Market based analysis of interconnections between Nordic, Baltic and Poland areas in 2025

BALTSO

Nordel

PSE Operator S.A.

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Executive summary

The transmission system operators in Baltic Sea region from NORDEL, UCTE and BALTSO have signed the mutual Memorandum of Understanding, the "Coordination of Multi-Regional System Planning in The Baltic Sea Region between BALTSO, NORDEL and PSE Operator S.A." in the end of 2007. The aim and purpose of this cooperation is to set mutual understanding and principles for system planning cooperation between the parties around the Baltic Sea. The practical value of the co-operation includes the development of coordinated extension plan of interconnections from the Baltic States to Poland and to Nordel area in order to satisfy transmission needs between areas.

This study is executed by the following transmission system operators:

- PSE Operator S.A. (Polish TSO, UCTE)
- Svenska Kraftnät (Nordel)
- Fingrid Oyj (Nordel)
- Lietuvos Energija AB (Baltso)
- AS Augstsprieguma Tīkls (Baltso)
- OÜ Põhivõrk (Baltso).

The market analysis is based on following assumptions:

- Perfect competition in the electricity market
- Security of Supply issues are not explicitly included to this study
- All transmission capacity (NTC) is available in the electricity market
- There are no cross-border tariffs between the market areas
- Management of transmission capacity and congestions are based on bid areas and on implicit capacity auction
- The marginal costs for each area are calculated with a simulation model and they are based on minimizing the cost of production needed to cover the demand in the given scenarios. This means they are not any kind of prognoses for future market prices and should not be used as such.

The objective of this study was to evaluate the socioeconomic profitability of the following new interconnections to whole Baltic Sea region: Estonia-Finland (650 MW), Lithuania – Poland (500/1000 MW) and Baltics - Sweden (700 MW). Following elements are included in the cost-benefit analysis: investment costs, internal reinforcement costs, producer surplus, consumer surplus, congestion rent and grid losses of the interconnections. The long term perspective (2025) of the study has been chosen due to long lead time for implementation of new interconnections and their long life time.

Four scenarios were used in the study. Business as Usual scenario 2015 and three main supply scenarios for the year 2025 were considered: Business as Usual, Climate&Integration and National Focus. Each particular scenario describes one of the possible supply situations in the Baltic Sea Region. The cost-benefit analysis has been performed for scenarios Business as usual 2025 and Climate&Integration 2025. The timing of each proposed interconnection project has been simplified so, that all 1, 2 or 3 interconnections are assumed to be ready during the same year.

Main results of this study are:

- According to this study, the best market based solution (without Security of Supply aspect) is to implement two interconnections: Finland-Estonia and Lithuania-Poland. This results in good socioeconomic benefit for both projects and it also improves the security of supply and integration of Nordic-Baltic-European electricity market.
- The second best market based alternative is to implement Lithuania-Poland link only. The third option is to implement both Lithuania-Poland and Sweden-Baltics interconnections and the fourth option in decreasing order of net market benefit is to build all three interconnections respectively.
- However, taking into account the security of supply and market integration aspects, a set of three proposed interconnections would probably be the best solutions but this should be further studied in more detail.
- The interconnections Finland-Estonia and Sweden-Baltics can be seen as parallel paths between Nordel and The Baltics as far as the simulated marginal costs of production are at the same level in Sweden and Finland. Thus, the Gross market benefits are practically the same. However, the net market benefit of Finland-Estonia interconnection is higher due to its shorter length and thus lower costs than the Sweden-Baltics interconnection.
- According to scenario 2015 there is already a need for additional transmission capacity. This means that the quicker the implementation time of the new interconnection the higher market benefits can be achieved.

Following tasks should be taken into agenda in 2009 when continuing the cooperation between the regions. These tasks shall be finalised before June 2009.

- cost-benefit analysis until 2025 including estimation of security of supply benefits of new interconnections
- prerequisites and estimated realisation time for each project
- selection of cost effective technology for each interconnection e.g. making future extensions possible
- coordinated timetable for each project.

In addition, the results of this project will be included to the first common Baltic Sea Multi-regional Grid Plan which will be done by ENTSO-E in 2010.

1 Introduction

1.1 The multiregional grid planning

In order to maintain high power system security and sufficient adequacy, considering European electricity market, the new approach for the transmission grid planning is needed.
For developing efficient European electricity market the parallel approach in transmission grid development is used. The new approach is described and illustrated below:

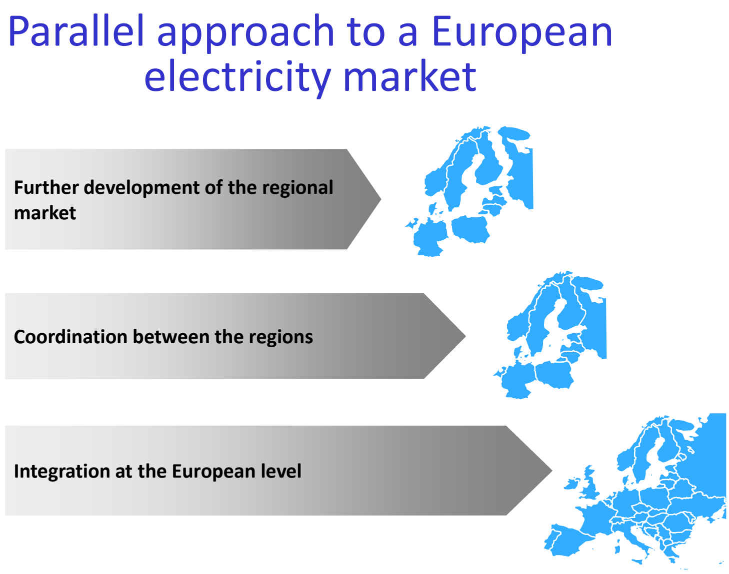


Figure 1.1 Transmission grid planning in regional, multiregional and European level.

The parallel approach in co-operation is being launched to establish coordinated and transparent planning practice between the regions. Therefore, initiated by the Nordel Planning Committee, the transmission system operators in Baltic Sea region from NORDEL, UCTE and BALTSO (IPS/UPS) have signed the mutual Memorandum of Understanding, the "Coordination of Multi-Regional System Planning in The Baltic Sea Region between BALTSO, NORDEL and PSE Operator S.A." in the end of 2007.

The aim and purpose of this cooperation is to set mutual understanding and principles for system planning cooperation between the parties around the Baltic Sea. The practical value of the co-operation includes the development of coordinated extension plan of interconnections from the Baltic States to Poland and to Nordel area in order to satisfy transmission needs between areas. Moreover, it is an objective to create the continuous co-operation between system planning experts around the Baltic Sea region.

1.2 Present situation of power system and electricity market

Baltic electricity markets

The total generation capacity in the Baltic countries is above 9000 MW and total annual consumption 24 TWh.

In Lithuania, electricity production is today mainly based on nuclear and at some extent natural gas fuels. The biggest electricity producer is the Ignalina Nuclear Power Plant which covers about 70 % from total electricity demand. According to the European Union Accession Treaty 2003, Lithuania has committed to close Unit 2 of the Ignalina Nuclear Power Plant (INPP) by the end of 2009, which will strongly affect the security of power supply in Lithuania and whole Baltic region. Other generators in the Lithuanian power sector are mainly the Lithuanian Power Plant (LPP) and CHP plants. Lithuania has a large pumped storage facility (900 MW installed capacity), which provides reserve capacity for covering peak demand.

In Latvia the biggest share of energy is produced by hydro power stations in Daugava river cascade and two major gas-fired CHP's in Riga. Latvia has the highest energy imports dependency expected compared to the other Baltic States because of the deficit in power production capacities.

Electricity production in Estonia is mainly based on oil shale. The Narva Power plants is the leading electricity producer in Estonia, generating about 95% of Estonian power.

During the accession negotiations, Estonia and the EU reached a compromise solution for further step-by-step opening of the electricity market. At least 35% must be opened before December 31, 2008 and for all non-household consumers (ca 77%) before December 31, 2012.

In Latvia and Lithuania electricity markets are formally opened. Due to reasons of dominant producers and market participants in all Baltic countries and low electricity market volumes, competition amongst market participants is imaginary. The other reasons for low competition include differences in legislation, market regulation and limited interconnections to other European electricity markets.

The only connection to other European markets is HVDC interconnection from Estonia to Finland with capacity of 350 MW.

Polish electricity market

Net generating capacity of power plants operating in Poland equals 32.5 GW (at the end of 2007).

Net electricity production in 2007 amounted to 148.4 TWh. The Polish generation sources are dominated with consumption of solid fuels (hard coal and lignite). Production of electricity based on solid fuels equals ca. 95% of total generation in Poland. The other generation concern utilization of natural gas, hydro and renewable energy sources. No nuclear power plants have been installed in Poland until now.

Poland has interconnections with Germany, Czech Republic, Slovak Republic, HVDC interconnection to Sweden with capacity of 600 MW and interconnections to Belarus and to the Ukraine. The transmission capacity to/from UCTE is allocated trough coordinated explicit auctions.

The termination of long-term supply contracts in Poland took place in the first half of 2008 due to modification of national law approved by the European Commission in 2007.

The electricity market in Poland has been fully opened since July 2007. Most of the trade of electricity is done through bilateral contracts since the spot market (PolPx) is characterised by low liquidity.

Nordic electricity market

The total generation capacity in the Nordic countries is over 96000 MW and total annual consumption 413 TWh. More than 60 percent of the installed capacity is from renewable production. Most of the renewable power production is from hydropower units in Norway, Sweden and Finland totalling over 47000 MW and about half of the total Nordic generation capacity. In Denmark and Finland the majority of the production capacity is from thermal units, while the Swedish production portfolio is evenly parted between thermal, mainly nuclear, and renewable. Almost all capacity in Norway originates from hydropower units. About 13 percent of the total generation capacity in the Nordic countries originates from nuclear power production units in Sweden and Finland. In 2005, the nuclear unit Barsebäck 2 (600 MW) in Sweden was decommissioned, while the work on a new reactor in Finland (Olkiluoto – 1600 MW) is ongoing and expected commissioning is in 2012.

Nordic power market is excellent example of well-functioning electricity market, where market is totally opened for fair competition. Most of the trade of electricity is through Nord Pool and Nord Pool spot markets.
The transmission capacity to UCTE system is 3400 MW and from UCTE 2900 MW. The transmission capacity from Russia is 1600 MW.

The key Figures of different areas are presented in the table 1.1

Table 1.1 Key Figures in the end of 2007

Country	NORDEL [1)]	BALTSO	Poland	Germany and Netherlands
Total consumption, TWh [2)]	401	25.5	142	698
Maximum load, GW	68	4.6	22.7	117
Electricity generation, TWh	398	26.4	148	832
Installed Generation Capacity, GW	94.3 [3)]	9.1	32.5	161

1) Nordel area, not including Iceland

2) The sum of electricity generation and net imports.

3) Mothballed capacity not included.

1.3 Multiregional planning project

The first comprehensive study, comprising an evaluation of introduction of new interconnections between three synchronous areas was carried out from December 2007 to January 2009. This study is executed by the following transmission system operators:

- PSE Operator S.A. (Polish TSO, UCTE)
- Svenska Kraftnät (Nordel)
- Fingrid Oyj (Nordel)
- Lietuvos Energija AB (Baltso)
- AS Augstsprieguma Tīkls (Baltso)
- OÜ Põhivõrk (Baltso).

The organization consists of a steering group and a working group. The groups consist of representatives from the Transmission System Operator in each of the six involved countries. The co-operation is arranged through the working group in which each party has one permanent member. The chairmanship rotates between the parties on an annual basis in following order: Fingrid, Põhivõrk, Augstsprieguma Tīkls, Lietuvos Energija, PSE Operator and Svenska Kraftnät. A complete list of participants is presented in Appendix A.

The aim of the first project was to analyze the electricity markets in three regions at different future development situations. The objective was also to evaluate the socioeconomic profitability of the following new interconnections to whole Baltic Sea region.

- New interconnection Estonia-Finland, 650 MW
- New interconnection Lithuania – Poland, 500/1000 MW
- New interconnection Baltics - Sweden, 700 MW.

The long term perspective (2025) of the study has been chosen due to long lead time for implementation of new interconnections and their long life time.

Furthermore, one of the objectives of the study was also the creation of a common platform of understanding and establishing a common electricity market modelling tool, which also could be used for future analyses.

The present Report gives an overview of the electricity markets in the Baltic Sea region, a description of methodology and assumptions used and the results of the analyses.

The preparation of this study was financed by the involved transmission system operators.

2 Methodology

2.1 Market analysis

This market analysis is based on following methodological assumptions

- Perfect competition in the electricity market
- Security of Supply issues are not explicitly included to this study
- All transmission capacity (NTC) is available in the electricity market
- No cross-border tariffs are used
- Management of transmission capacity and congestions are based on bid areas and on implicit capacity auction
  - Implicit auction is when the flow on an interconnection is found based on market data from the marketplace/s in the connected markets. Thus the handling of capacity is included in the auctions of electricity in the market. In implicit Auctions the capacity between bid areas (price areas/control areas) is made available to the spot price mechanism in addition to bid/offers per area, thus the resulting marginal costs per area reflect both the cost of energy in each internal bid area (price area) and the cost of congestion.
- The marginal costs for each area are calculated with a simulation model and they are based on minimizing the cost of production needed to cover the demand in the given scenarios. This means they are not any kind of prognoses for future market prices and should not be used as such.

The analysis of proposed interconnections is based on analysis of the costs and socioeconomic benefits, i.e. the analysis rest upon the principle of market economics. The Figure below shows the main workflow.

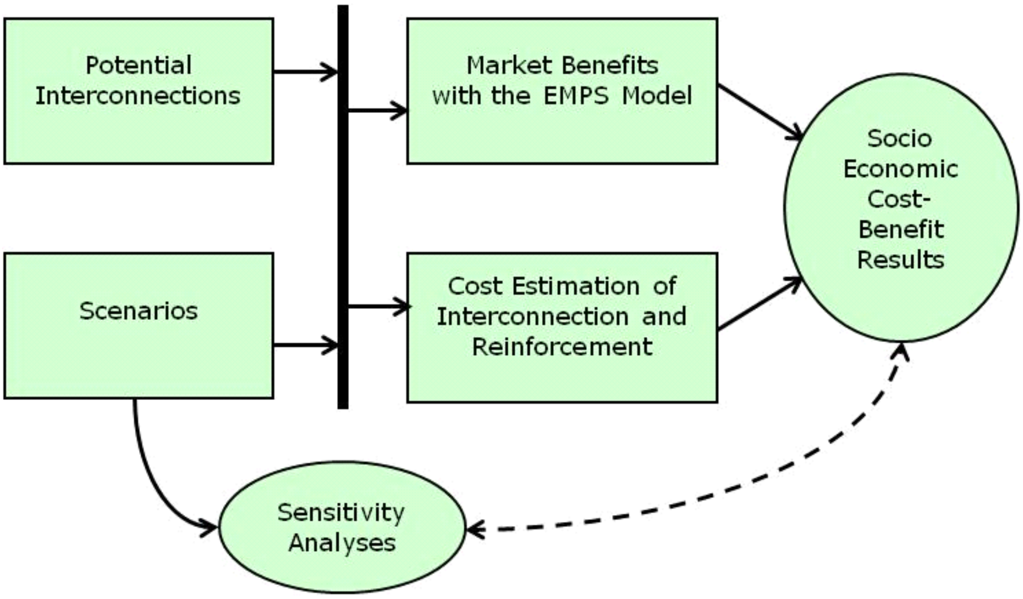


Figure 2.1 Workflow of the socio-economic analysis of interconnections

The future demand of the infrastructure is estimated on the basis of three scenarios developed for 2025, which all rests upon the reference scenario for the year 2015, Business As Usual 2015. Each of the scenarios for 2025 describes different, but possible situations in the Baltic Sea region. A list of analysed interconnections has been set up based on input from the TSOs.

Analyses of benefits from new interconnections are estimated with the EMPS model (EFIs Multi area Power Scheduling model), also known as the Samkjørings model. Investment cost of the interconnection with eventual grid reinforcements has been estimated. The costs are annualised and benefits are summarised, and a net benefit has been set up for all potential interconnections.

Several sensitivity analyses have been made to investigate the impact of uncertainties. The sensitivity analyses are all based on the Business As Usual 2025 and Climate and Integration 2025 scenarios, in where some uncertainties, factors, have been modified. No socioeconomic cost-benefit analysis has been made for the sensitivity analyses (except for "Low Nuclear" sensitivity case); instead area marginal costs are presented as a result. The idea is to compare area marginal costs from the sensitivity analyses with area marginal costs from the scenarios, for which benefit analysis has been made, to get an idea of the impact of sensitivity factor on the profitability of interconnections. The base principle is that the larger the marginal cost difference there is between two areas, the larger is the incentive to build new interconnection. But this is not always valid due to marginal cost variation which can occur during day/night trading.

2.2 The cost-benefit approach

The cost-benefit analysis has been performed for scenarios Business as usual 2025 and Climate&Integration2025. The timing of each proposed interconnection project has been simplified so, that all 1, 2 or 3 interconnections are assumed to be ready during the same year.

The cost analysis includes following elements:

- Investment in a given interconnection and auxiliary parts
- Internal reinforcements due to investment in respectively national grid
- Administration and contingency.

Same costs for similar investments are applied, i.e. same prices for stations etc. The length of the cables and lines has been considered by using same price per length unit, €/km, for the different interconnections.

Following elements are included in the benefit analysis (see the Fig. 2.2):

- Producer surplus
- Consumer surplus
- Congestion rent
- Grid losses of the interconnections.

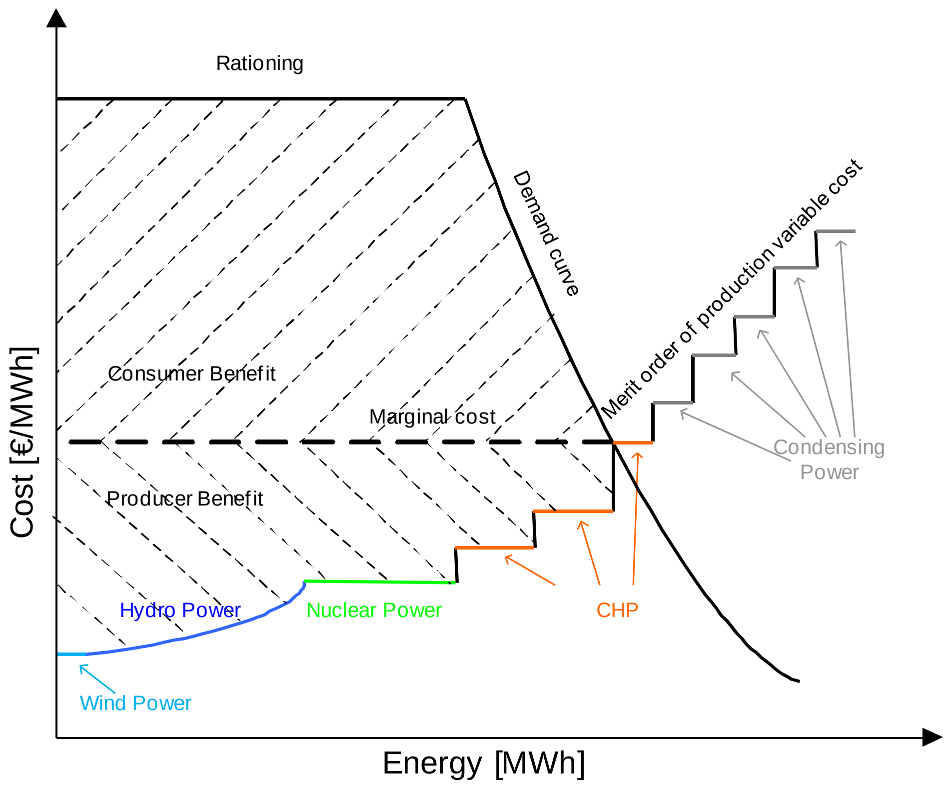


Figure 2.2 Definition of consumer benefit and producer benefit in one area.

The simulations for the Sweden – Baltics link are made for the link which is connected to Lithuania in the model. But the results of this report are valid for the link which is connected to the other countries in the Baltics as well due to same marginal costs in the Baltic countries.

The costs and benefits for each year have been analysed for a total lifetime of 30 years. The annualising of costs has been calculated by using a 7% rate of interest. The simulation model gives directly the annual socioeconomic benefit, thus separate annualising is not needed for benefit. Elements in the benefit analysis are results that arise from the EMPS model.

The total benefits, which include the Baltic, Nordic and Polish areas *as a whole*, have been calculated as:
Annual benefits = Annual benefits *with* investment – Annual benefits *without* investment.

The net benefit has been calculated as:
Net benefit = Annual benefits for all areas - Annual cost of investment.

Cost-benefit analysis has been made for the scenarios Business As Usual 2025 and partly for the Climate and Integration 2025. The results require that the Baltic- and Polish areas are fully de-regulated.

The benefit analyses of the interconnections are made in sequences. All 6 variants to build 3 new interconnections are studied. All 6 variants to build the

3 new interconnections are studied in the Business As Usual 2025 scenario. In Climate and Integration 2025 scenario, 3 variants to build the 3 new interconnections are studied. It is assumed that time between building second and third interconnection after the first one is so short that it has no impact on the results (only the benefit after all interconnections are implemented will be noticed).

The benefit of the first interconnection equals to the socioeconomic benefit with investment minus the socioeconomic benefit without the investment (reference case). In case of Finland-Estonia interconnection the reference case includes the existing 350 MW transmission capacity. The benefit of the second interconnection equals to the benefit of first two interconnections minus the benefit of first interconnection. The benefit of third interconnection equals to the benefit of the three interconnections minus benefit of first two interconnections. A result of this is that the first interconnection will usually have the highest benefits, and the second will have lower benefits. This is obvious, because of the first interconnection will get the benefits in a certain area before the second interconnection will get them. This is similar to; the more capacity (to a certain level) an interconnection is planned for the less are the benefits.

Transmission investments can help to mitigate the possible exercise of market power, depending on if there is different power supplier in respectively areas or not. Usually transmission capacity contributes to enlarging the market and thereby possibly reducing the risk of abusing market power. But such benefits are difficult to quantify and there is no sufficient tool available for such calculations.

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.

2.3 Market simulation model - The EMPS

The most commonly used electricity market model in Nordic countries is called EFI's Multi Area Power Scheduling (EMPS). The development of Samkjørings model has started in 1960's and its primary function was to optimize hydro power plant production. Later during deregulation of electricity markets market participants and transmission systems operators started to use EMPS as a market modelling and analyzing tool. At that time the modelling of thermal power generation has been developed as well.

Electricity markets may be analyzed with EMPS in a various ways. Typically EMPS is used to make market forecasts which will predict future power exchanges and system prices and other market behaviour. Socio-economic benefit of new interconnections or additional transmission capacity can be estimated as well. All simulation results can be studied in a detailed level (depending on the resolution of simulation).

2.4 Modelling the electricity market with EMPS

EMPS input data consist of consumption data, generation data including their marginal costs and transmission capacity data. All data is modelled for certain area, e.g. a country or a price area.

Input generation data is given in a weekly level accuracy and consumption data is divided to sub weekly level using proportional factors. In the dataset used for this study five sub weekly level units are used. They are called load periods. These load periods are peak, day, morning-evening, night, and weekend periods which describe respectively 25h, 35h, 25h, 49h and 34h of one week.

Consumption is modelled in two categories. First category is fixed consumption where total consumption of a year and division of the consumption with proportional factors for all weeks is given as input. Second category is price elastic consumption where same input data as in fixed consumption must be given. In addition threshold price of demand that consumer is willing to pay must be given. The calculated annual energy of price elastic consumption may be lower than modelled consumption as an input data due to high purchase cost.

Thermal production is divided into energy and capacity based categories. Energy based category mainly consists of CHP and nuclear power plants which have high utilization period of maximum load. In this category annual production is given as energy (GWh) and it is divided with proportional factors to weekly periods. Also marginal cost for production has to be given. Capacity based category mainly consists of condensing power and peak power plants which have medium or low utilization period of maximum load. This category is modelled as available generation capacity (MW) and as marginal cost of production. Capacity based category power plant is operational only when purchase cost of electricity is higher than its marginal cost of production.

Hydro power in the Nordic area is modelled detailed level with possible hydraulic connections between hydro power plants. Power plants may be modelled with a reservoir or as a run of river type power plants. Inflow for both power plant types are given as input data. In the dataset used for this study inflows for years from 1950 to 2000 are used in simulation to have spread of different hydrological situations. Most important part of modelling of hydro power is the value of water. Value of water is the alternative cost for water when considering using it to produce electricity (i.e. marginal cost of hydro power). Water values are computed for each area by EMPS based on the stochastic dynamic programming. Hydro power is modelled with weekly energy series in the Baltic countries representing average weekly generation energy for each week. This method corresponds to the modelling of thermal power.

Wind power is modelled in the Nordic area as hydro power with run-of-river - type generation. Totally 51 different wind production series with weekly resolution are included. Wind power is modelled with weekly energy series in the Baltic countries representing average weekly generation energy for each week. This method corresponds to the modelling of thermal power.

Transmission capacity between modelled areas is implemented as Net Transfer Capacity (NTC). NTC is Total Transfer Capacity (TTC) minus Transfer Reliability Margin (TRM). TTC is the maximum transfer capacity that can be physically transmitted in accordance of with the system security criteria taking into account the thermal, voltage and system stability limitations. TRM covers the forecast uncertainties of tie-line power flows due to imperfect information from market players and unexpected real time events. The fixed NTC capacity for a whole year has been used in the model. In addition in the Baltic countries the available transfer capacities are strongly dependent on placement of power production in other regions of IPS/UPS. If a capacity of an interconnection between areas was exceeded the modelled area marginal costs would separate from each other. There are more price areas in the model compared to real Nordic market due to better treating of possible transmission capacity congestions in the model.

2.5 Simulation process

The simulation in EMPS can be divided into two parts: water value calculation + aggregated simulation and detailed simulation.

In the first part the weekly values of generation and demand are solved based on the merit order of generation (including water values) and linear optimization. The optimization task is to minimize the cost of production needed to cover the demand. Weekly results are further divided to sub weekly values in the first simulation part according to load periods.

In the second part the aggregated hydro power generation per area is divided to each modelled hydro power plant taking into account the power plant specific restrictions.

Simulation may be performed as a serial or a parallel simulation. In this study the serial simulation has been used. In serial simulation typically, calculation through one year are performed with all different hydrological years (different inflow input data). In this method the reservoir level of hydro power plants may vary from year to year allowing the utilization of multi-annual reservoirs which are typical in Sweden and in Norway. This kind of simulation fits well for long term planning.

3 Assumptions and input data

3.1 Assumptions for supply scenarios

In addition to one reference scenario 2015, three main supply scenarios for the year 2025 were considered in the study. Each particular scenario describes one of the possible supply situations in the Baltic Sea Region (BSR).

The *Business as Usual* (BAU) scenario is the best estimate for the future developments. It assumes more dynamic development of electricity markets and cross border interconnections. This is the case, when liquid day-ahead, forward, intra-day and balancing markets are established in the Baltic states, price regulation is abolished in the whole BSR, as well as market based mechanisms are introduced for the support of cogeneration and renewable energy sources. No subsidies for producers and no prioritised generation are assumed. Electricity market provides signals for the development of generation and transmission capacity. This scenario is calculated for the years 2015 and 2025.

The main priority of the *National Focus* (NF) scenario is security of electricity supply by domestic resources. This might be the case, when the crises of the global economic and financial system as well as slowdown of market liberalisation, uncertainty in energy policy and development of electricity prices, resulted in lack of investments into generation and transmission capacity. In this situation each state shall decide about the measures for enhancement of electricity supply security independently. National projects are supported. Lower integration between regions (fewer interconnections) is assumed in this scenario. It is calculated for the year 2025.

The biggest challenge for the *Climate&Integration* (C&I) scenario is mitigation of the climate change, which in fact is one of the highest priorities of the European Commission. This scenario assumes achievement of the following targets by 2020: reduction of CO_2 emissions by 20%, increase of the share of renewable energy to 20% (in the whole European Union) and enhancement of energy efficiency by 20%. This scenario is highly possible, if high oil and other fuel prices, as well as high CO_2 emission prices are reached. In this case investments into renewable energy sources and CO_2 abatement measures will become feasible. This scenario also assumes higher integration of regions. It is calculated for the year 2025.

Table 3.1 provides description of considered supply scenarios. BAU2025 is the base case, from which majority of sensitivity cases has evolved.

Table 3.1 Definition of supply scenarios

Scenario	Abbreviation	Description
Business as Usual	BAU2015	Enhanced market liberalisation; Strong EU energy integration and coordination; Market coupling; Oil: 70 $/barrel, CO_2: 25 €/ton. For the year 2015.
	BAU2025	The same but for the year 2025; Oil: 95 $/barrel, CO_2: 50 €/ton.
Climate &Integration	C&I2025	Strong climate obligations; 20% reduction of CO_2 emission level by 2020, Increased share of energy (electricity) from renewable energy sources; Energy efficiency measures (lower energy demand growth); Strong EU integration; For the year 2025; Oil: 140 $/barrel, CO_2: 75 €/ton.
National Focus	NF2025	Weak EU integration; National focus when solving security of supply problems; For the year 2025; Oil: 95 $/barrel, CO_2: 50 €/ton.

3.2 Assumptions for sensitivity cases

To verify the calculation results in the presence of market uncertainties, six sensitivity cases were calculated. In the table 3.2 the sensitivity cases are listed.

Table 3.2 Sensitivity studies and corresponding base scenario

Name	Reference	Description
High fuel price	BAU2025	Oil price $190/barrel
Low RES price	C&I2025	Subsidy of renewable energy included
Low Russian import price	BAU2025	41 % lower import price (73 -> 43 €/MWh)
Low nuclear	BAU2025	Less nuclear power in Estonia, Lithuania, Poland Finland and Sweden (Total 7200 MW) and CO_2 allowance price is 0 €/ton.
SWE-GER link	BAU2025	Additional transmission capacity (800 MW) between Sweden and Germany
Ukrainian import	BAU2025	New import possibility from Ukraine to Poland (1200 MW)

Sensitivity case with "*High Fuel Price*" was considered to take more drastic increase of fuel prices into account. Despite on dramatic drop of oil prices, following recession and global economic crisis, the high fuel price situation is still highly probable. The major reason for that is the exhaustion of world's oil resources and higher costs of alternative energy sources. The highest oil price used in this study was $140/barrel ($95 for BAU2025). It was decided to use oil price of $190/barrel for the "*Higher Fuel Price*" sensitivity and update other fuel prices respectively: natural gas 65 €/MWh and coal 27 €/MWh. This sensitivity case is based on BAU2025 scenario.

Sensitivity case with "*Low RES price*" (including subsidies for RES) for the scenario C&I2025 was analysed to take RES-E support mechanisms into account. This situation in some member states is a reality. In the future even more serious measures to facilitate the development of renewable energy sources are possible. Subsidies (which make the marginal costs of renewable lower) for year 2015 are known but level of subsidies - if any – for year 2025 is uncertain. That is why, the sensitivity study with different levels of subsidies are thus necessary. This sensitivity case is based on Climate&Integration 2025 scenario.

Sensitivity case with clearly "*Low Russian Import price*" was studied for the BAU2025 scenario. The Russian import price was defined as follows: 50% lower price than marginal cost of gas production without CO_2-emission costs. This may be possible if liberalisation and opening of Russian gas and electricity markets for foreign market participants fail and if Russia does not join new international agreement on reduction of CO_2 emissions (and other environmental obligations). On the other hand, the strong increase of electricity demand in Russia increases the pressure to raise electricity prices. This sensitivity case is based on BAU2025 scenario

Sensitivity case with "*Low-Nuclear*" was proposed to get wider spread of power balances. The scenario is based on BAU2025 with zero nuclear production in Estonia and 1600MW nuclear production Lithuania and in Poland. In Finland only five nuclear reactors would be in operation, decommissioning of 1500 MW of nuclear capacity was proposed in Sweden. In addition CO_2-prices are assumed to be 0 €/ton. Low CO_2-prices mean that nuclear projects are less feasible in comparison to fossil fuel power plants. The second motivation for the scenario is possible "green movement" which could get support from the wider part of population.

Sensitivity case "*SWE-GER link*" was proposed to investigate the impact of improved transmission capacity between Sweden and Germany to the BAU2025 scenario. Existing Baltic Cable interconnection from Sweden to Germany has transmission capacity of 600 MW. In the sensitivity case the transmission capacity between Sweden and Germany is 1400 MW. This sensitivity case is based on BAU2025 scenario.

Sensitivity case with "*Ukrainian import*" was proposed to analyse possible re-connection of existing 750 kV line between Rzeszow, Poland and Chmielnitskaja NPP, Ukraine and wider utilisation of 220 kV line between Zamosc, Poland and Dobrotwor TPP, Ukraine. The transmission capacity 1200 MW was used and the annual maximum import energy of 10 TWh was assumed. The price for Ukrainian import was defined similarly as for Russian import in "*Low Russian Import price*" sensitivity. This sensitivity case is based on BAU2025 scenario.

3.3 Assumptions for transmission capacity

Table 3.3 describes transmission capacity scenarios, which were considered in the study. Grid benefit study was made for BAU2025 and C&I2025 scenarios.

Table 3.3 Definition of transmission development scenarios. The capacities are valid for both directions.

	Estonia-Finland-Estonia	Lithuania-Poland-Lithuania	Sweden-Poland-Sweden	Sweden-Baltics-Sweden	Latvia-Estonia-Latvia	Lithuania-Latvia-Lithuania
BAU2015	350	0	600	0	1200	1600
BAU2025	1000	500	600	700	1200	2400
NF2025	350	0	600	0	1200	1600
C&I2025	1000	1000	600	700	2000	2400
Reference BAU2025	350	0	600	0	1200	2400
Reference C&I 2025	350	0	600	0	2000	2400

Figure 3.1 illustrates new interconnections from the Baltic market.

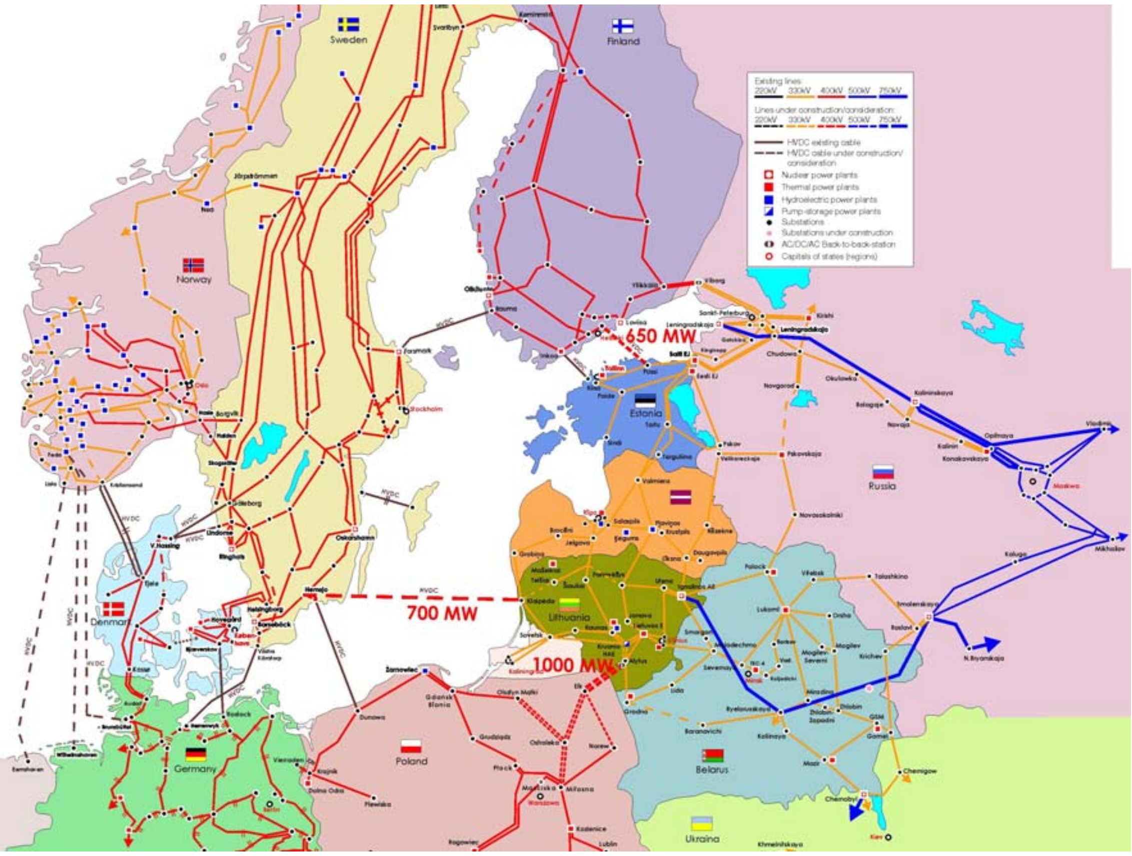


Figure 3.1 New interconnections from the Baltic market

3.4 Input data: Price of fuel and CO_2 allowances

Table 3.4 Fuel and CO_2 allowance prices in different scenarios

Scenario	Oil price, $/barrel	Natural gas price, €/MWh	Coal price, €/MWh	CO_2 emission allowance price, €/t	Price[1)] of Russian electricity import, €/MWh
BAU2015	70	24.5	9.0	20	52.1
BAU2025 SWE-GER link UkrainianImport	95	38.5	13.7	50	72.7
NF2025	95	38.5	13.7	50	72.7
C&I2025 LowRESprice	140	56.1	20.2	75	106.0
High fuel price	190	65.0	27.0	50	122.8
Low Russian import price	95	38.5	13.7	50	42.8
Low Nuclear	95	38.5	13.7	0	72.7

1) The price of Russian electricity is based on the gas fired generation <u>without</u> the cost of CO_2-allowances. The fuel price of gas is the same for all countries.

It was assumed, that fuel prices for all the major fuels are harmonised – the same forecasts were used for all 10 simulated countries. They were specified for each scenario depending on oil price level. The IEA World Energy Outlook 2007 was used as the reference source. Table 3.4 shows fuel and CO_2 prices for the main cases.

3.5 Input data: Market areas and consumption

The **Baltic area** has been modelled in **3** sub-areas: Estonia, Latvia and Lithuania, **Nordel-area** includes **17** sub-areas: Finland-North, Finland-South, Sweden-SNO1, Sweden-SNO2, Sweden-SNO3, Sweden-SNO4, Norway-East, Norway-West, Norway-Central, Norway-Middle, Norway-South, Norway-North, Norway-Finnmark, Denmark-East, Jutland-North, Jutland-South, Fyn-isle and the **Continental Europe 3** sub-areas: Germany, Holland and Poland.

Consumption level has been kept unchanged between scenarios in the Baltics and in Poland. Table 3.5 summarizes annual electricity consumption used in the scenarios.

Table 3.5 Electricity consumption volumes (TWh)

Area/year	2015	2025
Estonia	10,0	12,4
Latvia	10,2	13,6
Lithuania	13,0	16,3
Poland	177	210
Germany & The Netherlands[1)]	673	673
Nordel[1)]	438	443-462

1) Results of simulation have been shown instead of input data. Simulation results are not the same as input data in these areas due to price sensitive consumption.

3.6 Input data: Generation

Table 3.6 summarizes overall production figures in the study.

Table 3.6 Available generation capacity (MW) and annual theoretical maximum generation per area (TWh). Gas turbines for peak load are also included.

	BAU2015		BAU2025		NF2025		C&I2025	
	MW	TWh	MW	TWh	MW	TWh	MW	TWh
Estonia	3 096	25	3 808	31	3 808	31	4 008	32
Latvia	3 144	25	3 447	28	3 747	30	3 747	30
Lithuania	2 855	23	6 405	51	6 405	51	6 405	51
Poland	31 586	254	39 243	316	39 243	316	39 243	316
Nordel	66 614	536	69 051	555	72 276	581	74 689	601

The generation values for The Netherlands and for the Germany are not available in the model due to different modelling of generation and demand in those areas. The purpose of generation values in the areas is to form supply curve which creates reasonable marginal costs in the areas. The absolute generation values do not need to correspond to real generation as long as area marginal costs are reasonable.

The development of generation per area up to 2025 has been described shortly in the following section.

Estonia:

It is estimated that 2000 MW (BAU2015) of oil-shale based capacity decreases by 2025 to 1000 MW (BAU and NF) and 400 MW in C&I scenario.
In order to diversify the power generation and secure the supply of primary energy in Estonia the nuclear power plant has decided to be in place by the year of 2023 in all scenarios.
Approximately 700 MW of wind power generation is expected by the year 2015, of which 200 MW on-shore and 500 MW off-shore wind generation. For the year 2025, the installed wind power generation capacity is expected to be in a range from 1000 MW to 1500 MW (C&I).
For the year 2015 there will be installed 300 MW of distributed combined electricity and power generation units, which are running mainly on natural gas or biomass and peat mix. During the next decade the capacity will not increase credibly, it is assessed to be around 310 MW.
TSO has planned build a gas turbine plant, with the capacity circa 100 MW for year 2011. For the year 2025, the estimated disturbance reserve gas turbines capacity is in the range from 300 MW to 400 MW (C&I). The industrial gas turbines capacity is estimated to be in the range from 200 MW to 400 MW, depending on scenario. Gas turbine units are mainly used as shadow generation for wind power.

Latvia:

The following options for development of power generation capacity were considered for Latvia. Construction of 400 MW gas-fired combined cycle (CCGT) unit in the territory of Riga CHP-2 (unit Nr. 1), 400 MW Kurzeme coal (and biomass) power plant and 560 MW of small RES-E capacity were considered in the *BAU2025* scenario. Construction of 400 MW CCGT unit in the territory of Riga CHP-2 (unit Nr. 1) and 1300 MW of small RES-E capacity were considered in the *C&I2025* scenario. Construction of 800 MW CCGT units (2 x 400 MW) in the territory of Riga CHP-2, 400 MW Kurzeme coal (and biomass) power plant and 560 MW of small RES-E capacity were considered in the *NF2025* scenario. Latvian participation in new nuclear power plant in Lithuania was assumed in BAU2025 and C&I2025.

Lithuania:

For all scenarios in Lithuania were assumed that until year 2012 a new CCGT unit with the capacity of 400 MW in Lietuvos Power Plant will be launched into operation. It will substitute two units of 150 MW each assigned for conservation, because their lifetime is approaching the end and no rehabilitation works are planned in 2010. Until year 2015 in Lietuvos PP will be installed another CCGT unit with the capacity of 400 MW.

The existing second unit of Ignalina Nuclear Power Plant will be shut down at the end of 2009 according to the EU requirements. Construction of the first unit of the new Visaginas nuclear power plant with the capacity of 1600 MW in Lithuania is expected to be finished in year 2018, and the second unit with the capacity of 1600 MW is expected to be finished in year 2021.

It was assumed that installed capacity of new wind farms in Lithuania will reach 350 MW in year 2015 and 500 MW in year 2025.

Poland:

The situation of Polish power sector in the future will be significantly determined by the requirements of Large Combustion Plants (LPC) Directive, Integrated Pollution Prevention and Control (IPPC) Directive and EU Emission Trading System (EU ETS). Substantial investments into lignite and coal power plants will be needed to comply with EU environmental standards. Two large projects are in construction stage at the moment: Łagisza TPP (460 MW, 2009) and Bełchatów II TPP (833 MW, 2010). More solid fuel capacity would be build to substitute old lignite and coal units. According to the Polish Energy Policy passed by Parliament in 2005 year, it is planned to introduce nuclear energy for electricity generation in Poland after 2020 year. Future expansion of electricity generation from RES will be based mostly on co-firing biomasses with hard coal and utilization of wind energy.

Nordel area:

In the Business as Usual (BAU2025) scenario, a new nuclear capacity and CHP mostly using domestic resources are planned in Finland, more wind power is assumed in Denmark, rehabilitation and extension of nuclear capacity, additional hydro, wind and CHP plants are planned in Sweden and more hydro, wind and CHP capacity are assumed in Norway (Figure 3.2).

In the Climate & Integration (C&I2025), a significant increase in wind power and hydropower and a decrease in condensing production are assumed.

In the National focus (NF2025) scenario a significant increase in CHP and less production at nuclear power plants are found as shown in Figure 3.2.

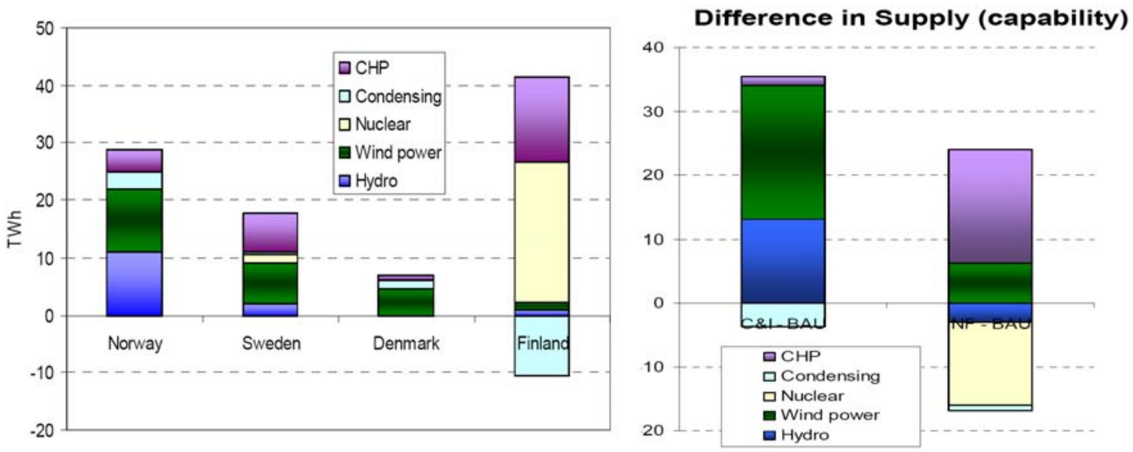


Figure 3.2 Net changes in production from 2005 to the BAU2025 scenario and difference from NF2025 and C&I2025 to BAU 2025

Area of Germany and the Netherlands:

The supply curve has formed to induce area prices which corresponds the historical market prices in the area. In practice EEX (European Energy Exchange) prices from year 2006 has been used as a basis for the supply curve in Germany. For the supply curve in the Netherlands, EEX prices from the years 2000-2003 have been utilised.

The marginal costs of base case supply curve have been changed according to changed assumptions for each scenario.

4 Results

In this Chapter the results of market simulations and benefit of investigated interconnections are presented. The analysis of results and conclusions are presented in Chapter 5.

4.1 Base scenarios

The simulated annual energy balances of year 2015 and 2025 with each scenario are presented in the Figure 4.1. The positive energy balance shows energy surplus in the presented area. On the other hand, the annual energy surplus or deficit in the area indicates the annual net export or net import respectively.

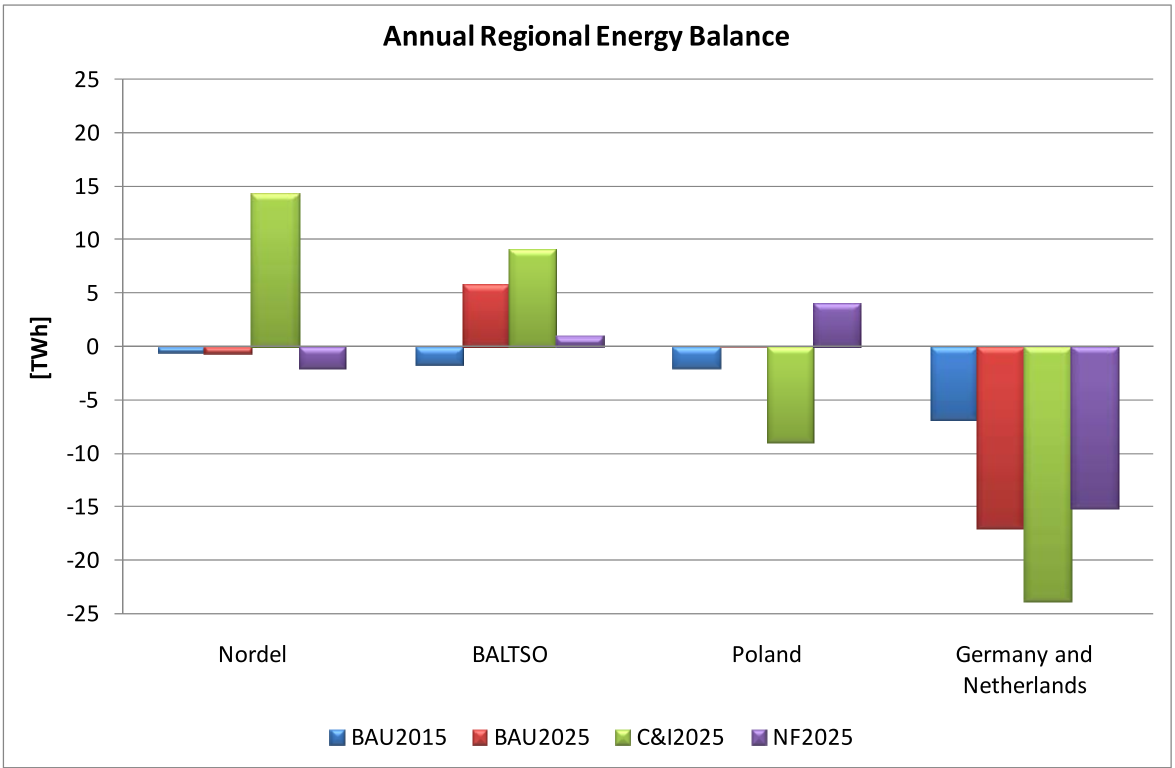


Figure 4.1 Annual energy balances of the base scenarios.

The annual average marginal costs for Nordel and Baltic areas as well as for Poland and Central-Europe (Germany and The Netherlands) are presented in the Figure 4.2. The marginal cost can deviate significantly from the average values during a year. The marginal costs inside the Baltic countries in certain scenario remain in the same level due to strong transmission grid between the internal areas inside BALTSO area. The same situation is in the Finland and Sweden areas: separate area marginal costs appear only seldom between Finland and Sweden.

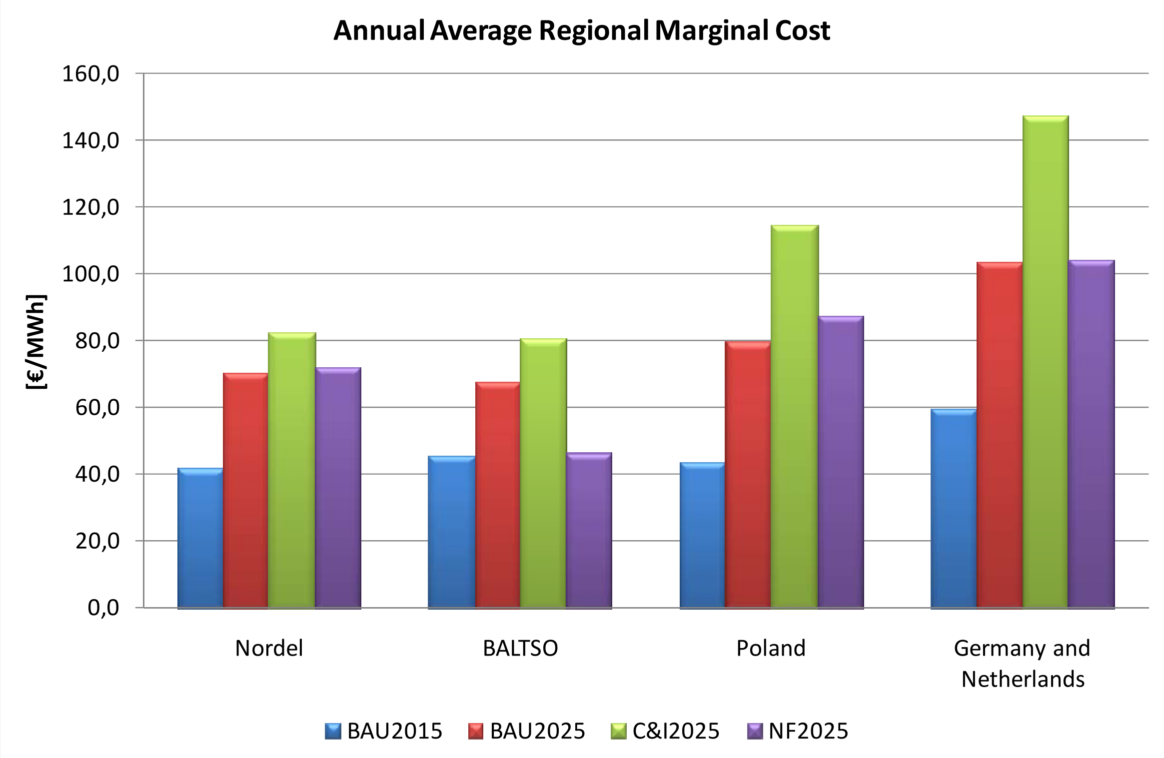


Figure 4.2 Annual average marginal costs of regions.

The detailed results of the base scenarios are presented in Appendix B. The detailed results consists simulation results of demand, production, power exchanges, area marginal costs per modelled area and congestion hours of certain transmission connections.

4.2 Sensitivity studies

Six different sensitivity studies were investigated. Variation of the simulated annual energy balances of each sensitivity study are presented in the next Figure 4.3.

Furthermore the annual average marginal costs for Nordel and Baltic areas as well as for Poland and Central-Europe (Germany and The Netherlands) are compared against the base scenario in the Figure 4.4. on next page.

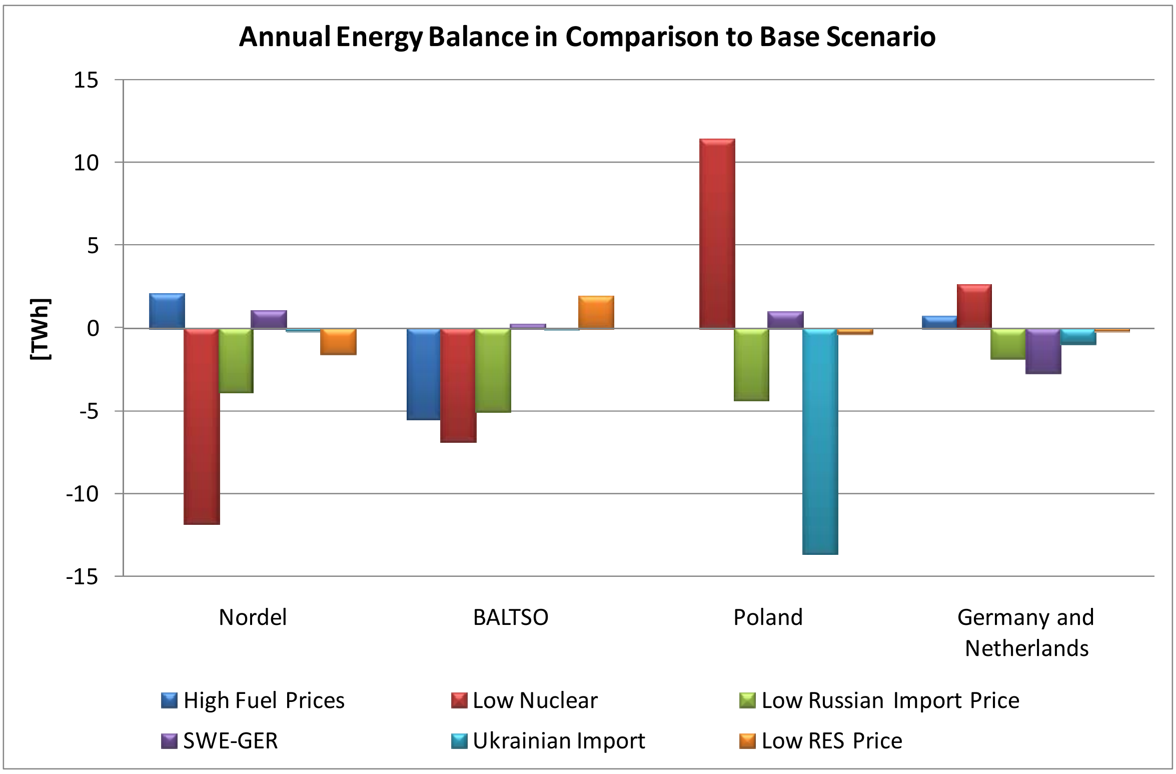


Figure 4.3 Change of annual average energy balance of sensitivity study compared to base scenario BAU2025 except the Low Marginal RES where the base scenario is Climate&Integration 2025. The positive change indicates that energy balance is greater in the sensitivity case. The energy balance is difference between annual production and annual consumption.

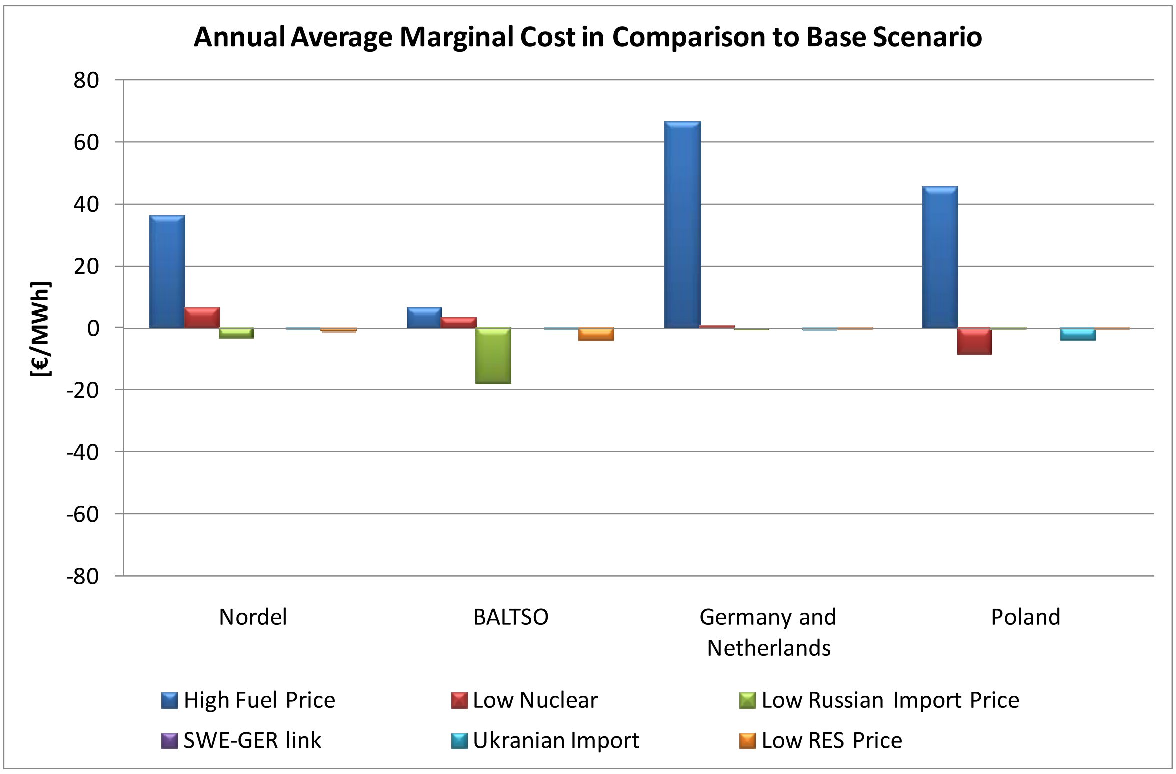


Figure 4.4 Change of annual average marginal costs compared to base scenario BAU2025 except the Low Marginal RES where the base scenario is Cimate&Integration 2025.

The detailed results of area marginal costs and power exchange between areas in different sensitivity studies can be seen in Appendix C.

4.3 Cost-benefit analysis of interconnections

The main cost-benefit analysis is based on the Business As Usual 2025 scenario. In addition, analysis is performed partly for Low Nuclear sensitivity case and partly for Climate&Integration 2025 -scenario.

The costs of studied interconnections are presented in the table below.

Table 4.2 Cost of interconnection including required grid reinforcements

Interconnection	Capacity (MW)	Total cost (M€)	Annual cost (M€)
Finland-Estonia	650	278	22
Poland-Lithuania	500	632	51
Poland-Lithuania	1000	1110	89
Sweden-Baltics[1]	700	610	49

1) Cost of this is connection between Sweden-Lithuania

The annual socioeconomic benefit of each interconnection is studied taking into account the order of building the interconnection. The building order variants are numbered for indexing purposes from 1 to 6 according to following list.

1: Finland-Estonia, Poland-Lithuania, Sweden-Baltics
2: Finland-Estonia, Sweden-Baltics, Poland-Lithuania
3: Poland-Lithuania, Finland-Estonia, Sweden-Baltics
4: Poland-Lithuania, Sweden-Baltics, Finland-Estonia
5: Sweden-Baltics, Finland-Estonia, Poland-Lithuania
6: Sweden-Baltics, Poland-Lithuania, Finland-Estonia.

The annual socioeconomic Gross benefit of each interconnection is presented in the Figure 4.5.

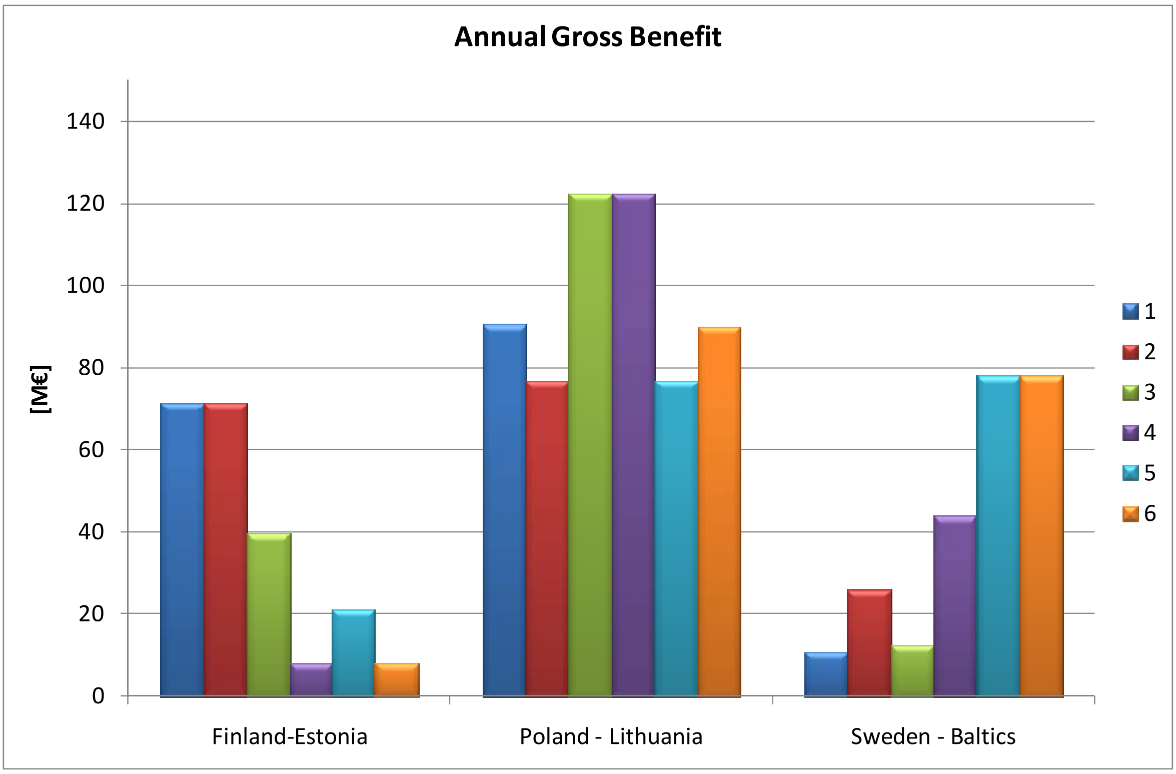


Figure 4.5 Annual Gross benefit of each interconnection depending on the building order. This analysis is based on the Business as Usual 2025 scenario.

The annual net profit of interconnection including costs is illustrated in the Figure 4.6.

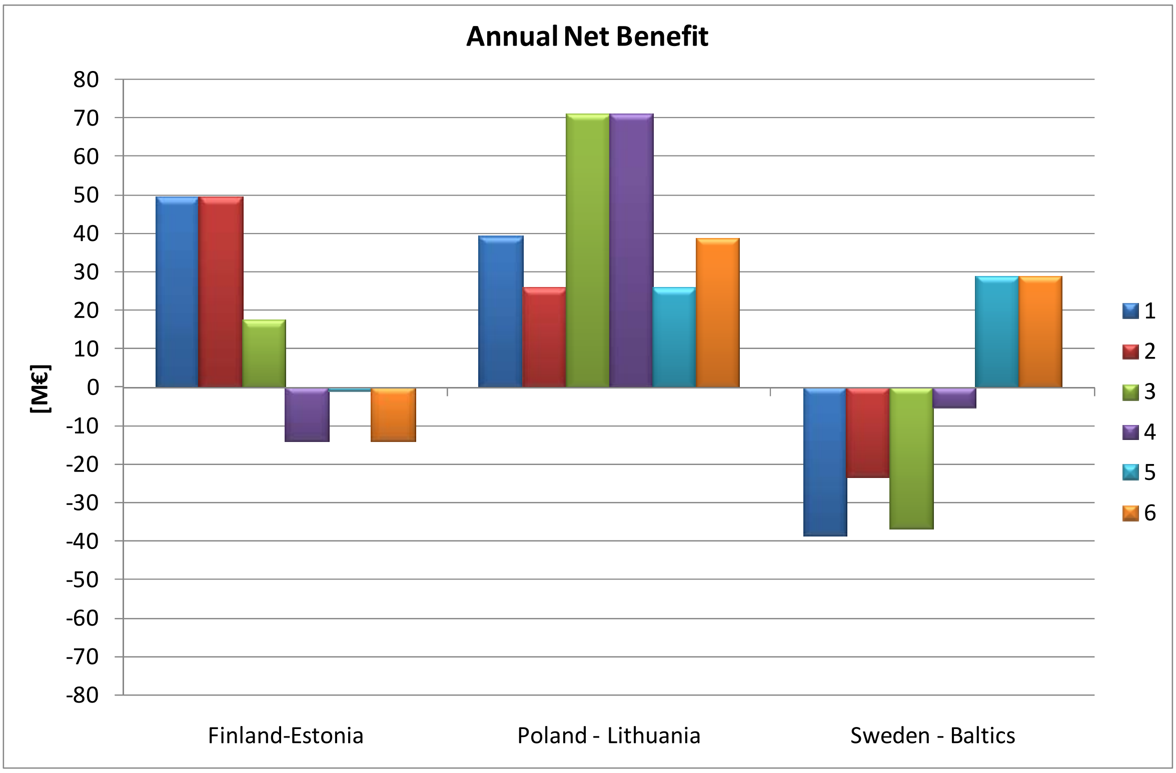


Figure 4.6 Annual net benefit of each interconnection depending on the building order. This analysis is based on the Business as Usual 2025 scenario.

The net benefit of new interconnections depending on the combination and amount of interconnections is presented in the Figure 4.7.

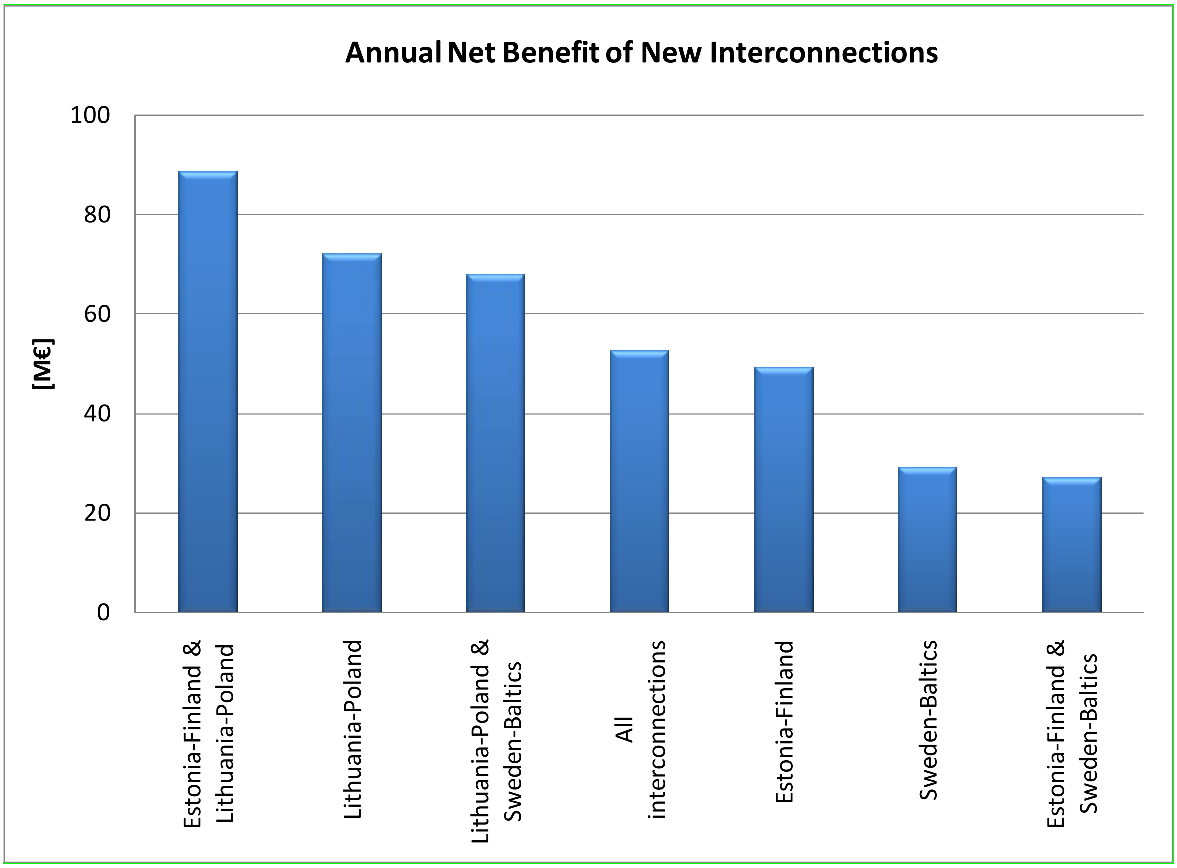


Figure 4.7 Net market benefits of one, two or three new interconnections. The net benefit of two interconnections can depend on the building order and average benefits of the two values are used in case of two interconnections. However, the difference of benefit between building orders is only 2 M€/year or less. This analysis is based on the Business as Usual 2025 scenario. The benefit calculation includes the Baltic, Nordic and Polish areas as a whole.

The benefits are also calculated with one sensitivity case. The applied sensitivity case is BAU2025 with decreased amount of nuclear power (Low nuclear) and used building orders are numbers 1, 3 and 6. The calculated benefits are presented in the Figure 4.8. In the Appendix D the energy balance of Low nuclear sensitivity case is presented.

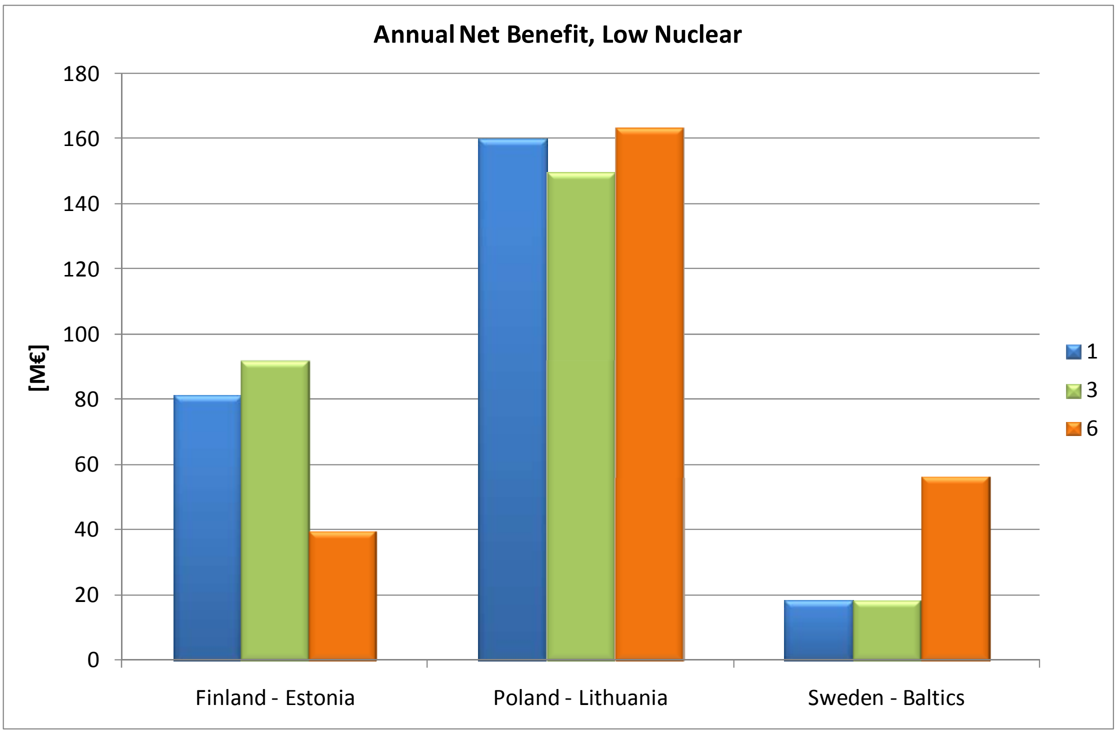


Figure 4.8 Annual benefit of each interconnection in a sensitivity scenario "Low nuclear". 1 = Finland-Estonia is built first, Sweden-Baltics last, 3 = Poland-Lithuania first, Sweden-Baltics last and 6 = Sweden-Baltics first and Finland-Estonia last.

The net market benefit of interconnections in Climate&Integration 2025 -scenario is presented in the Figure 4.9.

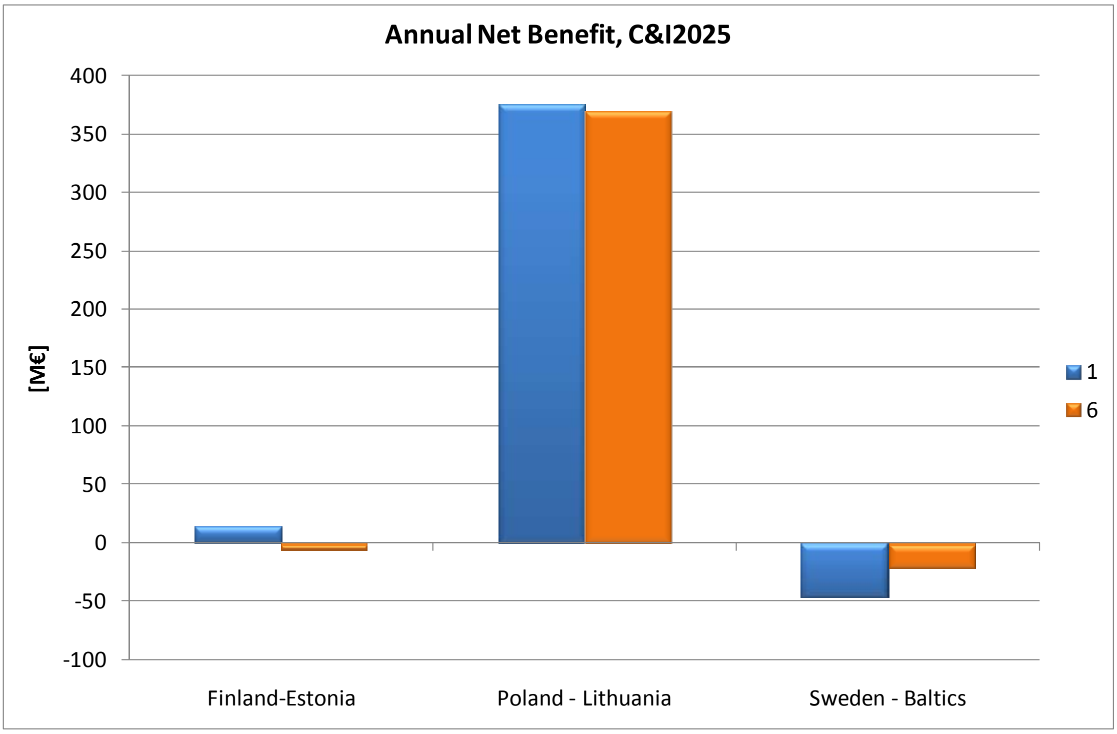


Figure 4.9 Annual net benefit of each interconnection depending on the building order. This analysis is based on the Climate&Integration 2025 -scenario. Transmission capacity of Lithuania-Poland interconnection is 1000 MW in C&I2025 scenario.

The duration curves of power flow of three investigated interconnections are presented in the following three Figures. The duration curve of each interconnection is presented in case that it will be built first from three suggested links. The duration curves of Finland Estonia and The Baltic states-Sweden links are illustrated in case that two other links have already been built. In case of connection between Finland and Estonia also the power flow duration with existing transmission capacity is illustrated.

The remarkable amount of hours with power flow equal to zero is due to modelling reasons: marginal cost difference between the areas must be higher than certain minimum cost for allowing the power flow between the areas. Minimum cost is needed for the modelling purposes.

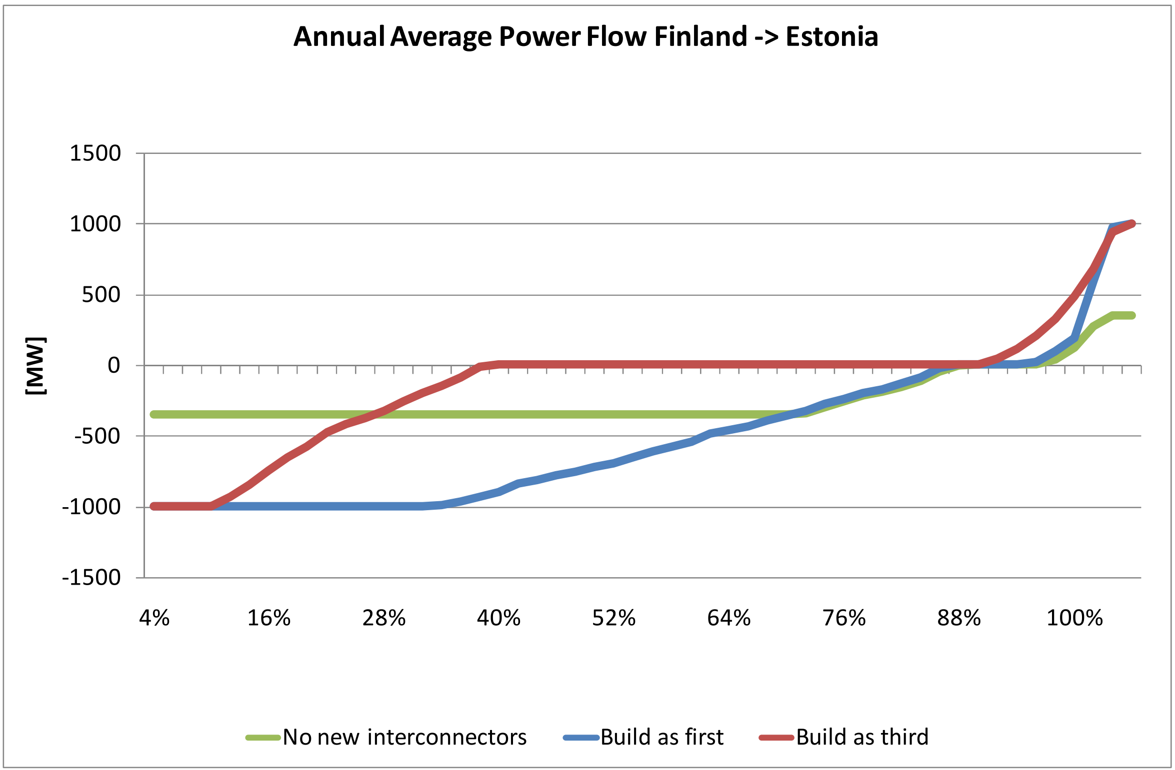


Figure 4.10 Average power flows from Finland to Estonia (positive direction) with different construction sequence options.

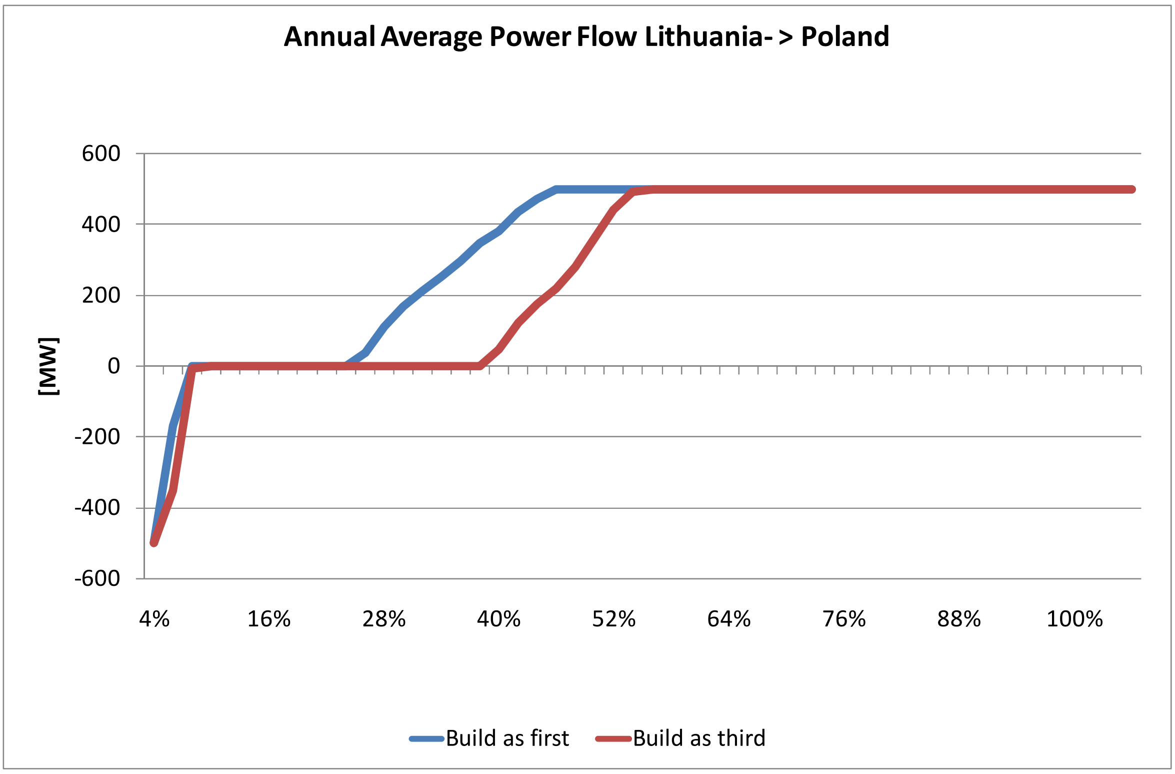


Figure 4.11 Average power flows from Lithuania to Poland (positive direction) with different construction sequence options.

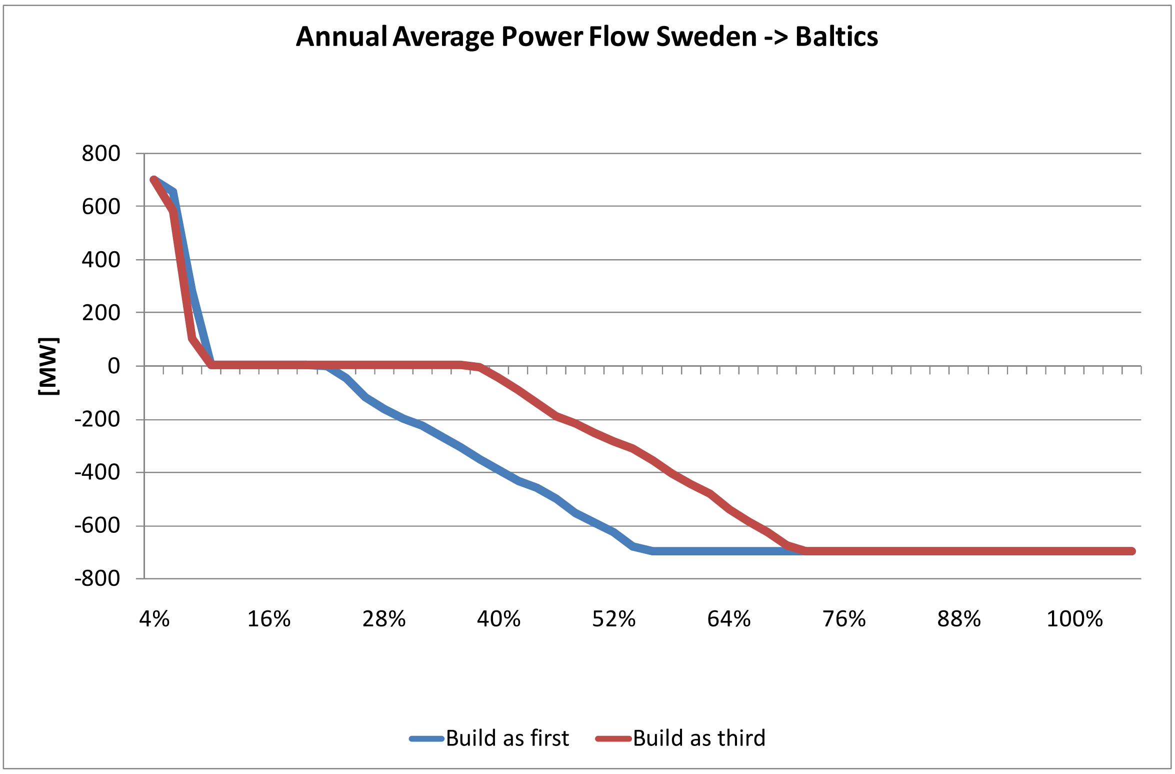


Figure 4.12 Average power flows from Sweden to Baltics (positive direction) with different construction sequence options.

The average time of congestion or full load hours can be seen from the horizontal part of duration curve in the end of lines.

4.4 Discussion

There are certain uncertainties, simplifications and other factors in the study which have to be considered when interpreting the results. However, the most important uncertainties have been studied in a sensitivity analyses.

The market model is based on the perfect competition in the electricity market which is not always the case in reality.

Development plans of generation may be too optimistic and difficult to implement according to today's realities. Replacement of old power generation sources in Baltics will require huge investments and long time. If generation plans will not realize according to scenarios of this study, the marginal cost differences between Baltic and Nordic market areas will be larger than results in this study which will result in higher use of interconnections (see e.g. the sensitivity of Low Nuclear case).

In the Nordic area, different inflow years are included to the input data (i.e. wet and dry years). The energy balance in the Nordic area may change tens of Terawatt hours due to different inflow years. The average hydro generation results are used in the analysis including also the extreme years. Generally, the benefit of interconnections is higher during extreme years when more transmission capacity is required. In addition, the hydro power generation in Latvia is modelled according weekly average generation. Thus, hydro power variation from year to year has not been considered in Latvia.

The standard costs of the investigated interconnection have been used even the market situation may have an impact on the cost of the interconnections. There are also many technological alternatives available for the interconnections, e.g. HVDC classic and VSC HVDC which have impact on the overall costs and profitability of interconnections.

The internal grid reinforcements of related area for the proposed interconnections are also included to the total costs. The allocation of costs of all planned internal reinforcements to the cost of interconnection is difficult to estimate. In this study each responsible TSO has evaluated the needed reinforcements. The transmission limitations and congestions may be higher between Baltics and Poland in reality than in this study due to relatively weak Polish internal grid.

The timing of each proposed interconnection project has been simplified so, that all 1, 2 or 3 building projects are assumed to be ready during the same year.

Poland has a lot of possibilities to increase transmission capacity to other neighbouring countries instead of Lithuania as well. These possibilities are not investigated in this study (except Ukrainian import sensitivity) even they may have an impact on the results.

The impact of large capacity of wind power plants on transmission capacity available for the market is not analysed in the study. The example of German and Polish case shows, that large amount of wind power reduces transmission capacity for the market and affects additional limitations and congestions.

5 Conclusions

Conclusions for the Multiregional planning study are made based on the market analysis conducted with EMPS model. Only market benefits are included to the analysis ignoring the Security of Supply issues. The main analysis is done for the year 2025.

5.1 Main conclusions

The detailed conclusions are described in Sections 5.2-5.4. The main conclusions are collected here.

- According to this study, the best market based solution (without Security of Supply aspect) is to implement two interconnections: Finland-Estonia and Lithuania-Poland. This results in good socioeconomic benefit for both projects and it also improves the security of supply and integration of Nordic-Baltic-European electricity market.
- The second best market based alternative is to implement Lithuania-Poland link only. The third option is to implement both Lithuania-Poland and Sweden-Baltics interconnections and the fourth option in decreasing order of net market benefit is to build all three interconnections respectively.
- However, taking into account the security of supply and market integration aspects, a set of three proposed interconnections would probably be the best solutions but this should be further studied in more detail.
- The interconnections Finland-Estonia and Sweden-Baltics can be seen as parallel paths between Nordel and BALTSO as far as the market marginal costs are at the same level in Sweden and Finland. Thus, the Gross market benefits are practically the same. However, the net market benefit of Finland-Estonia interconnection is higher due to its shorter length and thus lower costs than the Sweden-Baltics interconnection.
- According to scenario 2015 there is already a need for additional transmission capacity. This means that the quicker the implementation time of the new interconnection the higher market benefits can be achieved.

5.2 Base scenarios

The energy balance of the Baltic States will change from a deficit area to surplus area during the period starting from year 2015 and heading to 2025. Energy production in Baltic States in year 2015 is mainly based on oil shale in Estonia, on hydro and coal in Latvia and on natural gas in Latvia and Lithuania. Lithuania will import more than half of the demand due to closing of existing Ignalina nuclear power plant.

According to simulations for 2015 there is mainly power exchange from Nordel to Lithuania and Poland. Existing interconnection between Finland and Estonia (Estlink 1) transfers annually 1,5 TWh electricity from Finland to Estonia being highly congested interconnection. Transmission capacity between Finland and Estonia improves also the Security of Supply. Thus, additional transmission capacity between Finland and Estonia is needed already in 2015 situation, according to simulation results.

According to simulations for 2025 the marginal costs are higher compared to 2015. In Poland there will be surplus in generation capacity only in National Focus 2025 scenario. There are new nuclear power plants in Estonia and Lithuania in year 2025. Therefore the Baltic States together becomes energy surplus area, while Latvia is still a deficit area.

The marginal cost differences between Finland and Sweden in 2025 scenario occur rather seldom (8 % of time) indicating relatively low harm from transmission capacity available for the market. The situation is even better between the Baltic States; there is common price area most of the time. According to simulations, the annual average marginal cost in the Nordel, in the Baltic states and in Poland is between 40 and 115 €/MWh while in Germany and in The Netherlands the marginal cost level is generally about 20 €/MWh higher.

The average area marginal cost in Climate&Integration scenario is higher than in other scenarios even the generation capacity of renewable energy is higher. This is due to higher CO_2-cost which increases the marginal cost of thermal production. Thermal production typically defines the area marginal cost.

Due to high share of coal fired generation, greatly exposed to environmental risks and comparatively insignificant capacity of existing cross border interconnections, the highest electricity marginal costs (practically in all scenarios) are expected in Poland.

According to simulations for BAU2025 the main power exchange is from the Baltics to Poland and from the Baltics to Nordel area. There is a capacity limitation over 50 % of time (annually) on the Poland-Lithuania interconnection in case of 500 MW transmission capacity. In spite of transmission capacity of 1700 MW between Nordel and Baltics (1000 MW between Finland and Estonia and 700 MW between Sweden and Baltics), the transmission path between Baltics and Nordel is occasionally congested towards Nordel.

5.3 Analysis of interconnections

All the analysis made here is based on BAU2025-scenario if not otherwise mentioned.

The interconnection which is built first gets the highest socio-economic benefit due to the highest need to exchange energy between areas and hence the highest marginal cost differences between areas. The more transmission capacity between investigated areas the smaller marginal cost differences between areas and the less profitable it is to build new interconnections. The interconnection which is built first may receive the best benefit only during the period before other interconnections have not been built. In the end, all interconnections will deal with the reduced socioeconomic benefit due to improved total transmission capacity.

From the net market benefit point of view it is most profitable to build two interconnections. The second profitable alternative is to build only one interconnection, but this option does not promote the integration of electricity markets towards European market. In addition, more than one new interconnection is recommended to enable better security of supply. Building all three interconnections gives the profit which is still clearly positive.

The Gross benefit of Sweden-Baltics interconnection is in the same range with Gross benefit of Finland-Estonia interconnection but Finland-Estonia connection has a lower cost due to shorter distance. The similar Gross benefit between two proposed connections is due to relatively small congestions in commercially available transmission capacity between Sweden and Finland, which can be seen often as one price area. The same is valid for the Baltic States, situation in 2025 scenario gives almost same spot marginal costs and also the Baltics can be seen as one price area.

The new link between Lithuania and Poland has a better capacity utilisation factor (especially in direction to Poland), and hence greater socio-economic benefits compared to other proposed links. The profitability of the link, however, is reduced by extremely large investments, necessary for the reinforcement of internal grid in Lithuania and Poland. The larger option (1000 MW) from the two studied transmission capacity alternatives is recommended to choose if the connection will be built.

Sweden-Baltics interconnection with further connections to Germany is a parallel option to Lithuania-Poland interconnection with further connection to Germany. These both options integrate Baltic market to Central-European market, from the Central-European point of view.

In case that two links are going to be built, the combination Finland-Estonia and Lithuania-Poland is the best alternative independent of the building order.

In the Climate&Integration scenario the Gross benefit of Finland-Estonia connection and Sweden-Baltics connection would decrease due to increased capacity (1000 MW) Lithuania-Poland link. The Gross benefit of Lithuania-Poland link would increase significantly due to increased transmission capacity. The highest increase of marginal cost is in Poland compared to Baltic States causing relatively higher marginal cost difference between the areas Baltic States and Poland than between Nordic countries and Baltic countries. The high benefit of Poland-Lithuania interconnection is due to high marginal cost difference between Lithuania and Poland. High marginal cost difference is due to high marginal cost of production in Poland. High marginal costs are due to high price of CO2-allowances in C&I2025 -scenario.

5.4 Sensitivity of market factors

Two major factors, which have the highest impact on the direction and volume of power flows on the investigated interconnections, are the generation capacity In the Baltic-Poland region and marginal cost of Russian electricity.

In the following, each sensitivity case's impact on the feasibility of new interconnections is analysed shortly.

High fuel price:

The increase of marginal costs of production will increase the price of electricity in the Baltic area relatively less than in the Nordic area or in Poland. Due to increased import from Russia to Baltics the utilisation and the profitability of the investigated interconnections will be increased even though the own power generation energy decreases in the Baltic area.

Low cost for renewable:

Most of the time the cost of renewable power does not determine the marginal cost of electricity in the Baltic area or in Poland. Thus, having subsidies for the renewable decreases the marginal cost of renewable but does not have any notable impact on the area marginal costs or on the profitability of three suggested interconnections.

Low Russia import marginal cost:

The profit of all investigated interconnections will increase due to transferring the electricity from Russia to Europe through the interconnections. Domestic generation and electricity marginal costs will decrease practically in all market areas.

Low nuclear:

Having only 1500 MW nuclear power in Poland, 1600 MW in Lithuania and 0 MW in Estonia, this sensitivity case will show a deficit in the Baltic area balance. In addition nuclear power capacity has been decreased 1500 MW from Sweden and 1600 MW in Finland. The most probable direction of power flows are from Poland to Baltic countries and from Baltic to Nordic countries. In BAU2025 scenario the main direction of power flow is from Lithuania to Poland. According to benefit analysis the profitability of all three interconnections is very good in this scenario independent of the building order. The profitability of Lithuania-Poland interconnection increases relatively more than the profitability other studied connections.

The annual energy generation in Poland is higher compared to BAU2025 scenario even the nuclear power capacity is reduced by 50% due to increased need of energy in the surrounding areas. The average marginal cost is lower compared to BAU2025 scenario even there is more production in Poland. This is due to price of CO_2 allowance which is set to zero in Low nuclear scenario. In Poland there is lot of generation which is impacted by CO_2 emissions.

Swe-Ger link:

Increased capacity between Sweden and Germany would increase the utilisation of transmission capacity between the countries. The flows would increase into both directions; pumping of energy between the Continental Europe and Nordic countries during a night and a day. The impact of new capacity has only minor impact on three investigated interconnections. Minor increase of utilisation on Sweden-Baltics and Finland-Estonia connections could be seen.

The transmission capacity between Germany and the Sweden is assumed to be 1400 MW in this sensitivity study. The increase of transmission capacity between the countries would have an impact on the benefits of studied interconnections as well.

Ukrainian export to Poland:

Increased import to Poland decreases generation and area marginal cost in Poland. Other power exchanges between areas stays almost constant compared to BAU2025 scenario. This sensitivity case does not have impact on the profitability of Finland-Estonia or Sweden-Baltics connections and it slightly decreases the profitability of Lithuania-Poland connection due to smaller marginal cost differences between the areas.

The impact of sensitivity cases on the benefit of studied interconnections is the highest with Low nuclear and with Low Russian import price -cases. The low nuclear power generation in the market area increase the need to export energy from surrounding areas to Baltic area and to Poland increasing the profitability of proposed interconnections. The low electricity marginal cost in Russia increases the transit flow from Russia through Baltic States to Poland, Central-Europe and to Nordic countries increasing also the profitability of studied interconnections.

5.5 Further actions of Multiregional Grid Planning

Following tasks should be taken into agenda in 2009 when continuing the cooperation between the regions. These tasks shall be finalised before June 2009.

- cost-benefit analysis until 2025 including estimation of security of supply benefits of new interconnections
- prerequisites and estimated realisation time for each project
- selection of cost effective technology for each interconnection e.g. making future extensions possible
- coordinated timetable for each project.

In addition, the results of this project will be included to the first common Baltic Sea Multi-regional Grid Plan which will be done by ENTSO-E in 2010.

Appendix A: List of Multiregional Planning Project participants

List of Participants

The members of the Steering Group have been:

Balodis Maris	Latvenergo
Gluszek Artur	PSE Operator S.A.
Kilk Kalle	OÜ Põhivõrk
Moberg Ulf	Svenska Kraftnät
Antanas Jankauskas	Lietuvos Energija AB
Kuronen Pertti (Chair in 2008)	Fingrid Oyj

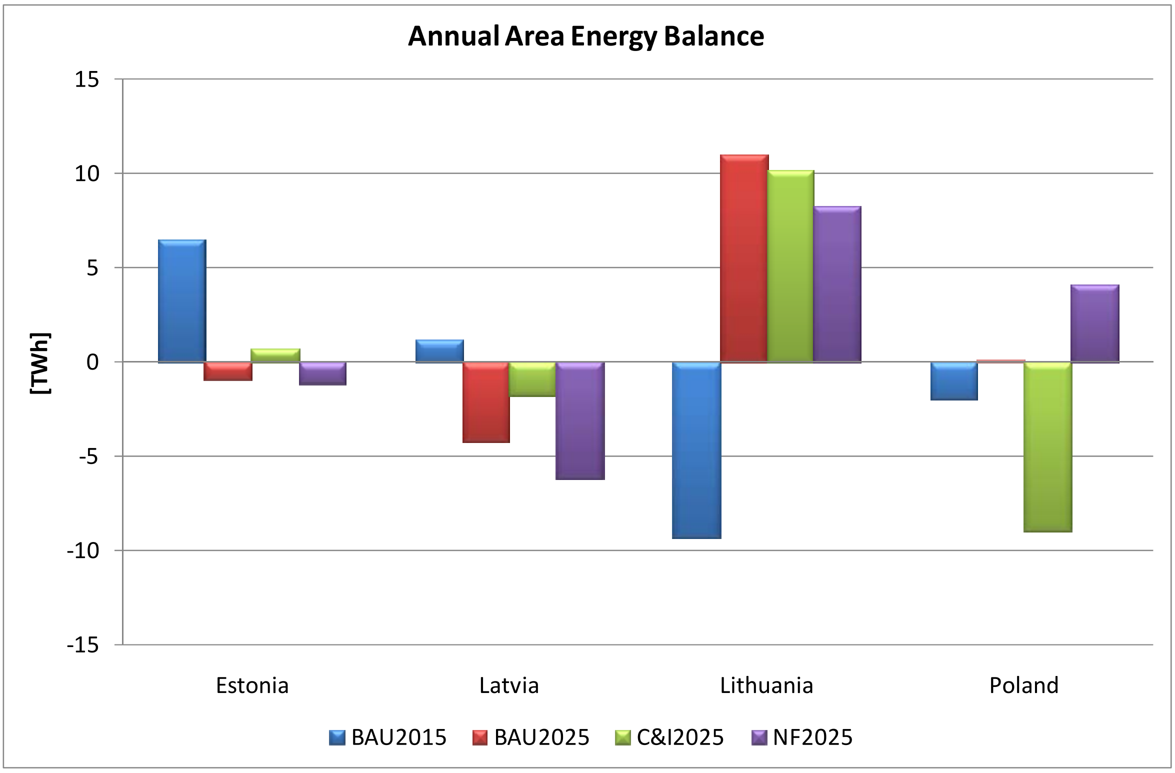
The members of the Working Group have been:

Linkevics Olegs	Latvenergo
Tymorek Andrzej	PSE Operator S.A.
Landsberg Mart	OÜ Põhivõrk
Sabbagh Habib	Svenska Kraftnät
Rutkauskas Rimantas	Lietuvos Energija AB
Matilainen Jussi (Chair in 2008)	Fingrid Oyj

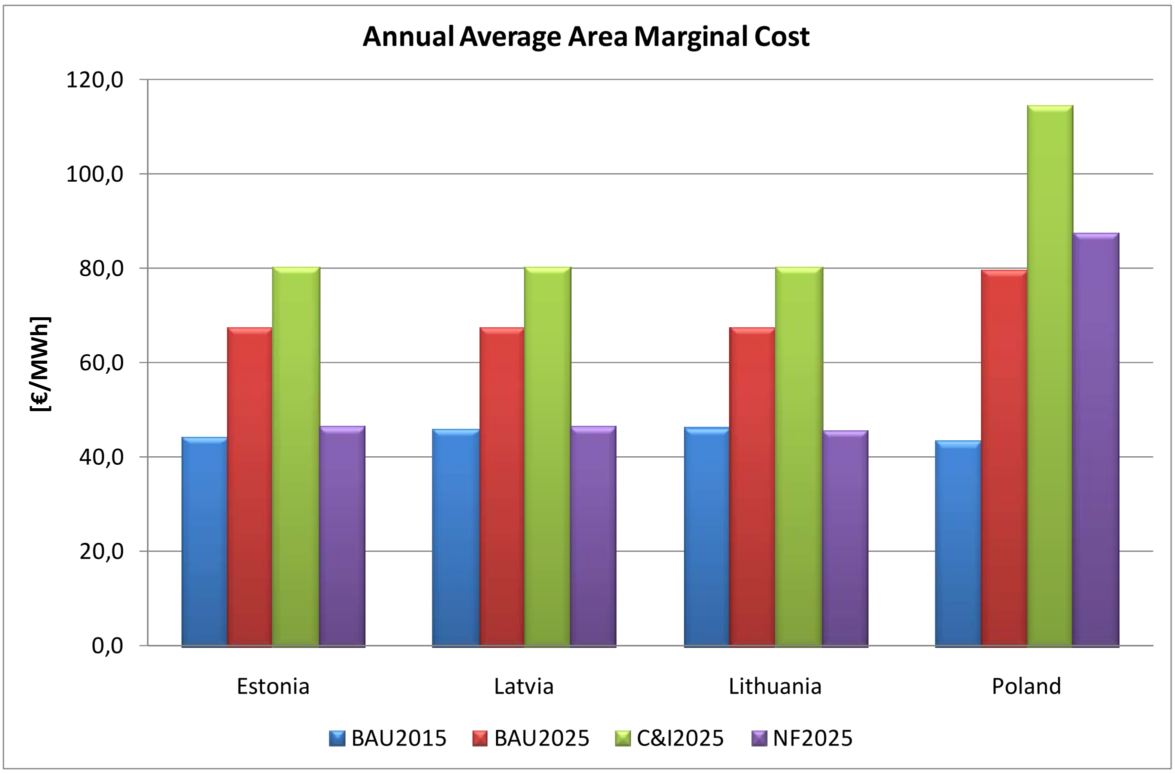
Experts participated in the study:

Šulcs Didzis	AS Augstsprieguma Tīkls
Osītis Jānis	AS Augstsprieguma Tīkls
Ponelis Ramunas	Lietuvos Energija AB
Gailevicius Giedrius	Lietuvos Energija AB
Koskinen Mikko	Fingrid Oyj
Konttinen Lasse	Fingrid Oyj

Appendix B: Energy balance, congestion hours, power exchange and area marginal costs of base scenarios



Annual energy balance in the Baltic countries and in Poland in different scenarios.



Annual average marginal cost of production in the Baltic countries and in Poland in different scenarios.

In the following section beneath are shown:

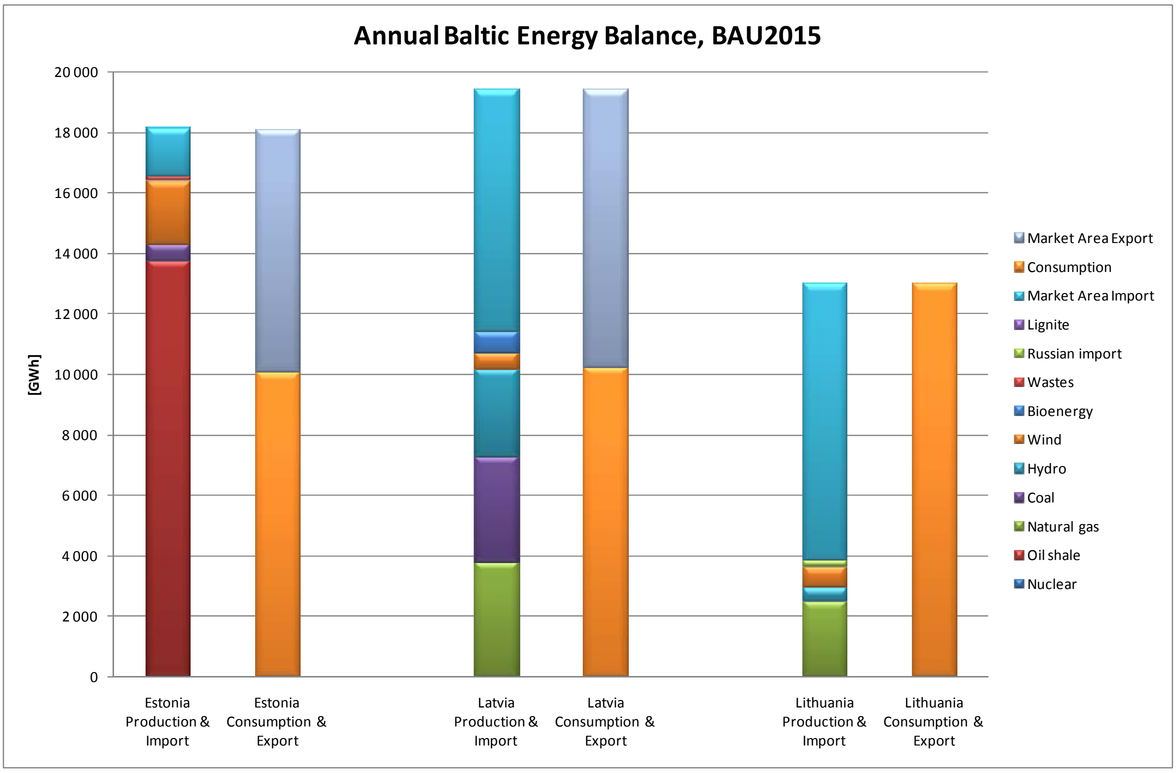
In first graph are production and consumption bars for Estonia, Latvia and Lithuania.

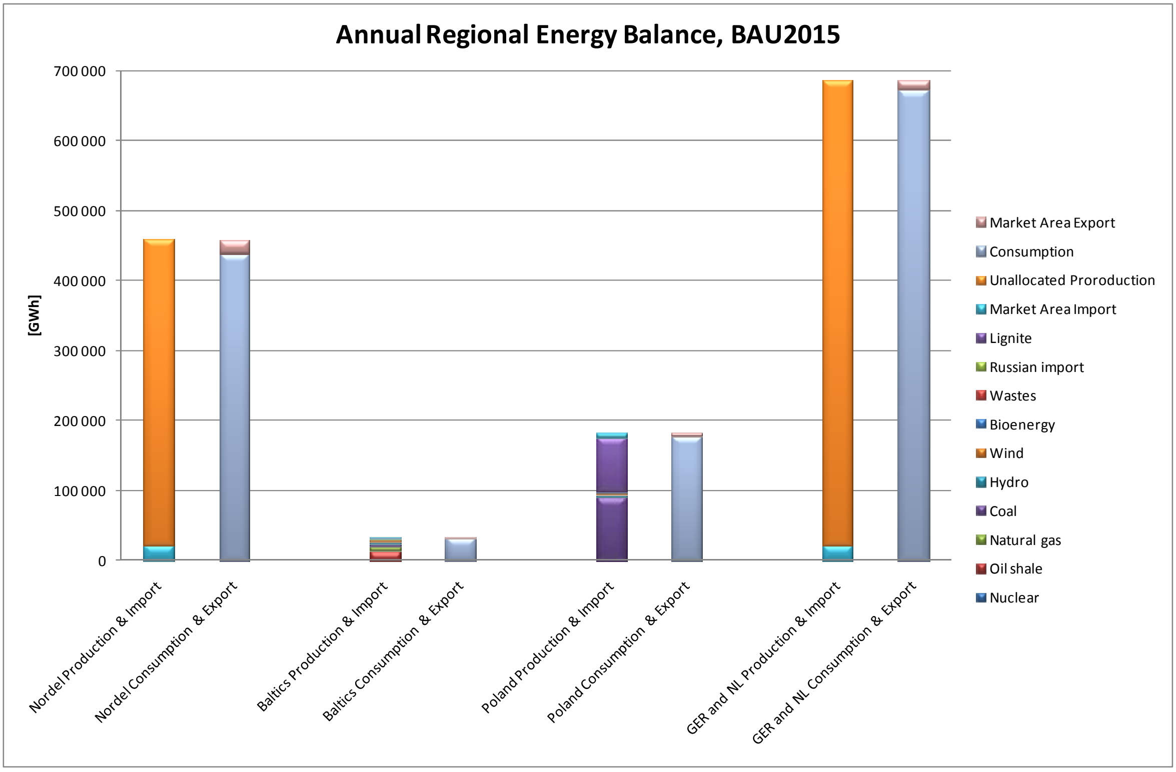
In second graph are production and consumption bars for Baltics, Poland, Nordic area and for The Netherlands & Germany.

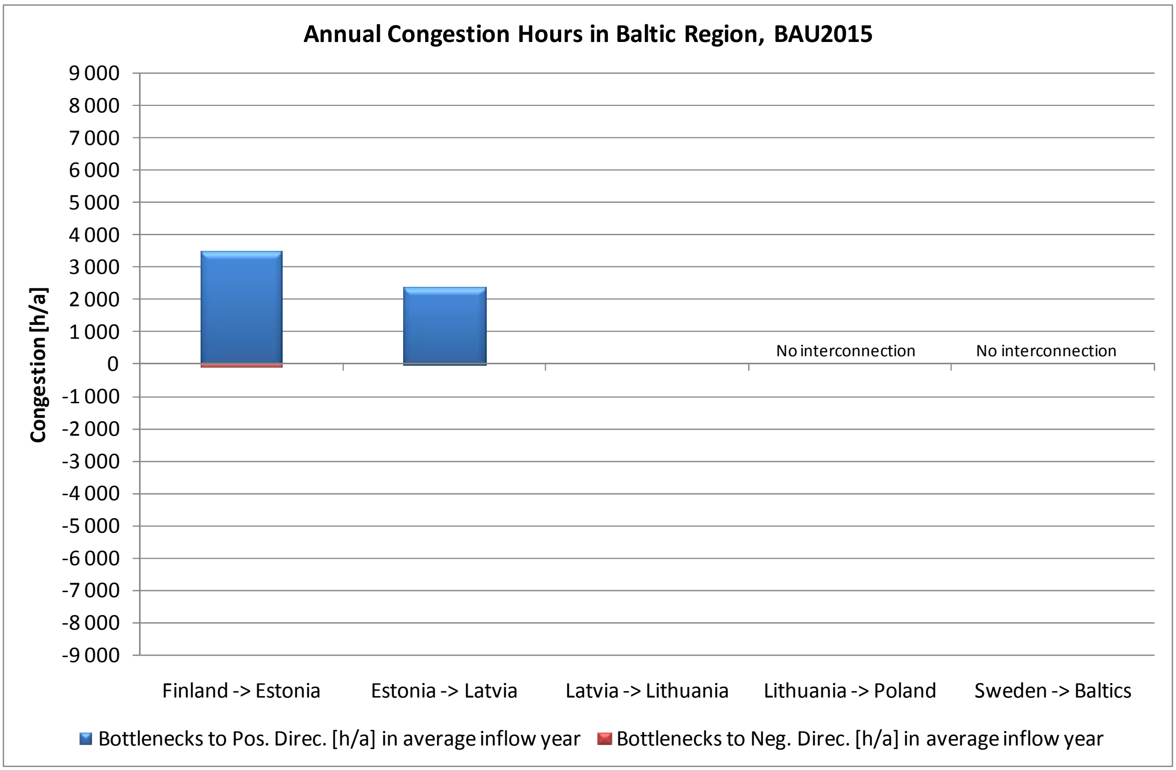
Third graph contains bottlenecks for different interconnections and fourth graph the flows.

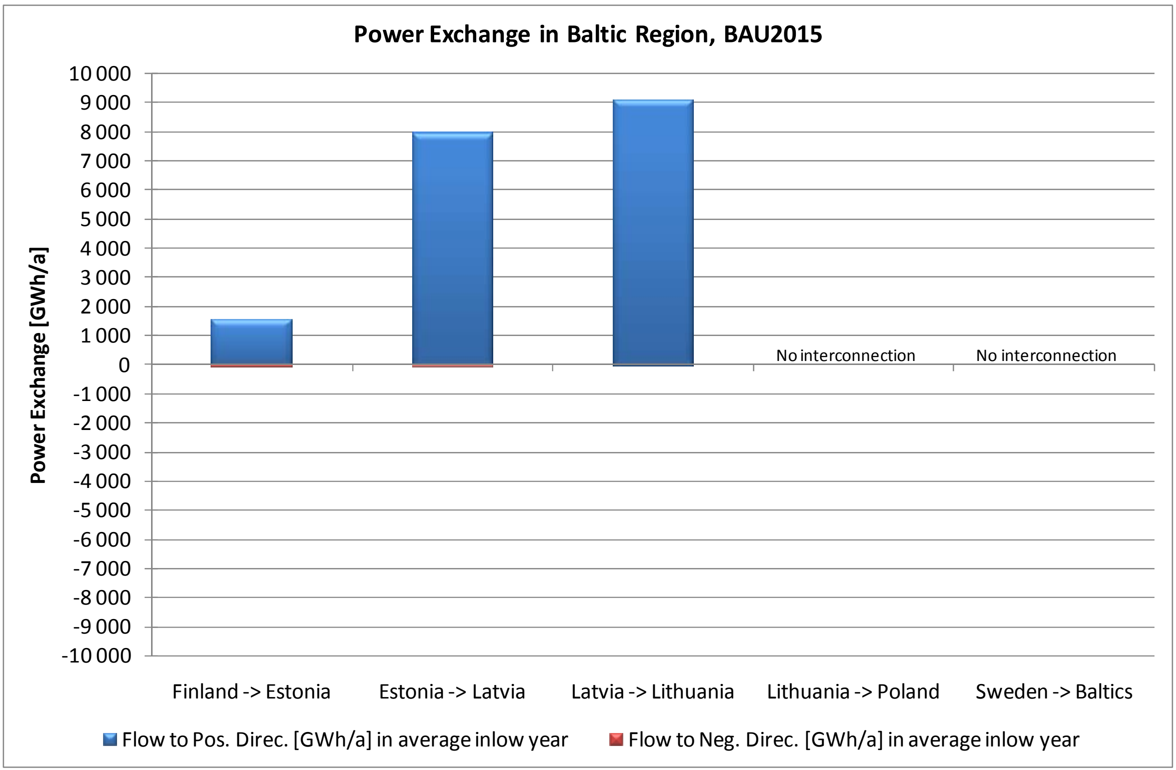
Fifth picture expresses area marginal costs for all areas.

All graphs have the same order through BAU2015, BAU2025, C&I2025 and NF2025.

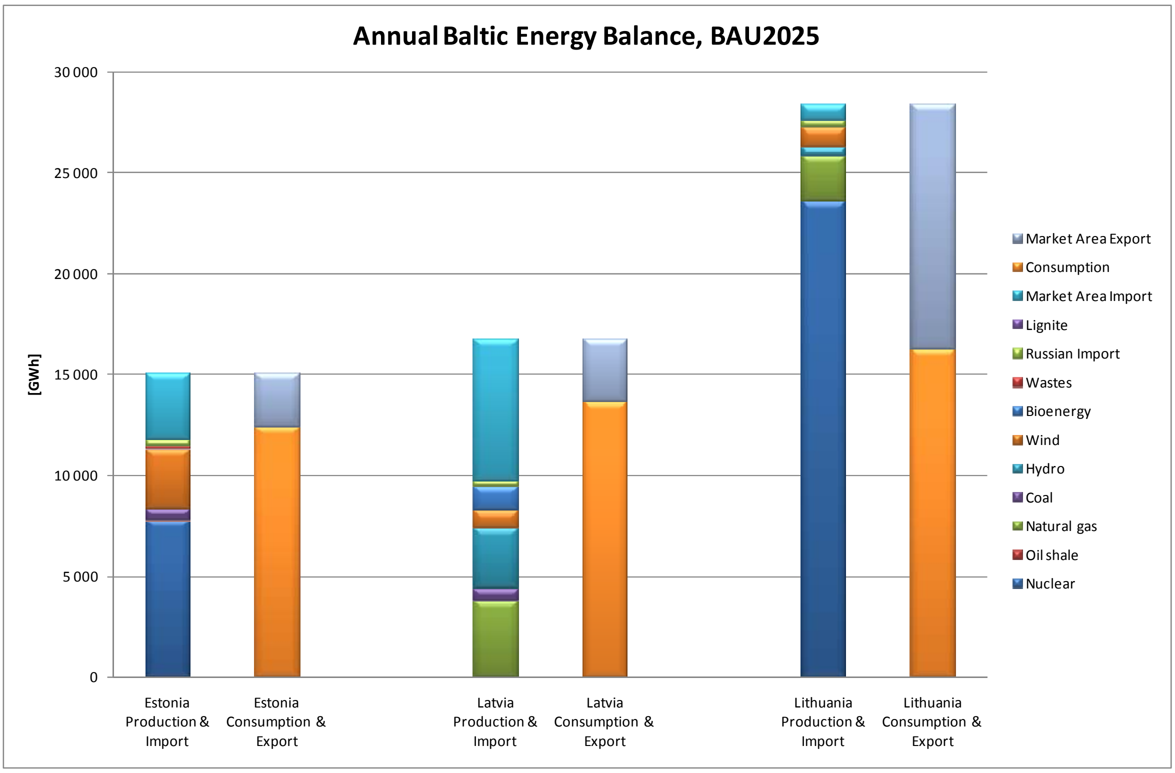


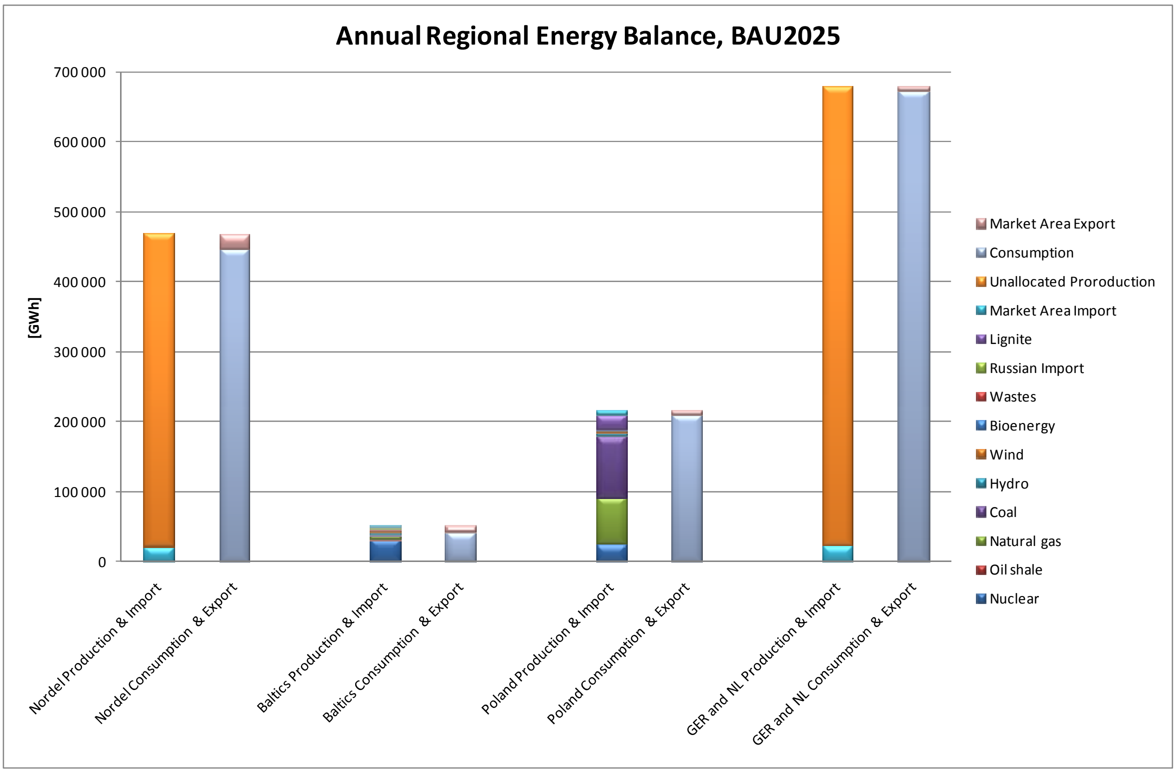

Annual Regional Energy Balance, BAU2015
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
[GWh]
Nordel Production & Import
Nordel Consumption & Export
Baltics Production & Import
Baltics Consumption & Export
Poland Production & Import
Poland Consumption & Export
GER and NL Production & Import
GER and NL Consumption & Export
Market Area Export
Consumption
Unallocated Proroduction
Market Area Import
Lignite
Russian import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear

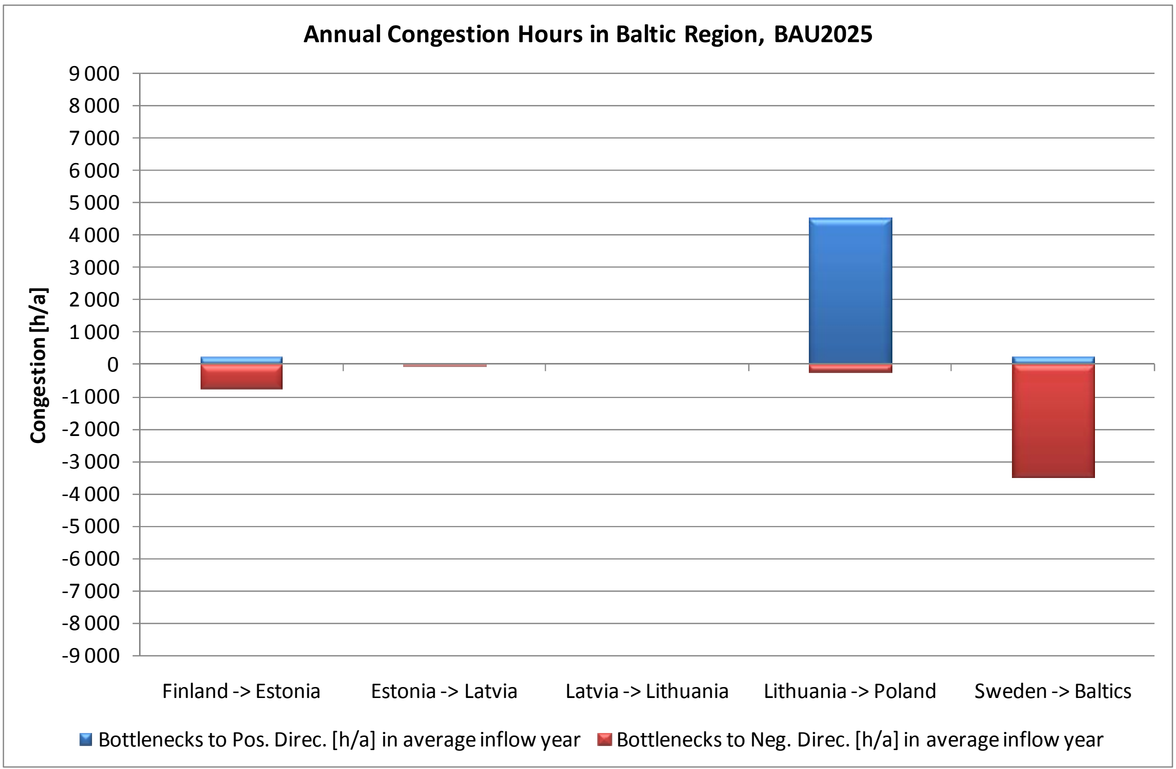

Annual Congestion Hours in Baltic Region, BAU2015
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
Congestion [h/a]
No interconnection
No interconnection
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Bottlenecks to Pos. Direc. [h/a] in average inflow year
Bottlenecks to Neg. Direc. [h/a] in average inflow year

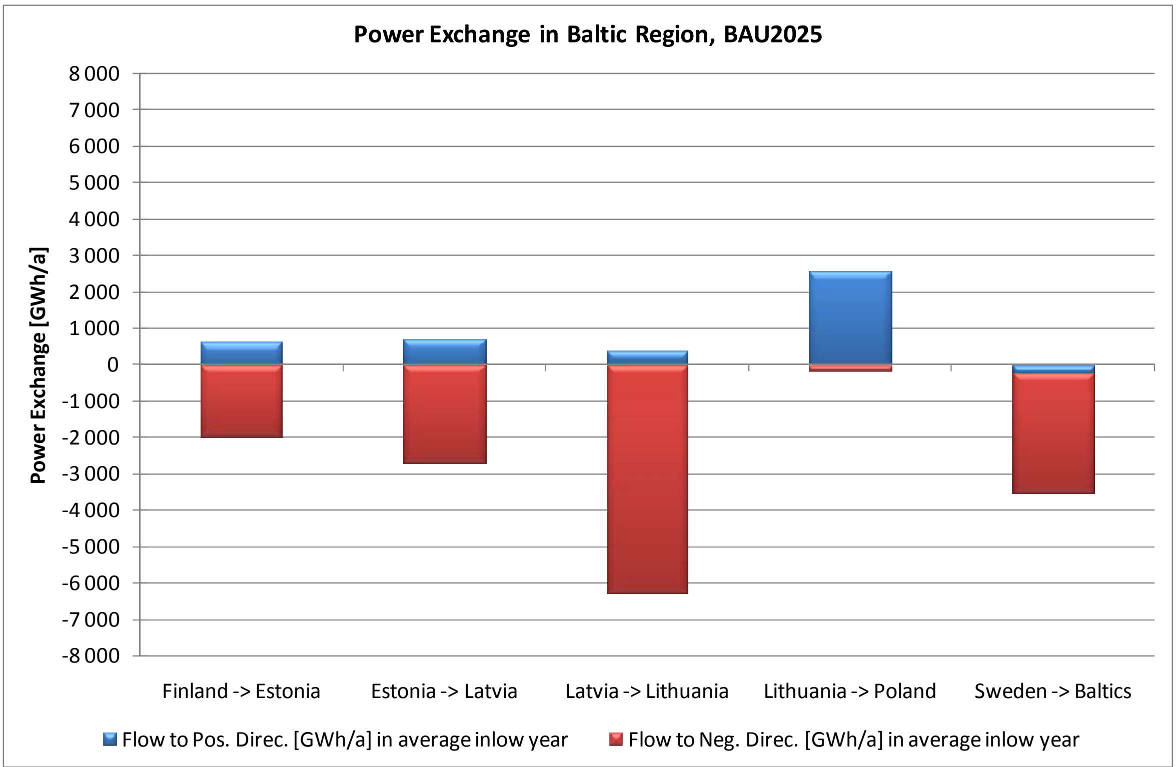

Power Exchange in Baltic Region, BAU2015
Power Exchange [GWh/a]
10 000
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
-10 000
No interconnection
No interconnection
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Flow to Pos. Direc. [GWh/a] in average inlow year
Flow to Neg. Direc. [GWh/a] in average inlow year


Average Annual Area
Marginal Costs BAU2015
41.9 €/MWh
41.4 €/MWh
41.5 €/MWh
41.3 €/MWh
42.5 €/MWh
41.4 €/MWh
41.5 €/MWh
41.4 €/MWh
41.5 €/MWh
41.4 €/MWh
41.5 €/MWh
44.3 €/MWh
41.4 €/MWh
46.1 €/MWh
41.9 €/MWh
41.6 €/MWh
42.1 €/MWh
46.2 €/MWh
41.9 €/MWh
41.9 €/MWh
43.5 €/MWh
59.5 €/MWh
59.6 €/MWh


Annual Baltic Energy Balance, BAU2025
[GWh]
30 000
25 000
20 000
15 000
10 000
5 000
0
Estonia Production & Import
Estonia Consumption & Export
Latvia Production & Import
Latvia Consumption & Export
Lithuania Production & Import
Lithuania Consumption & Export
Market Area Export
Consumption
Market Area Import
Lignite
Russian Import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear

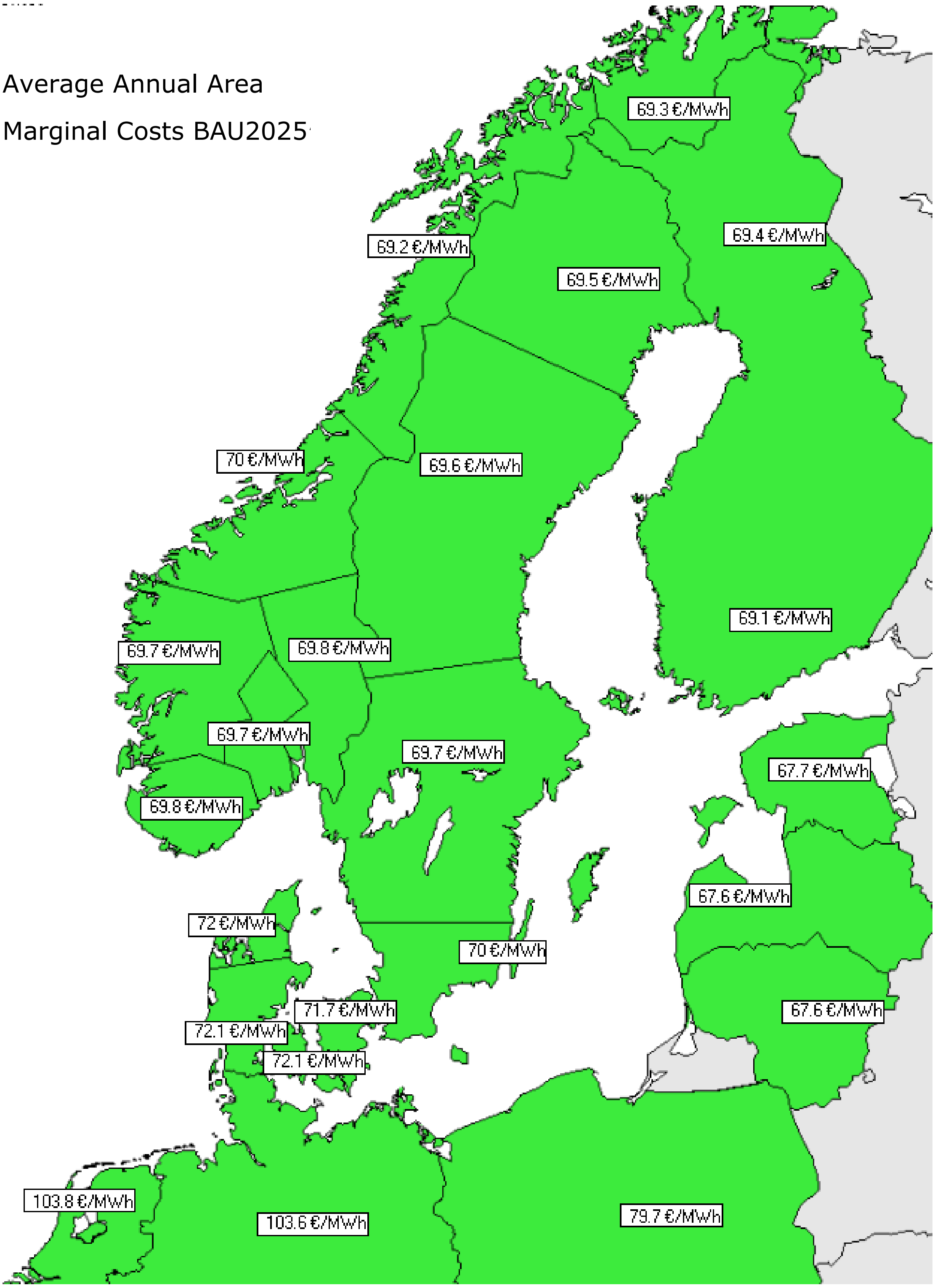

Annual Regional Energy Balance, BAU2025
[GWh]
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
Nordel Production & Import
Nordel Consumption & Export
Baltics Production & Import
Baltics Consumption & Export
Poland Production & Import
Poland Consumption & Export
GER and NL Production & Import
GER and NL Consumption & Export
Market Area Export
Consumption
Unallocated Proroduction
Market Area Import
Lignite
Russian Import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear

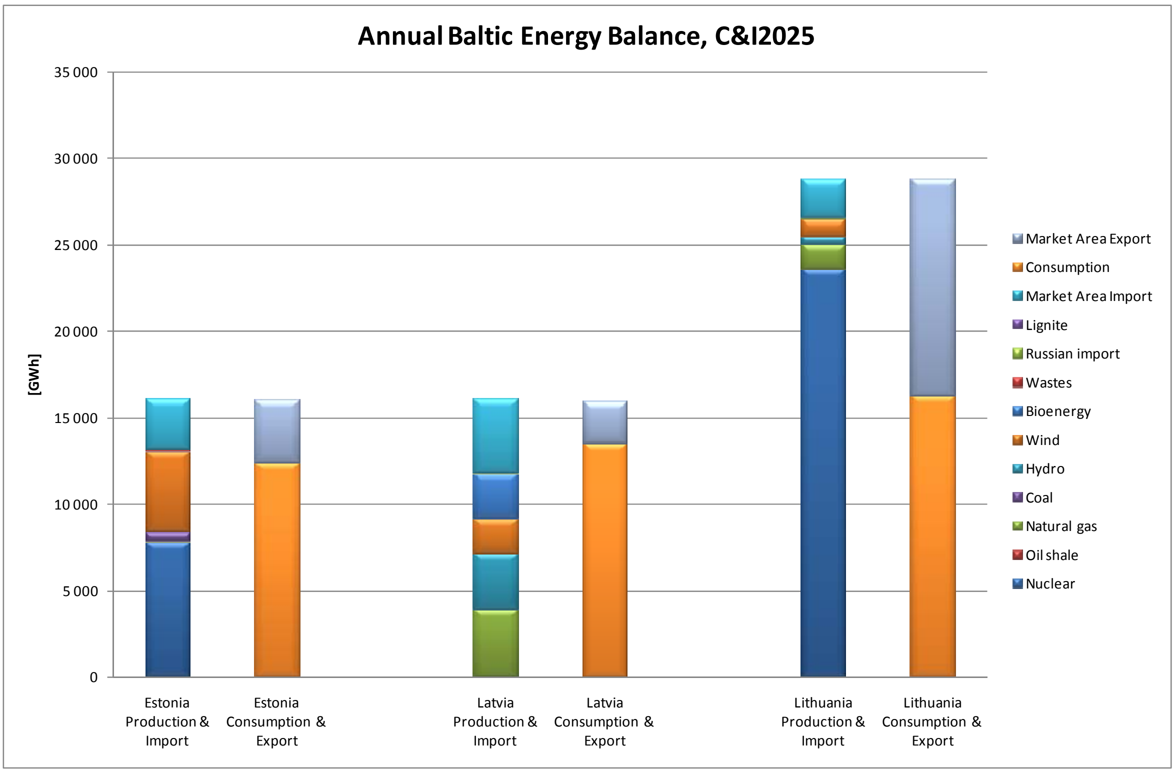

Annual Congestion Hours in Baltic Region, BAU2025
Congestion [h/a]
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Bottlenecks to Pos. Direc. [h/a] in average inflow year
Bottlenecks to Neg. Direc. [h/a] in average inflow year


Power Exchange in Baltic Region, BAU2025
Power Exchange [GWh/a]
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Flow to Pos. Direc. [GWh/a] in average inlow year
Flow to Neg. Direc. [GWh/a] in average inlow year

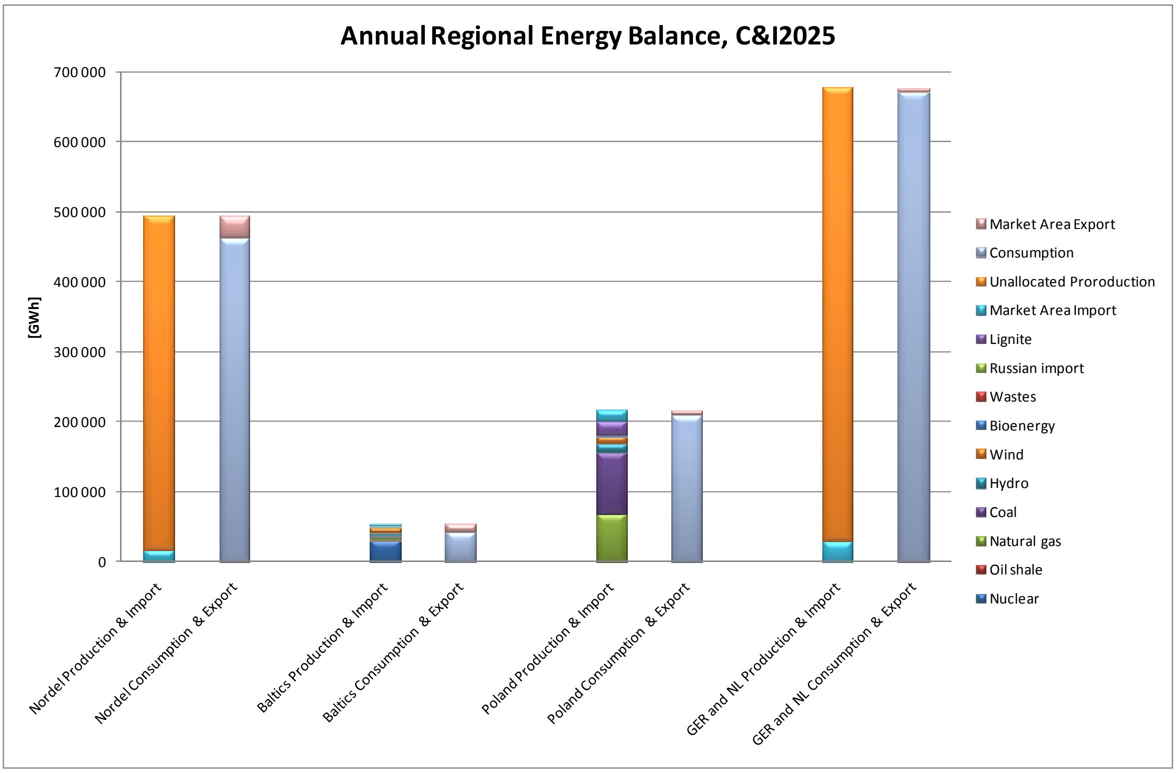
Average Annual Area

Marginal Costs BAU2025

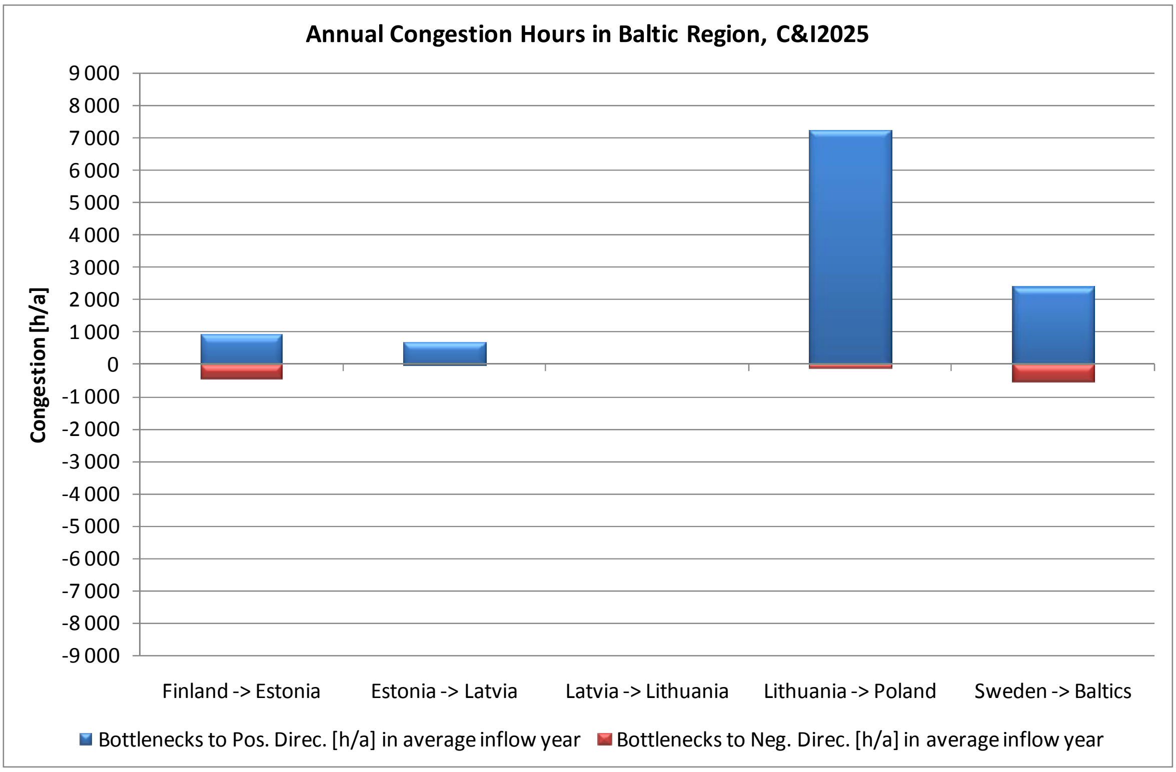


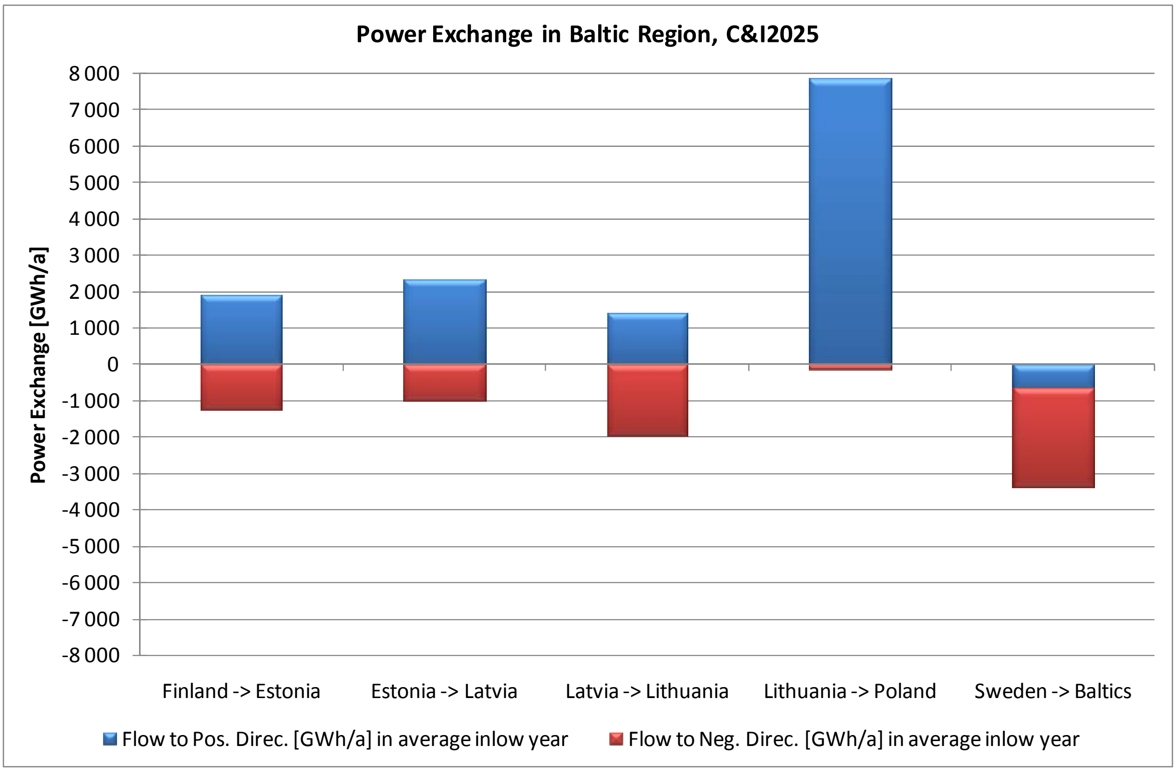


Annual Baltic Energy Balance, C&I2025
[GWh]
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
Estonia Production & Import
Estonia Consumption & Export
Latvia Production & Import
Latvia Consumption & Export
Lithuania Production & Import
Lithuania Consumption & Export
Market Area Export
Consumption
Market Area Import
Lignite
Russian import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear



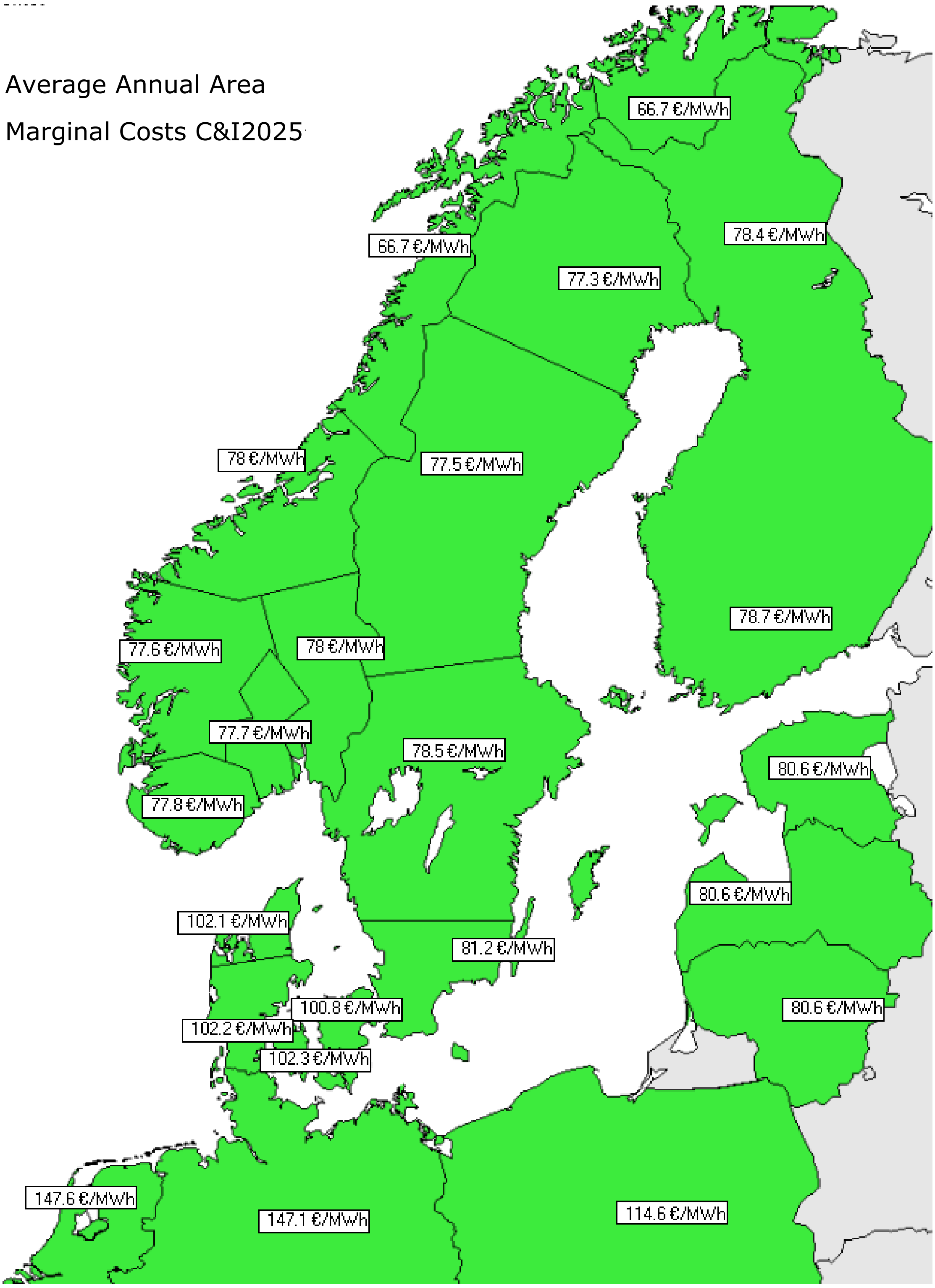
Annual Regional Energy Balance, C&I2025
[GWh]
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
Nordel Production & Import
Nordel Consumption & Export
Baltics Production & Import
Baltics Consumption & Export
Poland Production & Import
Poland Consumption & Export
GER and NL Production & Import
GER and NL Consumption & Export
Market Area Export
Consumption
Unallocated Proroduction
Market Area Import
Lignite
Russian import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear

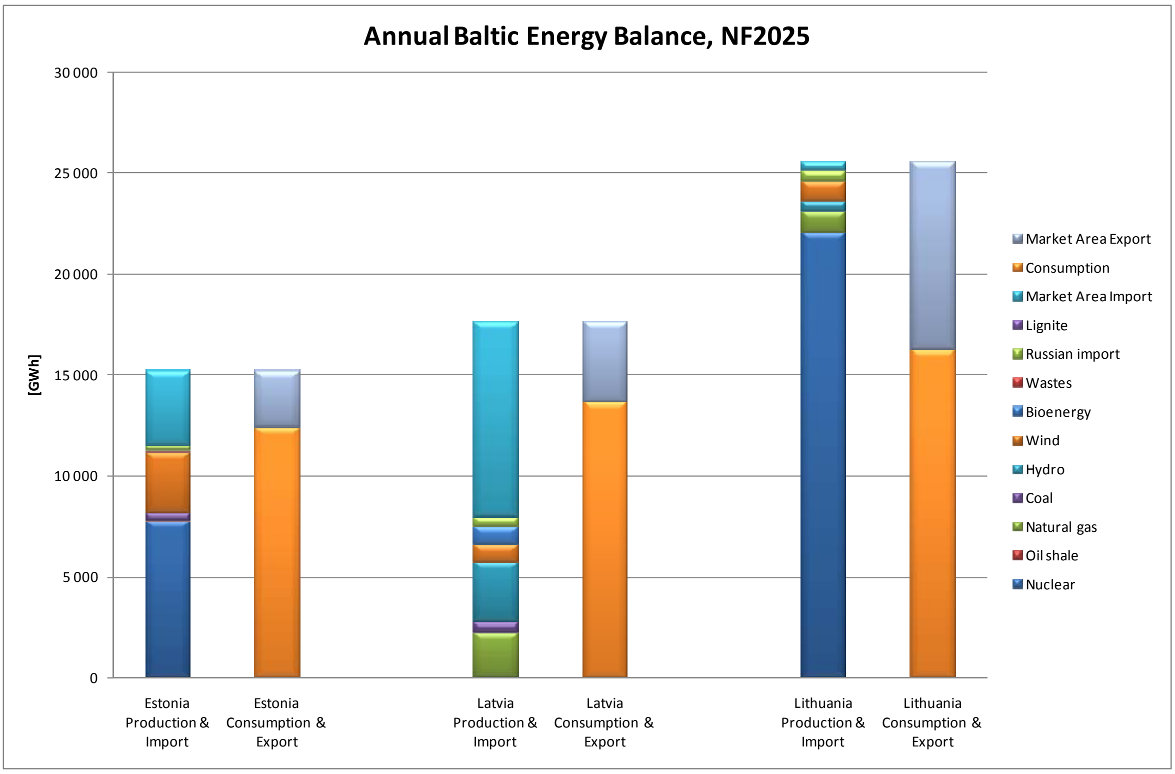

Annual Congestion Hours in Baltic Region, C&I2025
Congestion [h/a]
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Bottlenecks to Pos. Direc. [h/a] in average inflow year
Bottlenecks to Neg. Direc. [h/a] in average inflow year

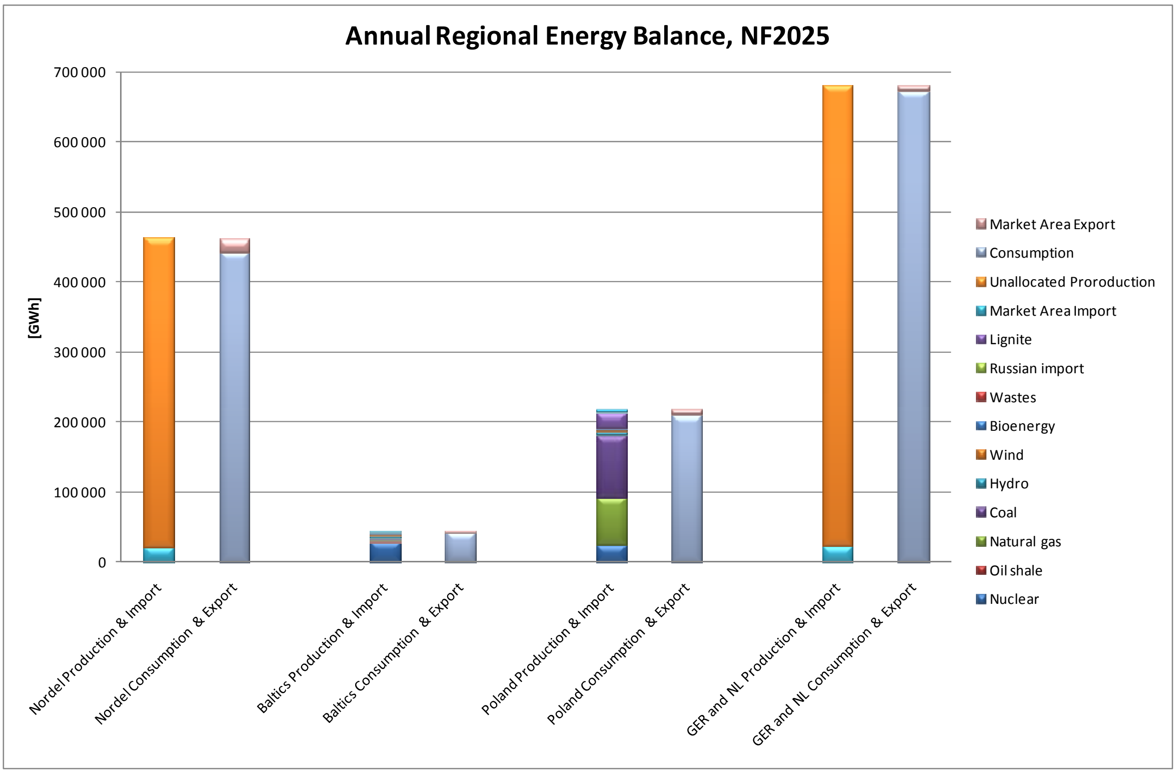

Power Exchange in Baltic Region, C&I2025
Power Exchange [GWh/a]
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Flow to Pos. Direc. [GWh/a] in average inlow year
Flow to Neg. Direc. [GWh/a] in average inlow year

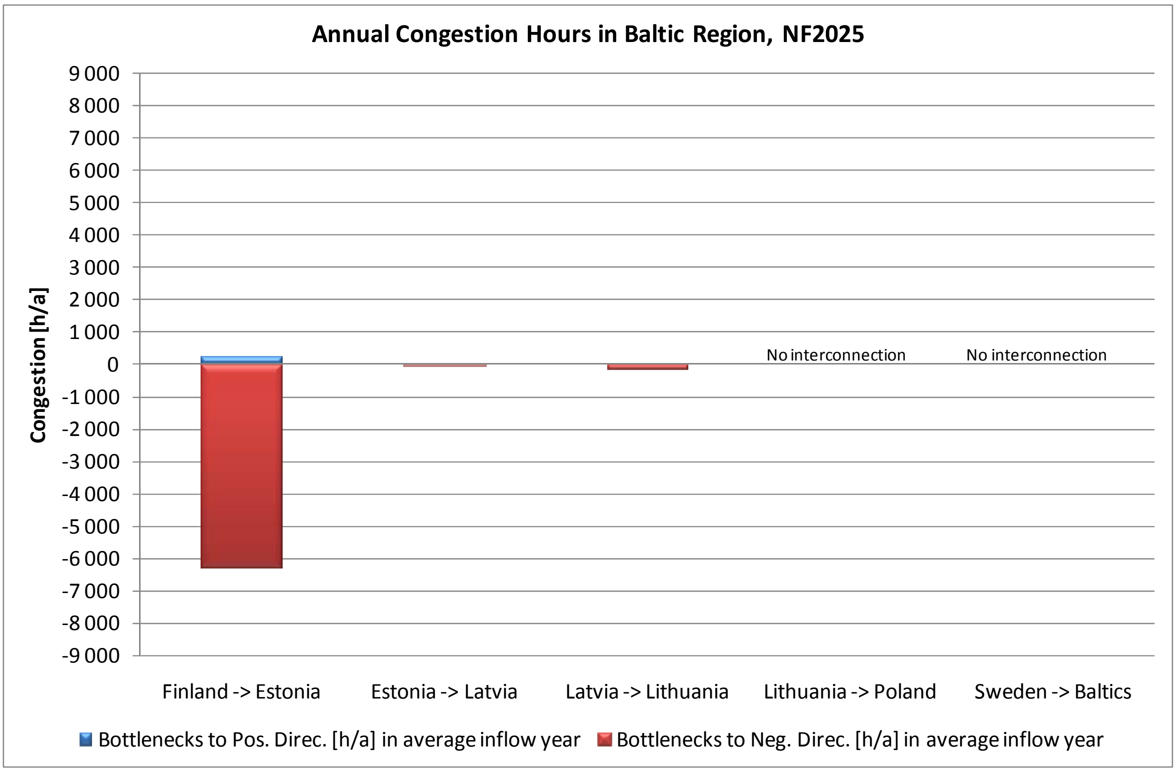
Average Annual Area

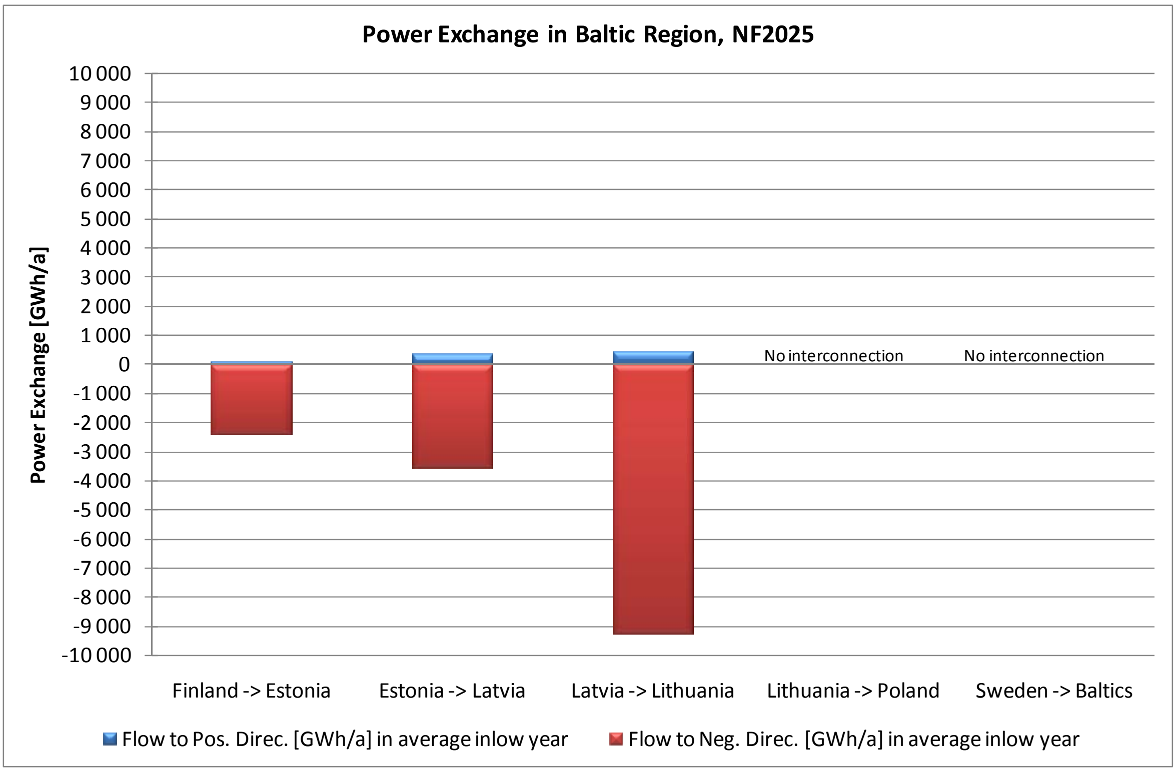
Marginal Costs C&I2025

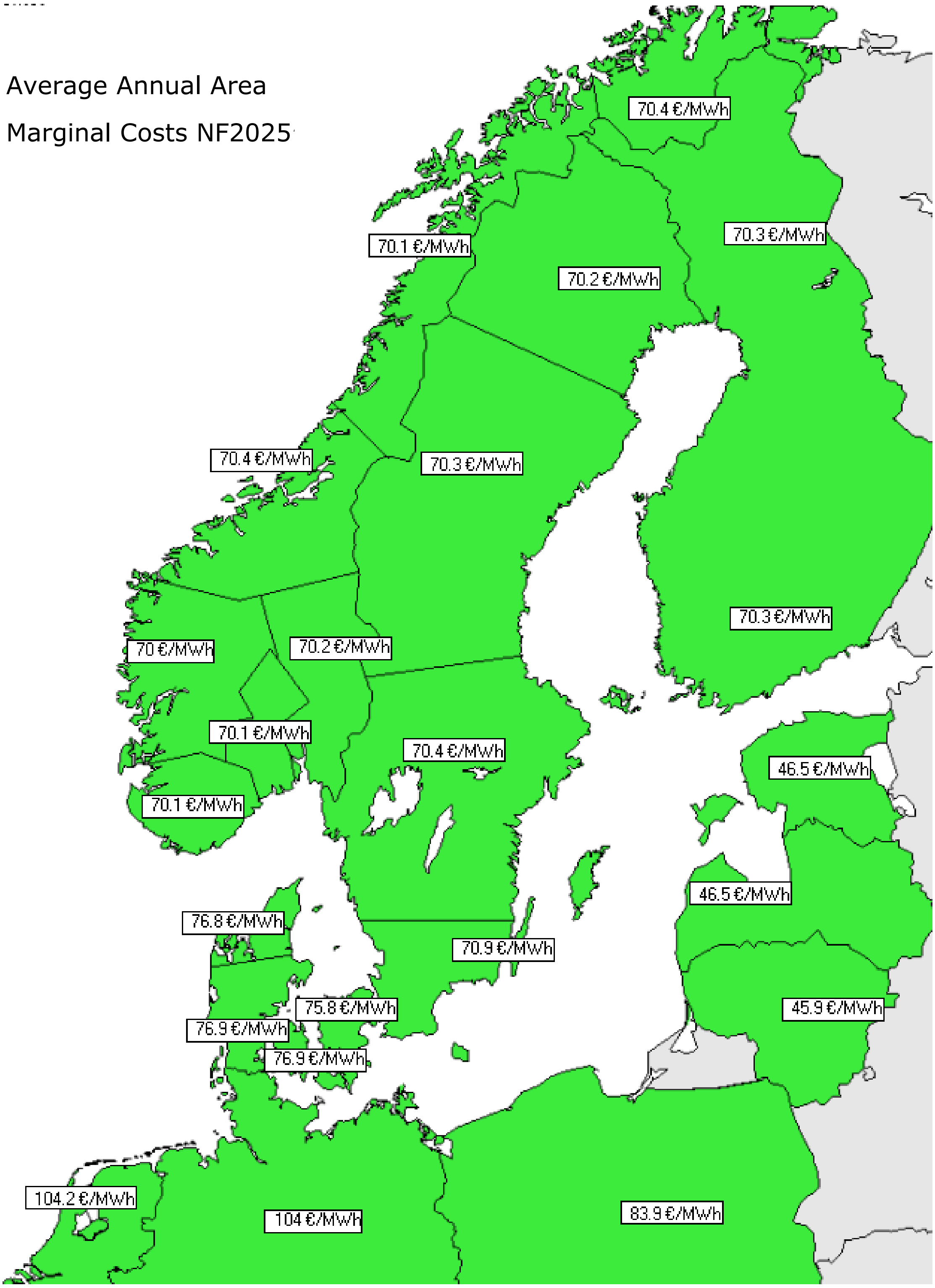



Annual Baltic Energy Balance, NF2025
[GWh]
30 000
25 000
20 000
15 000
10 000
5 000
0
Estonia Production & Import
Estonia Consumption & Export
Latvia Production & Import
Latvia Consumption & Export
Lithuania Production & Import
Lithuania Consumption & Export
Market Area Export
Consumption
Market Area Import
Lignite
Russian import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear


Annual Regional Energy Balance, NF2025
[GWh]
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
Nordel Production & Import
Nordel Consumption & Export
Baltics Production & Import
Baltics Consumption & Export
Poland Production & Import
Poland Consumption & Export
GER and NL Production & Import
GER and NL Consumption & Export
Market Area Export
Consumption
Unallocated Proroduction
Market Area Import
Lignite
Russian import
Wastes
Bioenergy
Wind
Hydro
Coal
Natural gas
Oil shale
Nuclear

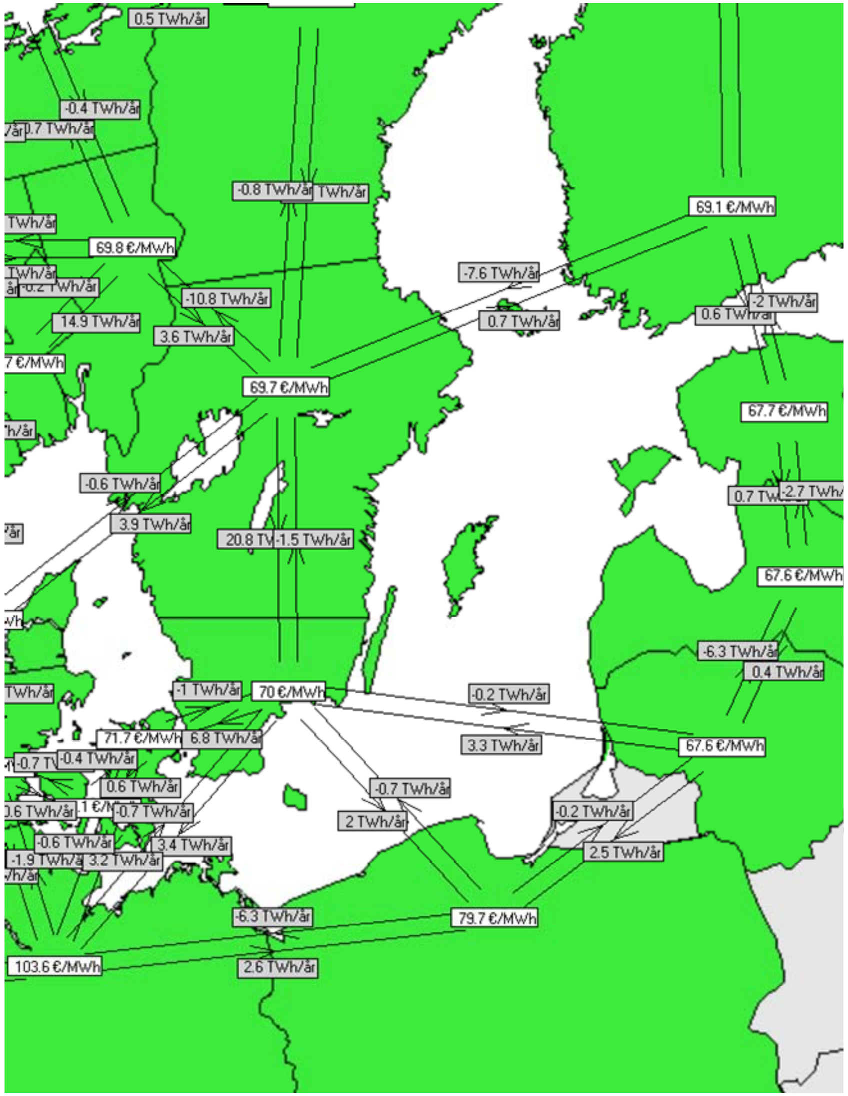

Annual Congestion Hours in Baltic Region, NF2025
Congestion [h/a]
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
No interconnection
No interconnection
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Bottlenecks to Pos. Direc. [h/a] in average inflow year
Bottlenecks to Neg. Direc. [h/a] in average inflow year

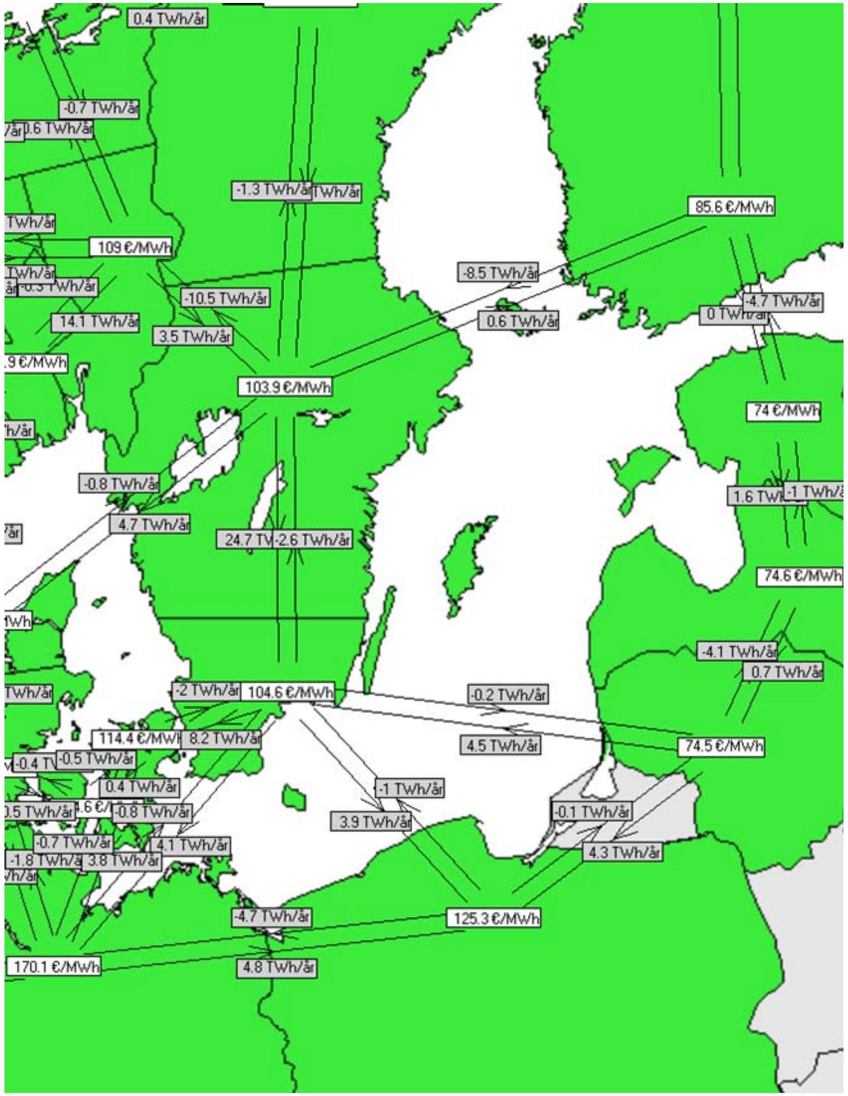

Power Exchange in Baltic Region, NF2025
Power Exchange [GWh/a]
10 000
9 000
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
-1 000
-2 000
-3 000
-4 000
-5 000
-6 000
-7 000
-8 000
-9 000
-10 000
No interconnection
No interconnection
Finland -> Estonia
Estonia -> Latvia
Latvia -> Lithuania
Lithuania -> Poland
Sweden -> Baltics
Flow to Pos. Direc. [GWh/a] in average inlow year
Flow to Neg. Direc. [GWh/a] in average inlow year


Average Annual Area
Marginal Costs NF2025
70.4 €/MWh
70.3 €/MWh
70.1 €/MWh
70.2 €/MWh
70.4 €/MWh
70.3 €/MWh
70.3 €/MWh
70 €/MWh
70.2 €/MWh
70.1 €/MWh
70.4 €/MWh
46.5 €/MWh
70.1 €/MWh
46.5 €/MWh
76.8 €/MWh
70.9 €/MWh
75.8 €/MWh
45.9 €/MWh
76.9 €/MWh
76.9 €/MWh
104.2 €/MWh
104 €/MWh
83.9 €/MWh

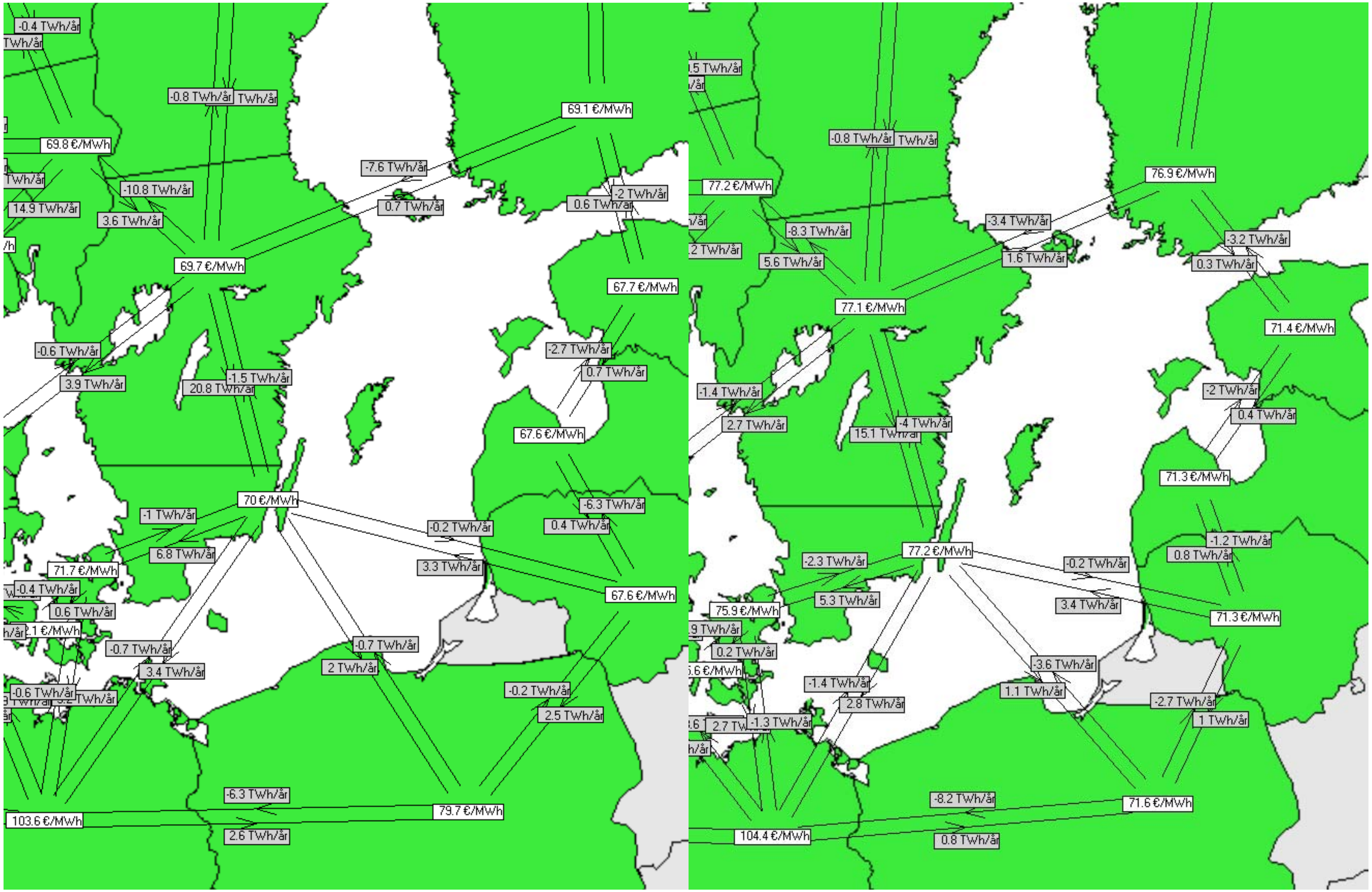
Appendix C: Area marginal costs and power exchange of sensitivity cases

Reference case is on the left and sensitivity case on the right.

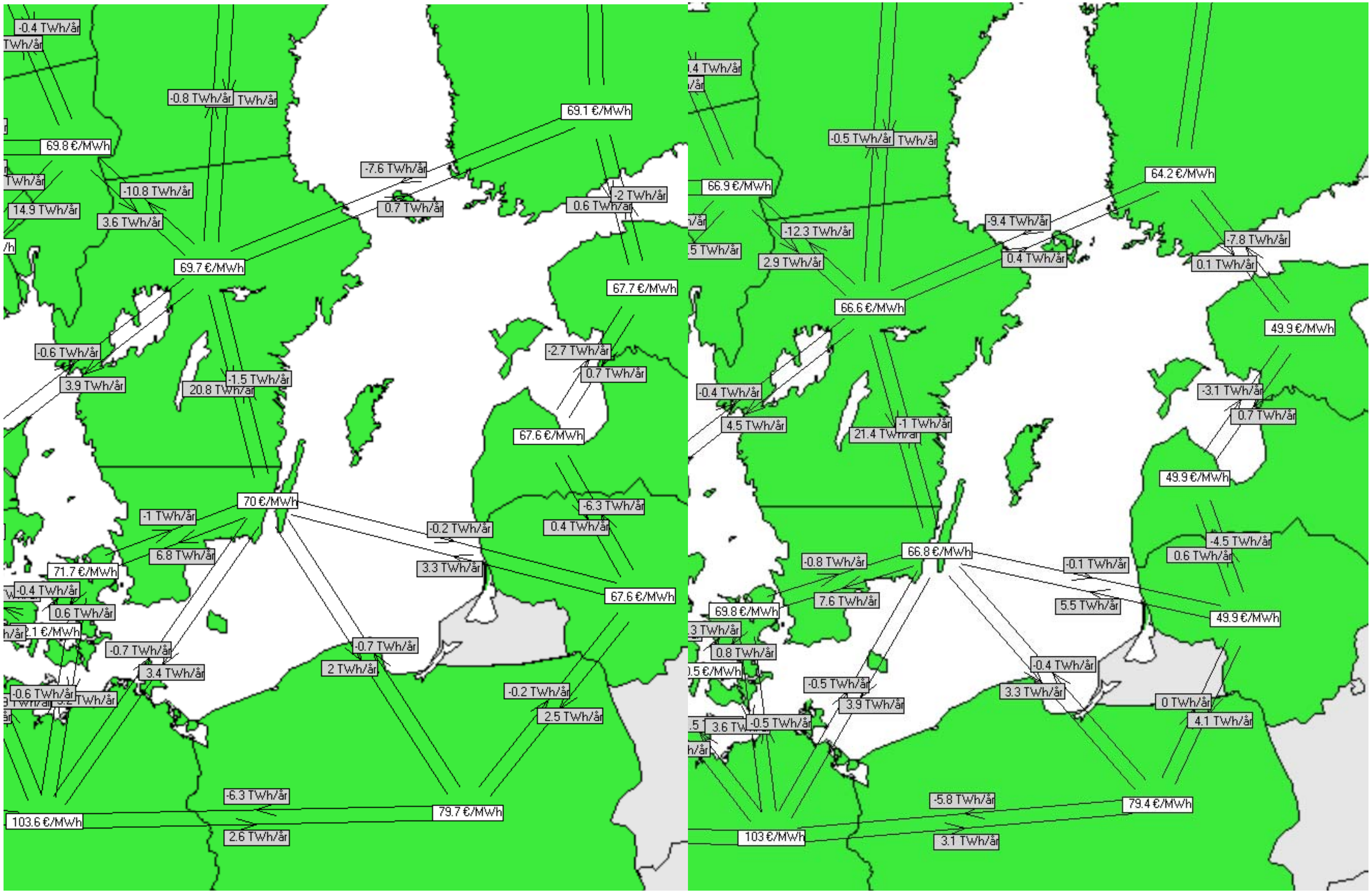




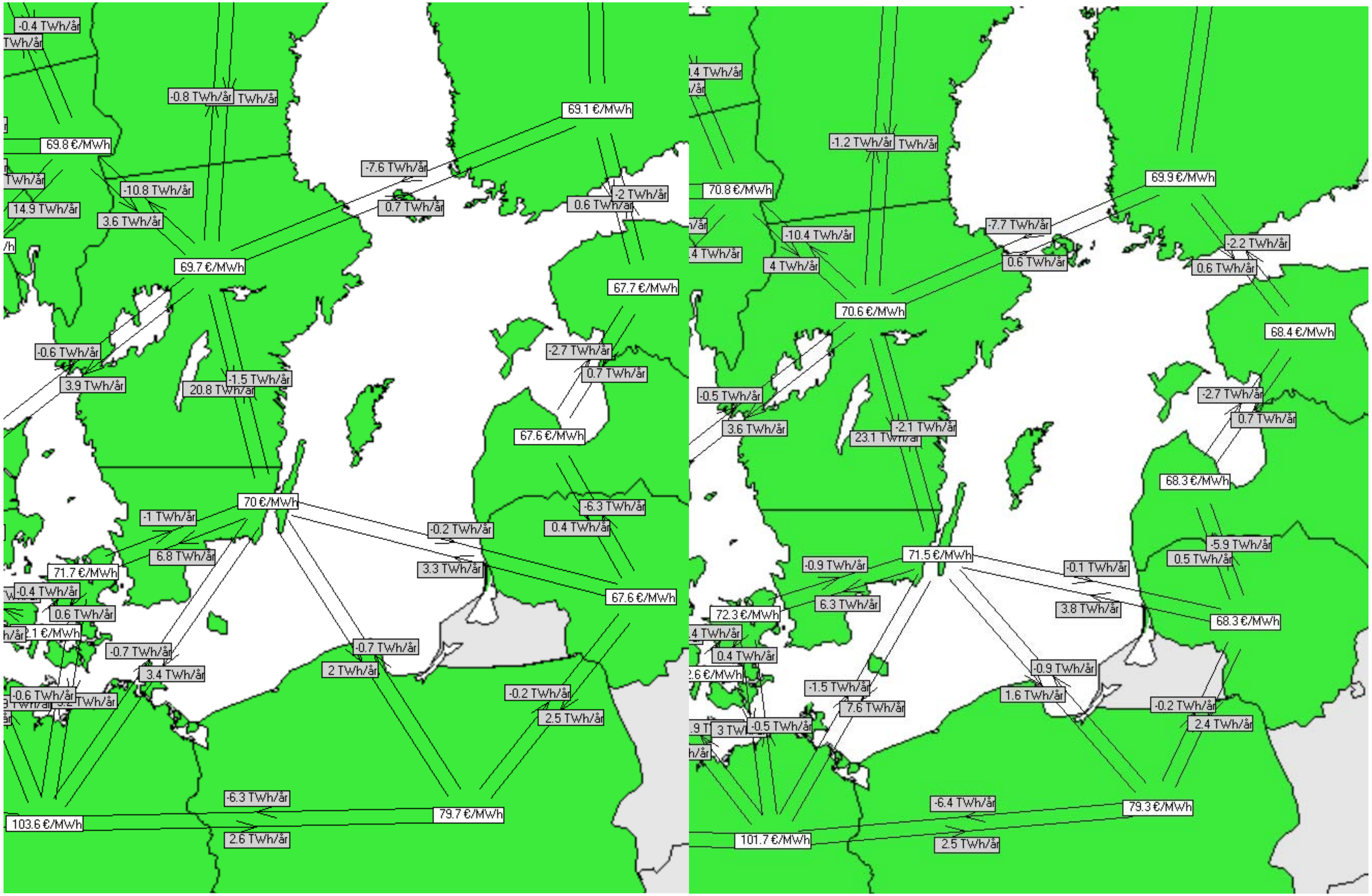
High fuel price


-0.4 TWh/år
-0.8 TWh/år
69.1 €/MWh
69.8 €/MWh
-7.6 TWh/år
-10.8 TWh/år
0.7 TWh/år
-2 TWh/år
14.9 TWh/år
3.6 TWh/år
0.6 TWh/år
69.7 €/MWh
67.7 €/MWh
-0.6 TWh/år
-2.7 TWh/år
3.9 TWh/år
-1.5 TWh/år
0.7 TWh/år
20.8 TWh/år
67.6 €/MWh
70 €/MWh
-6.3 TWh/år
-1 TWh/år
-0.2 TWh/år
0.4 TWh/år
6.8 TWh/år
71.7 €/MWh
3.3 TWh/år
-0.4 TWh/år
67.6 €/MWh
0.6 TWh/år
-0.7 TWh/år
-0.7 TWh/år
2 TWh/år
3.4 TWh/år
-0.6 TWh/år
-0.2 TWh/år
2.5 TWh/år
-6.3 TWh/år
79.7 €/MWh
103.6 €/MWh
2.6 TWh/år
-0.8 TWh/år
77.2 €/MWh
76.9 €/MWh
-3.4 TWh/år
-8.3 TWh/år
1.6 TWh/år
-3.2 TWh/år
5.6 TWh/år
0.3 TWh/år
77.1 €/MWh
71.4 €/MWh
-1.4 TWh/år
-2 TWh/år
0.4 TWh/år
2.7 TWh/år
-4 TWh/år
15.1 TWh/år
71.3 €/MWh
-1.2 TWh/år
77.2 €/MWh
0.8 TWh/år
-2.3 TWh/år
-0.2 TWh/år
5.3 TWh/år
3.4 TWh/år
75.9 €/MWh
71.3 €/MWh
0.2 TWh/år
-3.6 TWh/år
-1.4 TWh/år
1.1 TWh/år
2.8 TWh/år
-2.7 TWh/år
-1.3 TWh/år
1 TWh/år
-8.2 TWh/år
71.6 €/MWh
104.4 €/MWh
0.8 TWh/år

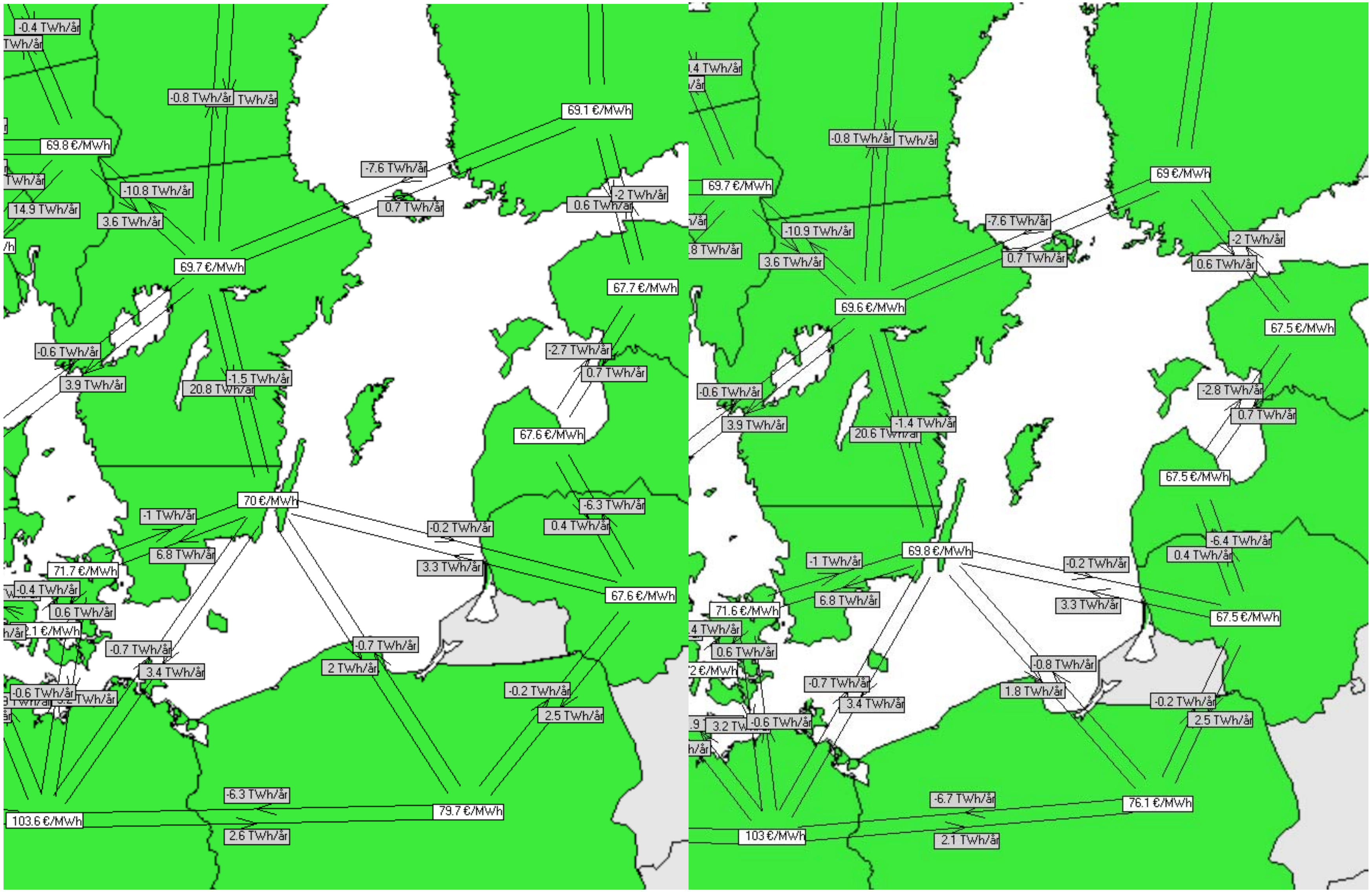
Low nuclear



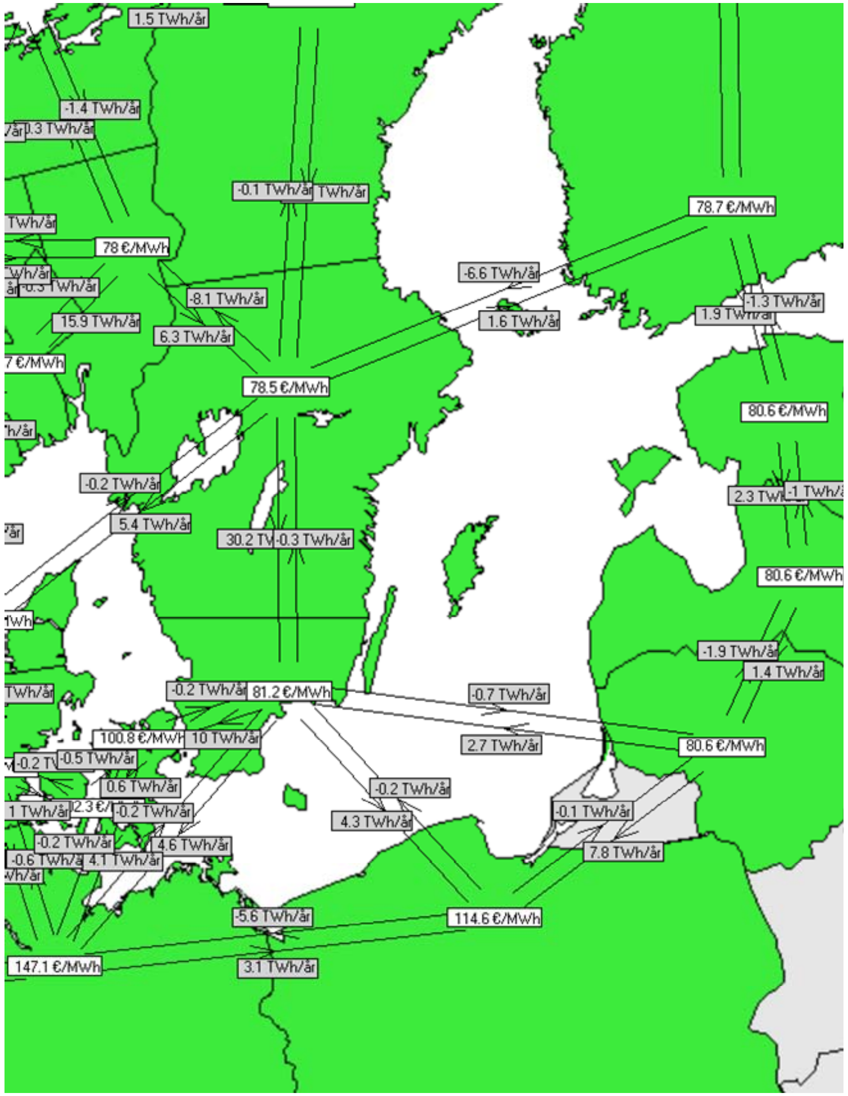
Low Russian import price

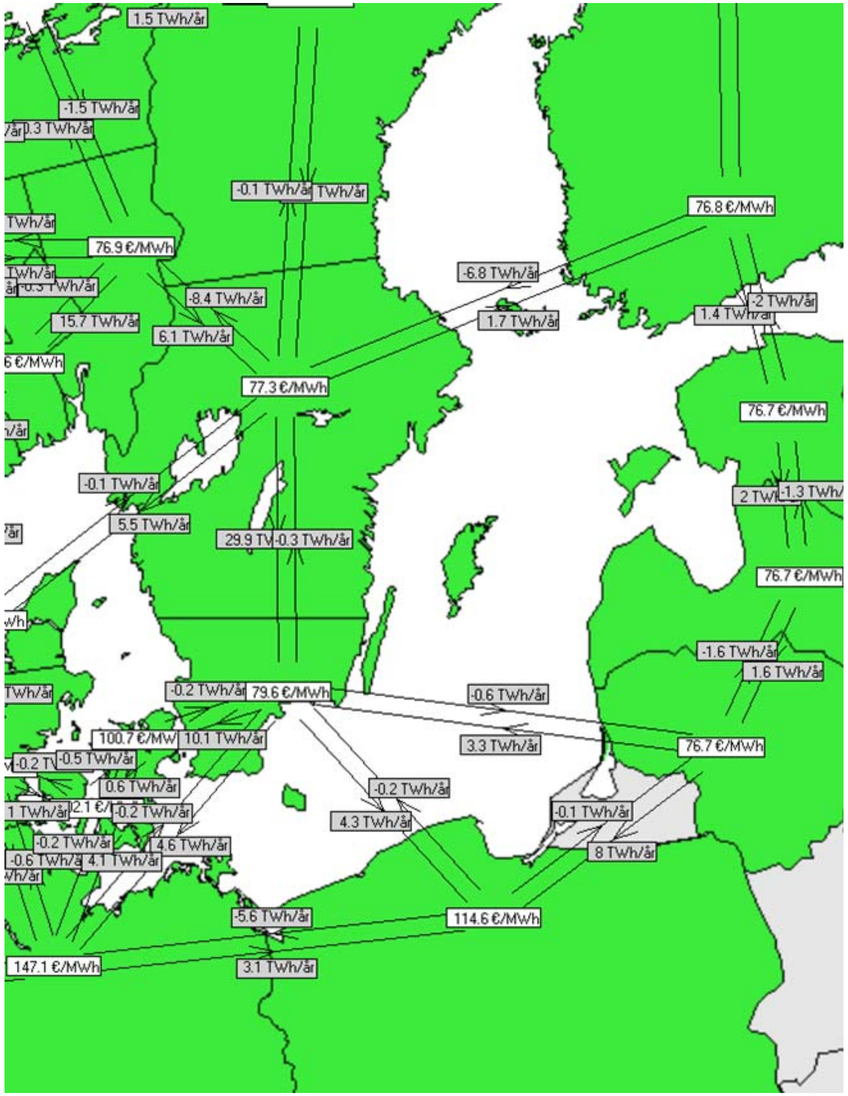

-0.4 TWh/år
-0.8 TWh/år
69.1 €/MWh
69.8 €/MWh
-7.6 TWh/år
-10.8 TWh/år
-2 TWh/år
0.7 TWh/år
0.6 TWh/år
14.9 TWh/år
3.6 TWh/år
69.7 €/MWh
67.7 €/MWh
-0.6 TWh/år
-2.7 TWh/år
0.7 TWh/år
3.9 TWh/år
-1.5 TWh/år
20.8 TWh/år
67.6 €/MWh
70 €/MWh
-6.3 TWh/år
-1 TWh/år
-0.2 TWh/år
0.4 TWh/år
6.8 TWh/år
71.7 €/MWh
3.3 TWh/år
-0.4 TWh/år
67.6 €/MWh
0.6 TWh/år
-0.7 TWh/år
-0.7 TWh/år
3.4 TWh/år
2 TWh/år
-0.2 TWh/år
-0.6 TWh/år
2.5 TWh/år
-6.3 TWh/år
79.7 €/MWh
103.6 €/MWh
2.6 TWh/år
-1.2 TWh/år
69.9 €/MWh
70.8 €/MWh
-7.7 TWh/år
-10.4 TWh/år
-2.2 TWh/år
4 TWh/år
0.6 TWh/år
0.6 TWh/år
70.6 €/MWh
68.4 €/MWh
-0.5 TWh/år
-2.7 TWh/år
0.7 TWh/år
3.6 TWh/år
-2.1 TWh/år
23.1 TWh/år
68.3 €/MWh
-5.9 TWh/år
71.5 €/MWh
-0.9 TWh/år
-0.1 TWh/år
0.5 TWh/år
6.3 TWh/år
3.8 TWh/år
72.3 €/MWh
68.3 €/MWh
0.4 TWh/år
-1.5 TWh/år
-0.9 TWh/år
7.6 TWh/år
1.6 TWh/år
-0.2 TWh/år
-0.5 TWh/år
2.4 TWh/år
-6.4 TWh/år
79.3 €/MWh
101.7 €/MWh
2.5 TWh/år

SWE-GER link



Ukrainian import

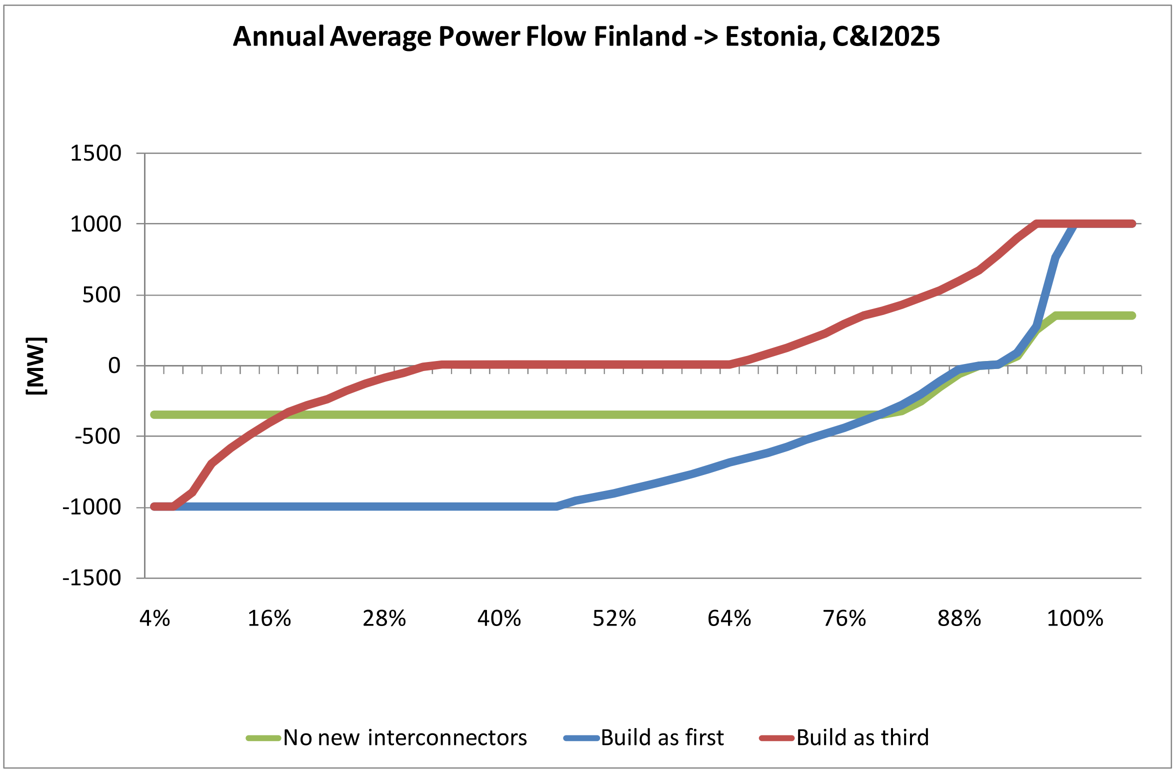


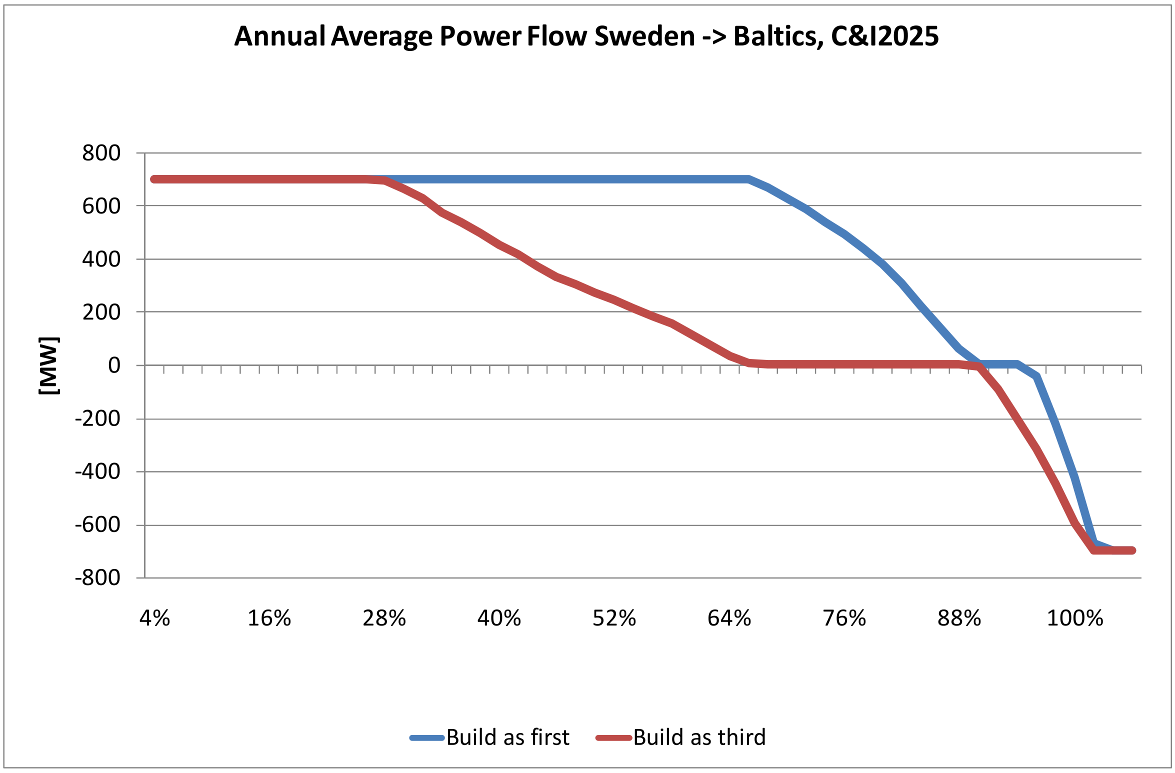


Low RES price

Appendix D: Power flows of C&I2025 scenario and energy balance of Low nuclear case

The next two Figures present the power flow duration of two studied interconnections in case of Climate&integration2025 scenario.





The next two Figures presents the detailed energy balances for the sensitivity case "Low Nuclear".