# Regional Investment Plan 2015
# Baltic Sea region

## - Final version after public consultation

30 October 2015

## Contents





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# 1 EXECUTIVE SUMMARY

## 1.1 Regional Investment Plans as foundation for the TYNDP 2016

The TYNDP for Electricity is the most comprehensive and up-to-date planning reference for the pan-European transmission electricity network. It presents and assesses all relevant pan-European projects at a specific time horizon as defined by a set of scenarios. The TYNDP is a biennial report published every even year by ENTSO-E and acts as an essential basis to derive the next Projects of Common Interest (PCI) list, in line with the Regulation (EU) No. 347/2013 ("the Energy Infrastructure Regulation").

ENTSO-E is structured into six regional groups for grid planning and other system development tasks. The countries belonging to each regional group are shown in Figure 1-1.

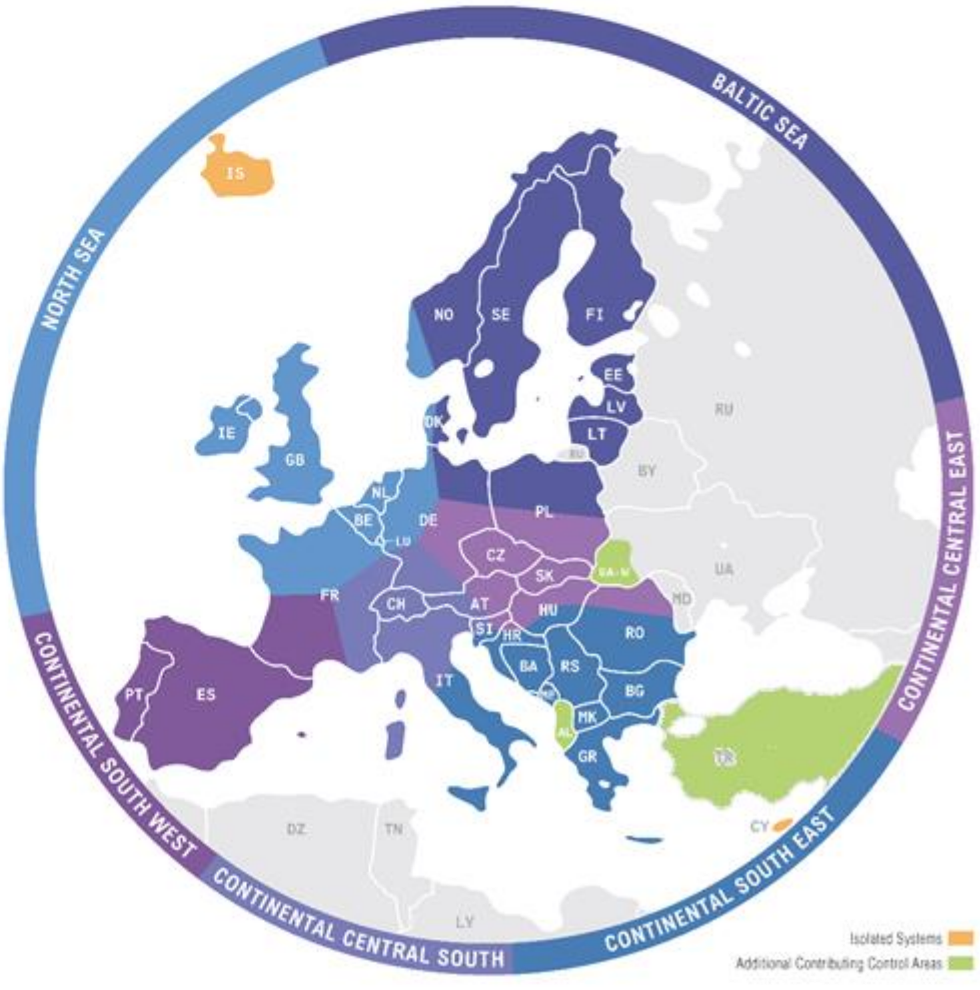


Figure 1-1 ENTSO-E System Development Regions

The TYNDP 2016 and the six Regional Investment Plans associated are supported by regional and pan-European analyses and take into account feedback received from institutions and stakeholder associations. The work of TYNDP 2016 has been split in two key phases:

- The first phase (summer 2014 to summer 2015) is devoted to common planning studies and results in the six Regional Investment Plans and the identification of a list of TYNDP2016 project candidates. During this phase also a set of TYNDP scenarios are developed.
- The second phase (summer 2015 to end 2016) will be dedicated to coordinated project assessments using the Cost Benefit Analysis Methodology (CBA) and based on common 2020/2030 scenarios. The results will be published in the TYNDP2016 report.

The common planning studies as basis of the Regional Investment Plans report are built on past TYNDP, on recent national plans, and follow a consolidated European network planning approach. It is worth noting that this is an intense and continuous work, where during the finalization of one TYNDP, the development of the next is already being initiated.

These common planning studies aim to identify the grid bottlenecks and potential investment solutions of pan-European significance for a 2030 time-horizon, in a robust, unified and consistent manner based on best available joint TSO expertise. Specifically, this report identifies cross-border and internal projects of regional and/or European significance, which allow the main European energy targets to be met with particular regard to the strengthening of the Internal Energy Market (IEM), the integration of Renewable Energy Sources (RES) and addressing security of supply (SoS) issues.

Proposed cross-border interconnections will also build on the reasonable needs of different system users, integrate long-term commitments from investors, and identify investment gaps.

The European Council has recently (October 2014 and March 2015) sent a strong signal that grid infrastructure development is an essential component of Europe’s Energy Union goals, by confirming the need of an interconnection ratio of at least 10% of the installed generation capacity in every Member State by 2020. In addition, the Council also endorsed the objective of reaching a 15% level by 2030 "while taking into account the costs aspects and the potential of commercial exchanges", aiming at strengthening security of supply and facilitating cross-border trade and mandated the EC to report on their implementation. According to the Council, this is one of the pre-requisites to accomplish an effective internal market for electricity.

This panorama is one of the challenges for ENTSOE in order to establish the most efficient and collaborative way to reach all defined targets of a working Internal Energy Market and a sustainable and secure electricity system for all European consumers.

## 1.2 Key messages of the region

There are several drivers for grid development within the Baltic Sea region. Some relate to the current trends in the European energy markets and some are due to specific characteristics of the region.

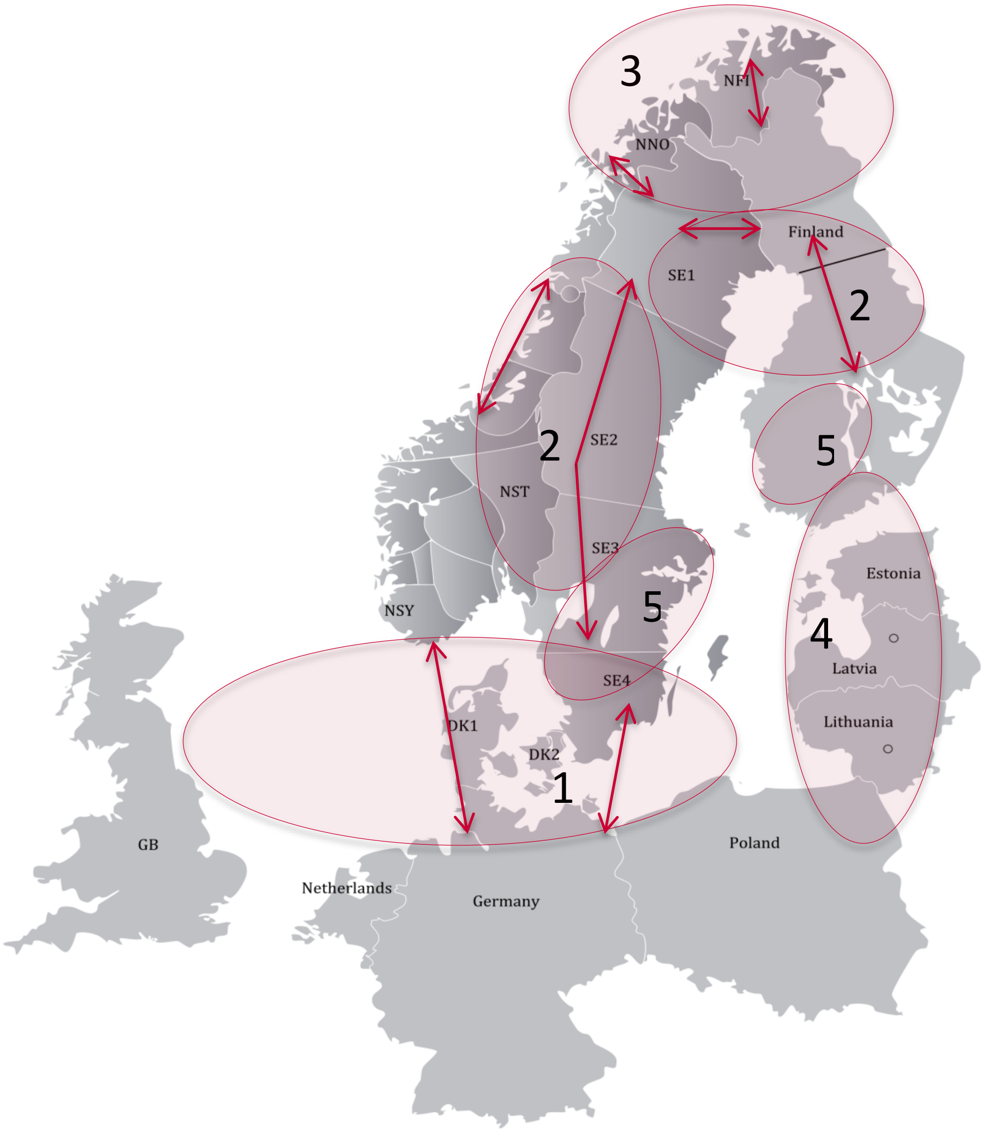


**Figure 1-2 Focus areas for grid development in the Baltic Sea Region.**

1. **New interconnectors**
   The Nordic part of the Baltic Sea region is likely to still have an annual energy surplus by 2030, even if some nuclear is decommissioned, which would make it beneficial to strengthen the capacity between the Nordics, Baltics and continental Europe. Additionally, for daily regulation purposes it is beneficial to connect the Nordic hydro based system to the thermally based continental and wind based Danish system, especially when large amounts of renewables are connected to the continental system.

2. **North-South flows**
   Depending on the location of new renewable energy and new interconnectors from the Nordics to the continent, there may be a need to increase the interconnection capacities in Sweden, Norway

and Finland in the north-south direction. Additional interconnectors between the Nordics and the continent also trigger higher internal north-south flows in the Nordics.

3. **Arctic consumptions**
Energy consumption in the arctic part of the region may increase, leading to a need for grid reinforcements to ensure security of supply in the area.

4. **Baltic integration**
To further integrate the Baltic States into the European market, enhance energy security, and decrease dependency on non ENTSO-E countries, the Baltic needs to be further interconnected to the Nordic and continental systems.

5. **Nuclear and thermal decommissioning**

A substantial proportion of Swedish and Finnish nuclear plants are expected to be decommissioned in the 2030 horizon. This would lead to an increased risk surrounding system adequacy.

## 1.3 New project candidates and main findings

The project candidates presented in TYNDP 2014 is the backbone of the cross border grid development[1] in the region until 2030. On top of this, the common planning studies were conducted to identify additional potential investment needs. These were carried out in a pan-European coordinated manner to ascertain the additional investments that seem beneficial in a scenario with a large amount of renewables. For this, Vision 4 from TYNPD 2014 was used. In addition, regional groups analysed scenarios relevant to the respective region. In the Baltic Sea region, analyses were performed using the regional bottom up scenario named *Baltic Sea Green Vision*. The main findings from these studies were the following:

- **The RegIP2015 confirms previous plan.** When the Baltic Sea green vision was analysed, no additional project candidates compared to RegIP2014 were identified when only the socio-economic welfare is considered. These results show that the project candidates from TYNDP 2014 are sufficient in a scenario with a Nordic surplus that is in line with the expectations of the regional TSOs
- **High RES trigger additional investments.** In the scenario Vision 4 from TYNDP 2014, with very high production from renewable energy sources (RES) located in the Nordics, the project candidates are not sufficient if only social economic welfare is considered. In TYNDP 2014 Vision 4 the Nordics would have a very large surplus, which would trigger a large price difference on the boundary between the Nordics and the continent. Market studies showed several potential borders at this boundary. The new project candidates, presented at the end of the common planning studies, are shown in the table below.

[1] There is also a large amount of national projects in the region with various drivers such as removing internal bottlenecks, enhancing security of supply, RES integration etc. These are found in the respective national grid development plan of each TSO

**Table 1-1. Additional projects candidates identified in the common planning studies**

| Border | Current capacity [MW] | Additional in TYNDP 2014 [MW] | Additional in RegIP2015 [MW] | Total evaluated capacity2030 [MW] |
|---|---|---|---|---|
| **SE-DE** | 600 (today) | 700 changed from 600 | 700 | 2000 |
| **DKe-PL** | 0 | 600 (in RegIP2014 only) | 600 | 600 |
| **DKe-DE** | 600 | 1000 | 600 | 2200 |

The common planning studies also found that projects from Norway to Denmark[2] and from Sweden to Poland showed potential from a socio-economic welfare point of view. These projects were however not nominated to TYNDP 2016. The reason why these projects were not nominated is that there are already several interconnectors between southern Norway and Southern Sweden to the continent and further studies are needed to verify the feasibility of additional interconnections. In the map below all re-nominated project candidates from TYNDP 2014 and new project candidates from the common planning studies from the Baltic Sea region are displayed. All of these projects will be assessed in TYNDP 2016. Please note that the project candidates SE3-FI and SE3-DKw on the map are nominated to TYNPD 2016 as reinvestments aiming to maintain or only slightly increase the current capacity.

[2] The Danish TSO Energinet.dk has voluntarily assessed this potential project by grid studies though no nomination for TYNDP-2016

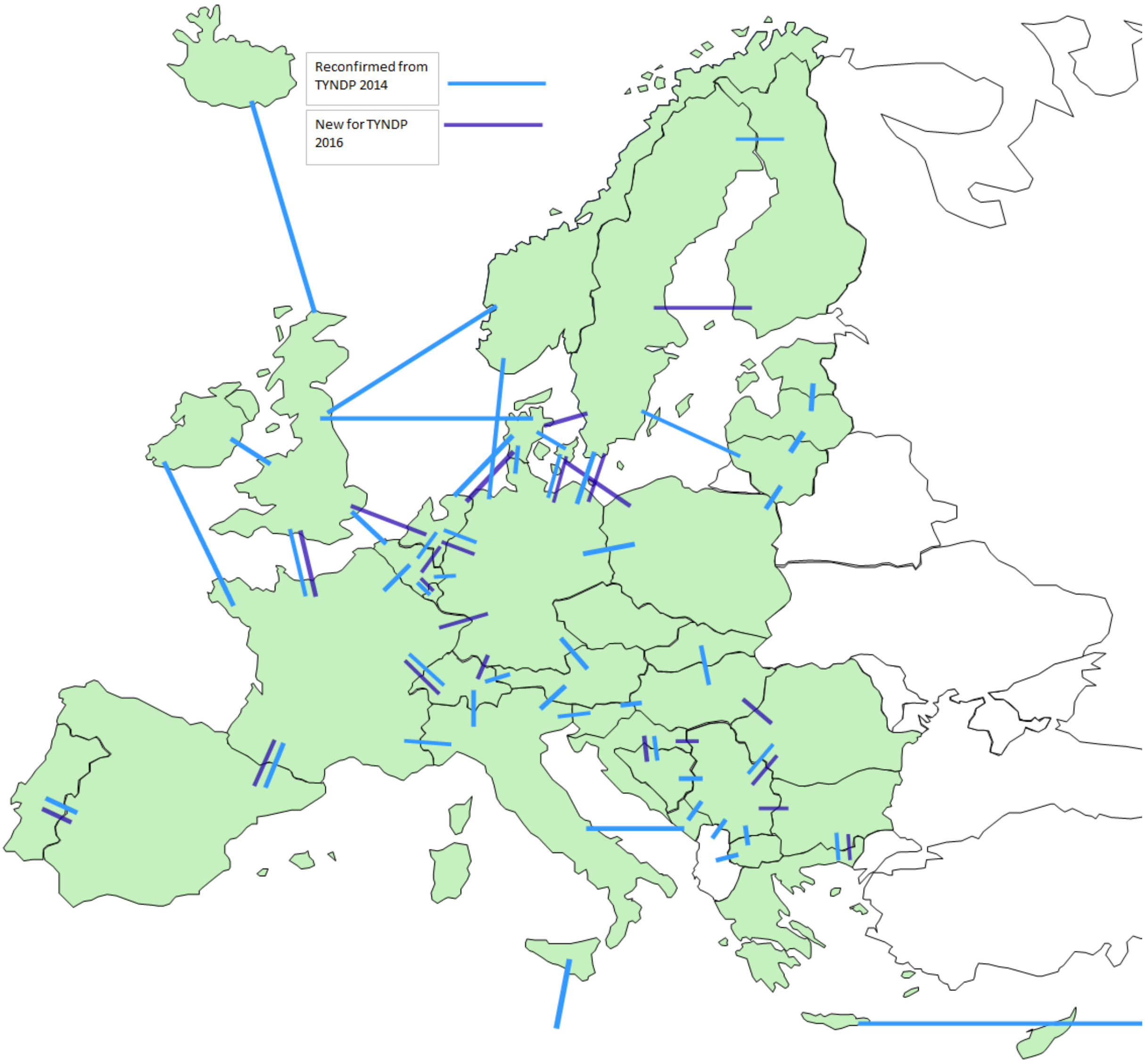


**Figure 1-3 - This map shows all cross-border projects to be analysed during TYNDP 2016. The map displays the projects of pan-European significance**

In addition to Vision 4 from TYNPD 2014 and Baltic Sea green vision, two sensitivity analyses based on the Baltic Sea green vision were performed. A scenario with very rapid nuclear decommissioning was studied, which resulted in high prices, especially in Finland. Some additional projects could be beneficial in such a scenario; however, no new project candidates are presented for CBA assessment in TYNDP 2016 based on this sensitivity. Also a scenario with a shortage of natural gas deliveries was analysed. This resulted in higher overall price level in the region, especially in Lithuania and Latvia; however, no new project candidate showed significant socio-economic benefits in this sensitivity.

# 2 INTRODUCTION

## 2.1 General and legal requirements

The TYNDP 2016 package, developed over the course of two years, will be composed of the following documents:

- The **TYNDP report** provides a helicopter view on the grid development in Europe, it shows where progress is made and where support is still needed, and it provides a standardized assessment of all projects of pan-European significance.
- The **six Regional Investment Plans** analyse the power system development from a regional perspective, based on common guidelines, and identify investment needs linked with a set of proposed projects.
- The **Scenario Development Report** sketches a set of possible futures, each with their own particular challenges, which the proposed TYNDP projects must address. All TYNDP projects are assessed in perspective of these scenarios.
- The **Scenario Outlook & Adequacy Forecast (SO&AF)** is delivered every year and assesses the adequacy of generation and demand in the ENTSOE interconnected power system on mid- and long-term time horizons.
- The **Cost Benefit Analysis Methodology (CBA)** as developed by ENTSO-E and adopted by the EC, allows the assessment of infrastructure projects in an objective, transparent and economically sound manner against a series of indicators which range from market integration, security of supply, integration of renewable energy sources (RES-E) to environmental impact.

The Regional Investment Plans are published in summer 2015 and focus on regional planning studies and the identification of the pan-European project candidates. It provides key information to understand the need for new projects, which are listed and published for public consultation until mid-September.

The Regional Investment Plans are complemented by a monitoring update of the TYNDP 2014 investments, providing insight in the changed status of these items and possible reasons.

The TYNDP report will be delivered by end of 2016 and will concentrate on individual project assessments based on common scenarios, data and CBA methodology.



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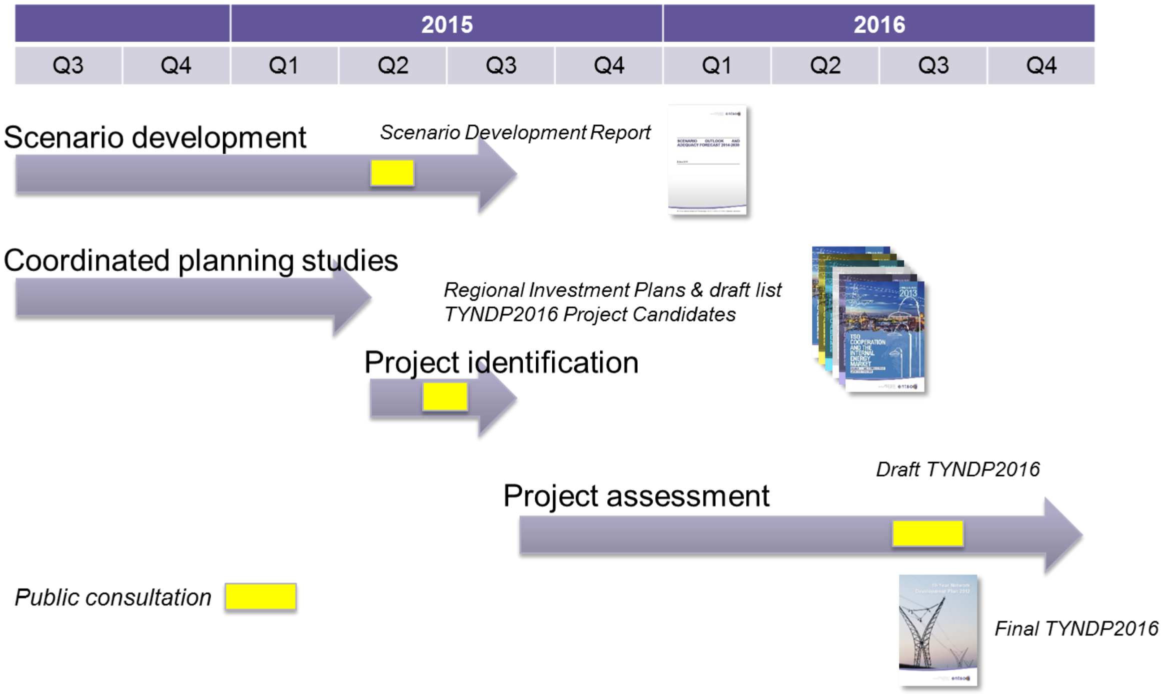


**Figure 2-1 Overview of a two-year TYNDP process**

The present publication complies with Regulation (EC) 714/2009 Article 12, where it is requested that TSOs shall establish regional cooperations within ENTSO-E and shall publish a regional investment plan every two years. TSOs may take investment decisions based on that regional investment plan. ENTSO-E shall provide a Community-wide ten-year network development plan which is built on national plans and reasonable needs of all system users, and identifies investment gaps.

As of 2016, the TYNDP package must also comply with Regulation (EU) 347/2013 ("the Energy Infrastructure Regulation"). This regulation organises a new European governance to foster transmission grid development. It establishes Projects of Common Interest (PCIs), foresees various tools (financial, permitting) to support the realisation of these PCIs, and makes the TYNDP the sole basis for identifying and assessing the PCIs according to a Cost-Benefit-Analysis (CBA) methodology. The ENTSO-E CBA methodology has been developed since 2012, based on stakeholder consultation, and the opinions of ACER, Member States and EC; it has been adopted by the EC in February 2015. Work continues to further improve the methodology

This Regional Investment Plan as such is to provide information on future European transmission needs and projects to a wide range of audiences:

- Agency for the Cooperation of Energy Regulators (ACER) who has a crucial role in coordinating regulatory views on national plans, providing an opinion on the TYNDP itself and its coherence with national plans, and giving an opinion on the EC's draft list of PCI projects;
- European institutions (EC, Parliament, Council) who have acknowledged infrastructure targets as a crucial part of pan-European energy goals, to give insight in how various targets influence and complement each other;
- Energy industry, covering network asset owners (within ENTSO-E perimeter and the periphery) and system users (generators, demand facilities, and energy service companies);

- National regulatory authorities and ministries, to place national energy matters in an overall European common context;
- Organizations having a key function to disseminate energy related information (sector organizations, NGOs, press) for who this plan serves as a “communication tool-kit”;
- The general public, to understand what drives infrastructure investments in the context of new energy goals (RES, market integration).

## 2.2 The scope of the report

The scope and focus of the present Regional Investment Plans has evolved as compared to the past editions of 2014. This Regional Investment Plan focuses on a set of common planning studies performed across ENTSO-E’s regions with particular attention for the context of each individual region.

The Regional Investment Plan presents the methodologies used for these studies, relevant results and assumptions, and the resulting list of the project candidates as nominated by project promoters.

At present no detailed CBA analysis is provided in the Regional Investment Plan. This will be a key element of further studies leading to the final TYNDP2016 report to be released next year. This regional report takes the opportunity also to inform readers on regional context, studies and projects.

These studies re-confirm the main findings past TYNDP studies as well as others in terms of main corridors, general scenarios, and the key conclusion that an energy shift requires targeted future-proof infrastructure.

## 2.3 General methodology

This Regional Investment Plan 2015 builds on the conclusions of a Common Planning Study carried out jointly across the six regions of ENTSO-E’s System Development Committee. The aim of this joint study is to identify investment needs triggered by market integration, security of supply, RES integration and interconnection targets, in a coordinated pan-European manner building on the expertise of all TSOs. These investment needs are translated to new project candidates where possible, and give in most cases a re-confirmation of past TYNDP2014 projects. This chapter explains the overall planning process of how project candidates have been identified by market studies, network studies and regional knowledge. More details about this process as well as regional intermediate steps can be found in Appendix 7.1 and 7.2.



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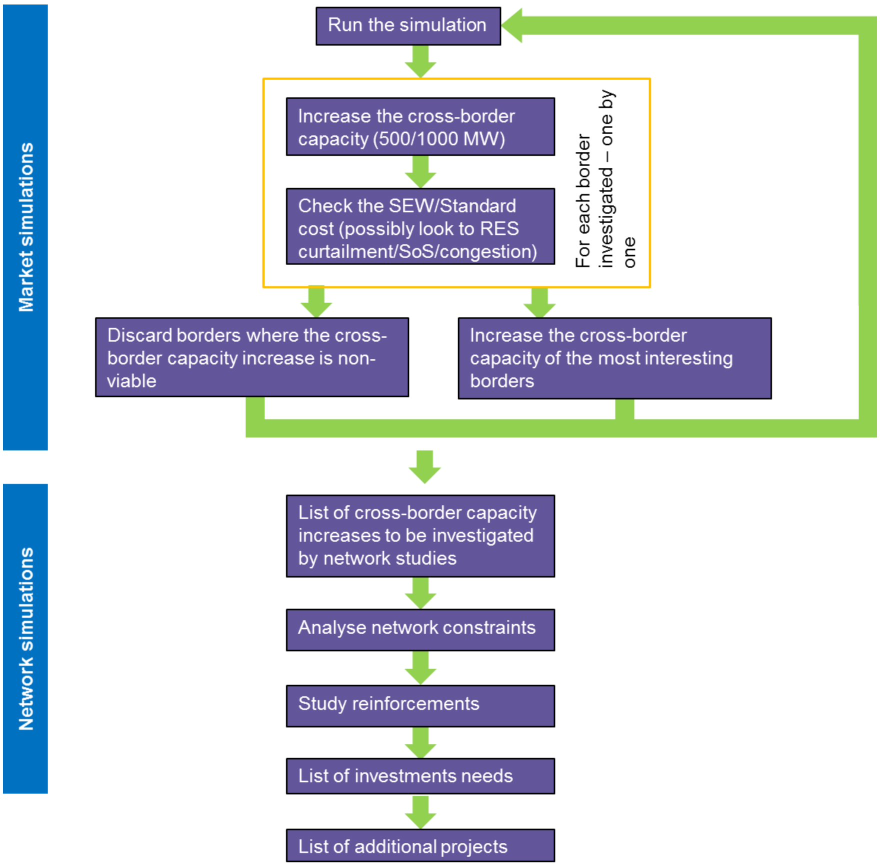


**Figure 2-2 Common Planning Study workflow**

### Market Studies

All regions have jointly investigated all borders in order to identify the most beneficial ones based on a criteria of SEW/cost-ratio. The SEW indicator represents the socioeconomic welfare of a full-year market simulation. The cost indicator is an estimation of the capex of a potential cross-border capacity increase, including necessary internal reinforcements. Note that both indicators for a given capacity do not represent the same level of detail as the cost and SEW indicator retrieved in a CBA assessment for a specific project.

The analysis is carried out across the ENTSO-E perimeter in several iterations, each time increasing border capacities identified as being most valuable for the European system.

It is worth pointing out that this approach includes some simplifications. The most important one is that it simplifies the benefits just as SEW, without taking into account additional benefits, which are possibly more difficult to monetize than the savings in variable generation cost. Another one is the fact that the candidate projects are not yet defined by the time they are simulated. Therefore the expected GTC increase is a standard value (e.g. 1 GW) and the costs of the projects are assessed by expert view, taking into account the specificity of the area (e.g. mountain, sea). Cost of internal grid reinforcements considered as needed to get the expected GTC increase is also included in the cost of the candidate projects.

As a reference scenario the TYNDP2014 Vision 4 is taken, which represents the most challenging scenario coming from the present day situation and the most useful to identify new investment needs. Even if this scenario does not become reality by 2030, it can for the purpose of this planning study still be seen as a step between 2030 and 2050. In addition to the pan-European study iterations, regions repeated the exercise or performed a sensitivity analysis on the outcome to gain additional insight in relevant investment needs that trigger project candidates.

**Network Studies**

Following these market simulations, network studies on detailed grid models show possible bottlenecks that would not allow the result from the market studies come true. This allows to explore reinforcements, to design suitable project candidates and update market-based target capacities resulting from the initial market study iterations. Depending on the models and tools used in a region, the translation from market to network studies can be done in two ways:

1. Select and study an adequate number of representative Points In Time (PiTs), based on the flow duration curves for the each studied border. Complemented this with a second analysis of the regional grid by means of a Power Transfer Distribution Factor (PTDF) matrix which gives approximate flows.
2. Compute all 8760 hours in a year with demand and generation dispatch profiles obtained from market studies in full DC load flow calculations.

These network analyses allow to test **project candidates**, as suitable grid reinforcements to eliminate bottlenecks.

**Regional knowledge**

Market studies focus primarily on SEW/cost-ratios. Network studies identify additional (internal) capacity needs. Sensitivity studies of market simulations (e.g. an extreme condition) and in particular network studies allow to capture additional views and model interpretations based on regional experts, and in many cases complementing the findings of national development plans and/or past studies.

## 2.4 Report overview

This chapter describes how the report is built up and the content of the different chapters.

***Chapter 1 – Executive Summary***

In this section the key take-aways of the region are presented and it is explained how the development of the report fits into the TYNDP2016 process.

***Chapter 2 - Introduction***

This chapter sets out in detail the general and legal basis of the TYNDP work, the overall scope of the report and its evolutions compared to the previous regional and TYNDP plans. The reader is presented with a short summary of the planning methodology used by all ENTSO-E regions.

***Chapter 3 – Regional Context***

This chapter describes the general characteristics of the region, in the as-is situation and in anticipated evolutions up to 2030 and beyond. It gives a general overview of TSO collaboration efforts in regional planning based on pan-European methodologies and coordination.

***Chapter 4 – Regional results***

It gives a synthetic overview of the basic scenarios and assumptions used in common planning and the overall results. The results are also placed in perspective of further ahead challenges and roadmaps leading up to 2050.

***Chapter 5 – Project candidates***

This chapter gives an overview of all projects proposed by promoters in the region, labelled as either TYNDP projects or projects of regional relevance. It links these projects to investment needs identified in ENTSOE joint TSO studies, clarifies possible barriers to address these system needs, and gives the baseline for future project CBA assessments (e.g. by means of boundary reference capacities).

***Chapter 6 – Next steps***

This chapter presents a look forward on how the TYNDP work will continue in the next year, leading to a full TYDNP2016 report.

***Chapter 7 – Appendices***



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This chapter gives more insight in the used methodologies, as well conducted market and network studies.

# 3 REGIONAL CONTEXT

## 3.1 Present situation

The Baltic Sea region comprises nine countries: Sweden, Norway, Finland, Denmark, Estonia, Latvia, Lithuania, Poland and Germany. Within the region there are three separate synchronous systems: the Nordic system, the Continental system, and the Baltic power system; the last is synchronous with the IPS/UPS system (i.e. Russia).

The Nordic power system is dominated by hydropower, followed by nuclear, Combined Heat and Power (CHP), and wind power. Most of the hydropower plants are located in Norway and northern Sweden and the nuclear plants in south Sweden and Finland. During a year with normal inflow, hydropower represents approximately 50% of yearly generation in the Nordics, but the variations between wet and dry years are significant. Consumption in the Nordics is characterised by a high amount of electrical heating and energy intensive industry. The power balance in the region is positive in a normal year, but varies significantly between wet/warm and dry/cold years. Sweden and Norway have a power surplus, whereas Finland has a power deficit and also depends on imports in high load hours.

The continental part of the Baltic Sea region and the Baltic States area in total is currently dominated by thermal power except the Danish power system, which is dominated by wind and renewable energy sources (RES), but this system is small in comparison to Germany and Poland. Consumption in the area is less temperature dependent compared to Nordic countries. Denmark, Germany, Poland, Estonia and Latvia have a neutral annual power balance in an average year whereas the power exchange with neighbouring countries is relatively intensive. Lithuania is currently operating with a large energy deficit.

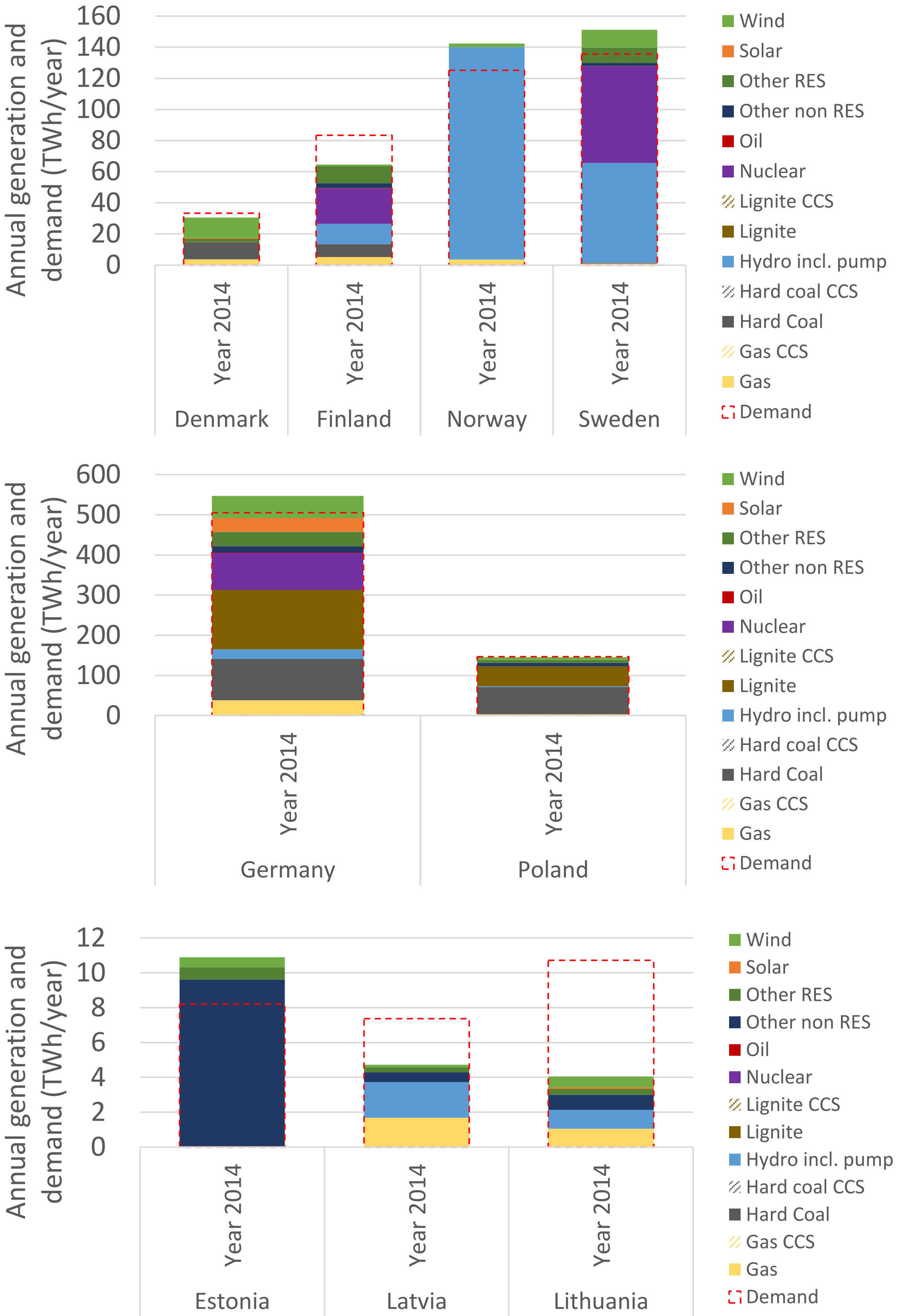


**Figure 3-1. Generation mix in the region per country**

The map in Figure 3-2 shows diverse level of Net Transfer Capacities (NTC) in the Baltic Sea Region. The NTC is the maximum total exchange capacity in the market between two adjacent price areas.

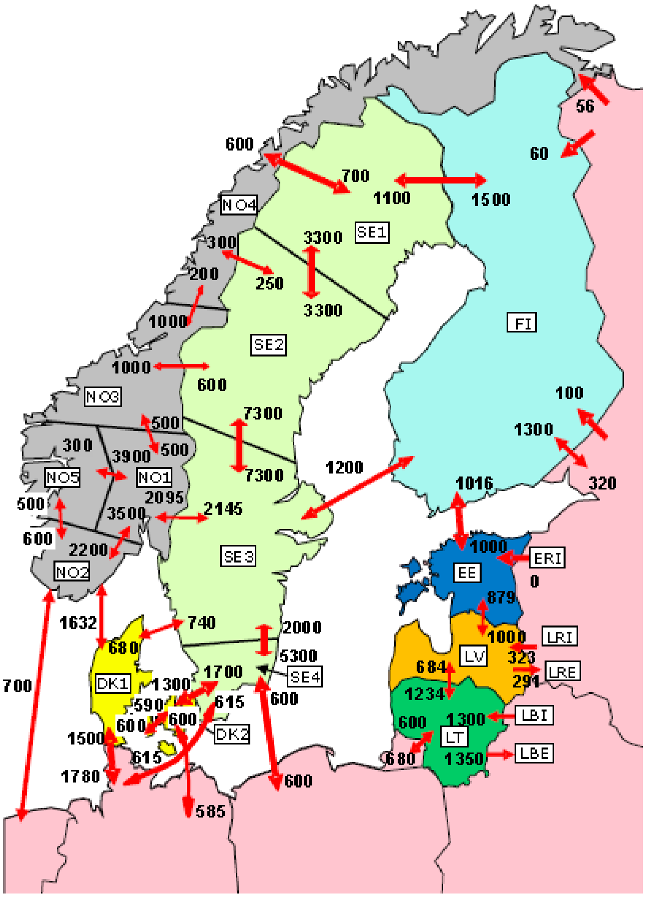


Figure 3-2 Illustration of Net Transfer Capacities in BS region (December 2014). Source: Nordpool Spot

The Nordic countries are strongly interconnected, both between themselves and to the continent. Further strengthening of the transmission capacity to the continent is expected in 2020, when two new HVDC interconnectors (in sum 2800 MW) from Norway to Germany and the UK will be commissioned.

Denmark consists of two synchronous areas: Denmark-East, which is part of the Nordic system, and Denmark-West, which is part of the continental system. Denmark serves as a transit corridor for power flows between the Nordic and the Continental areas. Denmark plans to commission two additional HVDC interconnectors before 2020. These new interconnectors are: Denmark-West-Netherland 700 MW capacity, and Denmark-East- Germany with a capacity of 400 MW (Krieger's Flak), which also connects both Danish and German offshore wind parks.

Today, the Baltic countries are interconnected to each other and to the Nordics via the Estlink HVDC cables between Estonia and Finland (1000 MW). A new HVDC interconnector between Sweden and Lithuania with capacity of 700 MW (NordBalt) is expected to be commissioned at the end of 2015. There are currently no interconnections with the continental European system; however, a DC Back-to-Back connection with capacity 500 MW between Poland and Lithuania (LitPol link) is expected to be commissioned at the end of 2015. Implementation of the second stage of LitPol link allows asynchronous operation with capacity exchange increase up to 1000 MW in 2020. The Baltic countries are currently in the same synchronous area with the Russian IPS/UPS power system and have several AC connections to Russia and Belarus. All power exchange with non ENTSO-E countries is market coupled with Lithuania. Interconnection capacities between the Baltic States are strongly dependent on non ENTSO-E countries operations, therefore there is a political motivation in the Baltic States to desynchronise with the IPS/UPS system and synchronise with the continental European system.

The typical flow pattern in the region (in a year with normal inflow) is affected by the characteristics of reservoir hydro to move generation in time almost without cost. The flow is southbound from Norway and Sweden to central Europe during daytime, when prices are high on the continent and hydropower generation is most profitable and northbound during night-time, when low continental prices make it more reasonable for reservoirs to save water. During summer, flows are more steady southbound due to low Nordic demand and high unregulated inflow to hydro plants. During wet years, exports out of the area are high, and during dry years, export is much reduced or turned into net imports. Sweden is almost constantly exporting power to Finland, which in general exports to Estonia. Finland and the Baltic countries generally import power from Russia, Belarus and Kaliningrad during low load hours, i.e. nights and weekends. During daytime, flow is usually zero due to capacity fees in Russia during the day, which makes Russian export more expensive than the market price in Finland and Baltics.

Typical situations that can occur due to grid constraints today are:

- Internal bottlenecks in Norway and Sweden can lead to price collapse or even hydro power spillage in Norway in cases of high reservoir levels and high inflows.
- Grid issues in northern Germany put limits on ATCs between Germany and Denmark and Sweden.
- Bottlenecks between southern and northern Sweden (SE2-SE3 and SE3-SE4).
- Bottlenecks between Sweden and Finland.
- Bottlenecks between Estonia-Latvia, resulting in high prices in Latvia and Lithuania.
- Dependency of non ENTSO-E countries network on internal Baltic transmission capacity.

With the planned grid and system developments up to 2020, and further 2030, most of these issues will be reduced. New interconnection capacity to the continent and UK will reduce the risk of hydro power spillage in southern Norway. Internal grid development and new power generation in several countries will reduce bottlenecks and curtailment of generation.

## 3.2 Investment drivers in the Baltic Sea region

The power system is undergoing a fundamental change, whereby conventional generation is being replaced with intermittent renewal production with different technical characteristics. These changes drive investments for various reasons in the Baltic Sea region (Figure 3-3).

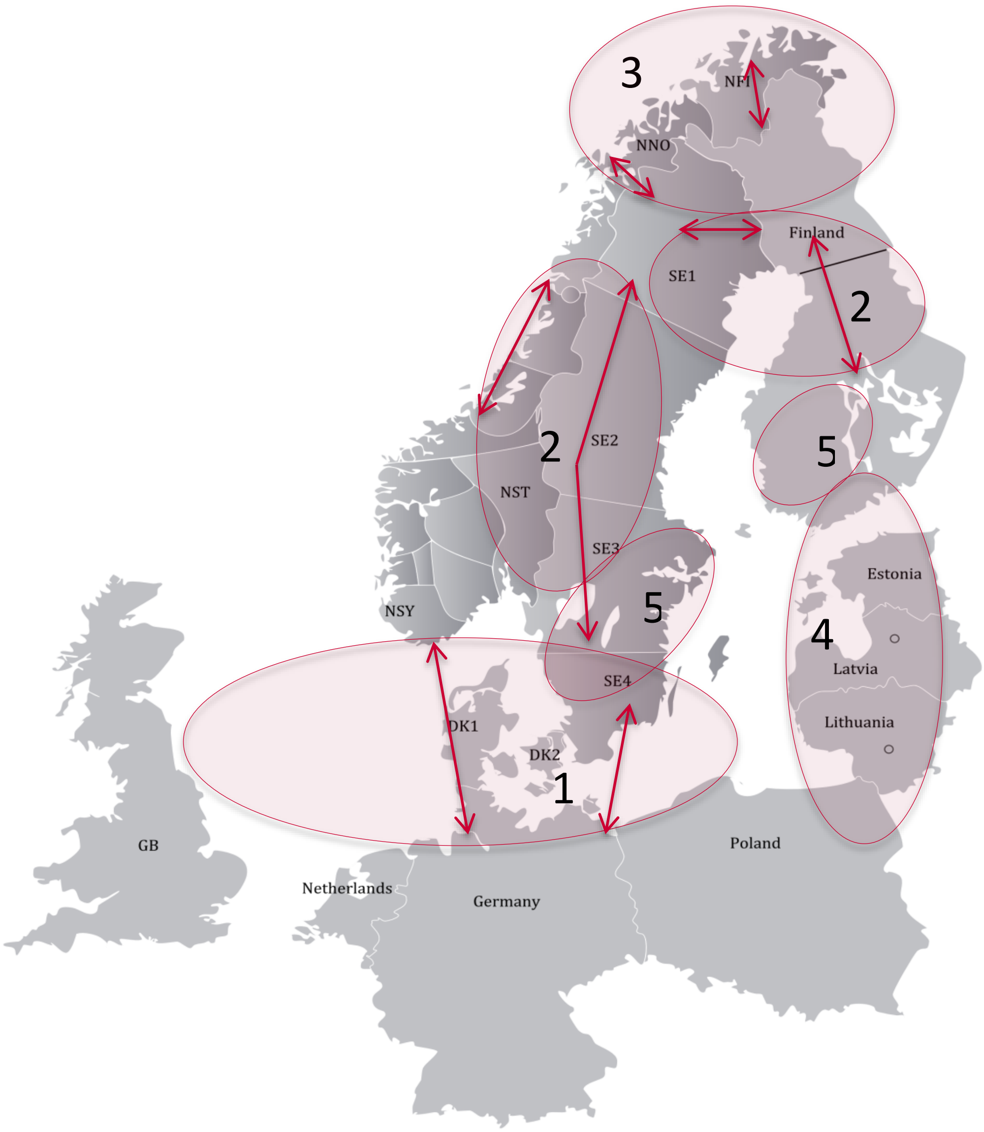


**Figure 3-3 - Focus areas for grid development in the Baltic Sea Region.**

The EU 2030 target of 27 % renewable energy requires a dedicated expansion of renewable power throughout Europe. The Baltic Sea region, with its wind, hydro and bio resources, has good prospects for taking a fair share of the investments needed. Large-scale development of renewables in the Baltic Sea region would affect the need for grid development in several ways. First, more renewable generating capacity would add to the region's power surplus and would thus increase the benefit of strengthening the interconnection between the Nordics, Baltics and the continent. (Focus area 1 in Figure 3-3). Second, more renewables could demand internal Nordic or Baltic grid reinforcements. This would depend on the location of the new renewable investments. The current trend of planning a large share of the renewable investments in the north of the Nordics could give greater cause for internal reinforcements, as the already existing north-south flows would increase. In addition, new interconnector capacity between Nordics, Baltics and the continent could also require internal reinforcements (Focus area 2) in several countries of region.

Depending on location and size, new consumption units may also trigger the need for grid investments. Especially in the far north of the Nordics, the establishment of new power intensive industries could create a need for substantial reinforcements. (Focus area 3). Industrial development in the far north is up for discussion in several sectors, such as petroleum, mining and data storage.

The need to increase security of supply drives grid development in different ways. In the Baltic Sea region, it is both about improving the operational reliability in local risk areas, e.g. larger cities, and about connecting regions with poorer system adequacy to stronger ones. One particularly important grid development driven by the need for increased energy security is to link the power system in the Baltic countries closer to the Nordic and the continental system (Focus area 4). There are several projects that aim to tighten the bond between the three systems. According to the eHighways2050 project, an increase of the capacities to and through the Baltics could be an alternative corridor from the Nordics to the European continental system.

A major uncertainty for power system development in the Baltic Sea region is the future of nuclear power in the region (Focus area 5). Several of the existing reactors in Sweden and Finland will reach end-of-life between 2025 and 2035, and it has already been announced that three nuclear reactors may be phased out before 2020. There is also considerable uncertainty regarding new build of reactors as a result of low energy prices. Nuclear power has many important features in today's system, and a phase out would probably require both new generation capacity, grid development, and system services developments. A similar situation occurs in several countries, when thermal plants are phased out as their operation is no longer profitable. Despite the expected decommissioning of nuclear and thermal power a surplus can still be expected in the 2030 perspective for the Nordic area.

On top of these drivers, there is also a great need for reinvestment in the grids of the Baltic Sea region. A large part of the transmission grids was built during the 1950s and 1960s. Reinvesting old lines and substations has already started, but the need for reinvestment will also be a longer term requirement.

# 4 REGIONAL RESULTS

## 4.1 Description of the scenarios

In the Baltic Sea region, two main scenarios were analysed during the common planning studies: TYNDP 2014 Vision 4 and a regional scenario named 'Baltic Sea Green Vision'. Analysing TYNDP 2014 Vision 4 was a common working item among all regions; the objective was to ensure common ground for the analysis between regions. TYNDP 2014 Vision 4 was the Green Revolution scenario from TYNDP 2014, constructed with top-down methodology. Baltic Sea Green Vision, instead, was a bottom-up scenario constructed from input from regional TSOs. The underlying story there, too, was an increase of renewable electricity generation, but at a less ambitious pace than in TYNDP 2014 Vision 4.

In the TYNDP 2014 Vision 4, the Baltic Sea region had a large surplus in the Nordic countries as well as Latvia, due to large increases in production of renewable electricity. In the Baltic Sea Green Vision, the amount of renewable electricity also increased substantially from levels seen today; however, the increase was smaller compared to TYNDP 2014 Vision 4, while also being more in line with the national targets and the development plans of member countries. Installed capacities and resulting generation mixes are displayed in Figure 4-1.

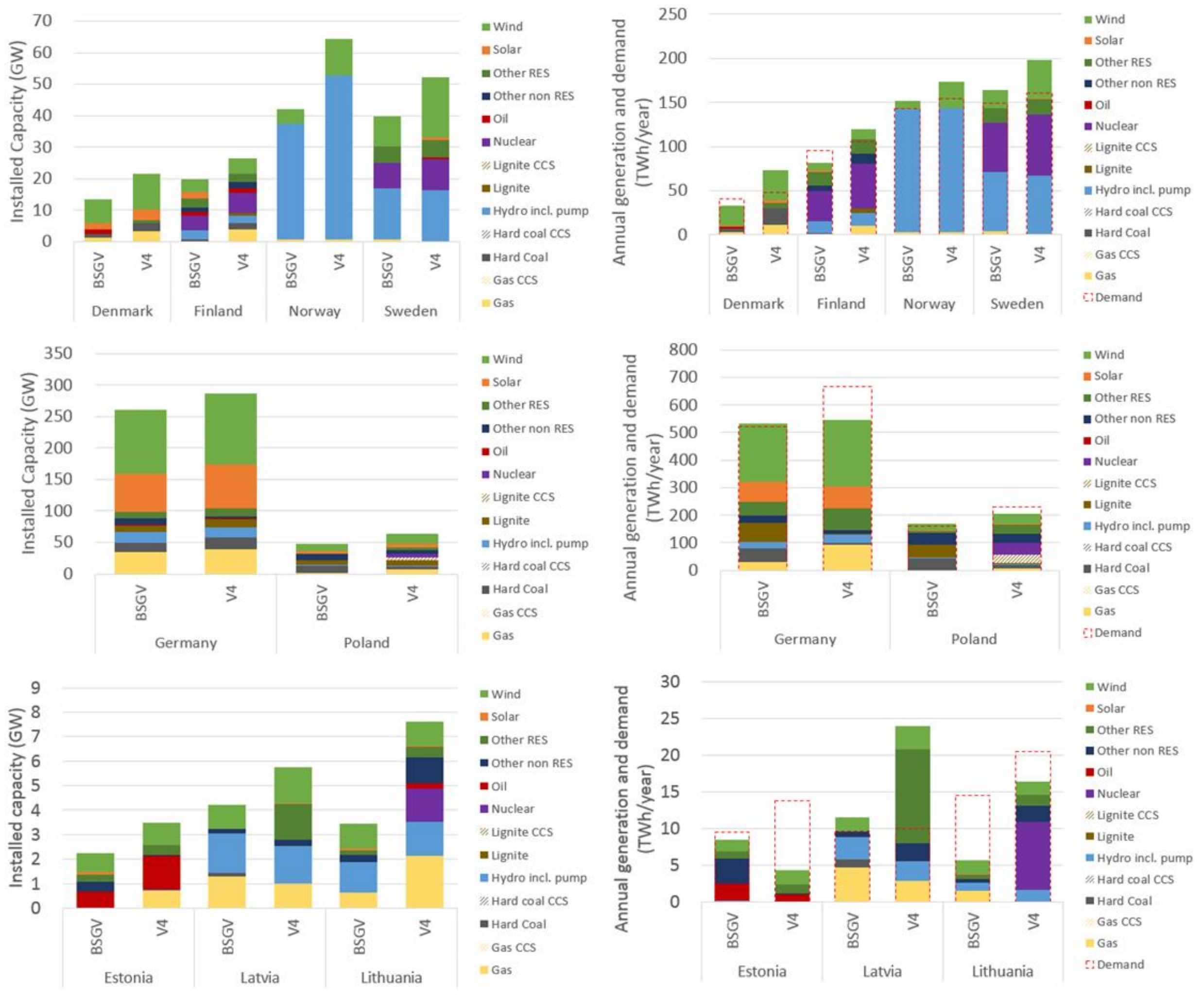


**Figure 4-1 Installed capacities and annual generation per generation type in Baltic Sea countries. Plants co-firing biofuels and fossil fuels are reported under the respective fossil fuel category, even when fuel is 100 % biofuel. Oil shale plants are reported under "oil".**

In Baltic Sea Green Vision, a CO2 price of 35 EUR/ton was used, compared to 93 EUR/ton in Vision 4. Consequently, the merit order of conventional thermal power plants differed: in Vision 4, gas was a cheaper source of base load generation than coal, while in Baltic Sea Green Vision this was the other way around due to the lower price of CO2. The price differences between the Nordics and the Continent were significantly lower in Green Vision compared to Vision 4, and therefore the calculated socioeconomic welfare increase of new interconnectors was substantially smaller in Baltic Sea Green Vision.

Table 4-1 shows an overview of fuel and CO2 prices in two scenarios. Fuel prices for Baltic Sea Green Vision are the same as in TYNDP 2016 Vision 3 (Green Transition), with the exception of the CO2 price, which is half of the CO2 price of Vision 3, reflecting national climate policies in addition to EU Emission Trading System.

**Table 4-1. Fuel and CO2 prices in the studied scenarios.**

| | **Price EUR/MWhfuel, expect CO2 EUR/ton** | |
|---|---|---|
| **Fuel type** | **TYNDP 2014 Vision 4 2030** | **BS Green Vision 2030** |
| Nuclear | 1,4 | 1,7 |
| Lignite | 1,6 | 4,0 |
| Hard coal | 8,0 | 10 |
| Gas | 28 | 26 |
| Light oil | 60 | 48 |
| Heavy oil | 36 | 36 |
| Oil shale | 8,3 | 8,3 |
| CO2 | 93 | 35 |

Two sensitivity cases were run based on Baltic Sea Green Vision: Low Nuclear sensitivity and Gas Reduction sensitivity.

Low Nuclear sensitivity focused on a development where existing Nordic nuclear power plants are decommissioned at a faster pace while new or replacing nuclear investments are not commissioned after Olkiluoto 3. Overview of the changes made compared to the standard version of Baltic Sea Green Vision is given in Table 4-2. In Baltic Sea Green Vision, there were no installed nuclear capacity in Lithuania and Poland; therefore, no corresponding reductions were made in Low Nuclear scenario.



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Table 4-2. Baltic Sea nuclear capacity in Baltic Sea Green Vision and Low Nuclear sensitivity.

| | Nuclear capacity in MW | |
|---|---|---|
| **Country** | **Baltic Sea Green Vision** | **Low Nuclear sensitivity** |
| Sweden | 7975 | 4602 |
| Finland | 4550 | 3350[3] |
| Lithuania | 0 | 0 |
| Poland | 0 | 0 |

## 4.2 Market results

The approach of the market simulations carried out during the Common Planning Studies for the Regional Investment Plan 2015, is explained shortly in chapter 2.3 and in detail in chapter 0. Figure 4-2 shows the socioeconomic welfare (in million euros per year) and the standard costs (in million euros) as the result of the first simulation with TYNDP 2014 Vision 4 for the Baltic Sea region.

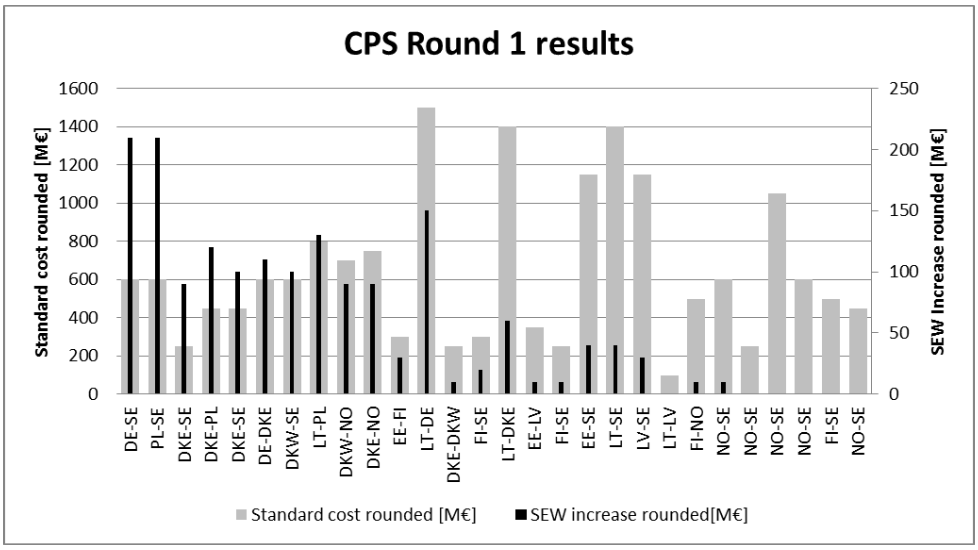


Figure 4-2 - Socioeconomic welfare compared to standard costs for all cross-border transmission capacity increases in the Baltic Sea region in round 1 simulation of Common Planning Studies with TYNDP 2014 Vision 4. The left-hand side axis shows the standard costs, the right-hand axis shows the socioeconomic welfare increase.

The assessment performed in the Common Planning Studies confirms the findings made in the Regional Investment Plan 2014: the project candidates based on this plan gives flexibility and provides a good, functioning infrastructure that is on track towards the European vision of a competitive internal market and a low-carbon energy future. In case of very high increase in renewable electricity generation in the region – assessed based on TYNDP 2014 Vision 4 – new increases in cross-border transmission capacity, additional to those presented in RegIP2014, could be beneficial. These were identified between Norway, Denmark, Sweden and Continental Europe; a more detailed description of the identified market-based reinforcement needs and their translation into actual project candidates is given in Chapter 0. No new reinforcement needs were identified based on Baltic Sea Green Vision; TYNDP 2014 reference grid was able to even out price differences between Nordic/Baltic countries and Continental Europe without additional reinforcements.

[3] An alternative with 1600 MW was also studied

Figure 4-3 shows country-level power balances in the two scenarios, while Figure 4-3 and Figure 4-5demonstrate price differences between the countries.

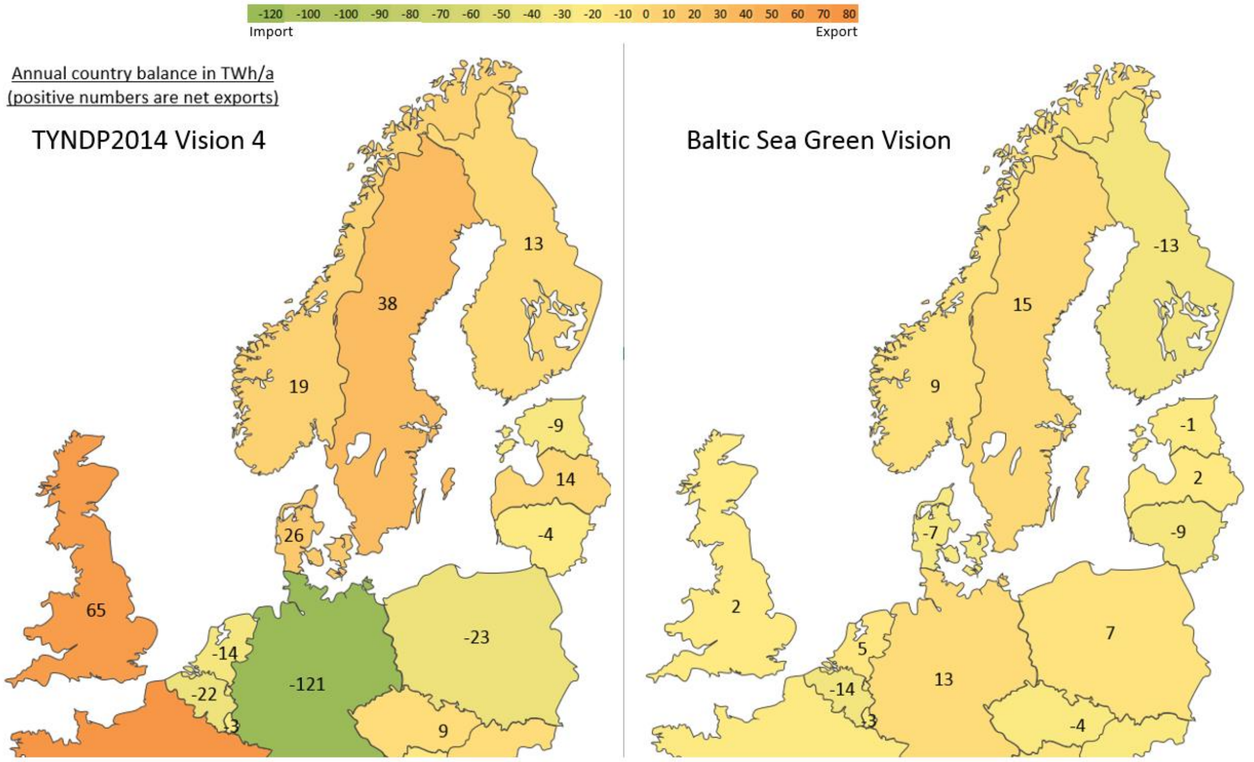


Figure 4-3 Map of annual power balances per country in TYNDP 2014 Vision 4 and Baltic Sea Green Vision. Reference grid includes TYNDP 2014 project candidates and capacity reinforcements discovered during Common Planning Studies.

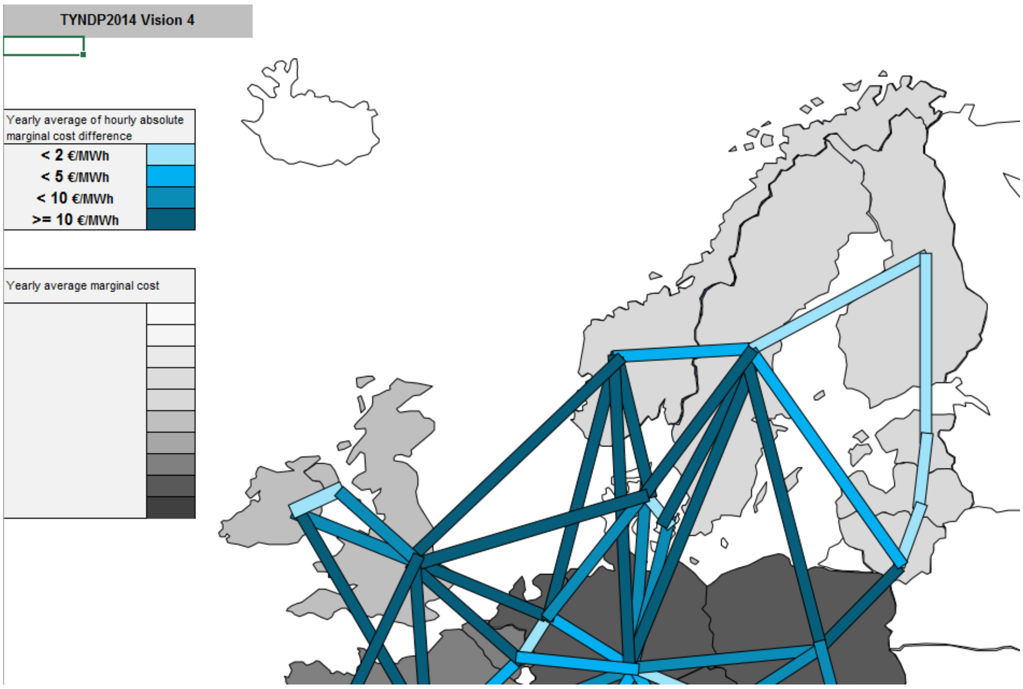


Figure 4-4 Map of price differences per country in TYNDP 2014 Vision 4. Reference grid includes TYNDP 2014 project candidates and capacity reinforcements discovered during Common Planning Studies.

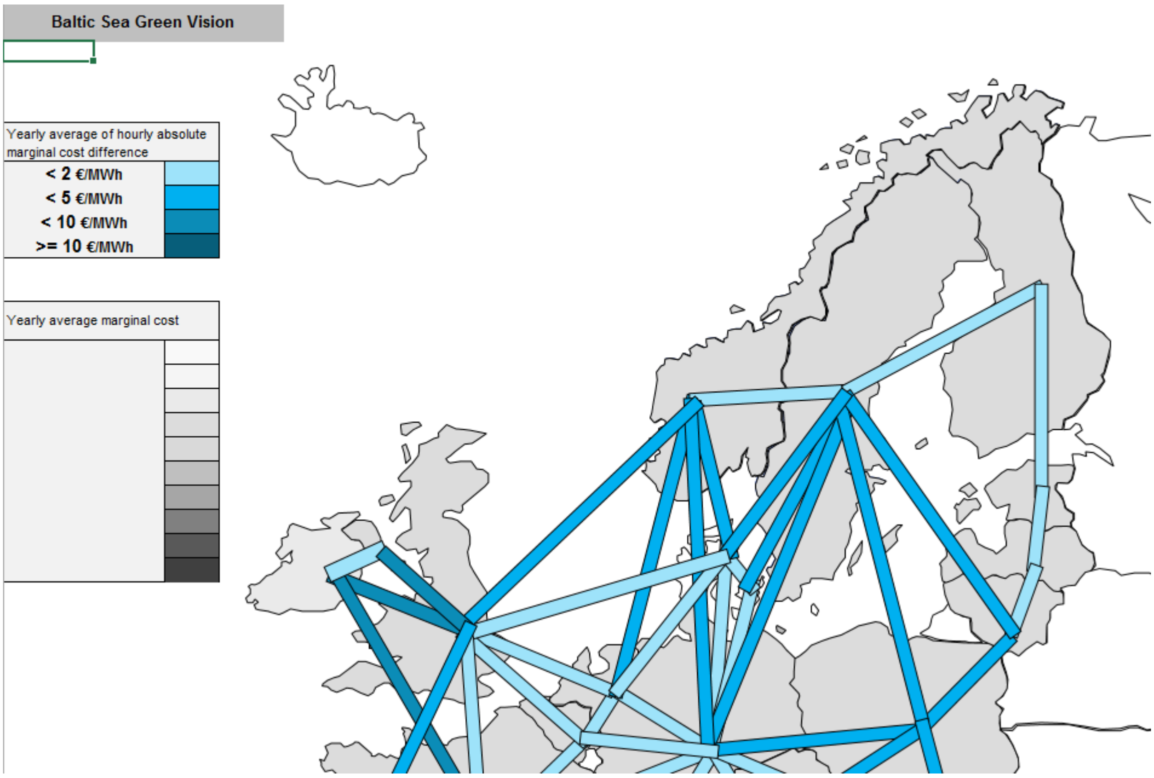


**Figure 4-5 Map of price differences per country in Baltic Sea Green Vision. Reference grid includes TYNDP 2014 project candidates and capacity reinforcements discovered during Common Planning Studies.**

Figure 4-6 shows a comparison of gross cross-border import and export volumes in Europe in Baltic Sea Green Vision and TYNDP 2014 Vision 4. In general, cross-border exchange is more balanced in Baltic Sea Green Vision compared to Vision 4. In BSGV, surpluses are smaller in e.g. the Nordics, France, and UK, while deficits in Germany and Italy are also smaller.

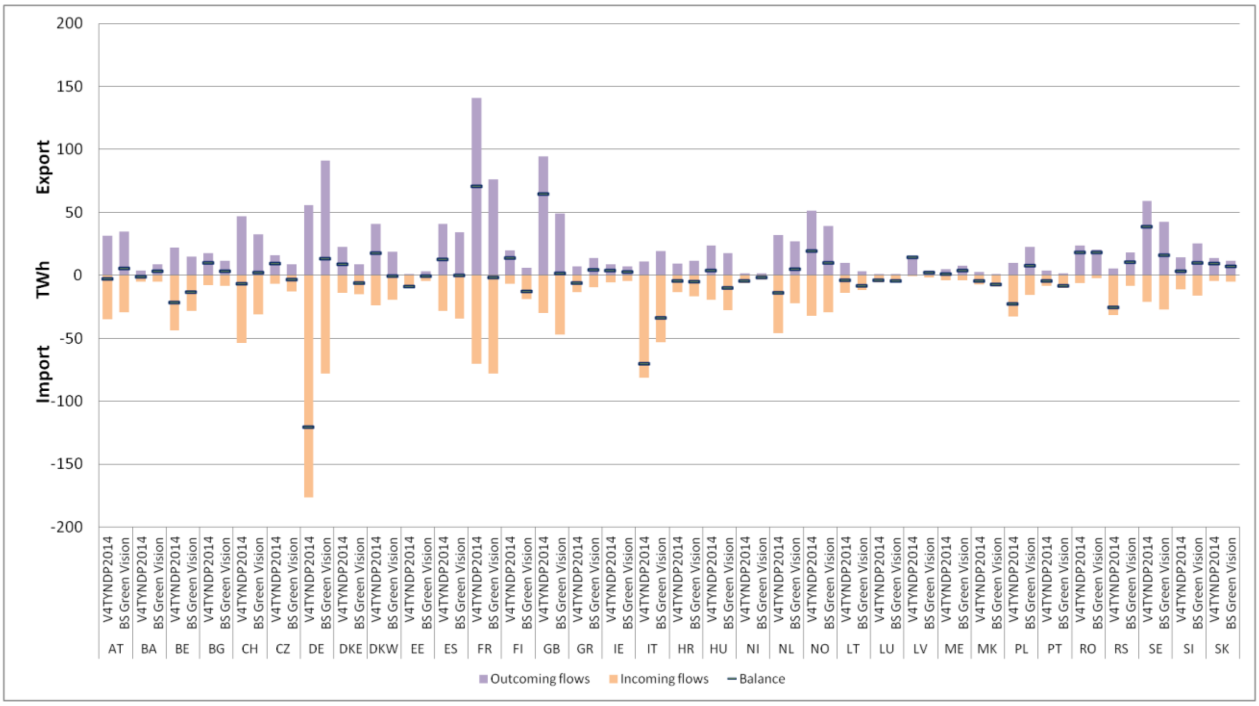


**Figure 4-6 Gross cross-border import and export volumes in Europe in Baltic Sea Green Vision and TYNDP 2014 Vision 4.**

As discussed in Chapter 4.1, two sensitivities were studied based on Baltic Sea Green Vision: Low Nuclear and Gas Reduction scenarios. Figure 4-7 provides a summary of effects of changes to annual energy balances in Baltic Sea countries in the sensitivities.

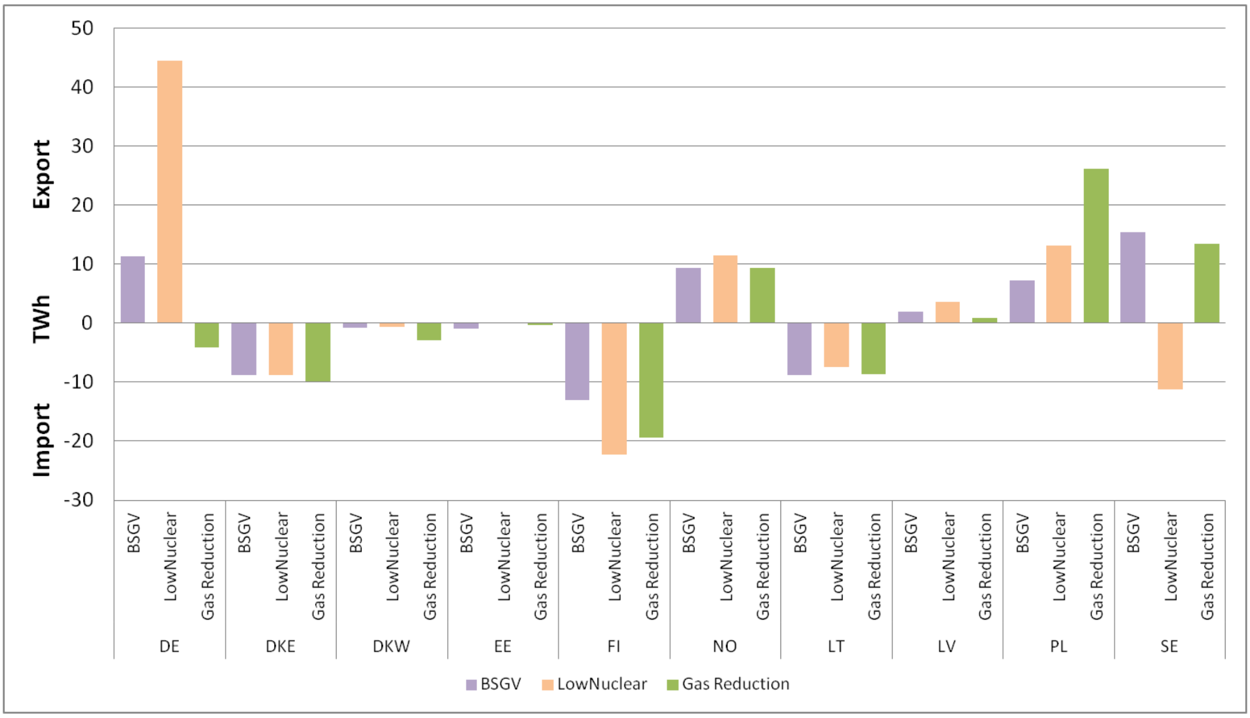


**Figure 4-7 Annual energy balances (in TWh/a) in Baltic Sea Green Vision and the two studied sensitivities.**

Lower nuclear capacity in Finland and Sweden triggered a significantly lower power balance of the two countries compared to standard Baltic Sea Green Vision. This decrease in generation is mostly met by increase of gas-fired generation in Germany, and in smaller extent, UK and other countries adjacent to Baltic Sea countries. In Sweden, lower nuclear capacity could, to a certain degree, be sustained without additional investment in alternative generation, since the country is well interconnected and had a sizable surplus in the reference case. Meanwhile in Finland lower nuclear capacity causes challenges with generation adequacy, given that the country already had a deficit in the reference case; the issues become rather extreme when investigating 'what-if' existing Finnish nuclear capacity was decommissioned at a faster pace than currently planned. The possibility of decreasing nuclear capacity consequently raises the question of what is the alternative technology to replace it. The assumption here (e.g. intermittent renewables / bio-based production / gas-based production / relying on imports) has a significant role in dictating the outcome of any study assessing it. In the what-if sensitivity, wind and solar capacity in Finland had to be increased to keep the assessment of the scenario functional. While this sensitivity indicated that in a Low Nuclear scenario additional interconnectors - compared to investment needs identified in earlier TYNDPs - within the Nordics could be profitable, no new project candidates were suggested for TYNDP 2016 based on this sensitivity. Rather, this is something that needs to be considered in post-2030 perspective, and it requires more clarity on the future of nuclear generation in the Nordics.

Gas reduction sensitivity focused on the possibility of disruption in availability of natural gas. To simulate this, availability of gas-fired power plants was decreased, price of natural gas for the remaining plants was increased, reflecting increased demand for gas from remaining sources, and electricity demand for winter months was increased in some countries, reflecting that some gas-based heating switches to electricity-based heating. Simulations showed increasing prices for the whole region with the largest effects in countries with significant amount of gas-based production, especially Latvia and Lithuania. Increase of coal-based production in Poland compensated for decreasing gas-based production. However no additional investment needs rose based on this analysis.

The resulting market-based target capacities under high-RES conditions are presented in Figure 4-8. The resulting capacities are based on the scenario TYNDP 2014 Vision 4, since no additional investment needs were found in the other scenarios and sensitivities.

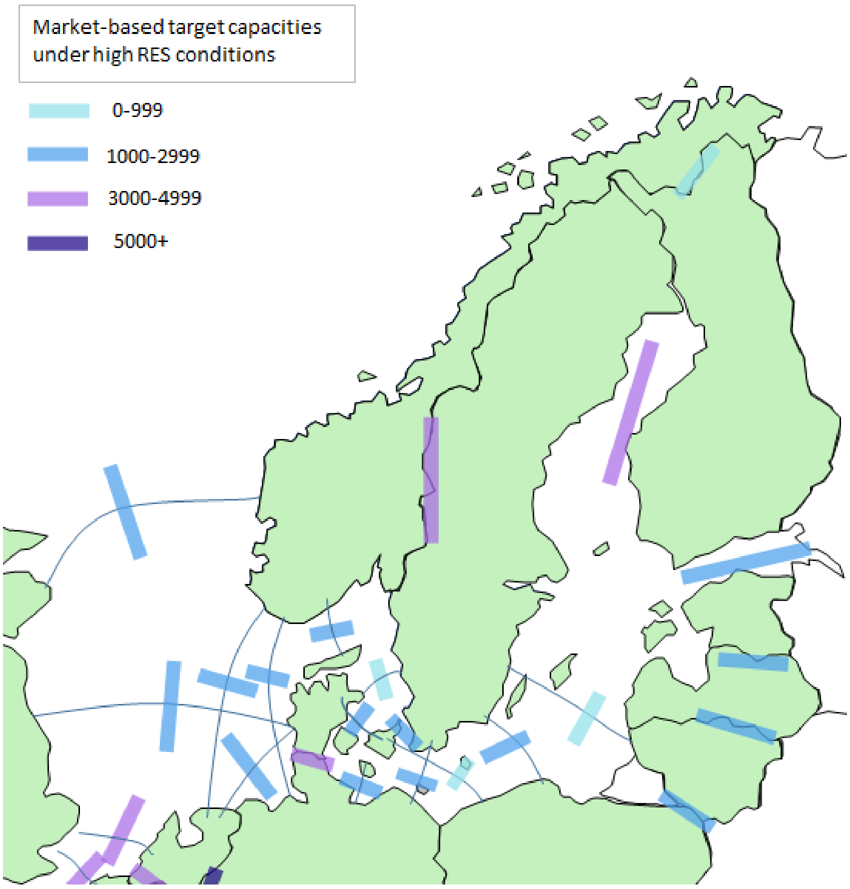


**Figure 4-8. Market-based target capacities after Common Planning studies.**

## 4.3 Main uncertainties related to market results

There are several uncertainties which might influence the results of the study, the most import uncertainties being:

- **A scenario uncertainty** relates to the general difficulty to forecast the future. No scenarios are fully and exactly able to capture the future decades onwards. Different development paths can tremendously change the world away from the circumstances and assumptions made in the studies.
- **A methodical** uncertainty is that due to the coordinated standardized procedure only one set of demand, inflow, wind etc. was used. To properly examine the Nordic system a large number of variations needs to be used to calculate the benefits of investments. For the Baltic Sea Green Vison however a large number of different inflow variations were used. If variation in inflow had been taken into account, benefits for the project candidates would likely be higher but it might also affect which projects are most beneficial considering SEW.
- **Model:** A power market model is always a simplification of the real world, the most important difference being the flexibility of hydro power which is overestimated in market models. The model also underestimates the influence of grid constraints other than NTC: s which is import in the region. These uncertainties results in overestimations of the benefits of connections between the Nordics and the continent.

- **Cost reductions and paradigm shift.** The study does not include new technologies or dramatic changes with paradigm shift (or revolutionary science) that would lead to a change in the basic assumptions.

## 4.4 Network results

Network studies were carried out to check and confirm reference capacities for each border found by market simulations for the TYNDP 2014 Vision 4. Network simulations had to identify network bottlenecks, i.e. congestions in the transmission grid caused by additional cross-border interconnectors, which need to be removed to achieve necessary network transfer capacities for future power (market) flows. Possible grid reinforcements and new project candidates that help to remove network bottlenecks should also be identified.

Previous TYNDP 2014 network studies identified the need to have strong, reinforced, north-south connections within the present transmission grid all over the Baltic Sea region. The main challenges with stability and operability of the transmission grid are divided between dynamic and static challenges. The static challenges relate to alleviation of contingency and bottlenecks in order to send more power through the lines without overloading. The dynamic challenges are found in attempts to transport excessive amounts of power through extremely long transmission corridors, with insufficient voltage support and control. The power transmission from south of Norway to south of Finland is through a long transmission corridor, which in certain stressed operation conditions may excite not-dampened power oscillations between the ends of the corridor, frequency excursions, voltage fluctuations and in the worst case dynamic voltage instability, i.e. outage of the transmission grid. Such dynamic issues can be initiated in undisturbed operation conditions at increasing power flows or due to grid disturbances and forced outage of main lines. Dynamic issues cannot solely be identified from or solved by grid reinforcements, e.g. adding parallel transmission lines, but instead need more careful assessment using dynamic models.

The present Common Planning Study highlighted that those conclusions and warnings are still valid. Possibilities to increase capacities on borders between Norway/Sweden and Denmark/Germany, as well as between Finland/Baltic countries, will be further analysed.

As the following subchapters describe, two out of three promoted projects involve Denmark. Network studies showed that significant impact from new market flows will affect the transmission grid of Denmark. Detailed analysis of the market results has confirmed that the new cross-border interconnectors to Denmark-West and to Denmark-East are mostly serving as transit flows between Scandinavia and Continental Europe – throughout Denmark. If the identified interconnectors were established as point-to-point HVDC connectors to the nearest suitable 400 kV AC substations in Denmark (Business as Usual), the transit flows would highly overload many internal transmission lines. Many lines would be overloaded already in N conditions and the overloading degree and severity would increase in N-1 conditions. The overloading would be removed by reinforcing the internal transmission grid which would lead to higher costs associated with cross-border interconnectors and the required internal reinforcements.

To cut costs and to meet market request for making greater transit flows throughout the transmission grid of Denmark, a solution of new multi-terminal HVDC technology was introduced and evaluated. The new cross-border interconnectors were merged into a multi-terminal HVDC system instead of the usage of point-to-point HVDC connectors. The **multi-terminal HVDC system** is introduced as an overlay grid to the present 400 kV AC transmission grid and has the main drivers:

- Reducing the impact on the 400 kV AC transmission grid
- Usage of less expensive VSC station
- Reducing conversion losses between AC and DC

The number of the VSC stations, required to be built in Denmark for connection of the assessed new HVDC connectors, can be reduced from six to four; these four VSC stations were arranged into the two HVDC hubs, which formed the multi-terminal HVDC system in Denmark. A short description about the proposed solution is given in Chapter 7.3. The cost-efficiency of the multi-terminal HVDC system, in this study, was proven due to the fact that the multi-terminal HVDC system would be in the range of 151,5 M€ to 261,7 M€ cheaper than the establishment of point-to-point HVDC connectors and reinforcements of the Danish 400 kV AC grid.

In the other countries, N and N-1 load-flow bottlenecks have not been reported from grid studies, which cannot exclude risks of bottlenecks due to load-flow or due to dynamic issues. Analysed target capacities during Common Planning Studies lead to following cross border project candidates for TYNDP 2016 described in more details in following chapter 4.5.

## 4.5 New project candidates

**New interconnection Denmark-East – Germany**

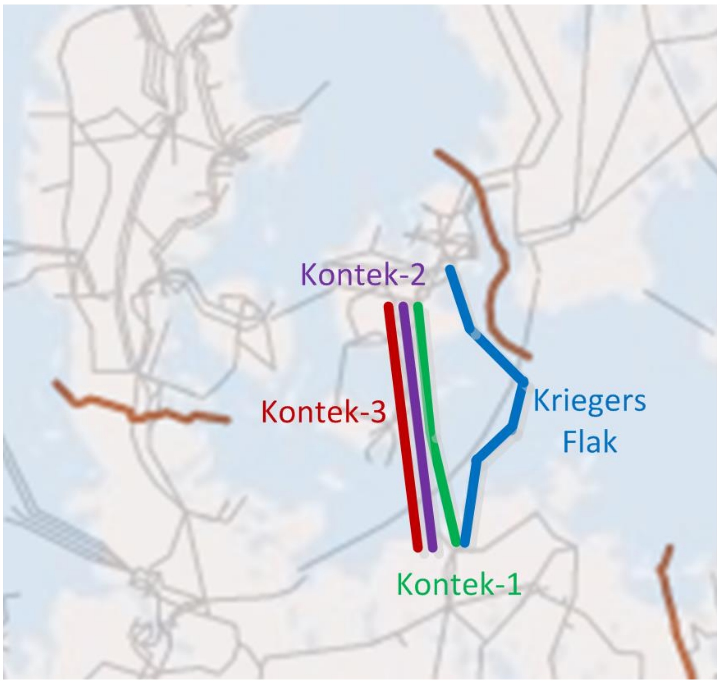


Figure 4-9 Illustration of Denmark-East – Germany interconnectors

At present, there is a single 600 MW transport capacity HVDC connector between Germany and Denmark-East, which is Kontek-1, which is illustrated in Figure 4-9. Commissioning of one more connector, 400 MW capacity constrained by offshore wind power at Kriegers Flak, is planned. TYNDP 2014 includes one more HVDC connector, Kontek-2, with the transport capacity of 600 MW.

The Common Planning Study's market results have shown the benefits of one more interconnector with the transport capacity of 1000 MW. In total, the proposed transport capacity between Germany and Denmark-East will become 2600 MW, which accounts for the existing Kontek-1, planned Kriegers Flak, and candidate Kontek-2 and Kontek-3 projects.

The total transport capacity of the interconnectors to Denmark-East will increase the difference between the generation capacity and consumption, while the border transport capacity between Denmark-East and Sweden-4 is kept unchanged. This means that the additional interconnectors will enhance the transit flows throughout Denmark-East, but only a reduced amount of energy is exchanged with this Danish area. Therefore, some of the interconnectors to Denmark-East have been merged into a multi-terminal HVDC system, which in short is described in Section 7. The multi-terminal HVDC system will allow the market transit flows with the minimum possible stress on the internal Danish grid.

The analysis of the Common Planning Study's market results has shown that this additional 1000 MW interconnector to Germany should remain as a point-to-point HVDC connector, because its market flows do not fit into the multi-terminal HVDC system with the other connectors. However, the presence of the multi-terminal HVDC system has been beneficial in such a way that internal grid reinforcements are not needed. Hence, the cost of this 1000 MW HVDC connector to Germany does not include grid reinforcements in Denmark-East, when some other connectors are merged into the multi-terminal HVDC system.

In both approaches, the 1000 MW interconnector to Germany has been kept with the same grid connection routing and topology. In Denmark-East, this connector is an HVDC cable to the existing 400 kV sub-station Bjaeverskov (BJS). When treated separately from any other interconnector, this one would not require additional grid reinforcements besides those already included in the TYNDP 2014 grid model of Denmark-East.

Attention should be paid to the fact that if the Danish sub-station Bjaeverskov accommodated so many additional interconnectors, there would be a significant impact on the Danish grid operation, with regards to security and increased vulnerability. This will introduce additional, significant cost (not assessed yet) on re-configuration and expansion of this sub-station. Therefore, at least one interconnector, Kontek-2 in this grid study, would be redirected to the other substation and likely have its HVDC VSC station outside Bjaeverskov. Substation Herslev cannot accommodate more large HVDC stations due to environmental impact on surroundings, i.e. restrictions on noise level, visual impact etc., and its limited space.

Final capacity for the third interconnection Denmark-East – Germany (Kontek-3) was decided to be 600 MW, i.e. nominated for the TYNDP-2016 Assessment Phase. This project would be good for market integration, as well as for additional RES connection.

List of preliminary identified investments needed to enable 600 MW HVDC connection:

- 1x 600 MW VSC station in Denmark
- 1x 600 MW VSC station in Germany
- 600 MW DC submarine cable, 85 km
- 600 MW DC onland cable, 85 km

Preliminary cost for this connection is about 550 MEur.

## New interconnection Denmark-East – Poland.

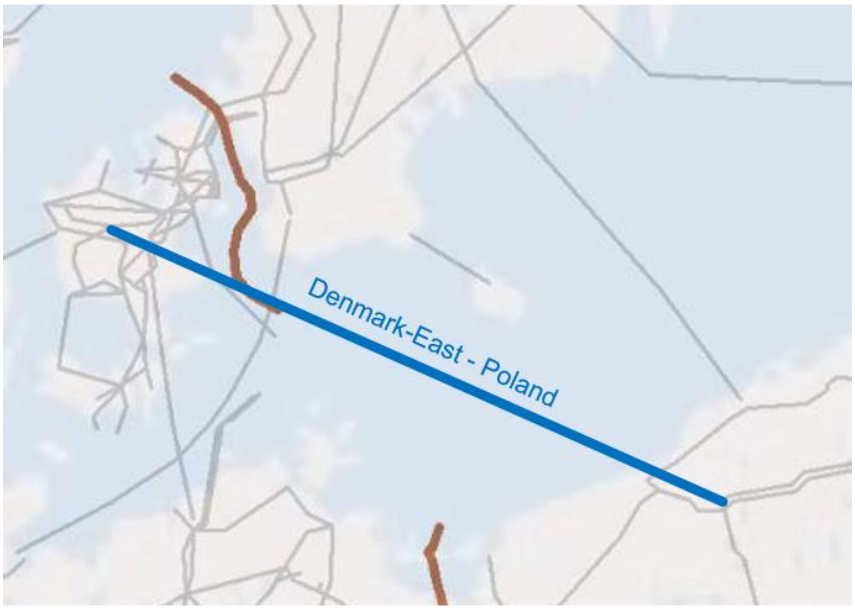


Figure 4-10 Illustration of Denmark-East – Poland interconnectors

At present, there are no connectors between Denmark-East and Poland. The Common Planning Study’s market results have shown benefits of one 500 MW interconnector on this direction.

During TYNDP 2014 already was analyzed project 166 DKE-PL 600 MW link between Bjæverskov (Denmark) and Dunowo (Poland). The cost was estimated in a range of 460-1100 MEur. The grid assessment of project under condition grid data set of 2030 Vision 4 in TYNDP 2014 has shown that connection of one 600 MW to the substation Dunowo on the Polish side does not require additional grid reinforcements.

For Denmark, with this additional interconnector to Poland and the other existing, envisaged and additional interconnectors to Denmark-East, the total transport capacity of the interconnectors will exceed the difference between the generation capacity and consumption in this Danish area. It is obvious that the additional interconnectors are used for the power transit throughout the Danish area and only a reduced energy amount is exchanged with this area.

The analysis of the Common Planning Study's market results has shown beneficial to merge this 500 MW interconnector with two other TYNDP 2014 projects into a multi-terminal HVDC system of Denmark-East. Figure 4-10 presents the Danish-Polish candidate project on the map, and the multi-terminal HVDC system is in short given in Section 7. When the multi-terminal HVDC approach is utilized, no internal grid reinforcements in Denmark-East are needed. In comparison, the point-to-point HVDC assessment will expose needs of internal grid reinforcements to facilitate the power transport between the involved interconnectors within the Danish 400 kV grid.

It was decided that the final capacity for the interconnection Denmark-East – Poland should be 600 MW, as analysed during TYNDP 2014. This project would be good for market integration as well as for additional RES connection.

List of preliminary identified investments needed to enable 600 MW HVDC connection Asnæs (DKE) – Dunowo (PL):

- 1x 600 MW VSC station in Poland
- 600 MW DC submarine cable, 305 km
- 600 MW DC on-land cable, 25 km
- 600 MW DC OHL x 75 km
- 1x 600 MW DC Breaker in Denmark

Preliminary costs for this connection could be about 500 MEur.

Notice that the other reinforcements in Denmark-East for the point-to-point HVDC approach are due to HVDC connectors to Germany, such as 600 MW Kontek-2 and 600 MW Kontek-3, all landing within the same part of the onshore transmission grid.

Notice also that expected reduction of the capital expenditure of the multi-terminal HVDC system is a consequence of fewer HVDC VSC stations. The above presented cost efficiency of the multi-terminal HVDC system also includes savings due to fewer grid reinforcements and transmission line routing, which is why the cost reduction distinguishes from the cost of a single HVDC VSC station. Furthermore, the multi-terminal HVDC system will be assessed as a whole, i.e. with all arriving HVDC connectors, to present a more accurate result of its cost efficiency; see Section 7.



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## New interconnection Sweden-Germany.

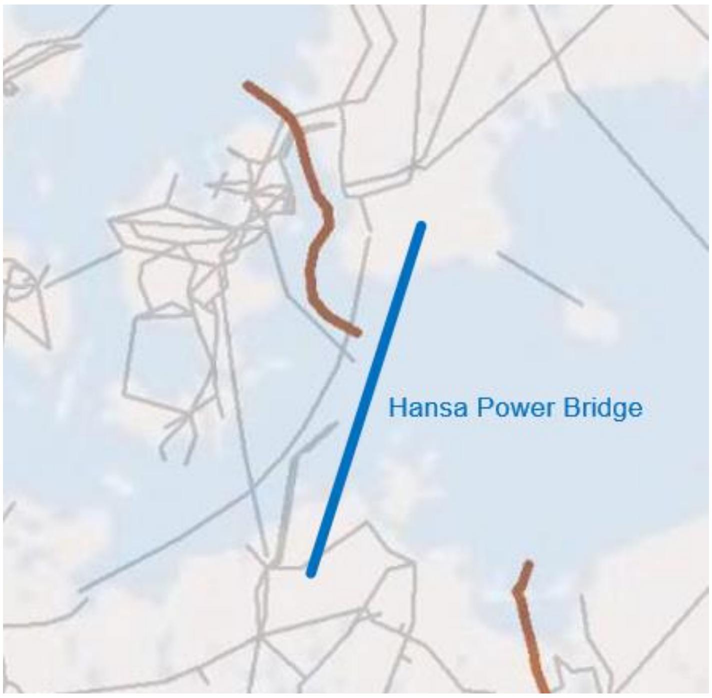


Figure 4-11 Illustration of Sweden – Germany interconnector Hanse Power Bridge

At present, there are already a 600 MW connection between Sweden and Germany. During TYNDP 2014 project 176 Hansa Power Bridge for 600 MW interconnection between Sweden and Germany was already analysed, which is illustrated in Figure 4-11. Costs were estimated in range 200-400 MEur, however the cost is likely to be higher according to more recent estimates. This project is re-confirmed for further analyses in TYNDP 2016.

The Common Planning Study's market results have shown benefits of additional 1000 MW interconnector between Sweden and Germany, however the capacity of that project candidate were changed to 700 MW.

The possible new interconnectors between Sweden and Germany draw motivation from the basic need to balance an increasing volume of RES in both Sweden and Germany, as well as from the large Nordic surplus presented in Vision 4 of TYNDP 2014. For Sweden, no detailed grid studies have been performed at this stage for these possible project candidates. The first new link to be established between Sweden and Germany, the Hansa PowerBridge, does not require any new major reinforcements of the internal Swedish grid apart from the large reinforcements already under way. If the capacity is increased even further between Sweden and Germany it is more likely that internal Swedish reinforcements may be needed. Depending on actual connection points for one of these project candidates, it may also be necessary to reinforce the local grid to avoid overloads.

Taking into account other planned projects in Germany, there is no additional reinforcements for the German network identified at this stage.

A 700 MW interconnection named Hansa PowerBridge phase 2 is nominated as new project candidate for TYNDP 2016. The capacity was set to 700 MW due to that it is considered to be a good size of an HVDC interconnector for the Nordic system from an operations point of view.

List of preliminary identified investments needed to enable a 700 MW HVDC connection:

- 1x 700 MW VSC station in Germany
- 1x 700 MW VSC station in Sweden
- 700 MW DC submarine cable, 305 km

The preliminary cost estimations indicate a total cost of about 700 MEur for each of the project candidates Hansa Power Bridge 1 and 2.

## 4.6 e-Highway 2050 scenarios perspective

The e-Highway2050 project is supported by the EU Seventh Framework Programme and aims at developing a methodology to support the planning of the Pan-European Transmission Network. The study project started in September 2012 and will end in December 2015.
The main goal is to develop a top-down methodology for the expansion of the pan-European electricity grid from 2020 to 2050, with a view to meeting the EU energy policy objectives. Concretely, the methodology will ensure that future EU grids can host large quantities of electricity from renewable energy sources and transport it over long distances as well as foster market integration.
The E-Highway2050 project is based on five future power system scenarios (Example, see figure below), which are extreme but realistic for a 2050 perspective. The corridors identified provide a modular development plan for a possible long-term architecture. The five scenarios span uncertainties (technical, economics, political, social...) as well as different future choices (RES incentives, energy market integration, regulations, industry standards...).

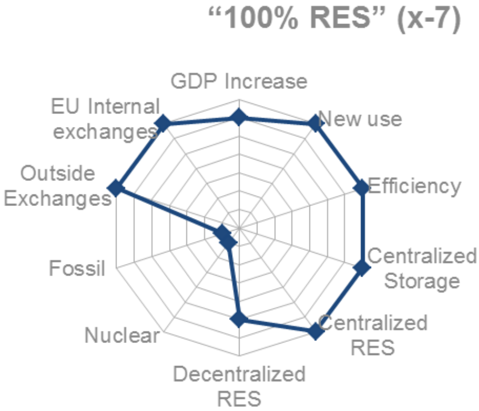


**Figure 4-12 - Example of scenario characteristics**

The methodology used in the e-Highway project, though different from the TYNDP planning, is still built around market and network studies. To focus on 2050 pan-European adequacy and efficiencies, it is based on stochastic analysis of unsupplied energy, energy spillage and thermal generation re-dispatching. The network model used is much simplified, based on a limited number of clusters all interconnected by equivalent impedance links (see figure below).

**Figure 4-13 - Reduced European grid**

A comparison between 2030 and 2050 scenarios is subjective and in essence a fast evolving energy domain can always move from one 2030 Vision to any 2050 scenario. Therefore the four TYNDP Visions all show rather different ways to move forward to the 2050 goals. Regardless of the scenario perspective taken, it is important to see the TYNDP2016 projects as no-regret options across the common corridors identified in the e-Highway project, meaning that TYNDP2016 projects are the first steps to be considered by 2030 in order to match with 2050 very long term perspectives.

The regional results in this report provide further insight on this.

While the proposals of E-Highway 2050 are understood as being transmission requirements, the project candidates of TYNDP are, to a large extent, project ideas. Nevertheless, the results of these two approaches still give the same main messages for the Baltic Sea Region that additional interconnection capacities between the Nordic countries and the Continental European System are favourable.

The figure below shows the increased corridors identified in at least two of the five scenarios run in the E-Highways 2050 project.

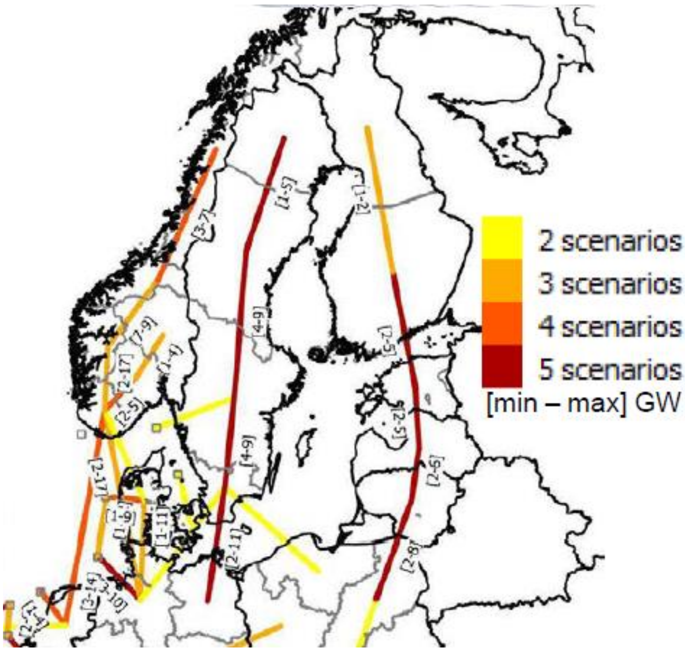


**Figure 4-14 - – Proposed routes and the number of e-Highway 2050 scenarios (of 5), where these routes showed beneficial**

An important observation in the E-Highway 2050 project is that there is no need for overlaying higher voltage transmission systems or long distance point-to-point connections. In all proposed additional transmission paths intermediate connections to local "clusters" or market areas/bidding zones are important to gain full potential of the benefits of new connections. This also means that E-Highway 2050 scenarios are not something separate or different from the gradual transmission system development with project by project.

# 5 PROJECTS

## 5.1 Introduction

This chapter lists all TYNDP projects to be assessed by ENTSO-E as part of the TYNDP2016 process. In addition, projects that have impact on the region but are not of pan-European significance are also presented in this chapter; these are not part of the TYNDP list and will not be further assessed in the final TYNDP report.

A project is defined as the smallest set of assets that effectively add capacity to the transmission infrastructure that can be used to transmit electric power, such as a transformer + overhead line + transformer. In situations where multiple projects depend on each other to perform a single function (i.e. a single project cannot perform its function without a certain other project) they can be clustered in order to be assessed as a group providing that they achieve a common measurable goal.

TYNDP2016 projects as well as regional projects are based on earlier TYNDP2014 projects, result from recent common planning studies, and/or are driven by political targets.

TYNDP projects in this list are structured by

- **Boundary** – which can be a specific border, a combination of borders, or an internal boundary;
- **Maturity** – based on commissioning date and national approval projects are grouped as
    - Mid-term projects: Projects to be commissioned by 2022 will be assessed by TOOT method against the expected 2020 network if is acknowledged in the latest national plans or is having intergovernmental agreement;
    - Long-term projects: Projects to be commissioned by 2030 will be assessed by TOOT method against the expected 2030 network and PINT method against the expected 2020 network if the project is acknowledged in the latest national plans or is having intergovernmental agreement;
    - Future project candidates: All other projects which do not fall under the previous categories will be assessed with PINT method against the expected 2030 network.

The following map shows all cross-border projects to be assessed in TYNDP2016:

- **Dark blue** – new TYNDP projects (among which the ones identified during the Common Planning Studies)
- **Light blue** – re-confirmed TYNDP2014 projects



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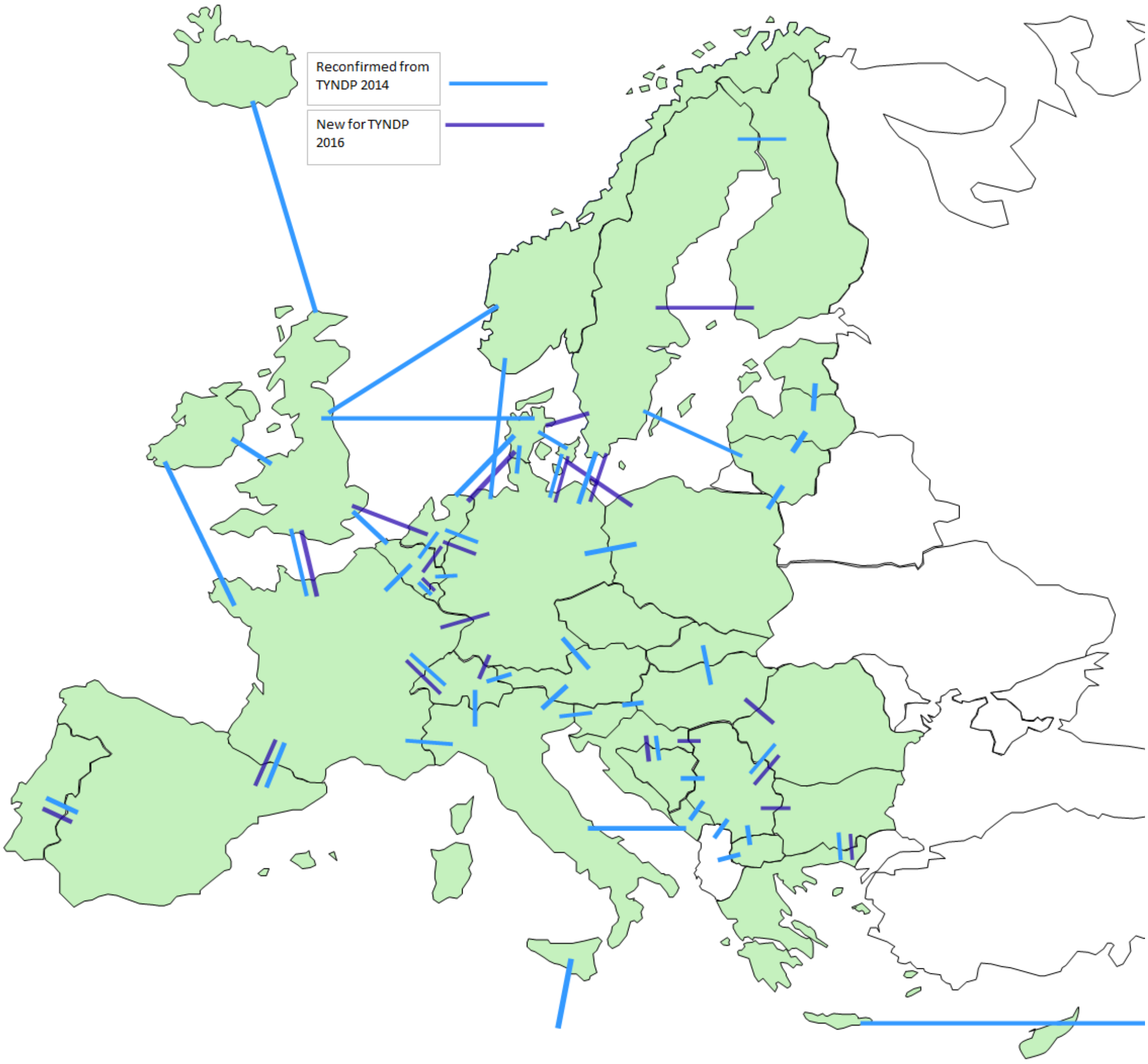


Figure 5-1 Borders with reconfirmed or new projects for TYNDP2016 assessment

## 5.2 Projects for assessment in TYNDP2016

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Baltics - Continental Europe** | 170 | Baltics synchro with CE | This is unique project as main driver for it is not to increase GTC but to disconnect from Russia system and connect with Continental European networks synchronously. Two different landing points and two differently routed interconnections are required to achieve physical separation of the two redundant interconnections in order to establish a reliable synchronous connection between the transmission systems of Baltic States and Continental Europe networks. The first Lithuania – Poland connection (LitPol Link) is already decided and it will be the first connection. The pre-feasibility study of second PL-LT line indicates significant risks, not allowing the effective implementation on PL territory. The list of investments provided during TYNDP2014 process was not final and including just a few of probable necessary investments. Some more investments will be transfered from another project 163 Baltic Corridor which will be not re-confirmed for TYNDP2016 but has identified investement needs that will be necessary for Baltic synchronisation project as well. This is PCI project. Additionally to previously mentioned investments also some new investments will be added in future development of the project, that were discovered during the planning process and will be determined and specified during ongoing studies. | 0-600 | 170 | Project is aimed at infrastructure development for deeper market integration and synchronous operation of the power systems of the Baltic States with the Continental European networks and will increase security of supply for Baltic systems (Estonia, Latvia, Lithaunia). | 2025 | Future Project | AST;ELERING;LITGRID |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Denmark-East - Germany** | 179 | DKE - DE | This project includes a HVDC subsea interconnector between Denmark-East (DKE) and Germany (DE) and is called Kontek-2. A final grid-connection solution is not prepared yet; one of the possible alternatives could establish the Danish HVDC converter station in the area of Lolland- Falster. This alternative comprises among other things an HVDC converter station being connected to the existing 400 kV substation Bjæverskov via 400 kV underground cables and/or 400 kV OHL. | 600 | 179 | The purpose of the project is to further integrate markets and renewables in both countries. | 2030 | Future Project | 50HERTZ;Energinet.dk |
| **Denmark-East - Germany** | 232 | Kontek-3 | The third HVDC connector between Denmark-East and Germany | 600 | Market integration, RES connection | Common Planning Studies 2015, with the preliminary market transport capacity 1000 MW (additional). | >2030 | Future Project | 50Hertz Transmission;Energinet.dk. |
| **Denmark-East - Poland** | 234 | DKE-PL-1 | The first HVDC connector between Denmark-East and Poland | 600 | Market integration, RES connection | Common Planning Studies 2015 with the preliminary market transport capacity of 500 MW (additional). | >2030 | Future Project | Energinet.dk.dk |
| **Denmark-West - Denmark-East** | 175 | Great Belt II | This project candidate includes an HVDC connector between Denmark-West (DKW) and Denmark-East (DKE). The connector is called Great Belt-2. It could among other variants be located between the 400 kV substation Malling in DKW and the reconstructed 400 kV substation Kyndby in DKE. | 600 | 175 | The main purpose of this project is to incorporate more RES into the Danish system by sharing reserves between both systems and improve market integration. | 2030 | Future Project | Energinet.dk |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Denmark-West - Sweden (SE3)** | 238 | Kontiskan 2 | Renewal of the existing Kontiskan 2 HVDC connectors between Denmark-West and Sweden (Bidding area SE3), approximately 380 MW, to maintain capacity between Sweden and Denmark. Final capcity to be determined later. | 0 | Maintaining existing capacity to ensure a good Market integration and Security of Supply.There are two options: Renewal without increase of capacity or no renewal at all which would mean a decrease from current level. | Bilateral and national socio-economic and technical studies. | 2030 | Future Project | Energinet.dk.dk;Svenska Kraftnät |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Estonia - Latvia** | 62 | Estonia-Latvia 3rd IC | Project nr 62 is a planned third 330 kV interconnection between Estonia and Latvia. The project consists of 2 investments of which nr 386 is the main inter-area investment, AC 330 kV OHL between Kilingi-Nõmme substation in Estonia and TEC2 substation in Latvia. Estonia-Latvia third interconnection associated investment nr 735 AC 330 kV OHL Harku-Lihula-Sindi in Estonian. It increases the capacity between Estonia and Latvia by 600 MW. The project also helps to improve SoS and contributes to RES increase in the Baltics western coastal areas. The project is also a precondition for construction of off-shore wind parks in Estonia and Latvia. The Estonia-Latvia third interconnection is the significant project for all the Baltic region, because it will increase competition for electricity market in Baltic States and between Baltic States and Nordic countries. It will provide reliable transmission network corridor will improve interoperability between Baltic states. In addition after commissioning the projects forming the Baltic Energy Interconnection Plan the reinforced Baltic States transmission system and its connections to Nordic and Central Europe can also serve as an alternative route for exporting Nordic surplus to the Central European power system. | 450-600 | 62 | Main objectives are market integration and increase of SoS. | 2020 | Mid-term Project | AST;ELERING |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Finland - Sweden** | 111 | 3rd AC Finland-Sweden north | Third AC 400 kV overhead line interconnector between Finland north and Sweden SE1. Strengthening the AC connection between Finland and Sweden is necessary due to new wind power generation. larger conventional units and decomissioning of the existing 220 kV interconnector. | Direction A: 500 - Direction B: 800 | 111 | Security of supply: The project enhances system security of whole Finnish system, especially during outages on other interconnections between the countries.<br><br>RES integration: The project helps integrating 500-800 MW wind power in Northern Sweden and Finland and improves the possibilities of balancing the system. | 2025 | Long-term Project | FINGRID;SVK |
| **Finland North-South** | 96 | Keminmaa-Pyhänselkä | The project is 400 kV overhead line in North Finland. Integration of new generation at Bothnian bay and increased transmisison capacity demand. Will help utilizing the Swedis/Finnish cross border capacity. | 500-1000 | 96 | The project is 400 kV overhead line in North Finland. Integration of new generation at Bothnian bay and increased transmisison capacity demand. Will help utilizing the Swedis/Finnish cross border capacity. | 2024 | Long-term Project | FINGRID |
| **Finland North-South** | 197 | N-S Finland P1 stage 2 | Several 400 kV AC lines are planned in Finland to be built to increase the North-South transmission capacity thus enabling the integration of new renewable and conventional generation in northern Finland and to compensate dismantling of obsolescent existing 220 kV lines. This project is 400 kV overhead line from connecting North Finland to South. | 1000 | 197 | Several 400 kV AC lines are planned in Finland to be built to increase the North-South transmission capacity thus enabling the integration of new renewable and conventional generation in northern Finland and to compensate dismantling of the obsolescent existing 220 kV lines. The commissioning of the lines is scheduled to take place in segments both in mid and long term. This project is 400 kV overhead line from connecting North Finland to South. | 2023 | Long-term Project | FINGRID |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Finland-Sweden (SE3)** | 239 | Fenno-Skan 1 renewal | Renewal of the existing 400 kV HVDC cable interconnection between Finland and Sweden. The projects capacity is estimated to range between 500-800 MW which could mean an updgrade compared to today. There are three options: a) renewal with an increase from current level (+300MW) b) no additional capacity (0MW) or c) no renewal at all (-500MW). | 300 | Renewal needed due to time and age of the existing equipment.Existing link has been commissioned 1989 and will be ca 40 years old in 2030. | | 2030 | Future Project | Fingrid;Svenska Kraftnät |
| **Germany - Sweden** | 176 | Hansa PowerBridge 1 | HVDC cable interconnector between Sweden (SE4) and Germany (50Hertz). There have been joint studies with 4 options for this project. A second connection (Hansa PowerBridge 2) is under investigation. | 700 | 176 | Comment on the RES integration: The project helps integrating wind power on both sides and improves power balancing.<br><br>Comment on the S1 and S2 indicators: The project will have a social and environmental impact. However, the project is in an early stage and there is not enough facts regarding the impact. | 2025 | Long-term Project | 50HERTZ;SVK |
| **Inside Germany** | 251 | Audorf-Dollern | New 380-kV-line Audorf – Hamburg/Nord – Dollern" in existing 220-kV-corridor. Main focus of the project is the integration of onshore-RES – mainly wind – in Schleswig-Holstein. The project is labeled as PCI 1.4.2. and 1.4.2. It is the southbound connection of PCI 1.4.1. and is necessary to increase the GTC between Dänemark/West and Germany by 720/1000 MW. | 3000 | | | 2017 | Mid-term Project | Tennet-DE |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Inside Germany** | 258 | Westcoast line | New 380-kV-line Brunsbüttel – Niebül inside Schleswig – Holstein. Main focus of the project is the integration of onshore-RES – mainly wind – in Western Schleswig-Holstein. The project is labeled as PCI 1.3.2. It is the southbound connection of PCI 1.3.1. and is necessary to increase the GTC between Dänemark/West and Germany by 500 MW. | 3000 | | | 2018 | Mid-term Project | Tennet-DE |
| **inside-DE** | 129 | OWP Northsea TenneT Part 4 | Connection of offshore wind parks in the North Sea to Germany. Mainly subsea DC cable. The OWP will help to reach the Eropean goal of CO2 reduction and RES integration | 3600 | 129 | | 2031 | Future Project | TENNET-DE |
| **inside-DE** | 191 | OWP TenneT Northsea Part 2 | Connection of offshore wind parks in the North Sea to Germany. Mainly subsea DC cable. The OWP will help to reach the Eropean goal of CO2 reduction and RES integration | 5400 | 191 | | 2022 | Mid-term Project | TENNET-DE |
| **inside-DE** | 192 | OWP Northsea TenneT Part 3 | Connection of offshore wind parks in the North Sea to Germany. Mainly subsea DC cable. The OWP will help to reach the Eropean goal of CO2 reduction and RES integration | 4500 | 192 | | 2027 | Future Project | TENNET-DE |
| **inside-inside** | 164 | N-S Eastern DE_central section | North-South transmission in Germany. AC links from Northern Germany towards the load centers of Bavaria and Baden-Württemberg. Due to ongoing political discussions a change of the connection point Grafenrheinfeld is under consideration. | 11800 | 164 | | 2022 | Mid-term Project | AMPRION;TENNET-DE |
| **inside-inside** | 204 | N-S transmission DE_par_line_2 | new 380-kV-OHL between Thuringa and Bavaria due to increase of RES in Northen Germany | 11800 | 204 | | 2024 | Long-term Project | 50HERTZ;TENNET-DE |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **inside-inside** | 205 | N-S transmission DE_par_line_1 | new 380-kV-OHL between Thuringa and Bavaria due to increase of RES in Northern Germany | 11800 | 205 | | 2015 | Mid-term Project | 50HERTZ;TENNET-DE |
| **inside-inside** | 206 | Reinforcement Southern DE | "AC-busbar" in Southern Germany for energy dispatching within Bavaria and Baden-Württemberg and gathering solar energy. | 11800 | 206 | | 2024 | Long-term Project | TENNET-DE;TRANSNET-BW |
| **inside-inside** | 207 | Reinforcement Northwestern DE | Integration of on- and offshore RES in Lower Saxony | 5500 | 207 | | 2024 | Long-term Project | AMPRION;TENNET-DE |
| **inside-inside** | 208 | N-S Western DE_section North_1 | Integration of on- and offshore RES in Lower Saxony | 5500 | 208 | | 2018 | Mid-term Project | AMPRION;TENNET-DE |
| **inside-inside** | 209 | Reinforcement Northeastern DE | New 380-kV-lines in the area of Schleswig-Holstein mainly for integration of Onshore-Wind. | 12000 | 209 | | 2021 | Mid-term Project | AMPRION;TENNET-DE |
| **Internal boundary in Germany** | 235 | HVDC Brunsbüttel/ Wilster to Großgartach/ Grafenrheinfeld | 4 GW HVDC connection from Northern Germany (areas of Brunsbüttel/Wilster) to Bavaria / Baden-Württemberg (areas of Großgartach/Grafenrheinfeld) | 4000 | Integration of RES and security of supply of Southern Germany | NEP (German NDP) | 2022 | Mid-term Project | TenneT TSO;TransnetBW |
| **Internal Boundary in North-East Germany** | 240 | 380-kV-grid enhancement between Area Güstrow/Bentwisch and Wolmirstedt | 380-kV-grid enhancement between the areas Güstrow/Bentwisch and Wolmirstedt. | 1500 | This Project will help to transport the expected amount of RES to the South of Germany. It will also help to increase the technical possibility in this area to integrate the expected new Interconnectors to Scandinavia (e.g. Hansa Power Bridge or Kontek 2). | NEP (German NDP) | 2020 | Mid-term Project | 50Hertz Transmission |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Internal Boundary in North-East Germany** | 242 | Offshore Wind Baltic Sea (I) | AC grid connections connecting Offshore Wind Farms in Cluster 1 of the Baltic Sea (see German Offshore Grid Development Plan). Cluster 1 is located north east of Rügen in the German Exclusive Economic Zone. | 750 | RES connection | German Offshore Grid Development Plan | 2018 | Mid-term Project | 50Hertz Transmission |
| **Internal Boundary in North-East Germany** | 248 | Offshore Wind Baltic Sea (II) | AC grid connections connecting Offshore Wind Farms in Cluster 1, 2 or 4 of the Baltic Sea (see German Offshore Grid Development Plan). Clusters are located north east of Rügen mainly in the German Exclusive Economic Zone. | 500 | RES connection | German Offshore Grid Development Plan | 2026 | Long-term Project | 50Hertz Transmission |
| **Internal Boundary in West-Germany** | 254 | Ultranet | 2 GW HVDC-connection from the Region of Osterath (Rhineland) to the Region of Philippsburg (Baden-Württemberg). New circuit on an existing route on the same pylons as AC lines. | 2000 | Integration of RES and security of supply of South-Germany. | NEP (German NDP) | 2019 | Mid-term Project | Amprion;TransnetBW |
| **Lithuania - Sweden** | 124 | NordBalt phase 2 | This is second phase of DC interconnector between Lithuania and Sweden that will connect the Baltic grid to the Nordic and integrate the Baltic countries (Estonia, Latvia, Lithuania) with the Nordic electricity market and will also increases security of supply. Second phase includes network reinforcements in Sweden and in Lithuania to be able to fully utilize the interconnector between Lithuania and Sweden.This is PCI project. | 0 | 124 | Internal investments after 2020 in Lithuania and Sweden are needed to be able to fully utilize the 700 MW interconnector between Lithuania and Sweden. Investments include new 330 kV OHL in Lithuania and new 400 kV OHL in Sweden. The project is a key for the SoS of the Baltic states. The project helps integrating RES, especially in the Baltic states but also in the southern Sweden. | 2023 | Long-term Project | AST;LITGRID;SVK |
| **North-South** | 42 | OWP TenneT Northsea part 1 | Connection of offshore wind parks in the North Sea to Germany. Mainly subsea DC cable. The OWP will help to reach the Eropean goal of CO2 reduction and RES integration | 5750 | 42 | | 2017 | Mid-term Project | TENNET-DE |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| North-South | 126 | SE North-south reinforcements | Sweden internal line. Overhead line 400 kV. Reinforcements, both lines and stations, in and between bidding area SE2 and SE3 will accomplish RES integration in northern Sweden. | 700 | 126 | Comment on the RES integration: the project will help integrating 700-800 MW of RES in northern Sweden and Norway. Comment on the S1 and S2 indicators: the project will have a social and environmental impact but the investments are in early stages so there are no facts regarding the impact. | 2025 | Long-term Project | SVK |
| North-South | 130 | HVDC Wolmirstedt to area Gundremmingen | 2 GW HVDC-connection from Wolmirstedt to the area of Gundremmingen. Capacity extension to 4 GW is under investigation. | 2000 | 130 | | 2022 | Mid-term Project | 50HERTZ;AMPRION |
| North-South | 132 | N-S Western DE_section North_2 | New 380-kV-OHL and one DC-Link in North-West Germany for integration of RES, mainly on- and offshore wind. | 5500 | 132 | | 2022 | Mid-term Project | AMPRION;TENNET-DE |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| North-South | 133 | Longterm German RES | internal German DC-Link for RES integration | 18000 | 133 | This project becomes necessary in case of further long-term strong increase in RES generation like in Vision 3 and 4. The project is not in Vision 1 and 2. It connects areas with high installed capacities of RES and areas with high consumption and storage capabilities. For this reason the development of new North-South and Northeast- Southwest electricity transmission capacity in Germany is necessary. This project begins in the North and North-East of Germany, areas with high RES generation (planned and existing) and connections with Scandinavia (planed and existing).The project ends in the South of Germany, an area with high consumptions and connections to Austria and Switzerland (transit to Italy and pump storage in the Alps). | 2034 | Future Project | 50HERTZ;AMPRION;TENNET-DE;TRANSNET-BW |
| North-South | 134 | N-S Western DE_section South | North-South transmission Western Germany - AC reinforcements and upgrades towards the load centers of Baden-Württemberg and Switzerland | 5500 | 134 | RES integration and system stability | 2021 | Mid-term Project | AMPRION;TRANSNET-BW |
| North-South | 135 | N-S Western DE_parallel lines | Grid reinforcement between North-West-Germany and South-West-Germany to integrate RES. | 5500 | 135 | RES integration and system stability. | 2022 | Mid-term Project | AMPRION |

| Boundary | TYNDP 2016 Project Index | Project name | Description | Provisional GTC (MW) | TYNDP2014 reference (if applicable) or motivation for new projects | Detailed studies | Expected Commissioning Year | Classification | Project promoter(s) |
|---|---|---|---|---|---|---|---|---|---|
| **Poland - Lithuania** | 123 | LitPol Link Stage 2 | The LitPol Link Stage 2 is a continuation of building of the interconnection between Poland and Lithuania in order to achieve the planned transmission capacity of 1000 MW in both directions. Building of additional internal investments in Poland and Lithuania are necessary.This is PCI project. | 500-1000 | 123 | The project improves connection the Baltic States to the Continental Europe and Baltic Sea ring. The analysis shows that the project improve Security of Supply, increase ability integrating RES and avoided spillage in Baltic States and Poland. | 2020 | Mid-term Project | LITGRID;PSE |
| **Sweden (SE4)-Germany** | 267 | Hansa PowerBridge 2 | Possible second HVDC cable interconnector between southern Sweden (Bidding area SE4) and Germany (50Hertz). This project candidate is motivated by market based target capacities found in the Common Planning Studies by Regional Group Baltic Sea. | 700 | Market integration, RES integration and Security of supply | Common Planning Studies for TYNDP 2016. Possible additional internal reinforcements are not included in project cost | 2025-2030 | Future Project | 50Hertz Transmission;Svenska Kraftnät |

In addition, the following storage projects will be assessed in the TYNDP2016, all matching the EC's draft guidelines

**Table 5-1. Storage projects for TYNDP2016 assessment**

| Project name | Promoter(s) | Country | Type of storage | Maximum active power [MW] | Total storage capacity [GWh] | Expected commissioning year |
|---|---|---|---|---|---|---|
| **Muuga HPSPP** | Energiasalv OÜ | Estonia | hydro pump storage | 500 | 6000 | 2023 |
| **Kruonis pumped storage power plant extension** | Lietuvos energijos gamyba | Lithuania | Pure hydro pumping | 225 | 10,8 | 2020 |

## 5.3 Projects of regional significance

In addition to the project candidates described in chapter 5.2, there are also a large amount of national projects in the region with various drivers such as removing internal bottlenecks, enhancing security of supply, RES integration etc. These can be found in the respective national grid development plan of each TSO.

## 5.4 Reference capacities

Reference capacities should not be confused with market based target capacities under a high RES scenario. These capacities were a result of the Common Planning Studies of TYNDP2014 vision 4 and they were one basis for promoted TYNDP2016 project candidates.
The aim of the reference capacities however, is to give a common ground for comparison and assessing benefits of the different projects. Reference capacities are formed by taking into account today’s capacities and the capacity increases on the borders by taking into account mid- and long-term projects as described in chapter 5.1. Projects will be assessed based on either TOOT- or PINT-methodology and a detailed description of how this will be done with respect to the reference capacities, will be provided in the TYNDP-report.



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**Table 5-2 Reference cross-border capacities for the Assessment phase, 2020 and 2030**

| | Reference Capacities (including present situation, Mid-term and Long-Term projects but not including future projects) (MW) | |
|---|---|---|
| **Border** | **2020 Expected Progress** | **2030 Visions** |
| DE-DKE | 1000 | 1000 |
| DE-SE | 615 | 1315 |
| DKE-DE | 1000 | 1000 |
| DKE-DKW | 600 | 600 |
| DKE-PL | 0 | 0 |
| DKE-SE | 1700 | 1700 |
| DKW-DKE | 600 | 600 |
| DKW-NO | 1640 | 1640 |
| DKW-SE | 740 | 740 |
| EE-FI | 1016 | 1016 |
| EE-LV | 1600 | 1600 |
| FI-EE | 1000 | 1000 |
| FI-NO | 0 | 0 |
| FI-SE | 2300 | 2800 |
| LT-LV | 1500 | 2100 |
| LT-PL | 1000 | 1000 |
| LT-SE | 700 | 700 |
| LV-EE | 1600 | 1600 |
| LV-LT | 1200 | 1800 |
| NO-DKW | 1640 | 1640 |
| NO-FI | 0 | 0 |
| NO-SE | 3695 | 3695 |
| PL-DKE | 0 | 0 |
| PL-LT | 1000 | 1000 |
| PL-SE | 600 | 600 |
| SE-DE | 615 | 1315 |
| SE-DKE | 1300 | 1300 |
| SE-DKW | 680 | 680 |
| SE-FI | 2400 | 3200 |
| SE-LT | 700 | 700 |
| SE-NO | 3995 | 3995 |
| SE-PL | 600 | 600 |

## 5.5 Interconnection ratios

The following figures show the interconnection ratios based on the TYDNP2016 scenarios for 2020 (Expected Progress) and 2030 (four Visions).
The objective set by the European Council is to reach 10% for all Member States in 2020 and to aim at 15% for 2030 “while taking into account the costs aspects and the potential of commercial exchanges”.



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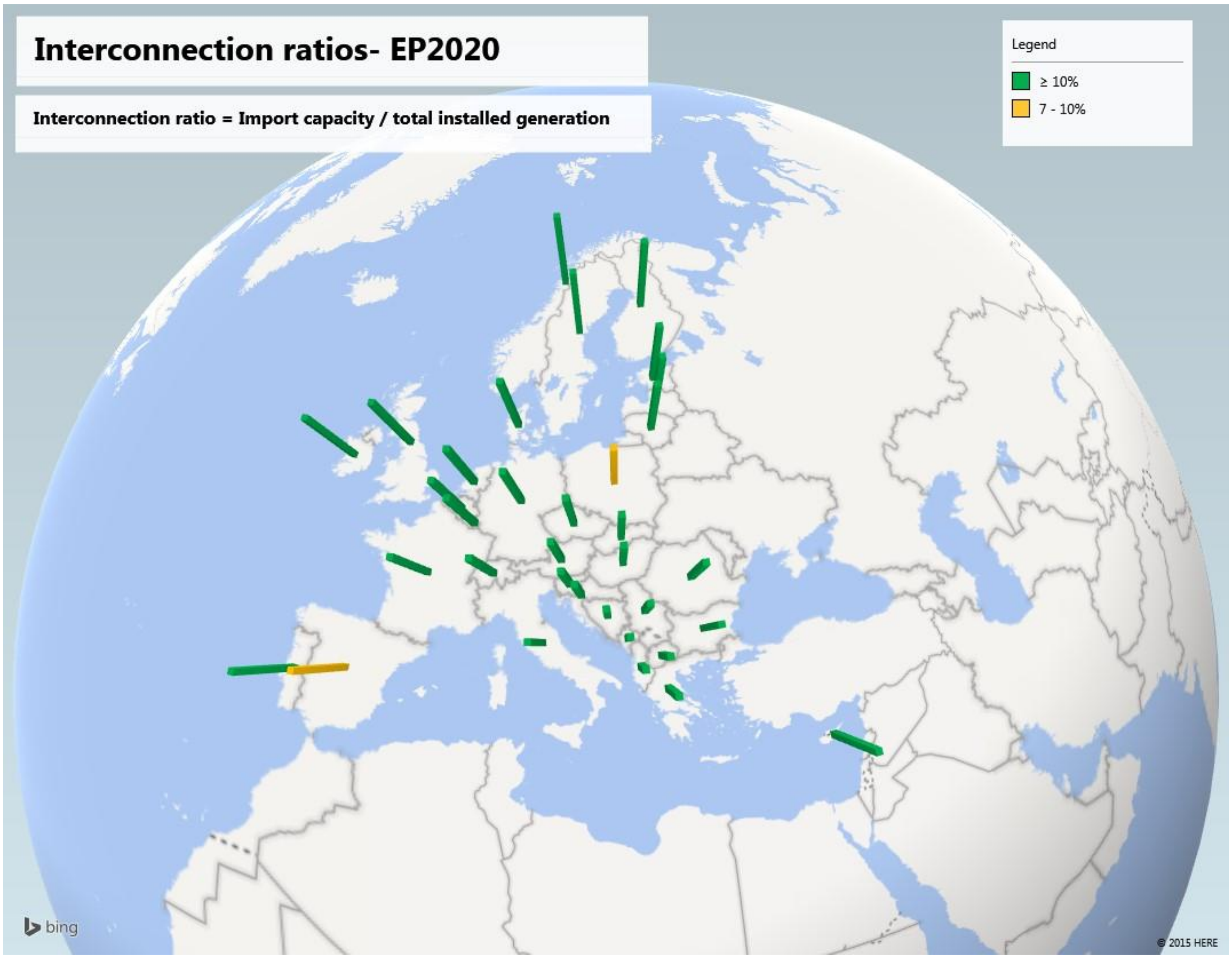


Figure 5-2 EP2020 Interconnection ratio

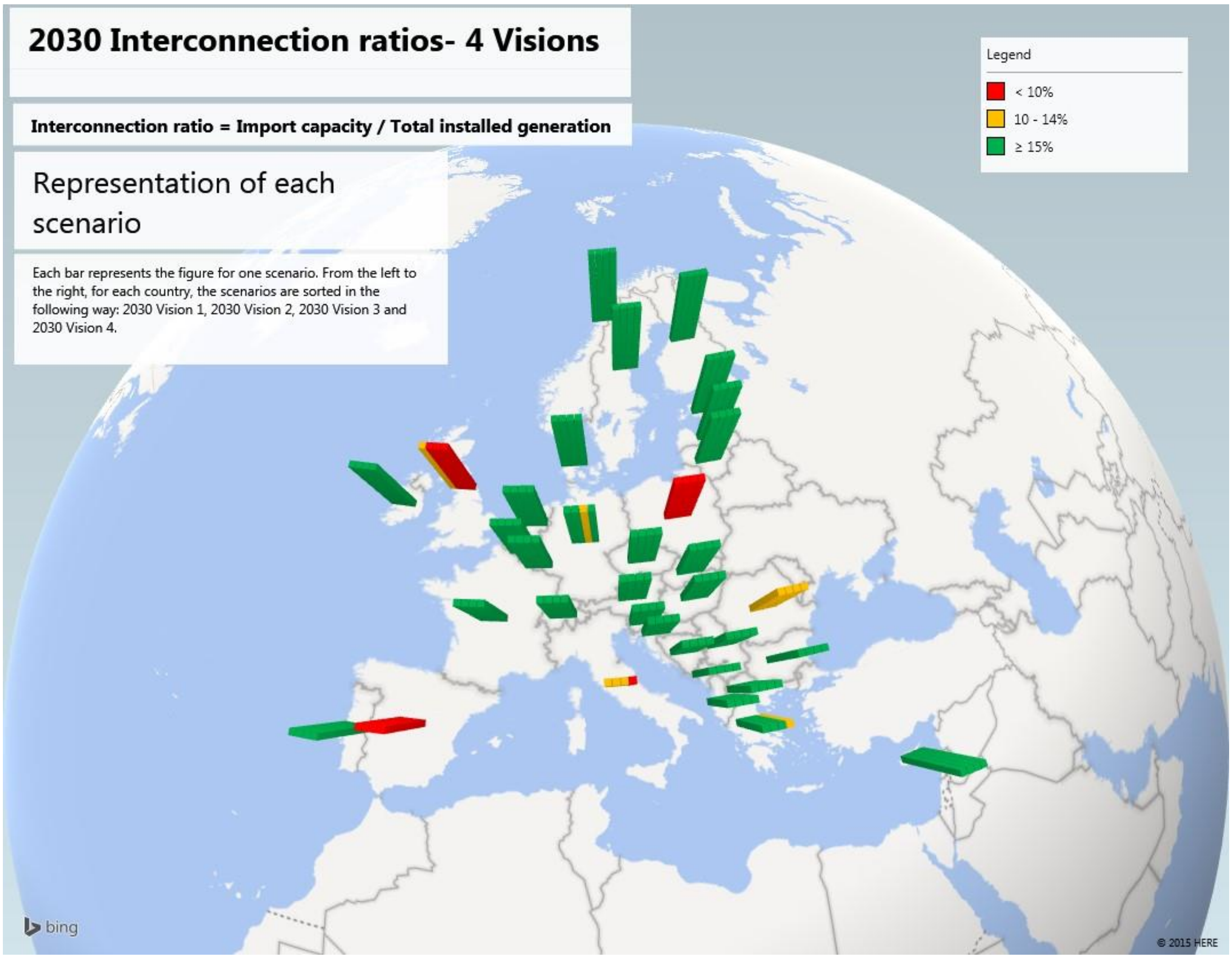


Figure 5-3 Interconnection ratio – 2030 Visions - import capacity divided by net generating capacity

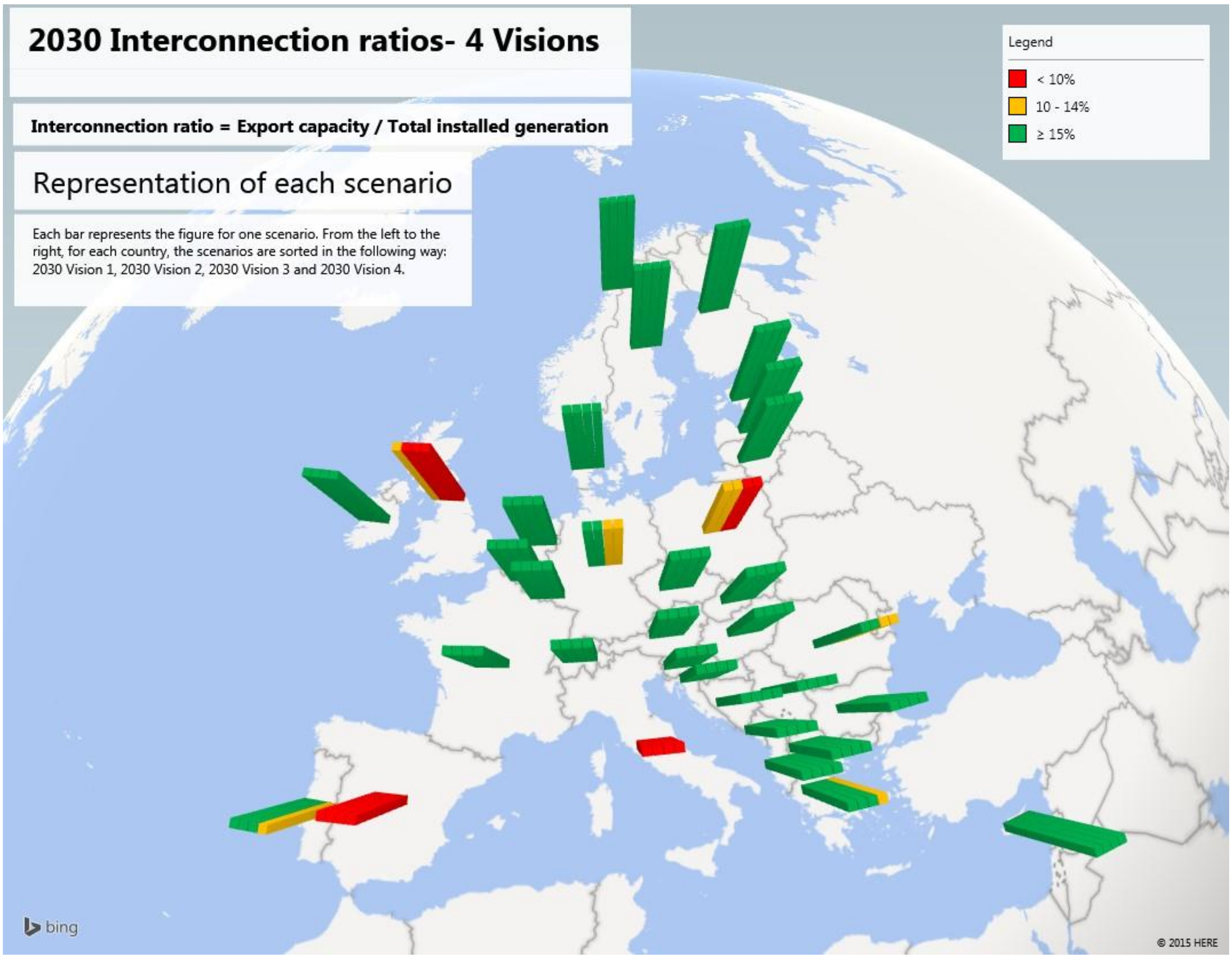


**Figure 5-4 Interconnection ratio - 2030 Visions - export interconnection capacity divided by net generating capacity**

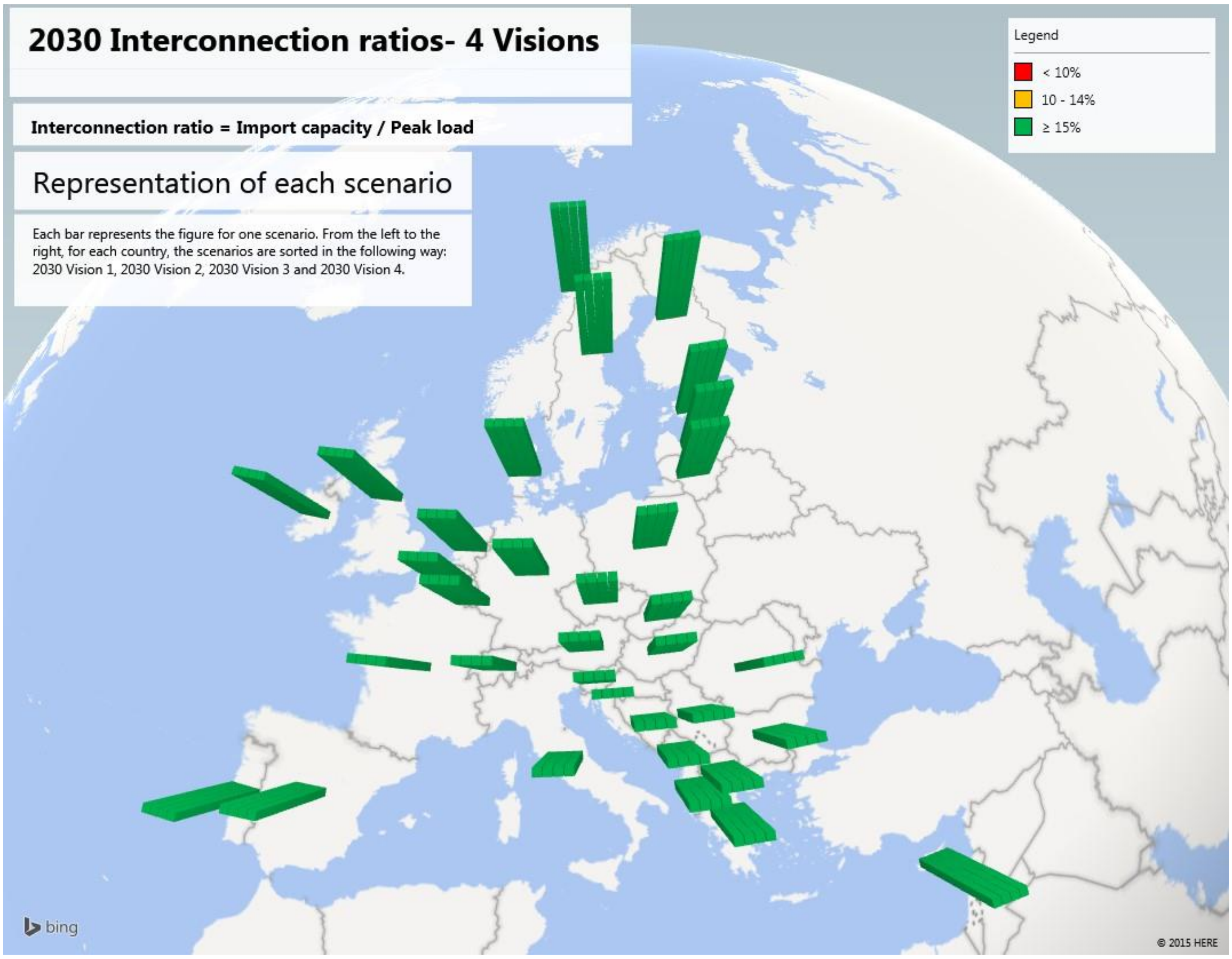


**Figure 5-5 Interconnection ratio – 2030 Visions - import interconnection capacity divided by peak load**

Three maps are presented for the 2030 interconnection ratios. These represent three different ways of defining the interconnection ratio for each country: the combined import capacity of its cross border interconnections divided by its total installed generation; the combined export capacity of its cross border connections divided by its total installed generation, and its import capacity divided by its peak load. The import and export capacities include planned mid and long term projects, but do not include future projects (those that would be commissioned beyond 2030).
Only one map is presented for the 2020 situation: this is as there is one accepted definition of interconnection ratio for the 2020 goal of 10% interconnection. This is import capacity divided by total installed generation.

## 5.6 Long term perspective, remaining challenges and gaps

When addressing the issue of long term perspective, TYNDP 2016 uses different visions in order to identify potential future outcomes. This means that the study is not to be understood as a forecast describing what will happen but rather what can happen.

In the Common Planning Study one of the visions from TYNDP 2014 was used. Vision 4 from TYNDP 2014 was selected since it is the vision from TYNDP 2014 that has the highest amount of renewable energy, leading to very high benefit of interconnectors. If the development follows the path of this vision extremely large investments in national, regional and pan-European networks will be required. A challenge to a fast and massive development of the network, often mentioned before in other studies, are permitting procedures taking long time primarily due to social acceptance and environmental protection such as Natura 2000 but also available resources for project realisation.

**The study**

The Common Planning Study consisted of two steps: in the first step, market simulations were used to identify so-called "market-based target capacities under high-RES conditions" using methods and techniques described in Chapter 0. In the second step, based on grid studies, project candidates that could meet the identified reinforcement needs, were studied.

Though the Common Planning Studies have shown potential benefits of the fifth interconnector between Denmark-West and Norway, Statnett and Energinet.dk have agreed at this stage to not nominate this interconnector as a new project-candidate for assessment in TYNDP-2016. This agreement is due to the following reasons:

- Statnett is building three new interconnectors out of southern and western part of Norway in quick succession up until 2021
    - Skagerrak 4 (2014) which is the fourth interconnector to Denmark-West
    - NordLink (2020) - a planned interconnector between Norway and Germany
    - NSN (2021) – a planned interconnector between Norway and Great Britain
- To assess further increase in capacity out of southern Norway, there is firstly a need for Norwegian investigations of internal grid challenges when implementing all these interconnectors.

An interconnector between Sweden and Poland also showed potential benefits. However, the decision by Svenska Kraftnät and PSE was not to nominate this as a new project candidate for inclusion in the TYNDP 2016. There are several reasons for this decision and the most important is that there is already two new interconnectors between Sweden and Germany included in this RegIP as well as one to Lithuania being commissioned in 2015. It is not clear if another interconnector could be connected to the already congested grid in southern Sweden. On top of this there is massive reinvestment need in the Swedish grid in the 2030 horizon including total renewal of DC –links between Sweden and Finland (Fenno-Skan 1) as well as Sweden-Denmark-West (Konti-Skan 1). When taking this into account, Svenska Kraftnät and PSE consider it as unrealistic to include another interconnector between Sweden and Poland in the RegIP.

As shown in the table, capacity additions based on market simulations do not exactly match the suggested project candidates. This is due to the chosen approach: in market simulations, reinforcements were studied in 500 MW steps in all borders, and in grid studies these capacity needs were translated into actual project candidates, where capacity depends on chosen technical solution and internal grid conditions.



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**Figure 5-6. Market-based target capacities under high-RES conditions and additional project candidates discovered in Common Planning Studies.**

| Border | Market based target capacity under high-RES conditions | Project candidates suggested for TYNDP-2016 Assessment Phase |
|---|---|---|
| SE-DE | +1000 | +700 |
| DKe-DE | +1000 | +600 |
| DKe-PL | +500 | +600 |
| NO-DKw | +500 | 0 |
| SE-PL | +500 | 0 |

# 6 NEXT STEPS

## 6.1 A two-year cycle & CBA evolvement

***Assessment methodology***

The present version of the Cost Benefit Analysis (CBA) methodology, developed by ENTSO-E in close collaboration with stakeholders and ACER, was officially approved by EC in February 2015. The TYNDP2016 assessments of projects will be carried out based on this version as required by Regulation (EU) 347/2013. The previous TYNDP2014 was already to a large extent based on a nearly final CBA methodology, and the lessons learned in this process will contribute to the TYDNP2016 process. The CBA methodology provides for a multi-criteria assessment of all TYNDP projects across a wide range of indicators as presented in the figure below.

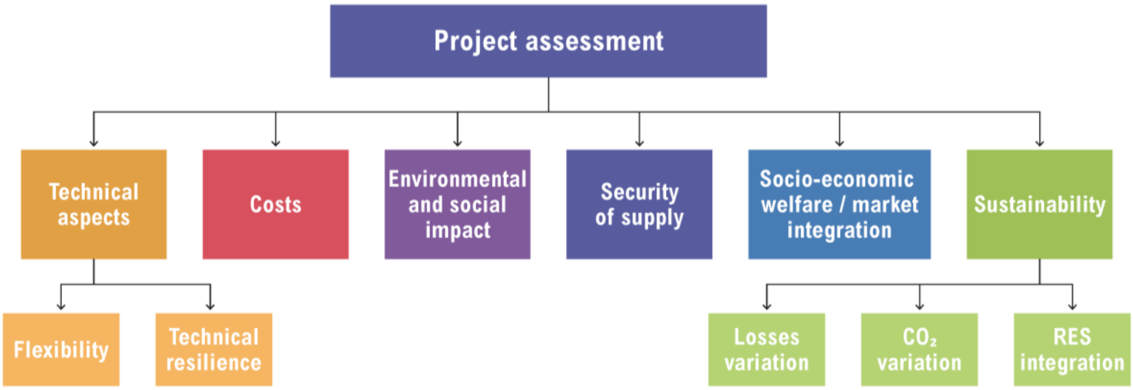



**Figure 6-1 CBA Indicators**

Even as an approved CBA methodology is ready for use in TYNDP2016, work is continuing to further improve the methodology for future TYNDPs. Several elements which are already being explored further is how storage, Security of Supply and Ancillary Services can be addressed in a transparent, objective, and European consistent manner.

In the final TYNDP2016 report, the reader can expect to see an assessment sheet for each individual TYNDP project in the following format:

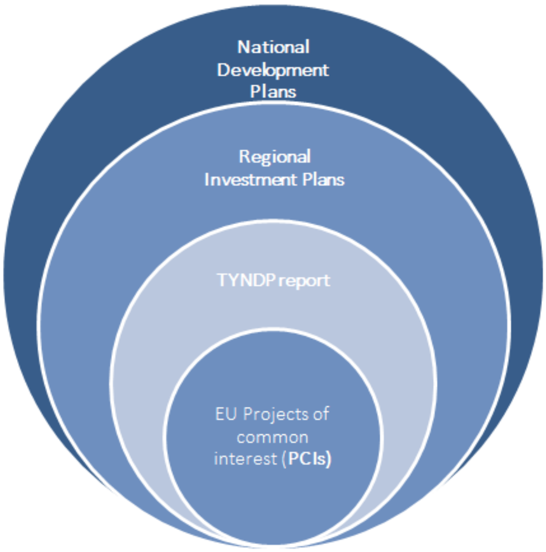
| | CBA results non specific scenario | | CBA results for each scenario | | | | | | | CBA results non specific scenario | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GTC increase - direction 1 [MW] | GTC increase - direction 2 [MW] | TYNDP scenarios | Contribution to Intercon-nection rate [%] | B1 - SoS [MWh/y] | B2 - SEW [M€/y] | B3 - RES integration [MWh/y or MW/y] | B4 - Losses [MWh] | B5 - CO2 Emiss [kT/y] | B6 – Technical Resilience | B7 – Flexibility | S1 - protected areas [km] | S2 - urban areas [km] | C1 - Estimated cost [M€] |
| Assessment results CLUSTER | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

*Scenarios*

While this set of Regional Investment Plans is being published in summer 2015, ENTSO-E recently concluded a public consultation on a proposed Scenario Development Report in May-June 2015[4]. This report proposes a set of possible futures, describing storylines, methodologies, assumptions, and resulting load/generation mixes. One best estimate scenario for 2020 and four possible contrasting visions for 2030 have been proposed. These provide the mid- and long-term horizons as referred to in the CBA methodology against which all TYNDP2016 projects will be assessed.

*Other infrastructure plans*

It is worth highlighting how the TYNDP and the Regional Investment Plans are related to national plans and EU support measures.




- National Development Plans: provided by TSOs at specific time intervals and based on (national) scenarios which not always one-to-one relate to those of the Community-wide TYNDP. These are developed according to Article 22 of Directive 2009/72/EC.

- Regional Investment Plans: developed by TSOs in ENTSO-E's cooperation structure, following Article 12 of Regulation (EC) 714/2009.

- Community-wide Ten Year Network Development Plan: a key ENTSO-E deliverable as mandated by Regulation (EC) 714/2009. It inter alia needs to build on national investment plans, taking into account regional investment plans and, if appropriate, Community aspects of network planning.

- Projects of Common Interest: Procedure set forth in Regulation (EU) 347/2013, aiming to stimulate particular infrastructure projects with direct funding, financial leverage and/or permitting streamlining. PCIs are adopted by the EC in every year in between two TYNDP publication years. To be eligible for PCI labelling, inclusion in the last available TYNDP is an explicit condition.

[4] https://www.entsoe.eu/news-events/announcements/announcements-archive/Pages/News/TYNDP-2016--ENTSO-E-calls-for-views-on-the-scenarios-report.aspx

# 7 APPENDICES

## 7.1 Detailed description of the methodology used

In chapter 2.3 General methodology, the overall process overview was described, for the readers for faster orientation and better understanding of the whole Common Planning Studies process. This chapter will describe both market and network methodologies used in more details, also with practical examples given.
The Common Planning Studies are an important part of the TYNDP2016 process. They were carried out jointly and coordinated by all regional groups of ENTSO-E for the TYNDP2014 Vision 4 model. Beside this, regional groups could carry out additional regional scenarios and sensitivities, to analyze specific impacts, issues or particularities of the regions, which they wanted to be shown in this report.

**Market modelling description of the approach**
The aim of the Common Planning Studies was to identify beneficial borders that will be increased in 500 or 1000 MW steps. Preliminary to the market studies members of the regional network-groups provided a list of costs for each possible increase and border. These costs included necessary internal reinforcements to make the additional cross-border capacity possible.
It was not necessary to specify costs for borders where new projects are not feasible. However – a good reason for why an increase of the cross-border capacity at this border is not feasible had be provided and agreed with the regional groups involved.
The following approach has been used.

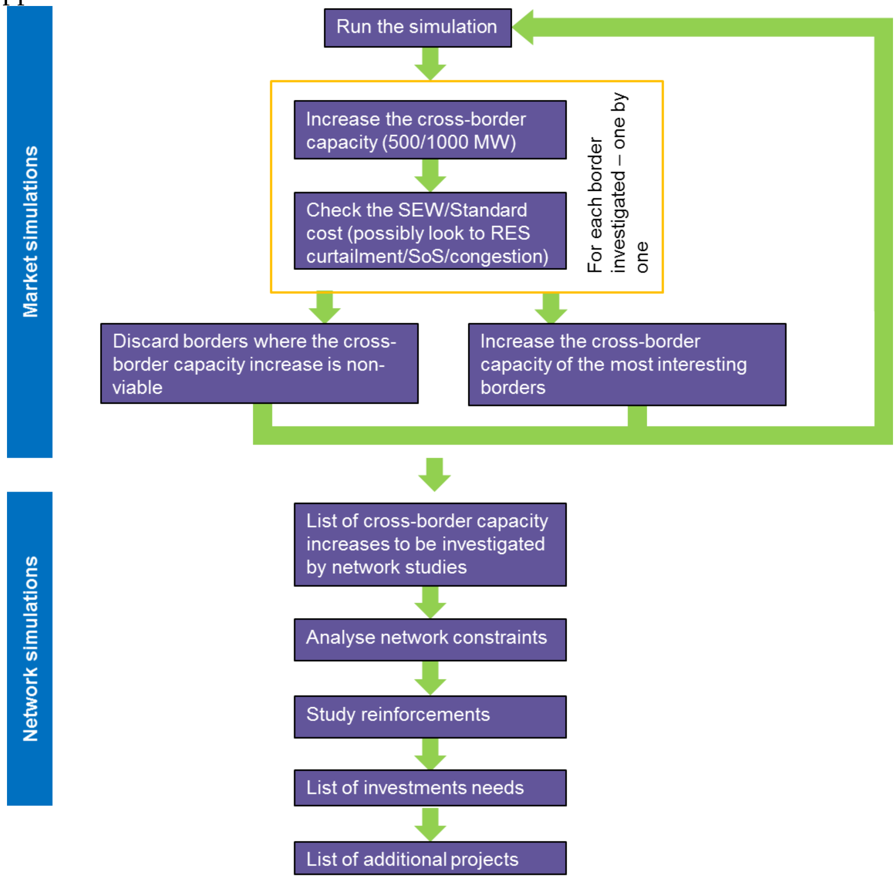



Figure 7-1 Overall overview of the Common Planning Studies process

1. The market simulation were run for the base case which was defined:
    - on the base of data used TYNDP2014 V4 2030 Regional assessment (high RES conditions),

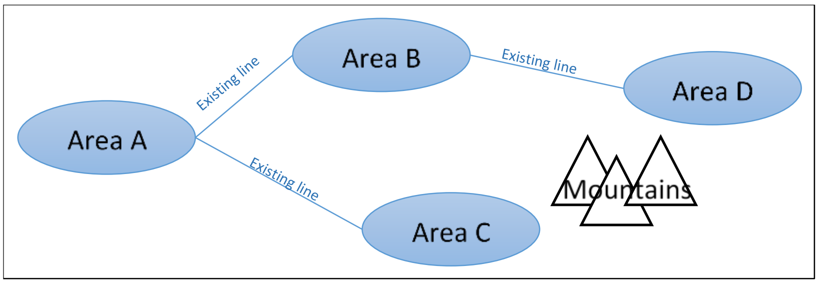
- on the base of an alignment performed by Project Group Market Modelling (PG MM) members respect the installed generation capacity and the generation profile (provided by PECD – Pan European Climate Database) for photovoltaics and wind,
- on the base of an update of the reference capacities (in order to guarantee consistency with the TYNDP 2014 projects list).

Additional details were permitted in the Regional area.

2. One market simulation was run for each border with an increased capacity of 500 or 1000 MW.
3. The socioeconomic welfare of all increases were calculated (by subtracting the SEW from the base case simulation of step 1 from each simulation of step 2)
4. The increase(s), which gave the highest SEW/cost ratio in the region ("the most interesting borders"), were put into the (new) base case
5. Some borders shown results that make further simulations and checks of these borders unnecessary. These borders could be removed from the list and were not analyzed any more in this process. However, it was needed to be careful which borders might be removed. A bottleneck can indeed move from one border to another when the border capacity is increased. It was important not to remove borders from the list too early.
6. Then the loop started again with the updated base case. Unless no more beneficial increases could be identified, process went back to step 2[5].
7. After every beneficial increases on all borders of the region were identified, the market groups could present a list of borders, which capacity should be increased and the amount of these increases (the same border can be chosen in more than one loop, increasing the capacity by 500MW each time).
8. Regional network subgroups investigated the new "target capacities" and converted these into possible project candidates.

**Practical example**

Purpose of this practical example is to visualize the above mentioned market modelling approach and process. This example assumes four market areas A, B, C and D. Areas A-B, A-C and B-D are already connected. Due to geographical constraints it is not possible to connect area C and D. To connect area A with area D is not possible either because of too large distances.




1. The network group has specified the following list of costs for increasing cross border capacity (only as example):

| Border | +500 MW (first increase of 500 MW) | +1000 MW (second increase of 500 MW) | +1500 MW (third increase of 500 MW) |
|---|---|---|---|

[5] New base case do not need to be re-calculated. This simulation has just been done!

| | | | |
|---|---|---|---|
| A-B | 100 M€ | 110 M€ | 100 M€ |
| A-C | 100 M€ | 120 M€ | 100 M€ |
| B-C | 70 M€ | 140 M€ | 200 M€ |
| B-D | 300 M€ | 300 M€ | 500 M€ |

2. The picture above shows the base case.
3. The market simulation is run for the base case.
4. Market simulations for all feasible borders (A<->B, A<->C, B<->C and B<->D) are run
5. Socioeconomic welfare are calculated for all border increases
6. Project B-C has for instance a SEW of 20 M€, giving a SEW/cost ratio of 2/7 which is the highest value of the four projects. Project B-C is put into the base case.
7. Project B-D has for instance only a SEW of 5M€ and with a cost of 300 M€ this gives a ratio of 1/60. This border is considered not necessary to be investigated further.
8. In this stage the market groups run again market simulations for all remaining feasible borders (A<->B, A<->C and B<->C) – by continuing the loop with step 4.

**Network modelling description of the approach**

This chapter describes the primary network studies performed by the regional groups during the Common Planning Studies for TYNDP2016. The aim was to simulate the impact of the increased border capacities, as simulated in the market simulations of the Common Planning Studies, on the European grid and detect the corresponding new concerns for grid development ("investment needs"). The outcome of this study was a map of internal bottlenecks in each country and a list of additional network reinforcement investments, with a brief technical description and the associated transfer capacity contribution (order of magnitude).
In the framework of the Common Planning Studies, the scope of Network Studies was to analyse, according to the market studies[6] findings, the most promising borders in terms of transfer capacity increase and identify the candidate projects which would achieve such potential transfer capacity increases in a feasible and cost efficient manner.
The work of the network studies during this phase is described below:

- The Common Planning Network Studies were based on market outputs results in each Region (8760 hours simulations).
- Duration curves were displayed directly using market study results. For example, by sorting out the hours according to exchange between 2 countries or Wind in North Sea and PV in Southern Europe. These curves were used as one of the indicators for selection of points in time.
- RG Network Studies selected a number of representative snap-shots so called points in time (PiT) within the market study outputs and PTDF (Power Transfer Distribution Factor) Matrix. For instance wind production, high market exchanges on long distances, low load, high load etc. The selection of PiT was a regional specific process, according to the regional most important parameters.
- Based on PTDF Matrix, the market data of each hour were transposed into the simplified grid represented by the PTDF Matrix. Then a PTDF flows were calculated for each of the 8736 hours and on each synchronous borders. Each synchronous are was represented through grid parameter duration curves showing loading of profiles. As mentioned above these PTDF flows were used to define detail points in time calculated by full AC load flow calculation to obtain particular line loadings together with voltage profile.
- The results of calculation were displayed on a regional map (based on a Pan European common tool), allowing possible further reinforcement identification. This map of was based on a visualisation of the combined frequency and severity of line loading (e.g. overloads).
- Project candidates with its investment items were identified based on the described process above without any preference whether internal or cross-border project.
- Expected grid transfer capacity per project candidate was appointed proceeding to load flows on already selected PiT. At this stage no detail calculation according to CBA were performed yet (carried out in assessment phase from mid 2015).

[6] The input reference capacities data of Market Studies are aligned to Vision4 TYNDP14 and projects assessed in the TYNDP14, including several updates



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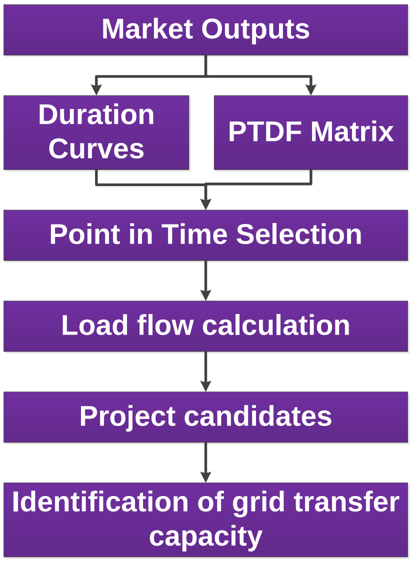


**Figure 7-2 workflow of the Network Studies during Common Planning Studies**

**Network modelling**

Network analyses were performed under the following framework:

- Network datasets used to perform network simulations: the starting point for each region was the 2030 Vision4 regional grid data set developed in TYNDP 2014 covering entire continental synchronous area.
- Models were updated according to the new projects listed in TYNDP 2014 and if relevant by other cross-border or national investment items.
- At the end of the Common Planning Studies, the network models will be updated accordingly.

**Inputs from market results**

The following detailed Market outputs from final market simulation run were required to create points in time (per country and per hour):

- Thermal generation per fuel type and efficiency
- Renewable generation sources (wind, solar, …)
- Hydro generation (pumping, turbine)
- Dump energy per country
- Demand
- Energy not supplied
- Balances
- Market exchanges on the border of the modelled perimeter (mostly HVDC connection to Northern countries or UK)

**Load flow simulations**

First of all, the main critical activities of the network simulation were an AC convergence after a PiT is implemented under the condition of scenario assumptions.

**Bottleneck identification**



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In order to evaluate the importance of bottleneck, following “FS²” criteria can be used, where:

- F: frequency of occurrence ( % of the year);
- S: severity (% of overload)

Example of calculation of FS² in N conditions for a line (based on 5 PiT, with winter and summer limits):

| PiT (N condition) | Weight (%) | F | P (MW) | Limit (MW) N condition | Overload (%) | S |
|---|---|---|---|---|---|---|
| WINTER 1 | 0,10 | 10 | 750 | 1000 | - | 0 |
| WINTER 2 | 0,40 | 40 | 1100 | 1000 | 0,10 | 10 |
| SUMMER 1 | 0,30 | 30 | 850 | 800 | 0,06 | 6 |
| SUMMER 2 | 0,15 | 15 | 550 | 800 | - | 0 |
| SUMMER 3 | 0,05 | 5 | 900 | 800 | 0,13 | 13 |
| | | | | | | |
| | FS² | 5 925 | | | | |

Figure 7-3 Workflow of the Network Studies during Common Planning Studies

The reinforcement projects:

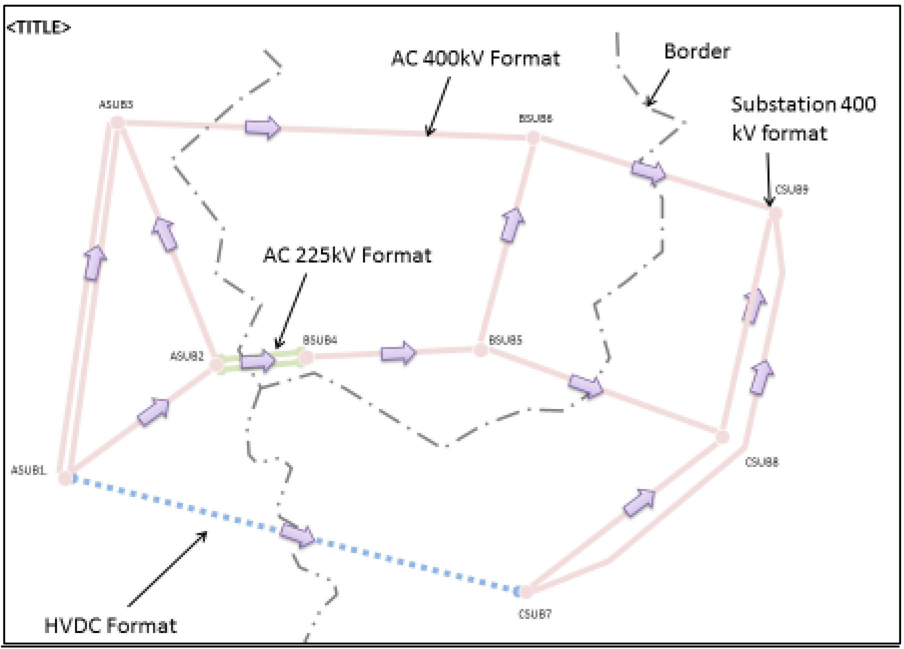
- were selected considering the severity and frequency of the bottlenecks
- considered first the border concerned by market increased target capacities

**Map representation**

*Maps to illustrate physical flows:*

Following types of map can were used:

- bulk power flow maps (e.g. percentile 95% or 80% and 5% or 20% of the cross-border yearly distribution from PTDF flows)
- map of link loadings using AC load flow calculation




*Maps to illustrate bottlenecks:*

- Map illustrating bottlenecks in N and N-1 condition, using a qualitative approach with colors, based on the results of the FS² criteria:
  - Color green = no bottleneck
  - Color yellow = occasional bottleneck in N-1
  - Color red = structural bottleneck in N-1
  - Color highlighted red = bottleneck in N

## 7.2 Detailed regional walkthrough of process

In the Baltic Sea region, the Common Planning Studies have started to identify borders, where it would be possible to increase the cross-border capacities. Figure 7-4 - Regional Baltic Sea cross-area borders investigated during Common Planning Study in the TYNDP 2016 which borders have been evaluated. As could be seen a lot of cross-borders was checked, even not very realistic ones, like very long sea-cable connections between Lithuania and Denmark or Germany. During the Common Planning Study there was carried out discussions among Baltic Region TSO’s if all such borders should be analysed even if one or both TSOs consider a project unrealistic because of different reasons. It was decided that, during the Common Planning Studies process, all borders were investigated – even the less realistic ones.

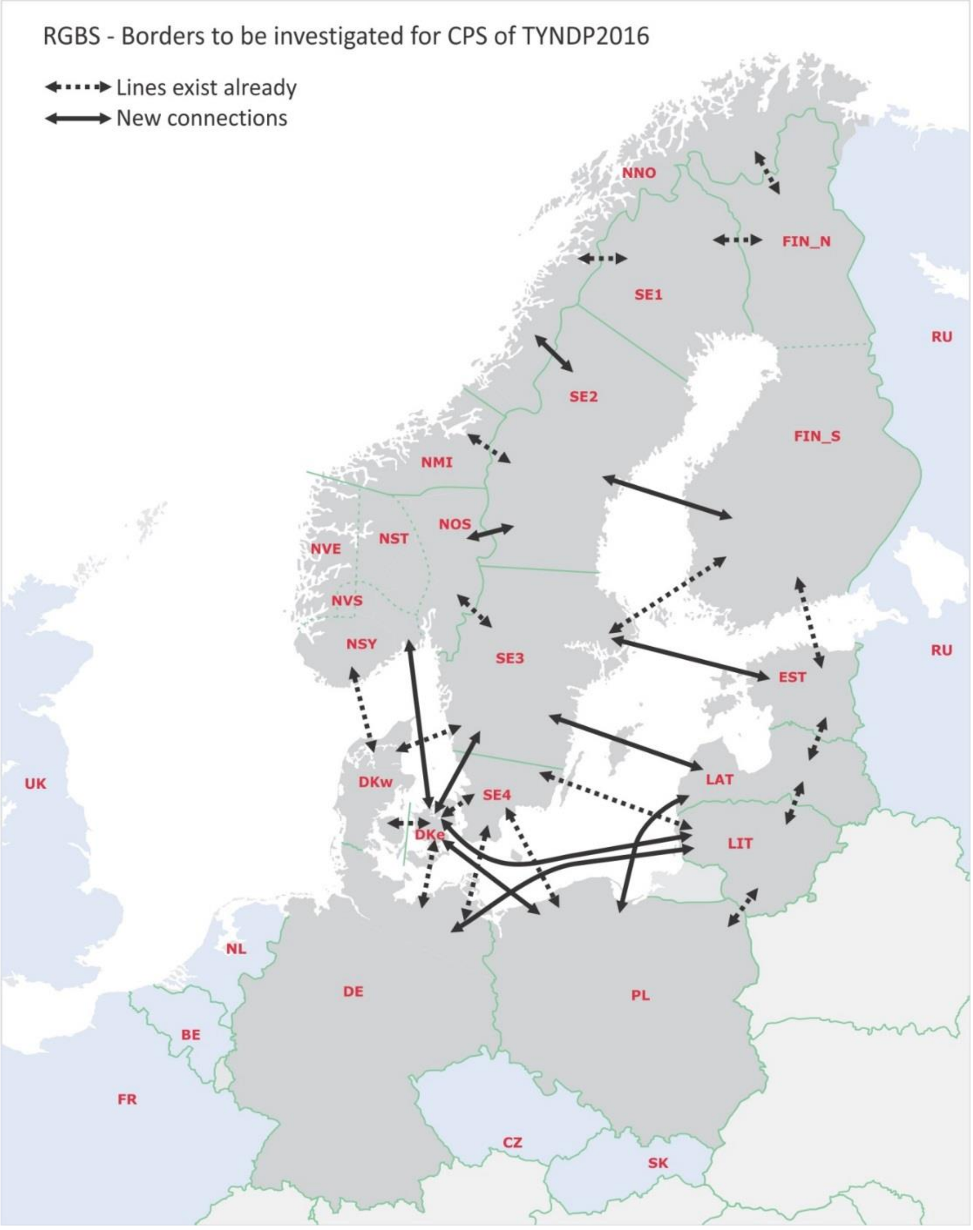



**Figure 7-4 - Regional Baltic Sea cross-area borders investigated during Common Planning Study in the TYNDP 2016**

The expert groups of RGBS followed the guidelines regarding how the Common Planning Studies should be carried out. First, four main loops of market based investigations, based on the jointly used dataset of TYNDP2014 Vision 4, have been used. Borders have been investigated one-by-one and the most beneficial ones (based on the ratio SEW/cost) have been identified. The list in Table 7-1 shows the borders investigated and the estimated costs for increasing the capacities on these borders by steps with 500 MW or with 1000 MW. The cost estimates include the investment of the interconnection itself as well as expected internal reinforcements needed but are very rough estimated based on standard component costs and expert views. Cost estimates have been updated during the process; Svenska Kraftnät has updated the estimated costs for projects from Sweden after first project SE4-DE has been identified and Energinet.dk (Denmark) has also refined the candidate project costs following the Danish grid study and introducing the multi-terminal HVDC approach.

Table 7-1. Costs pr. MW increase pr. border (rounded to nearest 50 M€)

| | Loop 1 & 2 costs (M€) | | Loop >2 costs (M€) | |
|---|---|---|---|---|
| **Border/MW increase** | **500** | **1000** | **500** | **1000** |
| DE-LT | 1500 | 2600 | 1500 | 2600 |
| DE-SE | 600 | 1150 | 600 | 1150 |
| DE-DKE | 600 | 900 | 600 | 900 |
| DKE-DKW | 250 | 500 | 250 | 500 |
| DKE-LT | 1400 | 2400 | 1400 | 2400 |
| DKE-PL | 450 | 1050 | 450 | 1050 |
| DKE-SE3 | 450 | 600 | 700 | 1150 |
| DKE-SE4 | 250 | 450 | 750 | 1400 |
| DKW-NO | 700 | 1500 | 700 | 1500 |
| DKW-SE3 | 600 | 1100 | 850 | 1600 |
| EE-FI | 300 | 650 | 300 | 650 |
| EE-LV | 350 | 750 | 350 | 750 |
| EE-SE | 1150 | 2550 | 1150 | 2550 |
| FI-SE1 | 250 | 400 | 250 | 400 |
| FI-SE2 | 500 | 650 | 500 | 650 |
| FI-SE3 | 300 | 950 | 300 | 950 |
| FI-NO | 500 | 1150 | 500 | 1150 |
| LT-LV | 100 | 150 | 100 | 150 |
| LT-PL | 800 | 1600 | 800 | 1600 |
| LT-SE | 1400 | 2100 | 1800 | 2900 |
| LV-SE | 1150 | 2550 | 1150 | 2550 |
| NMI-SE2 | 250 | - | 250 | - |
| NNO-SE1 | - | - | - | - |
| NNO-SE2 | 450 | - | 450 | - |
| NOS-SE2 | 600 | 750 | 600 | 750 |
| NOS-SE3 | 600 | 1300 | 600 | 1300 |
| DKE-NO | 750 | 900 | 750 | 900 |
| PL-LV | 900 | 1300 | 900 | 1300 |
| PL-SE | 600 | 1150 | 1000 | 1950 |



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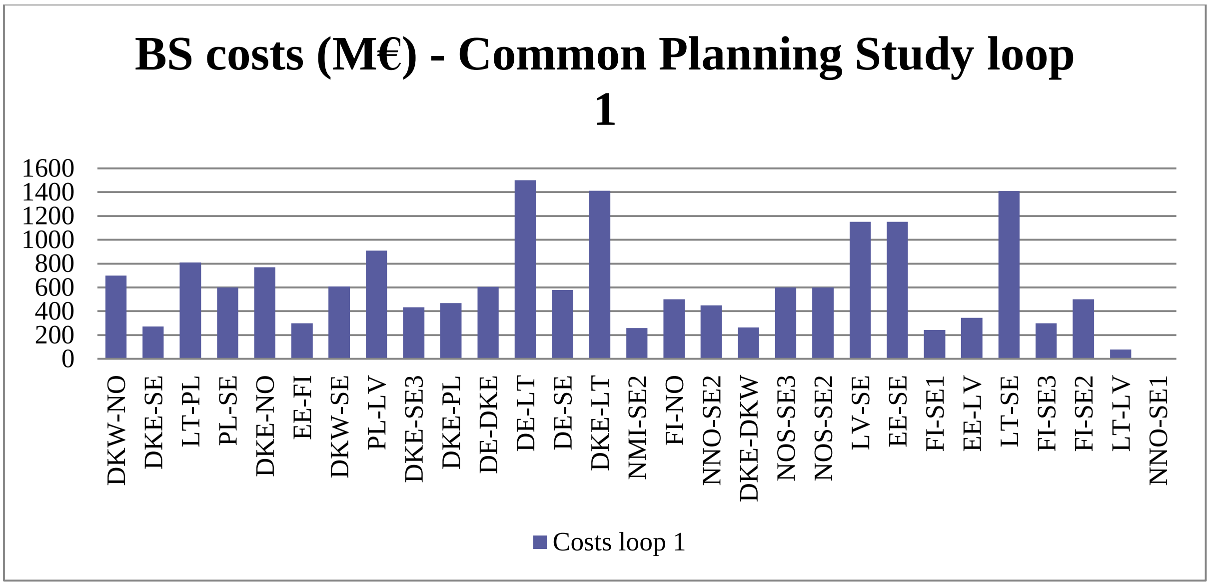


Figure 7-5 Cross-border costs after loop 1 during Common Planning Study

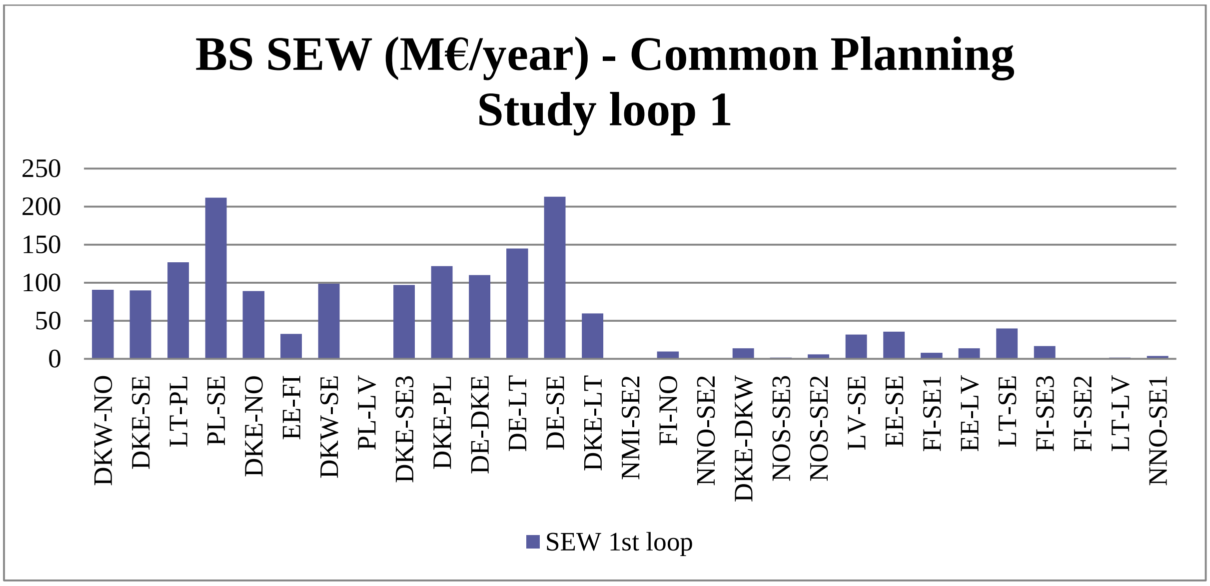


Figure 7-6 SEW values after loop 1 during the Common Planning Study

The market based target capacity increases identified this way are as follows:

Table 7-2. Market based target capacity increases identified during the Common Planning Study for RG Baltic Sea

| Round | Project candidate |
|---|---|
| 1 | SE4-DE (+500MW) |
| 1b | SE4-DE (+500MW) |
| 2 | DKe-PL (+500MW) |
| 3 | SE4-PL (+500MW) |
| 3b | NSY-DKw (+500MW) |
| 4 | DKe-DE (+1000MW) |

Svenska Kraftnät (Sweden) and (PSE) Poland both consider it infeasible to increase both the SE4-DE border and the SE4-PL border until 2030 (see Chapter 5). Because of this and since the SE4-DE increase had a higher ratio, the project candidate of SE4-PL was removed from the final list of project candidates.

For the NO-DKw border, the same is true. This border was identified to have an increased market-based target capacity in a high-RES scenario, but no project was promoted on this border. The reason for not including a project at this border is due to Norwegian constraints (see chapter 5.6).

The list of project candidates (also shown in Figure 4) for later investigations in network studies is therefore:

- SE4-DE (+1000MW)
- DKe-PL (+500MW)
- DKe-DE (+1000MW)

The market based investments needs that are needed to reach target cross-border capacity values were provided to network group experts and were based on preliminary lists of necessary network reinforcements.

Network studies were performed in order to:

- Check and approve target capacities for each border, based on market simulations;
- Find new network reinforcement projects and their costs that matches target capacities;
- Identify network bottlenecks that could arise as a result of increased power flows.

Network simulations were performed either by hourly load flow simulations, or only some hours per year (PiT - Points in Time). Selecting one or other method depends on available tools and time resources, as hourly simulations usually take much more time to evaluate, especially for large systems.

Market simulations during Common Planning Study gave hourly results about power flows between different countries and regions, as well as hourly generation and demand patterns. Those results were used for network simulations. Depending on available tools and time resources for each TSO, network simulations were conducted either hourly or only for some PiT.

For hourly simulations, data from market simulations were used, i.e. demand and generation patterns for each area/country. Then network simulations were repeated in 8760 steps, recording power flow results for normal situation and worst N-1situation for each step. For PiT simulations, the first step was evaluation of market results, and selecting the PiT where most network stressed situations were expected. Then network simulations for the selected PiT were evaluated, analysing normal and contingency situations.

Network simulations results:

- identified bottlenecks in the network;
- load flow duration curves for normal and N-1 situations, showing how many hours per year identified bottlenecks could happen;
- identified new projects and internal network reinforcements – that could remove identified bottlenecks.

Hourly simulations for network studies were performed by Denmark TSO, and PiT analyses by Swedish TSO. Norway needs to perform further studies to assess the feasibility of additional reconnection. Taking into account other planned projects in Germany, there is no additional reinforcements for the German network identified at this stage.  Poland do not need any additional network reinforcements to meet target cross-border capacity values, as previously planned reinforcements will be enough.

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**Denmark - not-project motivated for grid reinforcements**

The Danish grid study examples the common regional process of alleviation of bottlenecks in the transmission grid. The Danish grid study started with TYNDP-2014 Vision 4 – Stage 0. For Denmark-West, the grid study has identified bottlenecks due to wind power transport; the relevant wind power locations are in the north and north-west to Denmark-West. The bottlenecks have been alleviated by the internal reinforcements, in two steps. Step 1, which is the grid development from Stage 0 to Stage 1, is the grid reinforcement by a 400 kV OHL from Idomlund to Endrup. Step 2, which is the grid development from Stage 1 to Stage 2, is establishing a 400 kV OHL from Ferslev to Tjele.

Figure 7-7 presents the bottleneck alleviation process by the grid maps for Denmark-West. Before grid reinforcements there are overloaded lines; after adding two new lines, the network would be capable of sustaining increased power flows.

The process uses the N-0 and N-1 calculations on the grid model with the additional connectors been arranged into the multi-terminal HVDC system. The 95% percentiles of the transmission line loadings of the duration curves of year-round calculations are used for determination of possible bottlenecks. The transmission lines on the grid maps are marked according to the requirements: green - the line is not a bottleneck in (N-0) or in (N-1), yellow - the line is not a bottleneck in N-0 but it is in N-1 (occasional), red - the line is a bottleneck both in N-0 and in N-1 (structural).

For Denmark-West, the alleviation process has started with several lines marked in orange – occasional bottlenecks in N-1. By grid reinforcements in the right places, congested lines were eliminated and the grid map contains only green lines, which means no bottlenecks in N-0 or in N-1 situations.

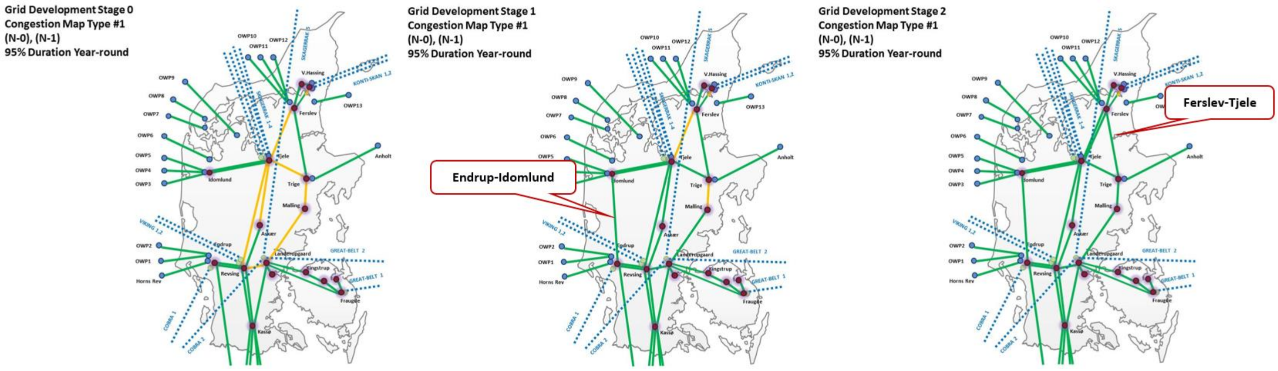


**Figure 7-7– Process of bottleneck alleviation for Denmark-West.**

For Denmark-East, no internal bottlenecks have been identified to begin with when the additional candidate projects were arranged into the multi-terminal HVDC system. No grid reinforcements have been added.

Attention shall be paid to the fact that the pre-condition for this favourable situation, i.e. only minor requirements for internal grid reinforcements in Denmark not motivated by the candidate projects, is the usage of the multi-terminal HVDC system instead of the BaU approach using the point-to-point HVDC connectors to the nearest suitable 400 kV substations. This pre-condition is explained and demonstrated in the following Section.

## 7.3 Denmark as a multi-terminal HVDC system

The regional market results have foreseen numerous additional candidate projects to both Danish price areas: Denmark-West and Denmark-East. The foreseen candidate projects and envisaged TYNDP 2014 projects will be established as HVDC connectors because the Danish grid is asynchronous to the major foreign systems. The total transport capacity of the foreseen HVDC connectors heavily exceeds the difference between consumption and generation in both Danish price areas. The last-mentioned condition implies that the Danish grid becomes a transit area between the foreign systems, and only a lower energy amount is exchanged with the Danish grid itself.

The BaU (Business as Usual) practice would be to establish connectors as point-to-point HVDC connectors to the nearest suitable 400 kV substations in Denmark. If the additional candidate projects are envisaged as BaU, the Danish transmission grid becomes heavily constrained. The severity of the grid constraints are so significant that it is pronounced unfeasible to integrate the additional connectors into the assessed development stage grid without many and costly reinforcements. Figure 7-8 presents the Danish grid bottlenecks with the point-to-point connectors.

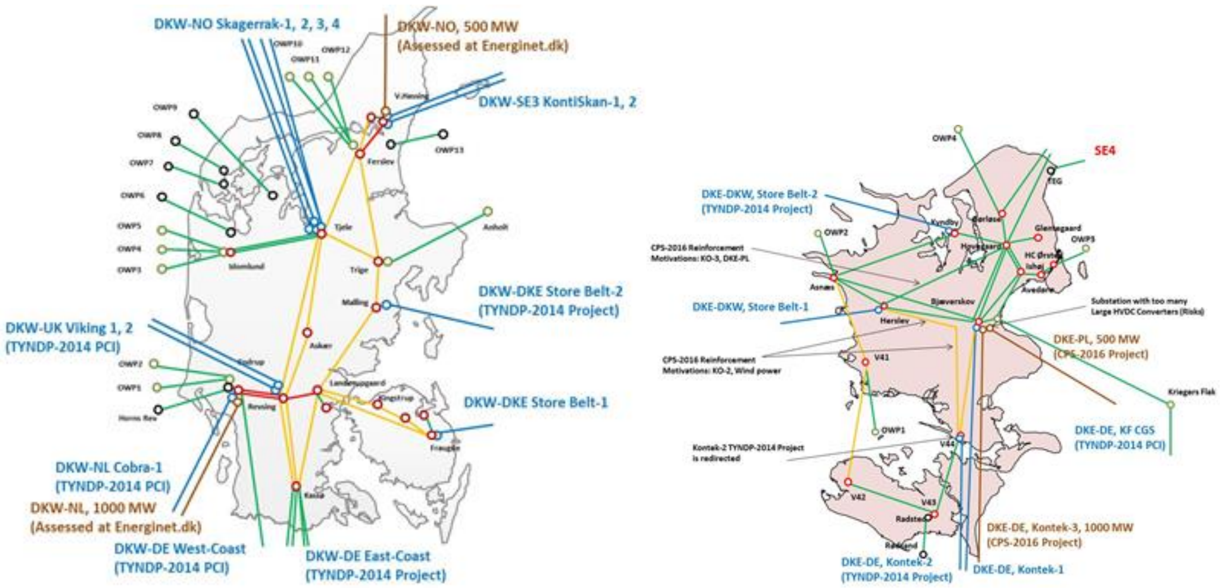


**Figure 7-8 (LEFT) – Denmark-West and (RIGHT) – Denmark-East with point-to-point HVDC candidate projects and TYNDP-2014 projects. Marking: blue –existing, planned and TYNDP-2014 projects, braun – candidate projects assessed at Energinet.dk within this Common Planning Study. Bottlenecks: Green – not bottleneck, yellow – occasional N-1 bottleneck, red – structural N-1 bottleneck, flashing red – structural N and N-1 bottleneck.**

This grid assessment result shows that integration of the additional projects calls for a new approach which shall reduce grid investments and at the same time allow full market flows throughout Denmark and the Region. The additional candidate projects and other connectors will be arranged into an overlay grid, for instance a multi-terminal HVDC system, which is above the conventional 400 kV transmission grid of Denmark, in this study. The main terms of the multi-terminal HVDC system are shortly presented here below. Figure 7-9 presents the bottleneck alleviations by means of the multi-terminal HVDC system. This result demonstrates that accurate and sufficient grid-planning efforts and search of new solutions may reduce investment into the transmission grid itself.

The energy exchange with the Danish grid means establishment and operation of the HVDC VSC stations where the energy and power flows are converted between DC and AC. Since only a lower energy amount is exchanged with the grid itself and a significant energy amount passes throughout the 400 kV grid, the number of the HVDC VSC stations can be reduced without reducing the market flows between the foreign systems through Denmark. The arriving HVDC connectors are combined into two HVDC hubs that will form the multi-terminal HVDC system in Denmark. Figure 7-10 explains the difference between conventional point-to-point HVDC connectors (BaU) and the multi-terminal HVDC system. Usage of point-to-point HVDC connectors has been a conventional method of energy and power transport between (two) asynchronous HVAC systems.

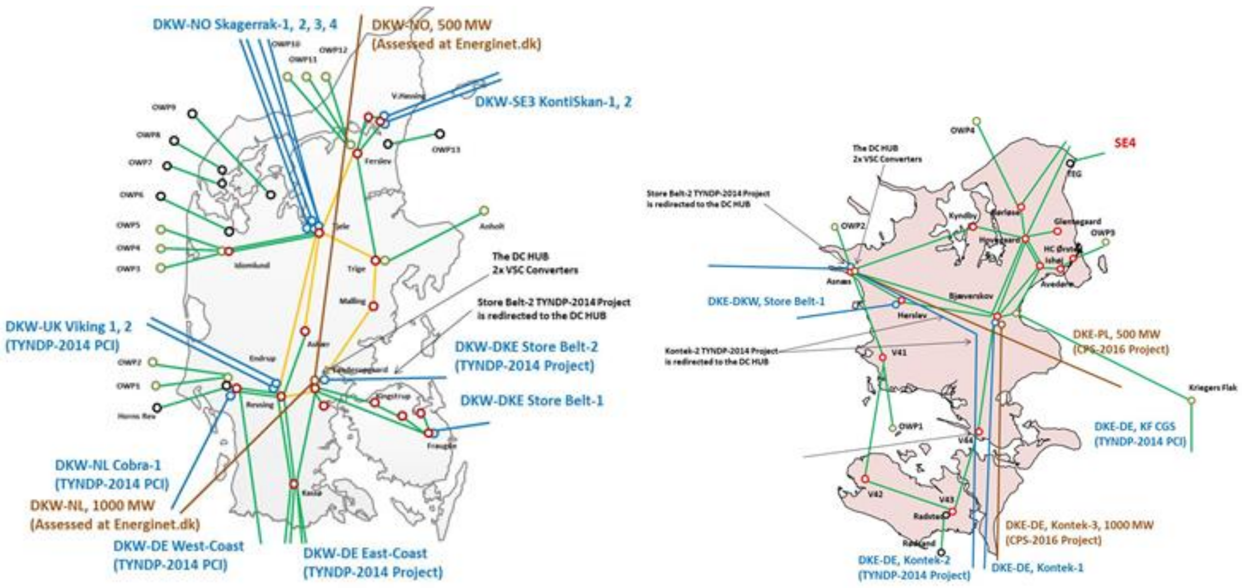


**Figure 7-9 (LEFT) – Denmark-West and (RIGHT) – Denmark-East with multi-terminal HVDC system including candidate projects and TYNDP-2014 projects. Marking: blue –existing, planned and TYNDP-2014 projects, broun – candidate projects assessed at Energinet.dk within this Common Planning Study. Bottlenecks: Green – not bottleneck, yellow – occassional N-1 bottleneck, red – structural N-1 bottleneck, flashing red – structural N and N-1 bottleneck. The occassional N-1 bottlenecks in Denmark-West are associated with wind power transport and heavy north-to-south transports throughout remaining point-to-point connectors. These bottlenecks are alleviated as explained in Section 7.2.**

The multi-terminal HVDC system utilises two fewer HVDC VSC stations in Denmark. The main drivers behind the multi-terminal HVDC system are the cost-efficiency, technical advance and reduced stress on the HVAC transmission system of Denmark. The cost-efficiency is emphasised through the fact that the multi-terminal HVDC system will need two fewer HVDC VSC stations in Denmark for facilitating the same number of HVDC connectors and the same energy and power flows with the foreign areas. The cost efficiency is proven through the assessment of the capital expenditure and the reduction of the energy conversion losses capitalized over the expected life-time of the projects. The cost reduction due to the multi-terminal HVDC system is summarised in Figure7-11.

Additional benefits of the multi-terminal HVDC system are that it requires no reinforcement investments in Denmark to facilitate the heavily increased border flows and expected reduction of the transmission losses. The transmission losses will be reduced because the losses in DC are lower than those in AC (presence of reactive power in the HVAC system causing higher losses, but not in the HVDC system).

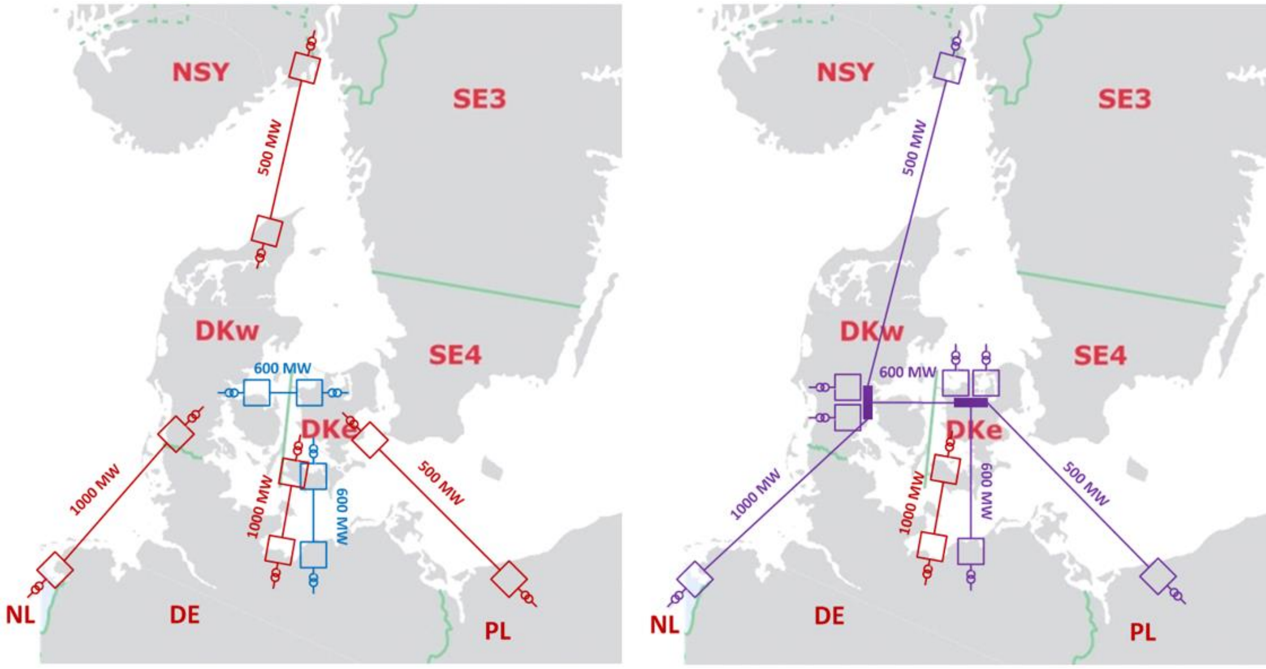


**Figure 7-10 (LEFT) – Denmark with point-to-point HVDC candidate projects and TYNDP-2014 projects uses seven HVDC VSC stations. (RIGHT) – Denmark as a multi-terminal HVDC system uses five HVDC VSC stations. Marking: blue – TYNDP-2014 projects, red – candidate projects of this Common Planning Study, violet: multi-terminal HVDC system.**

**Figure7-11 Cost reduction of the proposed multi-terminal HVDC system in comparison to establishment of point-to-point HVDC connectors in Denmark for the same energy transport with the foreign systems. Losses capitalization: 65 Eur/MWh in Denmark in average, 30 years expected life-time, 5% discount interest.**

| Multi-terminal HVDC system | Cost reduction [MEur] |
|---|---|
| Capital cost reduction<br>(Disregarding savings on internal grid reinforcements) | 185,7<br>(75,5) |
| Smaller energy conversion losses | 76 |
| Total cost reduction<br>(Disregarding savings on internal grid reinforcements) | 261,7<br>(151,5) |

The comparison has shown that the multi-terminal HVDC system will be in a range from 151,5 MEur to 261,7 MEur cheaper than conventional point-to-point HVDC connectors in Denmark at given pre-conditions of the market results. The results are indicative, volatile to energy and equipment prices as well as to other external factors beyond the scope of this Common Planning Study. The result shall be used with precaution.

It is important to state that the proposed multi-terminal HVDC system is with the two hubs on-land, and not offshore. Hence, the proposed system distinguishes itself from earlier studies about offshore HVDC Grids interconnecting countries and wind power plants over the seas. The main idea uses the same technology and general basic idea as discussed earlier in the context of offshore infrastructure considerations for bringing offshore wind power to land and interconnection of the North Seas' countries. Thus, some of the general findings above might also be translated into discussions and commercialisation of offshore grid infrastructure, but the difference in cost assumptions for on- and offshore assets has to be considered. The technology is becoming commercially available.

## 7.4 Guidelines for Project Promoters

In line with Regulation (EU) 347/2013, the EC provides a set of guidelines[7] for ENTSO-E to apply when handling all applications by project promoters for TYNDP inclusion. These guidelines ensure the same procedure, timeline and qualification criteria are used for all project promoters, and enshrine the rights and responsibilities of promoters, ACER, EC and ENTSO-E. It addresses Promoters of transmission infrastructure projects within a regulated environment, Promoters of transmission infrastructure projects within a non-regulated environment (i.e. exempted in accordance with Article 17 of Regulation (EC) No 714/2009, referred to as “merchant lines”), and Promoters of storage projects. All who aspire inclusion of their project in the PCI list in year X, need to be included in the latest available TYNDP of year X-1.

Based on the EC’s draft guidelines, and building on the experience of past TYNDPs, all promoters of electricity transmission and storage projects were invited by ENTSO-E to submit between 1 April and 30 April 2015 their application for inclusion in the Ten-Year Network Development Plan 2016.

During May 2015 ENTSO-E reviewed the data submitted in order to verify its completeness and compliance with the guidelines. Throughout May any promoter had the opportunity to complete or update its project details, and ENTSO-E was in regular contact with all promoters to ensure a smooth process. All promoters were invited to provide information via a dedicated Sharepoint platform. Ultimately it is the applicant’s responsibility to ensure the application was completed by end of May.

This procedure allowed ENTSO-E to compile a list of TYNDP project candidates which completes the picture of planning studies, regional context and investment needs sketched in the Regional Investment Plans[8]. This timely compilation of a list of TYNDP projects allows ENTSO-E to have a baseline reference architecture for CBA assessments starting in summer 2015. Any late request for TYNDP inclusion can be handled evidently in future TYNDP editions. Any request for significant change to TYNDP projects during the 2016 process will be assessed in line with ENTSO-E’s governance rules, with oversight from EC and ACER, and taking on board the role of ENTSO-E’s neutral Network Development Stakeholder Group.

The main drivers in this approach is to keep transparency over the development and updates of the TYNDP project list, and ensure clarity over the CBA assessment ‘ingredients’ (methodology, list of projects, scenarios, data).

7 https://www.entsoe.eu/Documents/TYNDP%20documents/TYNDP%202016/20150217_Guidelines_Update_ENER_TC_24.02.2015_1st%20draft.pdf

8 https://www.entsoe.eu/Documents/TYNDP%20documents/TYNDP%202016/150331_TYNDP_2016_FAQs_application_for_projects.pdf



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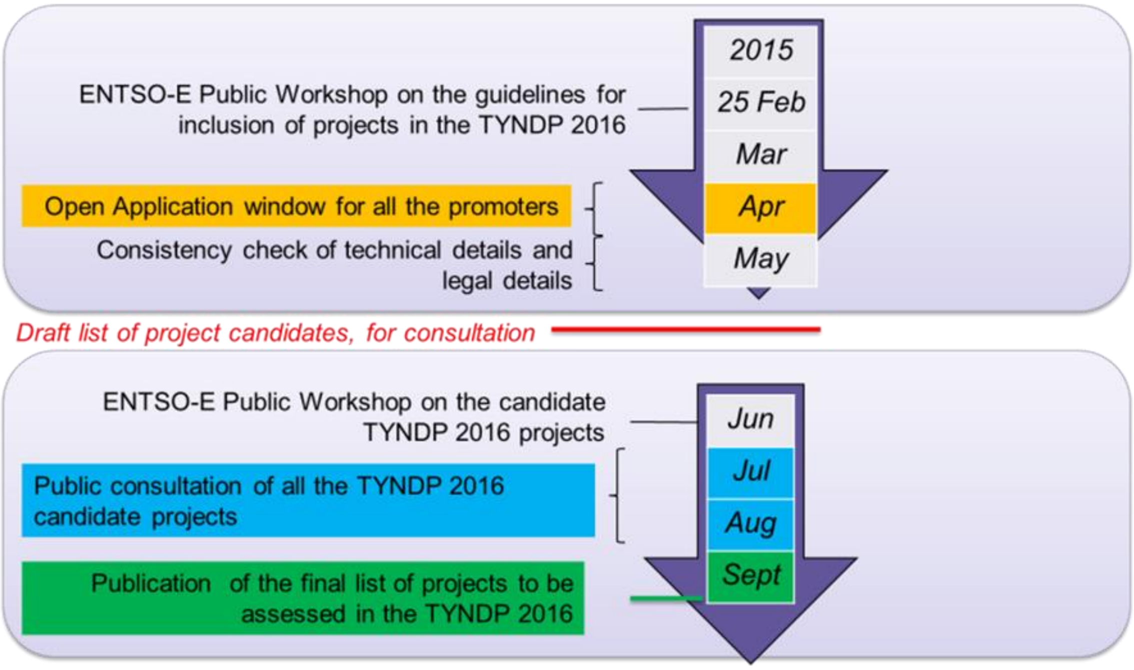


**Figure 7-12 Workplan for project promotors**

## 7.5 Abbreviations

The following list shows abbreviations used in the Regional Investment Plans 2015.

- AC Alternating Current
- ACER Agency for the Cooperation of Energy Regulators
- CCS Carbon Capture and Storage
- CBA Cost-Benefit-Analysis
- CHP Combined Heat and Power Generation
- DC Direct Current
- EH2050 e-Highway2050
- EIP Energy Infrastructure Package
- ENTSO-E European Network of Transmission System Operators for Electricity
- ENTSOG European Network of Transmission System Operators for Gas
- EU European Union
- GTC Grid Transfer Capability
- HV High Voltage
- HVAC High Voltage AC
- HVDC High Voltage DC
- IEA International Energy Agency
- KPI Key Performance Indicator
- IEM Internal Energy Market
- LCC Line Commutated Converter
- LOLE Loss of Load Expectation
- MS Member State
- MWh Megawatt hour
- NGC Net Generation Capacity
- NRA National Regulatory Authority
- NREAP National Renewable Energy Action Plan
- NTC Net Transfer Capacity
- OHL Overhead Line
- PCI Projects of Common Interest
- PINT Put IN one at the Time
- PST Phase Shifting Transformer
- RegIP Regional investment plan
- RES Renewable Energy Sources



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- RG BS Regional Group Baltic Sea
- RG CCE Regional Group Continental Central East
- RG CCS Regional Group Continental Central South
- RG CSE Regional Group Continental South East
- RG CSW Regional Group Continental South West
- RG NS Regional Group North Sea
- SEW Socio-Economic Welfare
- SOAF Scenario Outlook & Adequacy Forecast
- SoS Security of Supply
- TEN-E Trans-European Energy Networks
- TOOT Take Out One at the Time
- TSO Transmission System Operator
- TWh Terawatt hour
- TYNDP Ten-Year Network Development Plan
- VOLL Value of Lost Load
- VSC Voltage Source Converter

## 7.6 Terminology

The following list describes a number of terms used in this Regional Investment Plan.

**Congestion revenue/ congestion rent** – The revenue derived by interconnector owners from sale of the interconnector capacity through auctions. In general, the value of the congestion rent is equal to the price differential between the two connected markets, multiplied by the capacity of the interconnector.

**Congestion -** means a situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission systems concerned.]

**Cost-Benefit-Analysis (CBA)** – Analysis carried out to define to what extent a project is worthwhile from a social perspective.

**Corridors** – The CBA clustering rules proved however challenging for complex grid reinforcement strategies: the largest investment needs may require some 30 investments items, scheduled over more than five years but addressing the same concern. In this case, for the sake of transparency, they are formally presented in a series – a corridor – of smaller projects, each matching the clustering rules.

**Cluster** – several investment items, matching the CBA clustering rules. Essentially, a project clusters all investment items that have to be realised in total to achieve a desired effect.

**Grid transfer capacity (GTC)** – represents the aggregated capacity of the physical infrastructure connecting nodes in reality; it is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called “critical” domestic components. The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch; it is represented by a typical value across the year.



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**Investment** – individual equipment or facility, such as a transmission line, a cable or a substation.

**Net Transfer Capacity (NTC)** – the maximum total exchange program between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area, and taking into account the technical uncertainties on future network conditions.

**N-1 Criterion** – The rule according to which elements remaining in operation within TSO's Responsibility Area after a Contingency from the Contingency List must be capable of accommodating the new operational situation without violating Operational Security Limits.

**Project** – either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.

**Project candidate**– investment(s) considered for inclusion in the TYNDP.

**Project of Common Interest** – A project which meets the general and at least one of the specific criteria defined in Art. 4 of the TEN-E Regulation and which has been granted the label of PCI Project according to the provisions of the TEN-E Regulation.

**Put IN one at the Time (PINT)** – methodology, that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one-by-one and evaluates the load flows over the lines with and without the examined network reinforcement.

**Reference network** – the existing network plus all mature TYNDP developments, allowing the application of the TOOT approach.

**Reference capacity** – cross-border capacity of the reference grid, used for applying the TOOT/PINT methodology in the assessment according to the CBA.

**Scenario** – A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding gas demand and gas supply, gas infrastructures, fuel prices and global context occur.

**Transmission capacity** (also called Total Transfer Capacity) – the maximum transmission of active power in accordance with the system security criteria which is permitted in transmission cross-sections between the subsystems/areas or individual installations.

**Take Out One at the Time (TOOT)** – methodology, that consists of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement.

**Ten-Year Network Development Plan** – The Union-wide report carried out by ENTSO-E every other year as (TYNDP) part of its regulatory obligation as defined under Article 8 para 10 of Regulation (EC) 714 / 2009

**Total transfer capacity (TTC)** – See Transmission capacity above.

**Vision** – plausible future states selected as wide-ranging possible alternatives.



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