic model calculation

The difference between the values obtained with the models shows how much of an improvement the proposed model is over a simplistic approach and allows for a fair analysis of the proposed model potential. The simplistic model differentiates between weekdays and weekends. For example, when the values for a prognosis day as Monday are calculated, the average is taken from last 3 working days, while if the prognosis is made for a weekend day, such as Sunday, the average is taken from the previous 3 weekend days.

Actual Prices base

It is looked at the difference between the model results and the actual prices, an absolute error is calculated and analysis based on relative variation of the results is made. The resulting values are compared for each hour in the forecasted day, as in **Figure 7.6**

Date	Hour	A. Spot Price	Prog. Spot Price	abs. e prog.	S. Avrg. Spot Price	abs e Avrg
		EUR/MWh	EUR/MWh		EUR/MWh	
27-08-2007	8	38.7	29.2	9.5	32.5	-6.2
27-08-2007	9	44.4	26.3	18.2	32.5	-11.9
27-08-2007	10	43.5	32.5	11.0	42.9	-0.5
27-08-2007	11	46.0	31.3	14.7	46.0	0.0
27-08-2007	12	47.5	30.1	17.4	53.6	6.2

Figure 7.6 Difference between Actual Spot Price, price obtained through proposed prognosis and the simplistic model

A. Spot Price is the Actual Spot price

Prog. Spot Price is the price calculated through the proposed prognosis model

Abs. e prog. is the absolute error of the proposed prognosis model

S. Avrg. Spot price is the price calculated through the simplistic model

Abs. e Avrg. Is the absolute error of the simplistic model

The results are not conclusive and further modeling is required. The simplistic model approach has better results, with an average absolute error of 5.56 EUR/MWh, while for the data calculated with the proposed model; the average absolute error is 14.16 EUR/MWh. When considering that the average price in the 3 weeks time frame was 27.41 EUR/MWh, including weekends, the error is very high in the proposed model.

Clearly, the error in the proposed model is too high, demonstrating that the proposed model is not up to the task of calculating usable prognosis for spot prices. The issue is aggravated further by the apparent stability of the simplistic approach, where the error is much lower for more calculated hours.

8 Conclusions and Perspectives

The model proposed has not yielded conclusive results, although it seems clear when compared with the simplistic model that it is a flawed one. Its accuracy makes it unusable, even with accurate data for the variables involved, having a far too greater error (errors greater than 50% have been calculated).

Data available free of cost from internet sources is abundant, especially at the historical level, where records have been made dating back to 2005. It should be possible to develop a suitable model that takes advantage of this data. However, although fairly accurate prognosis on day ahead term might be possible, the issue of practicability remains unsolved, as extending such a prognosis over several days requires additional prognosis, which usually come with a price tag.

The issue of a gratis prognosis obtained by using free of cost available data from internet sources remains open. The model proposed is just one example in which data are integrated. It is not involving some of the most influential variable, as interconnections flow, which in essence is how Nord Pool regulates the prices.

Important improvements can be made through a more detailed model, which includes the interconnection flows, day cycles variations and a better definition of the demand variable.

A next step can be to use different data range, to determine which represents better future evolutions. Also this must be made on a greater scale, since in the present report the calculations are made for only for one day.

The type of model proposed can be integrated into a computer program (software) which eliminates the tedious work and makes integrations of further variables easier.

References

EMD International A/S. 2007. *Hvide sande CHP plant, DESIRE.* http://www.emd.dk/desire/hvidesande/ (accessed between March and September, 2007)

Nord Pool Spot. 2007. *Market Information.* http://www.nordpoolspot.com/Market_Information/ (accessed between March and September, 2007)

Nord Pool Spot. 2007. *Press Releases Information.* http://www.nordpoolspot.com/Market_Information/Press-releases-list/ (accessed between March and September, 2007)

Nordel. 2007. *Nordel Principles for determining the transfer capacity in the Nordic power market.* Nord Pool.

Nord Pool Spot. 2007. *Area Price*. http://www.nordpoolspot.com/reports/areaprice/ (accessed between March and September, 2007)

Nord Pool. 2007. *Urgent Market Messages (UMMs).* http://umm.nordpool.com/marketinfo/umm/web/tso_12_month.html

Danish Energy Authority. 2007. *Electricity Market Structure*. http://www.ens.dk/sw23517.asp#516_18657 (accessed August 10, 2007)

Hossein Arsham. 1994. *Time-Critical Decision Making for Business Administration.* http://home.ubalt.edu/ntsbarsh/stat-data/Forecast.htm#rboxjenkm (accessed between June and August, 2007)

Nord Pool Spot. 2007. http://www.nordpoolspot.com/ (accessed between March and September, 2007)

(Energinet.dk 2007) Energinet.dk. 2007. http://www.energinet.dk/ (accessed March and September, 2007)

Danish Energy Authority. 2007. http://www.ens.dk/ (accessed March and August, 2007)

Note:
Reference within the present report’s text are made using the Chicago Style (http://wwwlib.murdoch.edu.au/find/citation/chicago.html)

Annex: Notates and Observations

1. Production at zero when the spot price is zero

This is the hardest situation to predict when it comes to prognosis, because it depends so much on very unpredictable variables, such as wind turbines production outside temperatures. However it can occur, most probable during night time when the consumption is the lowest. If more than one producer offers at zero and their accumulated offer is higher than what is needed (the Load), they each get a share of production related perceptual with the initial bid, as illustrated in Figure A.1

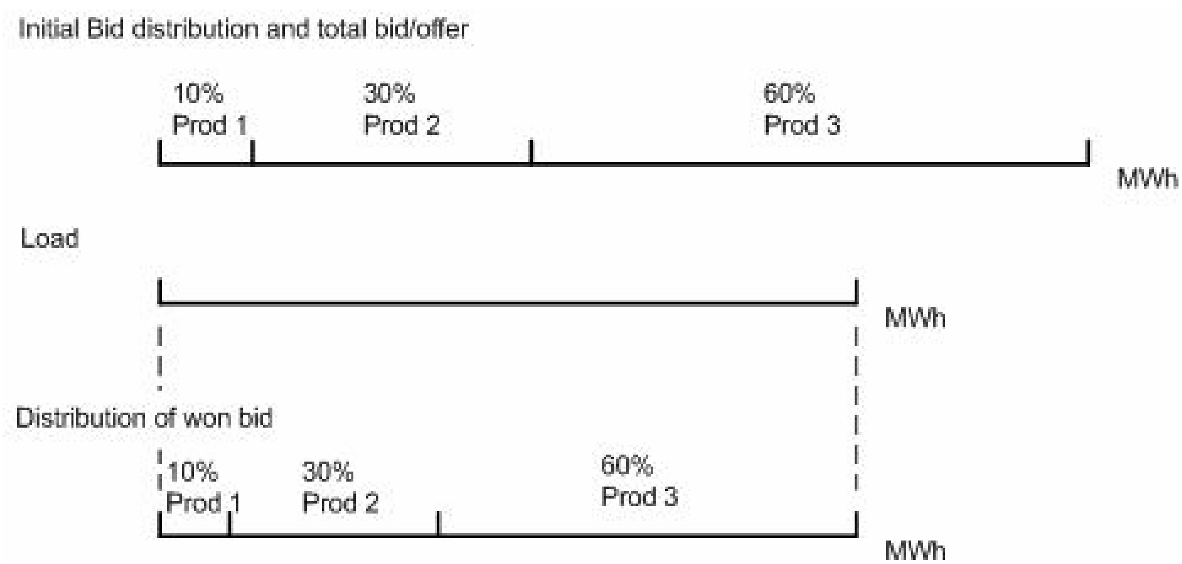

Figure A.1 Distribution of won bid at zero spot price, offers are made at zero

2. Power Losses

Power losses are the losses of electricity on the transmission and distribution grids. They are part of the consumption and are covered with the grid taxes paid by suppliers. The costs go through price to the end consumer.

3. Supply-Demand-Consumer

The supplier can mean both the producer that supplies power through market participation and the supplier that participates on the market and buys the power to supply to its customers/consumers. The demand is the quantity the consumer needs and willing to pay, as restricted by price. Hence the price dependent demand.