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# Visualization of electricity market fundamentals

*Case: Nordic market*

Final report
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# 1 INTRODUCTION

The deregulation of the Nordic electricity markets has implied a great change to the ways of working in the electricity companies. The electricity is traded at the Nordic Power exchange, Nord Pool, and changes in the fundamentals affecting the supply or demand of electricity are immediately reflected in the electricity market price.

The Nordic power exchange organizes trade in standardized physical and financial power contracts. The hourly electricity price is set by an equilibrium model where the supply and demand of all the market participants are matched day-ahead and the equalizing price, called spot price, acts as the basis for the derivatives.

Due to the non storable nature of electricity, the time dependent variation present in the demand results in a strong seasonal, weekly and daily profile in the electricity spot price. The Nordic market has a significant electricity heating customer base, considerable amount of Combined Heat and Power (CHP) production, and most significantly roughly 50 % of the electricity is hydro based. The hydropower allows the energy to be stored within certain limits in reservoirs, which decreases the short-term variation in the spot price. But the total amount of hydropower on the market depends on the amount of yearly rainfall and snowfall and that causes big variations in the yearly spot price levels.

As the electricity cannot be stored, there is no strong relation between the spot price present and the prices of financial derivatives on spot price. Instead, the future prices reflect the market expectations on the future supply and demand, which makes the financial electricity markets quite unique.

Since the number of fundamental factors that influence the spot price and the derivative prices is large, there is a need to systematize and visualize the information in a good way. A single person can not keep track of everything, so there is a need to do this in a centralized way that can be used throughout Fortum. Of course, different persons have different needs, but in general the basic important fundamentals are the same.

# 2 ASSIGNMENT

## 2.1 Goals

The primary goal of the project was to design and implement a fully functional web based market analysis device for the Nordic power market to be used within Fortum. The idea is that people throughout the organization that are in need of fundamental data for their decision making always should have access to the latest data and all the important data should be found in one place.

Key-indicators and -indices should be identified and visualized in a way that the user of the service will intuitively see the most important indicators and their effect on the price of electricity.

All the relevant data should be collected in one Excel-tool where the indices are calculated and the necessary pictures and tables created. This Excel-tool is what the analysts work with when they update the data and the planned pictures and tables. The tool needs to be well documented and dynamic enough to allow changes in the future. Most of the data available on the web page will be created by the Excel-tool so it needs to function flawlessly. It should be easy to connect the tool to other sources, so that the amount of manual work can be kept minimal. However, the connection to external sources is not considered in this project.

Finally, the web pages are where all the work done on the project comes together. The web pages should be implemented using Market Analysis’ existing web solution. In addition to displaying the data generated by the Excel-tool, an easy to use and intuitive interface for the page has to be designed so that the user of the page finds the relevant information quickly and easily. When the project is finished the web pages should be fully functional and documented.

## 2.2 Actions and timetable

We decided to divide the project into three parts. The first and most important part was to understand the fundamentals and the relations between them, as well as identifying key indices. In order to create a functional market analysis web service we felt it was important to first analyze historical data in order to identify the most important fundamentals and connections and the correlation between them. This analysis also helped to decide how the data available should be visualized and presented to the users. The second part consisted of planning and building the Excel-tool and the third part of planning and implementing the web-page structure. In addition to this everything had to be well documented and tested.

An important aspect was the actual needs of the potential users of the service. The fundamentals are already familiar to the users and can be accessed via different sources. The real task was therefore to try to unify all data in a way that is easy to understand and to try to visualize the data from different points of views. Since there is a lot of raw data and it is difficult for a single person to keep track of and update everything, there was a good possibility for this project to produce usable results.

### 2.2.1 Identified actions

The following main actions were identified by the project group.

1. Preparation of project plan

2. Planning of the methodological part

This part was considered to be the most important for the succeeding of the project. If the results derived here are poor, the benefit of the final visualization in the web solution will also be poor and of no practical use for Fortum. The task included clarification of customers needs, going through the fundamentals to be visualized, and acquiring of market data. Thinking of fundamentals’ inter-relations to be visualized and identification of indices and other key-values as well as appropriate and easy-to-understand visualizations methods were also important parts of this task. Finally an acceptance from customers was needed before this task could be considered to be completed.

3. Preparation of the intermediate report

4. Planning of the Excel tool

An important part of this task was the clarification of customer needs. After that the tool functionality and technical architecture could be planned.

5. Implementation of the Excel tool

The goal was to keep the Excel-tool as simple as possible without giving up any of the functionality. We thought this would make the tool easier to expand and develop further in the future.

6. Planning of the web pages

Again, the clarification of customer needs was important. After that we went on to plan the logical page structure.

7. Implementation of the web pages

Since the existing web solution of the Market Analysis function could be used, this task consisted of learning how it works and then implementing the pages according to our plan.

8. Testing

The testing part consisted of our own test of both the excel-tool and the web pages. Thereafter a user acceptance test was carried out.

9. Preparation of the documentation

A user's and developer's manual was written for both the Excel-tool and the web pages. In addition to this also the chosen fundamentals, analysis and visualization methods were documented.

10. Preparation of the final report and seminar presentation

11. Delivery of project results to the customer

12. Seminar presentation

See appendix A for a detailed list of actions and the time needed.

### 2.2.2 Timetable

The timetable of the identified tasks can be seen in the chart 2-1. The chart only visualizes the feasible time interval for each task and don't reflect the amount of time necessary to carry out the tasks.

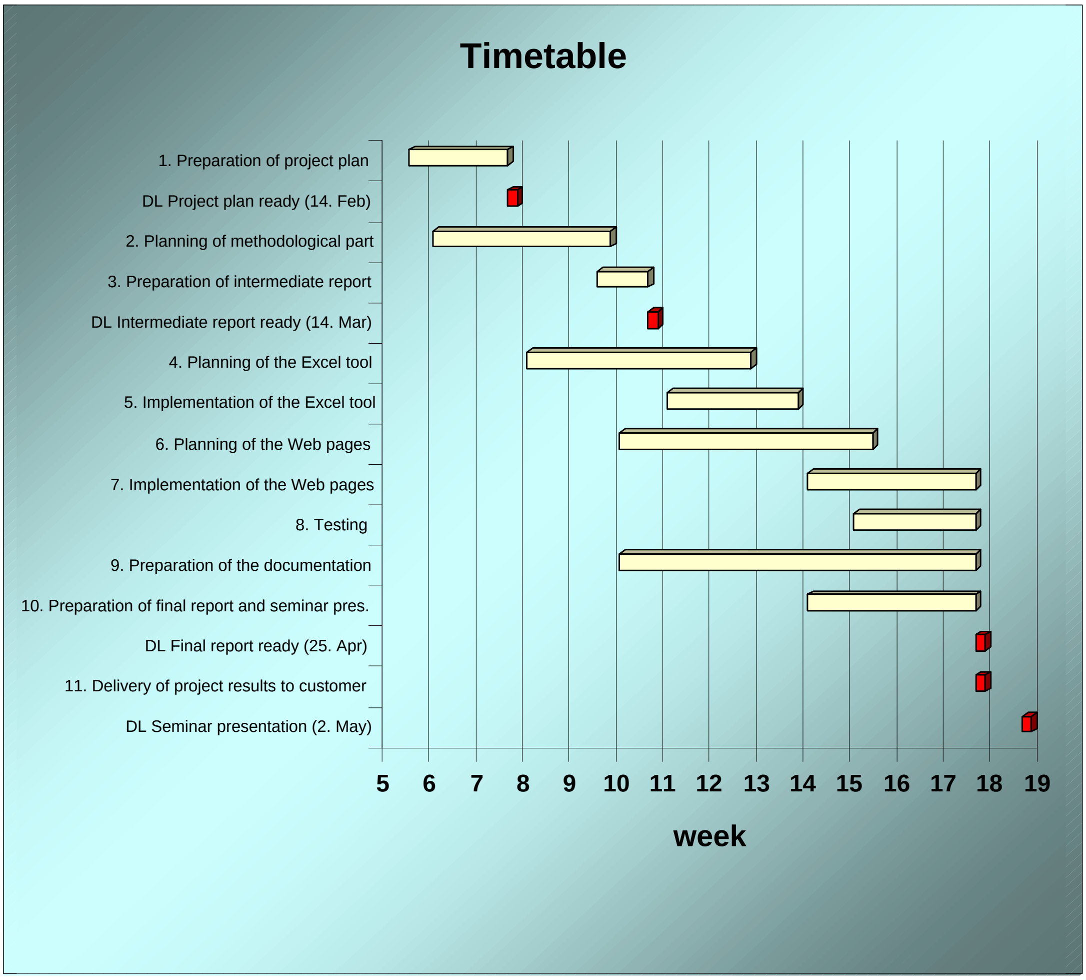



*Chart 2-1: The timetable of the identified tasks.*

# 3 MARKET ENVIRONMENT

At first we identified the relevant factors defining the situation in the Nordic electricity market. The interrelationship and joint dynamics was also considered. The set of factors was divided into three main categories: hydrology, production/supply and consumption/demand. The hydrology is identified to be so dominant in the Nordic market that it requires a separate category with a more detailed treatment. The difference between a dry and a wet hydrological year corresponds in hydro power production roughly to annual total normal consumption in Finland which represents some 21% of total annual consumption in Nordic market area [source: Nordel Annual Report 2001]. See the appendix B for a visual mapping of the identified factors, their interrelationships and a high level representation of the market price discovery process.

## 3.1 Hydrology

The hydrology category contains factors affecting the possibilities to produce hydro power. Some of the power plants have no water reservoir associated to them, so all incoming water from upstream must be discharged either via the turbines generating electricity or via channels leading past the turbines. The latter one is called spillage and it can not be used in electricity production in the associated power plant. This kind of hydro power plants without reservoir capacity are called run-of-river plants. For plants with reservoir associated to them the hydro power production requires discharge of water from the water reservoir. In this case the immediate production possibilities are defined mainly by the prevailing amount of water in the water reservoirs and the immediate water income from upstream to the reservoirs because the amount of water in reservoirs must be within certain minimum and maximum level boundaries set by power plant technical characteristics and legislation. Note that the total local incoming water in a cascaded multi reservoir system is a sum of the local inflow and discharge and spillage from all associated upstream power plants.

The inflow is typically divided into two parts: unregulated and regulated. The unregulated part is mostly inflow associated to run-of-river plants but part of it can be identified as ”must-run” type of discharge from the reservoirs in order to satisfy the reservoir level boundaries or to control the risk related to violating them. The total inflow originates from the precipitation and melting of snow. Most of the inflow flows through the soil surface before reaching the water reservoirs. Some of the inflow is stored to the soil as ground water. This water storage is usually called as soil water. There is a relatively strong (positive) correlation between the amount of precipitation and the temperature. The temperature also drives the development of the amount of snow. In the autumn when temperature falls below freezing point, part of the precipitation comes as snow and stays in the snow-pack over winter instead of flowing immediately into water reservoirs. In the spring when the temperature raises above the melting point, the snow-pack starts to melt. This melting occurs usually very rapidly leading to very high inflows for a couple of weeks causing unavoidable spillage in many power plants due to inability to store the water in the reservoirs with relatively limited storage capacity. This kind of rapid inflow peak is called spring flood. The start or magnitude of the spring flood is very hard to forecast well in advance due to general accuracy problems related to forecasting weather for time horizons longer than one week.

There usually exist a natural cycle of roughly one year in the development of the snow melting and accumulation of snow. The corresponding cycle can be observed in the inflow, water reservoir level and hydro power production as producers try to allocate the production into the expected highest spot price periods within the cycle period within the water reservoir limits. Note that the relatively large uncertainty in the timing of the spring flood together with the long time required to empty the water reservoirs requires in practice the producers to start emptying the reservoirs well in advance before the spring flood starts.

Because the Nordic electricity market is hydro power dominated, the production possibilities of hydro power affect the supply curve and thus also the spot price considerably. The pricing or bidding of water to the spot market is primarily done with respect to pricing of other production forms in the market. However, if the water and snow reservoirs are relatively empty compared to some history reference values possibly leading to shortage of water in case of unexpectedly low inflow, pricing of water could raise considerably as seen in the 1996 and especially late 2002 and early 2003. On the other hand, if the water and snow reservoirs are relatively full compared to some history reference values possibly leading to excess spillage of water in case of unexpectedly high inflow, pricing of water could decrease considerably as seen in the 2000.

Because the prices in the financial derivatives market can be considered as the market expectation of the future spot prices, the development of the water and snow reservoir levels drive heavily also the prices of financial derivatives like for example forwards and futures. However, the prices of financial instruments was set outside the scope of this project (however, this is one of the planned future extensions of the project outcome).

## 3.2 Production

The production or supply category contains relevant production forms present in the market and the related factors affecting the production possibilities of these power plants and the pricing of them.

The relevant production forms include hydro power, nuclear condensing power, conventional condensing power, combined heat and power (CHP). The conventional condensing power plants can be divided based on the associated fuel type as coal, oil and gas condensing power plants. The CHP plants can be divided based on the nature of the associated heat consumption process as industrial CHP and municipal CHP. The electricity production in a CHP plant is driven mainly by the associated process requiring heat. It is relatively difficult to forecast the development of the industry process especially if you are not the owner of the industrial facility. Typically some history average values are used as forecast for electricity production in industrial CHP plants. The heat demand in a municipal CHP plant is driven mainly by the district heating demand which in turn is driven mainly by the temperature. Within this project the CHP plants are considered as a whole due to lack of access to more detailed data.

The (annual) revisions, maintenance or outages of a plant mean that the plant can not be used for production during the outage period. Therefore the revisions affect the supply curve. The outages are typically publicly known well in advance according to legislation. The outages are primarily scheduled to periods with relatively low market prices. The revisions are especially relevant for plants which are typically used relatively much all the time like for example nuclear power plants which are used practically all the time outside the revisions due to their relatively low production costs and high cost of maneuverality. Revisions of coal condensing power plants are also relevant although these plants are not necessarily used outside the outage periods if the market price is relatively low compared to the variable cost of the plant. Oil and gas condensing plants are used relatively little annually and therefore the outages can normally be scheduled to periods in which the plant would not have been used in any case. The hydro power system consists typically from a large amount of relatively small power plants. This means that hydro power outages can be considered to be diversified over a relatively long period of time so that there are no major decreases in the overall available hydro power capacity on market area level.

The prevailing market price of fuel of condensing power plant affects the pricing or bidding of these plants. There is a relatively high level of uncertainty related to the future development of market price of coal, oil and gas. The price of the fuel of a nuclear power plant (uranium) is relatively stable compared to other fuel types so it is not so relevant factor affecting the market price level.

In general, the pricing or bidding of each production plant to the spot market is done with respect to the aggregated supply curve of the whole market according to general game theory for competitive markets. The basic factors affecting the bidding process are the production possibilities of the plants and (marginal) production costs. Additionally the realized spot prices and related forecasts are carefully analyzed to optimize the future bidding behavior.

## 3.3 Consumption

The consumption or demand category contains relevant consumption types present in the market and the related factors driving the amount of demand and the associated demand side pricing.

The relevant consumption types include industrial base consumption, electricity heating and interruptable industrial consumption. The behavior of the industrial base consumption is relatively similar to the behavior of the industrial CHP. The behavior of the electricity heating is relatively similar to the behavior of the municipal CHP. The pricing characteristics of the interruptable industrial consumption can be considered to depend on the source of power used to cover the utility's demand. If the utility uses its own production plants to cover its demand, the decrease in the demand should cause a corresponding increase in the supply curve of the spot market if the production is not also adjusted. Otherwise the interruption of consumption should cause a decrease in the demand curve of the spot market.

Most of the consumption is industrial base consumption and electricity heating. This means that the demand is normally relatively inelastic with respect to the spot price. The main driver of the total consumption is by far the temperature. Within this project the consumption is considered as a whole due to lack of access to more detailed data.

## 3.4 Formation of system level spot price

The spot price discovery process used in the Nordic electricity market is similar to the market price discovery process of any other free competitive market. Individual market participant's supply and demand curves are aggregated into one Nordic system level supply and demand curve, respectively. The total net import and export between the Nordic market area and surrounding areas is included in the curves. The spot price is found at the intersection of these curves. This setting is done separately for each hour of the next day in the afternoon of the preceding day.

Note that the direction of electricity exchange between the Nordic market area and other surrounding areas is typically very heavily driven by the relative market price differences between the two areas so that the electricity is exported from the area with lower price and imported to the area with higher price.

Note also that the physical characteristics of the electricity transmission system are ignored in the formation of the system level price.

The system level price, system price, is the underlying asset in the financial derivatives with highest liquidity and therefore it is a very relevant reference index.

## 3.5 Formation of price area level spot price

The production forms are distributed relatively unevenly among the price areas in the Nordic market. Almost all production in Norway is hydro power. In Sweden roughly half of the production is hydro power and the other half nuclear. Additionally there are a few marginal conventional condensing units in Sweden. Production plants in Denmark are mostly conventional (coal) condensing power although Denmark also has some wind power capacity. Finland has the most (evenly) diversified production plant portfolio including hydro power, nuclear power, conventional condensing power and CHP plants.

The areas of largest consumption (e.g. cities) are typically located relatively far away from the largest production facilities (e.g. hydro power plants up in the mountains in the North).

The above characteristics mean that typically the formation of the system price leads to a market clearing setting which can not be satisfied within the restrictions of the available physical electricity transmission system. In another words, the imbalances in regional supply and demand can not exceed certain level because the imbalance can be settled only by exchange of power with surrounding regions only within the available physical electricity transmission line system capacity.

The market based solution to rebalance the regional supply and demand so that the market clearing solution can be physically committed is to divide the Nordic area into several geographical price areas. The supply and demand curves are aggregated separately for each area taking into account the geographical area assigned to each bid. The initial price area specific spot price is obtained at the intersection of price area specific supply and demand curves. The initial price area specific spot prices are then adjusted separately and individually for each price area until the market clearing solution satisfies the physical electricity transmission line system constraints. For example if the export from Sweden to Finland based on system level market clearing would be above the available physical transmission line capacity between Sweden and Finland, the price area spot price of the Swedish area would be decreased and the spot price of the Finnish area would be increased. The committed supply would decrease and the demand increase in Sweden. The adjustment of price is continued until the export from Sweden to Finland has decreased to a level which can be physically committed. The price related to this regional equilibrium market clearing solution is then the price area price. The opposite adjustment process is done for the Finnish price area.

# 4 VISUALISATION METHODS

## 4.1 General

It was concluded that the needs of market analysis service users can be divided roughly to two categories: monitoring of current market situation with respect to certain predefined reference situation and analysis of dynamics of market fundamentals and their effect to the market price.

Before an analyst can say anything about the future development of the market situation the current market situation must be carefully studied. It is very important to know whether the market situation or the situation of a certain factor is relatively close to some longer-term history average level or relatively far away of such ”normal” level. Additionally it is relevant to know whether it is above or below this ”normal” level. Because most of the factors exhibit relatively strong mean-reverting behavior the future development of the factors is easier to forecast when the current situation with respect to the ”normal” level is known.

The history range representing the average or ”normal” conditions should contain at least the years from the market’s lifetime. In practice the commonly used range is from year 1996 till present day. The main reason is that year 1996 was the only very dry year within the lifetime of market environment which is still relatively similar to current environment. Another definition for the history range could be the last few decades for factors that are not dependent on the existence of an electricity market or even electricity, like for example weather. Both of these ranges are useful because the first one helps to identify whether the current situation is extreme in the history horizon of the market lifetime and is the situation of other factors also as extreme as suggested by the corresponding market history data. The second history range helps to forecast the future development of factors; e.g. how likely is it that the development of a factor goes further into extremes.

The recent history and previous year's situation at the same time are also very relevant because some longer-term history average market situation might not represent accurately the behavior of the current market in the average conditions as the development of the market environment has been relatively fast. Historical extreme cases and possible absolute boundaries based on e.g. technical characteristics can help when considering how extreme the current situation is and how likely is it that the development continues even further away from the ”normal” level. The visualization methods used in the monitoring category will help to understand the current market situation with respect to identified relevant and meaningful reference levels.

The main contribution of the analysis category is to quantify the most relevant interrelationships of the factors. The qualitative nature of most interrelationships is commonly known but the magnitudes of these dynamics is usually relatively poorly studied. When the joint dynamics of two or more factors is quantitatively estimated, it is easier to say in a consistent fashion something about the development of a factor when assuming or forecasting something about the development of the correlated factors. For example, forecasts for the development of temperature can be converted to corresponding expected development in consumption when the dependency of consumption on temperature is estimated.

A major problem in the quantitative estimation of the dynamics between factors is that most of the correlations are time dependent. Additionally, development of most factors is connected to the development of several other factors. It is relatively difficult to identify which observations could be considered to represent similar enough market situation that they could be used in the estimation process so that the resulting estimate would be meaningful and useful.

In addition to the three basic factor categories, production, consumption and hydrology, two new relevant categories were added: exchange and prices. The exchange category visualizes the electricity transmission between different geographical areas, price areas, both within Nordic market and between Nordic market and surrounding areas. The prices category visualizes the actual spot market prices. Naturally this price data is used also together within other categories when visualizing the interrelationships between certain factors and prices.

The table 4-1 summarizes the chosen factors and visualization methods.

| | Monitoring | Analysis |
|---|---|---|
| **Production** | Hydro<br>Nuclear<br>Coal<br>Oil<br>Gas<br>Wind<br>CHP | Correlation with price and temperature |
| **Consumption** | Total consumption per area | Correlation with temperature<br>Holiday effects |
| **Hydrology** | Precipitation<br>Inflow<br>Water reservoir level<br>Snow reservoir level<br>Soil water reservoir level | Correlation between inflow and precipitation, soil, snow and temperature<br>Correlation between spot price and water reservoir level, inflow<br>Correlation between hydro production and spot, water reservoir level and inflow |
| **Exchange** | Total net exchange per area<br>Total exchange between certain areas | Correlation between price difference and net exchange between certain areas |

*Table 4-1: The chosen factors and visualization methods.*

## 4.2 Monitoring

### 4.2.1 Production

The category contains pictures per each relevant production form and per price area. The relevant production forms include: hydro, nuclear, coal condensing, oil condensing, gas condensing, combined heat and power (CHP) and wind power. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark.

The first picture type illustrates the development of the factors for a calendar year. The data shown are the current and previous year, average, minimum and maximum. The currently available maximum capacity for nuclear, coal, oil and gas condensing power could be added as future development.

*Note! In order to make this document more readable, all pictures in this chapter can be found in appendix D.There are references to the pictures at appropriate places.*

*Pic4-1: hydro for Norway*

*Pic4-2: nuclear for Sweden*

*Pic4-3: coal condensing for Finland*

The second picture type illustrates the percentage of each production form of the total production of the related price area. The production forms and price areas are as in the first picture type.

*Pic4-4: hydro for Norway*

*Pic4-5: nuclear for Sweden*

*Pic4-6: coal condensing for Finland*

### 4.2.2 Consumption

The category contains pictures for the total consumption per price area. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark.

The first picture type illustrates the development of the factors for a calendar year. The data shown include the current and previous year, average, minimum and maximum.

*Pic4-7: consumption in Norway*

*Pic4-8: consumption in Sweden*

*Pic4-9: consumption in Finland*

Note that the behavior of consumption during mid-summer holiday season is quite different in different countries.

Because the main driver of the consumption is the temperature, the visualization of temperature is included within this category.

The temperature section contains pictures per relevant price area. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The picture illustrates the development of the temperature for a calendar year. The data shown are the current and previous year, average, minimum and maximum.

*Pic4-10: temperature in Sweden*

### 4.2.3 Hydrology

The category contains pictures per each relevant factor affecting the hydrologic situation and per price area. The relevant factors include: precipitation, inflow, water reservoir level, snow reservoir level and soil water level. The relevant price areas include: Norway, Sweden and Norway plus Sweden. The Finnish hydro power has relatively little relevance in the Nordic level because the annual normal hydro power production level in Finland is only some 6,5% of total annual hydro production in the whole Nordic market area [year 2001, source Nordel Annual Report 2001].

The precipitation and inflow picture types illustrate the development of the factors for a calendar year. The data shown are the current and previous year, average, minimum and maximum. The picture includes both density and cumulative curves. The cumulative values can help when considering for example whether most of the spring flood inflow amount has already realized. Another example is that higher than normal cumulative inflow amount together with normal hydro power cumulative production should indicate higher than normal reservoir levels according to reservoir level dynamics.

The water reservoir, snow reservoir and soil water level picture types illustrate the development of the factors for a calendar year. The data shown are the current and previous year, average, minimum and maximum. The water reservoir level picture has two-axis format where the first (vertical) axis represents the level in percentages of max level and second axis the level in equivalent production in energy units.

*Pic4-11: precipitation for Norway+Sweden*

*Pic4-12: inflow for Norway+Sweden*

*Pic4-13: water reservoir level for Norway+Sweden*

*Pic4-14: snow reservoir level for Norway+Sweden*

*Pic4-15: soil water level for Norway+Sweden*

### 4.2.4 Exchange

The category contains pictures per each relevant physical electricity transmission line connecting either two price areas within the Nordic market or some Nordic price area and some surrounding area outside the Nordic market area.

The first picture type visualizes the development of the net exchange (import – export) per each relevant price area for a calendar year. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The data shown are the current and previous year, average, minimum and maximum. The currently available maximum export & import capacity could be added to the pictures as future development. The picture includes both density and cumulative curves. The cumulative values can be used in a similar way than the cumulative inflow curves when considering how the longer-term energy balance between supply and demand should look like.

*Pic4-16: net exchange for Sweden*

The second picture type visualizes the net exchange between relevant price areas. The relevant connections (for weekly statistics) include: Sweden-Finland, Sweden-Norway, Sweden-Germany and Denmark-Germany. The connections Sweden-Poland, Sweden-Denmark, Finland-Russia could also be added as future development. The data shown is equivalent to the first picture type.

*Pic4-17: net exchange for Sweden-Finland*

*Pic4-18: net exchange for Sweden-Norway*

*Pic4-19: net exchange for Sweden-Germany*

### 4.2.5 Prices

The category contains pictures illustrating price development per each relevant price areas within the Nordic market or some surrounding area outside the Nordic market area for a calendar year. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland, Denmark and LPX (Leipzig power exhange) representing prices in (partly) deregulated German markets). The data shown are the current and previous year, average, minimum and maximum.

*Pic4-21: spot price data for System*

## 4.3 Analysis

### 4.3.1 Production

The most relevant factors affecting the production or supply bidding are identified to be temperature, precipitation, inflow, water reservoir level, fuel price and spot price. The temperature affects mainly the combined heat and power (CHP) production used for heating via the temperature dependent demand for heat. The supply bidding behavior of hydro power producers is mainly driven by water reservoir levels, precipitation, inflow and spot price. The hydrology related dynamics is studied in more detail in the hydrology section. The supply bidding behavior of conventional condensing power producers is mainly driven by fuel price and spot price.

The first picture type visualizes the correlation between the temperature and CHP production per each relevant price area for available history with a scatter graph. The relevant price areas include: System level (all areas within Nordic market), Sweden, Finland and Denmark. The recent data points corresponding to current year are indicated with another color from the longer-term history. The picture also shows the estimated linear regression model for production as a function of temperature with detailed model structure, coefficients and the $R^2$ fitness measure ($R^2 = 1 = 100\%$ means perfect fitness).

*Pic4-22: correlation between temperature and CHP production in Finland*

The second picture type visualizes the historical correlation between the fuel prices and (SYS) spot price for each relevant fuel type for available history as a chronological time series. The relevant fuel types include: coal and oil.

*Pic4-23: historical correlation between coal price and sys price*

*Pic4-24: historical correlation between oil price and sys price*

The third picture type visualizes the correlation between the spot price and hydro and conventional condensing power per each relevant price area for available history with a scatter graph. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The format of the picture is otherwise the same as for the first picture.

*Pic4-26: correlation between sys spot price and hydro power production in SYS*

*Pic4-27: correlation between HEL spot price and coal condensing power production in Finland*

### 4.3.2 Consumption

The most relevant factor affecting the (total) consumption or demand is identified to be temperature. The temperature affects mainly the demand for electricity for heating.

The first picture type visualizes the correlation between the temperature and total consumption per each relevant price area for available history with a scatter graph. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The recent data points corresponding to current year are indicated with another color from the longer-term history. The annual special periods like public holidays corresponding to Christmas and mid-summer are indicated with a special color. The picture also shows the estimated linear regression model for consumption as a function of temperature with detailed model structure, coefficients and the $R^2$ fitness measure.

*Pic4-29: correlation between temperature and consumption in Norway*

*Pic4-30: correlation between temperature and consumption in Sweden*

*Pic4-31: correlation between temperature and consumption in Finland*

Note that the mid-summer affects the consumption mainly only in Finland and Sweden.

The representativiness or added value of the fitted regression model is visualized with a picture showing the realized consumption, historical average consumption and the regression model output with average temperature for available history and per each relevant price area with a chronological time series. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The explanatory power of both the regression model and history average curve are shown as percentage of explained variation in the data ($R^2$). The added value of the regression model is approximated by the difference between the explanatory power of regression model and the history average data.

*Pic4-32: consumption in Norway: realised, history average & regression model*

*Pic4-33: consumption in Sweden: realised, history average & regression model*

*Pic4-34: consumption in Finland: realised, history average & regression model*

Note that the added value of the models is relatively modest, in some cases even lower than using directly the average values. This is because the holiday seasons were not taken into account separately. If the holiday seasons are included, the explanatory power of the model is better than the one of the history average model. However the purpose here is to visualize the historical effect of temperature on consumption rather than create a model for accurate prediction..

Finally the (possible) trend in the longer-term development of the consumption is visualized. The trend can not be seen by just calculating the 52-week moving average from the realized consumption because the corresponding temperature levels have been different in different years. One possible way to approximate the ”temperature corrected” trend is to find out what would have been the consumption in some normal (history average) temperature conditions in each year. The trendline can then be derived from this ”temperature corrected” consumption data for example by taking 52-week moving average. The temperature correction amount in consumption is equal to the change in consumption corresponding to the difference between the normal temperature and realized temperature. The estimated regression model coefficient approximates the unit change in consumption corresponding to unit change in temperature. The consumption in normal temperature conditions is then approximated by adjusting the realized consumption by a change in consumption given by the regression model using the temperature difference between normal and realized conditions.

The (possible) longer-term trend in consumption is visualized with a picture showing the realized consumption, history average consumption, temperature corrected consumption and the 52-week moving average consumption for each relevant price area as chronological time series. The relevant price areas include: System level (all areas within Nordic market), Norway, Sweden, Finland and Denmark. The picture includes the estimated slope of the trendline as annual percentage.

*Pic4-35: longer-term trend in consumption in System: realised, history average, temperature corrected & 52-moving average & 2nd axis percentual annual growth*

Note that the estimated trendline shows very modest (non existent) growth in the consumption.

### 4.3.3 Hydrology

The factors affecting the possibilities to produce hydro power are the most important factors driving the market price in the hydro dominated Nordic market. Therefore the analysis of these factors is given a more thorough treatment than others. The most relevant area is Norway plus Sweden together which approximates quite well the total Nordic area.

First the weather related factors are analyzed. The relevant dynamics is how the inflow depends on precipitation, soil water and snow reservoir melting driven by temperature. The analysis is done using 4-week averages (backward-looking) in order to filter out short-term noise. The data analyzed represents the deviation from the given longer-term average or ”normal” level. The snow reservoir data is shown in absolute units and the other data in percentages of normal value by using two-axis format. The dynamics is visualized with a picture containing the data for inflow, precipitation, soil water, snow reservoir and temperature for available history in chronological time series.

*Pic4-36: history correlation between inflow and precipitation, soil water, snow reservoir & temperature, Norway+Sweden*

Note that the recent low levels in soil water are reflected in low levels of inflow although the precipitation has been relatively normal or even higher.

Next the relationship between inflow and spot price is visualized with a picture containing inflow and spot price for available history in chronological time series in two-axis format. The first picture shows the history correlation in absolute values, the second one in deviation from normal level.

*Pic4-37: history correlation between inflow & spot price, Norway + Sweden*

*Pic4-38: history correlation between inflow & spot price (deviation), Norway + Sweden*

Note how the low inflow in year 1996 reflected in a relatively high spot price level. Note also that roughly the same inflow deficit reflected in a much higher spot price level in past 6 months.

Then the relationship between water reservoir level and spot price is visualized with a picture containing water reservoir level and spot price for available history in chronological time series in two-axis format. The first picture shows the history correlation in absolute values, the second one in deviation from normal level.

*Pic4-39: history correlation between water reservoir level & spot price, Norway + Sweden*

*Pic4-40: history correlation between water reservoir level & spot price (deviation), Norway + Sweden*

Note how the low inflow year 1996 is reflected in low reservoir levels also in the first part of year 1997 causing also the spot price to be above normal level. Note also that roughly the same reservoir deficit reflected in a much higher spot price level in past 6 months.

The relationship between inflow and hydro production is visualized with a picture containing inflow and hydro production for available history in chronological time series in two-axis format. The first picture shows the history correlation in absolute values, the second one in deviation from normal level.

*Pic4-41: history correlation between inflow & hydro production, Norway + Sweden*

*Pic4-42: history correlation between inflow & hydro production (deviation), Norway + Sweden*

Note that possibility to store water to some of the reservoirs is reflected in the relatively low correlation between inflow and production in shorter-term horizon However, during the spring flood period, the correlation between inflow and production is relatively strong. This is because the storage capacity does not enable to store the extremely high short-term inflow levels. The alternatives are either to use the inflow immediately in production or spill. Spilling the water means that it can not be used at production so the loss of revenue value can be considered to be equal to water amount in equivalent energy unit multiplied with the prevailing spot price.

The relationship between hydro production and spot price is visualized with a picture containing inflow and hydro production for available history in chronological time series in two-axis format. The first picture shows the history correlation in absolute values, the second one in deviation from normal level.

*Pic4-43: history correlation between hydro production & spot price,  Norway + Sweden*

*Pic4-44: history correlation between hydro production & spot price (deviation), Norway + Sweden*

Note that the strategy for a rational hydro producer is to allocate the production during periods with highest prices within the planning period. However, the restrictions to e.g. water reservoir levels forced producers to deviate from the initial allocation into some extent. The above pictures show what is the net effect on aggregate level.

The relationship between hydro production and water reservoir level is visualized with a picture containing hydro production and water reservoir level for available history in chronological time series in two-axis format. The first picture shows the history correlation in absolute values, the second one in deviation from normal level.

*Pic4-45: history correlation between hydro production & water reservoir level, Norway + Sweden*

*Pic4-46: history correlation between hydro production & water reservoir level (deviation),  Norway + Sweden*

The above pictures show how the restrictions to e.g. water reservoir levels force producers to adjust the hydro production into some extent on aggregate level. Part of the behavior is explained by changes in supply pricing of hydro power based on expectations about future spot price levels compared to prevailing levels as producers try to (re)allocate the production into periods with highest spot price levels.

Finally relatively simple linear regression models for the correlation between the key factors are fitted to history data. The goal is to estimate roughly the leverage of the correlation quantitatively. The result could serve as a rule-of-thumb in the statistical sense, but the validity of the results must be carefully studied before applying them into any specific case. The key correlations considered are: 1) leverage of precipitation, soil water, snow reservoir & temperature on inflow, 2) leverage of infow & water reservoir level on spot price, and 3) leverage of inflow, water reservoir level & spot price on hydro production. The general idea is to explain the realized behavior by adjusting the history average (”normal”) values with the contribution of each leveraging factor. The contribution of a factor is modeled as the product of a coefficient and the deviation of the value of the factor from its ”normal” value. The coefficients are estimated from the history data using the least-squares method.

The explanatory power of both the regression model and history average curve is approximated as percentage of explained variation in the data. The added value of the regression model is approximated by the difference between the explanatory power of regression model and the history average data. The detailed model structure, coefficients and the $R^2$ fitness measure are given in the picture in a table. The effect of snow reservoir and temperature on inflow is taken into account only within ”melting season” of snow reservoir in spring. The ”melting season” includes calendar weeks 13 – 28.

*Pic4-47: leverage of precipitation, soil water, snow reservoir & temperature on inflow, Norway + Sweden*

*Pic4-48: leverage of inflow & water reservoir level on spot price, Norway + Sweden*

*Pic4-49: leverage of inflow, water reservoir level & spot price on hydro production, Norway + Sweden*

Note that the goal is not to fully explain the variation in the history data but to quantify the leverage of each explanatory factor on the factor to be explained. Naturally the fitted coefficients try to explain as well as possible the total variation so they try to explain the contribution of all other factors as well. However, the added value of each model is clearly positive.

### 4.3.4 Exchange

The electricity exchange between areas is analyzed visually with a picture of the correlation between the net sales between price areas and price difference between price areas per each relevant physical electricity transmission connection for available history as a scatter graph.

The relevant transmission connections include: Germany-Sweden, Germany-Denmark, Sweden-Norway, Sweden-Finland.

The corresponding price areas are: LPX-Sweden, LPX-Denmark, Sweden-Norway and Sweden-Finland, respectively.

The recent data points corresponding to current and previous year are both indicated with another color from the longer-term history and each other.

The picture also shows the estimated linear regression model for exchange as a function of price difference of associated price areas with detailed model structure, coefficients and the $R^2$ fitness measure in a table. However, the explanatory power is quite small because more things should be taken into account. The exchange analysis should ideally be done using hourly data, but this was not in the scope of this project. The pictures give an initial idea of how the exchange depends on the price.

*Pic4-50: correlation between net sales between price areas and price difference between price areas – Germany-Sweden*

*Pic4-51: correlation between net sales between price areas and price difference between price areas – Germany-Denmark*

*Pic4-52: correlation between net sales between price areas and price difference between price areas – Sweden-Norway*

*Pic4-53: correlation between net sales between price areas and price difference between price areas – Sweden-Finland*

### 4.3.5 Prices

The more detailed analysis of prices than the monitoring part was set outside the scope of the project in the detailed assignment.

# 5 TECHNICAL IMPLEMENTATION

## 5.1 Excel tool

According to the assignment the tool should be implemented in Excel, so there was not so much to argue about this. We decided to try to keep everything in one Excel-file, in order to keep the updating easier. Because much of the same data was needed in the different analysis and monitoring parts, it also spoke for this solution. The documentation of the tool has been divided into a user's manual and a developer's manual. The user's manual is intended for the ordinary users who update the tool, in reality the operative analysts and it explains the contents of the sheets and the necessary tasks needed to update the tool. The developer's manual is intended for persons who develop the tool further in the future and contains information on how to add new pictures or categories.

The purpose of the Excel tool is to generate the pictures for the web tool. The pictures are divided into two different categories, monitoring pictures and analysis pictures. The Excel tool is divided into sheets with a unique sheet for monitoring and analysis pictures for the following categories: Production, Hydrology, Consumption and Exchange. There is also a sheet for Price monitoring pictures.

## 5.2 User's Manual for the Excel-tool

The tool is basically an excel-file (WeeklyWebAnalysisTool.xls, located in directory W:\Projects\MAWebTool\Excel tool\), which consists of different worksheets. Different things are handled on the different sheets. For example is all input data collected in one sheet, all pictures are in there own sheets and calculations in their own sheets. Since the visualization is divided into a monitoring and an analysis part, the same division has been done in the Excel-tool.

### 5.2.1 The general structure of the tool

The different worksheets and what they contain are explained below:

***Read me***

The read me sheet contains general information about the pictures and formats in the Excel workbook.

***Configuration***

The Configuration sheet contains important information about the pictures and a link to the vba-macro that exports the pictures from the Excel-sheet to the correct directory. The first thing on the Configuration sheet are the cells that tell the sheet what the current year is. This information must be updated at the start of every year.

Cells E4 to E6 should always contain the current year and two previous years. This information is used by all the monitoring pictures on the sheet. Cells F4 to F6 contain the number of the first cell on the Input Data sheet that contains data for the corresponding year. For example, at the beginning of year 2004 the cells should be updated so that cells E4, E5 and E6 contain the numbers 2004, 2003 and 2002 and cells F4, F5 and F6 contain the numbers 475, 423 and 319. Generally the numbers in column F will differ by 52, but some years will have data for 53 weeks and this must be taken into account.

Cell C26 contains the path to which the pictures are exported with the vba-macro.

The button marked “Export Pictures” will run the vba-macro that exports all the necessary pictures from the Excel tool to the directory where they will be available for the web tool. Information on which charts are to be exported and the corresponding filenames can be found in appendix C. **Notice that the pictures in the web tool are not updated automatically, so the pictures should be exported every time new data is added to the Excel tool**.

The information below the “Export Pictures”-button should not be changed during standard updates. More information on this is found in the Developers Manual. If for some reason you only wish to export some of the pictures, you can make the macro skip pictures by writing the letter “x” (without the quotation marks) to the “Missing”-column.

***Input data***

The “Input Data”-sheet is the most important sheet for typical updates. A normal update should consist only of adding new data to the “Input Data”-sheet and activating the “Export Pictures”-macro from the “Configuration”-sheet. The layout of “Input Data”-sheet is by design close to the layout of the “Weekly”-sheet in the Weekly "Statistics of Nordel" file where almost all of the data on this sheet is taken from. Columns A and B contain information on which weeks data is on what row. This data is not used in creating the pictures, the current year and number of the first row containing data from this year must always be updated on the “Configuration”-sheet by hand. **All possible future links to external sources can be handled in this sheet here.**

Row 1 has information on the source of the data in each column. If not specified otherwise all the data is from the “Weekly”-sheet in the Weekly Statistics of Nordel – file. Rows 2 to 5 contain information on what data is in which row. New data is added on the sheet simply by copying and pasting the new data on the correct row. The sheet should automatically calculate all the data marked with “Calculated on this sheet” on row 1, however the formulas for these calculations have only been entered for a limited time period. If these columns are not updating simply copy the formula from the latest updated row and paste as required.

Also included on the sheet are some columns for making the necessary calculations for updating the “Normals”-sheet. The columns start at cell GU104. The columns calculate weekly averages, minimum values and maximum values for a single row for the time period specified. To calculate these values for a row simply change all the pointers to rows to the correct row with the Search and Replace function. If more years need to be calculated, add years with the OFFSET function. See the Excel tool for examples.

***Normals***

The “Normals”-sheet contains data for weekly averages and minimum and maximum values that are used in the pictures as reference levels. Rows 6 to 57 have the weekly averages, 61 to 112 have the weekly minimum values and 116 to 167 have the weekly maximum values. Row 170 has information on what time period has been used in calculating the values. The format for entering the time period is (yy-yy) and the information on row 170 is automatically added to the pictures using the data. Notice that the current year is never used when calculating the values on the “Normals”-sheet. The “Normals”-sheet has to be updated manually every year if the last complete year is to be in the statistics. This is easiest with the cells on the “Input Data”-sheet described earlier.

***Monitoring + category***

There are monitoring sheets for each different category (the categories are as stated earlier production, consumption, hydrology, exchange and prices). Monitoring sheets contain data used for continuous monitoring of different parameters. Monitoring sheets contain data linked to the input sheet and simple calculations if needed. All monitoring sheets should work automatically and need no updating.

***Analysis***

There are also analysis sheets for each category. Analysis sheets contain more complicated calculations such as model results etc. Analysis-pictures can contain the whole history of a parameter. Normally, the analysis pictures are not updated with new information each week, but some analysis sheets need updating from time to time. Here is some sheet specific information:

*Prod Analysis*: The rows for the scatter plot pictures have formulas that are currently pasted until week 36 in the year 2004. If more data is available the formulas should be pasted to more rows as required.

*Consumption Analysis*: As above, some scatter plot data columns need to be extended if necessary. Consumption Analysis also includes simple regression analysis on the effect of temperature on consumption. This is done with the method of smallest sum of squares with Excel’s Solver by minimizing the value of the cell on row 5 two cells right of the cell containing the value of *const* by changing the cells marked Temp, Diff and Const. Temp is the coefficient of the weeks temperature, Diff is the coefficient of the difference of temperature between the week and previous week and Const is the constant term. The equation for the dependence of consumption on temperature is Consumption(i)=Temp*t(i)+Diff*(t(i)-t(i-1))+Const, where Consumption(i) is the consumption of week i in GWh and t(i) is the temperature of week i in degrees Celsius. Notice also that this equation must be updated to the legend of the corresponding picture by hand. Also included in the picture is the value of R square. This is most easily calculated by calculating the correlation of the row marked Prediction with the row marked Consumption and raising this value to the second power. Also as before, the formulas used in these computations must be copied and pasted to additional rows as required.

***Monitoring + category + Pict***

There are "Monitoring pict" sheets for each category. These sheets contain the pictures from the corresponding Monitoring-sheets. Monitoring pictures have an x-axes with 52 weeks and contains data for the current year and the two most previous years. The labels of the time series are linked to the "Input data" and "Normals" sheets. The pictures should update automatically, so the “pict”-sheets need not be visited when making updates.

***Analysis + category + Pict***

There are "Analysis Pict" sheets for each category. These sheets contain the pictures from the corresponding Analysis-sheets. Analysis-pictures can show the whole history of a parameter. Also scatter-plot pictures and model results belong here.

### 5.2.2 Formats that have been harmonized

The same type of data should be represented in the same way everywhere. The labels, colors and types of lines follow the following rules:

- "previous year YY" (green)
- "current year YY" (dark blue)
- "average YY-YY" (thick red)
- "min/max YY-YY" (thin red)
- density vs. cumulative (solid line vs. dashed line)
- Picture background color (light yellow)
- time stamp representation (YYYY_WW)

### 5.2.3 Short guide to using the tool

**How to update the tool with new data**

The tool can be updated with new data by typing it in on the "Input data" sheet. After that the pictures are updated automatically.

**Exporting pictures to the webtool**

When all the necessary data have been updated, the pictures are transferred to the web tool by pressing the button "Export pictures" on the "configuration" sheet.

**Changing the current year**

When year changes to another, all the pictures would naturally have to be updated. This is handled automatically in the tool. All that needs to be done is changing the year information on the "configuration" sheet in cells E4 to F6. See the "Configuration sheet" above for more information.

**Changing a picture**

Any of the pictures in the tool can be changed by the user by just editing the picture. The changes are available in the web tool after the pictures have been exported to it.

## 5.3 Developer's Manual

### 5.3.1 Introduction

This manual contains information needed to do fundamental changes to the Excel tool. Refer to the Users Manual for information on basic updates.

The basic operating principle of the tool is that all the necessary calculations are done in the excel-file. The pictures are previously made and linked to the data-sheets ("input-data" and "Normals"). The pictures are then exported as gif-files to a directory where the web-tool can fetch them. All the names of the pictures and the directory is specified in the "configuration" sheet.

#### 5.3.2 Environment

The tool is optimized to work in Windows XP and 2000. It does not work properly in Windows NT.

#### 5.3.3 Technical solution

This section contains a short explanation of how the calculation logic and the exporting of the pictures works.

**The "Configuration"-sheet**

When adding new pictures to the Excel tool some information about the pictures has to be given to the tool on the "Configuration"-sheet so that the "Export pictures"-macro will correctly locate and export the new pictures. Here's a column by column breakdown of the data required.

***Missing***: if this column contains only the letter "x" the picture detailed on that row will be ignored by the "Export Pictures"-macro. If this column contains the word "END" the macro will stop.

***Main menu***: this column has information on which main menu the picture will be located in the web tool.

***Sub menu (2,3)***: more information about the pictures location in the web tool.

***Sheet***: what sheet the picture in question is located in. Remember that all pictures should be in the sheets ending in "Pict".

***Object Name***: the name of the object on the sheet. These names are given by Excel and as far as we know cannot be changed. The objects are numbered in order of creation with Chart 1 being the first chart created on the sheet. To find out an objects name, record a macro where you choose the object as the active object and edit the macro to find out the objects name. Typically the name of the object should be one larger than the largest number found on that sheet in the "Configuration"-sheet. Remember that if you delete a chart and create a new one the Object Name information for that chart must be changed.

***Picture Name***: the name of the file the object is to be transported to. This must match the information in the web tool.

***Name with Path***: this is automatically generated by concatenating the path-cell with the contents of the Picture Name column.

**The "Input Data"-sheet**

New data can be added freely. When entering new types of data remember to add the source of the data to row 1 to facilitate updating. If you wish to move data on the sheet you should use the cut/paste function (as opposed to copy/paste) so that the pointers pointing to the cells are automatically updated.

**The "Normals"-sheet**

Data for the "Normals"-sheet can be calculated easily with the cells on "Input Data"-sheet. Refer to the Users Manual for more information.

### 5.3.4 How add new pictures

**Adding New Monitoring Pictures**

The recommended way for adding new monitoring pictures is to copy and paste one of the existing blocks used for presenting the necessary values, changing the relevant information and changing all pointers to the correct columns with Find and Replace. Remember that unless a cells value is #N/A Excel will plot the cell in a chart with value 0. All the data should be linked from “Input Data”-sheet or “Normals”-sheet so that the pictures update automatically when new data is entered.

When the data is ready you should add the chart itself to the corresponding Pict-sheet. The format for monitoring charts is saved in the Custom Types -> User Defined section of Chart Wizard, but by far the easiest way of making new charts is doing a copy of an old chart with cut and paste and changing the values as needed. Monitoring pictures should contain the values for three newest years and average, min and max references from the “Normals”-sheet. Also remember to add the necessary data to the “Configuration”-sheet.

**Adding New Analysis Pictures**

The analysis pictures don’t always follow the strict patterns of monitoring pictures. If possible try to use formats similar or preferably identical to ones used before in the Excel tool, but if your new chart is unlike anything before feel free to make your own template. When adding new kinds of analysis pictures, necessary updating information should be added to the Users Manual and preferably also to the analysis sheet in question. As much of the data as possible should be linked to make updating easier. All analysis pictures should go on sheets ending in “Analysis Pict”. Remember to also update the “Configuration”-sheet.

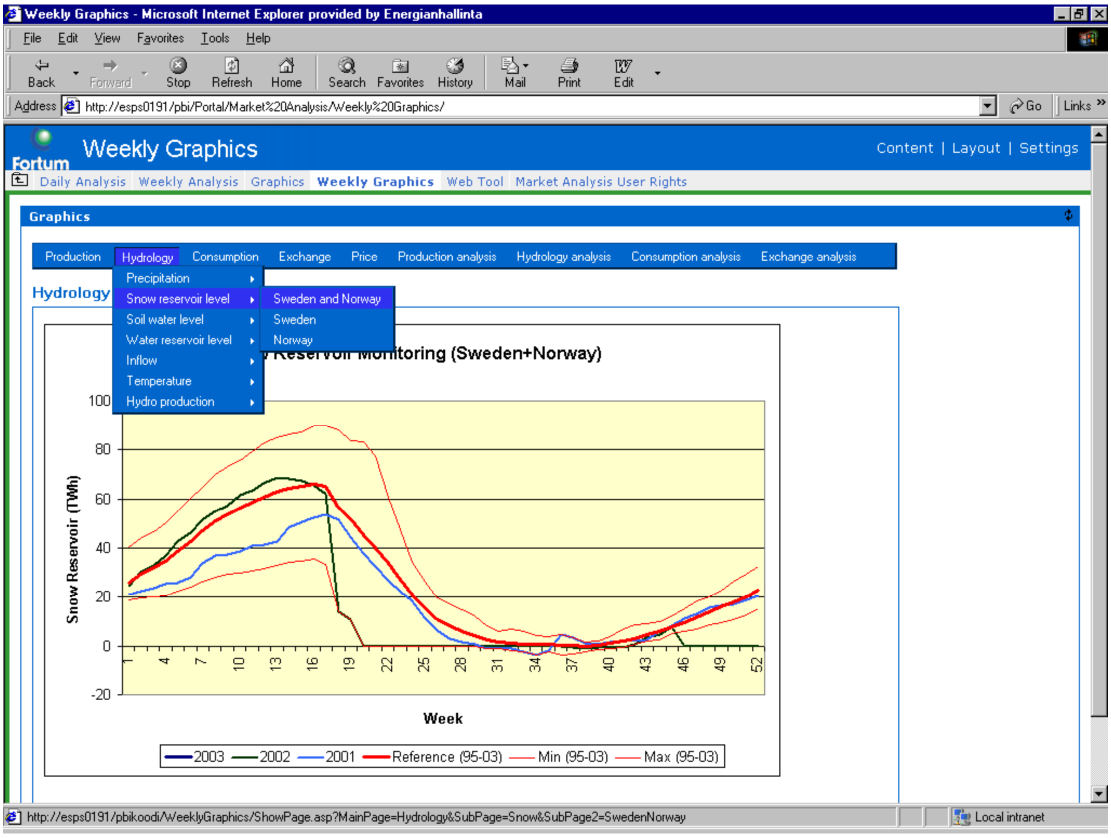
NOTE! A list of the current picture names and their location as well as their place in the web structure can be found in appendix C

## 5.4 Web tool

### 5.4.1 Web tool User’s manual

Since the web tool is very easy and intuitive to use, no actual user's manual is needed. The necessary information can be found below.

The web tool is used via a simple menu structure. The menu opens when the mouse is moved over the bar and the picture can be seen after a click on a selected item, see picture 5.1 for a screenshot of the web-tool.




*Picture 5.1. Web tool screenshot*

The picture in the window can be copied into another document (i.e. MS Word document) by clicking the right button of the mouse and choosing ‘Save target as’. Then one must choose ‘Insert’ -> ‘Picture’ -> ‘From file’ in the MS Word application.

### 5.4.2 Web tool Developer’s manual

Because a Developer's manual already existed for the web tool, we did not need to write a new one. This section only contain important information that is needed to develop the these specific web pages further.

The menu structure and names of the pictures can be seen in the appendix C. The structure was developed in close collaboration with the customer. The idea behind the solution was to divide monitor pictures and analysis pictures in the different submenus. Hence there are nine items in the menu bar, corresponding to the monitoring and analysis parts of the categories described in the previous chapters 3 and 4.

Inside a category the pictures are divided mainly by the method (i.e. nuclear production) or subcategory and the country or area under consideration is selected last. Because of the differences in the classification of the production methods in different countries, the aforementioned idea cannot be fully implemented in the production-monitoring submenu.

The web pages were made using ASP (active server pages) and XML (extensible markup language) standards. The solution consists of two main files named ‘menu.asp’ and ‘PageContent.xml’ (these are not in the appendix because of their size) which are located in the following directory: Pbikoodi/WeeklyGraphics/ on server Esps0191 (under Nestecorp). The pictures are located in two folders (Weekly_Monitoring_Pictures and Weekly_Analysis_Pictures) in the webfolder http://esps0191/pbi/Documents/Market_Analysis/Weekly_Analysis/. The picture names and the folder, in which each is located, can be seen in the appendix C.

The current version of the tool uses only gif-pictures and no tables and textual explanations. It is possible to add such things in the pages. If more detailed technical information on this or other changes in the web pages is needed, the reader is referred to the document 'Market analysis web tool, appendix 3 - Technical document – Stage 1' written by Harri Pöysti.

# 6 PROJECT EVALUATION

## 6.1 Timetable

The timetable of the project was tight but realistic. Looking back, the only thing that caused bigger problems was the implementation of the Excel-tool. As usual when developing IT-systems, a lot of time has to be allocated to error-searching and problems that come up along the way. In our case, the time allocated for this task was heavily underestimated. Also the manual work needed to generate the pictures took longer time than estimated.

Otherwise we managed quite well to carry out several tasks in parallel. The time used for planning the tasks and the timetable was well spent. During the project the timetable was easy to follow-up and we made no changes to it along the way. What also was quite demanding was that all of the project members were unavailable at different times at the end of the project due to vacation and other matters. This required us to think even more carefully about the task allocation when making the initial timetable. We managed to take it into account, but could have emphasized the risk even more and added some slack time at the end.

## 6.2 Risks

At the beginning of the project the following risks were identified.

### 6.2.1 Inappropriateness of chosen analytical methods

If the chosen analytical methods are inadequate to capture the relevant characteristics of market data, the accuracy of the results obtained might be poor and even misleading the decision making.

We tried to minimize the risk by testing each hypothesis with real market data before considering which methods to include in the final solution.

We think that the chosen methods were quite successful, but of course they have to be tested in practice before any final judgement can be made. The customer has taken part of the results and the comments have been taken into account.

### 6.2.2 Missing of project timetable deadlines

If the planned analysis methods or tool functionality would turn out to be inadequate, additional effort must be put to develop adequate methods or tools. The required additional effort might cause delays to the initial project timetable.

We tried to minimize the risk by testing each hypothesis as soon as possible with real market data before considering which methods to include to the final solution.

We managed quite well to keep the project timetable deadlines. As stated earlier the implementation of the Excel-tool was delayed and caused us to re-allocate some tasks between the project members in order to catch up the timetable.

### 6.2.3 Unsustainable implementation

If the chosen methods are implemented in a quick & dirty fashion, the resulting tool might be very difficult to maintain and develop further.

Risk is to be minimized by planning and documenting the tool thoroughly according to proper application development discipline before any actual implementation work is carried out.

The documentation is done, but it is difficult the evaluate the risk at this stage. A user acceptance test has been carried out using real environment.

### 6.2.4 Future expansion and development of tool difficult

If the future expansion and development of the tool functionality is not properly taken into account in the implementation planning phase, the enhancement of the tool might be difficult (although the implemented part could be done in a sustainable fashion).

Risk is to be minimized by including the foreseeable future expansion and development needs into the planning and documenting phase according to proper application development discipline.

This is still a risk to some extent, but it is heavily reduced since the tool is well documented. The basic things, like changing and adding new pictures can be easily done.

### 6.2.5 Complex and inadequate documentation

If the documentation is too complex and/or inadequate, the existing functionality of the tool might not be possible to clarify. Lack of proper documentation could hinder the future development of the tool as well.

Risk is to be minimized by preparing proper documentation including a user's manual and a developer's manual. Use of tool will be tested within the project by future end-users and developers of the tool.

The documentation is adequate and reasonably transparent according to us, but we have not received any feedback from the customer about this.

### 6.2.6 Personnel risks

If crucial parts of the project workload are scheduled for a small set (e.g. one individual) of people, the possible unexpected unavailability of these resources might cause severe problems like delays in project timetable, additional costs etc.

Risk is to be minimized by dividing the workload evenly among project group and preparing proper follow-up documentation of the work done so far throughout the project.

The personnel risk as such was not that big. What would have caused problems was the increased workload on the other project members if someone should have got sick, especially at the end of the project.

Generally, the identified risks were appropriate. What could have been done better was to go through the risks and try to think about them more often. If a risk factor occur at the end of the project, it is difficult to find the time to correct it, especially when so many people in the project group were unavailable at the end of the project.

## 6.3 Results

The initial feedback we have received from the customer has been good. The results of the projects can be taken into operative use. We managed to identify the key-fundamentals and visualize them as well as group them together in an intuitive way. The collection of the data and the manual work done to draw the necessary graphs is in itself something that had to be done. Even if most of the visualization things are intuitively clear we managed to provide some new ideas on how certain things could be visualized. Things that previously have been qualitatively clear are now also quantitatively confirmed.

The Excel-tool is functioning and documented, but it is now up to the customer to link it to the necessary sources and take it into operative use. What made the development of the tool even trickier was the fact that in Excel in Windows NT could not handle the amount of data and pictures that the tool needed. As it worked well in Windows XP and the customer is changing to that operative system before the project deadline, we decided to develop the tool in that environment.

Also the web-tool is working as it should. Since all the pictures are available in the web, more people will have easier access to them which also most probably will decrease the workload of the analysts.

All in all, the assignment can be regarded as completed.

## 6.4 Team work

The teamwork worked well and we managed to keep up with each other by having a meeting once a week. This was good because we got some continuity in our work and could go through what everybody had done since last time. This also decreased the risk of misunderstandings about the tasks. We also went through the next steps and allocated the work according the initial project plan.

In the beginning, the base knowledge of the electricity market was quite different between the project members. We tried to take this into account by going through the fundamentals thoroughly during the first weeks of the project.

We tried to allocate the tasks based on the members skills and their personal timetables. This succeeded quite well, but the implementation of the Excel-tool took more time than estimated, thereby increasing Pasis workload.

We also managed well to carry out different tasks at the same time. When the initial studies on the data and the visualization methods had been done, the development of the Excel-tool, the web-tool and the documentation proceeded quite independently of each other, but coordinated by the project manager.

What could have been done better is to split the work on the Excel-tool more efficiently into parallel tasks, for example by dividing it into one file containing monitoring-pictures and another containing analysis-pictures.

### 6.5 About the course

The course served as a good introduction to project management as well as generally working in projects.

What was positive was that the groups were able to work quite independently and got feedback on the presentations. Because the presentation time was so short it reflects the real world business quite well, where you get limited time to sell your ideas and be convincing.

The course also offered a good opportunity to more business oriented work, at least in this specific project. The request from the customer arose from a real need and it was motivating to know that if we succeeded the results would be used in practice.

The workload compared to the credits received for the course is fair to a little high. Of course it depends very much on the project itself and how you succeed with the planning. In this case at least the project management and the implementation of the Excel-tool took more time than expected. The workload could in this specific project have been slightly reduced by leaving out some parts. Building a tool that has to be in operative use is in itself quite a big task and is better suited for an IT course. All in all, the time spent for this project was quite high compared to the credits received.

# Appendix A

| Actions | Time (weeks) | Deadline date | 5 TQ | 5 TP | 5 PV | 5 VR | 6 TQ | 6 TP | 6 PV | 6 VR | 7 TQ | 7 TP | 7 PV | 7 VR | 8 TQ | 8 TP | 8 PV | 8 VR | 9 TQ | 9 TP | 9 PV | 9 VR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Work hours/week | | | 2 | 2 | 2 | 2 | 17 | 12 | 9 | 9 | 9 | 9 | 7 | 7 | 23 | 23 | 16 | 16 | 19 | 22 | 16 | 16 |
| **1. Preparation of project plan** | **0,6** | | 2 | 2 | 2 | 2 | 6 | 3 | 3 | 3 | | | | | | | | | | | | |
| *Project plan ready* | | **14.helmi** | | | | | | | | | **Deadline** | | | | | | | | | | | |
| **2. Planning of methodological part** | **4,5** | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Clarification of customer needs | 0,3 | | | | | | 4 | 2 | 2 | 2 | | | | | | | | | | | | |
| 2.2 Fundaments to be visualized | 0,3 | | | | | | 3 | 3 | 2 | 2 | | | | | | | | | | | | |
| 2.3 Acquire required data | 0,4 | | | | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| 2.4 Fundament inter-relations to be visualized | 0,9 | | | | | | 4 | 4 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | | |
| 2.5 Indeces and other key-values | 1,5 | | | | | | | | | | 5 | 5 | 3 | 3 | 6 | 10 | 3 | 3 | 5 | 8 | 5 | 5 |
| 2.6 Visualization methods | 1,0 | | | | | | | | | | | | | | 3 | 3 | 3 | 3 | 8 | 8 | 5 | 5 |
| 2.7 Acceptance from customers | 0,2 | | | | | | | | | | | | | | | | | | 2 | 2 | 2 | 2 |
| *Methodological part planned* | | 28.helmi | | | | | | | | | | | | | | | | | Deadline | | | |
| **3. Preparation of intermediate report** | **0,2** | | | | | | | | | | | | | | | | | | | | | |
| *Intermediate report ready* | | **14.maalis** | | | | | | | | | | | | | | | | | | | | |
| **4. Planning of the Excel tool** | **1,0** | | | | | | | | | | | | | | | | | | | | | |
| 4.1 Clarification of customer needs | 0,3 | | | | | | | | | | | | | | 6 | 2 | 2 | 2 | | | | |
| 4.2 Planning of tool functionality and architecture | 0,7 | | | | | | | | | | | | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| *Excel tool planned* | | 21.maalis | | | | | | | | | | | | | | | | | | | | |
| **5. Implementation of the Excel tool** | **1,3** | | | | | | | | | | | | | | | | | | | | | |
| *Excel tool ready* | | 31.maalis | | | | | | | | | | | | | | | | | | | | |
| **6. Planning of the Web pages** | **0,9** | | | | | | | | | | | | | | | | | | | | | |
| 6.1 Clarification of customer needs | 0,3 | | | | | | | | | | | | | | | | | | | | | |
| 6.2 Planning of logical page structure | 0,6 | | | | | | | | | | | | | | | | | | | | | |
| *Web pages planned* | | 10.huhti | | | | | | | | | | | | | | | | | | | | |
| **7. Implementation of the Web pages** | **0,8** | | | | | | | | | | | | | | | | | | | | | |
| *Web pages implemented* | | 20.huhti | | | | | | | | | | | | | | | | | | | | |
| **8. Testing** | **0,7** | | | | | | | | | | | | | | | | | | | | | |
| 8.1 Own test of Excel tool | 0,3 | | | | | | | | | | | | | | | | | | | | | |
| 8.2 Own test of web pages | 0,3 | | | | | | | | | | | | | | | | | | | | | |
| 8.3 User acceptance test | 0,2 | | | | | | | | | | | | | | | | | | | | | |
| *Testing completed* | | 22.huhti | | | | | | | | | | | | | | | | | | | | |
| **9. Preparation of the documentation** | **1,7** | | | | | | | | | | | | | | | | | | | | | |
| 9.1 Chosen fundaments, analysis & visualization methods | 0,8 | | | | | | | | | | | | | | | | | | | | | |
| 9.2 Technical Excel tool implementation (user's & developer's manual) | 0,5 | | | | | | | | | | | | | | | | | | | | | |
| 9.3 Technical Web page tool implementation (user's & developer's manu | 0,4 | | | | | | | | | | | | | | | | | | | | | |
| *Documentation completed* | | 23.huhti | | | | | | | | | | | | | | | | | | | | |
| **10. Preparation of the final report and seminar presentation** | **1,3** | | | | | | | | | | | | | | | | | | | | | |
| *Final report ready* | | **25.huhti** | | | | | | | | | | | | | | | | | | | | |
| *Seminar presentation ready* | | 25.huhti | | | | | | | | | | | | | | | | | | | | |
| **11. Delivery of project result to customer** | | 25.huhti | | | | | | | | | | | | | | | | | | | | |
| **12. Seminar presentation** | | **2.touko** | | | | | | | | | | | | | | | | | | | | |

| Actions | 10 TQ | 10 TP | 10 PV | 10 VR | 11 TQ | 11 TP | 11 PV | 11 VR | 12 TQ | 12 TP | 12 PV | 12 VR | 13 TQ | 13 TP | 13 PV | 13 VR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Work hours/week | 9 | 8 | 7 | 4 | 5 | 9 | 11 | 8 | 5 | 7 | 9 | 8 | 5 | 0 | 18 | 8 |
| **1. Preparation of project plan** | | | | | | | | | | | | | | x | | |
| *Project plan ready* | | | | | | | | | | | | | | x | | |
| **2. Planning of methodological part** | | | | | | | | | | | | | | x | | |
| 2.1 Clarification of customer needs | | | | | | | | | | | | | | x | | |
| 2.2 Fundaments to be visualized | | | | | | | | | | | | | | x | | |
| 2.3 Acquire required data | | | | | | | | | | | | | | x | | |
| 2.4 Fundament inter-relations to be visualized | | | | | | | | | | | | | | x | | |
| 2.5 Indeces and other key-values | | | | | | | | | | | | | | x | | |
| 2.6 Visualization methods | | | | | | | | | | | | | | x | | |
| 2.7 Acceptance from customers | | | | | | | | | | | | | | x | | |
| *Methodological part planned* | | | | | | | | | | | | | | x | | |
| **3. Preparation of intermediate report** | 3 | 2 | 2 | 2 | | | | | | | | | | x | | |
| *Intermediate report ready* | | | | | **Deadline** | | | | | | | | | x | | |
| **4. Planning of the Excel tool** | | | | | | | | | | | | | | x | | |
| 4.1 Clarification of customer needs | | | | | | | | | | | | | | x | | |
| 4.2 Planning of tool functionality and architecture | | | 3 | | | | 1 | | | | 1 | | | x | | |
| *Excel tool planned* | | | | | | | | | Deadline | | | | | x | | |
| **5. Implementation of the Excel tool** | | | | | 3 | 3 | 8 | 3 | 3 | 3 | 8 | 3 | 3 | x | 10 | 3 |
| *Excel tool ready* | | | | | | | | | | | | | | x | | |
| **6. Planning of the Web pages** | | | | | | | | | | | | | | x | | |
| 6.1 Clarification of customer needs | 6 | 2 | 2 | 2 | | | | | | | | | | x | | |
| 6.2 Planning of logical page structure | | | | | 2 | 2 | 2 | 5 | 2 | | | 5 | 2 | x | | 5 |
| *Web pages planned* | | | | | | | | | | | | | | x | | |
| **7. Implementation of the Web pages** | | | | | | | | | | | | | | x | | |
| *Web pages implemented* | | | | | | | | | | | | | | x | | |
| **8. Testing** | | | | | | | | | | | | | | x | | |
| 8.1 Own test of Excel tool | | | | | | | | | | | | | | x | | |
| 8.2 Own test of web pages | | | | | | | | | | | | | | x | | |
| 8.3 User acceptance test | | | | | | | | | | | | | | x | | |
| *Testing completed* | | | | | | | | | | | | | | x | | |
| **9. Preparation of the documentation** | | | | | | | | | | | | | | x | | |
| 9.1 Chosen fundaments, analysis & visualization methods | | 4 | | | | 4 | | | | 4 | | | | x | | |
| 9.2 Technical Excel tool implementation (user's & developer's manual) | | | | | | | | | | | | | | x | 8 | |
| 9.3 Technical Web page tool implementation (user's & developer's manu | | | | | | | | | | | | | | x | | |
| *Documentation completed* | | | | | | | | | | | | | | x | | |
| **10. Preparation of the final report and seminar presentation** | | | | | | | | | | | | | | x | | |
| *Final report ready* | | | | | | | | | | | | | | x | | |
| *Seminar presentation ready* | | | | | | | | | | | | | | x | | |
| **11. Delivery of project result to customer** | | | | | | | | | | | | | | x | | |
| **12. Seminar presentation** | | | | | | | | | | | | | | x | | |

| Actions | 14 TQ | 14 TP | 14 PV | 14 VR | 15 TQ | 15 TP | 15 PV | 15 VR | 16 TQ | 16 TP | 16 PV | 16 VR | 17 TQ | 17 TP | 17 PV | 17 VR | 18 TQ | 18 TP | 18 PV | 18 VR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Work hours/week | 0 | 9 | 0 | 14 | 24 | 11 | 0 | 25 | 34 | 5 | 17 | 0 | 6 | 3 | 8 | 0 | 0 | 0 | 0 | 0 |
| **1. Preparation of project plan** | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Project plan ready* | x | | x | | | | x | | | | | | | | | x | | | | x |
| **2. Planning of methodological part** | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.1 Clarification of customer needs | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.2 Fundaments to be visualized | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.3 Acquire required data | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.4 Fundament inter-relations to be visualized | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.5 Indeces and other key-values | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.6 Visualization methods | x | | x | | | | x | | | | | | | | | x | | | | x |
| 2.7 Acceptance from customers | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Methodological part planned* | x | | x | | | | x | | | | | | | | | x | | | | x |
| **3. Preparation of intermediate report** | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Intermediate report ready* | x | | x | | | | x | | | | | | | | | x | | | | x |
| **4. Planning of the Excel tool** | x | | x | | | | x | | | | | | | | | x | | | | x |
| 4.1 Clarification of customer needs | x | | x | | | | x | | | | | | | | | x | | | | x |
| 4.2 Planning of tool functionality and architecture | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Excel tool planned* | x | | x | | | | x | | | | | | | | | x | | | | x |
| **5. Implementation of the Excel tool** | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Excel tool ready* | Deadline | | | | | | x | | | | | | | | | x | | | | x |
| **6. Planning of the Web pages** | x | | x | | | | x | | | | | | | | | x | | | | x |
| 6.1 Clarification of customer needs | x | | x | | | | x | | | | | | | | | x | | | | x |
| 6.2 Planning of logical page structure | x | | x | | | | x | | | | | | | | | x | | | | x |
| *Web pages planned* | x | | x | | Deadline | | | | | | | | | | | x | | | | x |
| **7. Implementation of the Web pages** | x | | x | 8 | 8 | | x | 8 | 8 | | | | | | | x | | | | x |
| *Web pages implemented* | x | | x | | | | x | | | | | | Deadline | | | | | | | x |
| **8. Testing** | x | | x | | | | x | | | | | | | | | x | | | | x |
| 8.1 Own test of Excel tool | x | | x | | | | x | | 4 | | 7 | | | | | x | | | | x |
| 8.2 Own test of web pages | x | | x | | 3 | | x | 7 | | | | | | | | x | | | | x |
| 8.3 User acceptance test | x | | x | | | | x | | 5 | | 2 | | | | | x | | | | x |
| *Testing completed* | x | | x | | | | x | | | | | | Deadline | | | | | | | x |
| **9. Preparation of the documentation** | x | | x | | | | x | | | | | | | | | x | | | | x |
| 9.1 Chosen fundaments, analysis & visualization methods | x | 6 | x | | 4 | 6 | x | | 4 | | | | | | | x | | | | x |
| 9.2 Technical Excel tool implementation (user's & developer's manual) | x | | x | | | | x | | | | 5 | | | | 5 | x | | | | x |
| 9.3 Technical Web page tool implementation (user's & developer's manu | x | | x | 3 | 3 | | x | 7 | 3 | | | | | | | x | | | | x |
| *Documentation completed* | x | | x | | | | x | | | | | | Deadline | | | | | | | x |
| **10. Preparation of the final report and seminar presentation** | x | 3 | x | 3 | 6 | 5 | x | 3 | 10 | 5 | 3 | | 6 | 3 | 3 | x | | | | x |
| *Final report ready* | x | | x | | | | x | | | | | | **Deadline** | | | | | | | x |
| *Seminar presentation ready* | x | | x | | | | x | | | | | | Deadline | | | | | | | x |
| **11. Delivery of project result to customer** | x | | x | | | | x | | | | | | Deadline | | | | | | | x |
| **12. Seminar presentation** | x | | x | | | | x | | | | | | | | | x | **Deadline** | | | |

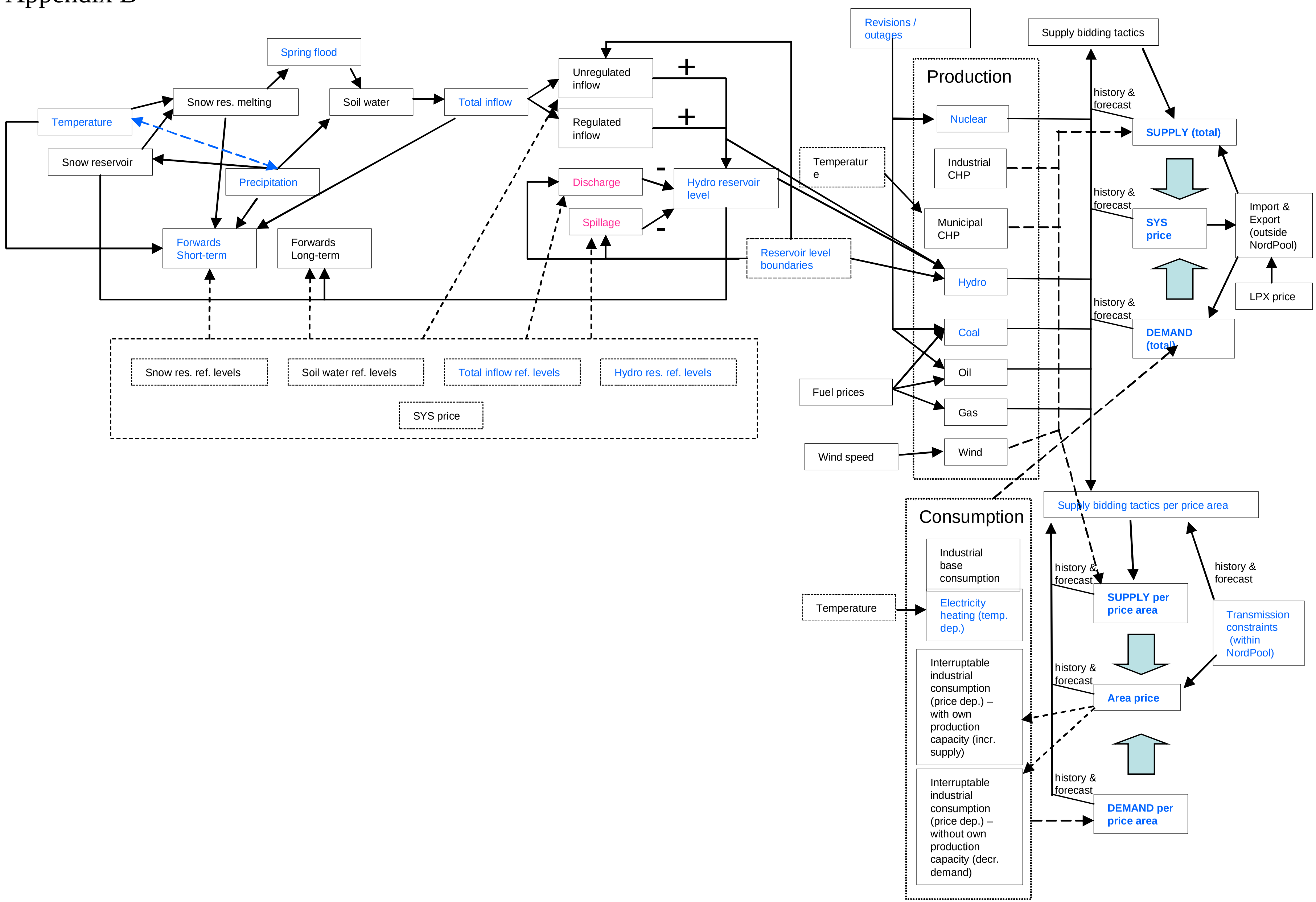
**Total working weeks:** **12,9** weeks
1 week = 40 hours
**Total time/person**

| | |
|---|---|
| Tomas Q | 158 hours |
| Tuomas P | 120 hours |
| Pasi P | 120 hours |
| Vesa R | 117 hours |

**Descriptions**

| | |
|---|---|
| (green) | Task completed |
| (red) | Task not completed |
| **Deadline** | Deadline in the course |
| Deadline | Own deadline |
| x | Person absent |

# Appendix B



Spring flood
Temperature
Snow res. melting
Soil water
Total inflow
Snow reservoir
Precipitation
Forwards Short-term
Forwards Long-term
Unregulated inflow
Regulated inflow
+
+
Discharge
Spillage
-
-
Hydro reservoir level
Reservoir level boundaries
Snow res. ref. levels
Soil water ref. levels
Total inflow ref. levels
Hydro res. ref. levels
SYS price
Revisions / outages
Temperature
Fuel prices
Wind speed
Production
Nuclear
Industrial CHP
Municipal CHP
Hydro
Coal
Oil
Gas
Wind
Supply bidding tactics
history & forecast
SUPPLY (total)
history & forecast
SYS price
history & forecast
DEMAND (total)
Import & Export (outside NordPool)
LPX price
Consumption
Industrial base consumption
Electricity heating (temp. dep.)
Temperature
Interruptable industrial consumption (price dep.) – with own production capacity (incr. supply)
Interruptable industrial consumption (price dep.) – without own production capacity (decr. demand)
Supply bidding tactics per price area
history & forecast
SUPPLY per price area
history & forecast
Area price
history & forecast
DEMAND per price area
history & forecast
Transmission constraints (within NordPool)

# Appendix C

| Main menu: | Sub menu: | Sub menu 2: | Sub menu 3: | Picture name: |
|---|---|---|---|---|
| Production | Hydro | GWh in Nord Pool area | | Weekly_Monitoring_Pictures\hydro_gwh_nordpool.gif |
| Production | Hydro | GWh in Sweden | | Weekly_Monitoring_Pictures\hydro_gwh_sweden.gif |
| Production | Hydro | GWh in Norway | | Weekly_Monitoring_Pictures\hydro_gwh_norway.gif |
| Production | Hydro | GWh in Finland | | Weekly_Monitoring_Pictures\hydro_gwh_finland.gif |
| Production | Hydro | % in Nord Pool area | | Weekly_Monitoring_Pictures\hydro_pc_nordpool.gif |
| Production | Hydro | % in Sweden | | Weekly_Monitoring_Pictures\hydro_pc_sweden.gif |
| Production | Hydro | % in Norway | | Weekly_Monitoring_Pictures\hydro_pc_norway.gif |
| Production | Hydro | % in Finland | | Weekly_Monitoring_Pictures\hydro_pc_finland.gif |
| Production | Wind | GWh in Nord Pool area | | Weekly_Monitoring_Pictures\wind_gwh_nordpool.gif |
| Production | Wind | GWh in Sweden | | Weekly_Monitoring_Pictures\wind_gwh_sweden.gif |
| Production | Wind | GWh in Denmark | | Weekly_Monitoring_Pictures\wind_gwh_denmark.gif |
| Production | Wind | % in Nord Pool area | | Weekly_Monitoring_Pictures\wind_pc_nordpool.gif |
| Production | Wind | % in Sweden | | Weekly_Monitoring_Pictures\wind_pc_sweden.gif |
| Production | Wind | % in Denmark | | Weekly_Monitoring_Pictures\wind_pc_denmark.gif |
| Production | Nuclear | GWh in Nord Pool area | | Weekly_Monitoring_Pictures\nuclear_gwh_nordpool.gif |
| Production | Nuclear | GWh in Sweden | | Weekly_Monitoring_Pictures\nuclear_gwh_sweden.gif |
| Production | Nuclear | GWh in Finland | | Weekly_Monitoring_Pictures\nuclear_gwh_finland.gif |
| Production | Nuclear | % in Nord Pool area | | Weekly_Monitoring_Pictures\nuclear_pc_nordpool.gif |
| Production | Nuclear | % in Sweden | | Weekly_Monitoring_Pictures\nuclear_pc_sweden.gif |
| Production | Nuclear | % in Finland | | Weekly_Monitoring_Pictures\nuclear_pc_finland.gif |
| Production | Thermal | Total (GWh) in Nord Pool area | | Weekly_Monitoring_Pictures\thermal_gwh_nordpool.gif |
| Production | Thermal | Total % in Nord Pool area | | Weekly_Monitoring_Pictures\thermal_pc_nordpool.gif |
| Production | Thermal | Sweden | Total (GWh) | Weekly_Monitoring_Pictures\thermal_gwh_sweden.gif |
| Production | Thermal | Sweden | Industrial CHP (GWh) | Weekly_Monitoring_Pictures\ichp_gwh_sweden.gif |
| Production | Thermal | Sweden | Municipal CHP (GWh) | Weekly_Monitoring_Pictures\mchp_gwh_sweden.gif |
| Production | Thermal | Sweden | Condensing (GWh) | Weekly_Monitoring_Pictures\condense_gwh_sweden.gif |
| Production | Thermal | Sweden | Gas turbines (GWh) | Weekly_Monitoring_Pictures\gas_gwh_sweden.gif |
| Production | Thermal | Sweden | Industrial CHP % in Sweden | Weekly_Monitoring_Pictures\ichp_pc_sweden.gif |
| Production | Thermal | Sweden | Municipal CHP % in Sweden | Weekly_Monitoring_Pictures\mchp_pc_sweden.gif |
| Production | Thermal | Sweden | Condensing % in Sweden | Weekly_Monitoring_Pictures\condense_pc_sweden.gif |
| Production | Thermal | Sweden | Gas turbines % in Sweden | Weekly_Monitoring_Pictures\gas_pc_sweden.gif |

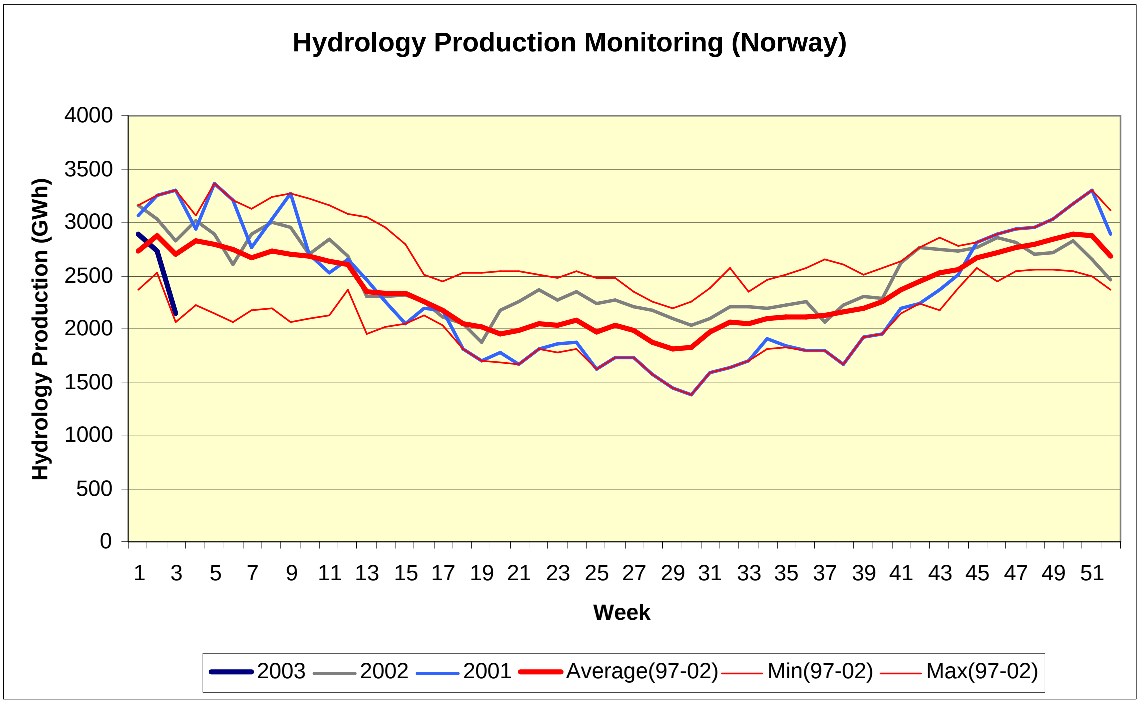
| | | | | |
|---|---|---|---|---|
| Production | Thermal | Norway | Total (GWh) | Weekly_Monitoring_Pictures\thermal_gwh_norway.gif |
| Production | Thermal | Finland | Total (GWh) | Weekly_Monitoring_Pictures\thermal_gwh_finland.gif |
| Production | Thermal | Finland | Industrial CHP (GWh) | Weekly_Monitoring_Pictures\ichp_gwh_finland.gif |
| Production | Thermal | Finland | Municipal CHP (GWh) | Weekly_Monitoring_Pictures\mchp_gwh_finland.gif |
| Production | Thermal | Finland | Condensing (GWh) | Weekly_Monitoring_Pictures\condense_gwh_finland.gif |
| Production | Thermal | Finland | Gas turbines (GWh) | Weekly_Monitoring_Pictures\gas_gwh_finland.gif |
| Production | Thermal | Finland | Industrial CHP % in Finland | Weekly_Monitoring_Pictures\ichp_pc_finland.gif |
| Production | Thermal | Finland | Municipal CHP % in Finland | Weekly_Monitoring_Pictures\mchp_pc_finland.gif |
| Production | Thermal | Finland | Condensing % in Finland | Weekly_Monitoring_Pictures\condense_pc_finland.gif |
| Production | Thermal | Finland | Gas turbines % in Finland | Weekly_Monitoring_Pictures\gas_pc_finland.gif |
| Production | Thermal | Denmark | Total (GWh) | Weekly_Monitoring_Pictures\thermal_gwh_denmark.gif |
| Production | Thermal | Denmark | Central (GWh) | Weekly_Monitoring_Pictures\central_gwf_denmark.gif |
| Production | Thermal | Denmark | Central (GWh) in Eltra | Weekly_Monitoring_Pictures\central_gwh_eltra.gif |
| Production | Thermal | Denmark | Central (GWh) in Elkraft | Weekly_Monitoring_Pictures\central_gwh_elkraft.gif |
| Production | Thermal | Denmark | Central % in Denmark | Weekly_Monitoring_Pictures\central_pc_denmark.gif |
| Production | Thermal | Denmark | Decentral (GWh) | Weekly_Monitoring_Pictures\decentral_gwh_denmark.gif |
| Production | Thermal | Denmark | Decentral GWh in Eltra | Weekly_Monitoring_Pictures\decentral_gwh_eltra.gif |
| Production | Thermal | Denmark | Decentral GWh in Elkraft | Weekly_Monitoring_Pictures\decentral_gwh_elkraft.gif |
| Production | Thermal | Denmark | Decentral % in Denmark | Weekly_Monitoring_Pictures\decentral_pc_denmark.gif |
| Production | Thermal | Sweden and Finland | Industrial CHP (GWh) | Weekly_Monitoring_Pictures\ichp_gwh_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | Municipal CHP (GWh) | Weekly_Monitoring_Pictures\mchp_gwh_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | Condensing (GWh) | Weekly_Monitoring_Pictures\condense_gwh_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | Gas turbines (GWh) | Weekly_Monitoring_Pictures\gas_gwh_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | ICHP % in Sweden and Finland | Weekly_Monitoring_Pictures\ichp_pc_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | MCHP % in Sweden and Finland | Weekly_Monitoring_Pictures\mchp_pc_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | Cond % in Sweden and Finland | Weekly_Monitoring_Pictures\condense_pc_swedenfinland.gif |
| Production | Thermal | Sweden and Finland | Gas % in Sweden and Finland | Weekly_Monitoring_Pictures\gas_pc_swedenfinland.gif |
| Hydrology | Precipitation | Sweden and Norway | | Weekly_Monitoring_Pictures\precipitation_swedennorway.gif |
| Hydrology | Precipitation | Sweden | | Weekly_Monitoring_Pictures\precipitation_sweden.gif |
| Hydrology | Precipitation | Norway | | Weekly_Monitoring_Pictures\precipitation_norway.gif |
| Hydrology | Snow reservoir level | Sweden and Norway | | Weekly_Monitoring_Pictures\snow_swedennorway.gif |
| Hydrology | Snow reservoir level | Sweden | | Weekly_Monitoring_Pictures\snow_sweden.gif |
| Hydrology | Snow reservoir level | Norway | | Weekly_Monitoring_Pictures\snow_norway.gif |
| Hydrology | Soil water level | Sweden and Norway | | Weekly_Monitoring_Pictures\soil_swedennorway.gif |

| | | | |
|---|---|---|---|
| Hydrology | Soil water level | Sweden | Weekly_Monitoring_Pictures\soil_sweden.gif |
| Hydrology | Soil water level | Norway | Weekly_Monitoring_Pictures\soil_norway.gif |
| Hydrology | Water reservoir level | Sweden and Norway | Weekly_Monitoring_Pictures\water_swedennorway.gif |
| Hydrology | Water reservoir level | Sweden | Weekly_Monitoring_Pictures\water_sweden.gif |
| Hydrology | Water reservoir level | Norway | Weekly_Monitoring_Pictures\water_norway.gif |
| Hydrology | Inflow | Sweden and Norway | Weekly_Monitoring_Pictures\inflow_swedennorway.gif |
| Hydrology | Inflow | Sweden | Weekly_Monitoring_Pictures\inflow_sweden.gif |
| Hydrology | Inflow | Norway | Weekly_Monitoring_Pictures\inflow_norway.gif |
| Consumption | Nord Pool area | | Weekly_Monitoring_Pictures\consumption_nordpool.gif |
| Consumption | Sweden | | Weekly_Monitoring_Pictures\consumption_sweden.gif |
| Consumption | Norway | | Weekly_Monitoring_Pictures\consumption_norway.gif |
| Consumption | Finland | | Weekly_Monitoring_Pictures\consumption_finland.gif |
| Consumption | Denmark | | Weekly_Monitoring_Pictures\consumption_denmark.gif |
| Consumption | Temperature | Nord Pool area | Weekly_Monitoring_Pictures\temperature_nordpool.gif |
| Consumption | Temperature | Sweden | Weekly_Monitoring_Pictures\temperature_sweden.gif |
| Consumption | Temperature | Norway | Weekly_Monitoring_Pictures\temperature_norway.gif |
| Consumption | Temperature | Finland | Weekly_Monitoring_Pictures\temperature_finland.gif |
| Consumption | Temperature | Denmark | Weekly_Monitoring_Pictures\temperature_denmark.gif |
| Exchange | Net exchange of an area | Nord Pool area | Weekly_Monitoring_Pictures\exchange_nordpool.gif |
| Exchange | Net exchange of an area | Sweden | Weekly_Monitoring_Pictures\exchange_sweden.gif |
| Exchange | Net exchange of an area | Norway | Weekly_Monitoring_Pictures\exchange_norway.gif |
| Exchange | Net exchange of an area | Finland | Weekly_Monitoring_Pictures\exchange_finland.gif |
| Exchange | Net exchange of an area | Denmark | Weekly_Monitoring_Pictures\exchange_denmark.gif |
| Exchange | Net exchange between areas | Germany - Sweden | Weekly_Monitoring_Pictures\exchange_germanysweden.gif |
| Exchange | Net exchange between areas | Germany - Denmark | Weekly_Monitoring_Pictures\exchange_germanydenmark.gif |
| Exchange | Net exchange between areas | Sweden - Norway | Weekly_Monitoring_Pictures\exchange_swedennorway.gif |
| Exchange | Net exchange between areas | Sweden - Finland | Weekly_Monitoring_Pictures\exchange_swedenfinland.gif |
| Price | Spot price | System | Weekly_Monitoring_Pictures\price_system.gif |
| Price | Spot price | Stockholm | Weekly_Monitoring_Pictures\price_stockholm.gif |
| Price | Spot price | Oslo | Weekly_Monitoring_Pictures\price_oslo.gif |
| Price | Spot price | Helsinki | Weekly_Monitoring_Pictures\price_helsinki.gif |
| Price | Spot price | Odense | Weekly_Monitoring_Pictures\price_odense.gif |
| Price | Spot price | Copenhagen | Weekly_Monitoring_Pictures\price_copenhagen.gif |
| Price | Fuel price | Oil | Weekly_Monitoring_Pictures\price_oil.gif |

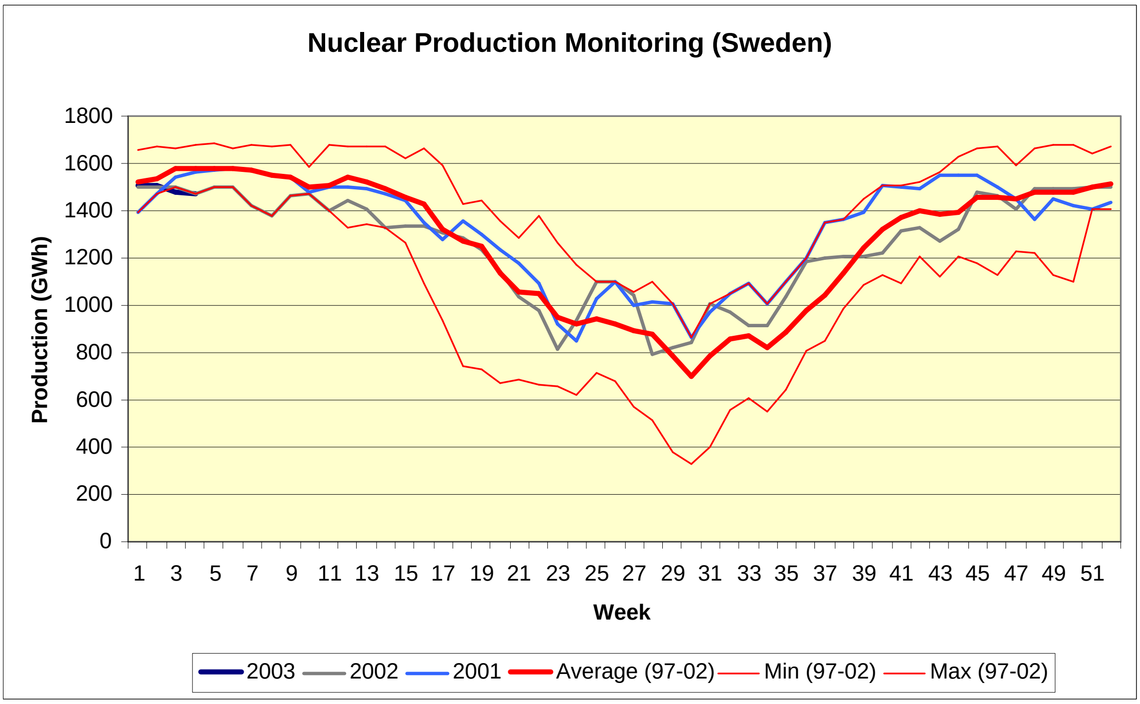
| | | | |
|---|---|---|---|
| Price | Fuel price | Coal | Weekly_Monitoring_Pictures\price_coal.gif |
| Production analysis | System price and fuel price | Oil | Weekly_Analysis_Pictures\price_oilprice_system.gif |
| Production analysis | System price and fuel price | Coal | Weekly_Analysis_Pictures\price_coalprice_system.gif |
| Production analysis | MCHP production vs temperature | Sweden and Finland | Weekly_Analysis_Pictures\mchp_vs_temperature_swedenfinland.gif |
| Production analysis | MCHP production vs temperature | Sweden | Weekly_Analysis_Pictures\mchp_vs_temperature_sweden.gif |
| Production analysis | MCHP production vs temperature | Finland | Weekly_Analysis_Pictures\mchp_vs_temperature_finland.gif |
| Production analysis | Hydro production vs price | Nord Pool, System spot | Weekly_Analysis_Pictures\nordpoolhydro_vs_systemprice.gif |
| Production analysis | Hydro production vs price | Sweden, Stockholm | Weekly_Analysis_Pictures\swedenhydro_vs_stockholmprice.gif |
| Production analysis | Hydro production vs price | Norway, Oslo | Weekly_Analysis_Pictures\norwayhydro_vs_osloprice.gif |
| Production analysis | Hydro production vs price | Finland, Helsinki | Weekly_Analysis_Pictures\finlandhydro_vs_helsinkiprice.gif |
| Production analysis | Conv. cond. production vs price | Sweden, Stockholm | Weekly_Analysis_Pictures\swedencondense_vs_stockholmprice.gif |
| Production analysis | Conv. cond. production vs price | Finland, Helsinki | Weekly_Analysis_Pictures\finlandcondense_vs_helsinkiprice.gif |
| Production analysis | Gas production vs price | Sweden, Stockholm | Weekly_Analysis_Pictures\swedengas_vs_stockholmprice.gif |
| Production analysis | Gas production vs price | Finland, Helsinki | Weekly_Analysis_Pictures\finlandgas_vs_helsinkiprice.gif |
| Production analysis | Danish thermal production | Central production vs temperature | Weekly_Analysis_Pictures\denmarkcentral_vs_temperature.gif |
| Production analysis | Danish thermal production | Decentral production vs temperature | Weekly_Analysis_Pictures\denmarkdecentral_vs_temperature.gif |
| Production analysis | Danish thermal production | Central prod. in Eltra vs Odense price | Weekly_Analysis_Pictures\eltracentral_vs_odenseprice.gif |
| Production analysis | Danish thermal production | Decentral prod. in Eltra vs Odense price | Weekly_Analysis_Pictures\eltradecentral_vs_odenseprice.gif |
| Production analysis | Danish thermal production | Central prod. in Elkraft vs Copenh. price | Weekly_Analysis_Pictures\elkraftcentral_vs_copenhagenprice.gif |
| Production analysis | Danish thermal production | Decentral prod. in Elkraft vs Copenh. price | Weekly_Analysis_Pictures\elkraftdecentral_vs_copenhagenprice.gif |
| Hydrology analysis | Historical correlation | Prec, snow, soil, temp and inflow | Weekly_Analysis_Pictures\ precipitation_snow_soil_temperature_inflow_swedennorway.gif |
| Hydrology analysis | Historical correlation | Spot price and inflow | Weekly_Analysis_Pictures\price_inflow_swedennorway.gif |
| Hydrology analysis | Historical correlation | Spot price and water reservoir | Weekly_Analysis_Pictures\price_waterreservoir_swedennorway.gif |
| Hydrology analysis | Historical correlation | Hydro production and water reservoir | Weekly_Analysis_Pictures\hydro_waterreservoir_swedennorway.gif |
| Hydrology analysis | Historical correlation | Hydro production and inflow | Weekly_Analysis_Pictures\hydro_inflow_swedennorway.gif |
| Hydrology analysis | Historical correlation | Hydro production and spot price | Weekly_Analysis_Pictures\hydro_price_swedennorway.gif |
| Hydrology analysis | Analysing effects | Prec, snow, soil and temp on inflow | Weekly_Analysis_Pictures\ inflow_regression_precipitation_snow_soil_temperature_swedennorway.gif |
| Hydrology analysis | Analysing effects | Inflow and water reservoir on spot price | Weekly_Analysis_Pictures\ price_regression_inflow_waterreservoir_swedennorway.gif |
| Hydrology analysis | Analysing effects | Price, inflow and water on hydro production | Weekly_Analysis_Pictures\ hydro_regression_inflow_waterreservoir_price_swedennorway.gif |
| Consumption analysis | Consumption vs temperature | Nord Pool | Weekly_Analysis_Pictures\consumption_vs_temperature_nordpool.gif |

| | | | |
|---|---|---|---|
| Consumption analysis | Consumption vs temperature | Sweden | Weekly_Analysis_Pictures\consumption_vs_temperature_sweden.gif |
| Consumption analysis | Consumption vs temperature | Norway | Weekly_Analysis_Pictures\consumption_vs_temperature_norway.gif |
| Consumption analysis | Consumption vs temperature | Finland | Weekly_Analysis_Pictures\consumption_vs_temperature_finland.gif |
| Consumption analysis | Consumption vs temperature | Denmark | Weekly_Analysis_Pictures\consumption_vs_temperature_denmark.gif |
| Consumption analysis | Effect of temperature on cons. | Nord Pool | Weekly_Analysis_Pictures\consumption_regression_temperature_nordpool.gif |
| Consumption analysis | Effect of temperature on cons. | Sweden | Weekly_Analysis_Pictures\consumption_regression_temperature_sweden.gif |
| Consumption analysis | Effect of temperature on cons. | Norway | Weekly_Analysis_Pictures\consumption_regression_temperature_norway.gif |
| Consumption analysis | Effect of temperature on cons. | Finland | Weekly_Analysis_Pictures\consumption_regression_temperature_finland.gif |
| Consumption analysis | Effect of temperature on cons. | Denmark | Weekly_Analysis_Pictures\consumption_regression_temperature_denmark.gif |
| Consumption analysis | Trend | Nord Pool | Weekly_Analysis_Pictures\consumption_trend_nordpool.gif |
| Consumption analysis | Trend | Sweden | Weekly_Analysis_Pictures\consumption_trend_sweden.gif |
| Consumption analysis | Trend | Norway | Weekly_Analysis_Pictures\consumption_trend_norway.gif |
| Consumption analysis | Trend | Finland | Weekly_Analysis_Pictures\consumption_trend_finland.gif |
| Consumption analysis | Trend | Denmark | Weekly_Analysis_Pictures\consumption_trend_denmark.gif |
| Exchange analysis | Exchange vs price difference | Germany - Sweden | Weekly_Analysis_Pictures\exchange_vs_pricedifference_germanysweden.gif |
| Exchange analysis | Exchange vs price difference | Germany - Denmark | Weekly_Analysis_Pictures\exchange_vs_pricedifference_germanydenmark.gif |
| Exchange analysis | Exchange vs price difference | Sweden - Norway | Weekly_Analysis_Pictures\exchange_vs_pricedifference_swedennorway.gif |
| Exchange analysis | Exchange vs price difference | Sweden - Finland | Weekly_Analysis_Pictures\exchange_vs_pricedifference_swedenfinland.gif |

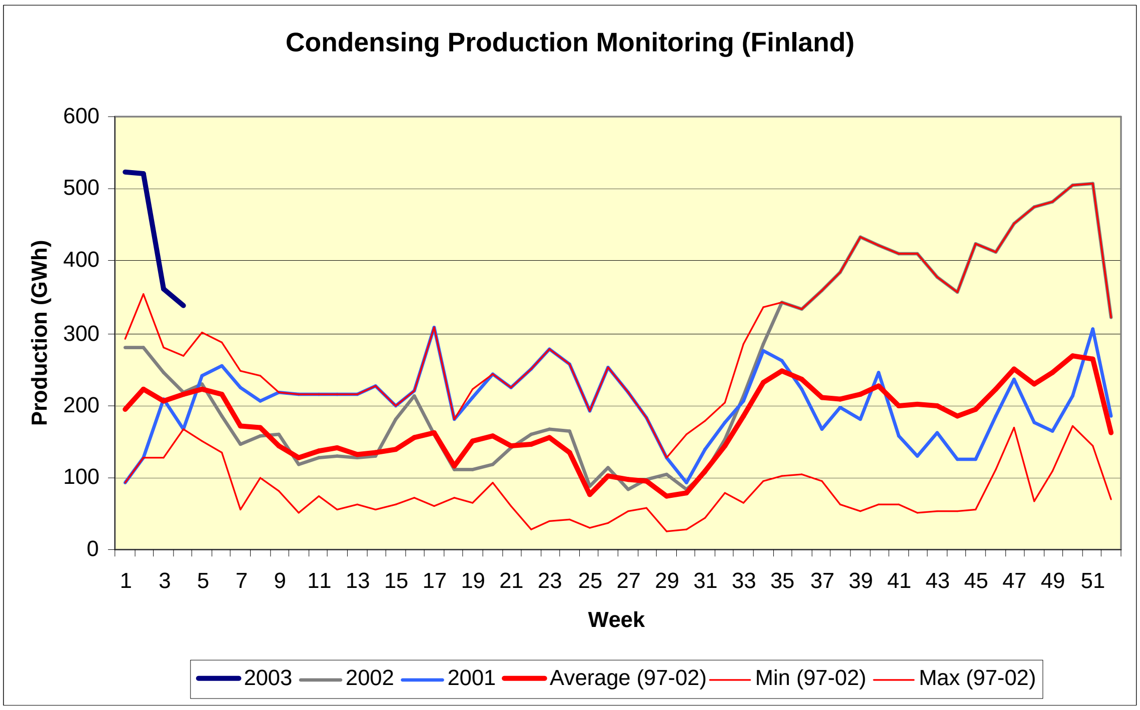
Appendix D. Picture Gallery



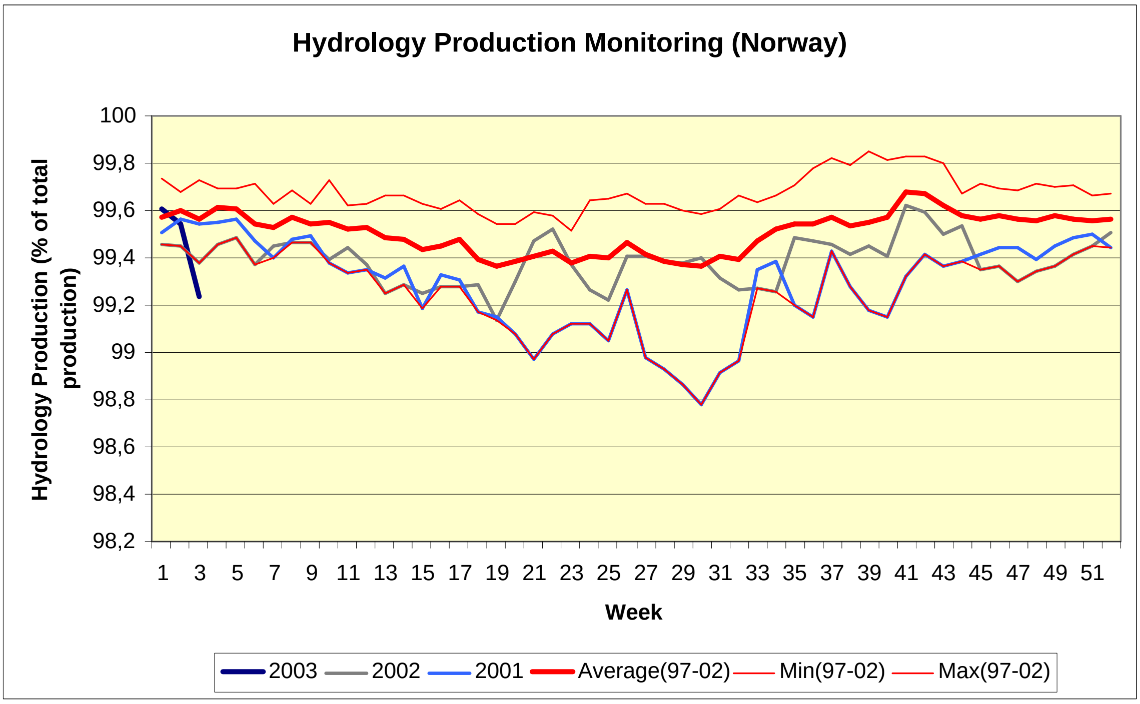

*Pic4-1: hydro for Norway*



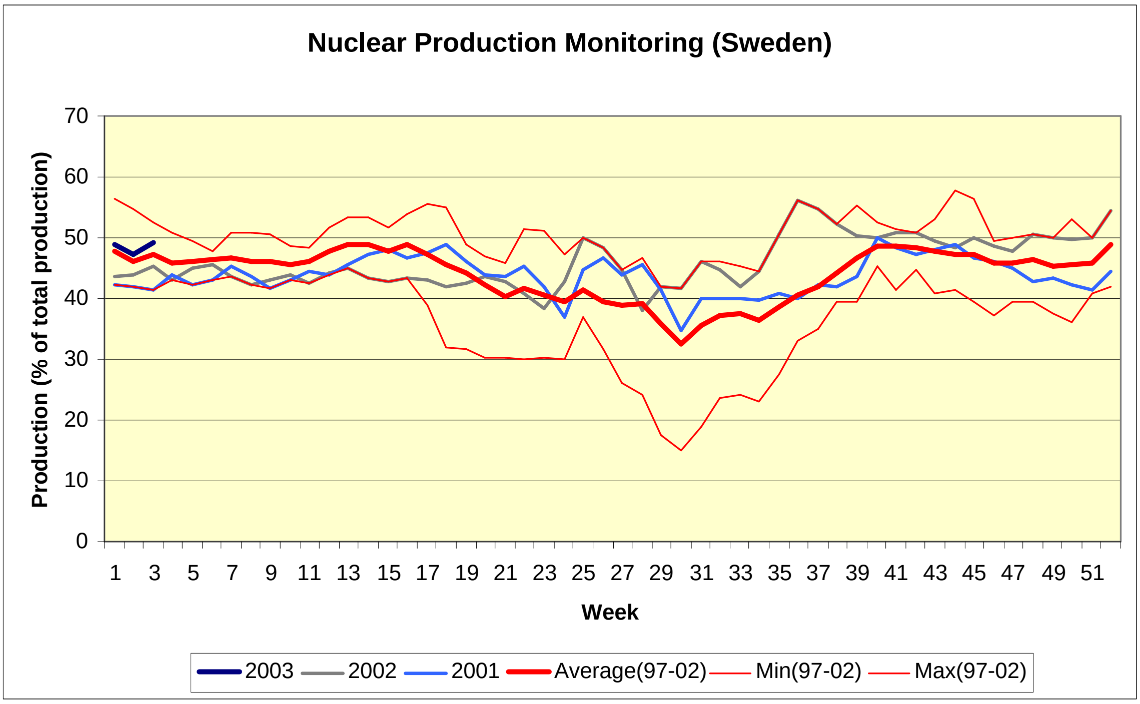

*Pic4-2: nuclear for Sweden*



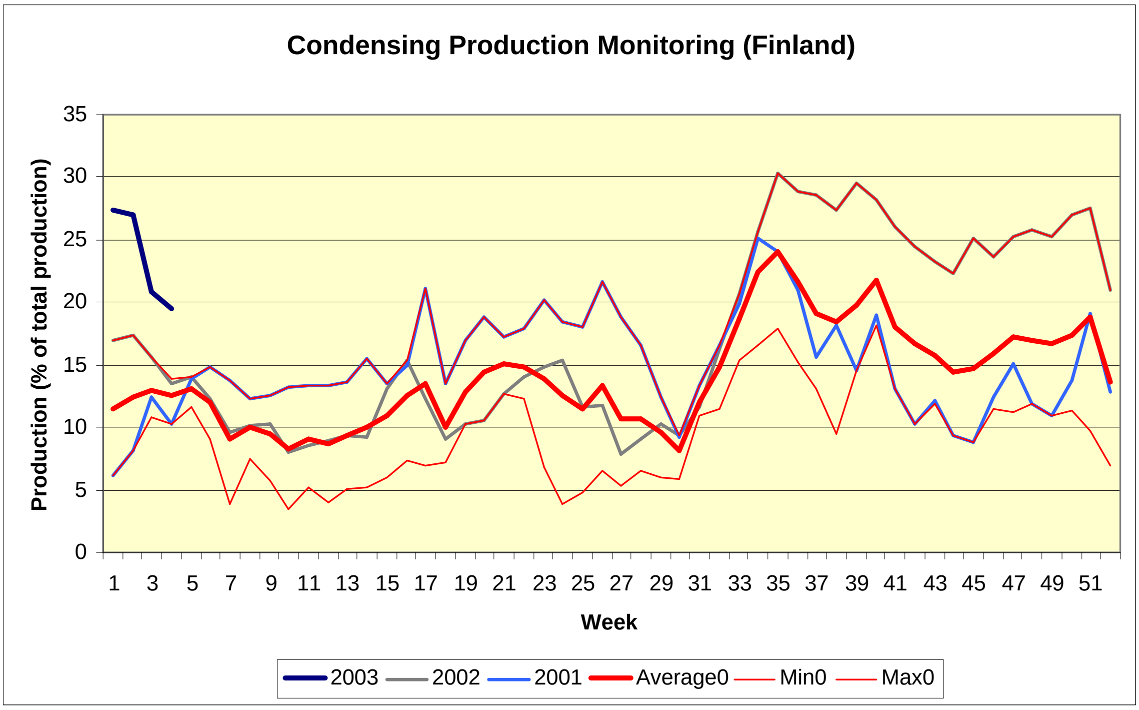

*Pic4-3: coal condensing for Finland*



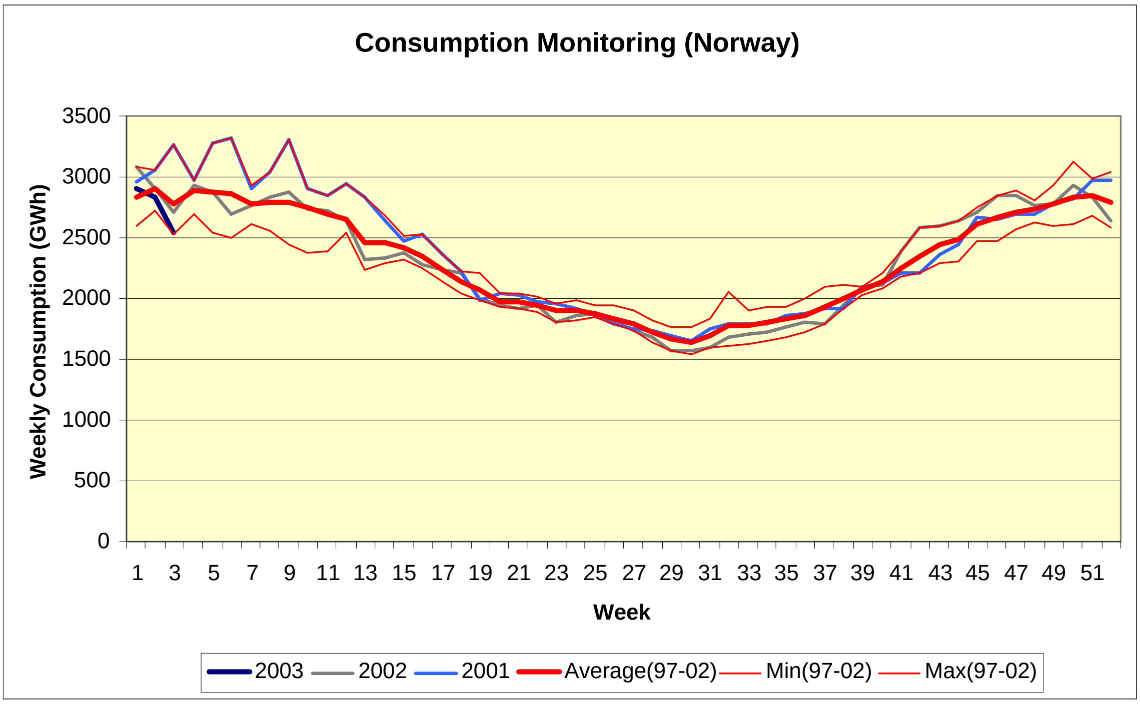

*Pic4-4: hydro for Norway*



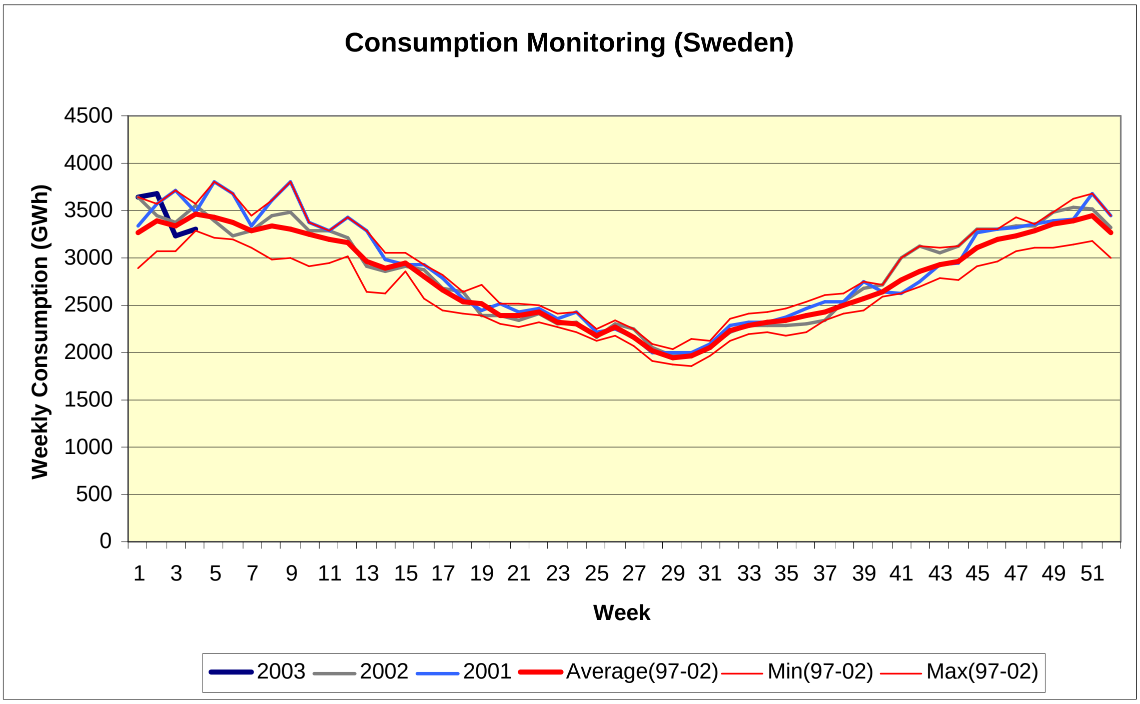

*Pic4-5: nuclear for Sweden*



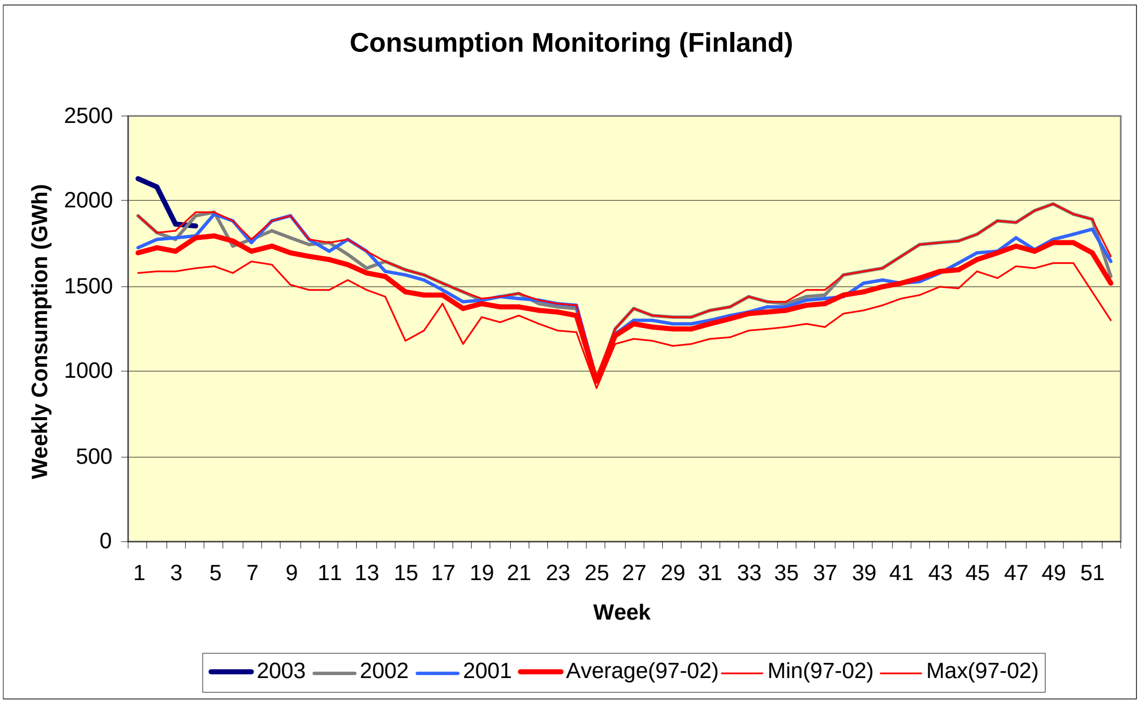

*Pic4-6: coal condensing for Finland*



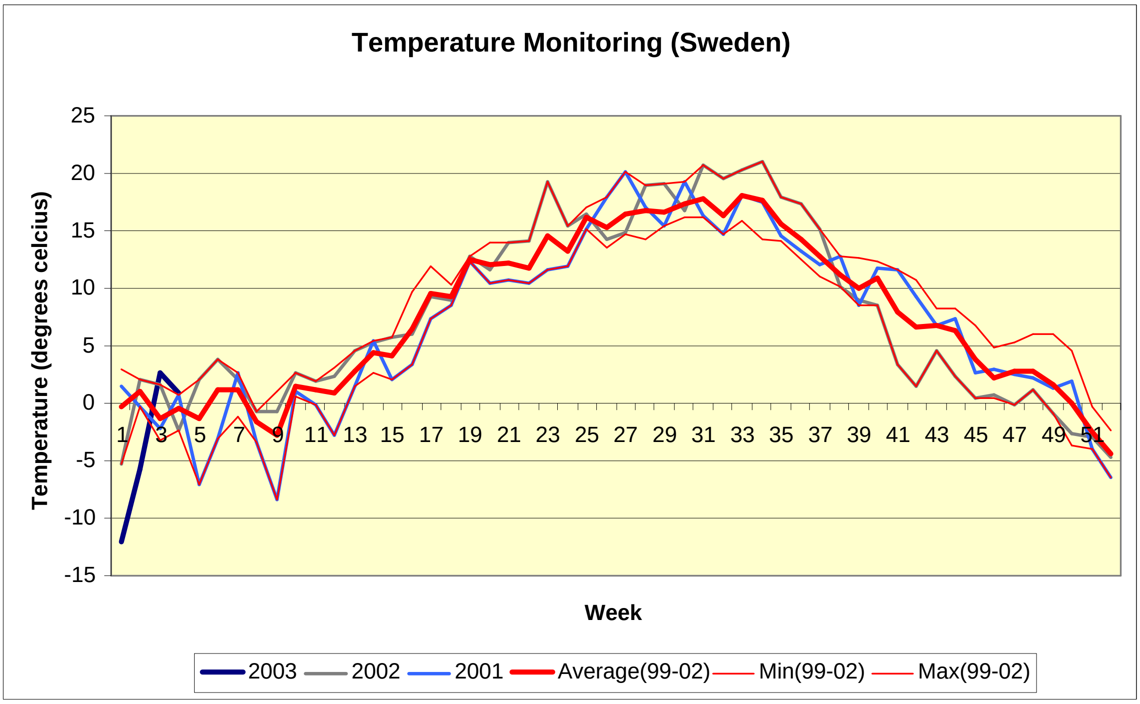

*Pic4-7: consumption in Norway*



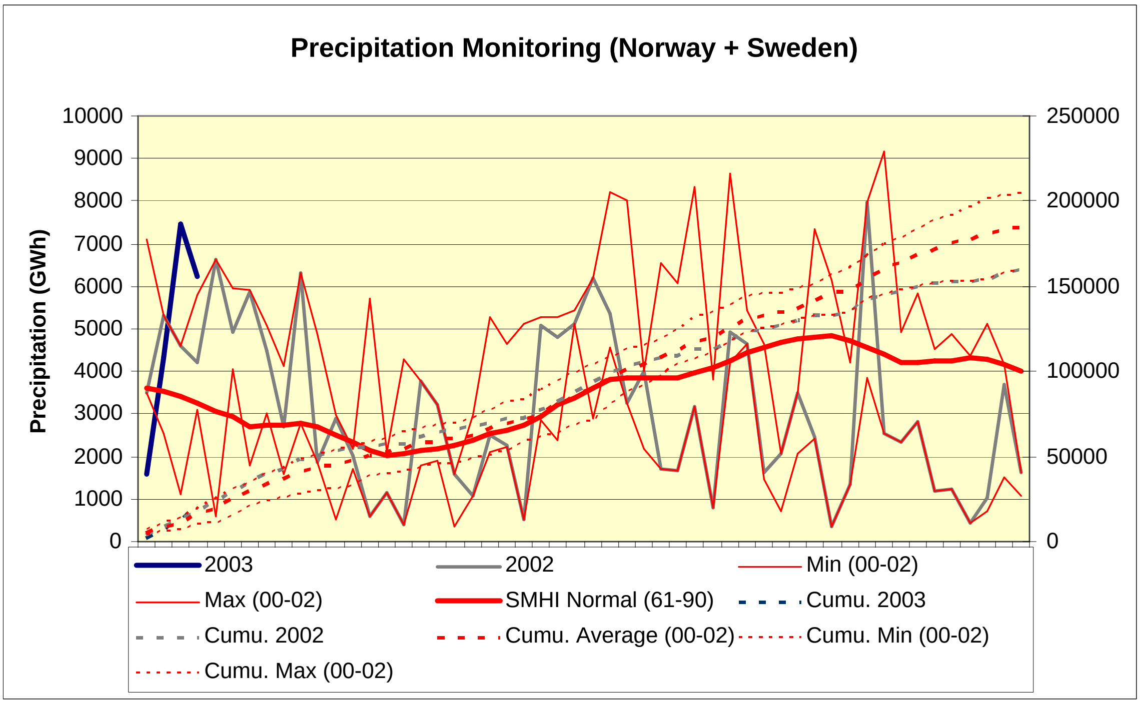

*Pic4-8: consumption in Sweden*



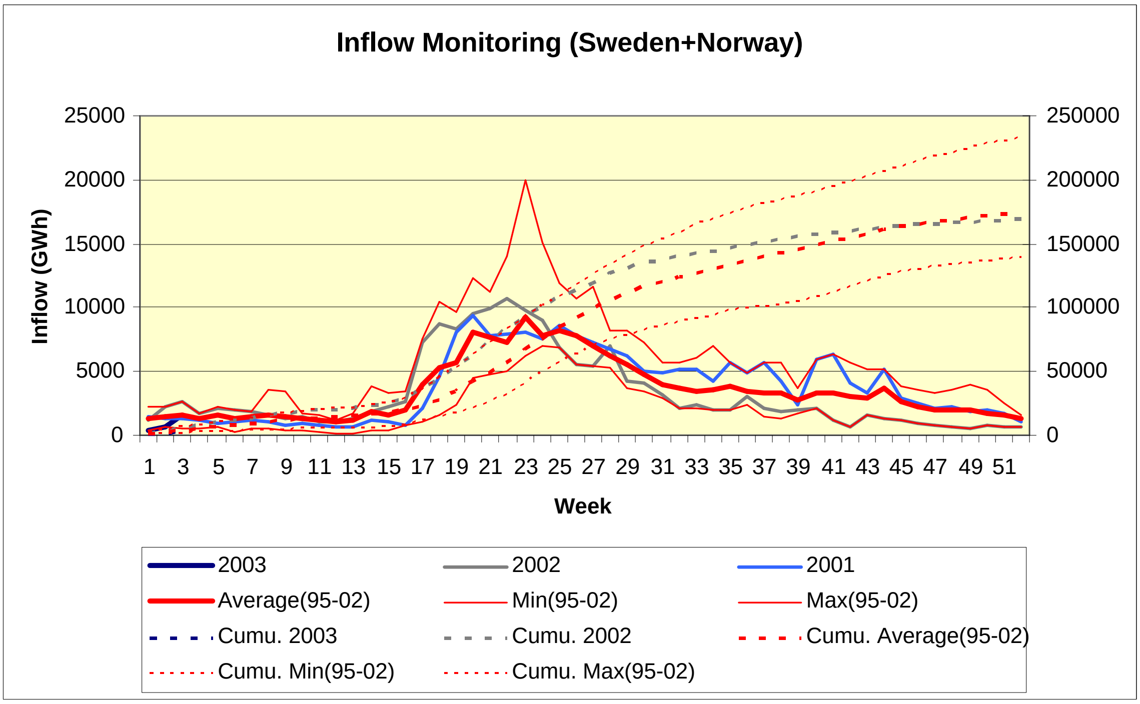

*Pic4-9: consumption in Finland*



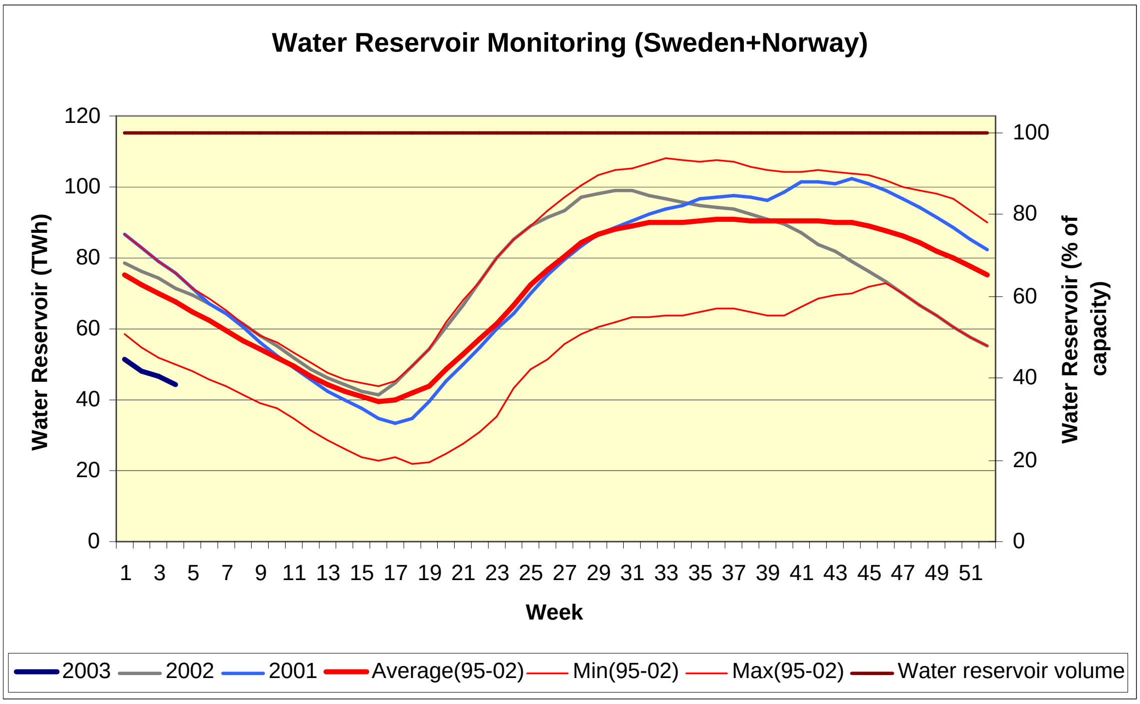

*Pic4-10: temperature in Sweden*



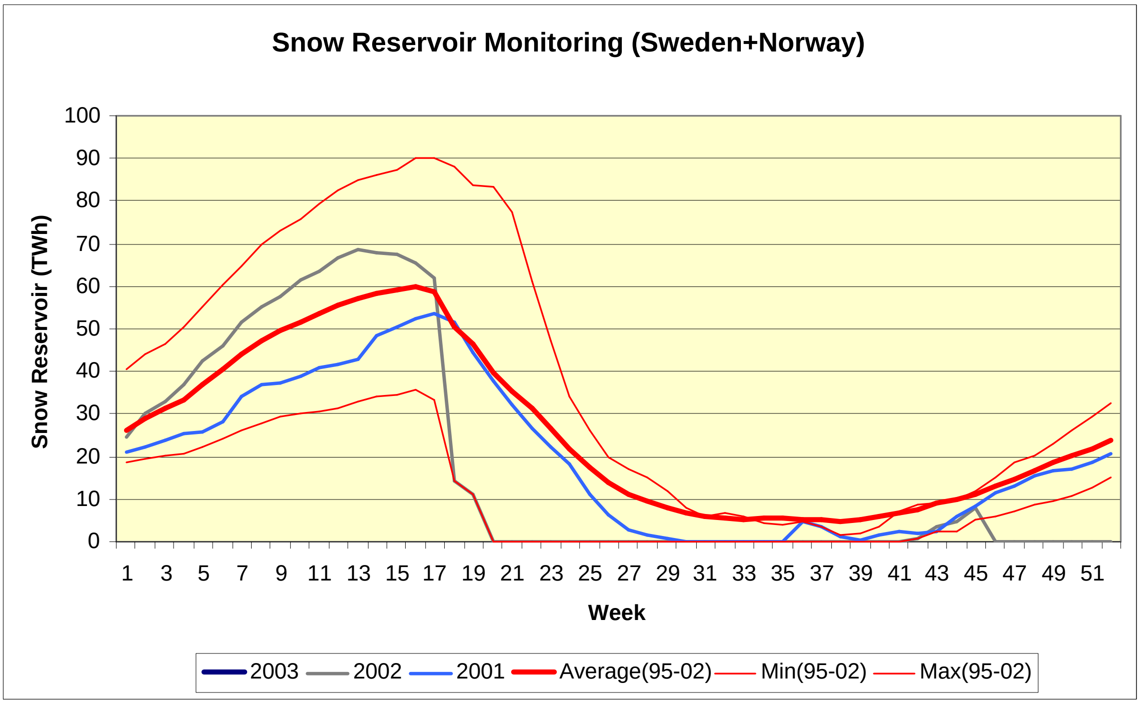

*Pic4-11: precipitation for Norway+Sweden*



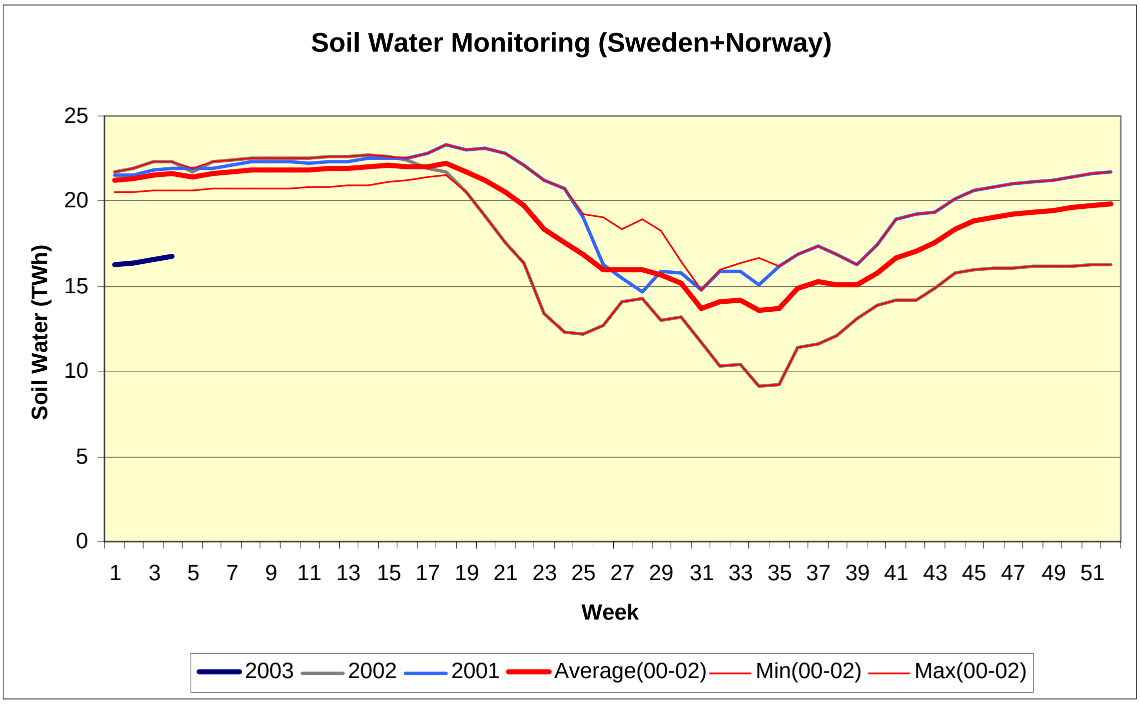

*Pic4-12: inflow for Norway+Sweden*



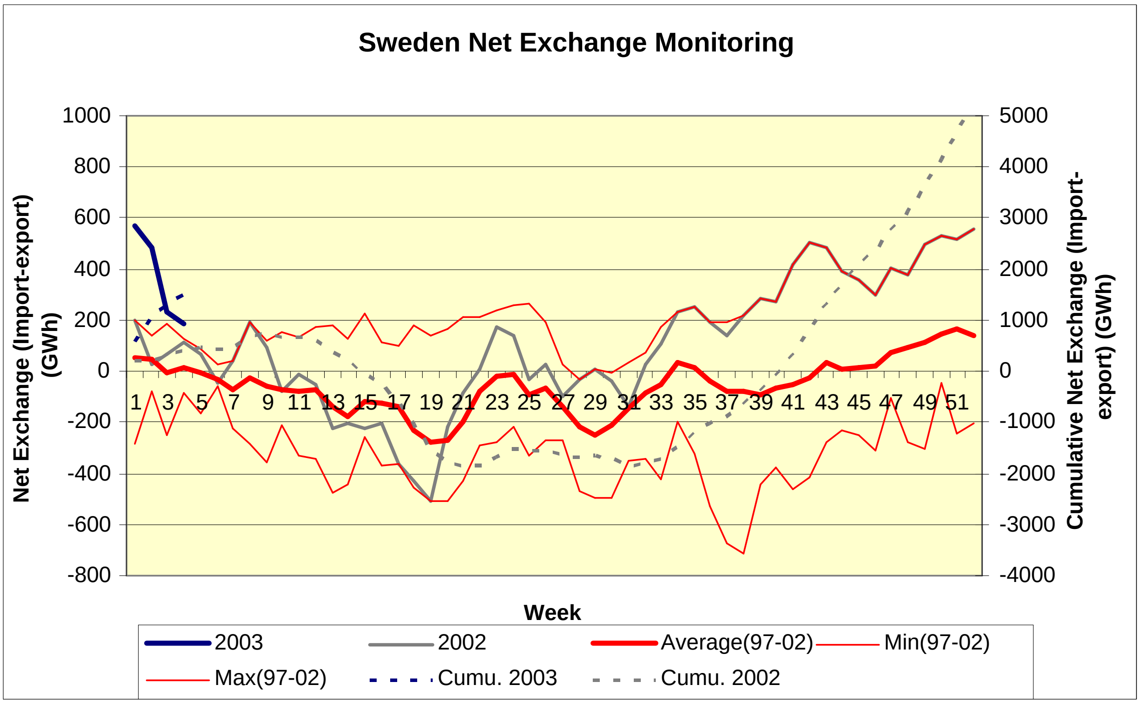

*Pic4-13: water reservoir level for Norway+Sweden*



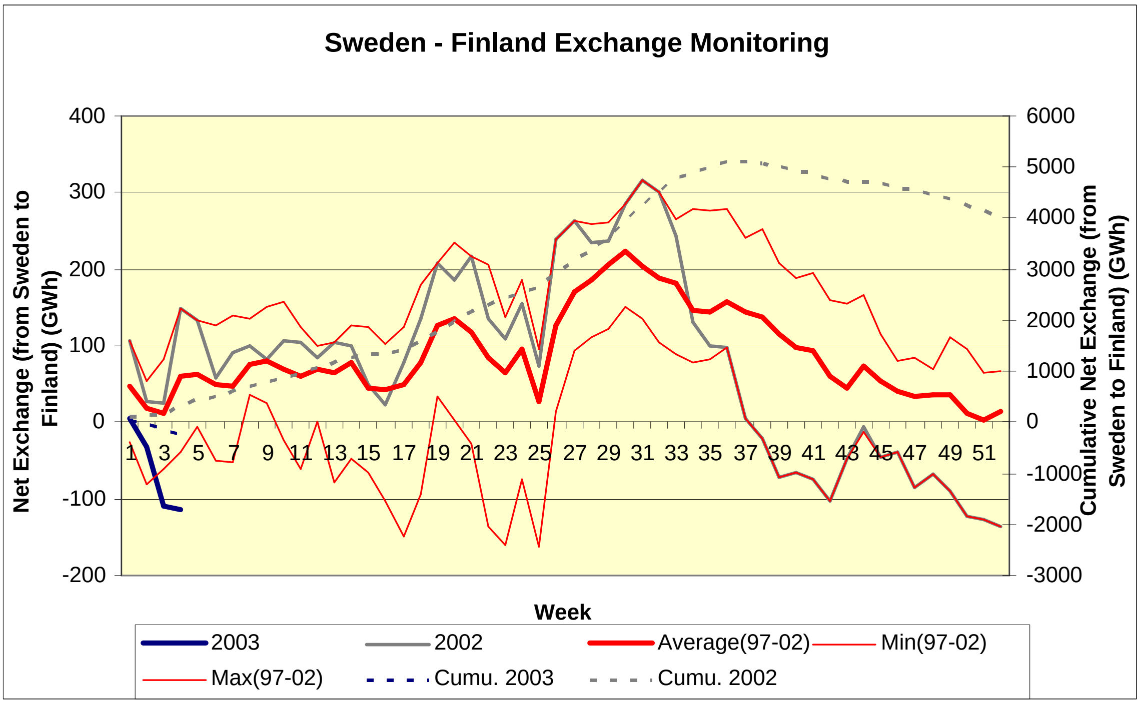

*Pic4-14: snow reservoir level for Norway+Sweden*



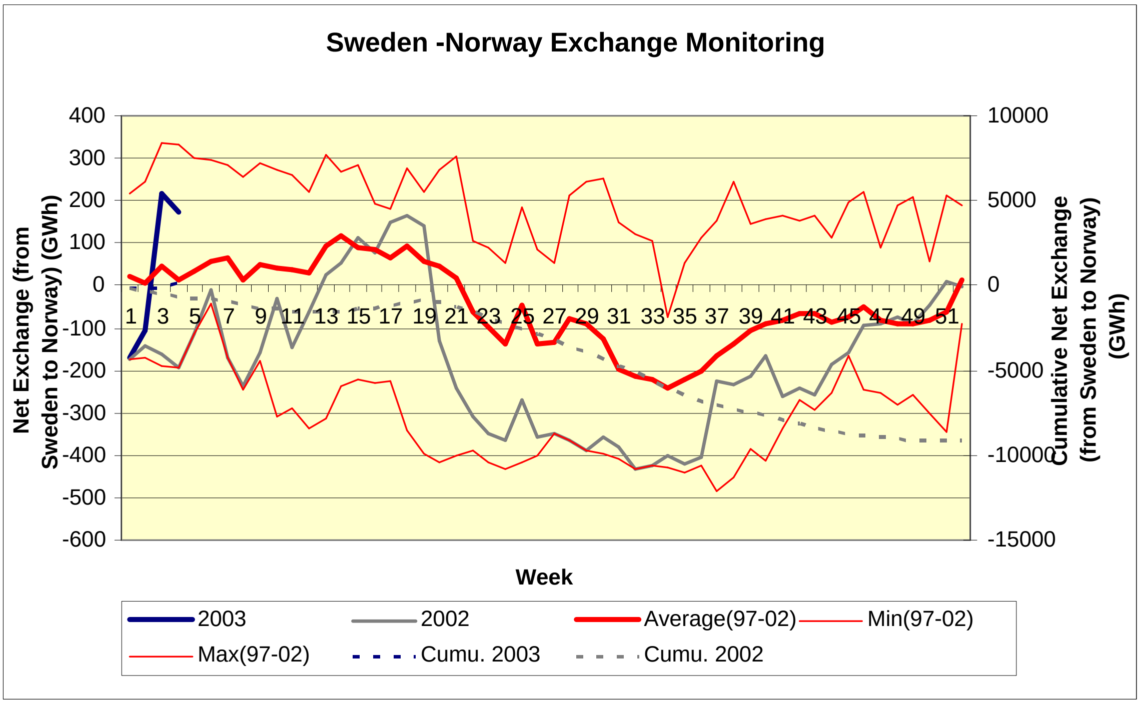

*Pic4-15: soil water level for Norway+Sweden*



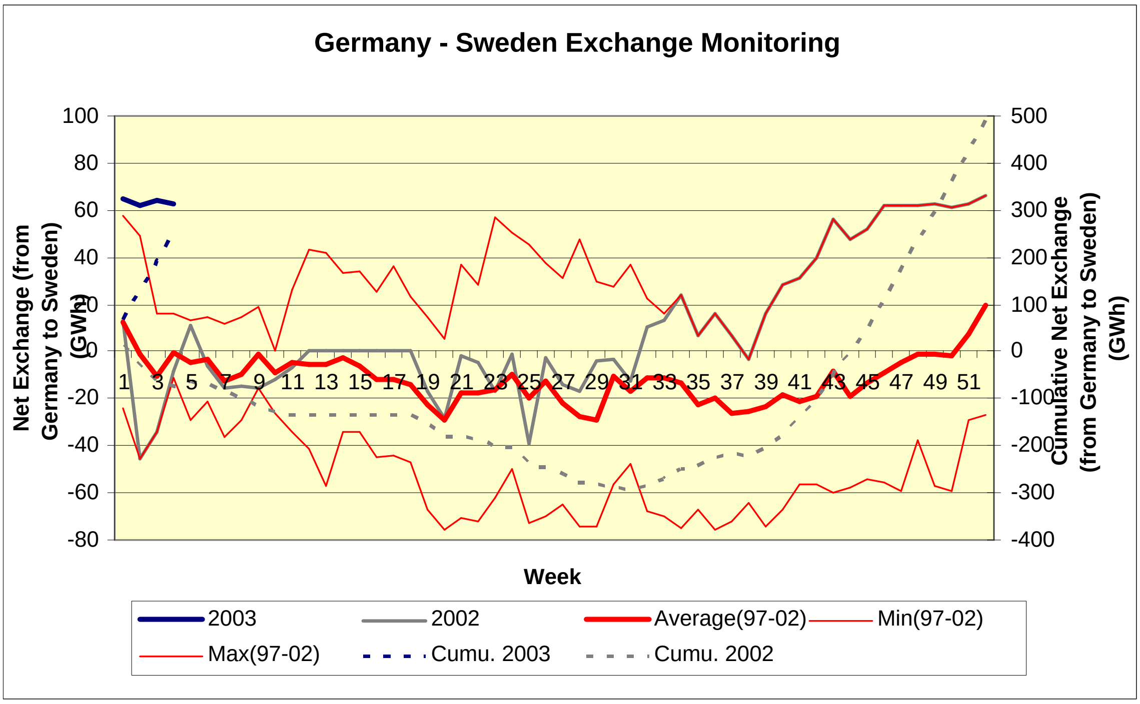

*Pic4-16: net exchange for Sweden*



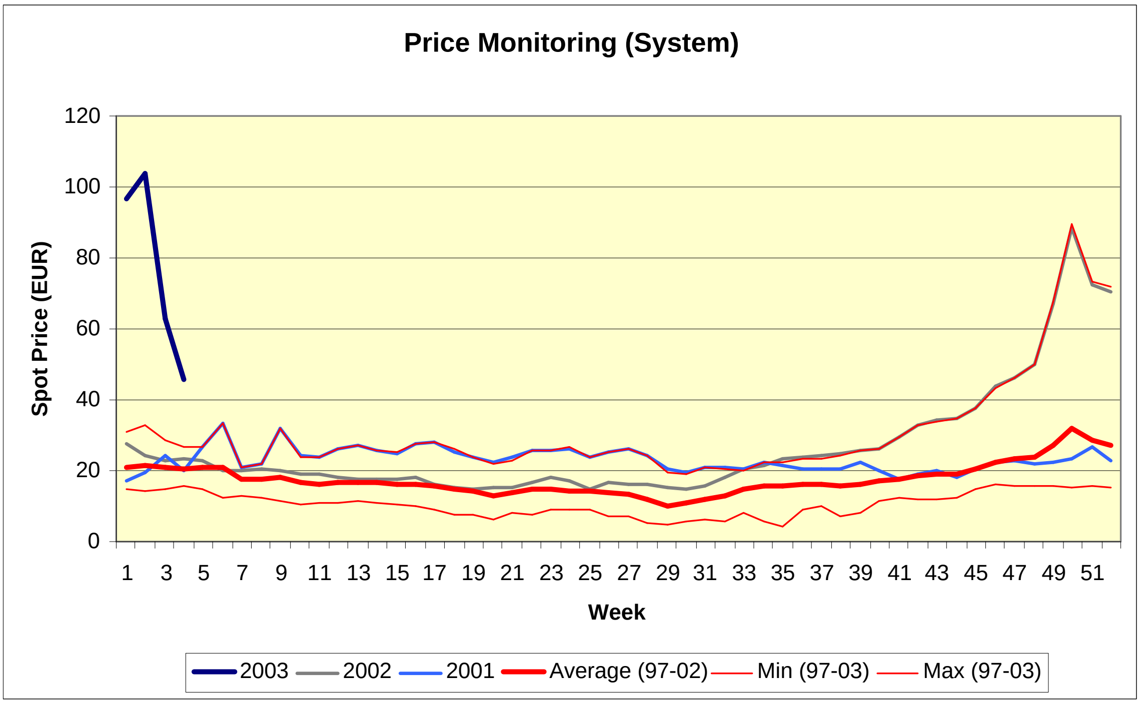

*Pic4-17: net exchange for Sweden-Finland*



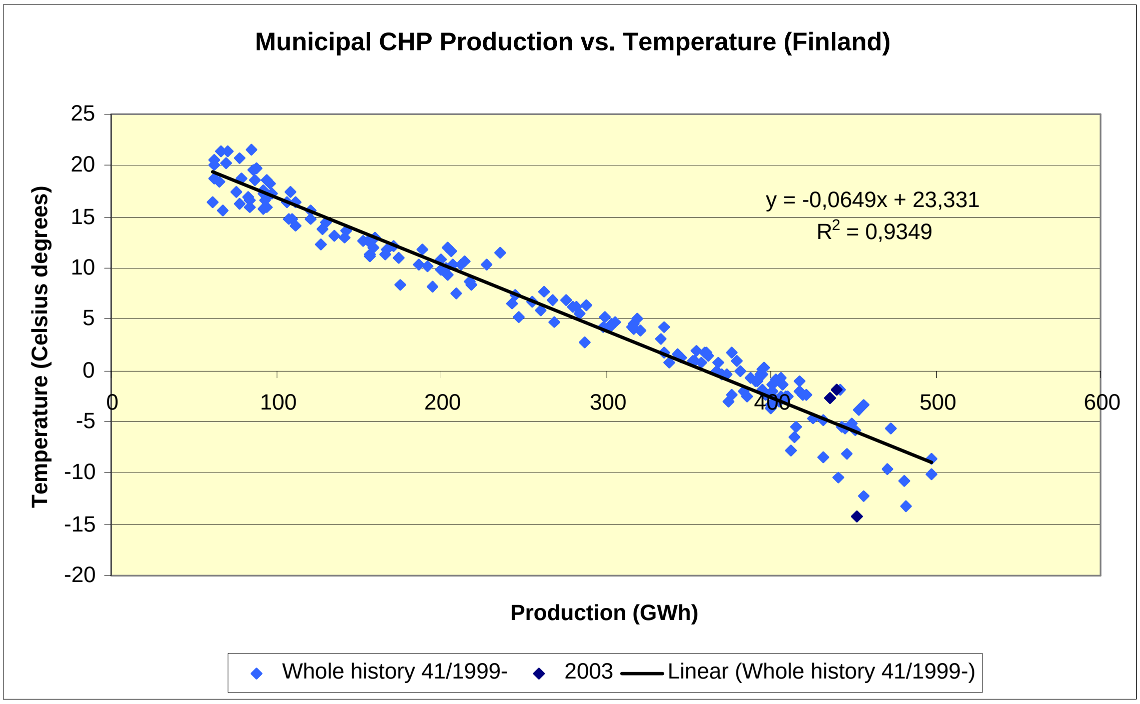

*Pic4-18: net exchange for Sweden-Norway*



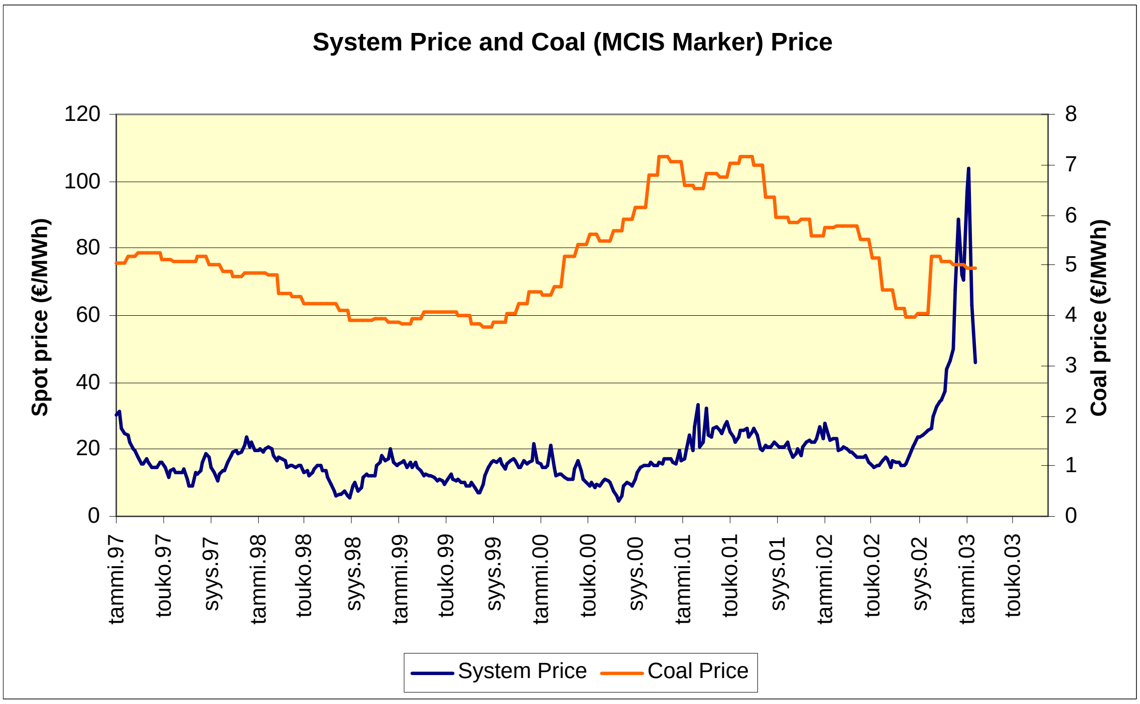

*Pic4-19: net exchange for Sweden-Germany*



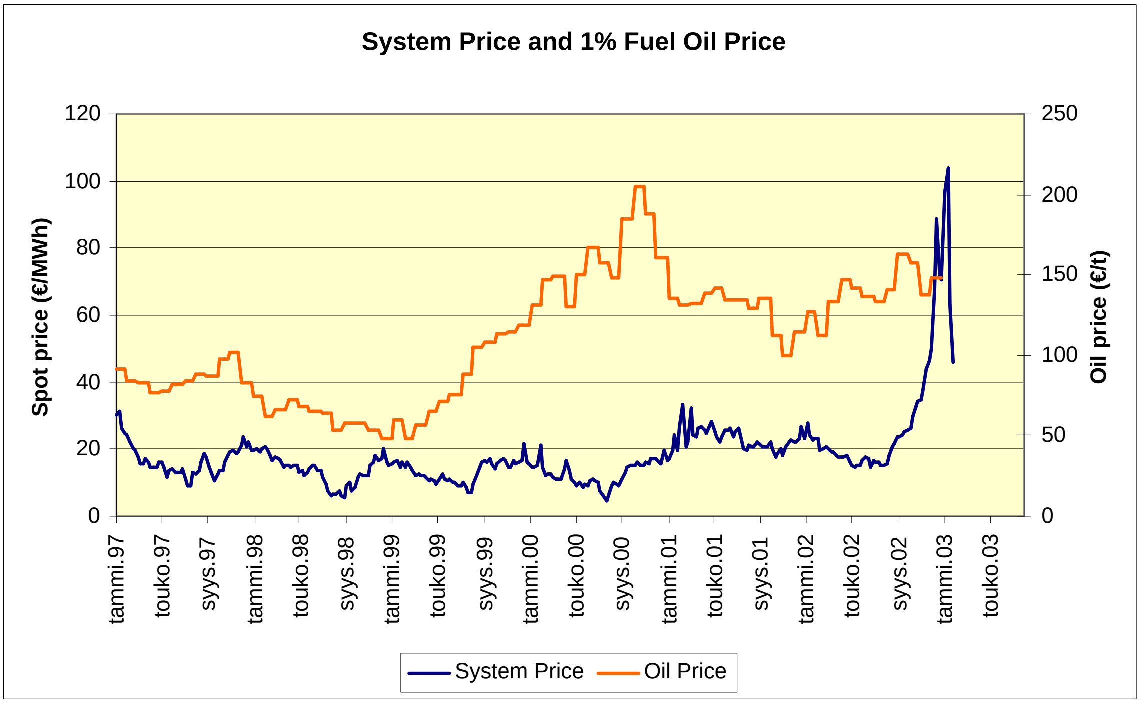

*Pic4-21: spot price data for System*



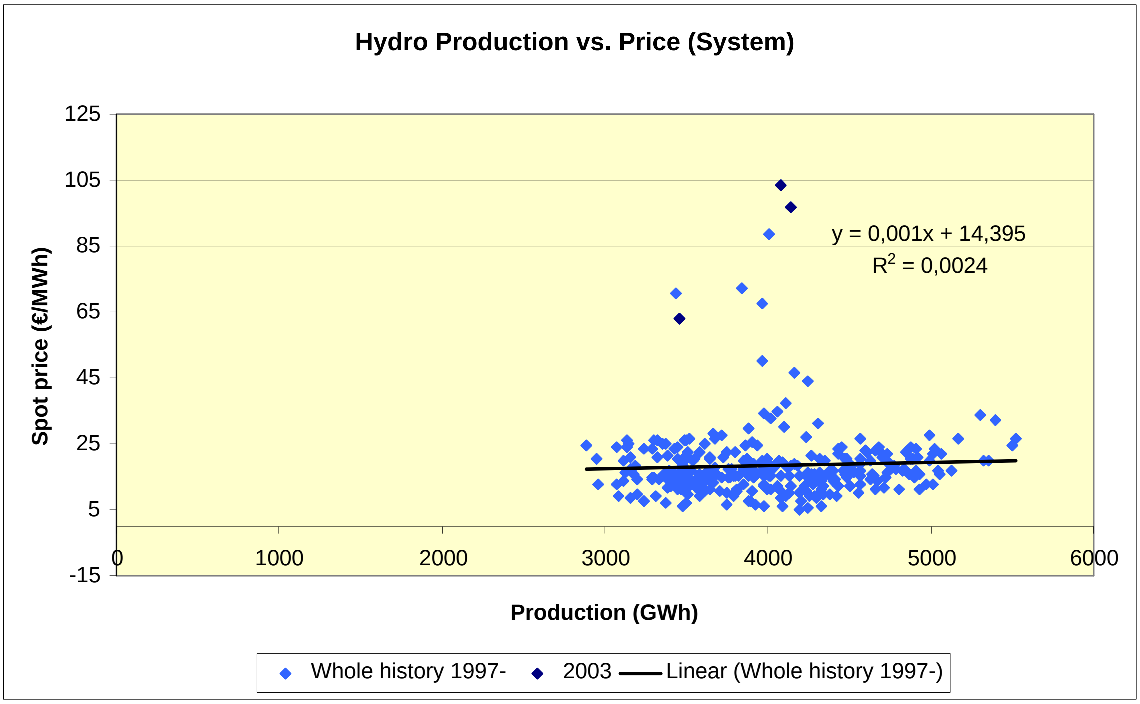

*Pic4-22: correlation between temperature and CHP production in Finland*



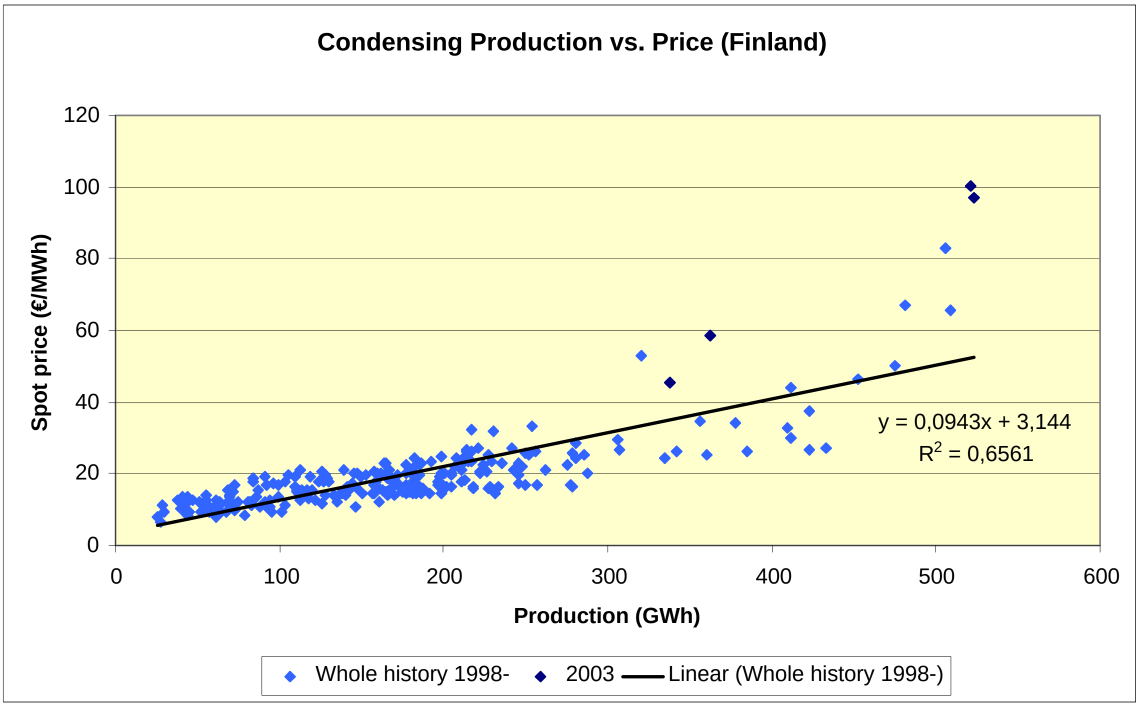

*Pic4-23: historical correlation between coal price and sys price*



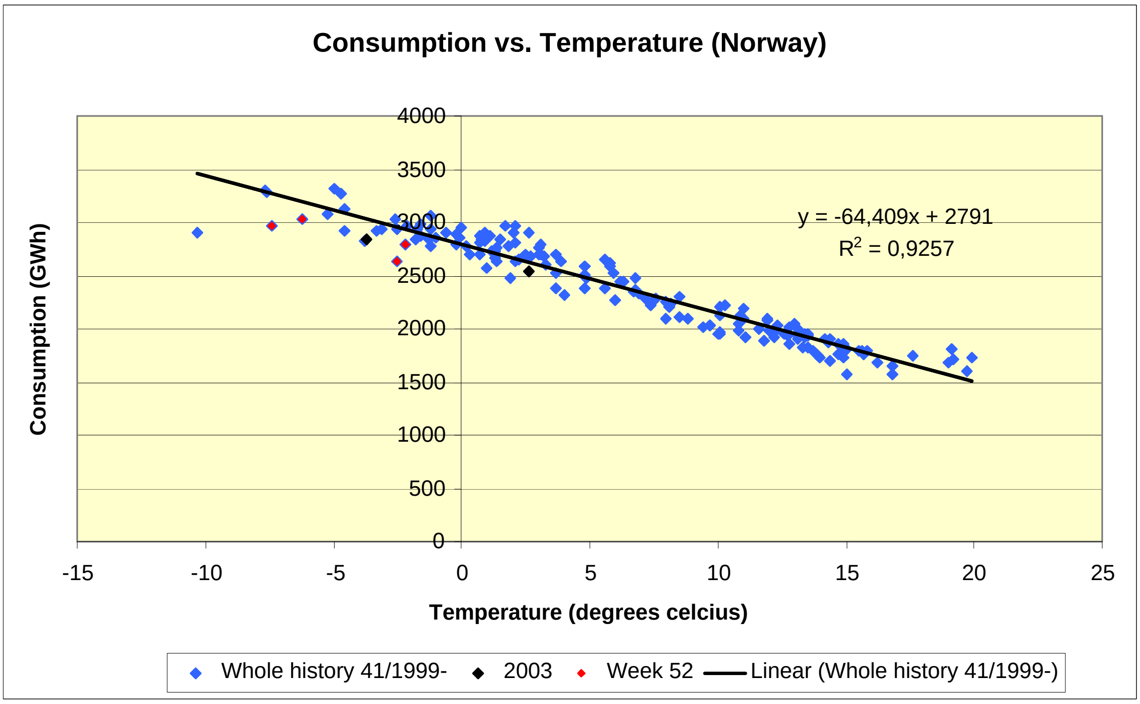

*Pic4-24: historical correlation between oil price and sys price*



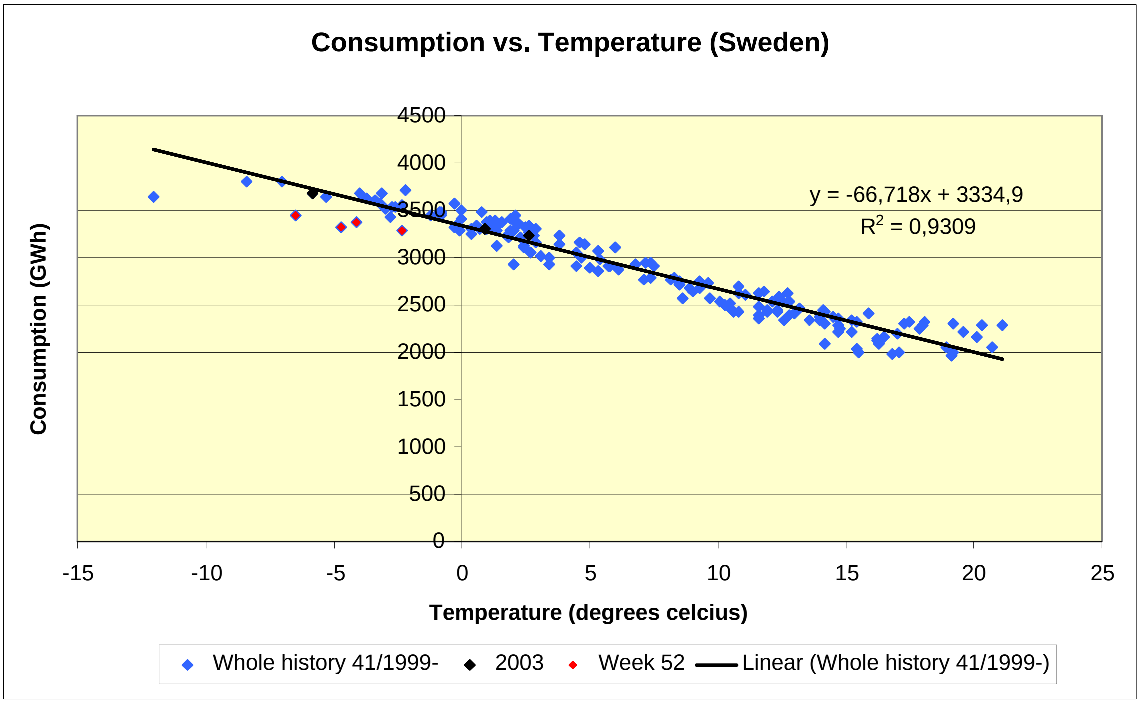

*Pic4-26: correlation between sys spot price and hydro power production in SYS*



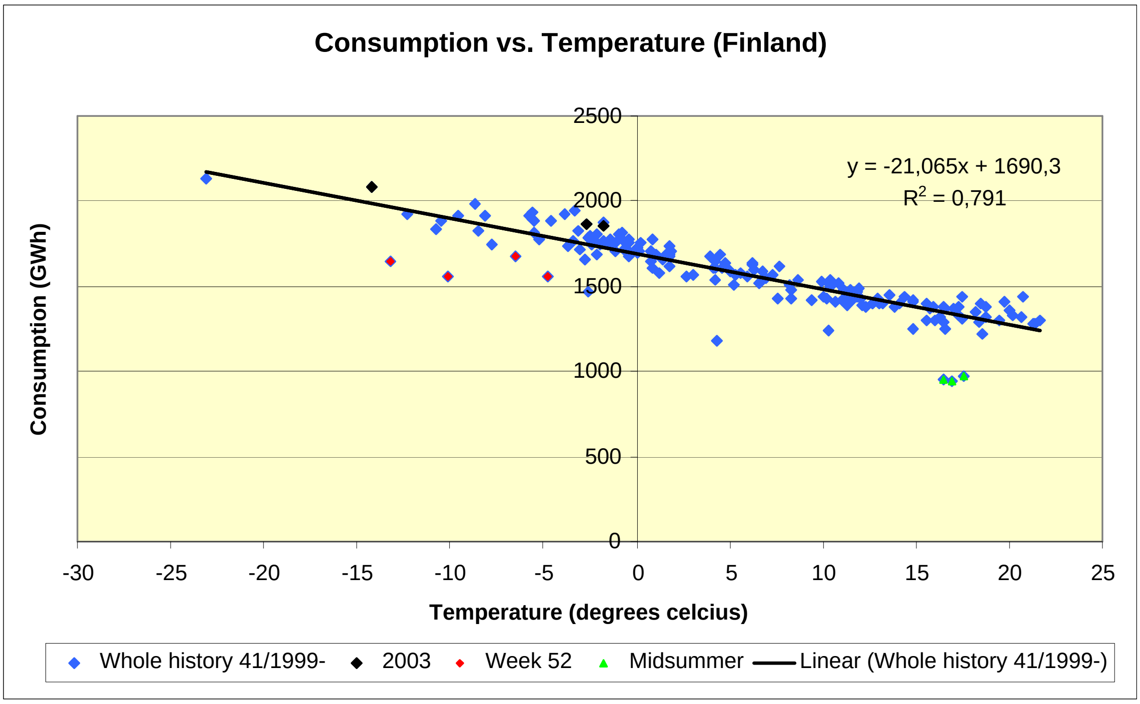

*Pic4-27: correlation between HEL spot price and coal condensing power production in Finland*



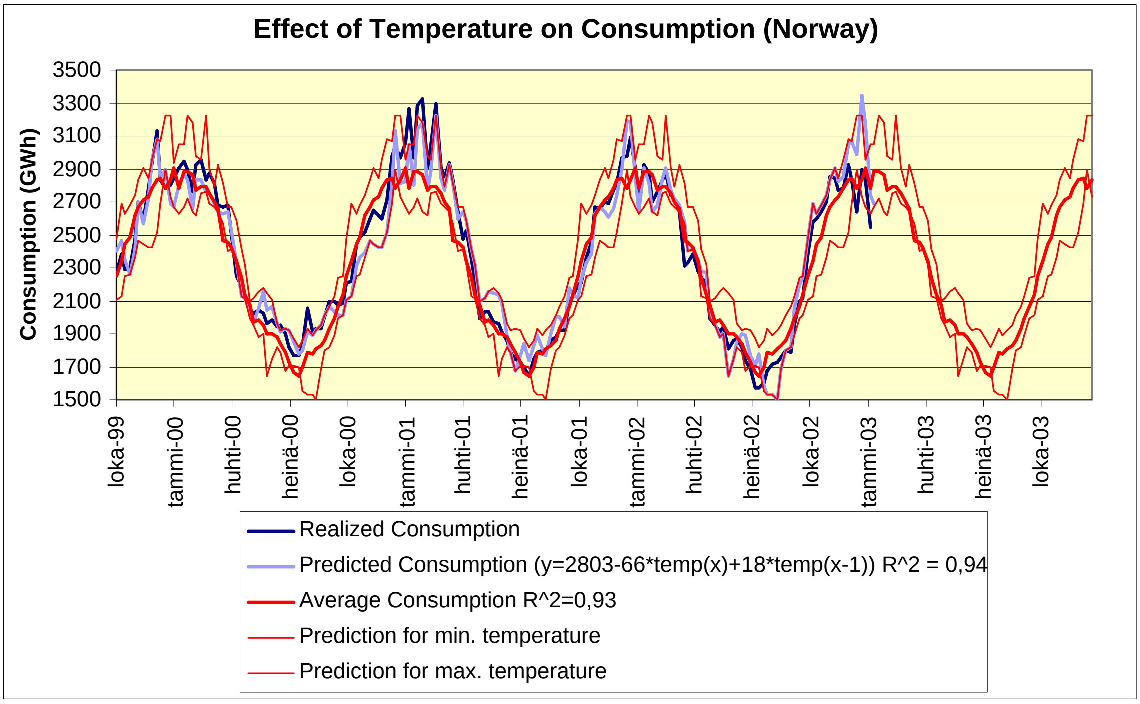

*Pic4-29: correlation between temperature and consumption in Norway*



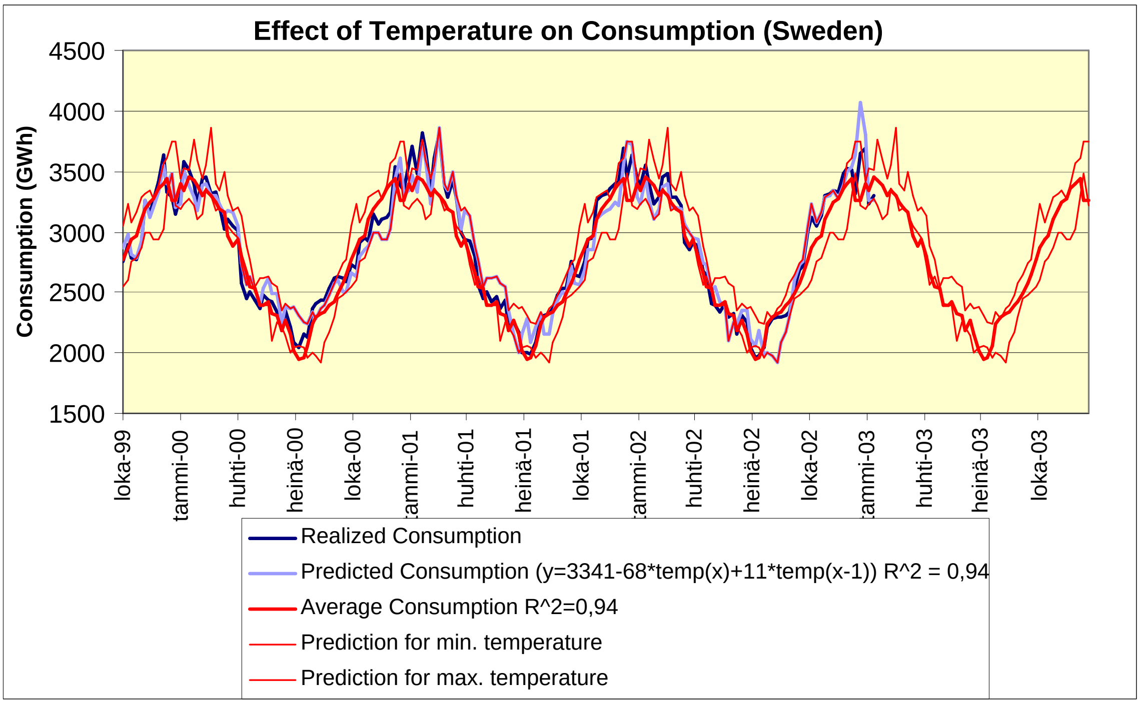

*Pic4-30: correlation between temperature and consumption in Sweden*



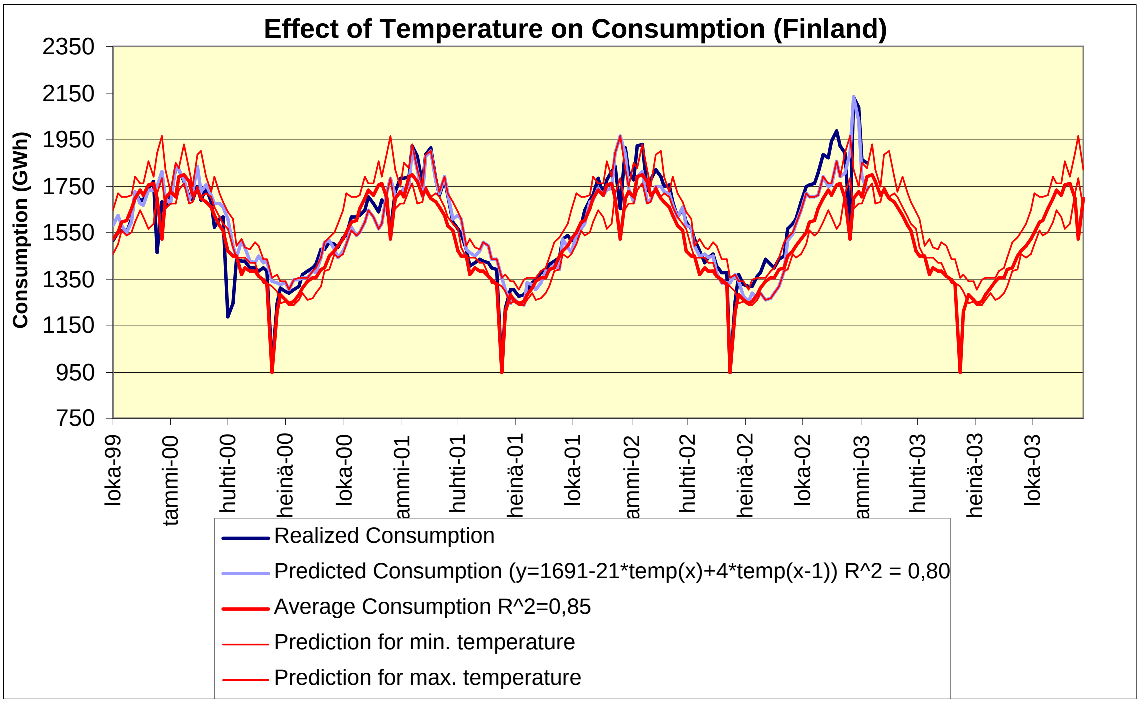

*Pic4-31: correlation between temperature and consumption in Finland*



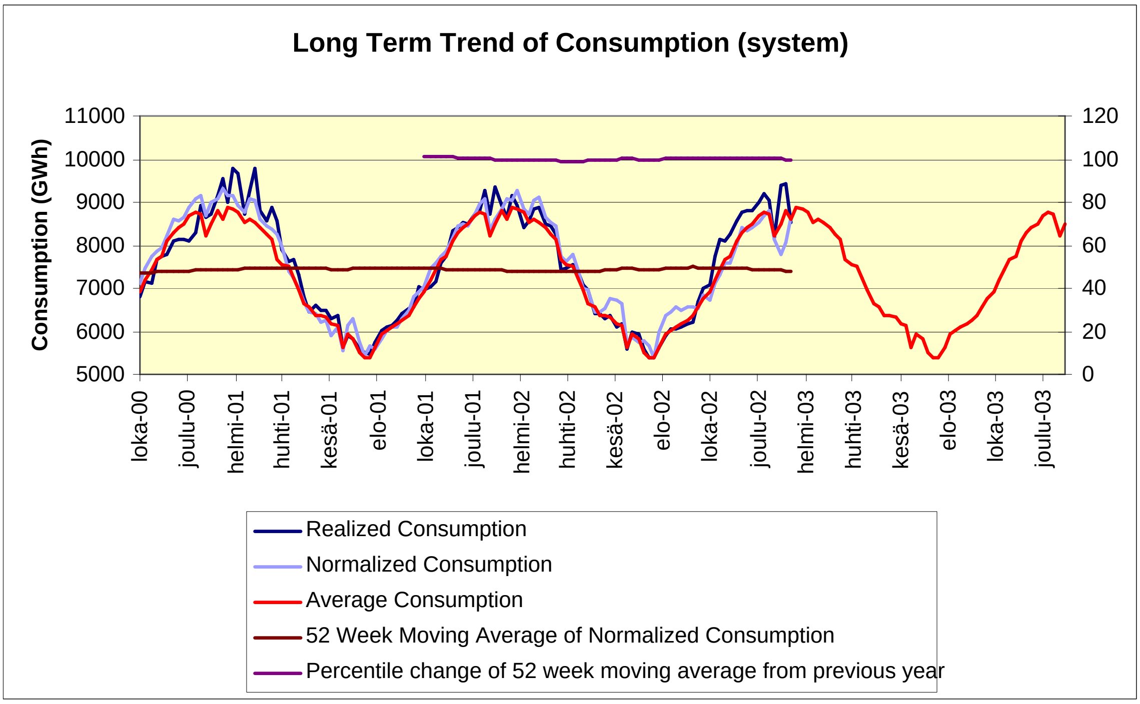

*Pic4-32: consumption in Norway: realised, history average & regression model*



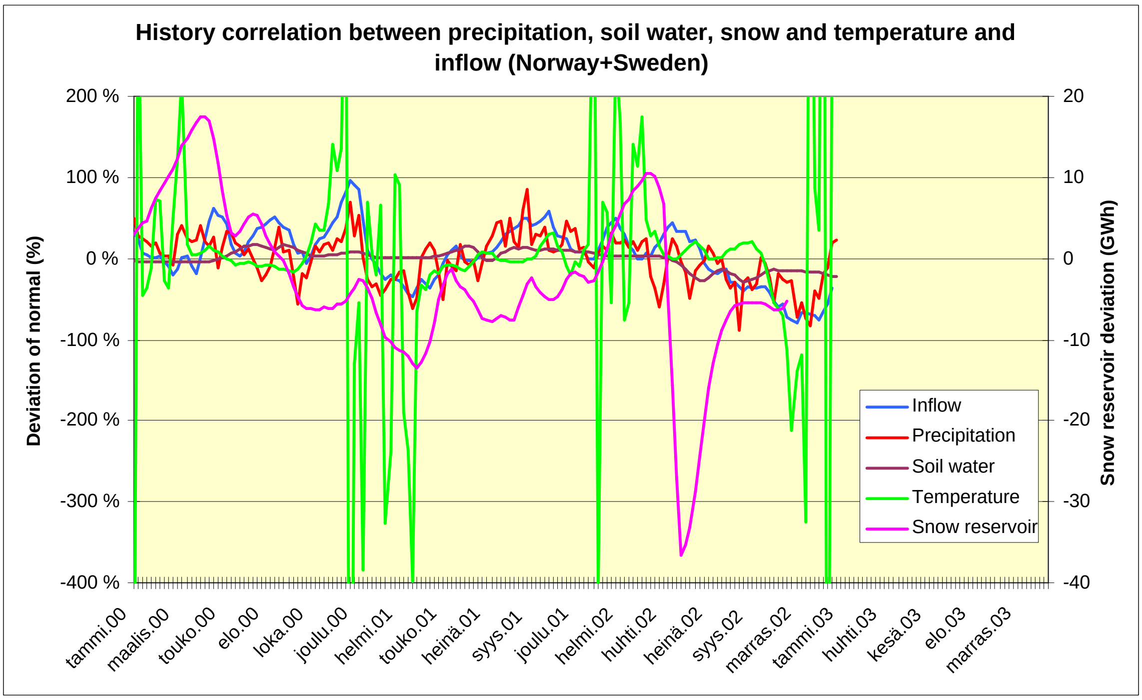

*Pic4-33: consumption in Sweden: realised, history average & regression model*



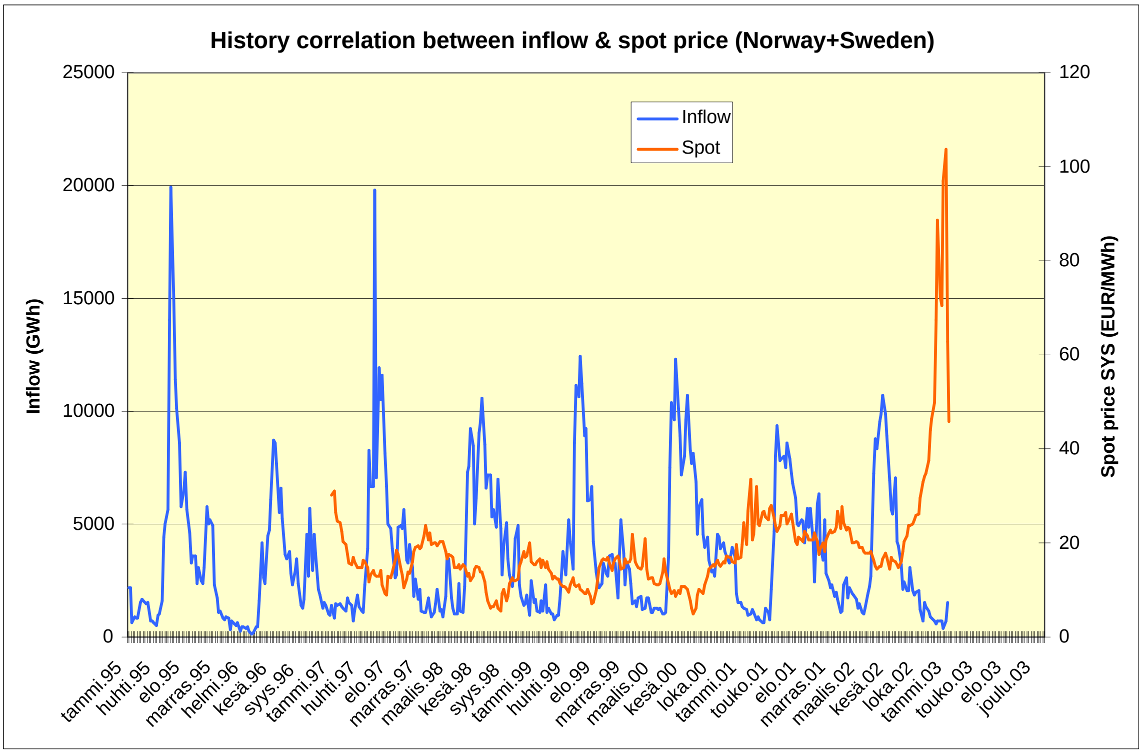

*Pic4-34: consumption in Finland: realised, history average & regression model*



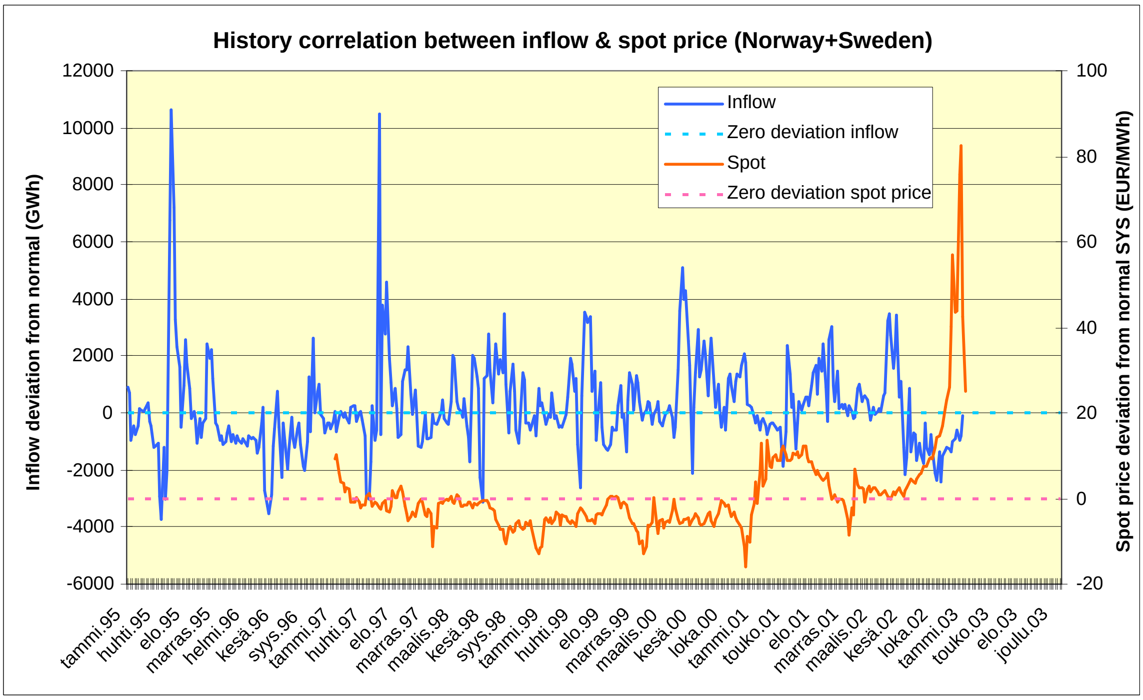

*Pic4-35: longer-term trend in consumption in System: realised, history average, temperature corrected & 52-moving average & 2nd axis percentual annual growth*



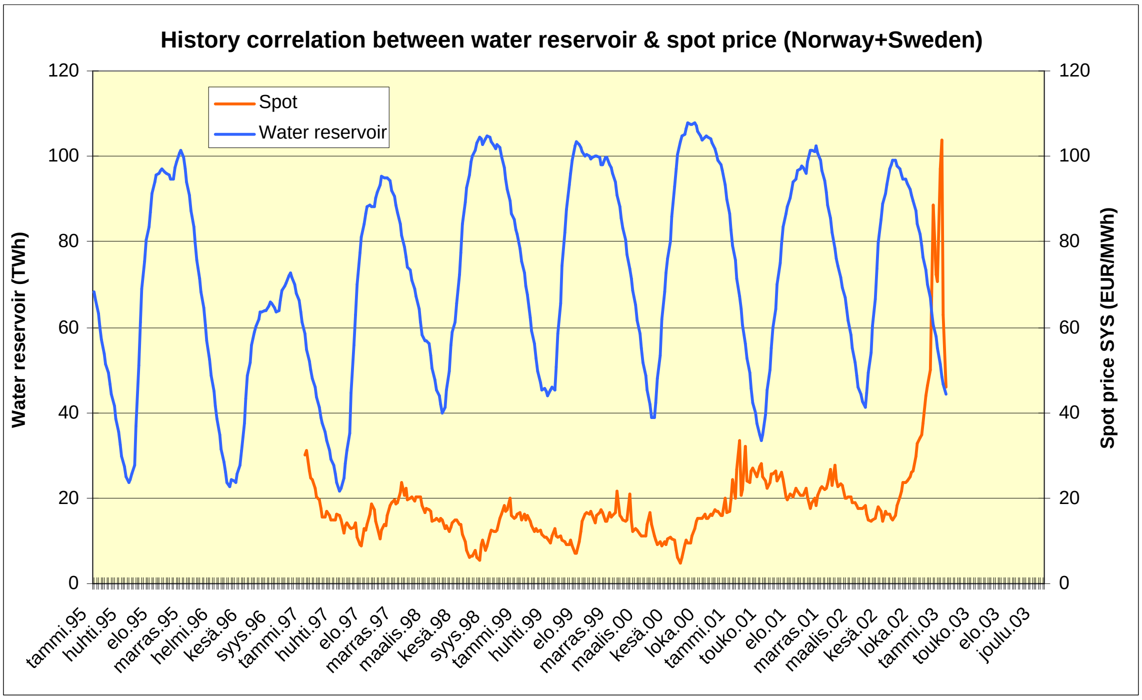

*Pic4-36: history correlation between inflow and precipitation, soil water, snow reservoir & temparature, Norway+Sweden*



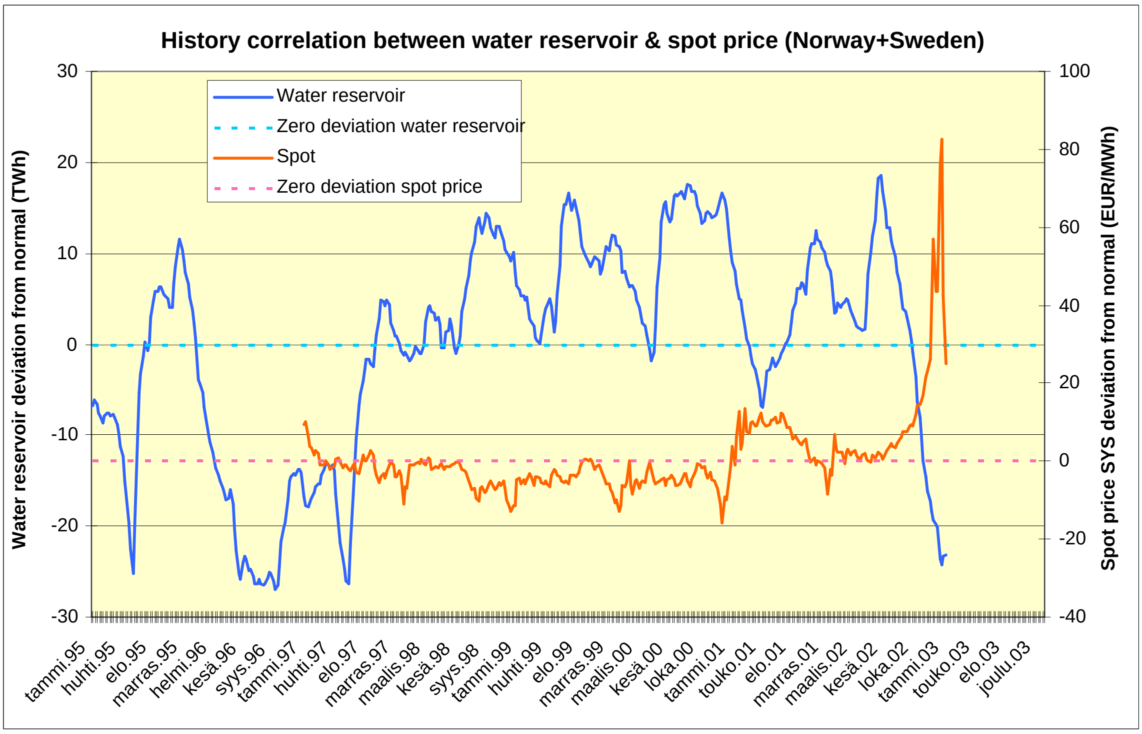

*Pic4-37: history correlation between inflow & spot price, Norway + Sweden*



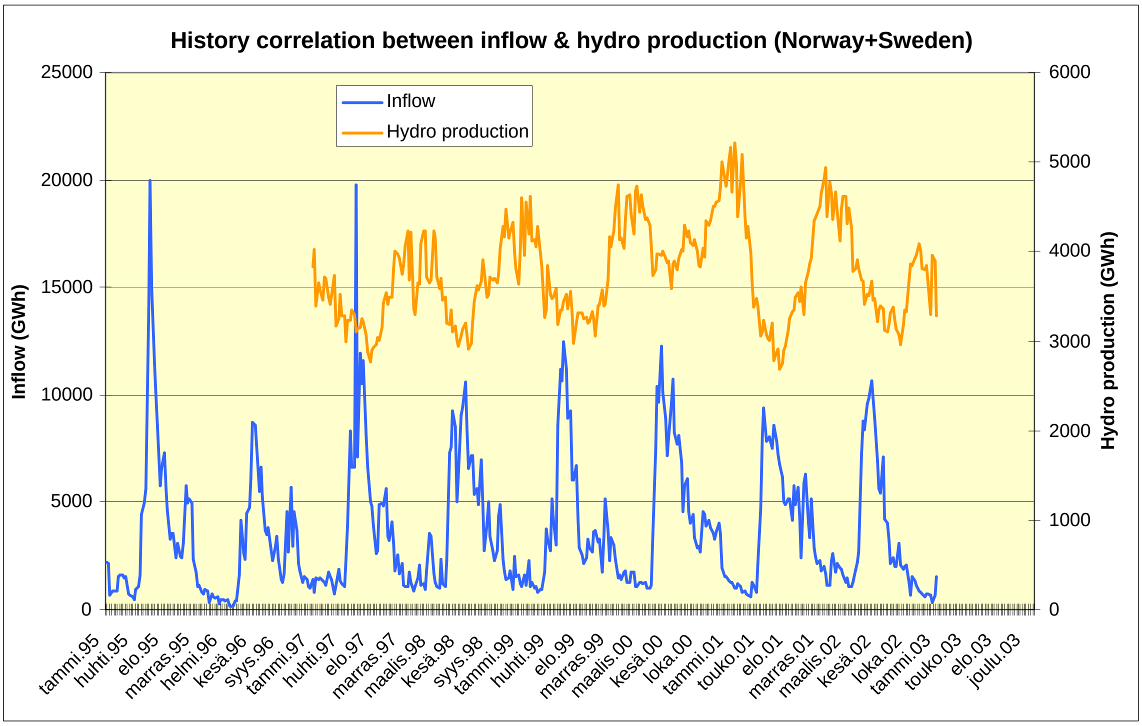

*Pic4-38: history correlation between inflow & spot price (deviation), Norway + Sweden*



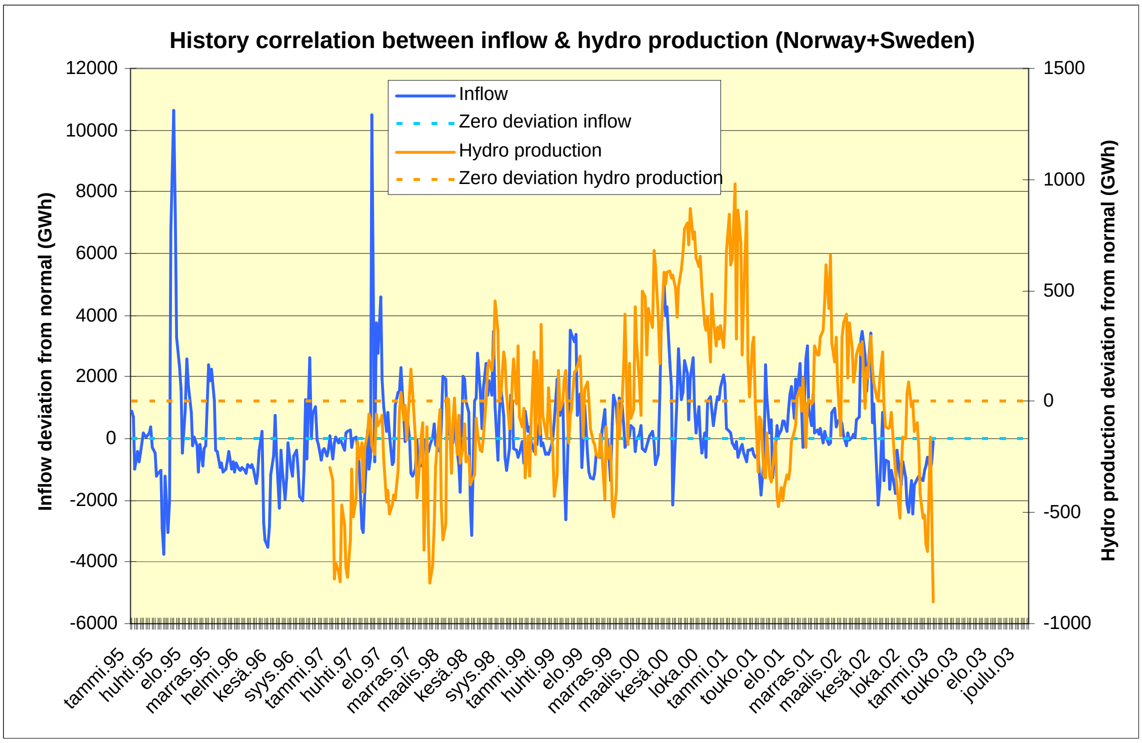

*Pic4-39: history correlation between water reservoir level & spot price, Norway + Sweden*



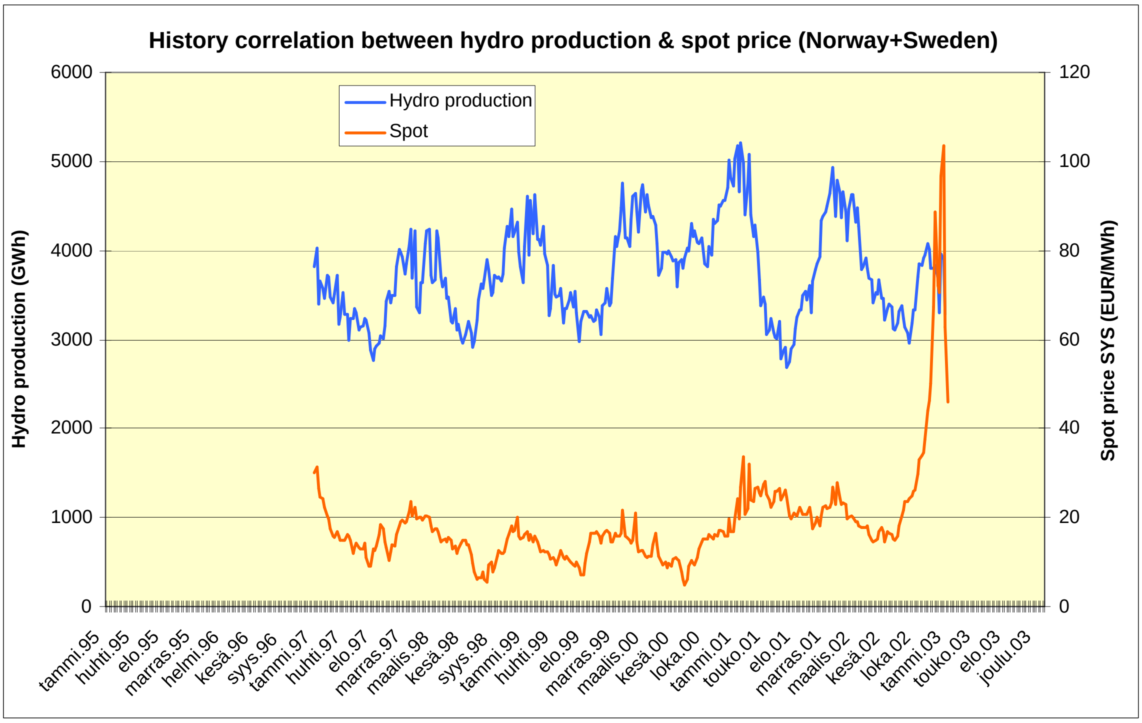

*Pic4-40: history correlation between water reservoir level & spot price (deviation), Norway + Sweden*



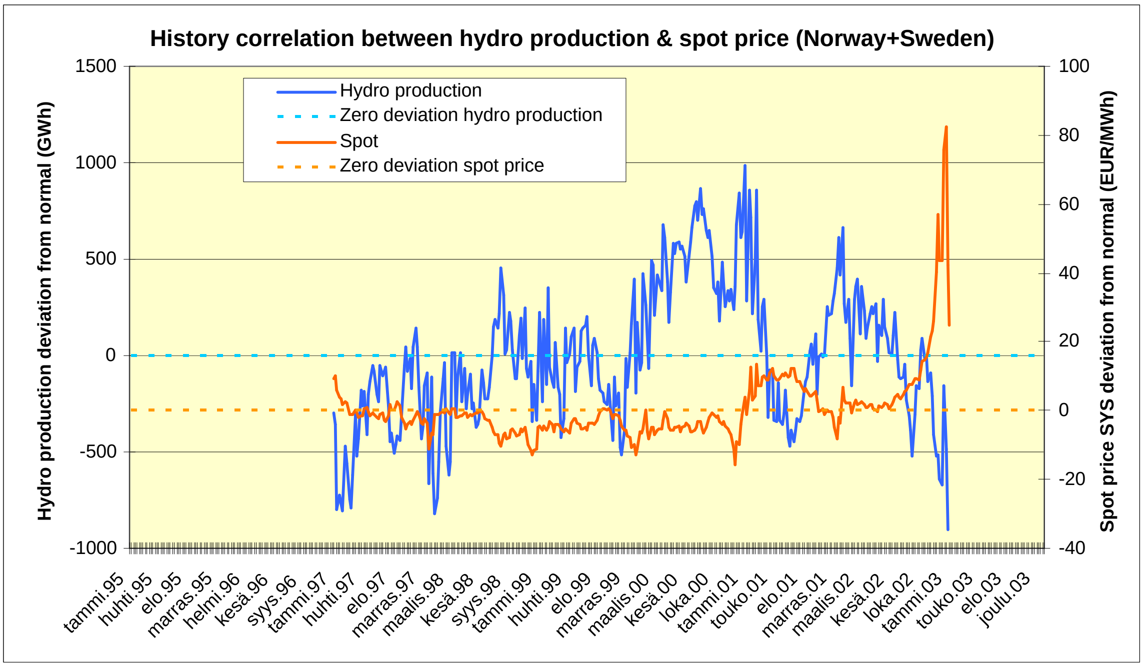

*Pic4-41: history correlation between inflow & hydro production, Norway + Sweden*



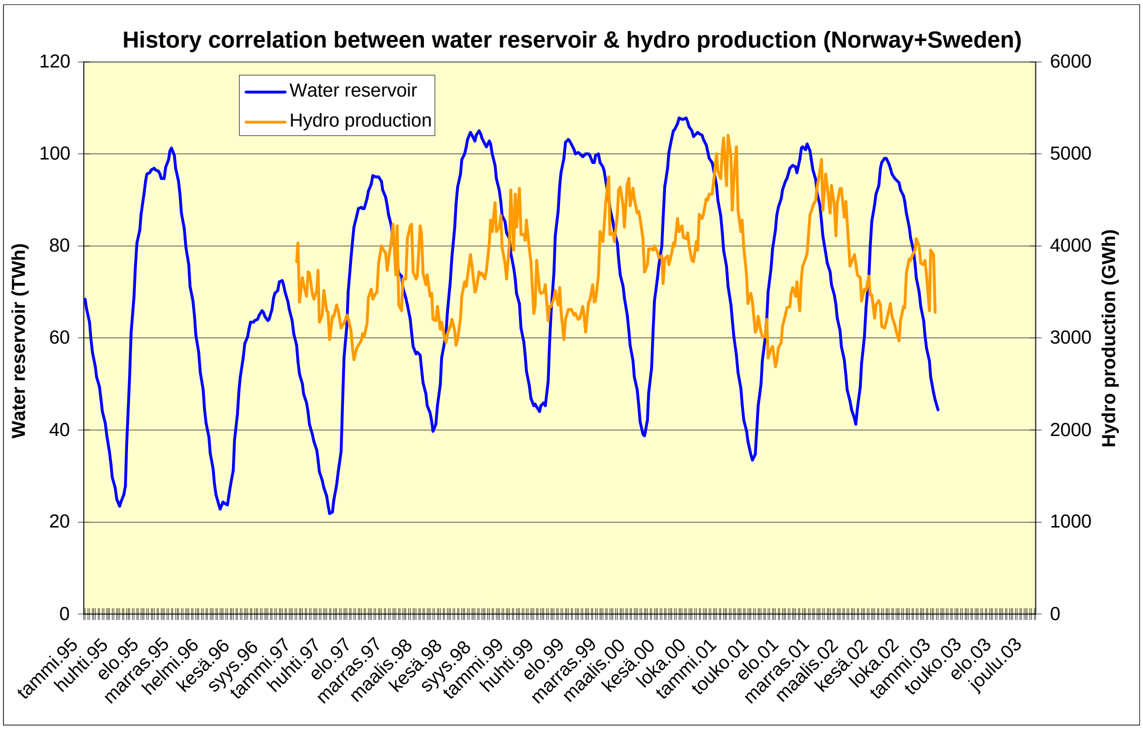

*Pic4-42: history correlation between inflow & hydro production (deviation), Norway + Sweden*



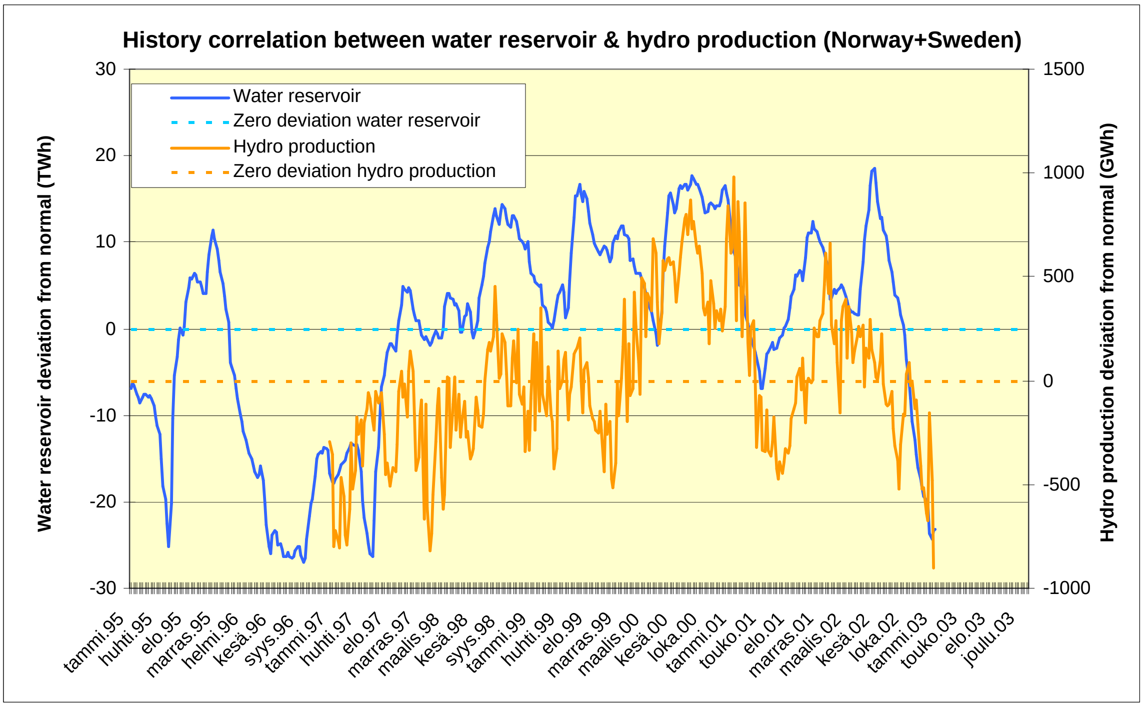

*Pic4-43: history correlation between hydro production & spot price, Norway + Sweden*



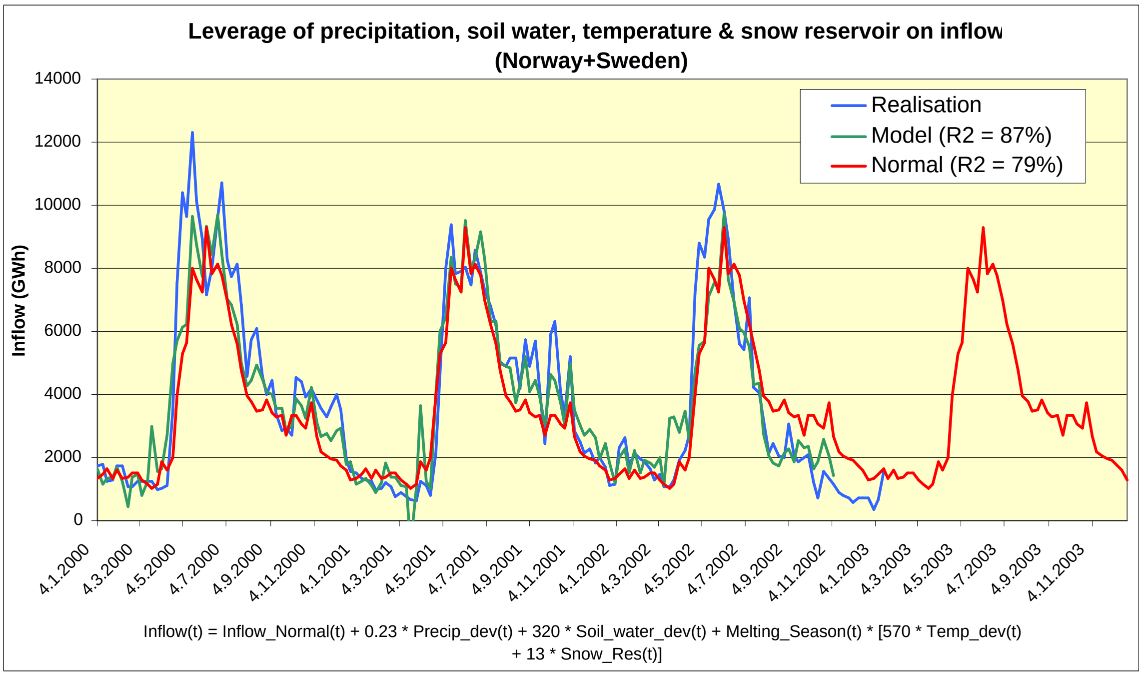

*Pic4-44: history correlation between hydro production & spot price (deviation), Norway + Sweden*



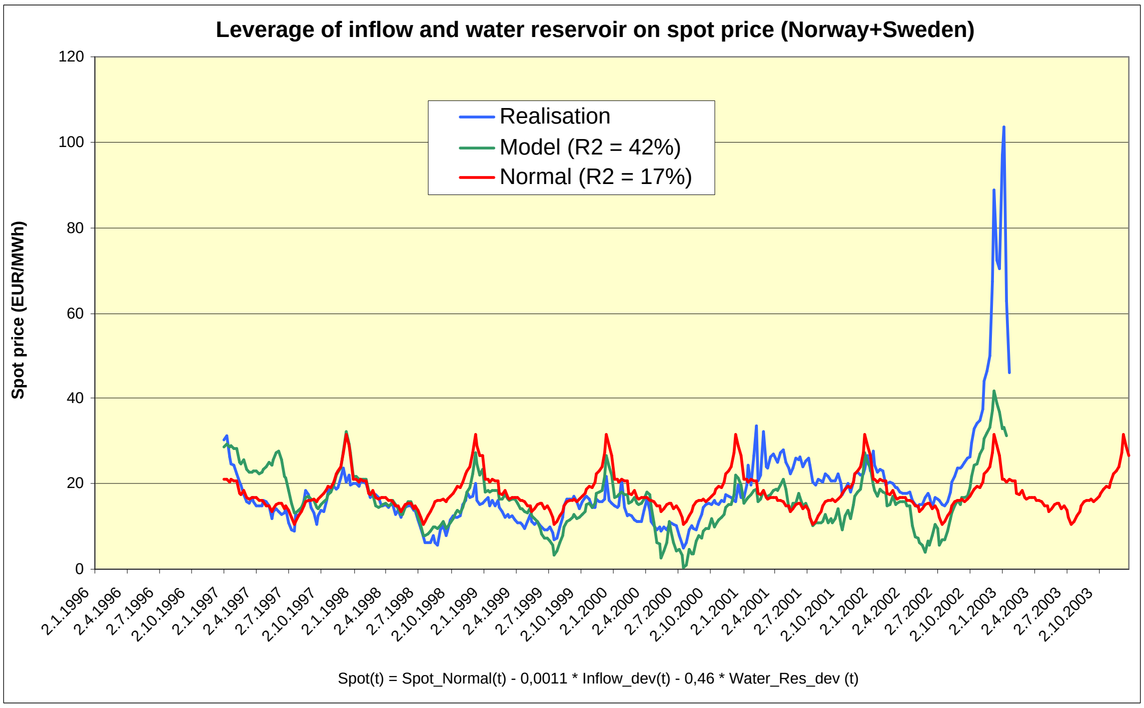

*Pic4-45: history correlation between hydro production & water reservoir level, Norway + Sweden*



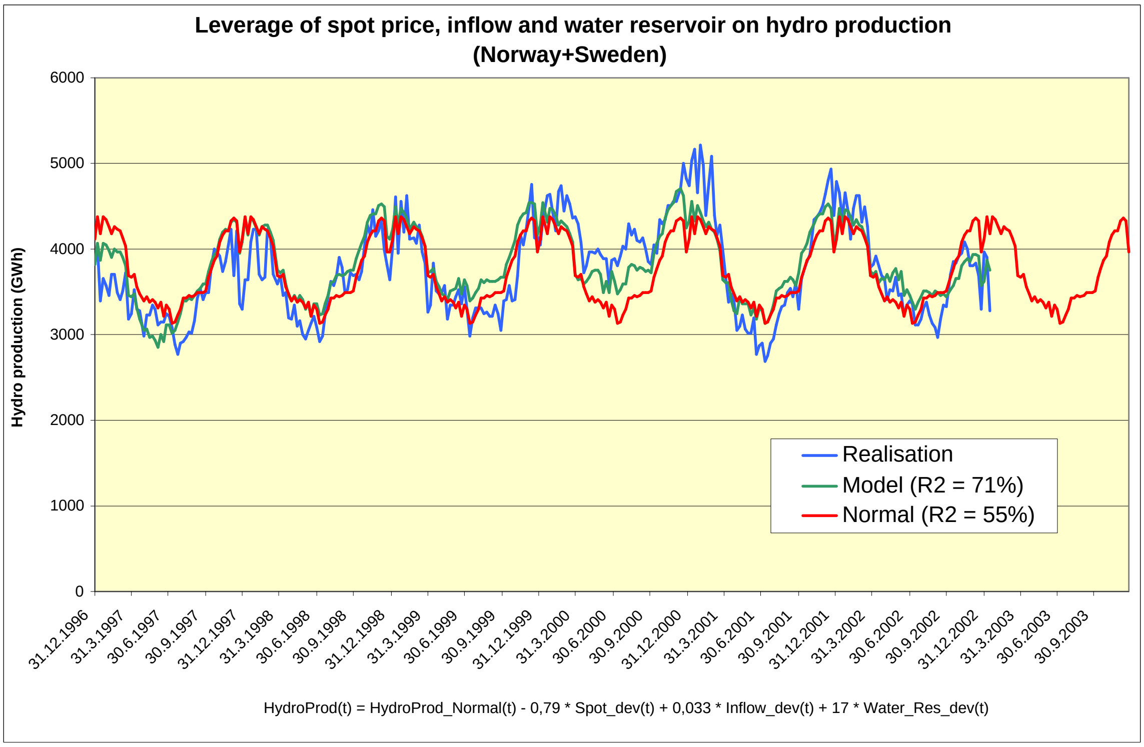

*Pic4-46: history correlation between hydro production & water reservoir level (deviation), Norway + Sweden*



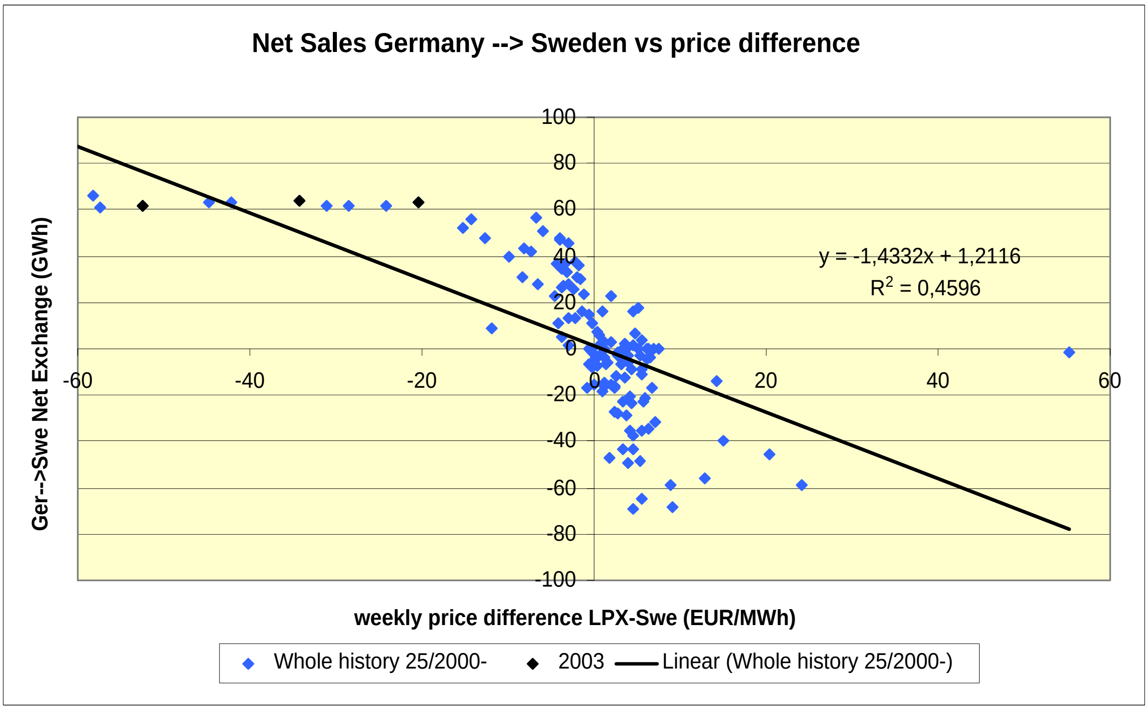

*Pic4-47: leverage of precipitation, soil water, snow reservoir & temperature on inflow, Norway + Sweden*



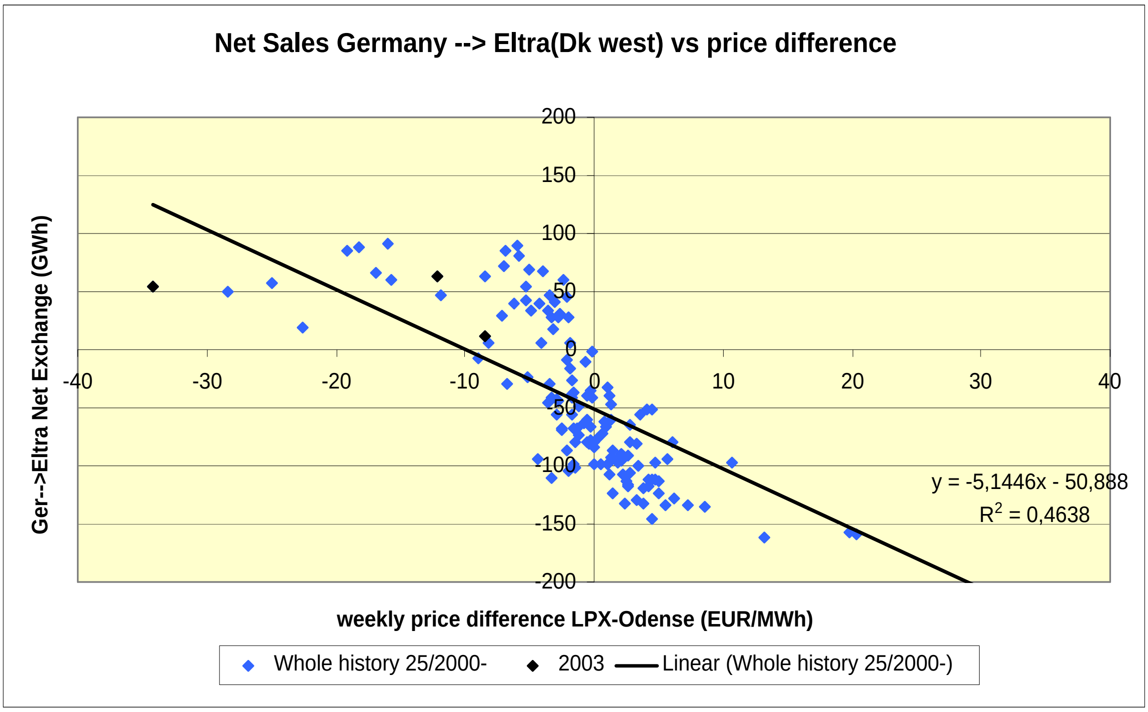

*Pic4-48: leverage of infow & water reservoir level on spot price, Norway + Sweden*



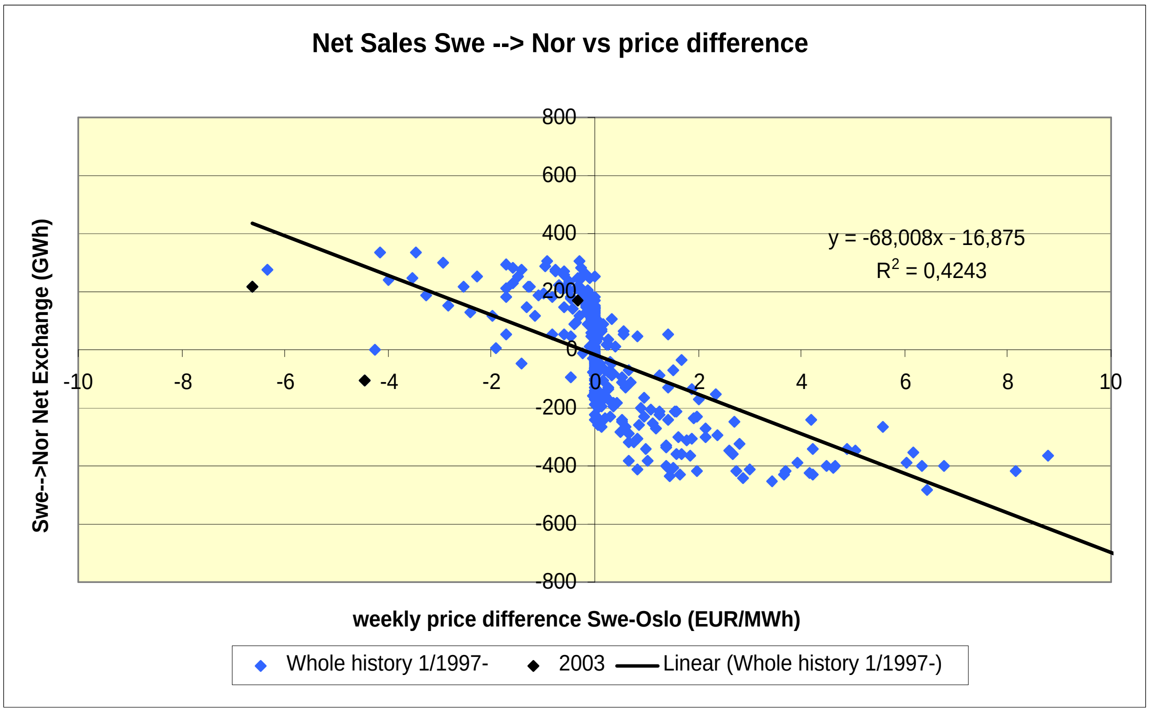

*Pic4-49: leverage of inflow, water reservoir level & spot price on hydro production, Norway + Sweden*



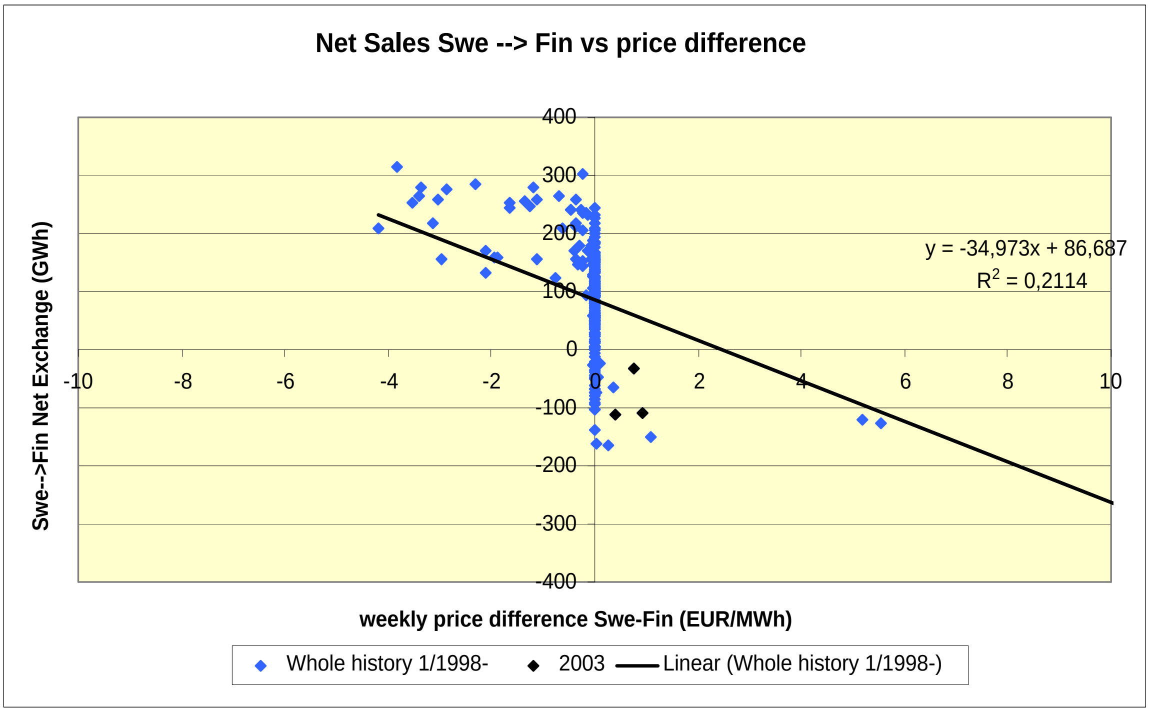

*Pic4-50: correlation between net sales between price areas and price difference between price areas – Germany-Sweden*




*Pic4-51: correlation between net sales between price areas and price difference between price areas – Germany-Denmark*




*Pic4-52: correlation between net sales between price areas and price difference between price areas – Sweden-Norway*




*Pic4-53: correlation between net sales between price areas and price difference between price areas – Sweden-Finland*