March 2008

Nordic Grid Master Plan 2008

Organisation for the Nordic Transmission System Operators

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1 Summary and recommendation

1.1 Background

During the last decade, the planning process of Nordel has proceeded in the direction of integrated Nordic co-operation concerning grid reinforcements and expansions. This regional co-operation is unique in Europe and shows that Nordel is a forerunner in the work to ensure a well functioning regional electricity market. The successful Nordel co-operation on system planning aims at developing the grid from a Nordic perspective taking into account the international aspects and paying attention to environmental impacts. The work has resulted in three common Nordic grid master plans in the last 10 years.

In 2004, a comprehensive analysis was carried out of the potential for new investments in the Nordic electricity transmission infrastructure. The results were published in *Nordic Grid Master Plan (NSUP2004)* with proposals for grid reinforcement in five *Prioritised cross-sections (*Fenno-Skan, Nea-Järpströmmen, South Link, the Great Belt and Skagerrak IV).
By 2006, four of the proposed reinforcements had been decided. The first reinforcement to be taken into operation already in 2009 is Nea-Järpströmmen, followed by the Great Belt Link in 2010 and Fenno-Skan 2 in 2011. As part of the new SouthWest Link, the South Link will be taken into operation not long after that. Only Skagerrak IV has not yet been decided. However a letter of intent has been signed for this interconnection.

The number of other investments made in the Nordic grid has also increased substantially. There is an increasing volume of investments in all the Nordic countries caused by connection of new production and other necessary reinforcements. This can clearly be seen from the investments in the Nordic grid that have risen to more than € 500m/year, more than double the amount in previous years.

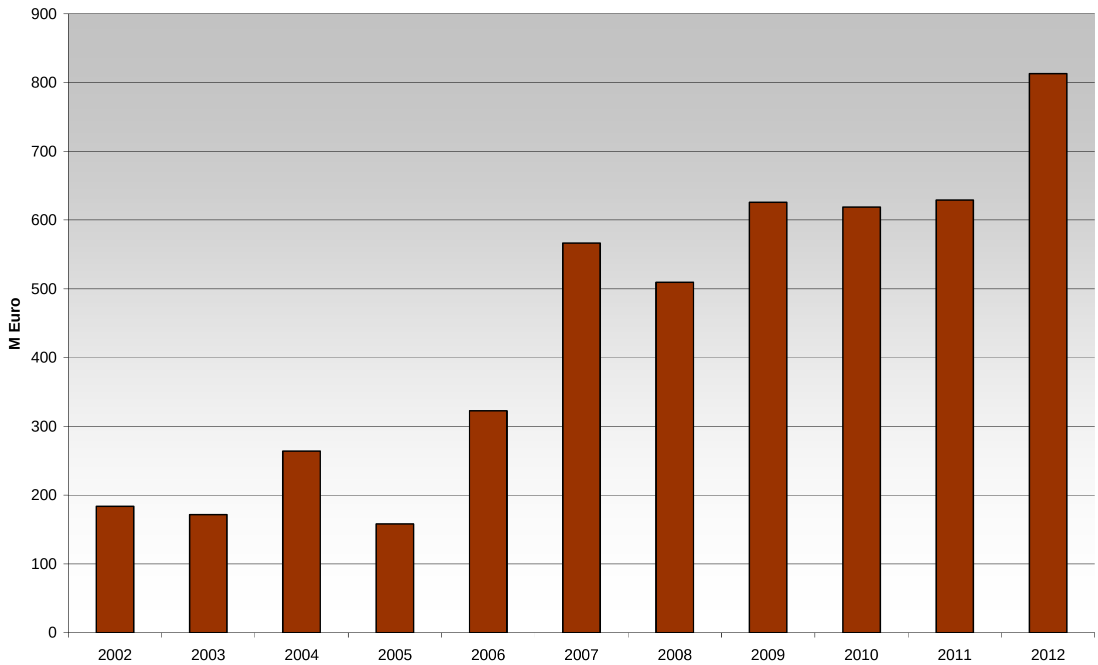


Figure 1.1: Nordic grid investments 2002 - 2012

In 2007, it was decided to make a new analysis of the potential for future investments in the power infrastructure beyond 2015. The analysis is called *Nordic Grid Master Plan 2008.* This report presents the main results from the Nordel study. Reinforcements to Iceland are not included in the analysis since Iceland is not part of the Nordic interconnected power system because of its geographical position.

Apart from grid investment, other important issues for Nordel to handle are congestion management and transit compensation.

Congestion management
Congestions in the grid will naturally occur, and must be handled. Transmission investments are resource demanding and the lead times are also long. It is therefore important to have clear principles on how to operate the existing grid in the most efficient way. This is particularly important for so-called internal congestions. Efficient handling of congestions will then benefit the common Nordic electricity market, Nordic consumers or producers in general.

The principles for congestion management are:

- Congestions are in general handled where they are physically situated
- Structural congestions are removed or reduced by grid investments whenever socio-economically viable, otherwise market splitting is applied, i.e. dividing the market into separate price areas
- Temporary congestions shall be handled by counter trade (redispatching), if counter trade is possible

This is described in the Nordel report "*Status of Nordel's work on Enhancing Efficient Functioning of the Nordic Electricity Market"*(April 2006).

Transit compensation
Transit compensation will have consequences for the socio economic profitibilty of new investments. There has been a compensation model for transit in use in Europe since 2002. The Nordic countries have participated since 2004. The Nordic countries are net financical contributors to the European transit compensation scheme. ETSO has established a project to define a long term Inter TSO Compensation (ITC) model from 2010. The consequnces for the individual countries will vary. It is therefore important that the cost and benefit of transit and trade are taken into consideration when proposed invetments in grid reinforcements are analysed.

1.2 Approach taken in the analysis

The objective of the analysis was to identify cross-section reinforcements which will be cost-effective according to prospective for 2015 and 2025. This was carried out by means of a socio-economic cost-benefit calculation.

Prospective for the consumption and production of electricity were set up in the *Nordel scenarios* for 2015 and 2025. The scenarios have been developed by Nordel to illustrate different possible pathways for power infrastructure requirements. The scenarios used are a business-as-usual reference for 2015

(BAU 2015) and alternative scenarios for 2025. The alternatives are a business-as-usual scenario with two levels of production, a scenario with focus on climate and international integration (Climate & Integration) and a scenario with focus on national solutions (National focus).

An adequate list of potential power infrastructure reinforcements has been set up by the Nordel members. The list covers Nordel internal reinforcements and connectors to the Continent.

Costs and benefits for all potential reinforcements have been calculated and analysed. However, the costs for the reinforcements as well as the increase in capacity they provide have been estimated using “standard values”. It has been assumed in this analysis that all five previously prioritised reinforcements will be in operation in 2015. The Skagerrak IV connection has not been decided yet but a letter of intent has been signed. However in this analysis it has been assumed that the connection will have been established before 2015 and it is therefore part of the reference.

The analysis includes the calculation of benefits from improved market efficiency, improved security of supply and reduced electrical losses. Furthermore, market power has been generally discussed but is not included in the evaluation.

The robustness to the different future pathways (scenarios) has been analysed in the form of a sensitivity analysis. The mutual effect of the reinforcements has been quantified.

This report emphasises the main results and highlights the lines showing a sound economy by meeting a significant demand from the market and security of supply requirements.

1.3 Internal Nordic reinforcements

The results of the analysis show that some internal Nordic reinforcements are highly beneficial. Areas with significantly high benefit from internal Nordic reinforcements are found in Mid-Norway there a reinforcement also will strengthen the North-South transport axis in Sweden and Norway. Another area is the grid around Oslo, Norway and the connection between Sweden and Norway through the West-Coast corridor and finally in the Arctic region, as shown in figure 1.4.

Sweden - Norway (south) (6)
The cross-section between Sweden and Norway leads to a relatively high frequency of bottlenecks. This is mainly due to restrictions in the grid around the Swedish west coast and around the Oslo region. Reinforcing this cross-section will lead to reduced bottlenecks and improved security of supply for Norway (energy in dry year) and for Sweden (power in cold periods).

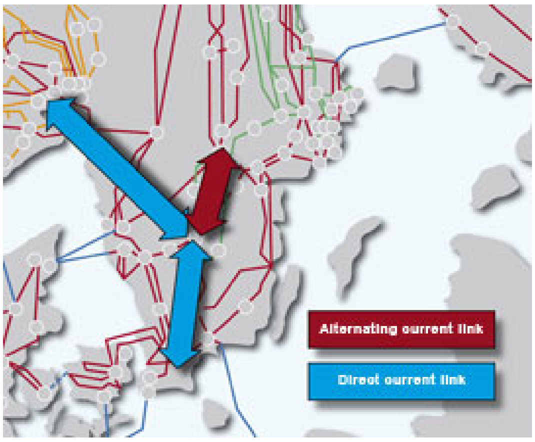


Figure 1.2: SouthWest Link reinforcing the connections between Sweden and Norway

Different alternatives have been studied in the analyses. The need for reinforcements is met by the recently presented ”SouthWest Link”. This link will combine the previously decided “South Link” in Sweden built with a combination of AC and HVDC with a new proposed HVDC connection to Norway, figure 1.2. The Swedish part of the joint reinforcement has been decided. The Norwegian part is proposed and needs more detailed planning before a formal decision can be taken. Nordel recommends Statnett and Svenska Kraftnät to start the planning process for strengthening the grid between Sweden and Norway.

Sweden – Norway (North – South axis) (7)
The transmission system in the North-South axis today is very weak in Norway compared to the Swedish system. The Swedish system consists of eight 400 kV lines wheras the Norwegian system consists of only one 300 kV line and two 132 kV lines. A new 420 kV line Ørskog-Fardal in Norway in combination with the new Nea-Järpströmmen line will strengthen the Swedish/Norwegian North-South capacity and at the same time decrease potential capacity problems related to cross-section 2 in Sweden. The Ørskog-Fardal line will also give increased import capacity to the Mid-Norway region, which has a negative energy balance caused by new power-intensive industries established in recent years. Investors have not found new production capacity attractive. The analysis shows that the Ørskog-Fardal line has a very positive cost-benefit result for the Nordic market. The economy has been found positive in all the scenarios. Nordel recommends that the Ørskog-Fardal line are decided.

Arctic region (8)
Historically the region has low consumption and long distances which has lead to a relatively weak grid in this region. Consumption and production are expected to increase in the next few decades. New petroleum-related activities are expected and large wind-power projects are at a planning stage. A cost-benefit analysis shows a positive economy in 2015 and 2025 for all scenarios, due to the planned Snøhvit 2 development.
Two alternative lines in the Arctic region have been investigated: the Ofoten-Balsfjord-Hammerfest and the Norway-Finland lines. Nordel recommends the Ofoten-Balsfjord-Hammerfest line be decided as a first step. In case of further growth in production and consumption a potential next step will be reinforcing the grid between Norway and Finland.

Reinforcements in these three areas show positive cost-benefit in all scenarios.

1.4 Reinforcements requiring additional analysis

Apart from the above mentioned projects, the analysis and other considerations indicate other potential reinforcements. The results are not conclusive and further analysis is required.

Sensitivity to different scenarios - Climate & Integration
A number of reinforcements are cost-effective in some of the scenarios.
In the *Climate & Integration 2025 scenario,* some additional lines get a positive cost-benefit value. This is found for the connections:

- Norway North - Sweden
- Sweden - Denmark-West
- Sweden - Denmark-East
- Norway - Denmark-West
- Norway - Denmark-East

The *Climate & Integration 2025 scenario* has a more positive energy balance in Norway and Sweden and a poorer energy balance in Denmark compared to the other scenarios. This is caused by the higher CO_2 prices in this scenario, which lead to a higher price difference and higher benefit for new connections between Denmark and Norway/Sweden.
These potential reinforcements should be observed as climate issues and wind power production will become more important in the future.

Sweden - Finland (#9)
Fingrid and Svenska Kraftnät have made some tentative studies of the socio-economic benefits of a new 400 kV AC connection between the northern parts of the countries. In projected year 2015 situation, congestions in the cross-section seldom occur and therefore the reinforcement does not show any significant benefit with the considered three criteria (consumer and producer benefit, bottleneck revenues and active power losses). In this the results are similar to the ones found in this study. However, revenue is estimated to increase later on towards 2025. By allocating part of the additional transmission capacity for reserves significant savings in power reserve costs (ancillary services) can be achieved, turning the total socio-economic balance of the project positive.

1.5 Potential external Nordic reinforcements

The Nordel area includes a border between the hydropower-dominated area in Norway/Sweden and the thermal-power dominated area in the south with connections to the Continent. This leads to significant benefits from external Nordic interconnectors interfacing with the Continental thermal market. This historical aspect may in the future be supplemented by a huge potential for offshore and coast-based wind power production in the Nordel area as well as in northern Continental Europe.

The analysis shows a positive socio-economic value from establishing or reinforcing connections from Norway to Germany/the Netherlands and from Denmark/Sweden to Poland/Germany/the Netherlands. In addition, connections from Finland/Sweden to the Baltic States and from Norway to the UK may have positive cost-benefit. The Nordel analyses have only considered the cost for those lines. Other studies indicate that such reinforcements show a potential for being profitable. Further studies of the lines will be made in the multiregional planning process. Planning groups will be started within Nordel for a western and an eastern planning area.

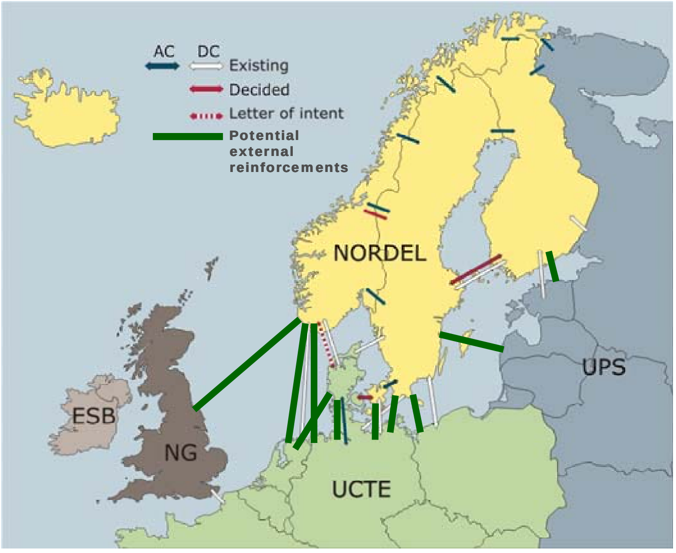


Figure 1.3: Reinforcement of external Nordic interconnections in general shows a positive cost-benefit. Potential reinforcements are not prioritised.

The analysis shows that the different reinforcements are not mutually exclusive. The benefit is typically reduced by less than 10% if another connection is built at the same time. There has been no dialogue with the TSO´s outside the Nordic countries to discuss connection costs and/or limitations in the receiving grid. The need for and cost of internal reinforcements are not included in the calculation.

Norway to the Continent or the UK
The highest potential benefit is found in the long-distance connections with direct connection of the hydropower market (Norway) to the Continental market. Such connections are expensive, and the economy is sensitive to future scenarios.

Denmark-West to Germany and the Netherlands
Reinforcement from Denmark-West to Germany shows a very positive cost-benefit in all scenarios. A connection from Denmark-West to the Netherlands also shows a positive economy in all scenarios. The benefits are to some extent higher than found in the connection to Germany, but the investment costs are at a significantly higher level. It has been assumed in the analysis that the Skagerrak IV line has already been established.

Sweden and Denmark-East to the Continent
A positive economy is found in all analysed connections from Sweden or Denmark-East to the Continent. Connections to Germany show a positive economy in all scenarios.

Finland and Sweden to the Baltic States
Separate analyses have also shown potential for positive overall economy of prospective new connections between the Baltic States and the Nordic countries. A separate study under the framework of the multiregional planning process has been launched to analyse further potential interconnections and coordinate different variants. The first results of these studies are expected by the end of 2008.

Fingrid and Federal Grid Company of Russia have started a technical survey of the possibility of modifying one of the Vyborg HVDC back-to-back links capable of bidirectional operation.

Sensitivity to different scenarios – Climate & Integration
As for the internal reinforcements the *Climate & Integration 2025 scenario* leads to even higher benefit for potential new connections between the Nordic countries and the external markets. This increased benefit is driven by higher CO_2 prices in this scenario which leads to higher price differences between the external thermal-dominated markets and the Nordic hydro-dominated market.

Nordel recommends that studies are initiated within the multiregional planning co-operation (Nordel – Baltso and Nordel – UCTE) to investigate further HVDC-interconnections between Nordel and these areas. Nordel also supports bilateral projects between the Nordic and external TSO:s.

1.6 National projects

Apart from the reinforcements identified in the analysis made for this report a number of reinforcements that are important to the Nordic power system are underway. The most important projects are shown in figure 1.4 and presented in more detail in chapter 6.

1.7 Recommendation

Based on the analysis performed, Nordel recommends that the planning process is initiated by the TSOs involved to reinforce the following internal Nordic grid areas:

- Sweden - Norway (south)
  SouthWest Link
- Sweden – Norway (North – South axis)
  Ørskog - Fardal
- The arctic region
  Ofoten – Balsfjord - Hammerfest

Based on the analysis as well as other studies, Nordel also recommends that studies are initiated within the multiregional planning co-operation (Nordel – Baltso and Nordel – UCTE) to investigate further HVDC interconnections between Nordel and those areas.

Nordel supports bilateral projects between the Nordic and external TSOs.

The decision to invest in the proposed reinforcements is taken by each involved TSO.

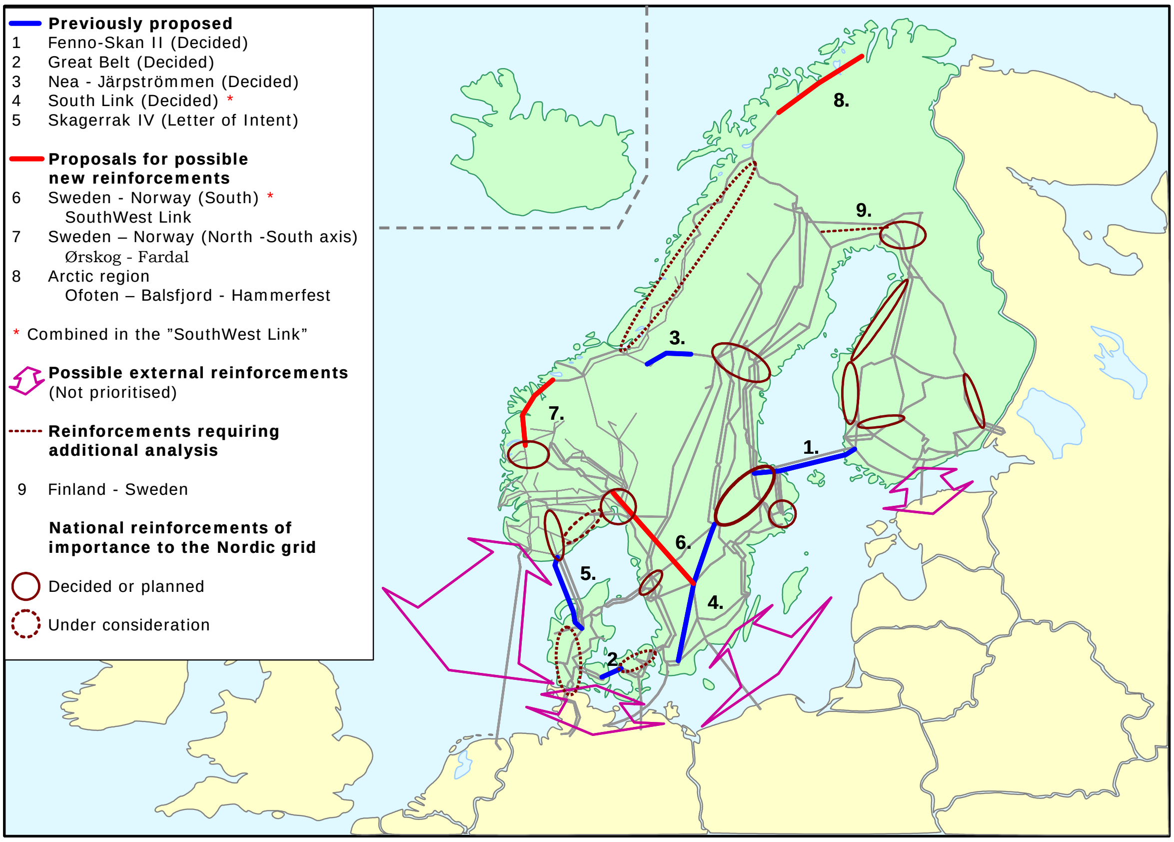
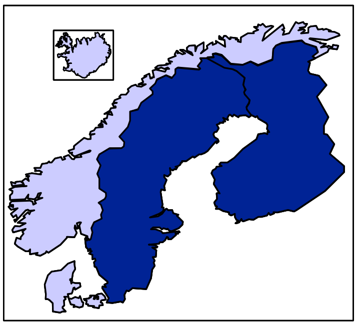


Figure 1.4: Previous and new proposals for reinforcements in the Nordic grid and to neighbouring system. In addition 2-3 external connections could be profitable.

An indicator for the market situation is the frequency of equal prices in different price areas. The development in equal prices (percentage of time of the year with difference under € 2/MWh) is shown in figure 1.5. For Nordel as a whole, equal prices were found in 44% of the time in 2006 (statistics) and 79% (in a calculated average year) after the five prioritised cross-sections and the new proposed internal Nordic reinforcements are built. However, these values are sensitive for other reinforcements. As an example increased capacity Jutland-Germany would lead to reduced time with equal Nordic prices.

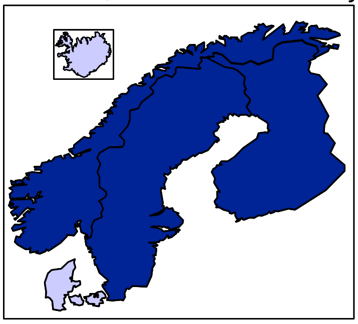
Sweden and Finland



Statistics
2005: 93 %
2006: 95 %

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 94 %

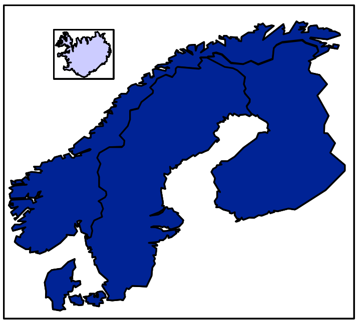
Sweden, Finland and Norway



Statistics
2005: 80 %
2006: 71 %

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 88 %

Total Nordel



Statistics
2005: 44 %
2006: 44 %

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 79 %

Figure 1.5: Percentage of time with an area price difference under € 2/MWh

2 Present situation

2.1 General demand for transmission

An efficient market within Nordel and efficient market relations between Nordel and the Continent are necessary for the appropriate utilisation of the production capacity.
The Nordic power system is dominated by hydropower and has a price structure that is significantly different from that of the European Continent and the southern part of the Nordel area, with its strong dominance of thermal power.

The hydropower dominance in Norway and Sweden leads to relatively stable prices during a typical day in contrast to the Continental prices with a wide variation between low-load periods and high-load and peak-load periods as shown in figure 2.1.

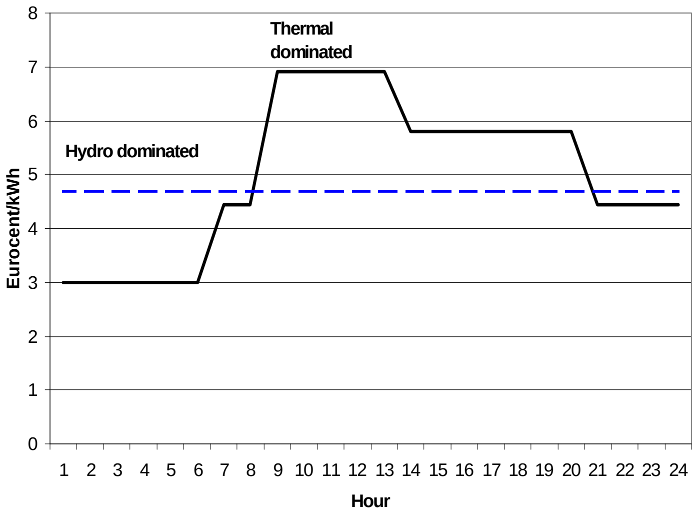


Figure 2.1: Illustration of price structure on the Nordic (hydro) and the Continental market (thermal)

This market structure leads to a demand for transport channels from the Continent to Norway/Sweden as shown in figures 2.2.a and 2.2.b.

A high-capacity East-West transport channel between the high consumption areas in Southern/Mid Sweden and Southern Finland is required to cope with natural fluctuations in the power flows between subsystems with different generation mixes and to ensure security of supply. The increased transmission capacity from Russia and Estonia to Finland also has an impact on required East-West capacity within the Nordel system as shown in figure 2.2.c.

The power flow to the Arctic region is increasingly brought into focus. New demand due to new consuming industries and more wind power projects in the Arctic region lead to a need for a transport channel from the Arctic region to the rest of the Nordel area as shown in figure 2.2.d.

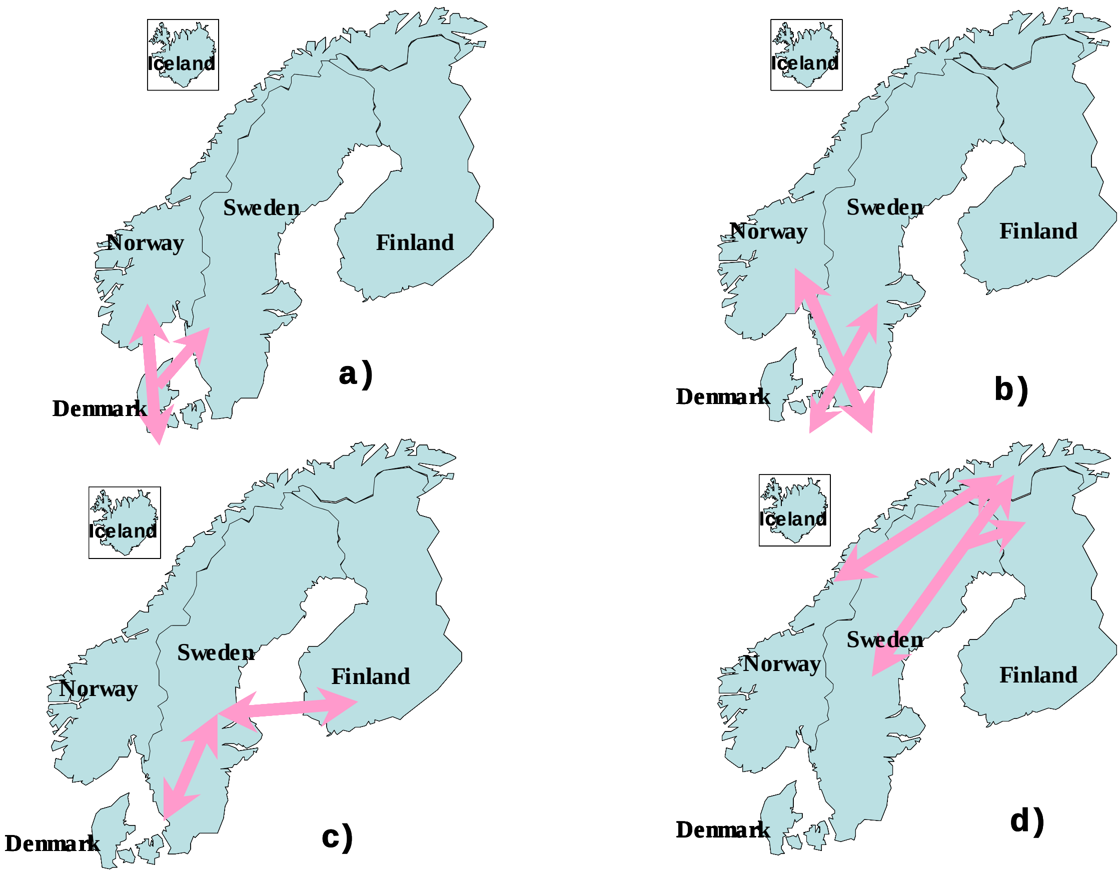


Figure 2.2: Transport channels and central cross-sections in the Nordel system.

The general demand for transmission capacity emphasises the need for an analysis of whether an appropriate level of connection capacity is reached by realising the five already proposed prioritised cross-sections and other already decided new lines and reinforcements.

2.2 Power balance

A power balance with country-specific peak demand in 2006/2007 is found in figure 2.3.a. In Sweden, Finland and Denmark-East, consumption was higher than production in the peak hours. Norway and Denmark-West managed the peak demand without imports. None of the Nordic countries experienced all time high peak demand in the last season. The national all-time high peak demands in the Nordic countries are as follows: Denmark East 2 700 MWh/h, Denmark West 3 780 MWh/h, Finland 14 900 MWh/h, Norway 23 050 MWh/h and Sweden 27 000 MWh/h.

The national peak demands corresponding to a probability of once in ten years 2010/2011 is shown in figure 2.3.b. The sum of these national peak demands corresponds to a probability of once in 30 to 40 years. The sum of peak demands in a 10-year winter day is estimated to be 3700 MWh/h higher than in average temperature conditions in 2010/2011.

The Nordic production capacity is estimated to be sufficient to cover the simultaneous peak demand in a 10-year winter day without imports in

2010/2011. The power balance is expected to be positive for all the Nordic countries in this situation.

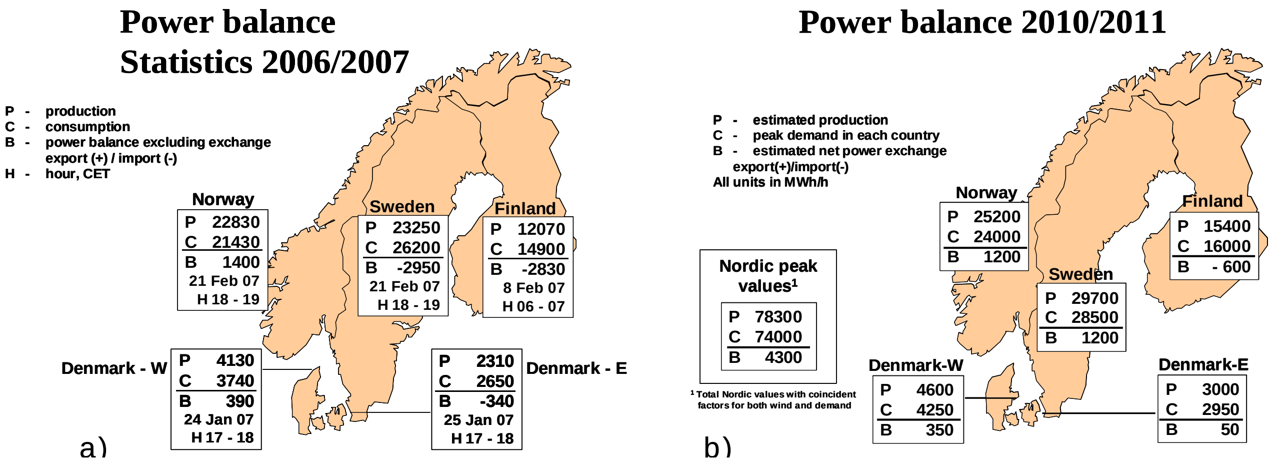


Figure 2.3: Power balance statistics (left) and available power capacity and peak demand in Nordel 2010/2011. Temperatures correspond to a 10-year winter day (right)

2.3 Energy balance

The total Nordel area had a negative energy balance with net imports from the Continent and Russia in 2006, which was a relatively average year.
An energy balance for 2006 (statistically corrected to be an average year) is shown in figure 2.4.a.
The balance for a business-as-usual development in 2010 is shown in figure 2.4.b. Investigations of the expected effect of climate changes invoke a need for adjusting the modelling of production and consumption.
Expected changes in the energy balance due to climate changes are incorporated in this figure. Data used in the analysis is not updated in line with the climate development. The changes in the energy balances will not influence the results of the analysis.

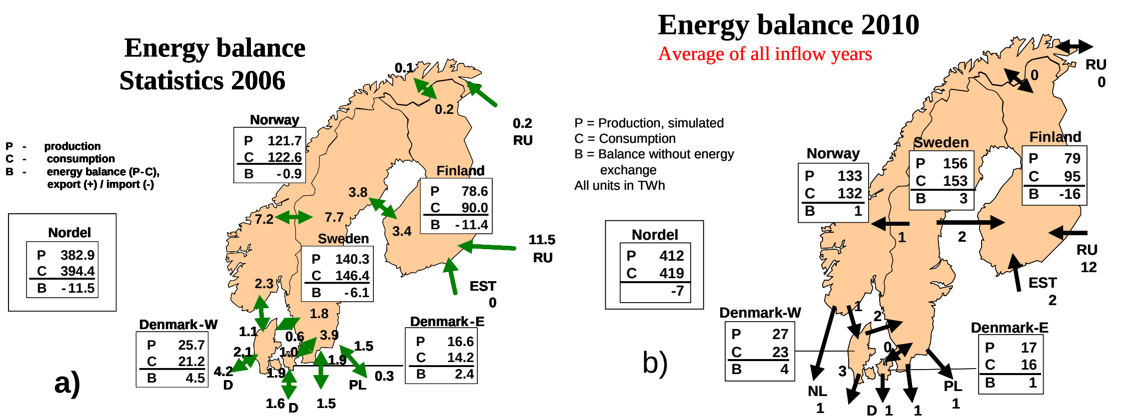
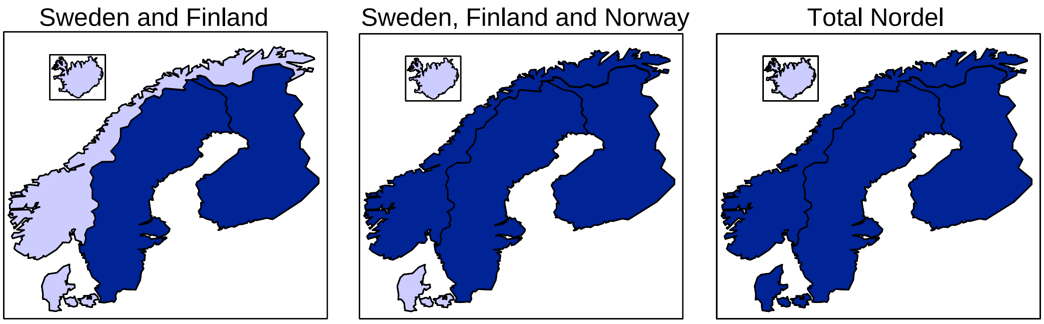


Figure 2.4: Energy balance statistics 2006 (left) and business-as-usual (BAU) in 2010 (right)

An improved energy balance is expected for the whole Nordel area and a situation with no net imports is expected for an average year in 2015.

2.4 Market situation

An indicator for the market situation is the frequency of equal prices in different price areas. The development in equal prices (percentage of time of the year with difference under € 2/MWh) is shown in figure 2.5. For Nordel as a whole, equal prices were found in 44% of the time in 2006 (statistics) and 65% when the five prioritised cross-sections are built for BAU 2015 (a calculated average year).



Sweden and Finland	Sweden, Finland and Norway	Total Nordel
Statistics 2005: 93 % 2006: 95 %	**Statistics** 2005: 80 % 2006: 71 %	**Statistics** 2005: 44 % 2006: 44 %
After the five prioritised cross-sections (BAU-2015) - all years: 99 % *- dry years: 97 %* *- wet years: 87 %*	**After the five prioritised cross-sections (BAU-2015)** - all years: 76 % *- dry years: 41 %* *- wet years: 55 %*	**After the five prioritised cross-sections (BAU-2015)** - all years: 65 % *- dry years: 25 %* *- wet years: 38 %*

Figure 2.5: Percentage of time with an area price difference under € 2/MWh

The share of times with equal prices for the whole of Nordel in scenario BAU 2015 is reduced to 25% in dry years and 38% in wet years.

2.5 Security of supply

In Nordel, all countries have system requirements for maintaining satisfactory security of supply. The security of supply is evaluated by using statistics of interruption and by using a calculated status indicator for the security of supply. This status indicator is called Loss of Load Probability (LOLP). The system requirement in Nordel is such that the Loss of Load Probability should not exceed 1 ‰ , which corresponds to the UCTE requirements for security of supply.
Nordel is using two different criteria for security of supply: one criterion for the risk of *system failure* and one for the risk of *market failure*. In a system-failure situation the supply capability is not sufficient to meet the demand in the hour of operation without disconnection of some load. In a market-failure situation, supply and demand do not meet in the day-ahead spot market as the supply bids are not able to meet the demand bids. Production units used for system reserves are not taken into account.

The security of supply calculations are made with the MAPS model. Internal transmission capacities are taken into account, and import possibilities from neighbouring systems are assumed to be half of the existing capacity.

Figure 2.6 shows the margins down to Nordel's system requirements of 1 ‰ for system failure and market failure for each country. According to the calculations, the risk of a system failure or a market-failure situation in the Nordic countries in 2015 is acceptable. This means that the security of supply situation for all the Nordic countries is calculated to be acceptable and within the European requirements (Nordel and the UCTE).

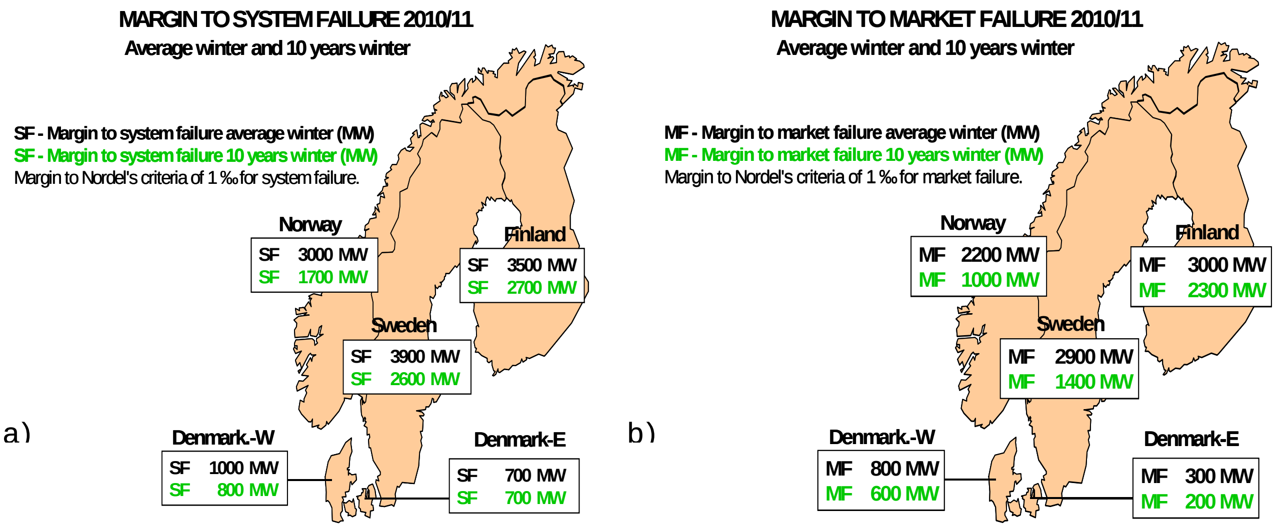
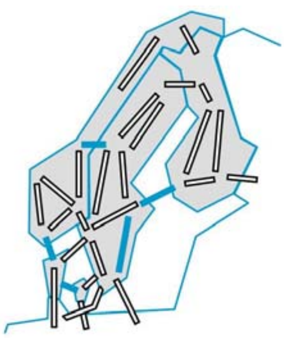


Figure 2.6: Margin to system failure (a) and margin to market failure (b) in 2010/11

A situation with a common-mode failure in nuclear power plants has also been analysed. In this analysis, the largest type of nuclear power plant, BWR units in Sweden and Finland (altogether 7950 MW), is out of operation. The analysis shows that this is a most dramatic situation for the Nordic grid and it would lead to a most difficult security of supply situation. However, the risk of such a situation is very low and has therefore not been dimensioning for the Nordel system.

2.6 Status for the five prioritised cross-sections



In June 2004, Nordel recommended reinforcement of five limiting cross-sections in the Nordic transmission grid. The present status of the five projects is described briefly here. A more detailed status report is available on Nordel web site.

Fenno-Skan 2

The project is in the tendering phase. The last permits are expected in mid-2008. The project time schedule has been postponed to the end of November 2011 mainly because of difficulties with the delivery of the submarine cable.

Nea – Järpströmmen

The project is proceeding according to the time schedule. Construction of the line starts in 2008 and it is expected to be in operation in summer 2009. The old line will subsequently be decommissioned.

South Link

Svenska Kraftnät has decided to implement the reinforcement but the selection of technology to be applied – AC or DC – was pending until early 2008. Svenska Kraftnät has now decided to combine the reinforcement with a link to Norway, using AC in the northern part and DC in the southern part as well as to Norway, see 4.2 for more detail. This new solution is called the SouthWest Link. The link is expected to be commissioned in 2012/2013 at the earliest.

Skagerrak IV

Statnett and Energinet.dk have signed a letter of intent. The earliest date of commissioning is 2012.

The Great Belt

Energinet.dk signed contracts with converter stations and cable vendors in spring 2007. The laying of the land cable is expected to start in 2008 and the laying of the submarine cable is scheduled for summer 2009. Planned start-up is in first half of 2010.

2.7 Nordic investments

Investments in the Nordic grid have risen to over € 500m/year. The level has more than doubled compared to the investments made in previous years. This higher level is expected to continue in the future, se figure 2.7. This increase in investments is caused by the large number of reinforcements that are underway in the Nordic countries - something that will lead to a significantly strengthened Nordic power grid. The most important projects are presented in more detail in chapter 6.

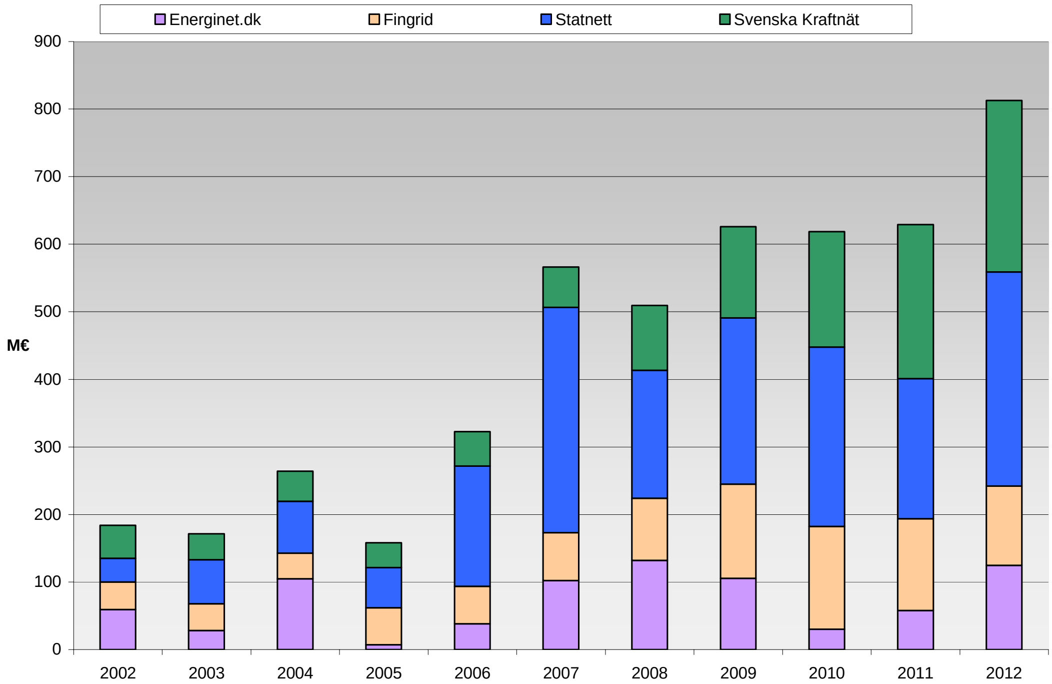


Fig 2.7: Nordic grid investments 2002 - 2012

2.8 Conclusions

The Nordic production capacity is estimated to be sufficient to cover peak demands on a cold winter day without imports from neighbouring countries both today and in the coming years. Expected new production capacity leads to a further increased power balance.

The energy balance in all the Nordic countries is expected to improve, and a positive power balance is expected in 2015 for an average year. The dry-year situation will also be further improved as a result of expected new production capacity and potential new links.

The security of supply situation for the Nordic countries is expected to be acceptable and within the European requirements. A situation with a common-mode failure in nuclear power plants would lead to a most difficult security of supply situation. However, the risk of such a situation is very low and has therefore not been dimensioning for the Nordel system.

All in all, the situation in the Nordic power system and market is good and is expected to become even better in the future with new power production and planned reinforcements of the grid.

3 *Analysis methods and assumptions*

3.1 General

The analysis is based on a socio-economic analysis of the costs and benefits of the potential cross-borders. Figure 3.1 shows the main workflow.

The future demand on the infrastructure is estimated on the basis of the Nordel scenarios developed for 2015 and 2025. A list of analysed cross-borders has been set up based on input from the countries.

Analyses of benefits from new lines are estimated with the Samlast model and MAPS model. The investment and operating costs of the new or reinforced lines have been estimated. The costs and benefits are summarised, and a cost-benefit ratio has been set up for all reinforcements.

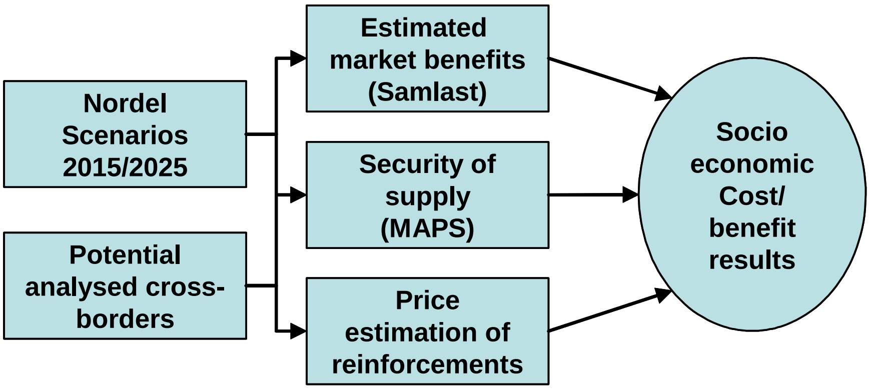


Figure 3.1: Workflow in socio-economic analysis of reinforcements

3.2 Elements in the cost-benefit approach

<u>Benefits included in the analysis</u>

The benefits are in accordance with criteria set up in September 2002 by Nordel's "Missing Link" group given as:

- Market value from production optimisation and energy turnover
- Reduced risk of power shortage
- Reduced electrical losses
- Reduced risk of energy rationing
- Trade in regulating power and ancillary services
- Value of reduced market power

The market value from production optimisation, reduced electrical losses and reduced risk of energy rationing have been calculated in the Samlast model developed by Sintef.

The reduced risk of power shortage has been calculated in the MAPS model. The MAPS model calculates the loss of load probability (LOLP), expected unserved energy (EUE) and expected power not served (EPNS).

Trade in regulating power and ancillary services and the value of reduced market power have not been analysed specifically. The influence on the benefit from the elements has only been estimated.

The socio-economic benefits are calculated both for the Nordic area and the Continental area. The results for the Nordic market are not divided between the different countries. The conclusions in the report are based on the total benefit and the total cost.

<u>Market power</u>

It is difficult to quantify the costs and benefits in a more well-functioning market. However, it is quite obvious that the energy market will become more robust and efficient when investments are made to remove congestion. Such investments should be based on socio-economic analyses to ensure that the benefits are higher than the costs. After the investments, the prices will be more stable at least in the short term.

Transmission investments will also help to mitigate the possible exercise of market power. Abuse of market power in the electricity market will lead to socio-economic losses. There is a clear link between transmission capacity and the possibility of exercising market power. Sufficient transmission capacity contributes to enlarging the market and thereby possibly reducing the risk of abusing market power.

It is not economically efficient to invest in transmission capacity that covers all patterns of trade. This is especially relevant for the Nordic market that has a large proportion of hydropower production. The hydro power situation will differ over the years and thereby affect the energy trade. A transmission system that covers all patterns of trade without any congestion will clearly have been over-invested, which is a waste of resources.

Deviations in the hydro inflows and failures in thermal-production units have exposed the Nordic electricity market to several tests during the last few years. More or less extreme situations have given high surplus as well as deficit in some areas with sharply increased and reduced prices as a result. Such situations often generate public discussions about the deregulated Nordic electricity market. It is common to the situations that confidence in the deregulated market is under pressure. Several national political and regulatory instruments are also launched and debated.

One question for the TSOs is to what extent these issues should be included into the calculation of new transmission investments. Today, the TSOs have no common model for this calculation. It is however obvious that the efficiency of the Nordic electricity market is based on the trust of all stakeholders and the value of a more well-functioning market should be considered and gives additional value when new transmission investments are considered.

Costs included in the analysis

The calculated investment costs include:

- Investments in a given transmission line and auxiliary parts
- Operation and maintenance of the line

Investments are based on a calculation of national cost levels for investments. Necessary reinforcements of the internal grid as a result of reinforcements of the interconnectors are not included in the investment costs. The total costs of the reinforcements is therefore higher and the resulting cost-benefit lower. This aspect must be investigated more thoroughly for the suggested reinforcements. This is of special interest when it comes to external Nordic reinforcements as there may be limiting intersections within the other countries that are not included in the analysis.

Cost-benefit for lifetime

The costs and benefits for each year have been analysed for a total lifetime of 30 years. The present value has been calculated by using a 5% rate of interest.

The total costs and benefits for the reinforcements have been calculated and the cost-benefit has been calculated as:

Benefit of reinforcements = Total benefits - Total costs

3.3 Transmission lines included in the analysis

The scope of *Nordic Grid Master Plan 2008* is to identify interconnector reinforcements with positive cost-benefit value.
All interconnecting transmission lines that could potentially be beneficial from a total socio-economic point of view should therefore be included in the analysis. The lines which have been analysed in the study are shown in figure 3.2.

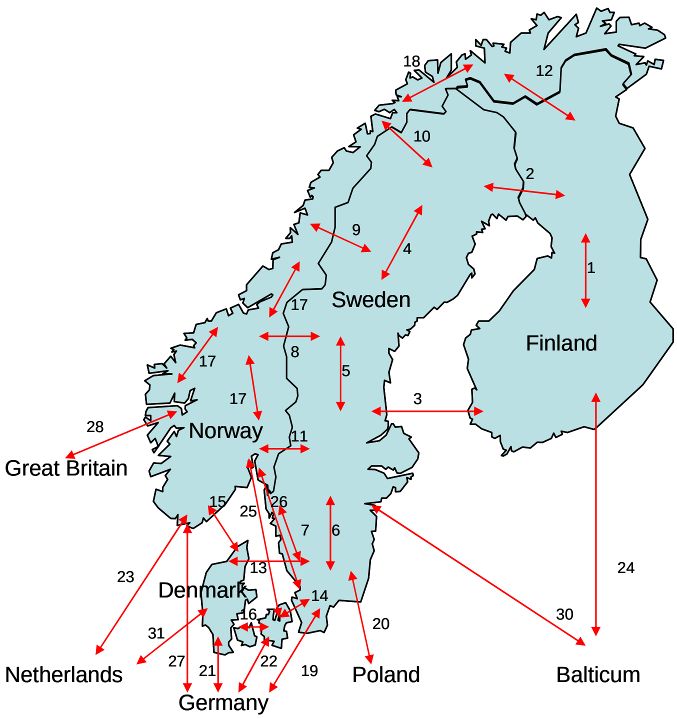


Figure 3.2: Analysed reinforcements

	No.
1) Denmark-East / Sweden ⇔ Norway	
Westcoast cross-section, Sweden South	7
Norway East - Sweden	11
Sweden - Denmark East	14
Norway - Denmark (Kattegat) (new)	25
Norway - Sweden (Kattegat) (new)	26
2) Denmark-West ⇔ Norway / Sweden	
Sweden - Denmark West	13
Norway - Denmark West	15
3) Finland ⇔ Sweden	
Sweden North - Finland North	2
Sweden South - Finland South	3
4) Sweden ⇔ Norway	
Norway North - Sweden (Nedre Røssåga - Ajaure)	9
Norway North - Sweden (Ofoten - Ritsem)	10
5) Sweden	
Cross section 1, Sweden	4
Cross section 2, Sweden	5
Cross section 4, South Link, Sweden	6
6) Mid-Norway	
Norway Mid - Sweden	8
Import Norway Mid	17
7) Arctic regions	
Norway - Finland	12
Norway North - Norway Finn	18
Other international Nordic	
Finland North - Finland South	1
Denmark West - Denmark East	16
External Nordic (existing)	
Sweden - Germany	19
Sweden - Poland	20
Denmark West - Germany	21
Denmark East - Germany	22
Norway - the Netherlands	23
Finland - the Baltics	24
External Nordic (new)	
Norway - Germany (new)	27
Norway - Great Britain (new)	28
Sweden - the Baltic (new)	30
Denmark West - Netherlands (new)	31

3.4 Nordel scenarios representing the future development

<u>Definition of the scenarios</u>

Investments in infrastructure have a typical lifetime of 30 years or more. The benefit of the investments depends on the future development in fuel prices, production systems and consumption demand.

Nordel has developed scenarios for the future electricity market situation in order to analyse the cost-benefit of investments given different future pathways. These scenarios are defined as a business-as-usual scenario in 2015 and three alternative paths for development until 2025. The three scenarios in 2025 are called *Climate & Integration 2025*, *National focus 2025* and the reference scenario *Business as usual 2025*. The Business-as-usual scenario has been divided into a scenario with small increase in capacity (BAU2025-) and a scenario with large increase in capacity (BAU2025+)

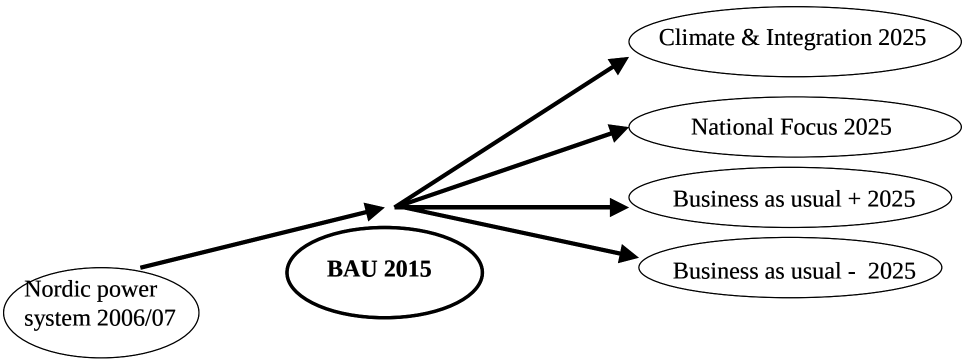


Figure 3.3: The Nordel scenarios used in Nordic Grid Master Plan 2008

The focus on environment and the level of international cooperation are some of the significant driving forces in the development in production and consumption.

The scenarios have been defined in the framework of these parameters (integration and climate focus). The three scenarios are defined as shown in figure 3.4.

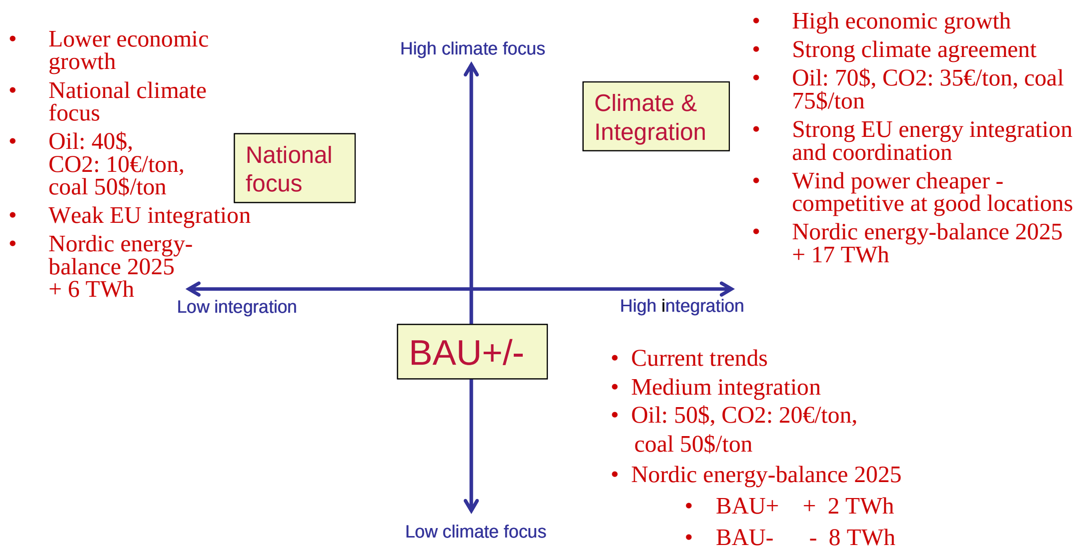
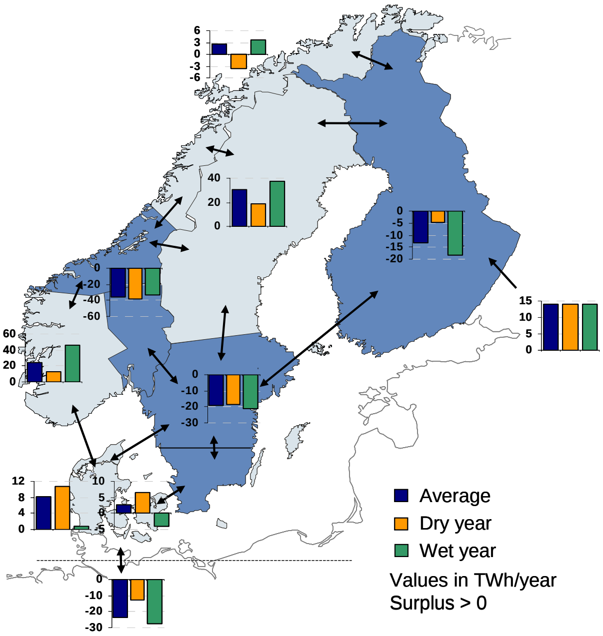


Figure 3.4: The three scenarios illustrated in the dimensions "integration" and "climate focus".

The "Business-as-usual" (2015 and 2025) scenario

This scenario is a projection of the current trends. A moderate focus is expected on the climate and on the integration of the market between the countries.

In this scenario, fuel prices are at a level corresponding to the IEA 2006 prognosis, and CO_2 prices are at a medium level. The growth is expected to be at a medium level as well.



Significant investments in production capacity are expected in the BAU scenario. The production capacity increases in all Nordic countries. Consumption increases in general and a specific sector increase is found in some of the countries as shown in figure 3.6.

Figure 3.5: Energy balances in BAU 2015 scenario

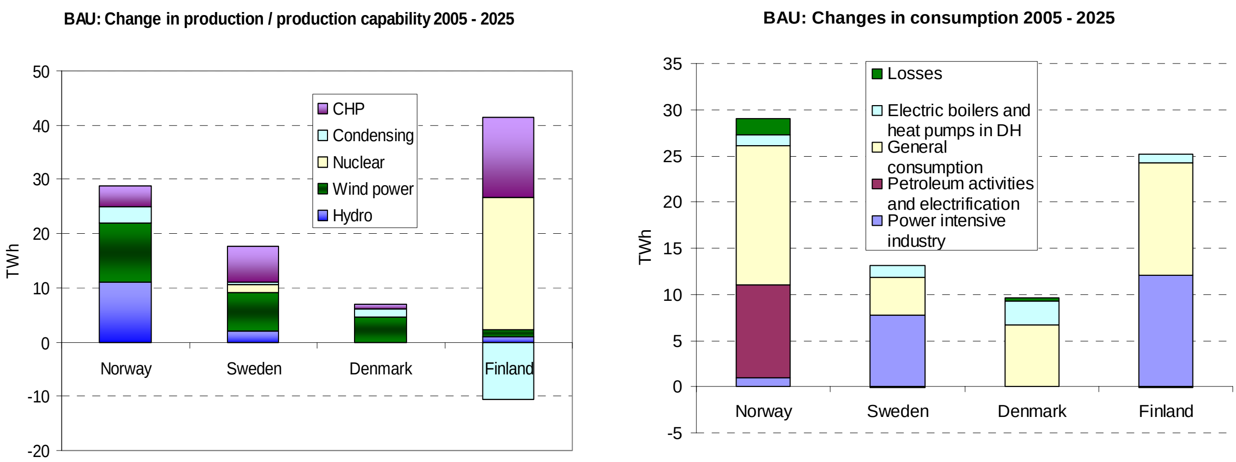


Figure 3.6: Net changes in production and consumption from 2005 to the "Business as usual 2025 scenario".

The National focus (2025) scenario

In this scenario there is focus on national solutions, with a low level of integration between the EU countries. The growth is relatively low.
The fuel prices in this scenario are relatively low (20% below IEA estimated level), and the CO_2 price is set to €10/ton. This scenario leads to less price difference between the hydro-dominated area and the thermal-dominated area, due to the low fuel prices. New lines from the Nordic countries to the Continent will therfore be less beneficial compared to the BAU scenario.

The Climate & Integration (2025) scenario

In this scenario there is high focus on climate with a strong international agreement on emission reductions. CO_2 prices are at a relatively high level (€ 35/ton), and fuel prices are at a level corresponding to $ 70/barrel of oil. In this scenario, wind power is competitive with fossil fuel-based electricity production at good locations. In general, more wind power and hydro power and less CHP is installed in this scenario.

Most of the new wind power is situated in the northern parts of Norway and Sweden. A summary of changes in production and consumption in this scenario compared to Business as usual is shown in figure 3.7.

The changes in production capacity made in this scenario leads to a stronger energy balance compared to BAU. There is also a larger price difference between the hydro- and wind-dominated Nordic area and the Continental thermal-dominated area because of the high fuel prices and the surplus of renewable energy in the Nordic countries. New lines from the Nordic area to the Continent are therefore more beneficial in this scenario than in BAU. Internal lines from the northern area to the southern area of Nordel will also gain value because of the need for transport of the increased wind power in the north.

Production and consumption in the scenarios compared to BAU 2025

In *Climate & Integration,* a significant increase in wind power and hydropower and a decrease in condensing production are assumed.

In the *National focus scenario* a significant increase in CHP and less production at nuclear power plants are found as shown in figure 3.7.

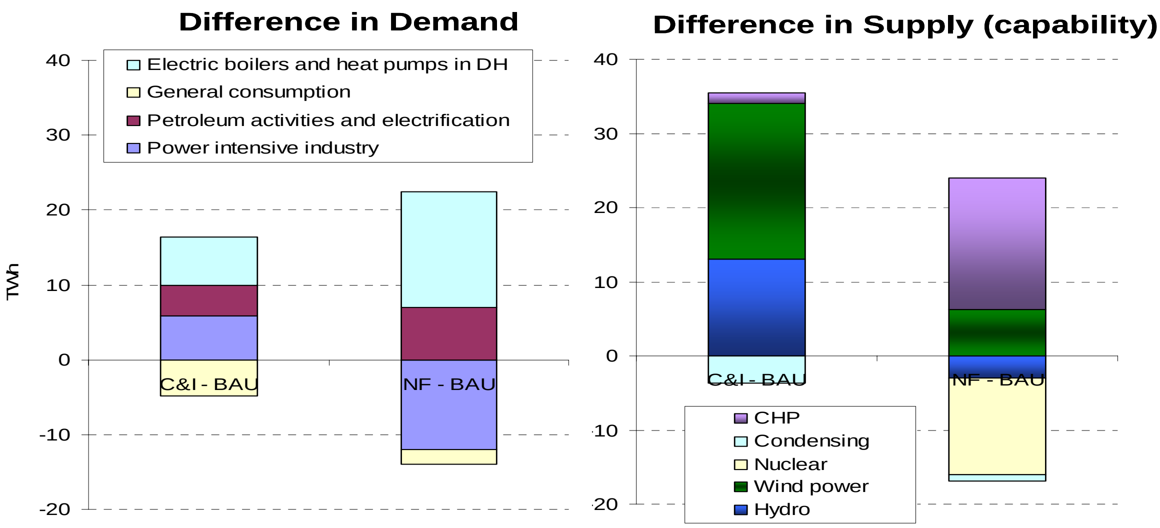


Figure 3.7: Difference in demand and supply for the scenarios "Climate & Integration 2025" and "National focus 2025" with reference to "Business as usual 2025"

Energy balances in the scenarios

Figure 3.8 shows the actual energy balances from 1990 to 2006 and the simulated balances from 2007 until 2025. In general, the energy situation for Nordel is getting more in balance or even getting into a surplus situation. This is due to investments in new production capacities, e.g. wind power, nuclear power and CHP. The *Business-as-usual scenario* has been divided into two conditions (BAU 2025+ and BAU 2025-) with a neutral and a negative energy balance. This has been done to analyse a situation corresponding to today's negative energy balance.

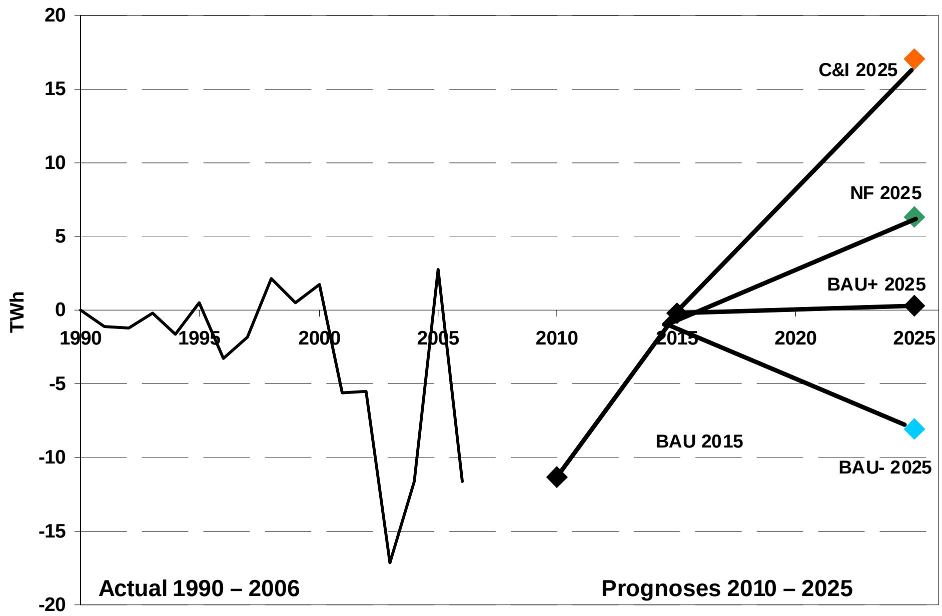


Figure 3.8: Energy balances for 1990 - 2025

The energy balances for the different scenarios are shown in figure 3.9.

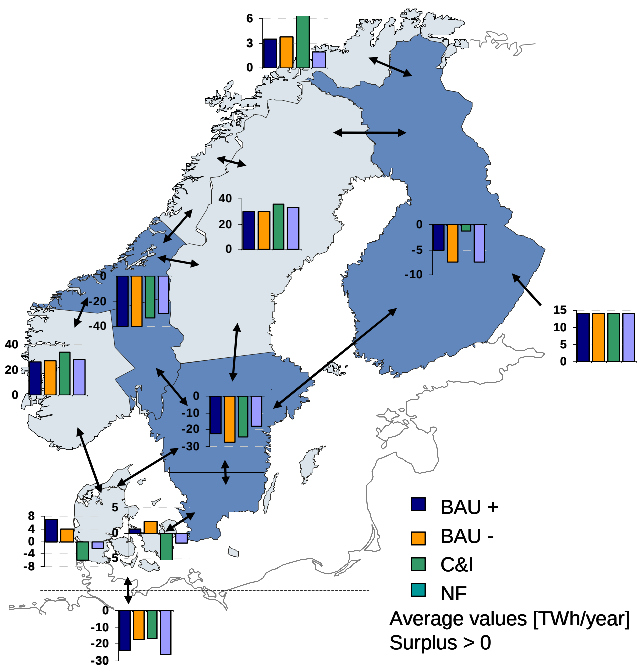


Figure 3.9: Energy-balances for the different scenarios.

Power balances and security of supply in the scenarios

In the scenarios for 2015 and 2025, investments in new production capacity is implemented, and the Nordic countries will have an energy balance or even an energy surplus, see figure 3.9. This increase in production capacity leads to an improvement in the power balance in the Nordic countries. New power production will also improve the margins to the system requirements for maintaining satisfactory security of supply.

4 Internal Nordic lines – Results of the analysis

4.1 Categorisation of lines

The cost-benefit of twenty internal lines has been investigated. The results of the analysed internal lines have been divided into seven areas as shown in figure 4.1. Areas with high positive cost-benefit have been marked with red circle. Areas with a positive benefit in only some of the scenarios are marked with a red dotted circle. Other analysed areas are marked with grey circles.

Analysis divided into areas:

1. Denmark East / Sweden – Norway
2. Denmark West – Norway / Sweden
3. Finland – Sweden
4. Sweden – Norway (North)
5. Sweden
6. Sweden – Norway (North – South axis)
7. Arctic region

Positive cost-benefit in all scenarios

Positive cost-benefit in *Climate & Integration scenario*

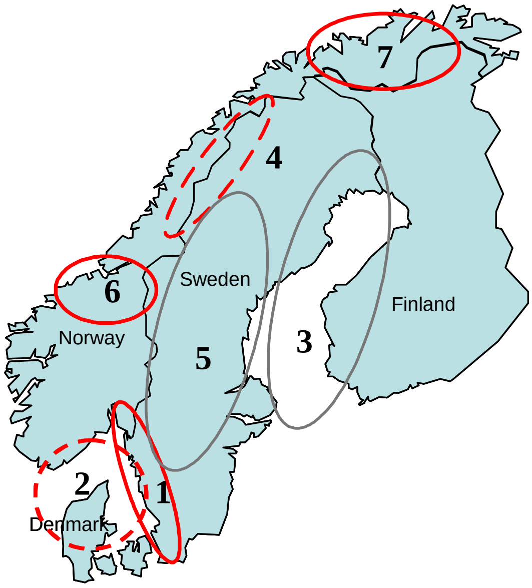


Figure 4.1: Studied reinforcements divided into areas.

High, positive cost-benefit has been found for reinforcements in the areas:

1: Denmark-East/Sweden ⇔ Norway
6: Sweden – Norway (North – South axis)
7: Arctic region

In the *Climate & Integration scenario* the following areas have also shown positive cost-benefit.

2: Denmark – Norway/Sweden
4: Sweden – Norway (North)

4.2 Reinforcement Sweden - Norway (South)

In relation to the Nordic market the cross-section between Sweden and Norway (South) often experinces bottlenecks. In dry periods and during nights/week-ends, the bottlenecks are most often related to problems in the so-called West-coast cross-section in Sweden. In wet periods and during daytime the bottlenecks are most often related to problems in the Norwegian grid near Oslo (the so-called Hasle-trappen).

In relation to security of supply in Norway (energy), the transmission corridor along the Swedish west-cost is important, especially in dry years, for energy imports to Norway, primarily from Denmark and the Continent. Along the corridor the nuclear power plants at Ringhals contribute to the power flows to Norway. In the past this corridor has limited the possibility for Norway to import power and several reinforcements have been made to increase the capacity. Among them is the new decided line outside of Gothenburg that will be built next year. As to security of supply for Sweden/Denmark/Finland (power), Sweden's possibilities of importing power from Norway in times with good availability of hydro power has been limited by the grid around Oslo. Some of these limitations will be removed by reinforcing the Norwegian grid.

A positive cost-benefit has been found for the reinforcement of capacity in the direction from Sweden to Norway by reinforcing the West coast cross-section between the Gothenburg region and the Oslo region. In the opposite direction a positive cost-benefit has been found for reinforcing the capacity in the direction from Norway to Sweden by reinforcing the Norwegian grid near Oslo. These reinforcements will lead to reduced bottlenecks for the market as well as improved security of supply.

Svenska Kraftnät and Statnett proposed in January 2008 to reinforce those areas by means of a new VSC HVDC connection between Norway and Sweden and combining it with the previously decided reinforcements of southern Sweden. The new project, called the SouthWest Link, will consist of a new AC line in Sweden, a new multi-terminal VSC HVDC connection with terminals near Oslo in Norway, around Jönköping in Sweden and at Hörby in southern Sweden.

<u>Sensitivity to the different scenarios and to other reinforcements</u>

The benefits of reinforcing the grid between Norway (South) and Sweden depend on the scenarios for 2025 as shown in figure 4.2. The benefit of the reinforcements seems to increase in all scenarios for 2025 compared to the BAU2015.

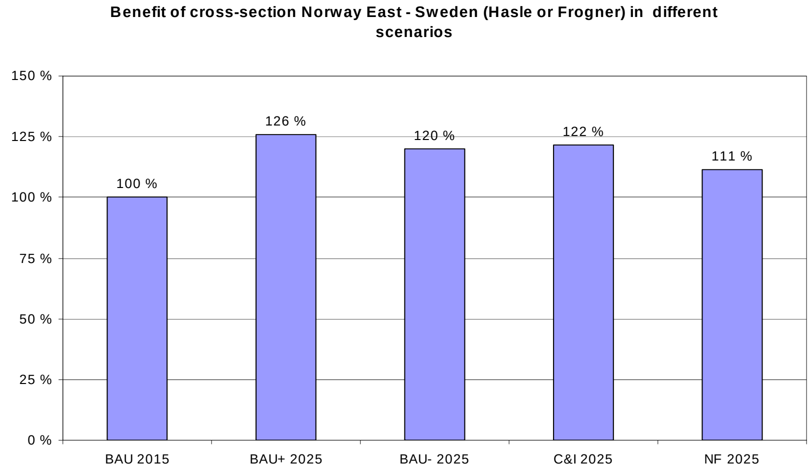


Figure 4.2: Sensitivity of benefit of reinforcing the grid between Sweden and Norway (South) in the various scenarios

The benefits of reinforcing the grid between Norway (South) and Sweden also depend on potential reinforcements of other connections. The sensitivity to reinforcement of other lines is shown in figure 4.3. An increased capacity from Sweden to Germany will significantly increase the benefit.

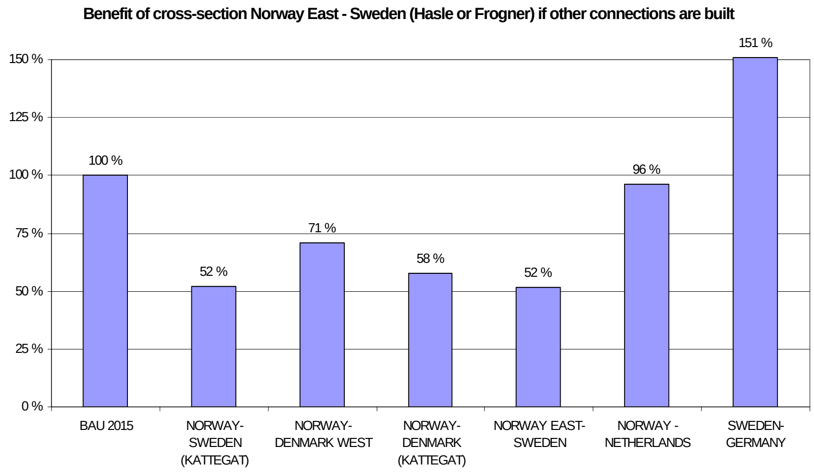
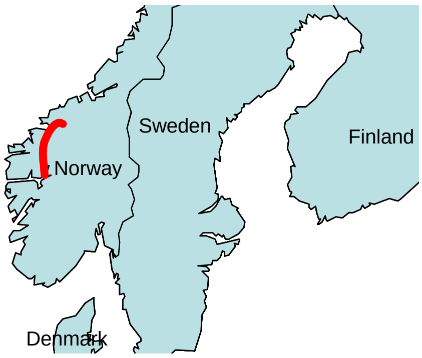


Figure 4.3: Sensitivity of benefit of reinforcing the grid between Sweden and Norway (South) if other connections are reinforced.

Conclusions

Nordel recommends Statnett and Svenska Kraftnät to start the planning process with the purpose of strengthening the grid between Sweden and Norway.

4.3 Reinforcement Sweden – Norway (North – South axis)



The transmission system in the north-south axis is today very weak in Norway compared to the Swedish system. The Swedish system consist of eight 400 kV lines whereas the Norwegian system consists of only one 300 kV line and two 132 kV lines. A new 420 kV line Ørskog-Fardal in Norway in combination with the new line Nea-Järpströmmen will strengthen the Swedish/Norwegian north-south capacity and at the same time decrease possible capacity problems related to cross-section 2 in Sweden. The Ørskog-Fardal line will also give increased import capacity to the Mid-Norway region, which has a negative energy balance caused by new power-intensive industries built in recent years. The Mid-Norway region has a negative energy balance of about 9 TWh. This has become worse in the last few years due to new power intensive consumption in the region. A new alumina-plant (Hydro Sunndalsøra, 5 TWh) was established in 2005; in 2007, a new petroleum-related industry was established (Ormen Lange, 1.3 TWh). This leads to the negative energy balance of about 9 TWh for a quite small area, which means that the import capacity to the Mid-Norway area must be increased.

Construction has commenced on the new 400 kV transmission line from Nea in Norway to Järpströmmen in Sweden. This line is a part of Nordels five prioritised cross-sections. In addition Statnett will install voltage regulation equipment at eight substations. Analyses in *Nordic Grid Master Plan 2008* show a positive economic net value for even higher capacity to the Mid-Norway area and in the Swedish/Norwegian north-south axis. This is related to both security of supply and to lower the number of hours with bottlenecks in the Nordic market. The analyses show highest benefit on a new line between Fardal and Ørskog in Norway. The analyses show that this line has a very positive effect in that the number of bottlenecks in the Nordic market decreases. Also the capacity in the Swedish/Norwegian north-south axis will be strengthened. The economy has been found to be positive in all the scenarios. The length of the line Fardal-Ørskog line is 300 km and the cost estimated at some € 250 million. A licence application for the line was submitted in 2007

<u>Sensitivity to the different scenarios</u>

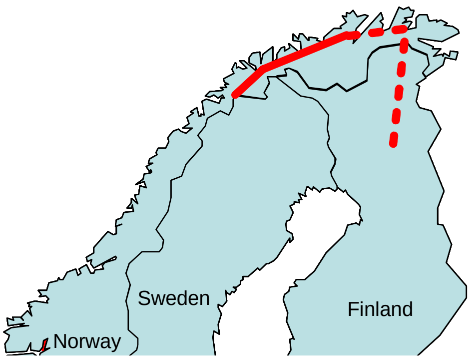
The cost-benefit calculations for the Fardal-Ørskog line show positive economic net value for the BAU-2015 scenario. For the 2025 scenarios the cost-benefit calculations in general show higher values than for the BAU-2015 scenario. This is due to higher consumption and hardly any new production in the area, which leads to an even higher negative balance in 2025 than in 2015. However, new gas power plants or new wind power plants will lead to an improved energy balance and also lower economic cost-benefit value for a new line. This can for example be seen in the *Climate & Integration-scenario* where high CO_2 taxes lead to many new wind power plants in the Mid-Norway region.

However, the calculations show positive cost-benefit value for all the scenarios.

Conclusions

Nordel recommends the construction of the 420 kV line Ørskog-Fardal line.

4.4 Reinforcement Arctic region



The arctic region, especially the county of Finnmark in Norway, has a grid with very low capacity. This is historically related to the fact that the region has low consumption, which used to give negative cost-benefit compared with the long distances for potential new lines. The total import/export capacity today into/out of the region is about 200 MW when assuming the N-1 criteria. However, new petroleum-related consumption (Snøhvit 2) and the potential establishment of new wind power plants change the assumptions of the analyses.

The county of Finnmark is almost in balance at the 2010 stage. Further ahead the balance can go either way, but most probably the arctic region will be an energy supplier exporting energy to other regions. As the consumption related to petroleum activities is expected to rise, the Snøhvit Phase 2 (300 MW) is implemented in all scenarios. On the production side there are currently a number of concrete plans for new wind power plants in Finnmark. Today application licences have been sent for about 1200 MW (3.5 TWh) wind power. Furthermore notifications for about 1600 MW (4.8 TWh) wind power have been sent. This leads to a possibility for Finnmark to become an energy supplier. The technical challenges in relation to such large amounts of wind power are huge, which also leads to a need to strengthen the grid.

A development that includes both petroleum-related consumption and large wind power volumes leads to a need for a stronger grid. This is related to both satisfactory security of supply, smaller number of bottlenecks, possible petroleum sector-related consumption and to possible new production. In summer 2007, Statnett therefore announced the construction of a new transmission line from Balsfjord to Hammerfest. Analyses also show potential positive cost-benefit in relation to reinforcing the grid in a southerly direction on the Ofoten-Balsfjord stretch of the line. The analyses show that this line has a very positive effect regarding decreased number of bottlenecks in the Nordic market. The capacity in the Swedish/Norwegian north-south axis will also be strengthened. In the analyses for *Nordic Grid Master Plan 2008*, the new line Ofoten-Balsfjord-Hammerfest has a positive cost-benefit net value in all the scenarios.

In addition, analyses on strengthening the grid between Norway and Finland have been made. Also for this line the cost-benefit calculations show a positive net value. However the calculations for these two lines assume that the other line has not been built. The two different reinforcements (1) Balsfjord-Hammerfest and (2) Norway - Finland are alternatives and are found to be mutually exclusive in BAU 2015.

Sensitivity to the different scenarios

The cost-benefit calculations for only one new line show positive economic net value for the BAU-2015 scenario. For the 2025 scenarios the cost-benefit calculations in general show higher values than for the BAU-2015 scenario. This is due to higher consumption and more varying wind production in the area, which leads to an even higher demand for imports/exports to the region than in 2015. This can for example be seen in the *Climate & Integration scenario* where high CO_2 taxes lead to many new wind power plants in the arctic region. The calculations show positive cost-benefit value for one new line for all the scenarios.

Conclusions

Given Snøhvit Phase 2, Nordel recommends the 420 kV Ofoten-Balsfjord-Hammerfest transmission line. As a next step in strengthening the power grid to the arctic regions Nordel recommends analyses of the connection between Norway and Finland.

4.5 Interconnectors with positive cost-benefit in specific scenarios

The cost-benefit value of the internal Nordic reinforcements depends on the future scenarios. In the *Climate & Integration 2025 scenario,* some additional lines get a positive cost-benefit value. This is found for the connections:

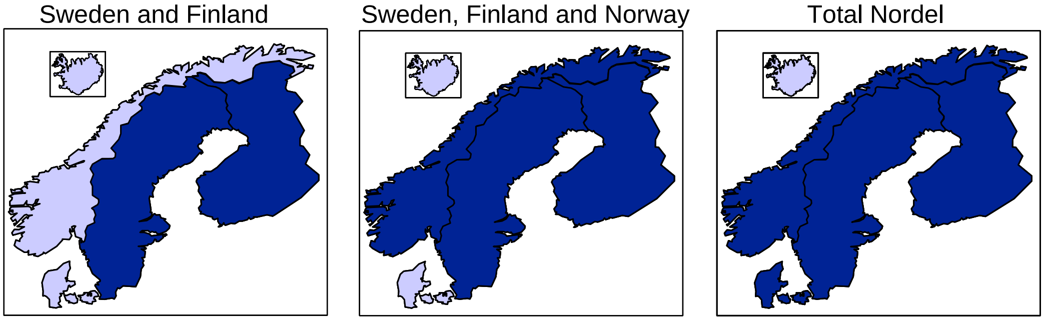
- Norway North - Sweden
- Sweden - Denmark-West
- Sweden - Denmark-East
- Norway - Denmark-West
- Norway - Denmark-East

The *Climate & Integration 2025 scenario* has a more positive energy balance in Norway and Sweden with more wind power. More wind power in northern Norway leads to an increased value for reinforcements for that area. The scenario also has a weaker energy balance in Denmark compared to the other scenarios. This is caused by the higher CO_2 prices and therefore lower production from coal fired plants in the scenario. This leads to higher benefit for new connections between Denmark and Norway/Sweden.
It has been assumed that the Skagerrak IV connection has already been established in the reference.

Conclusions

Nordel does not at this stage recommend the implementation of these reinforcements based on the fact that they are profitable only in one scenario. However, there is a clear trend that climate issues will be of increasing importance in the future. It is therefore important to study the reinforcements further at a later stage. They will be re-evaluated in future grid master plans.

The development in equal prices (percentage of time of the year with difference under € 2/MWh) is shown in figure 4.4. For Nordel as a whole, equal prices were found in 44% of the time in 2006 (statistics) and 65% when the five prioritised cross-sections are built for BAU 2015 (a calculated average year). After the new proposed internal Nordic reinforcements are in place that figure increases to 79%.



Sweden and Finland

Statistics
2005: 93 %
2006: 95 %

After the five prioritised cross-sections (BAU-2015)
- all years: 99 %
- *dry years: 97 %*
- *wet years: 87 %*

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 94 %

Sweden, Finland and Norway

Statistics
2005: 80 %
2006: 71 %

After the five prioritised cross-sections (BAU-2015)
- all years: 76 %
- *dry years: 41 %*
- *wet years: 55 %*

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 88 %

Total Nordel

Statistics
2005: 44 %
2006: 44 %

After the five prioritised cross-sections (BAU-2015)
- all years: 65 %
- *dry years: 25 %*
- *wet years: 38 %*

After the five prioritised cross-sections and the new proposed reinforcements
- average for all years: 79 %

Figure 4.4: Percentage of time with an area price difference under € 2/MWh

5 External Nordic interconnectors – Results of the analysis

5.1 Interconnectors analysed

In general, interconnectors between the Nordic countries and other markets will have a very positive potential. Such interconnectors will in a good way utilise the distinctive characteristics of the different markets. The characteristics of markets dominated by hydropower, thermal power or wind power differ greatly as to the physics of the generation and demand side, security of supply aspects (energy versus power) and the price structure of electricity in the different markets. Together, all these factors indicate that additional interconnectors between the Nordic area and other markets are very interesting both from an economic and a technical point of view. In addition reinforcement of the grid supports the political market view with a more integrated European energy market.

Interconnectors from Nordel to the UCTE (the Netherlands, Germany and Poland), the UPS (the Baltic States) and the NG (UK) have been analysed. The modelling of the Continent (UCTE) has been done at a more detailed level in these analyses than the modelling of the other systems. Interconnectors to the UPS and the UK have therefore only been analysed in relation to costs, and the benefit has not been quantified by a model.

<u>Following links analysed:</u>

1. Sweden - Germany
2. Norway - Netherlands
3. Norway - Germany
4. Norway - Great Britain
5. Denmark W - Netherlands
6. Denmark W - Germany
7. Denmark E - Germany
8. Sweden - Poland
9. Sweden - The Baltics
10. Finland - The Baltics

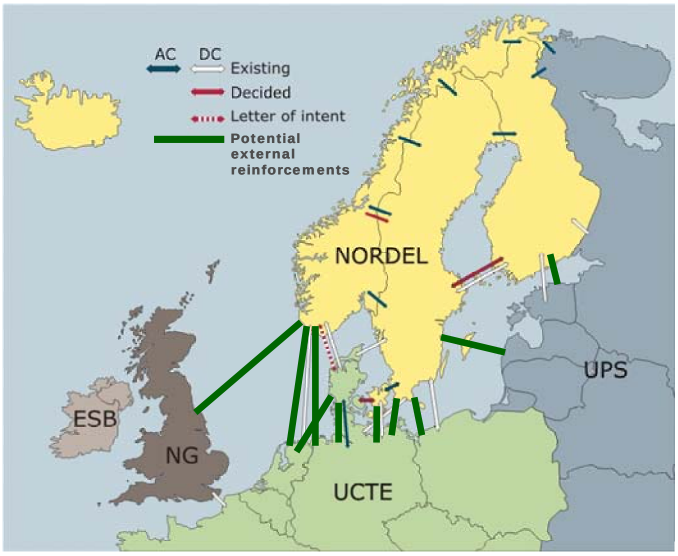
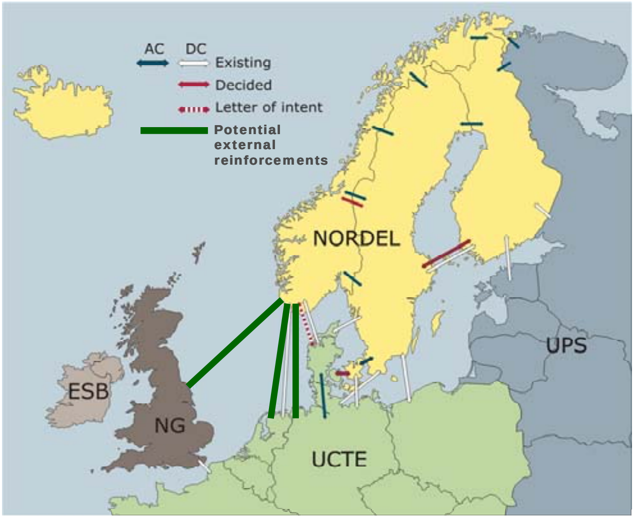


Figure 5.1: External Nordic interconnectors with positive cost-benefit

5.2 From Norway to the Continent and the UK



Interconnectors between Norway and the Continent or Great Britain have the potential for being very useful links. Regarding the economic side, the structural difference between the hydro-dominated market and the thermal-dominated market will cause price-differences, which will give high trading income on new links. Regarding security of supply, new links will strengthen the dry-year situation in Norway and also strengthen the peak-load situation for the Continent and/or Great Britain.

The analyses show positive cost-benefit net value for links to Norway. They also show that the potential interconnectors have higher trading income than other Nordic links, especially for dry/wet years. Furthermore, the security of supply to Norway in dry years is essential for the total benefit of the interconnectors. However, on the negative side, the investment costs relating to the links will be much higher than other investigated links due to the long distance between Norway and the Continent/Great Britain. The conclusions drawn from the analysis is that all the interconnectors have a positive socio-economic net value. This is both due to the high trading income, increased consumer/producer surplus and a strengthened security of supply situation.

Norway - Germany
High positive cost-benefit has been found for this connection. Additional costs of reinforcing the internal grid have to be investigated, and possible Continental bottlenecks are not included in the analysis. The economy is found to be positive for all scenarios. Statnett has in cooperation with E.ON Netz started a project (NORD.LINK) for analysing the possibility of a new link between Norway and Germany. Another project (NorGer) between Norwegian producers (Lyse/Agder) and EWE (Germany) is looking at the same possibilities.

Norway – The Netherlands
High positive cost-benefit has been found for this connection. Additional costs of reinforcing the internal grid have to be investigated, and possible Continental bottlenecks are not included in the analysis. The economy is found to be positive for all scenarios. As a result of the positive prospects, a new link between Norway and the Netherlands (700 MW) is built and planned commission is in April 2008. This link is included in the reference.

Norway – Great Britain

In the analysis only the cost-side has been evaluated. Statnett and National Grid (NG) of the UK have continued their discussions since the NSI project was stopped in the autumn of 2003. NG has accepted many of Statnett's demands for more balanced ownership and risk, and a simpler business model and power exchange system. The licences to build the facilities are still valid.

<u>Sensitivity to the different scenarios</u>

The cost-benefit calculations for new links between Norway and the Continent/Great Britain show positive economic net value for the BAU-2015-scenario. For the 2025 scenarios, the cost-benefit calculations show both higher and lower values than for the BAU-2015 scenario. The cost-benefit is sensitive to future fuel and CO_2 prices. As a result, the cost-benefit is increased in case of the *Climate & Integration scenario* and reduced in the *National focus scenario*. For the BAU-2025 scenarios there are only minor changes compared to BAU-2015. This is shown in figure 5.2, where the relative values of the benefit are shown for a potential link between Norway and Germany.

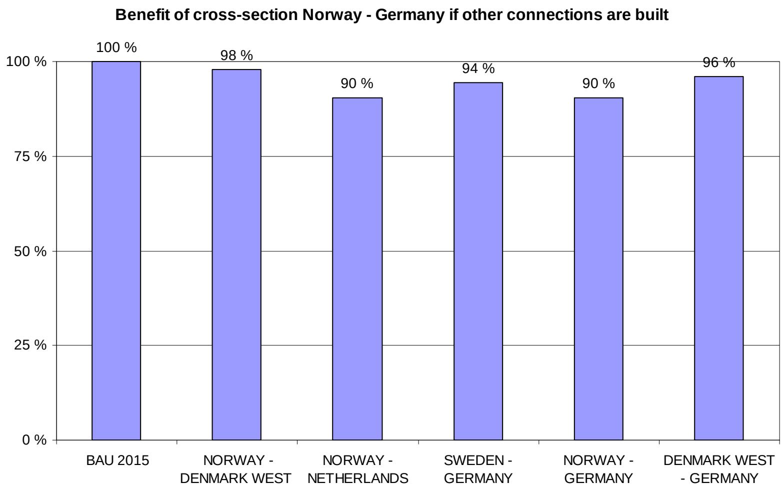


Figure 5.2: Benefits of the Norway-Germany interconnection depending on the various scenarios for 2025.

<u>Sensitivity to other reinforcements</u>

In addition to the sensitivity to the different scenarios, also sensitivity regarding other interconnectors being built is tested in the analyses. This is shown in figure 5.3, with Norway-Germany as an example. Figure 5.3 shows the relative values of the benefit of a potential link between Norway and Germany and the reduction in this benefit if other links are built. The figure shows that only

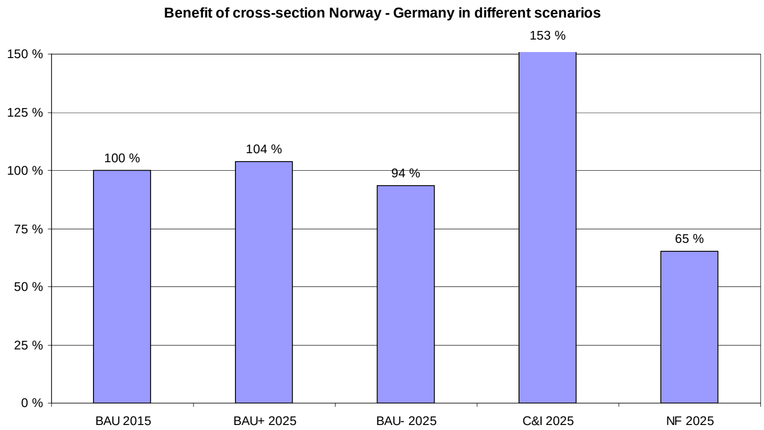


Figure 5.3: Sensitivity of benefit from Norway-Germany interconnection if other connections are established.The sensitivity to a Norway – Germanu connection established at the same time is also shown

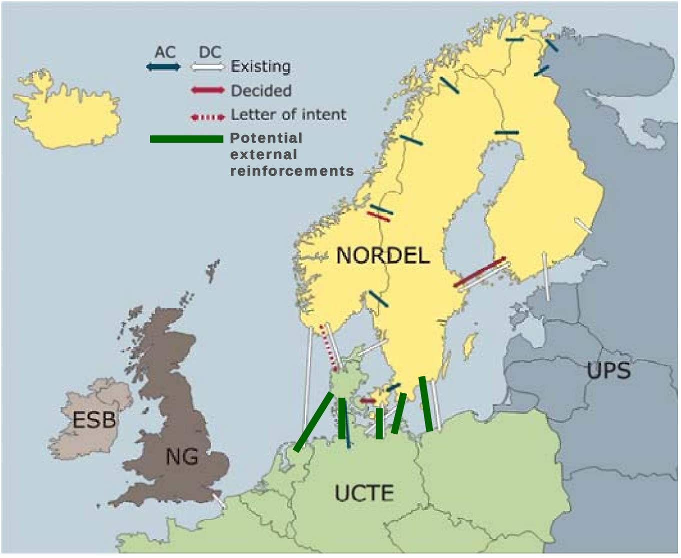
smaller reductions are found if other connectors in the transit path from Nordel to the Continent are built.

Conclusion

Nordel supports bilateral projects between Statnett and external TSOs

5.3 From Sweden/Denmark to the Continent

Connections from Denmark/Sweden to the Continent show high trading income. The distances are relatively short which leads to relatively lower investment costs



The lines listed below all show a positive cost-benefit.

Sweden - Germany
In addition to the positive cost-benefit shown in the analysis for all scenarios, this link has a potential for connecting wind power at Krieger's Flak. There have also been ideas for a multi-terminal HVDC link connecting Sweden, Denmark-East and Germany.

Sweden - Poland
This connection shows a lower benefit than the connection between Sweden and Germany and roughly the same investment costs. However, the analysis still shows a positive cost-benefit with the assumptions made for most, but not all of the scenarios.

Denmark-East - Germany
High, positive cost-benefit has been found for this connection. Additional costs of reinforcing the internal grid have to be investigated, and possible Continental bottlenecks are not included in the analysis. The economy is found to be positive for all scenarios.

Denmark-West - Germany
A very high cost-benefit ratio is found for this connection. The line has relatively low investment costs and high benefit, which leads to a very positive economy in all scenarios. Some increase in the capacity has already been obtained and further steps are planned. Internal reinforcement of the grid is necessary to obtain the benefits from increased capacity.

Denmark-West - the Netherlands
This connection shows a slightly higher benefit than for the connection to Germany, but the investment price is much higher. A positive economy is found, but the cost-benefit ratio is significantly lower than that for the other two connections between Denmark and the Continent.

Sensitivity to the scenarios for the connections from Denmark to Germany

The sensitivity to the various scenarios is shown in figure 5.4.
It shows that the benefit from the connection from Denmark-West to Germany will be reduced in the *Climate & Integration scenario* and even more in the *National focus scenario*. The total cost-benefit however will still be very positive for the connection.

The interconnection from Denmark-East to Germany also shows lower benefit in the *Climate & Integration scenario*. This is partly due to the fact that in a high climate scenario, the Danish coal-condensing capacity is assumed to be reduced, and the income from exports to Germany will decrease.

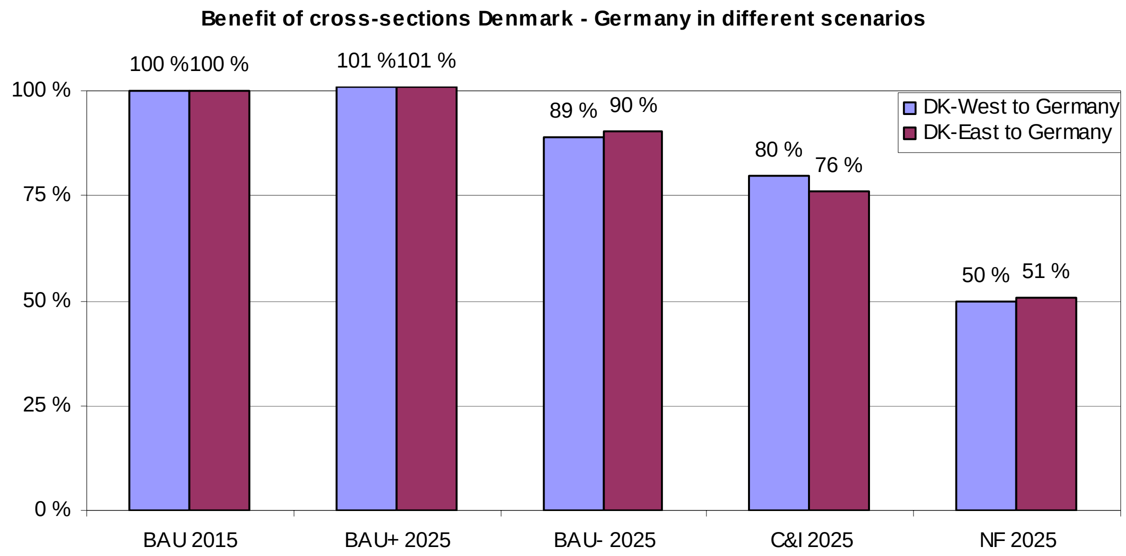


Figure 5.4: Benefits from Denmark to Germany connections in the different scenarios

Sensitivity to connection from Denmark to Germany if other connections are established

The benefit of these lines is not very sensitive to the establishment of other lines.
The benefit for the Denmark-West - Germany connection is shown in figure 5.5.

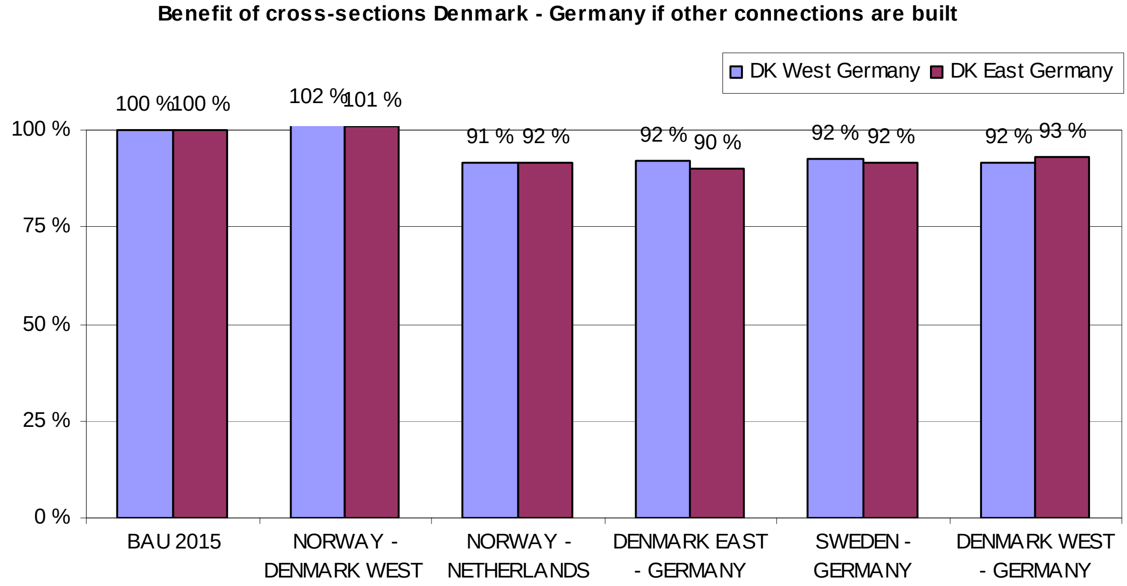


Figure 5.5: Sensitivity to benefits from Denmark-Germany interconnection if other connections are established

<u>Sensitivity to the scenarios for connections from Sweden to Germany</u>

For the Sweden-Germany connection the *Climate & Integration scenario* leads to significantly higher benefits and the *National focus scenario* leads to significantly lower benefit as shown in figure 5.6.

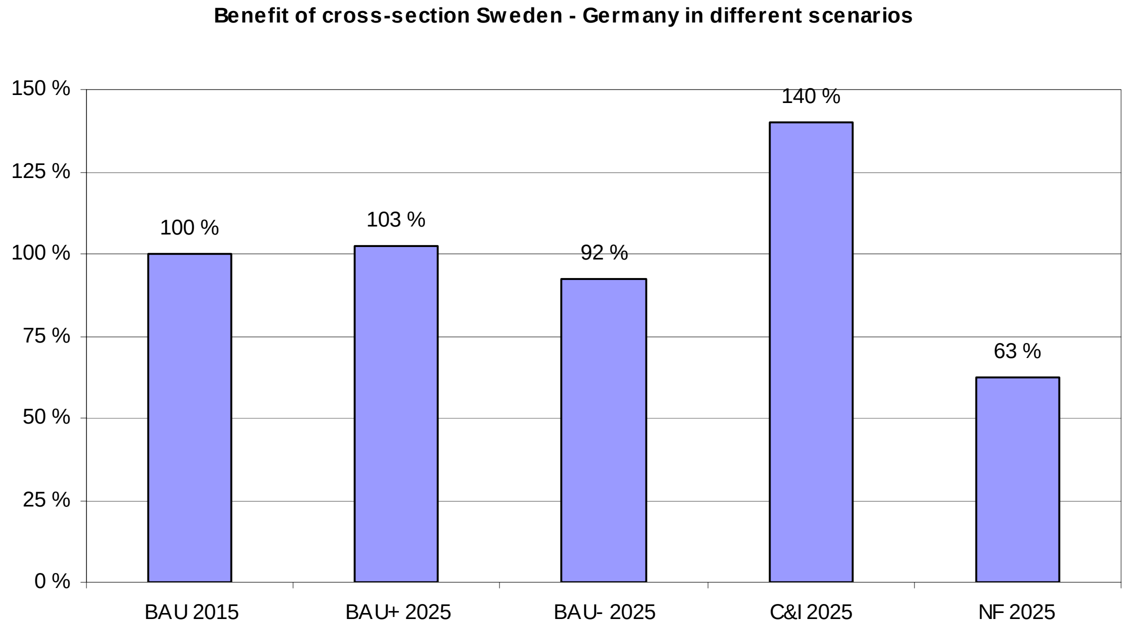


Figure 5.6: Benefits from Sweden-Germany connection in the different scenarios

Sensitivity to Sweden-Germany connection if other connections are established

The benefit of the line is not quite sensitive to the establishment of other lines. The benefit for the Sweden-Germany connection is shown in figure 5.7.

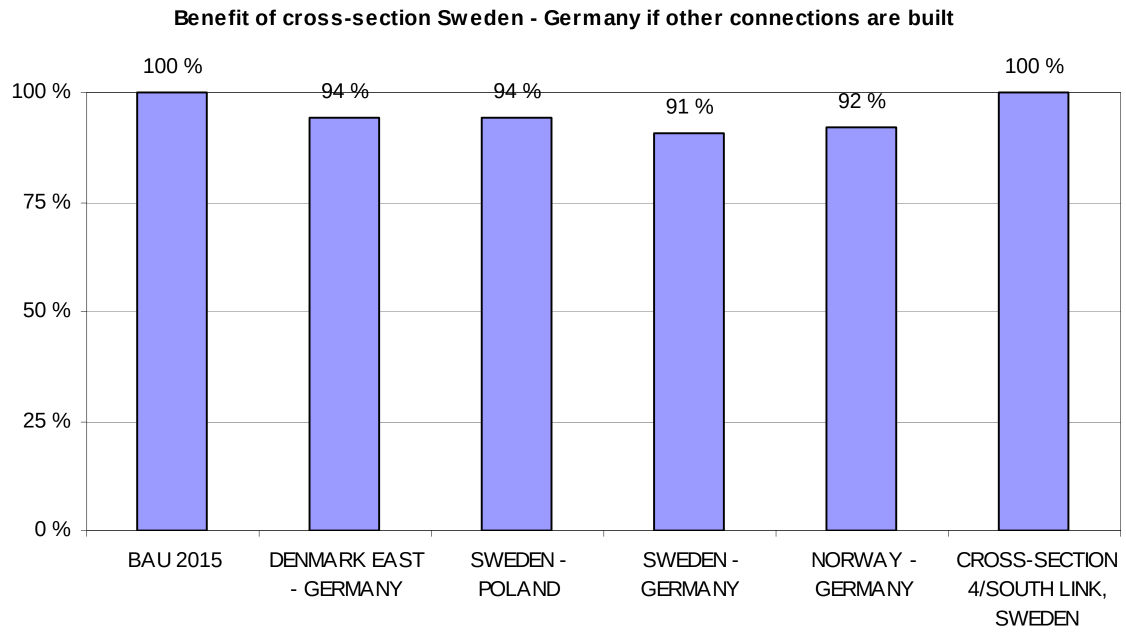
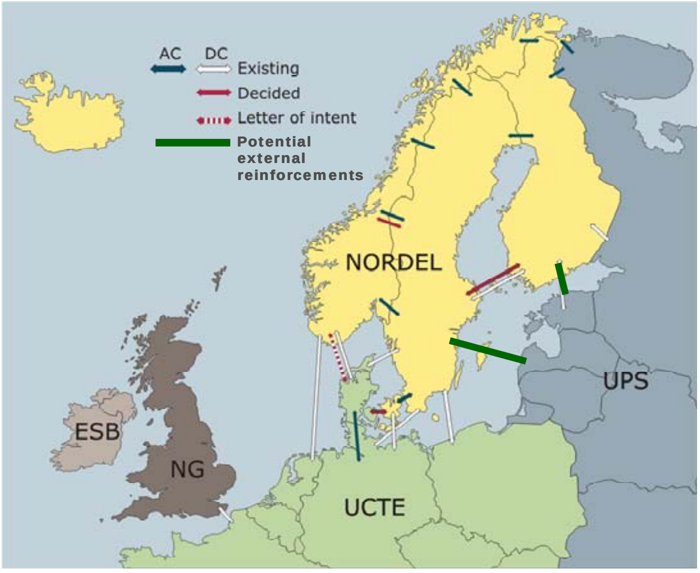


Figure 5.7: Sensitivity to benefits from Sweden-Germany connection if other connections are established.

Conclusion

Nordel supports bilateral projects between Svenska Kraftnät, Energinet.dk and external TSOs

5.4 From Sweden/Finland to the Baltic States



Connections from Sweden and Finland to the Baltic States have only been analysed in relation to costs. A model for the UPS area has so far not been implemented in the Samlast model.
The prospects for the Baltic market are uncertain but its development towards an open market is assumed in the analysis.
Nordel in co-operation with BALTSO and the polish PSE Operator has launched a multiregional study to evaluate socioeconomic benefits of prospective new connections to the Baltic Sea region as a whole and to coordinate different plans and projects.

Sweden - Lithuania
A joint Swedish - Lithuanian study is currently in its final stage. The results indicate that there may be a positive socio-economic value for an interconnection between Sweden and Lithuania. The results have to be thoroughly analysed and compared with the results from the study made within Nordel for other external Nordic reinforcements since the model and its data are different.

Finland – Estonia
A new Finland – Estonia link has been considered as an option in the Baltic Grid Master Plan under preparation by BALTSO. The applicability and cost-effectiveness of this prospective connection will be evaluated as a whole with other possible new connections in a multiregional planning study between BALTSO and Nordel.

<u>Conclusion</u>

Nordel supports bilateral projects between Fingrid, Svenska Kraftnät and external TSOs

5.5 Uncertain factors

The benefit of connections between Nordel and the Continent depends very much on the price structure in the hydro-dominated Nordel and the thermal-dominated UCTE as shown in chapter 2, figure 2.2. For instance, the technology development may lead to significantly lower start/stop costs, which will reduce the price fluctuations for the Continental market. This will lead to a lower benefit of the connections to the Continent. On the other hand, other factors in the model may lead to conservative results, ie too low benefits. The general conclusion is that the model gives results that are sufficient to serve as a basis for the conclusions drawn.

The future of the Baltic and Russian electricity markets is uncertain. The model used assumes a well-functioning market.

Oil, gas, coal and CO_2 price trends have a significant effect on the results. These aspects are elaborated in the scenarios, but will be a source of uncertainty all the same.

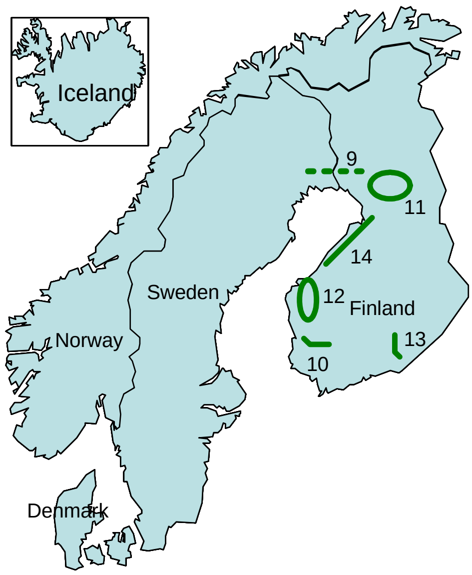
6 *National projects of importance to the Nordic system*

6.1 General

Apart from the joint Nordel studies made specifically for this report, studies are performed by each TSO of the national grids. There are many purposes for theses studies but one is to see how the grid needs to be reinforced to keep the good function of the Nordic electricity market with changing conditions. A short status is given below for larger projects and strategies with positive influence on the Nordel system. A presentation of other reinforcements with a more national focus can be found in each TSO's ordinary information materials. There is a clear increase in the amount of effort put into reinforcing the Nordic grid as can clearly be seen from the investments made in the Nordic grid. They have risen to over € 500m/year, which is twice the amount of previous years, see figure 2.7.

6.2 Finland

Fingrid has launched three 400 kV overhead line projects which also have Nordic significance:



Ulvila – Kangasala, 129 km 400 kV AC line (#10), to be commissioned in 2008, will strengthen the Finnish West Coast cross-section to fully utilise the upcoming Fenno-Skan 2 HVDC link. This regional reinforcement is also necessary due to the Olkiluoto 3 nuclear power plant project, which will increase power surplus on the West coast.

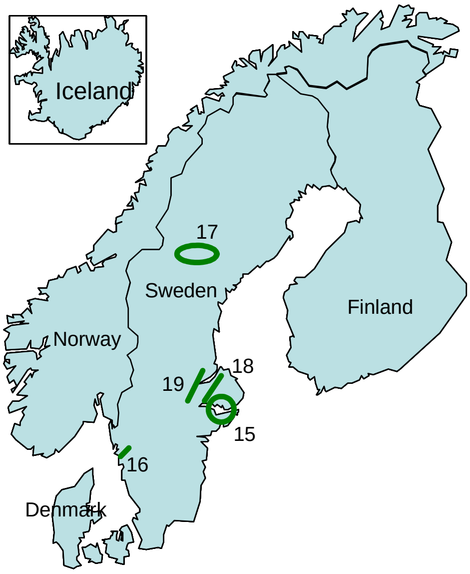
Petäjäskoski – Keminmaa, 63 km 400 kV AC line (#11) and series compensation of the existing 400 kV Petäjäskoski – Pyhänselkä and Pirttikoski – Pikkarala lines, to be commissioned in 2009. The projects will strengthen the AC interconnection between Sweden and Finland to cope with the new situation after start-up of Olkiluoto 3.

Seinäjoki – Tuovila, 55 km 400 kV AC line (#12), to be commissioned in 2010, will enable 400 kV operation on the line sections Kristiina – Tuovila and Tuovila – Ventusneva. Environmental Impact Analysis (EIA) for Tahkoluoto – Kristiinankaupunki line has also been started. When the line will be constructed, it will close the southern part of the 400 kV Ostrobothnia line loop and strengthens the West Coast cross-section. These extensions also pave way for abandonment of the 220 kV system.

Fingrid has started an update of earlier completed environmental impact analyses for the construction of a new 150 km 400 kV line connection Yllikkälä – Huutokoski, (#13). The reinforcement will help maintain a high availability of Russian imports to the Nordic/European market. The new line is also necessary to relieve bottlenecks in the underlying 110 kV network and to enhance transmission capacity on the South-Eastern cross-section.

Extension of the 400 kV Ostrobothnia line northwards up to the river Oulujoki is under consideration (#14). This line increase transmission capacity on the Borth-South cross-section.

6.3 Sweden

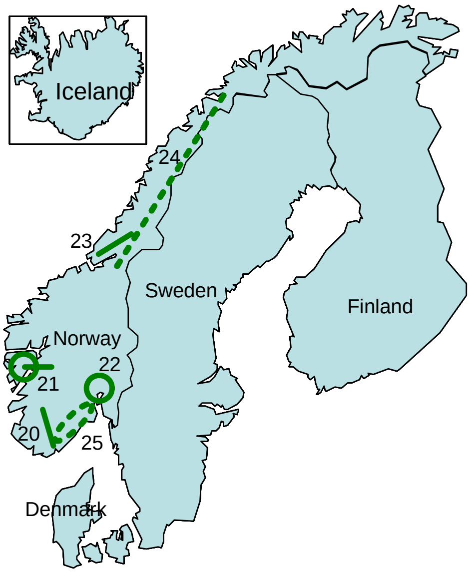


There are several ongoing activities to reinforce and strengthen the security of supply in the Swedish national grid. One programme improves the layout of important substations by replacing old switchyards with double-breaker, double-busbar configurations using disconnecting breakers. The programme has rebuilt 2-3 substations a year in recent years and will continue to do so in the coming years.
Another ongoing activity is to strengthen the grid around the capital region of Stockholm (#15). Among the planned projects is a new 400 kV cable connecting the 400 kV grids north and south of the city to each other.
Also the area around Gothenburg will be reinforced. A concession for a new 400 kV line is expected to be granted in autumn 2008 (#16). This line will have the added benefit of reinforcing the so-called “West-Coast” cross-section that has at times limited the power flow between Denmark and Norway until the proposed “SouthWest Link” is taken into operation.
Reactive resources are to be installed at several substations in the national grid to strengthen some cross-sections that are limited by voltage problems (#17). Of special interest to the Nordic market is the intersection called “Snitt 2” that will be reinforced in this way.

Future planned reinforcements include a new 400 kV line from Forsmark nuclear power plant to accommodate the increased power production at the plant (#18). A new 400 kV line is also planned from the area where the new Fenno-Skan 2 will be connected - an area that may also see a lot of wind power in the future (#19). These lines are important to ensure that the added production/import can be transported from the area to the market without jeopardising the security of the system.

6.4 Norway

There are several plans to upgrade and expand the Norwegian transmission grid in the near future. Projects, whose investment



has been decided or an application sent, are described below.

In southern Norway, an investment for a new line between Skåreheia and Holen (#20) has been decided and will be in operation in 2009. The line is important for the interconnectors to the Continent, for transferring power out of and in to Norway.

To maintain the security of supply in the western part of Norway (area around Bergen), a licence application for a new line, Sima-Samnanger (#21), was sent in June 2006. One of the key factors for grid development in western Norway is increased petroleum-related consumption in the area. In eastern Norway (Oslo), several components for generation of reactive power will be installed (#22) in order to to maintain security of supply in the area.

New wind power installations on the coast of Norway can generate a need for new transmission lines. As an example, an expansion of the wind power capacity in Fosen requires an improvement of the grid between Namsos and Roan (#23). A licence application for this transmission line was sent in autumn 2007. Further on an application for a new line Roan-Trollheim in the Mid-Norway region has been sent.

In the longer time horizon, several reinforcements could be of interest. For these projects no application have been sent. One of the largest would probably be an improved transmission grid between Mid-Norway and North-Norway (#24) The main driving forces for this extensive improvement are petroleum-related consumption and additional wind power in the northern part of Norway.

Another possible reinforcement will be the conversion of existing 300 kV lines into 420 kV lines in the southern part of Norway (#25). Such reinforcement will make it possible to build even more capacity between the Continent and the southern part of Norway.
Further on, electrification of Norwegian oil-drilling platforms and possible offshore wind-power installations in the North Sea can be relevant.

For a deeper view of ongoing and future projects in the Norwegian grid, see the Norwegian Grid Development Plan 2007 – 2025 by Statnett SF.

6.5 Denmark

In Denmark, a few large power infrastructure projects and some strategic analyses of the future power infrastructure are carried out.

A new Energy Strategy 2025

In 2007, the government published a proposal for a new energy strategy with a prospect for renewables in the energy sector until 2025. The strategy is expected to be discussed and passed by the Danish

Parliament in early 2008. The strategy proposes a significant increase in renewable electricity production. A major part of the production is expected to be produced at new offshore wind power plants.

Potential sites for new offshore wind power production were published by the Danish Energy Authority in 2007.

The power infrastructure requirements due to this potentially significant increase in offshore wind power were analysed by Energinet.dk in 2007. More detailed studies will be carried out in 2008.

New guidelines for using overhead lines and high voltage cables

A revision of the existing guidelines for using overhead lines and high voltage cables has proved to be necessary. A committee has been formed and new guidelines are expected to be published in 2008. Some of the larger infrastructure projects involving new overhead lines will await the new guidelines as they will influence the level of cost significantly.

Reinforcement from Jutland to Germany and Kassø-Revsing

A reinforcement of part of the connection from Jutland to Germany has been planned (#26). The project is awaiting the results of the general strategy for using overhead lines and cables in new transmission lines.

Possible new reinforcements

Reinforcement of the internal grid is investigated as a result of increased wind power production and increased capacity from Jutland to Germany etc. and to maintain the security of supply. The reinforcements may involve a new ring structure in Zealand (#27), a new enhanced capacity on Jutland's west coast (#28) and other reinforcements required.

6.6 Iceland

Landsnet is planning for several transmission system expansions and upgrades for the coming years.

There is still considerable interest to invest further in new aluminium plants and other heavy industries in Iceland. In conjunction with a future smelter near Húsavík, Landsnet is preparing and planning for new transmission lines and substations in Northern Iceland with the aim of connecting new and existing geothermal power plants in the area with the existing 132 kV grid and the smelter.

Landsnet decided in the beginning of the year 2007 to start the preparation and planning of strengthening the transmission system in Reykjanes in order to connect future geothermal power plants and new industry load in the area as well as being able to improve the availability of power delivery both to and from the region for the existing market.

A new connection from Nesjavellir geothermal power plant is under preparation to accommodate the increased power production at the plant, maintain the security of supply and avoid overloading of the existing connection.

Future geothermal power plant investments in Hellisheiði call for system expansions and upgrades in and around that area, which Landsnet is currently planning for.

The long term system development plan published in year 2007 presented a need for a few upgrade and expansion projects. Among others is the need to strengthen the connection and increase transmission capacity between the 220 kV system in southwest of Iceland and the load and generation areas in northeast. Several solutions were suggested, which are now being studied in further detail.

Appendix 1:

Figures A.1.1 and A.1.2 show the production and consumption in Nordel from 1990 to 2025.

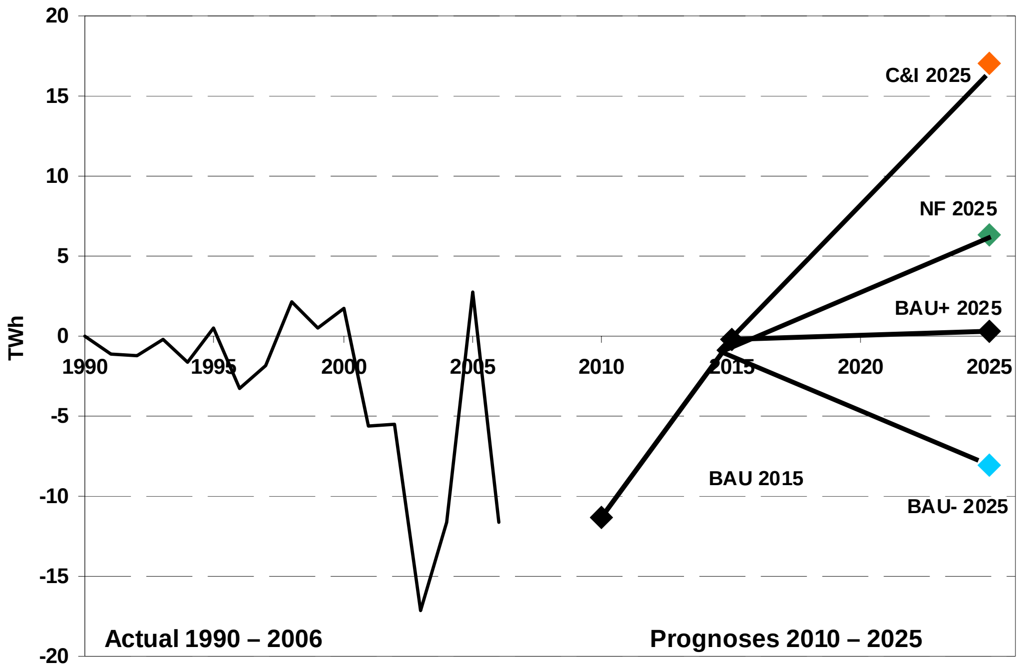


Figure A.1.1: Production in Nordel 1990 – 2025

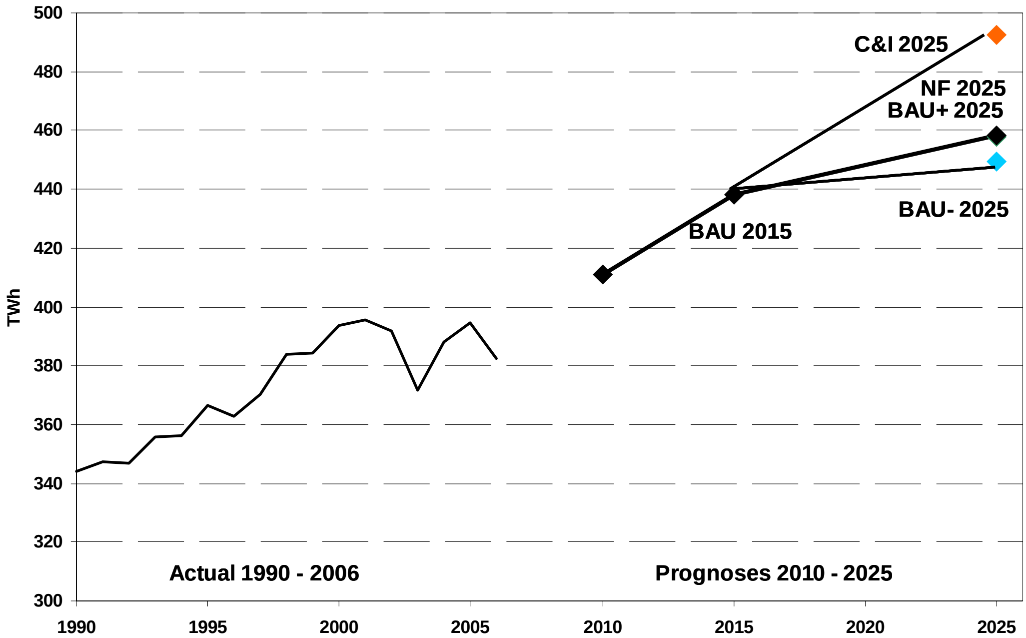


Figure A.1.1:Consumption in Nordel 1990 – 2025