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Steps for improved congestion management and cost allocation for transit

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Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

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Preface

This report is part of the project “Steps for improved congestion management and cost allocation for power exchange and transit” carried out for the Nordic Electricity Market Group, the Nordic Council of Ministers by Ea Energy Analyses and COWI.

The report gives relevant background information on electricity trade and transit in the Nordic electricity market (section 1 and 2). Section 3 presents the results of a number of quantitative analyses focusing on economic gains and losses from electricity trade, and finally, section 4 presents the results of two interview rounds with stakeholders from the transmission system operators (TSOs), regulators, and national producer associations in each country.

The report summary (next section) focuses in particular on a number of proposed steps for improved congestion management and cost allocation in the Nordic power market. These steps were discussed during a workshop on 27 March 2007 in Gardermoen, and feedback from the stakeholders is presented in the summary together with the proposals.

April 2007,

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Summary and proposed steps forward

The ambition of this project is to build consensus among the relevant Nordic stakeholders regarding congestion management and compensation for transit of power. It is our hope that this report may contribute to a common understanding of the problems and point to pragmatic solutions to the problems built on quantitative and qualitative analyses.

The project is based on four pillars:

- Literature review (section 1)
- Analysis of historical data of prices, power flows and transmission capacities (section 2)
- Economic analyses of trade (section 3)
- Stakeholder views (section 4)

Background

The Nordic electricity market is well-known for its success. Large volumes of electricity are traded on Nord Pool across national borders, and the transmission system operators (TSOs) share reserves through a coordinated planning. The volume of cross-border trade is increasing each year. See Figure 1.

Nord Pool was established in Norway in 1993, and in 1995 the Nordic energy ministers agreed to expand Nordic electric power co-operation. Sweden joined Nord Pool in 1996, Finland in 1998 and Denmark in 1999 (West) and 2000 (East). Traded volume on Nord Pool spot reached 250 TWh in 2006, corresponding to 60% of total electricity demand in the Nordic countries.

2007 may be the year when further integration takes place – see our suggested steps in this direction below.

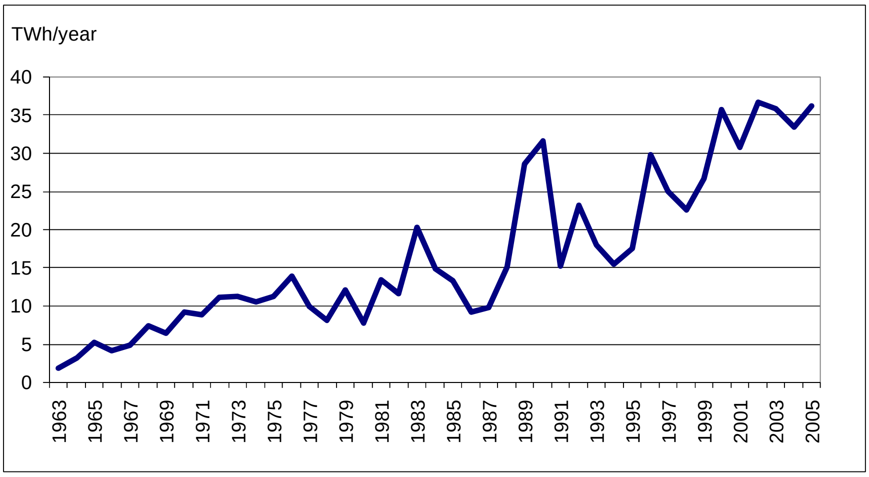

Figure 1: Exchange of power in the Nordic system. The curve shows the sum of flows between the four countries. For example from Sweden to Finland, from Finland to Sweden, from Norway to Denmark, from Denmark to Norway etc. Power exchange with the Continent is not included (Nordel, 2006)

As a result of cross-border trade, transit is also increasing. In current models, transit is defined as the minimum value of import and export for a given area. For example, if import to an area is 250 MW and export is 100 MW, then transit is 100 MW. Table 1 illustrates that all Nordic countries have some level of transit. Sweden has the largest absolute transit, while Denmark has the highest transit in relation to total demand.

Table 1: Average transit in five Nordic areas. January 2001 – November 2006

	Transit	Transit / Demand
Denmark	711 MW	13,0%
Finland	376 MW	3,0%
Norway	108 MW	0.5%
Sweden	1,011 MW	4,0%

The electricity market is in part commercial and in part regulated. The transmission lines and the TSOs are regulated monopolies, while power generation is a commercial activity. Concerns for the environment, security of supply, harmonisation of the market, and for misuse of market power are the reason for intensive public regulation.

Table 2: Regulatory set-up of the electricity market

National authorities	Define TSO activity Legislation regarding generation and trade
Nordic organisations	Nordic grid code (Nordel) Nord Pool
EU	Directives on free trade CO_2 quotas

Benefits of trade

As with any other goods, cross-border trade in electricity can add welfare to society. Nordic, as opposed to national, dispatch of power generation can reduce total costs. This is illustrated in this project by several model runs, each showing how different interventions in the electricity market would influence total welfare. See section 3.

As an example, calculations show that a theoretical 20% reduction in the transmission capacity between the Nordic countries (meaning less trade) will reduce total welfare by €66m (the examples are described in greater detail below, see Table 3). However, large differences exist between countries and between consumers and producers. In general, less trade is costly for consumers, while producers benefit by higher prices. Also, our results clearly show that the impact of an intervention is spread to all Nordic countries and even to the Continent. Half of the total losses in this example are located outside the Nordic countries.

Trade between the Nordic countries is encouraged by the variation in generation technology: Hydro, wind power, nuclear, fossil fuels (with and without district heating) and biomass. Each technology has its strengths and weaknesses, which can be offset by trade.

However, electricity is a special good. As it cannot easily be stored, a number of other issues arise:

- Mitigation of market power. In small electricity markets, a dominant producer can exercise misuse of market power. By different strategies he can collect an extra profit at the expense of consumers. Efficient trade between different areas can act as protection against such misuse.
- Security of supply. Without cross-border transmission lines, each area would need its own reserves. With power exchange, neighbouring areas can act as backup. In dry years, fossil fuel power plants play a special role of supplying the missing energy.
- Price stability. Efficient trade can level-out price variation, and a stable price and predictable future prices are important for potential power plants investors.

Congestion management

Congestion management is crucial for the electricity market. The theme is complicated and debated both in the Nordic countries and in Europe. Market splitting is used in the Nordic countries as the general method for congestion management. The methods include counter trade or the reduction of import and export capacities.

In the Nordic model for congestion management, the TSOs play an important role. Prior to bids being submitted to Nord Pool the TSOs publish the available capacity on the transmission lines between price areas. The capacity is often reduced to a level below the thermal capacities of the lines due to stability concerns or to potential overload of other lines. The capacity available for the market is on average 75% of the full capacity on several lines (see section 2). Reduced capacities have a severe impact on the market. The probability of congestion – different prices across the line – is high when capacities have been reduced.

The announced capacities are based on qualified presumptions by the TSOs about the power flow the next day. The power flow is determined by the dispatch of generation, which again is heavily influenced by the price formation in the spot market. When the operating hour approaches, many aspects are often different from what was anticipated. The possible available capacity in the operating hour can be higher or lower than announced the day before.

In Figure 2, the actual flow on a congested line is illustrated. 20% of the time the actual flow in less than 90% of the announced capacity, and 9% of the time the flow is more than 10% higher than the announced capacity. The same picture can be found on several other transmission lines.

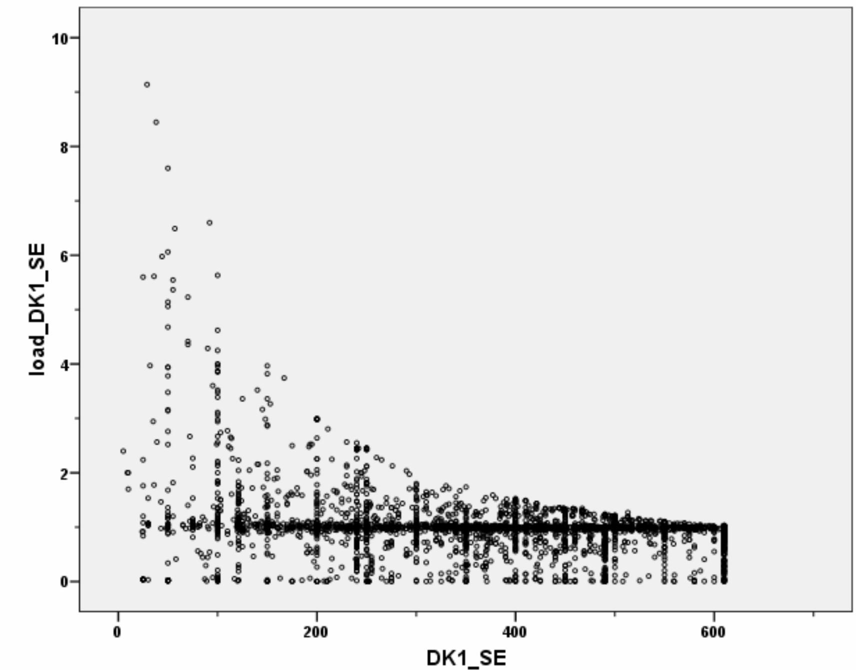

Figure 2: Actual flow vs. announced capacity. The x-axis shows the announced capacity for the transmission line between West Denmark and Sweden in MW. The y-axis is the actual flow divided by the announced capacity. A value of 1 means that the actual flow is equal to the announced capacity (as expected on a congested line). A value of 2 means that the actual flow is twice the announced capacity. Only hours with congestion are included (price in Sweden higher than in Denmark West)

These deviations can be caused by outage of power plants or unexpected flow patterns, or be a result of the security margins used in the evaluating of tomorrow's power flows. It may be costly not to use a congested line up to the limit defined by the need for security.

Compensation schemes for transit

The Nordic countries have participated in the ETSO compensation scheme for cost allocation since 2004. An interim arrangement has been designed for 2007. It is currently unclear how this system will develop in 2008. However, there is consensus in the Nordic countries that this is an issue to be solved in an EU context rather than a Nordic context.

An ideal compensation scheme could contribute to balanced incentives for investment in new transmission lines. New transmission lines will typically increase the transit, and local (national) benefits combined with the extra revenue from a compensation scheme could help pay back the investment.

Value of cross-border trade

In this project, the Balmorel model has been used to analyse the Nordic power system. The model is described in detail in section 3. The model is briefly described below.

- The model is a 10-area representation of the Nordic electricity system with detailed descriptions of the relevant production technologies.
- It finds optimal dispatch for the whole area, respecting electricity demand, district heating demand and transmission capacities between areas. The optimisation feature makes the model a powerful tool for comparing the impact of different interventions, for example the impact of transmission capacities or alternative generation technologies, because two or more optimal solutions can be compared.
- The model computes consumer surplus, producer surplus as well as congestion rents. In this way, the total welfare-economic consequences for a single price area or for the total studied area can be described.

The model has been calibrated for 2005, and assumptions have made for the years 2015 and 2025. For 2015, it is assumed that the five prioritised links have been built, and for 2025, three different scenarios have been tested including more wind power and increased transmission capacities to the Continent. For updated information on the model, please consult www.balmorel.com

Table 3 shows the impact of reducing cross-border transmission capacities between for four Nordic countries by 20% in a normal year. The total loss of welfare is €66m (calculated for one year). However, for producers there is a total surplus of €87m.

Congestion rents (bottleneck income or trade surplus) demand a special explanation: For each transmission line, congestion rents are calculated as the power flow multiplied by the price difference over the line. The congestion rents are divided equally between the countries connected by the line. Congestion rents are used to reduce TSO tariffs and can be seen as income for consumers. In Table 3, the internal Nordic lines generate an extra €20m when the transmission capacity is reduced, but the external lines generate €63m less, adding up to a total of €-43m. With the practice of dividing the congestion rents equally between the countries involved, consumers from the Continent lose €32m.

In section 3, model runs for dry and wet years are reported. Also in section 3, a series of different reductions are tested: 5 to 50% reduction in transmission capacities. It is found that a reduction of 20% or more has severe consequences in a dry year. With the applied assumption, the system only balances when consumers are disconnected in Norway South and Oslo.

Table 3: Welfare-economic consequence of a 20% reduction in transmission capacity in 2015 – Normal year. Million €.

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	0.7	-5.6	55.3	36.2	0	86.7
Consumer surplus	-4.4	2.4	-72.1	-35.2	0	-109.2
Sub total	*-3.7*	*-3.1*	*-16.7*	*1.0*	*0*	*-22.5*
Bottleneck incomes, internal	3.8	1.4	7.6	7.2	-	20.0
Trade surplus, on links to other countries*	-11.3	-0.3	-14.9	-5.2	-31.7	-63.4
Total	-11.2	-2.0	-24.0	3.0	-31.7	-65.9

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

Marginal benefits of transmission lines

Congestion management is most important when transmission capacity is a scarce resource. As mentioned in the assumption for 2015, all five prioritised lines are in use. In this section is it indicated which connection could be the next to expand.

The results for 2015 are clear (see Table 4): The marginal values of increased transmission capacities are highest for lines connected to the Continent, for example from Norway, Sweden or Denmark. If the line from the Netherlands to Norway could be expanded by 1 MW, the marginal benefit would be €280m/year in a weighted average year. A weighted average year represents the results from a wet year (weighted 15%), a dry year (also 15%) and a normal year (70%)

Table 4: Marginal benefits of increased transmission capacity (€/MW), 2015 and 2025 – Weighted average year. Values are rounded to one or two significant digits. In section 3, marginal benefit values can be found for all transmission lines.

	Marginal benefit, 1,000€/MW		
Transmission line between price areas	2015	2025/ Wind+gas	2025/ +Double capacity
Norway South – Continent (DC)	280	280	270
Sweden South – Continent (DC)	60	60	10
Denmark East – Continent (DC)	50	50	3
Denmark West – Continent	50	50	3
Norway South – Denmark West (DC)	9	9	60
Sweden Middle – Denmark West	5	4	50
Sweden South – Sweden Middle	0	2	50

For 2025, two scenarios are presented here (described in details in section 3, together with a third scenario). In the first scenario, *2025/Wind+gas*, extra production capacity is established: 4,000 MW gas turbines in Norway South and more wind power in all countries, resulting in a total annual wind production of 22 TWh. It can be seen from Table 4 that the results are practically unaffected by this. The increase in production capacity is offset by the increase in demand.

In addition to the assumption in the first scenario, all capacities to the Continent are assumed to have doubled in the second alternative, *2025/+Double capacity*. In this scenario the marginal benefit of the connection from the Continent to Norway is still high, while the value of other lines to the Continent has decreased significantly. However, new congested lines have emerged internally in the Nordic area. The new import possibility creates congestions, e.g. from Denmark to Sweden and Norway and internally in Sweden.

Nodal pricing

Market splitting, as used in Nord Pool spot, is a simplified way to find dispatch based on bids. The method only includes little information about the grid (the announced capacities between price areas). Nodal pricing, on the other hand, includes full information about the grid and gives the optimal dispatch. Because of the physics of power flow, the location of a power plant influences the power flow in the grid. Nodal pricing takes this into account and gives the marginal cost of supplying electricity to the node, which is the economically right signal.

To the market players, nodal pricing is not more complicated than market splitting. The players still make bids, e.g. price-dependent bids for demand and generation. Only they must indicate to which node the bid is made. A node can be a transformer in the transmission grid. For the power exchange more computing power is needed, but the task is possible to solve. Several markets, e.g. PJM[1] in the USA and New Zealand have practised nodal pricing for years.

Nodal pricing can be the key to a better utilization of the transmission system. This will result in better use of the costly investments and will improve competition in the market. More competition also means reduced possibilities for misuse of market power. Section 1 gives several references to literature about nodal pricing, including the issue of market power.

Stakeholder views

As part of this study, representatives from the TSO, the regulator and the national association of producers in the four countries have been interviewed.

All stakeholders state that the disagreements regarding congestion management are currently the most important issue to be solved in the Nordic electricity market. It is stated that efficient, harmonised and transparent handling of congestion is crucial for the market. Some stakeholders point out that capacity allocation is not part of the actual congestion management, but an important prerequisite.

Several stakeholders feel that also a fair transit compensation mechanism is extremely important, and that the two questions are interlinked.

Main challenges regarding congestion management. The main issue is the issue of reducing the transmission capacity at national borders. Several stakeholders state that the reasons for doing this are not sufficiently justified. All stakeholders feel that current controversies regarding congestion management are seriously threatening the Nordic cooperation.

All stakeholders agree that counter trade is not the best way to handle structural congestion. The majority point out that the current practice is not transparent, does not yield the “true” prices, and that unnecessary price fluctuations are induced. It is stated that the Nordic consumers are the real losers if the grid is not efficiently utilised and that the practise of reducing capacity in the morning increases risks and unpredictability and thereby reduces the amount of trade.

Regarding economy, it is stated that counter trade induces a cost to the TSO and thereby yields the right incentive to invest.

Main challenges regarding transit compensation. The main challenge is that there is no long-term agreement concerning compensation. Several stakeholders feel that a true and fair mechanism will be complicated and thus not transparent enough. Transparency and simplicity are stated to be important features.

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[1] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia – an area with a 51-million population.

It is stated that the ITC scheme (Inter TSO Compensation mechanism) suggested by the EU Commission is inadequate because it does not take the actual trading rules or benefits of trade into account. It is also stated that an important problem is that the regulated prices of the horizontal grid are unfair – costs should be based on standard prices.

Proposed steps forward

Congestion management

Based on the different types of analyses and the feedback from stakeholders the following practical steps are suggested:

Step no. 1: Make a new division into price areas with no special respect to national borders

Today, the Nordic regional electricity market is divided into seven to nine price areas. Finland and Sweden each have one price area, Denmark has two and Norway has two to four areas, depending on the need. Kontek on the border between Denmark and Germany is the latest area, introduced in 2005.

In the Nordic countries, there is a common understanding that structural congestion should be handled by market splitting (price areas). However, the current division has its roots in the historical development based on the merging of four national markets.

Some interconnectors are reduced to a level below their thermal capacity for several hours a year. Bottlenecks that are inside price areas are the main reason for this. This reduction of transmission capacity is not always optimal.

A way to improve congestion management in the Nordic marketplace is to split the market according to a set of commonly developed objective criteria which are the same in the whole regional market area and independent of national borders.

Stakeholder feedback:

> The step was discussed in three groups and was reported to be a very important one. It was agreed that political decisions are needed. The Nordic Energy Ministers were encouraged to make such a statement at their next ministerial meeting in September followed by the necessary national decisions. Regulators and TSOs are important stakeholders in the further process. Decisions should be prepared already in 2007. The groups mentioned that this decision is highly related to the proposed step 2.

Step no. 2: Develop a set of objective criteria for possible new division into price areas in the Nordic electricity market

In the ongoing debate regarding congestion management, three questions in particular seem to be of importance:

a) The questions of how to distinguish between structural and temporary congestion. How often must a specific cross section cause congestion before it is “structural”? A formal operational definition of structural congestion is missing.
b) The avoidance of market power is an important element in a well-functioning market. In the cases where the size and the location of price areas could increase the possible misuse of market power, this must be taken into consideration.
c) Possible common financing of counter trade.

Ad a) Structural congestion: We suggest that every relevant cross section in the Nordic market is given an index based on the amount of congestion it has caused for a specific amount of time. The relevant time could be the last 3–5 years. The index could include duration and volume (e.g. volume that could have been transported, or price differences created by congestion, or areas affected).

Additionally, a guideline must be drawn up to define when the index indicates a structural congestion. Inspiration for definition of the guideline can be found in the literature and from similar practice in other areas, e.g. in California.

Ad b) Market power: The incentive to exercise market power can be discouraged by increased local competition or by competition from neighbouring areas. Competition from neighbouring areas can vary, depending on the amount of congestion and on the level of market integration if the area is outside the Nordic countries.

We suggest studying the impact of different congestion management methods on market power, e.g. market splitting with price areas of different size, counter trade and nodal pricing.

It is our understanding that the division into price areas that yields the best or even optimal utilisation of the grid will also discourage misuse of market power the most. Possibly even with rather small price areas.

Ad c) Common financing of counter trade: Counter trade is an integrated part of congestion management. Counter trade is used when announced trading capacities must be reduced due to risk of overload on certain lines or components.

When the price areas are defined from a strictly Nordic rather than national point of view, it seems natural that all aspects of congestion management should be viewed in a regional context.

We therefore suggest developing a common financing model for counter trade.

Stakeholder feedback:

> It is a very important step in the right direction. Much work has been done already and progress is not possible without Nordic political commitment. Point a must be carried through by the TSOs. Point b is a very important task. Regulators and competition authorities should be given responsibility for this point. Point c probably needs new national legislation, and a roadmap for the implementation should be outlined. There was no clear recommendation as to who should lead this task, but possibly the TSOs should prepare the needed analysis of consequences. Point a, b and a roadmap for c should be commenced immediately after the common political will is expressed in step 1, hopefully in September 2007.

Step no. 3: Publish data and models

On some interconnectors, the capacity is quite often reduced to a level below the physical capacity based on expectations for next day's operations. Each day at 9.30, the TSOs publish maximum trading capacities between price areas for the following day of operation.

To increase transparency, a code is now published to describe the reasons for reduced trading capacities. This practice was initiated on 12 March 2007. Statistics based on the period 12–26 March show that the capacity on the interconnectors was reduced during 37% of the time.

Publishing codes is an important step forward, but we suggest improving transparency even further, by publishing the data and models that lead to the conclusion that capacities must be reduced.

By exercising full transparency, any doubt about the fairness of the action can be removed. Furthermore this could lead to a harmonisation of how the TSOs make their decisions, e.g. security margins, expectations for next day's production dispatch etc.

Stakeholder feedback:

> Also this step was considered important and was recommended by the groups discussing it. The TSOs should continue the process they have started in March 2007 by publishing codes describing the reason for capacity reduction. By publishing both data and relevant models immediately after the spot market has cleared, actors and analysts will better understand the background for the decisions.
>
> The issue of transparency will continue to exist. Regulators should follow the development. Some mentioned confidentiality as an issue in relation to generator data, however, power flows and expected prices cannot be considered confident.

Step no. 4: Increase intra-day trading to fully utilise congested capacity

Trading capacities are published at 9.30 on the day before the day of operation. Closer to the operating hour, new information is available and in many cases the actual maximum capacity can be increased. If congestion and price differences have occurred on the line, it is important to use intra-day trading to optimise utilisation of the grid and production capacity. This can be done by Elbas or by means of regulation power.

Elbas is a market with rather low liquidity. Expanding Elbas to the whole Nordic market could increase liquidity. Additionally the cost of using this market could be reduced, for example with a discount to small actors.

We suggest increasing the possibilities for intraday trading, e.g. by expanding Elbas to the whole Nordic market. Also it is suggested to streamline the effort to update available transmission capacity on a frequent basis to give Elbas the best possible conditions.

Stakeholder feedback:

> Denmark West has opened for Elbas on 11 April 2007. Norway can be expected to follow soon, e.g. in relation to EU requirements in 2008. This could increase the traded volume significantly. Norwegian power producers and Nord Pool are central players. The step was considered to be in the right direction but only of medium importance. Questions were raised as to how often the available capacities are updated. Close to the operating hour, more information about the power flow is available and capacities could be adjusted accordingly. The current practice should be reviewed to see if additional capacities could be released.

Step no. 5: Study nodal pricing as next generation power exchange

Nodal pricing can improve the utilisation of the transmission grid.

We suggest studying the advantages and drawbacks of nodal pricing in the Nordic system.

This could include building a model of the Nordic system and demonstrating the difference in dispatch of power generation in this model and in a model with traditional market splitting. The study should include evaluation of existing markets using nodal pricing.

Stakeholder feedback:

> Many issues were raised in relation to nodal pricing. Nodal pricing could be a relevant long-term possibility. However, the solution is very different from the system we know today. How can hedging be done?
>
> A research project about the costs and benefits of such a system – as well as practical experience from markets with nodal pricing – was highly recommended. This could broaden the understanding of nodal pricing. There was no clear recommendation as to who should take action. Some called for Nordel and the regulators to take the initiative. Others mentioned Nordic Energy Research. It was mentioned as important, however, that such a study should not be used as an excuse to delay other important activities (e.g. step 1 and 2).

Transit Compensation

Step no. 6: Define local benefits of transit

Transit through an area typically creates extra losses and the transmission lines must be expanded to cope with transit. However, also some local benefits of transit can exist. Congestion rents are one example of benefits. Other benefits are related to the trade of electricity, e.g. payment to power exchange or traders.

We suggest the Nordic countries demonstrate the local benefit related to transit and uses this as an argument in the European process concerning cross-border transit compensation.

Stakeholder feedback:

> The groups discussing this issue had some principal debate about the definition of transit. The question was mentioned as a European more than a Nordic issue, and ETSO is working on a new proposal. Congestion rents were mentioned as a local benefit. Transit is a result of several independent actions. The current compensation scheme is unfair. The dream of a single grid is unrealistic. Improved transit compensation should give the right incentive for new investments.

Step no. 7: Harmonise the value of the transmission grid

The value of the existing transmission grid is an important parameter in the different models for cost compensation. When using the values recognised by the national regulator, it is secured that transit power flow is not discriminated in paying for the grid. However, the regulated value is quite different between countries.

If standard values describing new infrastructure are used, more equal costs could be used across Europe. This could be a way to achieve consensus about a method.

We suggest to standardise the way the value of the grid is established in order to harmonise the payment for usage of the transmission grid.

Stakeholder feedback:

> The compensation method that is now elaborated in ETSO includes a combination of existing and future grids. The value of the future grid is calculated in standard prices. It is important with standardised methods. It was considered to be important that the Nordic countries harmonise their views on this, which is probably a task for the TSOs and for the regulators. No specific institution to take action was recommended by the groups.

Incentives for investments

Together with congestion management and transit compensation, investments in new transmission lines are three preconditions for an efficient electricity market. Transmission lines require heavy investments and the benefits are widespread.

Step no. 8: Prioritise transmission lines to the Continent

The economic analyses (section 3) give several examples of the broad grid impact of increased or reduced transmission capacity. The analyses also clearly indicate that the next round of investments in transmission capacity should be concentrated on increased transmission capacity between the Nordic countries and the Continent. The marginal benefits for such lines are in the order of 50,000 to 280,000 €/MW, which is a first indication of a potentially profitable investment even for costly DC lines.

A common Nordic and continental study could prioritise the potential lines to the Continent, taking total investment costs into consideration.

To fully benefit from new transmission lines between the Continent and the Nordic countries, the electricity market on both sides need to be harmonised or at least coordinated. This should have the same amount of attention as the concern for the investment in the lines.

1. Background

Electricity infrastructure has a long lifetime, and to a large degree the current system has been designed to fulfil local requirements for electricity. Liberalisation of the electricity market and the growth in intermittent generation create new power flow patterns with increased cross-border trade and transit of electricity.

The international exchange of electricity is less than 10% of all production – both in EU-15 and among the Nordic countries (Brunekreeft et al, 2005, and see Section 2 below). Historical trends indicate a continued increase in exchange of electricity. More efficient trade between regional markets as well as new transmission lines – like the Nordic five prioritised links – will increase the traded volume.

International power trade can lead to more efficient allocation of production, but raises several questions:

- How can congestion management best be performed? Is the Nordic tradition with market splitting and zonal pricing the best solution? Is frequent use of counter trading (re-dispatching) compatible with high cross-border trade?
- How should losses be paid for in relation to international trade? In the US, losses have been reported to as much as 20–35% of the power moved (Brunekreeft et al, 2005). Similar losses can be expected in long-distance European power transport. The question is of special interest for countries with a large volume of transit.
- How can market rules and regulations be constructed to ensure correct incentives for developing the transmission grid for international trade? This is of great interest for both transit countries (where investments in transmission lines could take place) and for countries sending or receiving the transit electricity.

These issues are heavily influenced by the EU regulation on cross-border trade of electricity (Regulation 1228/2003) and by the work of the Florence Regulatory Forum.

Congestion management

Congestion management is an important issue for the electricity trade. In the Nordic countries, congestion management takes place in a three-step approach:

- The TSOs (system operators) make an *ex ante* evaluation of the secure use of transmission lines. Then they submit the available transmission capacity to Nord Pool in every hour of the following market day. In many cases, this leads to a reduction in available capacity on certain transmission lines. Since the evaluation takes place before bids for the day-ahead market. it is based on an estimate of the next day's production pattern (which is influenced by the prices later obtained in the day ahead market) and on security rules, like the N-1-rule (that the system must be able to survive the loss of a the most critical component). This information is published each day at 9:30.
- Bids for demand and generation in the spot market are submitted to Nord Pool before 12:00 noon every day. The day-ahead market allocates production to each price area in a way which ensures that the use of the transmission lines IS below the announced available capacity. Whether congestion and price differences occur depends on a combination of the available capacity and the bids to the market. All cross-border trading among the Nordic countries takes place through the Nord Pool.
- In the operating hour, the TSOs activate regulating power if deviation from the planned power flow threatens to exceed the capacity of the transmission lines. However, the changes in actual power flow can also result in higher capacities: Often, the *ex ante* evaluation of the maximum power flow is relaxed in the operating hour, due to the more accurate information now being available. In the operation hour, detailed plans describing power flows exist for demand and generation. Unused capacity can e.g. be used to transport regulating power. In Section 2, we show that the available transmission capacities often change from the day-ahead situation to the operating hour.

The capacity allocated to the market is called net transfer capacity (NTC). Information on how to calculate NTC can be found in ETSO (2000) and Nordel (2006, b).

The determination of the net transfer capacity can be described as a chicken-and-egg dilemma: The generation pattern is required to determine if lines will be overloaded, and the available capacities are needed for the trading that determines the generation pattern (ETSO and EuroPex, 2005).

Glachant and Pignon (2005) present a critical view on the activity in the Nordic countries where the TSOs decide the available capacity – and the regulation of this activity. They underline that congestion in power systems is not hard facts that are easy to check. They argue that the TSOs have a "perverse incentive" to reduce the capacities and find that the Nordic TSOs are only "light handed" regulated. As one of several solutions, they recommend that TSOs frequently calculate the actual influence of internal and external flows on signalled interconnection congestion. Having to do so ex ante consistently with existing data and the most relevant grid scenarios will greatly facilitate any ex post evaluation of further decisions taken by the TSOs.

Ehrenmann and Smeers (2005) criticize the Florence Regulatory Forum for neglecting nodal pricing as a principle for congestion management. By using zonal pricing with a very limited representation of the transmission lines (as in Nord Pool), the dispatch of power plants is in-optimal in situations with congested lines.

Nodal prizing finds optimal power flows with respect to the actual transmission grid and the physical laws guiding power flow (Kirchoffs law).

Nodal prices are determined by calculating the incremental cost of serving one additional MW of load at each location subject to system constraints (i.e. transmission limits, ramp rates of resources, contingency analysis) (IMO, 2004).

Nodal pricing exists in New Zealand (since 1997), US Midwest: PJM (1998), New York (1999), New England (2003) and is being implemented in Texas.

Market splitting (zonal pricing) is a simplified version of nodal pricing, where several nodes are demanded to have same price. This increases the liquidity, but the result is less precise, since any dispatch within a price zone is considered as the same value – independent of the impact on the power flow.

Leuthold et al. (2005) describes how nodal pricing can improve the integration of wind power in the German electricity system.

Although market power can exist in both market designs, Harvey and Hogan (2000) argue in their article *Nodal and Zonal Congestion Management and the Exercise of Market Power* that nodal pricing reduces the monopoly profit that dominant generators can obtain. One of several arguments is that nodal pricing leads to a better use of transmission lines, compared to zonal pricing. This will in itself reduce misuse of market power.

Bjørndal et al. (2002) conclude in the article *Congestion Management in the Nordic Power Market – Counter Purchases and Zonal Pricing* that: "We have also seen that zonal pricing makes things completely different, as regards the prices of course, but also as regards the flows on the grid, the congestion, the social surplus and the grid revenue. Hence, zonal pricing is not a mere simplification of nodal pricing; the aggregation of nodes into zones with uniform energy price does really change the allocation of social surplus among the agents, thereby bringing about winners and losers in the market with different and conflicting incentives."

Considering the size of price areas, it could be a way forward to study the 5% rule that is applied in California as a guideline for when price areas should be created or merged (See Alvarado and Liu, 2003).

Investment in transmission lines

The Nordic electricity system is partly liberalised (e.g. investment in new generation capacity and trade in the physical and financial markets) and partly a monopoly (e.g. investment in transmission lines, payment for losses, as well as requirements of ancillary services). Subsidised environmental-friendly electricity production, e.g. wind power, makes up an in-between category.

The liberalised and monopoly parts are highly interdependent, e.g. since investments in new transmission lines influence prices, they also influence the profitability of investments in new power plants.

Regulators have the task of securing fair behaviour of the monopolies within EU and national laws.

It is generally recognised that the market for transmission lines cannot be left unregulated. If transmission lines should be financed only by congestion rents, too few lines would be built (Stoft, 2002).

Investments in new transmission lines are costly, e.g. the total costs of the five Nordic prioritised links amount to 940 M€. Nordel (2005, a) describes the value of new transmission lines as:

- Optimisation of generation and energy trading
- Reduced risk of energy rationing
- Reduced risk of capacity shortage
- Changes in active and reactive losses
- Trade in regulating power and ancillary services
- The value of a better functioning market.

The benefits of new transmission lines are generally spread over a large area, and it is a challenge to allocate the investment costs accordingly. Because of the nature of electricity flow, any new transmission line will affect the power flow in several countries.

The electricity market will continue to develop. In 2006, the EU published a vision for the electricity system named SmartGrids. In this vision, there is free trade throughout Europe, facilitated by open markets, harmonised rules and transparent trading procedures. European wide trading of regulating power from the Nordic hydro power plants is mentioned as an example of future trading (see European Commission, 2006, and Coll-Mayor, et al. 2007).

The issues of congestion management and cost allocation for transit must be settled to reach a fully integrated European market.

In a system with nodal marginal pricing, revenues are created over transmission lines that can be used to recover the cost of the network. *In ideal settings*, the revenues would exactly cover the cost of a line of optimal size.

However, the term “in ideal settings” is a strong requirement. With nodal pricing, the price is generally different in every node. With zonal pricing (as in Nord Pool), price difference only occurs when a congestion exists. Congestion rents can be high when the line is used at full capacity but zero in all other times. Congestion rents do not send any signal of the value of a line when the flow is less than full capacity. Furthermore, “in ideal settings” includes that transmission lines can be constructed at any size, and that the size of the line is only determined by the power flow (and not by security considerations like N-1).

Pérez-Arriaga et al. (1995) and Brunekreeft et al (2005) and Rubio-Oderiz, Pérez-Arriaga (2000) indicate that in practical settings only a fraction of the total network cost (20–30%) can be covered by “network revenues”. They conclude that additional mechanisms must be put in place to secure optimum investments in transmission lines.

Compensation schemes

A presentation of several European inter-TSO compensation methods can be found in Camacho and Pérez-Arriaga (2007). The two main types of compensation methods are: 1) Average participation (AP) and 2) With and Without Transit (WWT). Furthermore, the 2006 ETSO model is described as a provisional method (PM).

The physical laws governing electricity flow in a network tend to make the compensation methods complicated. Every power transaction influences the flow of several transmission lines – not only the ones directly between buyer and seller.

Camacho and Pérez-Arriaga (2007) recommend the AP method, but they acknowledge than even the WWT would represent an improvement in comparison to current practise.

Nordel (2005, a) describes the following possible methods to facilitate investments in transmission lines:

- Nordel bilateral financing (current model)
- Nordel bilateral financing with earmarked congestion rents (partially used in relation to the five prioritised links)
- Nordel grid planning and financing mechanisms
- The establishment of a Nordic grid investment company.

However, a fifth option exists: A European system for compensation for losses and the use of the grid by transit of electricity. An ideal compensation scheme would give the optimal incentive to a country to expand its network. By investing in a highly needed transmission line, transit (and compensation) would increase, and this could pay for the line in addition to the local benefit of the line.

The typical economic analysis for a new transmission line describes the total welfare consequences in a socio-economic analysis with and without the line. If the total consequences are positive (taking account for the cost of investment), then the project should to be implemented. This evaluation must not be taken as a return-on-investment analysis for the TSO (Delincé, 2007). Major benefits occur outside the TSO economy.

In the 2006 ETSO compensation scheme, 395 M€ were collected and redistributed according to the volume of transit in the participating 30 TSO-areas. In 2005, the funds were 370 M€. The compensation scheme is targeted losses and the use of the transmission lines. Payment for using the transmission lines is seen as a combination of payment for the existing network and as a source for investment in network expansion.

The current as well as the suggested compensation schemes redistribute costs between TSOs. Congestion rents are collected by the TSOs, and this revenue is not earmarked to any specific use.

It is a principle for the compensation schemes that transit users should pay the same for using the network as local users. Therefore, the value of the network has been set according to the values used by the local regulator. The practice for valuing the network has been different in the participating countries. In Sweden, the value has been set relatively low, leading to low compensation levels.

The 2006-type of compensation scheme, as well as the alternatives currently discussed, all have the structure of being ex-post compensations. The compensation does not (or only to a marginal extent) influence the allocation of production. This is by some seen as a quality, but is in contrast to the ideal of nodal prices where all cost are signalled in real-time and at each node. Such an ideal market is described in the 2006-EU vision, SmartGrids. Here computation and communication are abundant, and all cost of transporting electricity can be expressed in real-time nodal prices.

Current disputes

The congestion rents are generated when bottlenecks exist in the spot market. Dependent on the hydrological conditions, congestions rents within the Nordel area can vary from 25 to 100 M€/year. Congestion rents are collected by Nord Pool and have been divided equally by the involved TSOs. In a certain period, the congestion rents were allocated to contribute to the financing of investments in the five prioritized links. Generally, however, rents received by the TSOs are used to reduce tariffs. Since October 2006, no agreement has been found regarding the distribution of collected congestion rents.

Nordel agrees on the principle that structural bottlenecks shall be dealt with by market splitting and that temporary bottlenecks can be dealt with by counter trade. However, disputes exist about the practical interpretation of these rules, e.g. about the practise of reducing border capacities to relieve internal bottlenecks. See STEM (2004) and Copenhagen Economics (2006).

Since 2004, The Nordic countries have taken part in the ESTO scheme for compensation for costs associated to transit of power. The 2004–2006 system was expected to be renewed in an improved and fairer 2007 system. However, negotiations have not succeeded, and currently the scheme for 2007 is undecided.

The disputes are serious for the Nordic electricity market.

2. Trade, transit and congestion in the Nordic market

Trade

The exchange of power between the Nordic countries has taken place for 100 years, but has increased steadily for the past 40 years (see Figure 3). While the Nordic electricity demand has doubled since 1975, the exchange of electricity has increased by a factor 3.5. The drives behind this development have been new transmission lines (internal, between the Nordic countries as well as lines to the continental Europe), the change in generation technology (nuclear power and wind power) as well as the liberalisation of the electricity market. In 2005, the Nordic power exchange corresponded to 10% of the electricity demand.

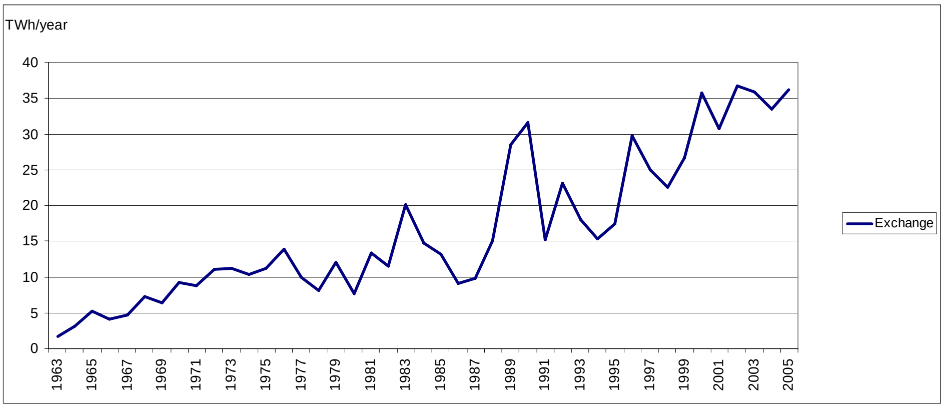


Figure 3: Exchange of power in the Nordic system. The curve shows the sum of the flows between the four countries. E.g. from Sweden to Finland, from Finland to Sweden, from Norway to Denmark, from Denmark to Norway etc. Power exchange with the Continent is not included. (Nordel, 2006)

The exchange of electricity is heavily influenced by the availability of hydro power. In dry years, the power flows north, while the opposite is the case in wet years. In the same way, wind power is motivating power exchange – but in much shorter cycles of hours and days instead of months and years. The large daily variations in prices in the German thermally dominated system also motivate power exchange.

Figure 4 shows how the spot market has increased – and covers 45% of the total demand in 2005. The growth increased dramatically in 2006: Traded volumes through Nord Pool Spot in 2006 amounted to 250 TWh.

This equals more than 60% of the total consumption of electricity in the Nordic countries. In January 2007, the daily volume on the spot market exceeded 1 TWh, corresponding to 70% of the electricity demand (www.nordpoolspot.com).

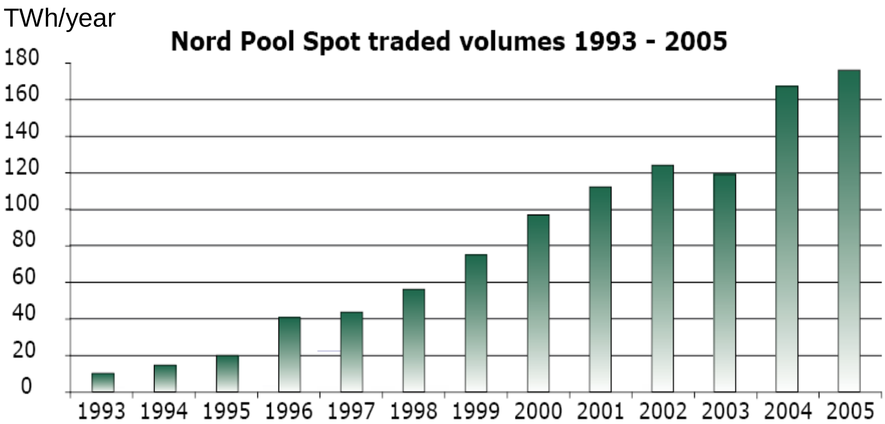


Figure 4: Traded volumes in Nord Pool Spot.

Transit

In this study, we focus on transit of power. Transit is defined as the minimum value of import and export over different lines for a given area, e.g. if import to an area is 250 MW and export is 100 MW, then transit is 100 MW. Unless otherwise noted, we will use hourly values for the calculation of transit.

All Nordic countries have transit. The absolute values are highest for Sweden (1.000 MW), while Denmark has the highest average transit compared to average demand (13%), see Table 5.

Table 5: Average transit in five Nordic areas. January 2001 – November 2006

	Transit	Transit / Demand
Denmark	711 MW	13,0%
Finland	376 MW	3,0%
Norway	108 MW	0,5%
Sweden	1.011 MW	4,0%

As illustrated for Norway in the table below, the transit increases when an area is subdivided.

Table 6: Average transit in sub-areas of Denmark and Norway. January 2001 – November 2006

	Transit	Transit
Denmark	711 MW	West: 452 MW East: 260 MW
Norway	108 MW	North: 125 MW Middle: 42 MW South: 153 MW

The introduction of the two optimization areas, DK1A and SEA (see Figure 5), serves to improve the allocation of power flow on congested lines. However, it is difficult for an outsider to understand or evaluate the capacities allocated to the "lines" connection to these two areas. E.g. DK1A-SEA does not represent a physical transmission line.

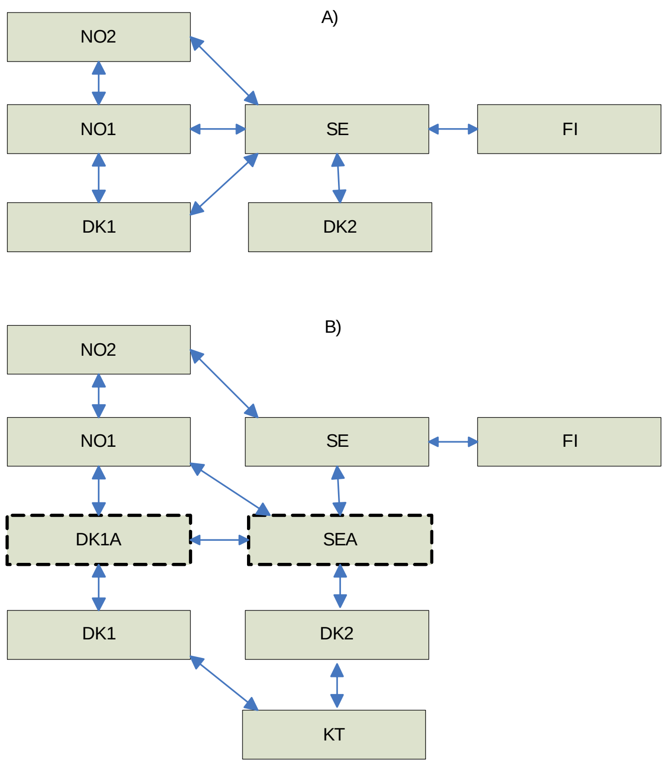


Figure 5: Price areas in the Nordic electricity market
The number of price areas is developing. Here is shown two examples. A) is from 2001 and B) from 2006. Norway has been divided into two to four areas dependent on the need. DK1A and SEA are two optimization areas; these areas are used to improve the use of congested lines between Sweden, Norway and Denmark. The areas DK1A and SEA were introduced on March 15th 2004. The KT area was introduced on October 5th 2005.

Nord Pool has only little public available description of how the optimization areas are used (see Nord Pool Exchange information 13/2004 and 73/2005). Nord Pool has informed us that the optimization areas will also exist in the planned new version of the Spot market algorithm.

The transmission capacities allocated to the spot market are very often reduced. Table 7 shows key values about the capacity for the various lines.

Table 7: Capacities allocated by the TSOs to the day-ahead market. Data are from March 15th 2004 to November 19th 2006 (i.e. after introduction of the optimizing areas).

	Minimum, MW	Mean, MW	Maximum, MW	Mean / maximum,%
SEA_SE	5.000	5.000	5.000	100
KT_DK2	0	520	550	95
DK2_SEA	0	1.568	1.700	92
NO1_SEA	200	1.852	2.050	90
SE_FI	375	1.804	2.095	86
SEA_DK2	0	1.099	1.300	85
NO2_SE	0	1.090	1.300	84
SEA_NO1	0	1.649	2.050	80
DK2_KT	0	436	550	79
SE_NO2	350	855	1.100	78
DK1_DK1A	50	1.108	1.440	77
FI_SE	0	1.364	1.785	76
NO1_DK1A	0	738	1.000	74
DK1A_NO1	-631	688	950	72
SEA_DK1A	-120	425	620	69
DK1A_SEA	-460	422	620	68
KT_DK1	0	420	1.257	33
DK1A_DK1	300	466	1.460	32
SE_SEA	0	2.918	10.031	29
DK1-KT	0	338	1.550	22
NO1_NO2	-400	31	500	6
NO2_NO1	-500	-31	400	-8

Negative values of the announced capacity exist on several lines, e.g. DK1A_NO1. A value –100 MW on this line indicate than at least 100 MW must flow from NO1 to DK1A.

The capacities between NO1 and NO2 (both directions) are special. The values are constructed so that the flow on the line is determined by the TSO, e.g. demanding a flow of 300 MW from NO1 to NO2. No room is left for the market. This reduces the benefit of having the two areas NO1 and NO2.

From 12 March 2007 a code is also publish to describe the reason for reduced trading capacities. Codes used from 12. March to 15. April 2007 are:

10 – Normal capacity (100 MW tolerance)	63%
11 – Planned outage on cross-border connection	7%
14 – Internal congestion due to planned outage	12%
16 – Internal congestion due to stability	3%
90 – Reason not available	15%
Other codes	1%

In this short period the normal capacity is only available in 63% of the time. The most frequent reason to reduce the capacity of a transmission line is internal congestion.

Congestion

Congestion rents (power flow times price difference) have been high in 2005 and 2006, see Figure 6.

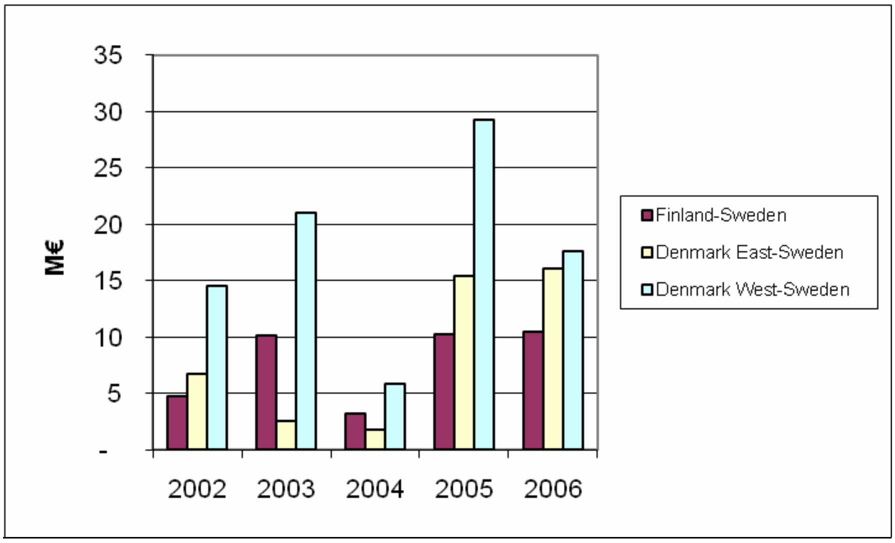


Figure 6: Congestion rents from Sweden to Denmark and Finland.2006 only include data until 19. November.

A reason for the high congestion rents in 2006 can be found in the high prices this year, see Figure 7.

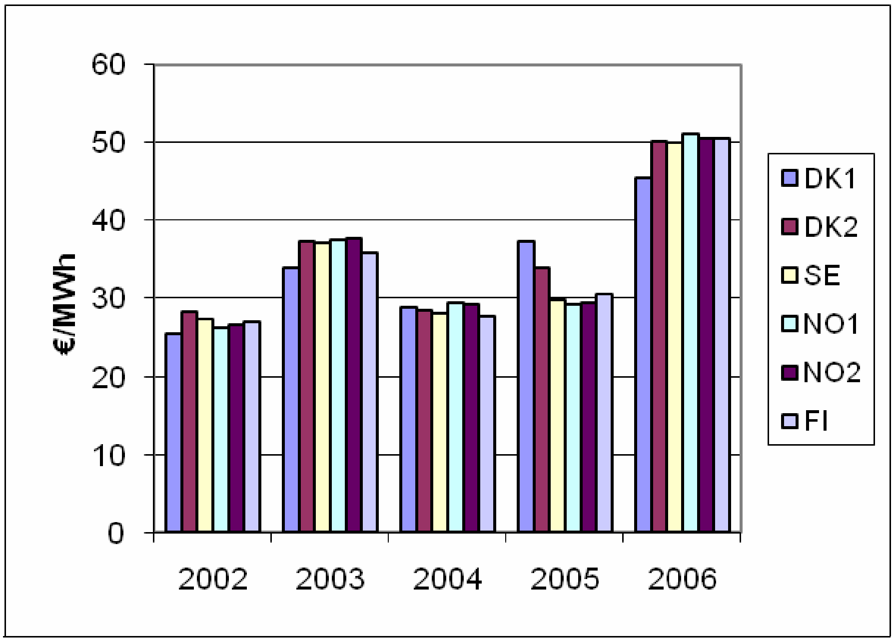


Figure 7: Average spot prices

Figure 8 illustrates that the actual flow on a congested line can be more or less than the announced capacity. A congested line is here defined from the spot prices. If the spot prices are different at each end of the line, it is defined as congested. However, in some cases it is possible to use the line at full capacity even though only a reduced capacity was announced the day before. The power flow in the overall system can be different than anticipated the day before. In other situations the opposite is the case, and the actual flow must be reduced below the planned value. Table 8 indicates that the actual flow in 20–25% of the time is less than 90% of the announced capacity. The lines analysed here are DC-lines, which are often congested (24–27% of the time).

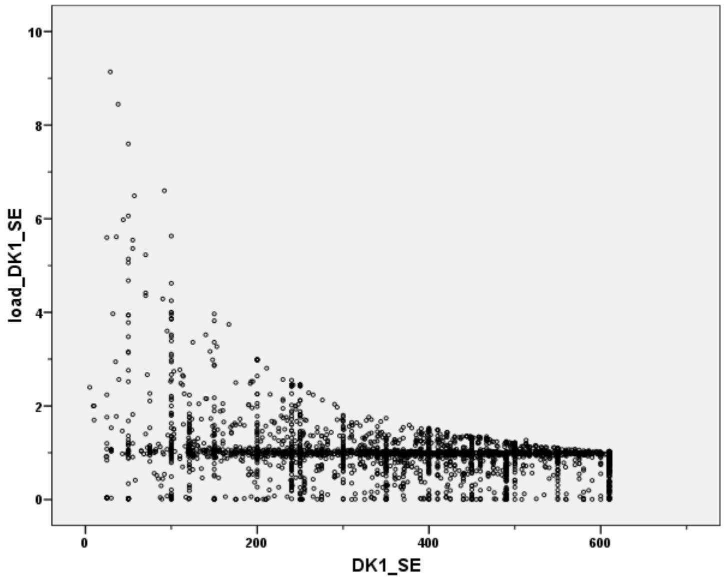


Figure 8: Actual flow vs. announced capacity. The x-axis shows the announced capacity for the transmission line between West Denmark and Sweden in MW. The y-axis is the actual flow divided by the announced capacity. Only hours with congestion are included (price in Sweden higher than in Denmark West).

Table 8: Variation of actual flow of congested lines

	DK1-SE	SE-DK1	DK1-NO1	NO1-DK1
Actual flow is 90% or less of announced capacity	20%	25%	22%	22%
Actual flow is +/-10% of announced capacity	71%	65%	75%	73%
Actual flow is 110% or more of announced capacity	9%	10%	3%	5%
Hours with congestion in this direction	8,795	2,994	9,440	4,547
(% of time)	(17%)	(6%)	(18%)	(9%)

Trade of regulation power can take place over a congested line, if the direction of the trade is opposite the congested flow.

3. Economic gains and losses from electricity trade

Introduction

This section presents the results of the quantitative analyses focusing on power balances, electricity prices, and the value of cross-border trade and transit within the Nordic region.

The questions to be answered are:

- What are the benefits of trade in the Nordic electricity market?
- What are the economic consequences of reducing transmission capacities (which happen every day due to different reasons)?
- How are the economic consequences distributed on countries and on different agent groups in each country, i.e. consumers, producers and TSOs?
- Where are the main bottle-necks in the system, i.e. what new lines seem to be most profitable?

Benefits of trade – in general

The quantitative analyses focus on the direct economic benefits of power trade that arise from differences in the power structure in different regions, and thereby differences in marginal production costs varying over time depending on electricity demand, wind power generation, hydro power generation, fuel prices and others. Apart from the direct economic benefits, strong cross-border interconnections also decreases the producers' possibility to exercise market power, increases the security of supply for all trading partners, and leads to more stable electricity prices and thereby lower risk premiums on investments. In this section, these benefits are discussed further.

Direct economic benefit

The figure below illustrates the direct economic benefit from trade between Area 1 (with supply curve S1 and demand curve D1), and Area 2 (with supply curve S2 and demand curve D2).

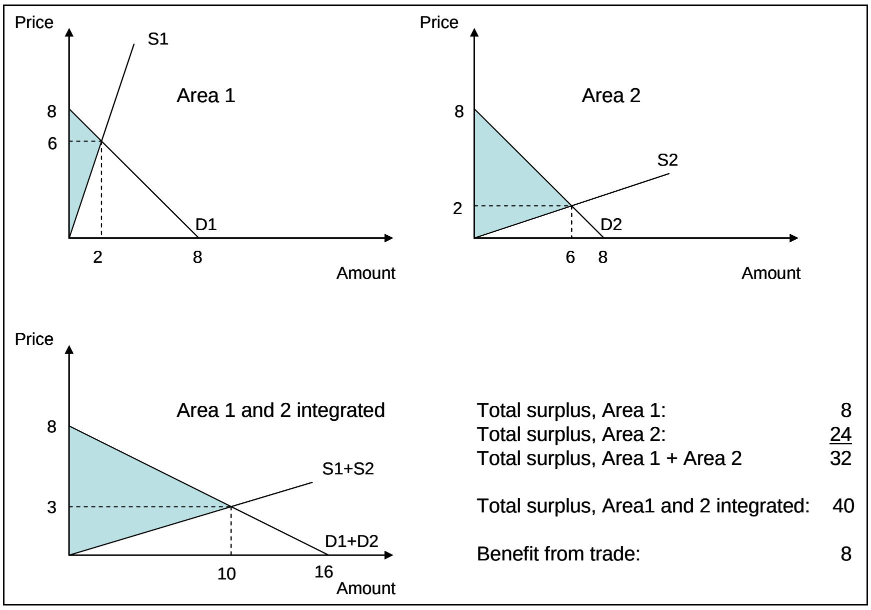


Figure 9: Illustration of economic benefit from trade

Demand curve D1 and D2 have been chosen to be similar to each other. Opposite, the two supply curves differ. In Area 2 the marginal production costs are in general lower than in Area 1, which means that for a given price, the supply of electricity is largest in Area 2. Area 2 could represent a situation with much available hydro power or with large wind power generation.

In the figure the total surplus is illustrated by the coloured area. The upper triangle in each situation shows the consumer surplus and the lower triangle shows the producer surplus. For instance, in Area 1 (upper left corner of the figure), some consumers are willing to pay a price up to 8, but they only pay the market price which is 6. Similar some producers are willing to supply at a price down to 0 but they receive the market price which is 6.

In Area 1, the total surplus, i.e. the sum of consumer surplus and producer surplus, can be calculated to 8, and in Area B, it can be calculated to 24. This sum up to a total surplus of 32 when having separate markets.

When the two markets are interconnected, it is possible to utilise the production units in Area 2 with low production costs, not only in Area 2, but also in Area 1. This may harm the producers in Area 1 (where the price decreases) and the consumers in Area 2 (where the price increases), but opposite the producers in Area 2 and the consumers in Area 1 will benefit. Most important is that the sum of benefits are larger than the sum of losses. It appears from the figure that the total surplus increases from 32 to 40.

From an overall point of view, trade between different areas (with different supply and/or demand curves) will always be a benefit. However, within each area there may be both winners and losers.

Market power

Electricity trading across national borders is a facilitator of – and almost a prerequisite for – the transition from regulated national monopolies on electricity generation, to well functioning competitive markets. All national markets in the Nordic countries have large incumbent producers which if uncontested would have been able to exercise market power. Without cross-border trading of electricity, the liberalisation of the electricity markets in the Nordic countries would haven been unsuccessful, unless the assets of individual monopolies were divided among a number of players. This would be counter to the general trend of consolidation in the sector, weakening Nordic interests in the competition on a European level.

A high degree of competition ensures that the optimal power dispatch solution is found, which maximises the total surplus. If market power is exercised, the producers may benefit excessively. But the consumer losses will be higher than the producer gains, and thereby market power will lead to not only welfare distributional consequences, but also to a total loss from an overall point of view.

The best method of countering market power, without putting regional business interest at an unfair disadvantage, is to increase the size of the relevant market. While this increases the level of competition on domestic markets – benefiting the consumers – it increases the potential for Nordic players to engage in the competition on adjacent markets. This can be done through timely investments in cross-border interconnections, as well as strengthening of local grid as required by the market. The prerequisite; transparent markets in which prices reflect the underlying strengths and weaknesses in the grid, and regional cooperation in developing markets and infrastructure.

An example of the impact on market power of increased capacity of inter-connectors is analysis that was carried out by Energinet.dk as part of the evaluation of the benefits of the Great Belt Connection from the Western to the Eastern part of Denmark. In this analysis the effect on the market function of the new interconnection was evaluated with the mathematical market model MARS. The benefit of an improved market function was estimated to 12 million EURO for the total Nordic system. Electricity prices will in general be decreased and consumers will benefit from the reduced market power.

Security of supply

Strong interconnections will normally increase the security supply of the region if the same quantity of reserves is upheld in the connected system. Alternatively the number of reserves can be reduced while maintaining the same level of security of supply. This will benefit the total system by reducing costs for reserves.

One exception is a case where two areas are interconnected with at a transmission line that exceeds the largest unit in one of the areas. In this case the N-1 criteria will mean that the demand for reserves will increase in this area.

Not only the power aspect of security of supply in the electricity system will benefit from trade. Also security of supply regarding energy in the hydro system will benefit. In low precipitation years there can be a risk of energy rationing in Norway and this risk can be reduced by strong interconnections and trade.

Price stability

An increase of the capacity of inter-connectors will increase price stability in the interconnected system. Differences of subsystems that are interconnected will contribute to higher price stability. An example is interconnection of the Swedish–Norwegian hydro power system with the thermal Danish–Continental system. The hydro system contributes to reducing price differences between day and night and the thermal system contributes to reducing price differences between dry years and wet years.

More stable prices and higher predictability of future price levels contribute to a more stable framework for potential investors in new production capacity. This will reduce risk premiums and thereby increase socio-economic benefits for the total system.

Cost elements of transit

One obvious consequence of large cross-border trade volumes is transit. Often electricity is traded – directly or indirectly – between countries that do not bordering each other. This is for instance the situation when Norway and Finland exchange electricity with the Continent.

In that respect, it is important that there are some compensation mechanisms to transit countries that gives incitements to invest in the optimal amounts of transmission lines – also in situations where the extension of transmission lines will mainly be used for increased transit.

Approach to analyses

The model simulations analysing the energy system with particular focus on transmission flows and welfare economy are carried out for the Nordic power system. The simulations have been carried out for 2005, 2015 and 2025 with most focus on 2015. It is a basic assumption that the electricity and district heating markets are well-functioning markets with full competition between power producers. Thereby, the electricity and heat prices equal the marginal production costs in the system.

The model simulations are carried out for different types of years with respect to precipitation, i.e. normal, wet and dry years.

The model used is the Balmorel model (www.balmorel.com), which is a technical/economic partial equilibrium model. The model finds optimal solution for the electricity and heat markets, taking into account:

- Electricity and heat demand;
- Technical and economic characteristics for each kind of production unit, e.g. capacities, fuel efficiencies, operation and maintenance costs, and fuel prices;
- Environmental taxes and quotas;
- Transmission capacities between regions and countries.

As output, the model comes up with production and transmission patterns on a total cost-minimizing basis. The model also comes up with estimates of electricity and heat prices assuming liberalised and well-functioning markets with full competition among power producers. Full information and full foresight are assumed, so e.g. hydro power is dispatched optimally through the year.

The specific model version used for this scope of work contains the electricity and CHP system in the Nordic countries (Denmark, Finland, Norway and Sweden). These countries are integrated in a common Nordic electricity market. Hydro-power accounts for approximately half of the electricity generation.

The transmission grid in the Nordic countries as well as the main power producers are shown in Figure 10 below.

Figure 10: The transmission grid in the Nordic countries

Source: www.nordel.org

The Nordic countries are subdivided in the model into ten price areas with limited transmission capacities between the areas. The areas are:

DK_E/DK_W	Eastern/Western Denmark
FI_R	Finland
NO_N/NO_M/NO_S/NO_O	Northern/Central/Southern Norway/ Oslo area

SE_N/SE_M/SE_S Northern/Central/Southern Sweden

Power trade with the Continent is included in the model by an assumed electricity price in each time segment to which there can be either import or export according to the transmission capacities.

In the Nordic energy perspectives project (Rydén et al., 2006: Ten Perspectives on Nordic Energy. Final report for the first phase of the Nordic Energy Perspectives project), Balmorel was used as one of eight energy system models with the purpose of analysing a wide range of problem issues. The eight models were of different types, Balmorel being one of the "Engineering-economic models". In particular, Balmorel was used to analyse how the Nordic electricity market will be affected (electricity prices, transmission patterns etc.) by the EU emission trading scheme.

Balmorel has the large advantage that both consumer surplus *and* producer surplus *and* changes in bottleneck incomes are analysed. This gives an overview of the total welfare-economic consequence of a given initiative analysed, and is different from some other models/methodologies that only focus on consequences for one particular group.

In the appendix to this report some of the main assumptions for the analyses are presented.

Results of analyses – 2005 & 2015

Power balances

Table 9 below shows the actual power balance in 2005.

Table 9: Actual power balance in 2005, GWh

	Denmark	Finland	Norway	Sweden	Total
Total generation	34,353	67,862	137,948	154,729	394,892
- Nuclear power	-	22,334	-	69,461	91,795
- Other thermal power	27,715	31,764	976	12,195	72,650
- Hydro power	23	13,597	136,465	72,143	222,228
- Wind power	6,615	167	507	930	8,219
Net import from Nordic countries	11,175	5,832	-12,255	-4,752	0
Net import from other countries	-9,800	11,312	215	-2,645	-918
Total consumption (including network losses and electric boilers)	35,728	85,006	125,908	147,332	393,974

Source: Nordel Annual Report, 2005

The water inflow in 2005 was higher than average, and the electricity generation from hydro was 222 TWh (which is approximately 18 TWh more than average).

From the table, it also appears that the power exchange with the Continent resulted in a net export from the Nordic region of 9.8 + 2.6 = 12.4 TWh, which more than counterbalanced the import from Russia to Norway and Finland of 11.3 + 0.2 = 11.5 TWh. Thereby, the net export out of the Nordic region in 2005 was 0.9 TWh.

Table 10 below shows the simulated power balance in 2005.

Table 10: Simulated power balance in 2005, GWh

	Denmark	Finland	Norway	Sweden	Total
Total generation	39,608	65,936	137,039	152,891	395,473
- Nuclear power	-	21,137	-	69,250	90,386
- Other thermal power	32,920	31,103	247	10,493	74,762
- Hydro power	-	13,594	136,428	72,171	222,194
- Wind power	6,687	102	363	977	8,130
Net import from Nordic countries	6,779	8,072	-11,113	-3,739	0
Net import from other countries	-10,655	11,000	0	-1,790	-1,445
Total consumption (including net-work losses and electric boilers)	35,731	85,008	125,927	147,361	394,028

Source: Calculation by Balmorel

Comparing the simulated power balance in 2005 with the actual one, it appears that the overall picture is more or less the same. However, the electricity generation is higher in Denmark and lower in Finland and Sweden in the simulated situation.

There are several reasons why the simulated situation is not fully identical to the actual one. First of all, the model finds an "optimal solution" based on full foresight, perfect competition and assuming that all transmission capacities are always fully available. Secondly, the model input, even though it is on a quite detailed level, can never reflect the real situation 100%. The deviation, however, is considered to be on a reasonable level, and the big advantage of simulating "optimal solutions" is that it is possible to make comparative analyses that are relatively easy to interpret and that are not disturbed by any "in-optimalities".

Table 11, Table 12 and Table 13 below show the simulated power balances in 2015 assuming a normal year, wet year and a dry year, respectively.

Table 11: Simulated power balance in 2015, GWh – Normal year

	Denmark	Finland	Norway	Sweden	Total
Total generation	49,247	93,732	121,529	165,460	429,967
- Nuclear power	-	33,870	-	68,882	102,752
- Other thermal power	40,774	46,843	4,375	18,824	110,816
- Hydro power	-	12,747	115,966	75,288	204,000
- Wind power	8,472	272	1,188	2,466	12,399
Net import from Nordic countries	-2,466	-7,580	14,754	-4,312	0
Net import from other countries	-4,418	13,000	5,256	-839	12,999
Total consumption (including net-work losses and electric boilers)	42,366	98,753	141,539	160,309	442,966

Source: Calculation by Balmorel

Comparing Table 11 with Table 10, it appears that the total generation is much higher in 2015 than in 2005, which is due to an increase in electricity demand (see Appendix).

It also appears that the net exchange with the Continent is close to zero in the normal year situation due to the assumption set up regarding electricity prices at the Continent (see Appendix). This results in a net import to the Nordic region of 11 TWh, corresponding to the assumed import from Russia to Finland.

Table 12: Simulated power balance in 2015, GWh – Wet year

	Denmark	Finland	Norway	Sweden	Total
Total generation	45,492	86,102	134,552	170,901	437,048
- Nuclear power	-	33,870	-	68,882	102,752
- Other thermal power	37,020	37,683	3,484	15,232	93,419
- Hydro power	-	14,277	129,881	84,321	228,479
- Wind power	8,472	272	1,188	2,466	12,399
Net import from Nordic countries	6,179	-348	1,725	-7,576	0
Net import from other countries	-9,302	13,000	5,256	-3,018	5,936
Total consumption (including network losses and electric boilers)	42,370	98,755	141,534	160,327	442,984

Source: Calculation by Balmorel

Table 13: Simulated power balance in 2015, GWh – Dry year

	Denmark	Finland	Norway	Sweden	Total
Total generation	54,212	99,313	102,059	156,215	411,799
- Nuclear power	-	33,870	-	68,882	102,752
- Other thermal power	45,740	54,591	4,619	22,376	127,325
- Hydro power	-	10,580	96,253	62,490	169,324
- Wind power	8,472	272	1,188	2,466	12,399
Net import from Nordic countries	-19,389	-13,562	34,231	-1,279	0
Net import from other countries	7,538	13,000	5,256	5,343	31,137
Total consumption (including network losses and electric boilers)	42,361	98,751	141,548	160,279	442,939

Source: Calculation by Balmorel

From Table 12 and Table 13, it is evident how the power balances differ in a wet and dry year, respectively, compared to the normal year situation in Table 11. In a wet year, the electricity generation increases in Norway and Sweden and decreases in Denmark and Finland, and opposite in a dry year. This has a strong influence on not only the power flows within the Nordic region, but also on the net exchange with countries outside the Nordic region. In a wet year, the net export to the Continent is 7.1 TWh, and in a dry year, the net import from the Continent is 18.1 TWh.

Electricity prices

The table below shows the simulated electricity prices in 2005 and 2015.

Table 14: Simulated average electricity prices, 2005 and 2015, €/MWh

	DK_E	DK_W	FI_R	NO_N	NO_M
2005	36.3	36.2	35.9	34.9	34.9
2015 - Normal year	44.1	44.1	43.9	44.0	44.0
2015 - Wet year	39.9	40.0	39.3	39.3	39.3
2015 - Dry year	56.3	55.6	57.7	58.6	58.6

	NO_S	NO_O	SE_N	SE_M	SE_S
2005	36.2	36.2	35.9	36.1	36.3
2015 - Normal year	44.7	44.8	43.9	44.4	44.4
2015 - Wet year	40.0	40.1	39.3	40.0	40.0
2015 - Dry year	59.7	59.8	58.3	58.3	58.3

Source: Calculation by Balmorel

In 2005, the average electricity price at the Nordpool spot market was 31 €/MWh whereas the simulated average electricity price has been estimated to approximately 36 €/MWh. One reason may be that the CO_2 price in 2005 was not fully passed on to the electricity price. If the CO_2 price is reduced from 17 €/ton to 10–11 €/ton, the simulated electricity price equals the 31 €/MWh. Another reason for the difference between the simulated price and the actual one may be inaccurate assumptions on fuel prices.

In 2015, the average electricity price varies between approximately 40 €/MWh in a wet year to 58 €/MWh in a dry year.

Value of cross-border trade and transit

In this section, the value of cross-border trade and transit is illustrated by comparing a number of Balmorel simulations in which the transmission capacities have been decreased with a baseline simulation in which all transmission capacities are fully available. The analyses focus on the total welfare-economic consequences of reducing the available transmission capacity as well as the welfare distribution consequences, i.e. how the total welfare consequence is divided on countries and different agent groups in each country.

Table 15 below shows the welfare-economic consequence of a reduction in the available cross-border transmission capacity (inside the Nordic region and at links to the Continent) by 20% in 2015 assuming a normal year. The table shows the difference between two simulations, i.e. the one with full capacities and the one with reduced capacities.

Table 15: Welfare-economic consequence of a 20% reduction in transmission capacity in 2015, M€ – Normal year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	0.7	-5.6	55.3	36.2	0	86.7
Consumer surplus	-4.4	2.4	-72.1	-35.2	0	-109.2
Sub total	*-3.7*	*-3.1*	*-16.7*	*1.0*	*0*	*-22.5*
Bottleneck incomes, internal	3.8	1.4	7.6	7.2	-	20.0
Trade surplus, at links to other countries*	-11.3	-0.3	-14.9	-5.2	-31.7	-63.4
Total	-11.2	-2.0	-24.0	3.0	-31.7	-65.9

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

When the transmission capacities are reduced, the electricity price in general increases. This gives benefit to the producers, and losses to the consumers. The largest benefit is found for the Norwegian producers (55.3 M€), while the largest losses is found for the Norwegian consumers (72.1 M€). Also Swedish consumers have high losses.

However, in Finland the picture is opposite, which is due to the annual import of electricity from Russia (which is not influenced by the decrease in transmission capacity within the Nordic region). The import of this amount of electricity to Finland at the same time as transmission capacities from Finland to other Nordic countries are reduced leads to a decrease in electricity prices in Finland. This is also the reason why the trade surplus at the link to Russia decreases. When the prices in Finland decrease, the benefit from importing electricity from Russia is reduced.

It also appears from the table that the bottleneck incomes increase as a consequence of the reduction in transmission capacities.

Finally, the total welfare-loss of decreasing the transmission capacity at all lines by 20% in a normal year has been estimated at 65.9 M€. The consequence to each of the Nordic countries varies from a loss of 24.0 M€ in Norway to a benefit of 3.0 M€ in Sweden.

Table 16 and Table 17 below show the consequence of reducing the transmission capacity by 20% in 2015 assuming a wet and dry year, respectively.

Table 16: Welfare-economic consequence of a 20% reduction in transmission capacity in 2015, M€ – Wet year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-16.5	-31.7	-45.3	-61.2	0.0	-154.8
Consumer surplus	12.7	35.8	46.8	55.6	0.0	150.9
Sub total	*-3.8*	*4.1*	*1.4*	*-5.6*	*0.0*	*-3.9*
Bottleneck incomes, internal	1.5	-0.4	1.4	3.0	-	5.5
Trade surplus, at links to other countries*	-12.2	-2.5	-14.3	-5.5	-34.6	-69.2
Total	-14.5	1.2	-11.5	-8.1	-34.6	-67.6

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

Table 17: Welfare-economic consequence of a 20% reduction in transmission capacity in 2015, M€ – Dry year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-0.4	-41.8	23,549.4	202.6	0.0	23,709.9
Consumer surplus	-10.5	32.9	-35,843.9	-208.8	0.0	-36,030.4
Sub total	*-10.9*	*-8.8*	*-12,294.5*	*-6.2*	*0.0*	*-12,320.5*
Bottleneck incomes, internal	1,883.5	13.1	6,155.4	2,543.4	0.0	10,595.7
Trade surplus, at links to other countries*	-14.1	-3.1	681.3	-4.9	659.3	1318.6
Total	1,858.5	1.2	-5,457.8	2,532.5	659.3	-406.2

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

In a wet year, the total welfare-economic loss is more or less similar to the loss in a normal year (for the reduction level of 20% as presented in the tables).

In a dry year, the total loss increases dramatically to 406.2 M€. The reason why the loss increases this much is that the electricity consumption cannot be fully satisfied and consumers are disconnected (at the price of 400 €/MWh). The results are heavily dependent (nearly proportional) on the assumption of the disconnection value.

The reason why Denmark and Sweden benefit so much from this situation is the large price difference between the high price in Norway and the prices in Denmark and Sweden, which result in large bottleneck incomes at the links that are divided equally.

Table 18 below shows consequence of decreasing the transmission capacity by 20% in 2015 in a “weighted average year” with respect to precipitation. A normal year is weighted by 70% and a wet and dry year is weighted by 15% each.

Table 18: Welfare-economic consequence of a 20% reduction in transmission capacity in 2015, M€ – Weighted average year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-2.0	-14.9	3,564.3	46.6	0.0	3,594.0
Consumer surplus	-2.8	12.0	-5,420.0	-47.6	0.0	-5,458.4
Sub total	*-4.8*	*-2.9*	*-1,855.7*	*-1.1*	*0.0*	*-1,864.4*
Bottleneck incomes, internal	285.4	2.9	928.8	387.0	0.0	1,604,2
Trade surplus, at links to other countries*	-11.9	-1.1	89.6	-5.2	71.5	143.0
Total	268.8	-1.0	-837.2	380.8	71.5	-117.2

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

It appears from the table that the average total welfare-economic loss of reducing the transmission capacity by 20% is 117.2 M€.[2] The losses for consumers are more than 5,000 M€, which can be compared to the typical annual costs of electricity of 15,000 M€.

Welfare-economic consequence from different reduction levels
Figure 11 below shows the welfare-loss for different reductions in transmission capacity. The figures for a reduction level of 20% is similar to the figures presented in Table 15, Table 16 and Table 17.

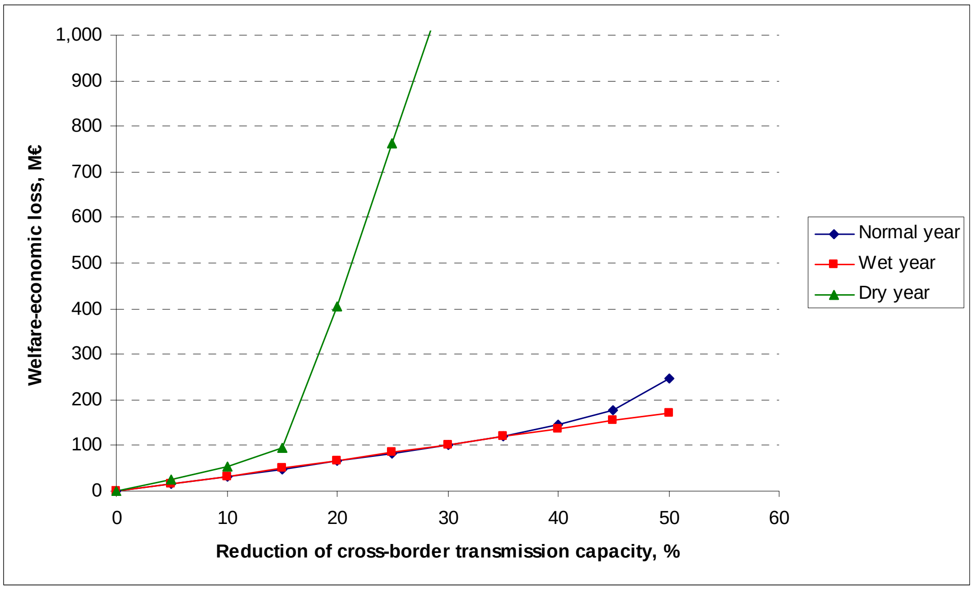


Figure 11: Total welfare-economic loss as a consequence of reduced cross-border transmission capacity

Source: Calculation by Balmorel

[2] This figure however, is very sensitive towards the assumed disconnecting price of 400 €/MWh which affect the dry year simulation.

From the figure, it appears how the marginal benefit of the transmission lines increases when the transmission capacity decreases. The dramatically increase in the dry year situation by a reduction level of more than 15% is due to the fact that the electricity demand cannot be fully satisfied and that consumers are disconnected to the disconnection cost of 400 EUR/MWh.

Consumer disconnection

As mentioned in Section 3, the reduction of transmission capacity in the dry-year simulations results in consumer disconnection. We have chosen this way of modelling the demand in order to be able also to test extreme reductions in transmission capacities.

The table below shows the amount of disconnected electricity depending on the reduction level.

Table 19: Disconnection of electricity consumption in the dry year simulation, 2015

Reduction in transmission capacity,%	0	5	10	15	20	25	30	35	40	45	50
Disconnected amount of electricity, TWh	0	0	0	0	1.5	3.3	5.1	6.9	8.7	10.5	12.4

Source: Calculation by Balmorel

As a consequence of an assumption in the model of full information and full foresight the disconnection (when occurring) affects all hours in the year.

The disconnection of electricity consumers occurs in NO_S and NO_O (and not in other regions).

Identification of main bottlenecks

This section focuses on the marginal benefit of increasing the transmission capacity at each transmission line in 2015. A high marginal benefit at a certain line tells that this line makes up a bottleneck in the system and that an extension of the line may be profitable depending on the costs of construction. To find the total marginal benefit the benefits in the two directions should be added. Some connections are DC-connections, and these are in general more expensive and needs higher marginal benefits to be profitable.

All benefits are calculated from the point of having all transmission capacities as presented in Table 39 (Appendix) fully available. Using another situation as a starting point, e.g. the situation in which the transmission capacities have been reduced by 20%, will probably lead to higher marginal benefits and may also change the ranking order.

Table 20 below shows the marginal benefit assuming a normal year.

Table 20: Marginal benefit of increased transmission capacity (€/MW), 2015 – Normal year

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		713	-	-	-	-	-	-	-	2827	46553
DK_W	192		-	-	-	5408	-	-	2412	-	46239
FI_R	-	-		1157	-	-	-	438	4069	-	-
NO_N	-	-	152		0	-	-	134	-	-	-
NO_M	-	-	-	0		5408	-	0	-	-	-
NO_S	-	3	-	-	0		0	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	0	697	747	-	-		3450	-	-
SE_M	-	37	0	-	-	-	3135	0		0	-
SE_S	0	-	-	-	-	-	-	-	0		46239
Continent	3925	3714	-	-	-	270268	-	-	-	6019	

Source: Calculation by Balmorel

It appears from the table that the largest marginal benefit is at the links to the Continent. Within the Nordic region, the largest benefit is at the link from DK_W and NO_M to NO_S. It also appears that some existing links have a marginal benefit of zero meaning that these links do not make up any bottlenecks in the system, and that there (based on these assumptions) will be no benefit of increasing the capacity of these links.

Table 21 below shows the marginal benefit at each link in 2015 assuming a wet year.

Table 21: Marginal benefit of increased transmission capacity (€/MW), 2015 – Wet year

To From	**DK_E**	**DK_W**	**FI_R**	**NO_N**	**NO_M**	**NO_S**	**NO_O**	**SE_N**	**SE_M**	**SE_S**	**Conti-nent**
DK_E		639	-	-	-	-	-	-	-	1021	69309
DK_W	1		-	-	-	841	-	-	425	-	69021
FI_R	-	-		38	-	-	-	8	5536	-	-
NO_N	-	-	323		1	-	-	188	-	-	-
NO_M	-	-	-	0		6050	-	11	-	-	-
NO_S	-	158	-	-	0		0	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	28	31	37	-	-		5505	-	-
SE_M	-	147	0	-	-	-	494	0		0	-
SE_S	119	-	-	-	-	-	-	-	0		69135
Continent	935	939	-	-	-	228967	-	-	-	1243	

Source: Calculation by Balmorel

Compared to the normal year shown in Table 20, it appears from Table 21 that in a wet year the marginal benefits at the links to the Continent are smaller in the import direction, i.e. from the Continent to the Nordic countries, and larger in the export direction. In the export direction the benefit is almost 70,000 €/MW reflecting the benefit of exporting electricity to the Continent in years with large amount of hydro power.

Within the Nordic region, the benefit is largest at the link from NO_M to NO_S.

Table 22 below shows the marginal benefit in a dry year of increasing the transmission capacity at each link in 2015.

Table 22: Marginal benefit of increased transmission capacity (€/MW), 2015 – Dry year

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		777	-	-	-	-	-	-	-	17204	2782
DK_W	6917		-	-	-	35860	-	-	23782	-	2265
FI_R	-	-		7220	-	-	-	4547	4816	-	-
NO_N	-	-	21		0	-	-	46	-	-	-
NO_M	-	-	-	0		9204	-	0	-	-	-
NO_S	-	0	-	-	0		0	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	0	2531	2677	-	-		47	-	-
SE_M	-	94	0	-	-	-	12301	0		0	-
SE_S	0	-	-	-	-	-	-	-	0		2359
Continent	44494	37482	-	-	-	401519	-	-	-	61155	

Source: Calculation by Balmorel

From the table it appears, that in a dry year the marginal benefit at the links in the system is in general higher than in both a normal year and a wet year. In the dry year situation the benefit at the links to the Continent is 40,000-60,000 €/MW (in the import direction).

Within the Nordic region, the benefit is in the dry year situation largest at the link from DK_W to NO_S.

Table 23 below shows the marginal benefit in a "weighted average year" with respect to precipitation of increasing the transmission capacity at each link in 2015.

Table 23: Marginal benefit of increased transmission capacity (€/MW), 2015 – Weighted average year

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		712	-	-	-	-	-	-	-	4713	43401
DK_W	1172		-	-	-	9291	-	-	5319	-	43060
FI_R	-	-		1899	-	-	-	990	4401	-	-
NO_N	-	-	158		0	-	-	129	-	-	-
NO_M	-	-	-	0		6074	-	2	-	-	-
NO_S	-	26	-	-	0		0	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	4	872	930	-	-		3248	-	-
SE_M	-	62	0	-	-	-	4114	0		0	-
SE_S	18	-	-	-	-	-	-	-	0		43091
Continent	9562	8363	-	-	-	283761	-	-	-	13573	

Source: Calculation by Balmorel

Within the Nordic region, two of the links supplying NO_S come up as the links with the highest marginal benefit.

The marginal benefit (the sum of the benefit from each direction of each link) should be held up against the construction costs of new lines which depends on among others the length and the type of line, and on the trace conditions. As a reference, the recently decided Great Belt 600 MW DC connection between DK_E and DK_W is expected to cost 160 M€. Assuming an economic pay back time of 30 years and an interest rate of 6%, this corresponds to 19,000 €/MW in annual capital costs.[3]

Illustration – Value of increased transmission capacity internally in Sweden

In this section some illustrative analyses are carried out illustrating the value of increased transmission capacity internally in Sweden. The analyses show the welfare-economic consequences of removing all internal bottle-necks in Sweden by increasing the transmission capacity to infinity.

Table 24 shows the consequences in a normal year.

Table 24: Welfare-economic consequence of removed internal Swedish bottle-necks in 2015, M€ – Normal year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-5.6	31.8	5.5	18.5	0.0	50.2
Consumer surplus	5.5	-32.7	-1.5	4.9	0.0	-23.7
Sub total	*-0.1*	*-1.0*	*4.1*	*23.5*	*0.0*	*26.5*
Bottleneck incomes, internal	0.1	-1.8	-2.1	-25.9	0.0	-29.8
Trade surplus, at links to other countries*	0.7	2.2	-0.2	0.3	3.0	6.0
Total	0.7	-0.6	1.8	-2.1	3.0	2.7

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

It appears that the total welfare-economic benefit is 2.7 M€ but for Sweden there is a loss of 2.1M€. This illustrates that increasing transmission capacities within one country can be of benefit not for the country itself but for other countries.

In the table it is implicit assumed that the internal bottle-neck incomes in Sweden are executed (and collected by the Swedish TSO). In practise, these bottle-necks are removed to the borders by counter trade, so Sweden can be one price area. This has the consequence that the bottle-neck incomes are shared with e.g. Denmark in situations where the bottle-necks are removed to the links across Øresund.

Table 25 shows the transit in the reference situation and in the situation with increased internal Swedish transmission capacities.

[33]In addition to the capital costs also the annual O&M costs should be taken into consideration, but these are almost neglible for transmission lines compared to the capital cost.

Table 25: Transit, TWh – Normal year

	Denmark	Finland	Norway	Sweden
Including internal Swedish bottle-necks	10.0	8.5	5.6	19.0
Removed internal Swedish bottle-necks	10.3	8.6	5.5	19.5

It appears that the transit in Sweden increases slightly from 19.0 TWh to 19.5 TWh.

Table 26 and Table 27 show the wet year situation.

Table 26: Welfare-economic consequence of removed internal Swedish bottle-necks in 2015, M€ – Wet year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-13.0	43.1	-2.3	11.8	0.0	39.6
Consumer surplus	12.6	-44.8	11.3	23.3	0.0	2.5
Sub total	*-0.4*	*-1.6*	*9.0*	*35.2*	*0.0*	*42.2*
Bottleneck incomes, internal	0.0	-3.0	-3.3	-41.6	0.0	-47.9
Trade surplus, at links to other countries*	1.7	3.0	-0.5	0.8	5.0	9.9
Total	1.3	-1.7	5.1	-5.6	5.0	4.1

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

Table 27: Transit, TWh – Wet year

	Denmark	Finland	Norway	Sweden
Including internal Swedish bottle-necks	9.3	4.4	6.3	13.7
Removed internal Swedish bottle-necks	9.6	4.3	6.6	13.9

From Table 26 it appears how the total benefit from removing the bottle-necks internally in Sweden in the wet year situation increases to 4.1 M€ and the loss in Sweden increases to 5.6 M€.

Table 28 and Table 29 show the dry year situation

Table 28: Welfare-economic consequence of removed internal Swedish bottle-necks in 2015, M€ – Dry year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-0.1	0.4	0.2	-0.2	0.0	0.4
Consumer surplus	0.1	-0.4	0.1	0.1	0.0	0.0
Sub total	*0.0*	*0.0*	*0.4*	*0.0*	*0.0*	*0.4*
Bottleneck incomes, internal	0.0	0.0	0.0	-0.4	0.0	-0.5
Trade surplus, at links to other countries*	0.0	0.0	0.0	0.0	0.0	0.1
Total	0.0	0.0	0.3	-0.3	0.0	0.0

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

Table 29: Transit, TWh – Dry year

	Denmark	Finland	Norway	Sweden
Including internal Swedish bottle-necks	11.1	10.8	2.3	24.5
Removed internal Swedish bottle-necks	11.1	10.8	2.2	24.5

Table 30 shows the figures for a weighted average year.

Table 30: Welfare-economic consequence of removed internal Swedish bottle-necks in 2015, M€ – Weighted average year

	Denmark	Finland	Norway	Sweden	Other countries	Total
Producer surplus	-5.9	28.8	3.5	14.7	0.0	41.1
Consumer surplus	5.8	-29.7	0.7	6.9	0.0	-16.2
Sub total	*-0.1*	*-0.9*	*4.3*	*21.7*	*0.0*	*24.9*
Bottleneck incomes, internal	0.1	-1.7	-2.0	-24.4	0.0	-28.1
Trade surplus, at links to other countries*	0.8	2.0	-0.2	0.4	2.9	5.7
Total	0.8	-0.7	2.1	-2.5	2.9	2.5

* Russia, Estonia & the Continent.
Source: Calculation by Balmorel

Table 31: Transit, TWh – Weighted average year

	Denmark	Finland	Norway	Sweden
Including internal Swedish bottle-necks	10.1	8.2	5.2	19.0
Removed internal Swedish bottle-necks	10.3	8.3	5.2	19.4

In general, the effects from removing the bottle-necks internally in Sweden are not very high. The welfare-economic consequences are low and also the changes in transit patterns are low. This indicates that in a situation with all transmission lines fully available (as the simulated one) the transmission capacity are at a sufficient level internally in Sweden. This could also be seen from the tables in section 3 showing the marginal benefit of each link. In these tables, only the link between SE_N and SE_M (in the southwards direction) had a positive benefit.

Analyses – 2025

Reference

In 2025, it has been assumed that the total wind power generation in the Nordic countries is 22 TWh. The figures for wind are consistent with the figures in the project "Climate 2050 – the path to 60–80% reductions in greenhouse gas emissions" which has recently been carried out for the Climate Group under Nordic Council of Ministers by COWI and Profu.
In addition to wind, an increase in gas capacity of 4,000 MW in Norway South has been assumed.

Table 32 shows the marginal benefit of increasing transmission capacities in the reference situation.

Table 32: Marginal benefit of increased transmission capacity (€/MW), 2025 – Weighted average year

To / From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		0	-	-	-	-	-	-	-	1715	39962
DK_W	886		-	-	-	2743	-	-	2534	-	40243
FI_R	-	-		552	-	-	-	325	4002	-	-
NO_N	-	-	1143		0	-	-	994	-	-	-
NO_M	-	-	-	0		608	-	887	-	-	-
NO_S	-	5831	-	-	0		4036	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	48	167	161	-	-		3633	-	-
SE_M	-	1730	6	-	-	-	222	0		1659	-
SE_S	157	-	-	-	-	-	-	-	0		40280
Continent	12622	11845	-	-	-	277290	-	-	-	14446	

Source: Calculation by Balmorel

Compared to the situation in 2015 (Table 23) some marginal benefits are now lower and some are higher. In particular, the links connecting NO_S with other areas have changed as a consequence of the assumption on 4,000 MW gas capacity in NO_S.

Higher CO_2 price

Apart from the reference situation, two more situations in 2025 have been analysed differing from the reference situation with respect to CO_2 price and transmission capacities to the Continent, respectively.

Table 33 shows the marginal benefits in the situation with increased CO_2 price. In this situation, the CO_2 allowance price has been assumed to 40 €/ton instead of 20 €/ton.

Table 33: Marginal benefit of increased transmission capacity (€/MW), 2025 – Weighted average year

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		0	-	-	-	-	-	-	-	2411	41962
DK_W	831		-	-	-	3520	-	-	3303	-	42229
FI_R	-	-		762	-	-	-	532	4561	-	-
NO_N	-	-	1237		0	-	-	924	-	-	-
NO_M	-	-	-	0		762	-	813	-	-	-
NO_S	-	4752	-	-	0		4340	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	148	173	153	-	-		4103	-	-
SE_M	-	294	15	-	-	-	234	0		172	-
SE_S	95	-	-	-	-	-	-	-	0		42283
Continent	10886	10085	-	-	-	274534	-	-	-	13440	

Source: Calculation by Balmorel

Compared to Table 32, it appears how some benefits are lower and some benefits are higher as a consequence of a higher CO_2 price. However, the benefits are not so much affected by the increase in CO_2 price. The overall picture is more or less the same as in the reference situation.

Higher transmission capacity to the Continent

Table 34 shows the marginal benefits in the situation with increased transmission capacities to the Continent. In this situation, the transmission capacity to the Continent has been assumed to be twice as much as in the reference situation.

Table 34: Marginal benefit of increased transmission capacity (€/MW), 2025 – Weighted average year

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Conti-nent
DK_E		0	-	-	-	-	-	-	-	6865	576
DK_W	1133		-	-	-	8456	-	-	7842	-	938
FI_R	-	-		823	-	-	-	150	9453	-	-
NO_N	-	-	1482		0	-	-	1314	-	-	-
NO_M	-	-	-	0		0	-	1214	-	-	-
NO_S	-	48192	-	-	32		10787	-	-	-	0
NO_O	-	-	-	-	-	0		-	0	-	-
SE_N	-	-	50	625	581	-	-		9314	-	-
SE_M	-	37259	7	-	-	-	663	0		37417	-
SE_S	3	-	-	-	-	-	-	-	0		780
Continent	2508	1664	-	-	-	268258	-	-	-	9461	

Source: Calculation by Balmorel

It appears how the marginal benefits of the links to the Continent in this situation are in general lower than in the reference situation. Opposite, the benefit of the links internally in the Nordic region are in general higher.

This can be explained by the fact that when the links to the Continent are increased, main bottle-necks are removed to other places in the system.

Conclusions

Every day transmission capacities are reduced by the Transmission System Operators due to different reasons. This have some total welfare-economic consequences for the Nordic power system, as it increases total generation costs in the system. Furthermore, it has some welfare distributional consequences both among countries and among different agent groups in each country.

The analyses have focusing on illustrating the welfare-economic consequences on such reductions in transmission capacity. For instance, a reduction of all cross-border transmission capacity by 20% in 2015 results in a loss of 117.2 M€ in a weighted average year. However, producers benefit in the order of 3.6 M€ and consumers loose in the order of 5.5 M€.

In dry years, the marginal loss of decreasing transmission capacity is much higher than in a normal year. In dry years, almost all the transmission capacity (or at least at the most critical links) are necessary in order to avoid very high electricity prices and disconnection of electricity consumers.

The analyses have also focused on identifying main bottle-necks in the system by estimating the marginal benefit of each link. The marginal benefit are in general highest at the links to the Continent. An alternative analysis in 2015 assuming larger transmission capacities at the links to the Continent shows how in this situation the marginal benefit decreases at the links to the Continent and increases at the links internally in the Nordic region illustrating how bottle-necks in this situation are removed to other places in the system.

4. Stakeholder views

As part of this study, representatives from the TSO, the regulator and the national association of producers in the four countries have been interviewed.

All interviewed persons agreed that the description of the current congestion management and transit regime is basically correct. However, some amendments and comments seem necessary, among which the most important are:

Clarifications

Market splitting is used between pre-defined Elspot areas in the day-ahead market. Counter trade is used during the trading day, if necessary, to guarantee the allocated capacity. There is no consensus as to what constitutes an ideal division of price areas. Two stakeholders pointed out that reducing trade capacity on the borders is not to reduce counter trade as stated in the paper, but due to security of supply reasons. Several stakeholders pointed out that there is no clear definition of the distinction between structural and temporary bottlenecks.

Regarding transit compensation, the current value of the horizontal network is based on regulated values. The EU Commission has stated that this model is not in accordance with the EU regulation. ETSO has stated that the IMICA model is too complicated, and it will not be adopted. The current ETSO system is in force only until 31. March 2007. There is no consensus about what will happen thereafter.

Relevance

All stakeholders state that the question of congestion management is presently the most pressing issue to be solved in the Nordic electricity market. It is stated that efficient, harmonised and transparent handling of congestion is crucial for the market. Several stakeholders feel that also a fair transit compensation mechanism is extremely important, and that the two questions are interlinked.

Main challenges regarding congestion management

The main issue is the issue of reducing the transmission capacity on National borders. Most stakeholders point out that this is practised to a high degree by SvK. Several stakeholders state that the reasons for doing this are not sufficiently justified. All stakeholders feel that the current controversy is seriously threatening the Nordic cooperation. The issue seems to have two angles: 1) The question of principle and 2) The question of Economy.

All stakeholders agree that counter trade is not the best way to handle structural congestion. Our (the Consultant) understanding is that Swedish stakeholders believe that there are important reasons for not subdividing Sweden into more than one price area. The main reasons are a) danger of market power b) that structural constraints are difficult to define in a meshed AC system c) that predictable prices are important.

Most other stakeholders point out that the current practice is not transparent, does not yield the "true" prices, and that unnecessary price fluctuations are induced. One stakeholder underlines that the Nordic consumers are the real losers if the grid is not efficiently utilised. It is also stated that the practise of reducing capacity in the morning increases risk and unpredictability and thereby reduces the amount of trade.

Regarding economy, one stakeholder points out that counter trade induces a cost to the TSO and thereby yields the right incentive to invest. Two stakeholders point out that increased costs from increased counter trade should be paid by those who benefit. One stakeholder feels that if the cost issue is solved, also the question of principle can be solved.

Congestion	Importance	In favour	Disfavour	Increase/decr.
1	H	S	D	D
2	H	S	D,N	D
3	H	0	N,D	I
4	H	S	D	D
5	H	0	D	D
6	H	S	D	D
7	H	-	-	-
8	H	S	D,N	D
9	H	-	-	D
10	H	-	-	D
11	H	S	D,N	I
12	H	-	-	D

Figure 12: Answers from 12 stakeholders. All say the issue has High importance. Most say Sweden is in favour of current regime. Most say Norway or Denmark disfavours current regime. Most predict that the issue has Decreased in 5 years from now

Main challenges regarding transit compensation

The main challenge is that there seems to be no agreement concerning compensation after 31 March 2007. Several stakeholders feel that a true and fair mechanism will be complicated and thus not transparent enough. Transparency and simplicity are stated to be important features.

One stakeholder feels that the suggested ITC scheme is wrong because it does not link to the actual trading rules or benefits of trade. Two stakeholders feel that the main problem is that the regulated prices of the horizontal network are unfair, costs should be based on standard prices.

Transit	Importance	In favour	Disfavour	Increase/decr.
1	-	-	-	-
2	M	0	S	D
3	M	-	N	D
4	M	D	N	-
5	L	0	S	D
6	H	N	S	D
7	H	D	S	D
8	H	D,S	N,F	-
9	H,M	0	S	D
10	H	0	0	D
11	M	N,F	S,D	D
12	L	-	-	D

Figure 13: Answers from 12 stakeholders. Most say the issue has High or Medium importance. Some say Denmark is in favour of current regime, but answers differ. Most say Sweden disfavours current regime but answers differ. Most predict that the issue has Decreased in 5 years from now.

References

Alvarado, F.L. and W. Liu (2003): Methodology for Automatic Zone Creation/Merging/Partitioning. California Energy Commission.

Brunekreeft, G., K. Neuhoff, D. Newbery (2005): Electricity transmission: An overview of the current debate. Utilities Policy 13 (2005), pp. 73–93.

Bjørndal, M., K. Jørnsten and V. Pignon (2002): Congestion Management in the Nordic Power Market – Counter Purchases and Zonal Pricing

Camacho, L.O., I. J. Pérez-Arriaga (2005): Comparison of several inter-TSO compensation methods in the context of the internal electricity market of the European Union. Energy Policy 35 (2007) 2379–2389.

Coll-Mayor, D., M. Paget, E. Lightner (2007): Future intelligent power grids: Analysis of the vision in the European Union and the United States, Energy Policy 35 (2007).

Copenhagen Economics (2006): The economic consequences of capacity limitations on the Oresund connection.

Delincé, J.M. (2007): The challenges for the TSO due to the changing environment – needs for new tools and methologies. Smart Grids Forum 2007. Elia, Belgium.

Ehrenmann, A, and Y. Smeers (2005): Inefficiencies in European congestion management proposals. Utilities Policy 13, pp. 135–152.

ETSO (2000): Net Transfer Capacities (NTC) and Available Transfer Capacities (ATC) in the Internal Market of Electricity in Europe (IEM). Information for User.

ETSO and EuroPex (2005): Flow-based Market Coupling. A Joint ETSO-EuroPEX Proposal for Cross-Border Congestion Management and Integration of Electricity Markets in Europe.

European Commission (2006): European Technology Platform: SmartGrids – Vision and Strategy for Europe's Electricity. Networks of the Future.

Glachant, J.-M, V. Pignon (2005): Nordic congestion's arrangement as a model for Europe? Physical constraints vs. economic incentives, Utilities Policy 13 (2005) pp. 153–162.

Harvey, S. M. and W. W. Hogan (2004): Nodal and Zonal Congestion Management and the Exercise of Market Power. http://ksghome.harvard.edu/~whogan/zonal_jan10.pdf

IMO (2004): Historical Nodal Pricing Analysis. Market Operations Standing Committee. Independent Electricity Market Operator. Ontario. www.theimo.com/imowebpub/200405/mo_pres_NodalAnalysis_2004jan14.pdf

Leuthold, F., I. Rumiantseva, H. Weigt, T. Jeske and C. von Hirschhausen (2005): Nodal Pricing in the German Electricity Sector – A Welfare Economics Analysis, with Particular Reference to Implementing Offshore Wind Capacities. Presentation at the ETE Modelling Workshop at K.U. Leuven, the 3rd INFRATRAIN seminar, and the GRJM Workshop at DIW. Trends in German and European Electricity Working Papers WP-GE-08b

Nordel (2005, a): Report on Financing and Organisation of Investments in Prioritized Cross-sections – A background report prepared by the Nordel Market Committée in the Nordel project on Enhancing efficient functioning of the Nordic electricity market

Nordel (2005, b): Enhancing Efficient Functioning of the Nordic Electricity Market. Summary and Conclusions

Nordel (2006, a): Prioritised cross-sections. Reinforcment measures within the Nordic countries. Status, June 2006

Nordel (2006, b): Principles for determining the transfer capacity in the Nordic power market.

Pérez-Arriaga, I.J., F.J Rubio, J.F. Puerta, J. Arceluz, J. Marin (1995): Marginal pricing of transmission services: an analysis of cost recovery. IEEE Transactions on Power Systems 10 (1), pp. 546–553.

Pérez-Arriaga, I.J., L. Olmos (2005): A plausible congestion management scheme for the internal electricity market of the European Union. Utilities Policy 13, pp 117–134.

Rubio-Oderiz, F.J., I.J. Pérez-Arriaga (2000): Marginal pricing of transmission services: a comparative analysis of network cost allocation methods. Power Systems, IEEE Transactions, pp.: 448–454. Volume: 15 Issue: 1

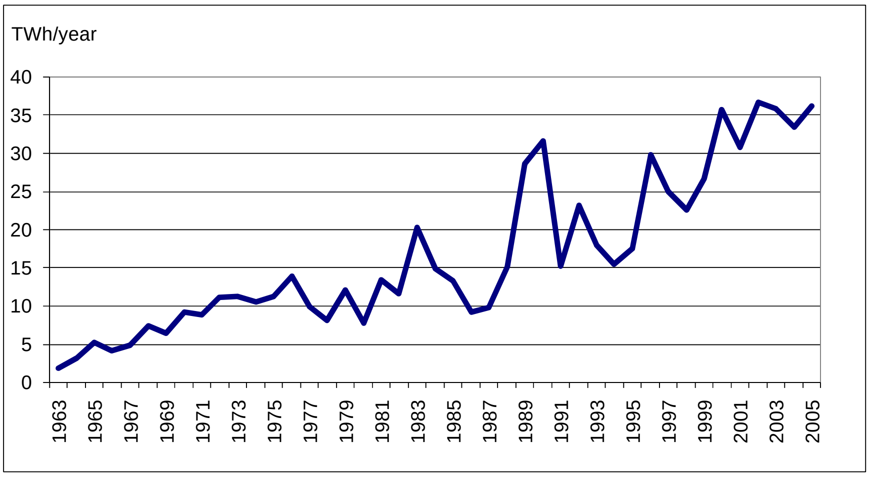
STEM (2004): Hantering av begränsningar i det svenska overföringssystemet för el – Ett nordiskt perspektiv. ER 2005:11.

Stoft, S. (2002): Power System Economics. Designing Markets for Electricity. IEEE Press and Wiley-Interscience.

Resumé på dansk

Otte anbefalinger om udvikling af det nordiske elmarked

Der har de sidste 40 år været en jævnt stigende udveksling af elektricitet mellem de nordiske lande. I dag udgør udvekslingen ca. 10 pct. af de nordiske landes forbrug, og hertil kommer udveksling med kontinentet. Den øgede udveksling er fremmet af liberaliseringen af elmarkedet og nye transmissionsforbindelser.



Figur 1: Udveksling af el i det nordiske system. Kurven viser summen af udveksling mellem de fire lande, fx fra Sverige til Finland, fra Finland til Sverige, fra Norge til Danmark, fra Danmark til Norge osv. Eludveksling med kontinentet er ikke medregnet (Nordel, 2006)

Øget handel udfordrer elmarkedets systemer, blandt andet i forbindelse med håndtering af flaksehalse i transmissionssystemet, og der har hersket uenighed om den hensigtsmæssige praksis på dette område. På denne baggrund har Nordisk Ministerråds Elmarkedsgruppe bedt Ea Energianalyse og COWI om at analysere det nordiske elmarked og fremlægge anbefalinger til, hvordan flaskehalshåndtering og kompensationsordninger i forbindelse med transit kan videreudvikles.

Håndteringen af transmissionsforbindelserne mellem de nordiske lande er overladt til den fælles elbørs Nord Pool. Dagen inden driftsdøgnet udmelder de systemansvarlige selskaber, hvor stor en del af den fysiske kapacitet på forbindelserne som kan anvendes. Ofte begrænses den tilgængelige kapacitet pga. stabilitetsforhold – enten på den aktuelle forbindelse eller internt i landet. Systemansvarets udmelding kan have stor betydning for prisdannelsen. Da udmeldelsen sker formiddagen før driftsdøgnet, er datagrundlaget forbundet med en vis usikkerhed.

Den øgede handel fører også til mere transit. Transit er defineret som samtidig import og eksport, og Sverige har den største transit i absolutte tal, mens Danmark har den største transit i forhold til områdets forbrug. Se tabel 1. Også forhold i forbindelse med kompensation for transit er under udvikling. De nordiske lande har siden 2004 deltaget i ETSOs ordning med kompensation for transit. Ordningen er stadig under udvikling.

Tabel 1: Gennemsnitlig transit i de fire nordiske områder. Januar 2001 – November 2006

	Transit	Transit / Efterspørgsel
Danmark	711 MW	13,0%
Finland	376 MW	3,0%
Norge	108 MW	0,5%
Sverige	1.011 MW	4,0%

Handel med el mellem landene har stor værdi. I denne rapport er dette blandt andet illustreret ved at beskrive omkostningerne ved reduceret handel. Ligeledes er værdien af at øge transmissionsforbindelsernes kapacitet beregnet. Beregningerne er udført i Balmorel, som er en detaljeret model af det nordiske elsystem. De viser, at en ændring i ét land påvirker producenter og forbrugere i hele det nordiske område. Beregningerne er primært gennemført for 2015, og med en række parametervariationer for 2025.

I tabel 2 er vist resultaterne af en teoretisk 20% reduktion af kapactiteten på alle transmissionforbindelser – såvel internt i norden og til kontinentet. Det samlede resultat er et årligt velfærdstab på 66 millioner €. Bag dette tal ligger imidlertid endnu større beløb som omfordeles mellem forbrugere og producenter – og mellem landene. Ser man på producenterne i alle lande, som har de et overskud på 87 millioner €, mens forbrugerne umiddelbart taber 109 millioner €. Endvidere er der store ændringer i flaskehalsindtægter (internt og i forhold til kontinentet). Beregninger er også foretaget for andre reduktionsprocenter og vådår og tørår. Se kapitel 3.

Tabel 2: Velfærds-økonomisk konsekvens af 20 procent reduktion af overførselskapaciteten i 2015 – Normalår. Millioner €.

	Danmark	Finland	Norge	Sverige	Andre lande	Total
Producent-overskud	0,7	-5,6	55,3	36,2	0	86,7
Forbruger-overskud	-4,4	2,4	-72,1	-35,2	0	-109,2
Subtotal	*-3,7*	*-3,1*	*-16,7*	*1,0*	*0*	*-22,5*
Flaskehalsindtægter, interne	3,8	1,4	7,6	7,2	-	20,0
Handelsoverskud på forbindelser til andre lande	-11,3	-0,3	-14,9	-5,2	-31,7	-63,4
Total	-11,2	-2,0	-24,0	3,0	-31,7	-65,9

Afhængig af brugen af transmissionsforbindelserne, så har det forskellig værdi at øge deres kapacitet. Vi har beregnet den marginale nytte ved at øge alle de nuværende forbindelser. Det viser sig at den største værdi findes ved at øge kapaciteten mellem norden og kontinentet.

Anbefalinger

Som en væsentlig del af dette projekt er der gennemført en række interviews med repræsentanter for de systemansvarlige, for regulatorer og for producenterne i de fire nordiske lande. Som afslutning på projektet blev der afholdt en workshop den 7. marts 2007 i Oslo. På baggrund af analysearbejdet, interviews og workshop er der i projektet udviklet otte anbefalinger om udvikling af det nordiske elmarked. De otte anbefalinger er kort beskrevet nedenfor.

På workshoppen i Oslo blev der især lagt vægt på anbefaling nummer et og to. Der var enighed om, at en politisk beslutning er nødvendig, og de nordiske ministre blev opfordret til at tage stilling til dette på næste møde i september 2007.

1. Opdel det nordiske elmarked i prisområder, som ikke tager hensyn til nationale grænser. Elmarkedets historiske udvikling har gjort at prisområderne i dag følger landegrænserne, og en nytænkning på dette område vil være et vigtigt skridt i retning af en øget effektivisering af elmarkedet.
2. Opstil objektive kriterier for opdelingen i prisområder, definer begrebet ”strukturel flaskehals” og vedtag en fælles finansiering af modhandel.
3. Øg gennemsigtigheden i forbindelse med de systemansvarliges udmelding af reducerede kapaciteter på transmissionsforbindelserne. Dette kan gøres ved, at de systemansvarliges efter hvert driftsdøgn offentliggør både data og modeller, som begrunder reduktionerne.
4. Styrk timemarkedet. Timemarkedet Elbas kan være med til at transmissionsforbindelserne udnyttes bedst muligt. Ikke mindst i perioder, hvor det tæt på driftstimen viser sig, at den tilladte kapacitet kan øges, kan handel på Elbas have stor værdi.
5. Analysér fordele og ulemper ved nodal pricing som et muligt system for næste generation af elmarkedet. Den nuværende markedsmodel for anvendelse af transmissionsforbindelserne med et begrænset antal prisområder er ikke ideel.
6. Definer lokale fordele ved transit. De nordiske lande kunne i fællesskab beskrive og fremføre lokale fordele ved transit (blandt andet flaskehalsindtægter) som et argument for udvikling af en hensigtsmæssig ordning for kompensation for transit.
7. Anvend harmoniserede værdier for transmissionsnettet i forbindelse med kompensationsordningerne. En af udfordringerne ved at udvikle

en ordning for kompensation for transit er, hvilken værdi som skal tillægges netværket. I dagens modeller anvendes meget forskellige værdier.

8. Analysér nytten af yderligere transmissionsforbindelser mellem det nordiske elsystem og kontinentet. Målet kunne være en prioriteret liste over mulige investeringer.

Appendix – Selected main assumptions for the quantitative analyses

In this Appendix, some of the main assumptions for the analyses are presented.

Capacities and demand

Table 35 and Table 36 below shows the electricity demand, heat demand and the installed capacity in the Nordic countries in 2005 and 2015. The heat demand included in the model is limited to the demand for district heating (DH). Depending on the composition of power plants, fuel prices etc., the model optimises whether heat should be produced in heat-only boilers or in combined heat and power plants (CHP).

Table 35: Capacities and demand, 2005

	Denmark	Finland	Norway	Sweden	Total
Electricity demand, TWh					
DH demand, TWh	34.8	34.0	1.6		
Installed capacity, MW	12,967	16,888	28,024	32,515	90,394
- hydro power	0	2,978	27,603	16,437	47,018
- nuclear	0	2,656	0	9,422	12,078
- natural gas	3,055	2,207	0	591	5,853
- coal	4,701	3,649	0	1,000	9,350
- peat	0	1,772	0	60	1,832
- oil	1,129	1,608	188	3,390	6,315
- waste	300	1,468	20	513	2,301
- biomass	614	490	30	528	1,662
- wind	3,168	60	183	574	3,985

Table 36: Capacities and demand, 2015

	Denmark	Finland	Norway	Sweden	Total
Electricity demand, TWh	40.2	93.8	134.3	151.9	420.3
DH demand, TWh	37.0	35.4	2.0		
Installed capacity, MW	12,874	18,588	29,039	34,010	94,511
- hydro power	0	2,978	27,603	16,437	47,018
- nuclear	0	4,256	0	9,372	13,628
- natural gas	2,825	2,207	600	1,261	6,893
- coal	4,288	3,649	0	1,000	8,937
- peat	0	1,772	0	60	1,832
- oil	1,129	1,608	188	3,390	6,315
- waste	300	1,468	20	513	2,301
- biomass	614	490	30	528	1,662
- wind	3,718	160	598	1,449	5,925

The total electricity demand is assumed to increase by 10.9% from 2005 to 2015, whereas the installed capacity increases by 4.6%. This leads to at tighter supply/demand balance in 2015 compared to 2005.

In Denmark, some old gas and coal units are assumed to be phased out during the period leading to a closure of 643 MW thermal capacity. In Finland, the capacity of nuclear power increases by 1,600 MW, and in Norway and Sweden the gas-fired generation capacity increases by 1,270 MW. In all four countries, the amount of wind power is assumed to increase. In total, the wind power capacity increases from 3,985 MW in 2005 to 5,925 MW in 2015.

The analyses are carried out, assuming the same decommissioning and expansion plan for all scenarios.

The analyses are carried out assuming the same electricity and heat demand for all simulations each year. However, the electricity consumption is reduced (disconnected) for electricity prices above 400 €/MWh.

Fuel prices

The table below shows the *fuel prices* used for the analyses. The prices do not include taxes.

Table 37: Fuel prices, €/GJ

	Coal	Nuclear	Gas	Fuel oil	Light oil	Peat	Straw	Wood chips	Waste
2005	2.1	0.6	4.9	5.0	8.9	1.9	4.5	4.4	0.0
2015	1.8	0.6	5.0	5.0	9.0	1.7	4.5	4.4	0.0
2025	1.9	0.6	5.3	5.2	9.3	1.8	4.5	4.4	0.0

Source: World Energy Outlook

In Norway, the gas price is assumed to be 10% lower than shown in the table due to better gas availability. Opposite, in Sweden, the gas price is assumed to be 10% higher due to higher infrastructure costs.

CO_2 allowance price

The analyses are carried out for a CO_2 allowance price of 17 €/ton in 2005 and 20 €/ton 2015 and 2025. In 2025, however, also an analysis assuming a CO_2 allowance price of 40 €/ton has been carried out.

Transmission capacities

Table 38 below shows the transmission capacities included in the analyses in 2005. The left column is the “from region” and the upper row is the "to region". For instance, the transmission capacity from SE_S to DK_E is 1,300 MW (and 1,700 MW in the opposite direction).

Table 38: Transmission capacities between price areas (MW), 2005

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Continent
DK_E		-	-	-	-	-	-	-	-	1,700	550
DK_W	-		-	-	-	1,000	-	-	730	-	1,400
FI_R	-	-		100	-	-	-	1,100	550	-	-
NO_N	-	-	120		900	-	-	700	-	-	-
NO_M	-	-	-	900		600	-	750	-	-	-
NO_S	-	1,000	-	-	600		5,200	-	-	-	-
NO_O	-	-	-	-	-	2,500		-	2,300	-	-
SE_N	-	-	1,600	700	750	-	-		7,000	-	-
SE_M	-	730	550	-	-	-	2,150	7,000		3,700	-
SE_S	1,300	-	-	-	-	-	-	-	3,700		1,000
Continent	550	1,400	-	-	-	-	-	-	-	1,000	

Table 39 below shows the transmission capacities in 2015 and 2025, where it has been assumed that the five prioritised links[4] and the Nord-Ned connection (600 MW from Norway to the Netherlands) have been established. The new links (extensions of existing lines and establishment of one new lines are marked with bold.

Table 39: Transmission capacities between price areas (MW), 2015 and 2025

To From	DK_E	DK_W	FI_R	NO_N	NO_M	NO_S	NO_O	SE_N	SE_M	SE_S	Continent
DK_E		***600***	-	-	-	-	-	-	-	1,700	550
DK_W	*600*		-	-	-	*1,600*	-	-	730	-	1,400
FI_R	-	-		100	-	-	-	1,100	*1,150*	-	-
NO_N	-	-	120		900	-	-	700	-	-	-
NO_M	-	-	-	900		600	-	*1,350*	-	-	-
NO_S	-	*1,600*	-	-	600		5,200	-	-	-	*600*
NO_O	-	-	-	-	-	2,500		-	2,300	-	-
SE_N	-	-	1,600	700	*1,350*	-	-		7,000	-	-
SE_M	-	730	*1,150*	-	-	-	2,150	7,000		*4,300*	-
SE_S	1,300	-	-	-	-	-	-	-	*4,300*		1,000
Continent	550	1,400	-	-	-	*600*	-	-	-	1,000	

Electricity prices at the Continent and import from Russia/Estonia

It is assumed that the average price level on the Continent corresponds to the price level in the Nordic countries in a normal year, and therefore the net exchange between the Nordic countries and the Continent will be close to zero. This restriction is enforced for the year on a net annual basis (in a normal year) and used to calibrate prices at the Continent.

[4] Priority Cross-sections – Joint Nordic Analysis of Important Cross-sections in the Nordel System, Main Report, Nordel, June 2004

During the year import and export take place in accordance with price signals.

In wet years, the electricity prices in the Nordic power system are relatively low compared to the prices at the Continent, and therefore, in these years there will be a net power flow from the Nordic countries to the Continent. Opposite, in dry years there will be a net power flow from the Continent to the Nordic countries.

Apart from the price dependent power exchange with the Continent, a fixed annual import to Finland from Russia of 11 TWh is assumed in the analyses. In 2015 and 2025 also a fixed annual import from Estonia of 2 TWh is assumed.

Time division

The analyses are carried out by a division of the year into 52 weeks, each subdivided into 5 periods, i.e. totally 260 time segments.

Water inflow

The analyses are carried out for both a normal year, wet year and dry year. Based on statistical variations in water inflow, a representative dry and wet year have been defined as a year with 17% lower and 12% higher water inflow, respectively, relative to average. The probability of a "representative" wet and dry year is 15% each, and the probability of a normal year is 70%. In some cases these probabilities are used to construct weighted results describing a combination of normal, wet and dry years.

In an extreme dry year, the water inflow is up to 23% lower than average (compared to the 17% that have been chosen for a representative dry year), and in an extreme wet year, the water inflow is up to 23% higher than average (compared to the 12% that have been chosen for a representative wet year).