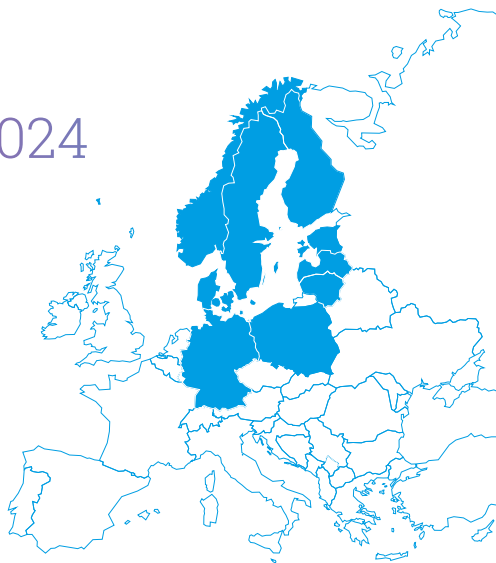


REGIONAL
INVESTMENT PLAN 2024

BALTIC SEA

June 2025



ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The **40 member TSOs**, representing 36 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the interconnected power system in all time frames at pan-European level** and the **optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources.

ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with **climate objectives** and **social welfare** in mind.

ENTSO-E is committed to using its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility**.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with **transparency** and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its **legally mandated tasks**, ENTSO-E's key responsibilities include the following:

- › Development and implementation of standards, Network Codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- › Assessment of the adequacy of the system in different timeframes;
- › Coordination of the planning and development of infrastructures at the European level (**Ten-Year Network Development Plans, TYNDPs**);
- › Coordination of research, development and innovation activities of TSOs;
- › Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

REGIONAL INVESTMENT PLAN 2024

BALTIC SEA

June 2025

How to use this interactive document

To help you find the information you need quickly and easily we have made this an interactive document.



Home button

This will take you to the contents page.
You can click on the titles to navigate to a chapter.



Arrows

Click on the arrows to move backwards
or forwards a page.



Interactive data visualisation tool

<https://www.entsoe.eu/outlooks/tyndp/2024/#SystemNeeds>



ENTSO-E Technopedia

www.entsoe.eu/Technopedia



Hyperlinks

Hyperlinks are highlighted in bold text and
underlined throughout the report.
You can click on them to access further information.

Questions?

Contact us as at tyndp@entsoe.eu



Contents

1	Executive Summary	6
2	Introduction to the Regional Investment Plans 2024	12
2.1	Scope of the RegIP 2024	14
2.2	Regional context	14
2.2.1	Overview of the region and current situation	14
2.2.2	Evolution compared to RegIP 2022	25
2.2.3	Current and expected challenges in the region	27
3	Regional System Needs	30
3.1	Regional results of the identification of system needs	30
3.2	Market results	34
3.3	Overview per indicator	34
3.3.1	RES energy surplus	35
3.3.2	Decreased CO ₂ emissions	39
3.3.3	Improved market integration and decreased average prices	42
3.3.4	How technology changes system implementation needs	45
3.3.5	Grid extension could reduce system costs	50
4	Roadmap for Addressing System Needs	51
4.1	Bridging the gap	52
4.2	How to address future challenges	55
4.3	Regional studies and initiatives	57
4.3.1	Baltic synchronisation	57
4.3.2	Baltic Offshore Grid Initiative – BOGI	60
4.3.3	Nordic Grid Development Perspective 2023	61
5	Conclusions	64
6	Appendix	66
	Appendix I: TYNDP Projects	66
	Appendix II: Regional projects	68
	Appendix III: Links to national development plans	78
	Appendix IV: Glossary	79
	Acknowledgements	89

1 Executive Summary

The electricity system in the Baltic Sea region is undergoing significant changes, as the electricity generation structure is rapidly decarbonising, and production is becoming more weather-dependent in hydro-dominant countries like Norway and Sweden. Rapid technological advances and national subsidies have accelerated the development of renewable energy in the region. The energy transition is producing more renewables and lessening the region's reliance on thermal power plants. These developments reduce carbon dioxide emissions but also increase the risk of adequacy issues in parts of the region, as identified in the past European Resource Adequacy Assessments (ERAAs). Simultaneously, society's dependency on electricity is increasing. As a result, the power systems of the future will be expected to provide even greater reliability to safeguard the vital functioning of society.

Large quantities of new renewable energy generation are still being planned across the region. These resources must be integrated successfully, while also maintaining the security of supply and facilitating an efficient and secure European energy market. The integration of renewables will further replace production from thermal power plants. The grid needs to facilitate flows to cover the deficit at load centres caused by the closure of power plants and the growing flows between synchronous areas. To solve load balancing and power generation challenges in all parts of the region, further grid development is necessary. The prospects for such development are favourable. The main driver for the region's energy system is the green energy transition, followed by climate and decarbonisation goals. Figure 1 presents the most important drivers from a grid development perspective, along with a map of the Baltic Sea region.

Drive of development in the Baltic Sea region

1. Rapid expansion of offshore wind
 - › Offshore infrastructure needed
2. Need for flexibility
 - › Further integration between synchronous areas
3. Integration of onshore renewables
 - › Increased north-south flows
4. Electrification/new consumption
 - › Reinforcing the grid
5. Baltic integration
 - › Improved security of supply for the Baltic system
6. Nuclear and thermal decommissioning
 - › Security of supply challenges
7. Smart sector integration and flexible loads
 - › Optimising decarbonisation
8. Accelerated transition due to current geopolitical developments

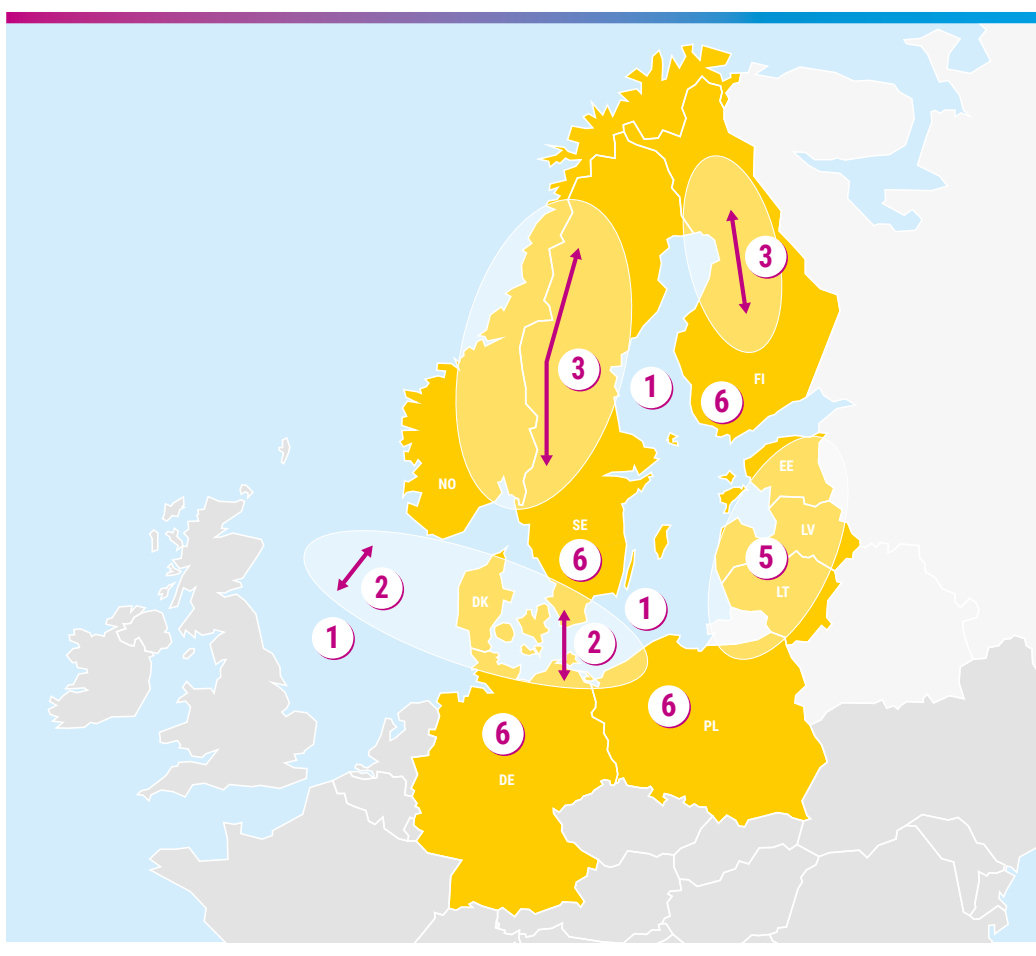


Figure 1: The most important drivers for the Baltic Sea region through 2050

— Driver 1:

Rapid expansion of offshore wind → Offshore infrastructure needed

The Baltic Sea area has significant potential for offshore wind development due to shallow waters and favourable wind conditions. The political goals of the European Union (500 GW by 2050), combined with good offshore wind prospects, have inspired high ambitions among many countries around the Baltic Sea. However, the potential for energy generation may exceed consumption needs. Sweden has even largely downscaled its offshore wind ambitions. Nevertheless, a planned and coordinated offshore wind development in the region would be wise. Strong coordination among the countries around the Baltic Sea in developing offshore infrastructure would be highly beneficial. Transmission system operators (TSOs) have established the Baltic Offshore Grid Initiative (BOGI) group for this purpose. An expansion of offshore and onshore infrastructure is necessary to integrate this energy source into the system and deliver energy to the main demand centres. Both the member states and TSOs of the Baltic Sea region have started forming the first cooperative platforms to accelerate offshore wind development within the Baltic Sea region. This also meets the requirements of the Trans-European Networks for Energy (TEN-E) Regulation, which asks ENTSO-E to publish an Offshore Network Development Plan (ONDP) for five sea basins, including the Baltic Sea. The first ONDP of the Baltic Sea¹⁾ was published in January 2024.

— Driver 2:

Need for flexibility → Further integration between synchronous areas

The transformation of the European power system is leading to a less flexible generation mix. However, the Nordic system will continue to be relatively flexible due to its hydro-dominated generation mix. In addition, the Nordic system might increase its annual energy surplus due to plans for new generation. Both the need for flexibility and the expected price differences between the systems will be drivers for the further integration of synchronous systems. In continental low wind situations, energy might be exported from the Nordic system, whereas in continental sunny and high wind situations, power might be imported and stored in the hydro-dominated Nordic system. Hybrid solutions may also integrate offshore wind energy. These factors are drivers for further integration towards other synchronous areas, like the continental system or the UK.

— Driver 3:

Integration of onshore renewables → Increased north–south flows

Based on the political goals of reduced CO₂ emissions and the cost development of wind and solar generation units, further integration of onshore renewables in the entire region is a significant driver. Especially in Germany, large amounts of solar energy are already being produced, and further increases are expected in the region overall. In Germany, Denmark, and Sweden, large amounts of onshore wind are already integrated, and development of onshore wind generation is increasing significantly in the Baltic states, Finland, and Poland. New interconnectors to the continent/Baltic states, in combination with these substantial amounts of new renewable generation capacity, are increasing the need to strengthen north–south transmission capacities in Germany, Sweden, Norway, Finland, and Denmark. In addition, Germany's nuclear phase out and the general decommissioning of thermal plants will further increase capacity needs in the north–south direction.

1) [ENTSOU-E TYNDP 2024 Sea-Basin ONDP Report – BEMIP Offshore Grids](#)



Driver 4:

Electrification/new consumption → Reinforcing the grid

To meet EU climate goals, the European energy system must become significantly more efficient. This will require more efficient and decarbonised energy use in industry, transport, and households, as well as solutions for lowering energy consumption. As a result, Europe's total energy demand should decrease. Electrification of all kinds of consumption will play a major role in this transformation to a more efficient and decarbonised system. In addition, new types of consumption, such as data storage, will increase electricity consumption. Over the coming decades, energy consumption is expected to decrease, while electricity consumption is expected to increase as more sectors shift to electricity. This increased electricity consumption and electrification will require considerable grid reinforcements.

Driver 5:

Baltic integration → Improved security of supply for the Baltic system

For historical reasons, the electricity system of the Baltic states has been operated synchronously with the Russian and Belarussian electricity systems (the Integrated Power System/Unified Power System (IPS/UPS) system). In recent years, significant progress has been made in integrating the Baltic countries with the European energy markets. The Baltic countries are now connected to Finland, Sweden, and Poland via high-voltage direct current (HVDC) connections, improving electricity market liquidity through deeper integration with the Nordic wholesale energy market, Nord Pool.

The three Baltic TSOs have long been preparing to desynchronise from IPS/UPS and instead synchronise with the Continental European Network (CEN) through the existing interconnection between Lithuania and Poland. This goal was met in February 2025, when the Baltic states switched to synchronous operation with Continental Europe (CE). In addition, a new HVAC double-circuit three-phase 220 kV land cable connection (the Harmony Link) is planned between Lithuania and Poland to support cross-border trade between CE and the Baltic states and improve security of supply. As a result of the Ukrainian conflict, work on the project was accelerated due to a high risk of sabotage to the critical infrastructure elements in the Baltic states.

— Driver 6:

Nuclear and thermal decommissioning à Security of supply challenges

Nuclear power plants in Germany have been decommissioned over the last 10 years. Additionally, several coal power plants have been decommissioned in the Baltic Sea area and the rest of Europe. In the next decade, most thermal power plants (except gas) are expected to be decommissioned as well. This is needed to achieve the EU's climate targets. The decommissioned power plants are to be replaced by renewables like solar and wind, which do not have the same system protection capabilities. This leads to security of supply challenges, including those related to low wind/sun/temperature periods, balancing the system, and the power system dynamic. Nuclear and thermal power are important in today's system, and a phase out will require new generation capacity, grid development, and further development of system services.

— Driver 7:

Smart sector integration and flexible loads à Optimising decarbonisation

Sector integration, demand-side response and flexible loads are critical for cutting emissions cost-effectively, while also replacing some of the system skills lost due to thermal and nuclear decommissioning. Smart sector integration (SSI) seeks the optimal solution for the overall energy system, supporting a fast and cost-optimised path to zero emissions by 2050. Electricity would be used directly in sectors such as transportation, industry, and for heating buildings, or indirectly to produce green hydrogen. Hydrogen can in turn be used directly for transportation, heating, and even power generation – for example, during hours of scarcity – or to produce methane, fuel, ammonia, or more. The benefits of SSI arise from the variable character and falling costs of wind and solar power. In addition to cutting emissions cost-effectively, SSI provides the flexibility to employ various energy systems, which leads to increased security of supply. Flexible loads and demand side response will help optimise the dimensioning and operation of the power system. Flexibility markets may be used in the future to solve system bottlenecks.

— Driver 8:

Accelerated transition due to current geopolitical developments

In 2022–2023, Europe, like the rest of the world, experienced an energy crisis. Energy carriers were already paying high prices before Russia invaded Ukraine. The Baltic Sea region is more dependent on Russia than most other regions in Europe. The long-term effects of the current situation are not yet known, but geopolitics and energy independence are expected to be crucial themes in decision-making. Improving security of supply in the region, accelerating the transition to renewables, and diversifying power production are key topics of discussion. In general, the current geopolitical development has accelerated the transition towards a climate-neutral energy system and society.



Future capacity needs

The drivers described above are the basis for further grid development. Short-term grid development needs can be studied by analysing the current measurements, trends, generation plans, and expected consumption changes. Grid infrastructure is a long-term investment, with a lifetime of decades. Building a new line, for example, can take 10 years or longer, particularly when factoring in planning and permitting. Therefore, it is important to consider the benefits of new infrastructure in the long term. It is not meaningful to try to forecast the future as “one truth”, because small changes, such as in policies or fuel prices, can have major impacts.

The European Climate Law sets an ambitious path towards decarbonisation, with an intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. The Fit for 55 Package and REPowerEU Plan will fast-forward the energy transition to carbon neutrality at a much greater scale with the increase of renewable energy and energy efficiency targets for 2030. The rapid replacement of fossil-fuel generation by renewable energy sources (RES), including the replacement of the Russian gas supply after February 2022, greater electrification of other sectors, improved energy efficiency, the development of new technologies (such as storage systems, electrical vehicles, etc.) and the interlinking of various energy sectors (hydrogen technology, power-to-X (P2X), etc.) will be key.

Input Section

2 Introduction to the Regional Investment Plans 2024

The Regional Investment Plans (RegIPs) developed by ENTSO-E offer a comprehensive regional analysis of key findings from the TYNDP, highlighting regional specificities while ensuring coordination across Europe. RegIPs may also include studies performed by TSOs at the regional level.

The RegIPs are published in accordance with Regulation (EU) 2019/943 (Articles 34 and 48), which mandates regional cooperation among transmission system operators (TSOs) within ENTSO-E and requires their biennial publication. TSOs may also use these plans to inform investment decisions.

In developing the RegIPs, ENTSO-E incorporates crucial elements of the TYNDP, including the [ONDP](#), [Scenario Report](#), and [System Needs Study](#). TYNDP scenarios outline potential European energy futures up to 2050, serving as a tool to evaluate prospective electricity and gas infrastructure needs and projects. These scenarios form the foundation for the RegIPs, illustrating the future challenges faced by each region. The System Needs Study examines opportunities to improve the system over the mid- and long-term time frames. The RegIPs then further analyse capacity enhancements identified in the System Needs Study at both the regional and national levels, providing detailed insights into infrastructure development needs. Finally, the ONDP assesses the need for offshore transmission infrastructure to integrate RES in alignment with Member States' targets.

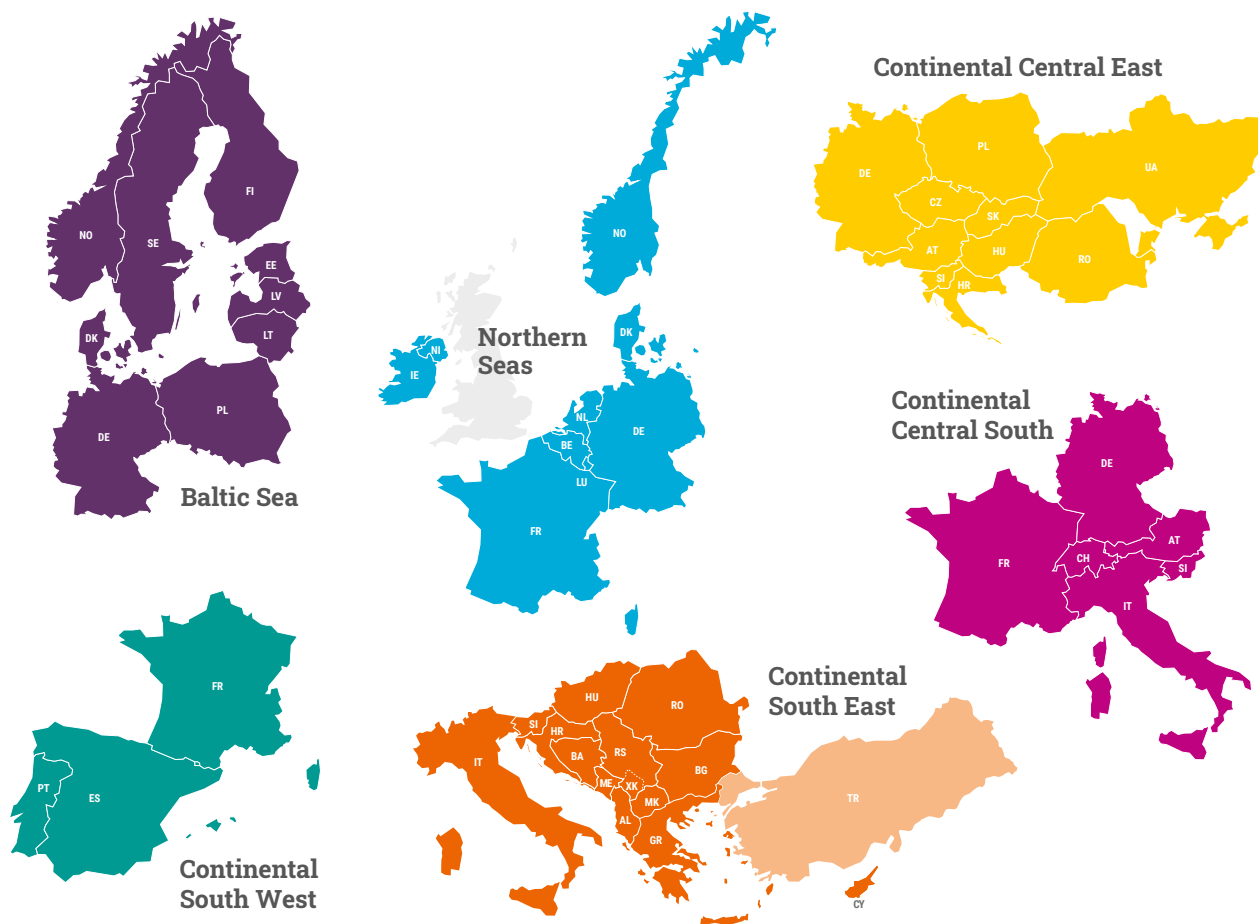


Figure 2: ENTSO-E's six system development regions, each region is covered by one RegIP

2.1 Scope of the RegIP 2024

RegIPs describe the current situation in each region as well as future regional challenges, considering 2030, 2040, and 2050 time horizons. The RegIP 2024 also investigates solutions that could help mitigate future challenges and offers projections for internal network reinforcements. In addition, this edition of the plan includes a study roadmap for the region, laying out ongoing and future studies that cover the priorities stemming from the pan-European TYNDP system needs analysis.

The present document comprises the following chapters:

Chapter 1 presents the key messages and significant drivers relating to the Regional Group Baltic Sea.

Chapter 2 outlines the legal requirements and scope of the RegIPs and presents an overview of the region's current situation, including regional context, challenges, and general overview.

Chapter 3 expresses regional system needs, with a detailed overview of each indicator.

Chapter 4 is dedicated to the roadmap to address system needs – with an emphasis on future challenges, bridging the gap to meet future needs, and additional regional studies to supplement system needs.

Chapter 5 presents the overall conclusions of the report.

Several **Appendices** include projects of regional importance and other supplemental information.

2.2 Regional context

This section presents the regional context of the Baltic Sea region, with an overall description of the region and an overview of the current power system situation in the Baltic states, Nordic countries, and part of CE – Poland, Germany, and part of Denmark. It reviews the transmission grid, power generation, and power consumption and power flow exchanges of the Baltic Sea regions. In addition, the most significant grid constraints among the Baltic Sea Regional Group countries are highlighted.

2.2.1 Overview of the region and current situation

The Baltic Sea Regional Group, under the scope of the ENTSO-E System Development Committee, is among the six regional groups that have been set up to cover short- and long-term transmission grid planning and system development tasks. The group has been working actively since 2010, with strong cooperation among the TSOs that has improved from year to year. The nine countries in the Baltic Sea Regional Group are shown in Figure 3.

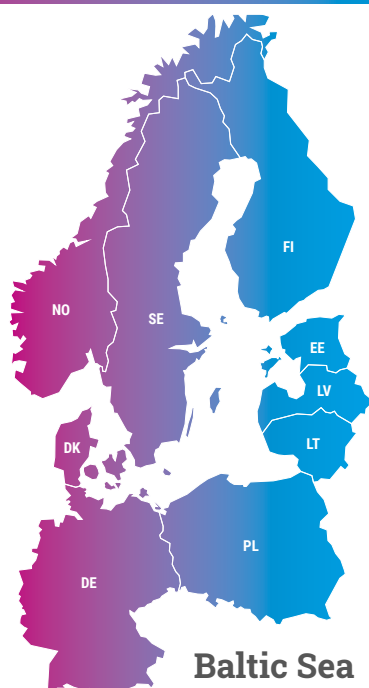


Figure 3: Baltic Sea region countries

Country	TSO
Denmark (DK)	Energinet – Energinet
Estonia (EE)	Elering – Elering AS
Finland (FI)	Fingrid – Fingrid Oyj
Germany (DE)	50Hertz – 50Hertz Transmission GmbH Amprion – Amprion GmbH TenneT DE – TenneT TSO GmbH TransnetBW – TransnetBW GmbH
Lithuania (LT)	Litgrid – Litgrid AB
Latvia (LV)	AST – AS Augstsprieguma tīkls
Norway (NO)	Statnett – Statnett SF
Poland (PO)	PSE – Polskie Sieci Elektroenergetyczne S.A.
Sweden (SE)	Svenska Kraftnät – Svenska Kraftnät

Table 1: ENTSO-E RGS members and guests

Within the Baltic Sea region are two separate synchronous systems: the Nordic power system and the CE power system, along with the Baltic states power system, which recently desynchronised from the IPS/UPS system (Russia and Belarus) and joined the CE power system. Note that Denmark is divided between two synchronous areas: Denmark-East, which is part of the Nordic system, and Denmark-West, which is part of the CE power system. Figure 4 presents the connections by voltage level and number of lines. The map provides a simple visualisation of the number of interconnections and voltage levels per cross-border link, without showing the precise geographical location of interconnectors.

Since 9 February 2025, the Baltic states have been operating in one common synchronous area along with the CE power system. The synchronisation project started on 28 June 2018, when the president of the European Commission, Jean-Claude Juncker, along with the heads of state or government of Lithuania, Latvia, Estonia, and Poland, agreed on a political roadmap for the synchronisation of the Baltic states' electricity networks with the CE network via Poland, with a target date of the end of 2025. In line with that political roadmap, the BEMIP High-Level Group (senior-official level) on the synchronisation project agreed on 14 September 2018 on the technical and economic feasibility of the synchronisation option. It will consist of the existing double-circuit, alternating-current line between Poland and Lithuania (LitPol Link), complemented by the construction of an onshore AC 220 kV link, together with other optimisation measures, including synchronous condensers. Since the 2022 start of the war in Ukraine, there has been political motivation in the Baltic states to desynchronise from the IPS/UPS system and synchronise with the CE system as soon as possible. Therefore, in 2023, the political decision was made to accelerate synchronisation with CE at the beginning of 2025. The detailed status and progress of the Baltic synchronisation project is described in Chapter 4.

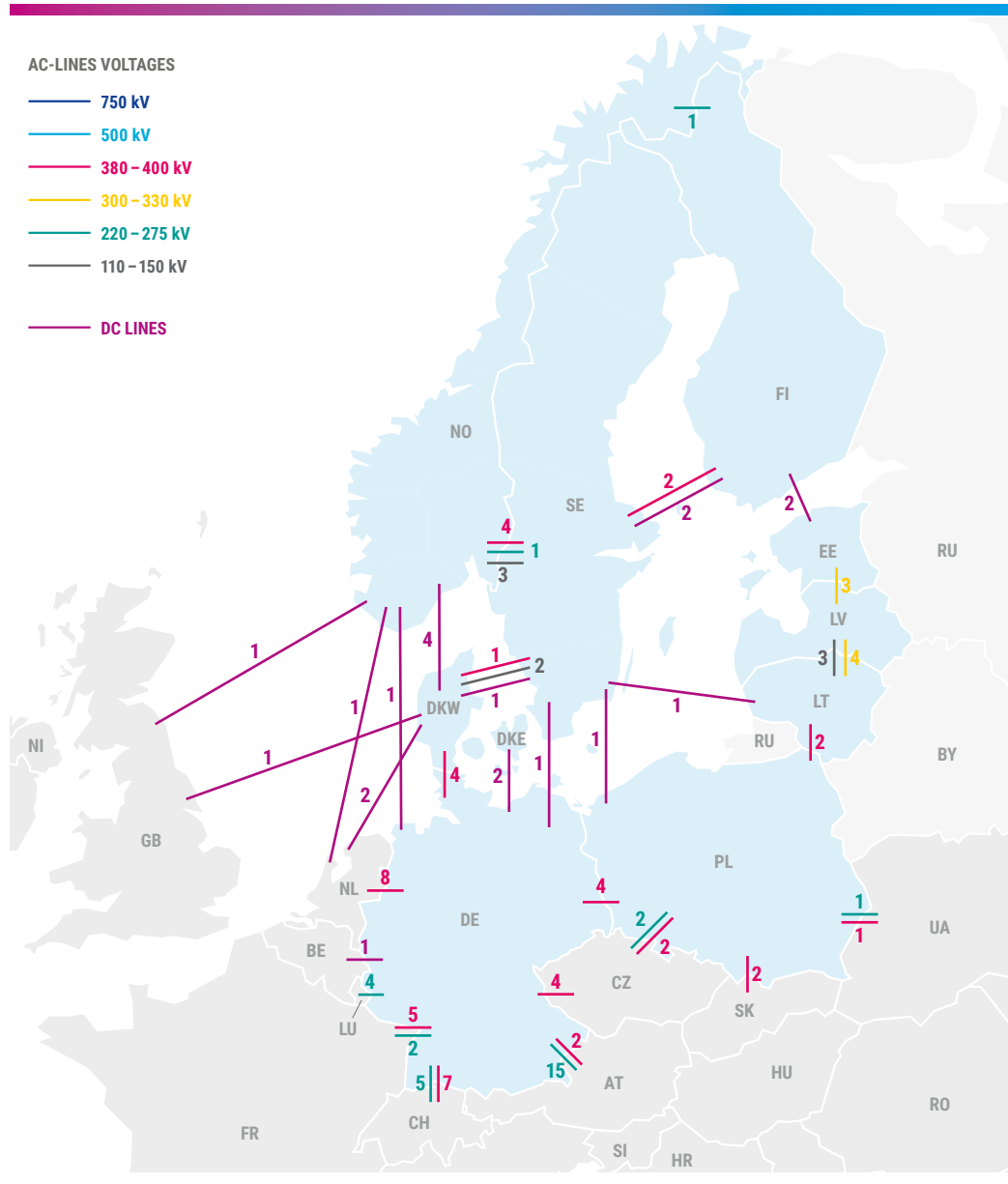


Figure 4: Connections by voltage level and number of interconnectors

Transmission capacity will play a key role in addressing future power system challenges. Adequate transmission capacity allows for the cost-effective utilisation of power, ensures access to adequate generation capacity, enables the smooth exchange of system services, and is key to a well-integrated market. A cost-effective transition towards a green power system depends largely on the strength of the transmission networks. Therefore, transmission network improvements must be completed in a timely fashion, which is very challenging.

Seven new interconnectors have been commissioned since 2010, which has increased total capacity by approximately 4,450 MW. These new interconnectors are Skagerrak 4 (Norway–Denmark); Fenno–Skan 2 (Sweden–Finland); Estlink 2 (Estonia–Finland); Nordbalt (Sweden–Lithuania); the LitPol link (Lithuania–Poland), which has been converted to HVAC mode after the Baltic states’ synchronisation with the CE system; Cobra (Denmark–Netherlands); and the Kriegers Flak CGS (Denmark–Germany) project. The HVDC links are presented in Figure 5.

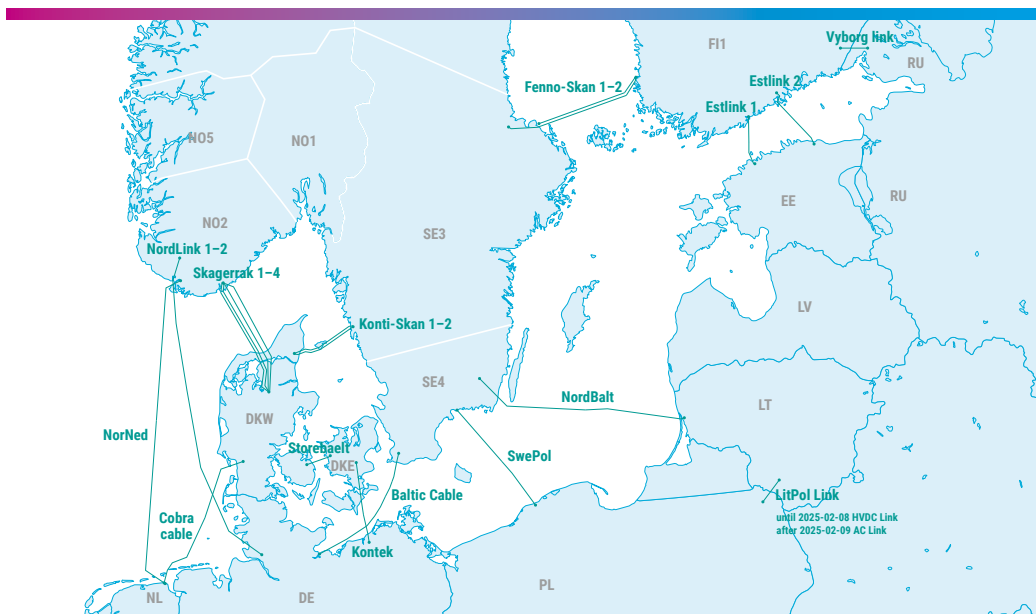


Figure 5: HVDC interconnectors in the Baltic Sea region

The Interconnected HVAC network in the Baltic Sea region is illustrated in Figure 6 and can also be found at <https://www.entsoe.eu/map/>. The Nordic and CE power systems utilise 400 kV AC as the main transmission voltage level and 220/130/110 kV AC as sub-transmission voltage levels. In the Baltic states' power system, the main transmission voltage level is 330 kV.

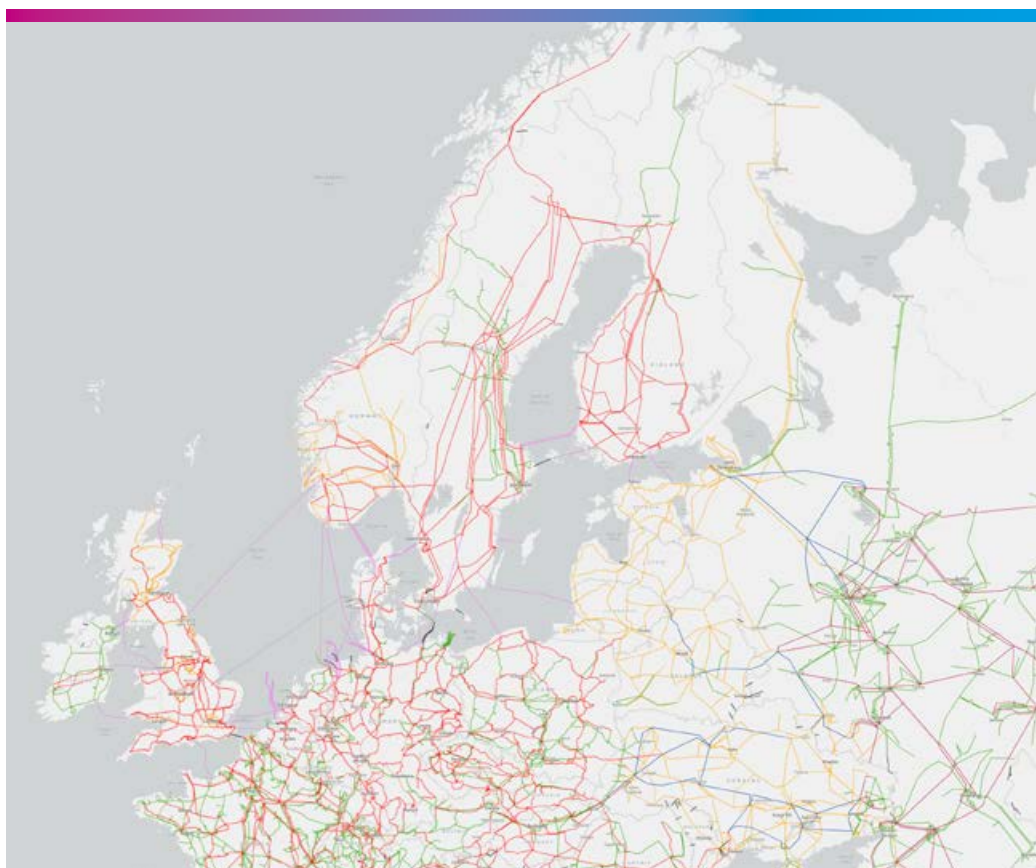


Figure 6: Interconnected network in the Baltic Sea region

The map in Figure 7 shows the diverse levels 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.

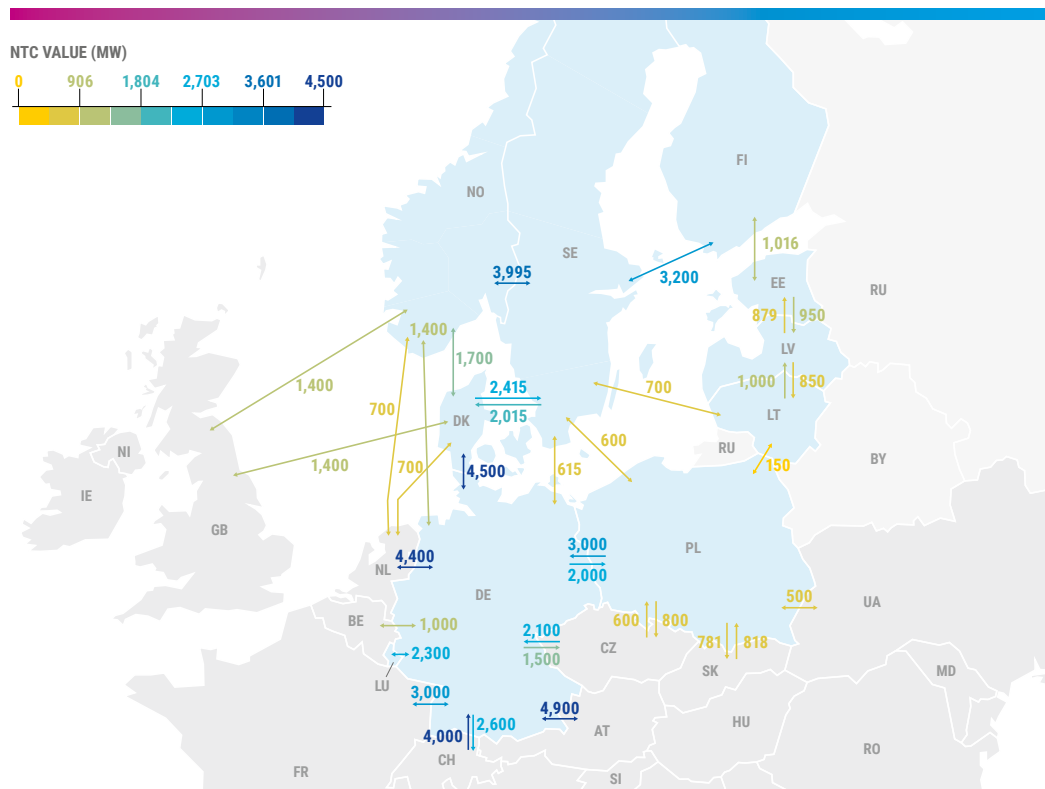
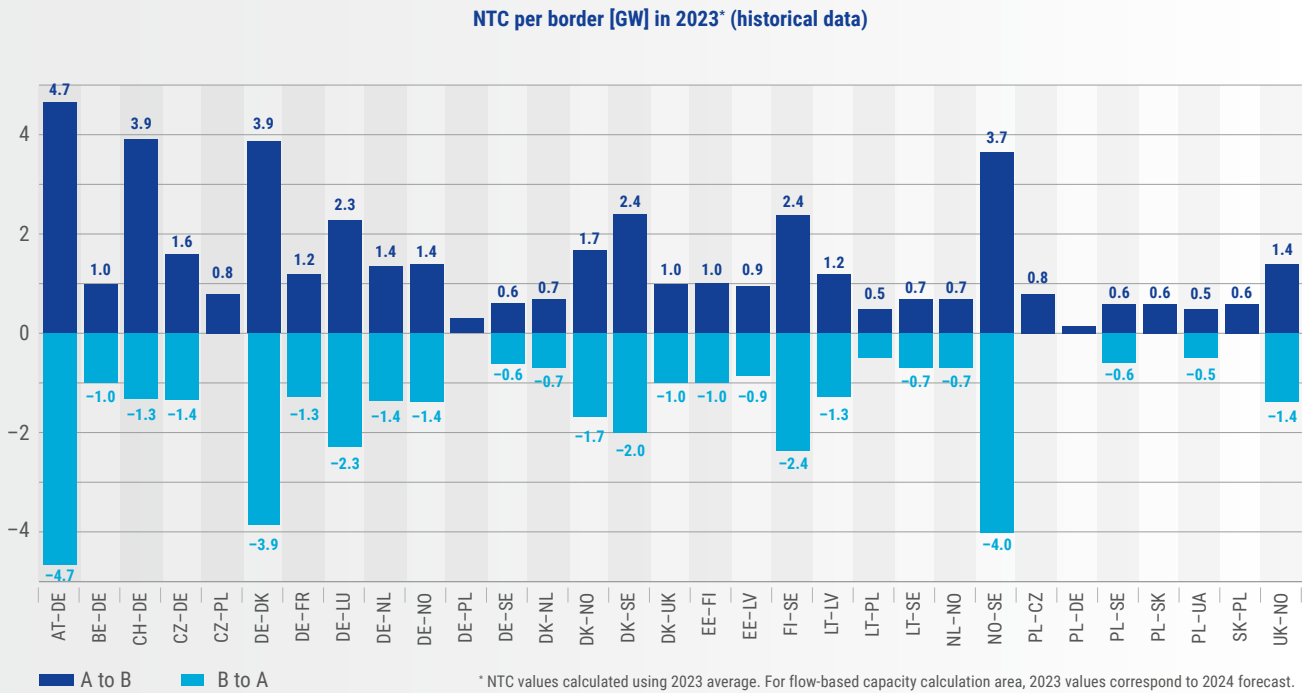


Figure 7: NTCs per cross-border [GW] in 2023 and map with NTCs per cross-border in 2025

Figure 8 presents installed capacities categorised by technology and fuel type in 2019 and 2023. From 2019 to 2023, installed generation capacity increased by 47.33 GW – almost 12% of the total installed capacity in 2019. The development of installed capacity shows a decline in fossil fuel installed capacity, replaced by growing installed capacities of solar, wind, and other RES. The overall picture shows that the Baltic Sea region is moving towards decarbonisation and reducing the fossil fuels installed capacities and high carbon-emitting generation sources.

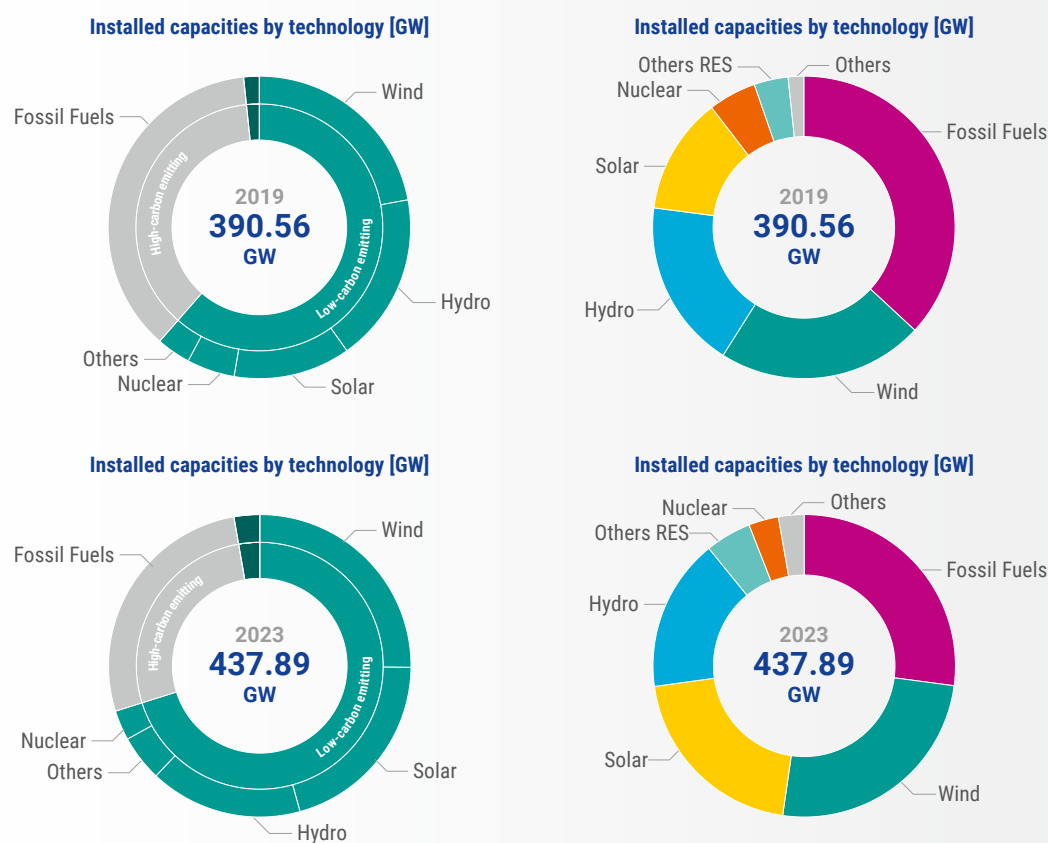


Figure 8: Installed capacity by technology in 2019 and 2023 (GW)

Variation in generation sources shows the recent dominance of solar and wind developments, as shown in Figure 9.

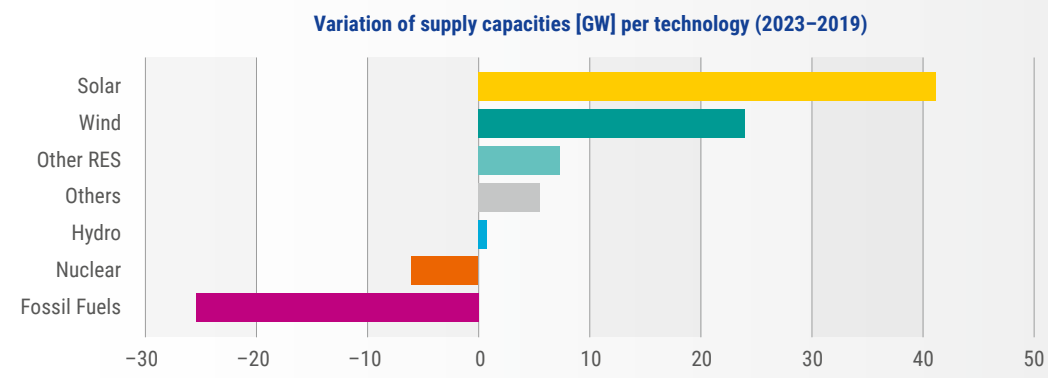


Figure 9: Increased/decreased generation capacity 2023–2019 (GW) per technology

In the Baltic Sea region, 2019 and 2023 saw reduced installed generation capacities for nuclear and fossil fuels. Fossil fuel capacities have declined due to ongoing natural gas supply problems since 2022, compounded by economic sanctions on gas imports from Russia, which have further complicated supply to the Baltic Sea region. Thermal, fossil fuel-fired generating capacity has decreased in the Nordic countries, while it has slightly increased in CE. The German nuclear phase out is also clearly visible in the figure.

Figure 10 shows installed generation capacities by generation source type in the Baltic Sea region, comparing 2019 vs 2023. The figure shows the share of each generation type by installed capacity for each country within the Baltic Sea region. As previously described, installed capacity has grown mainly through solar and wind generation in recent years, and that trend is expected to continue through 2050.

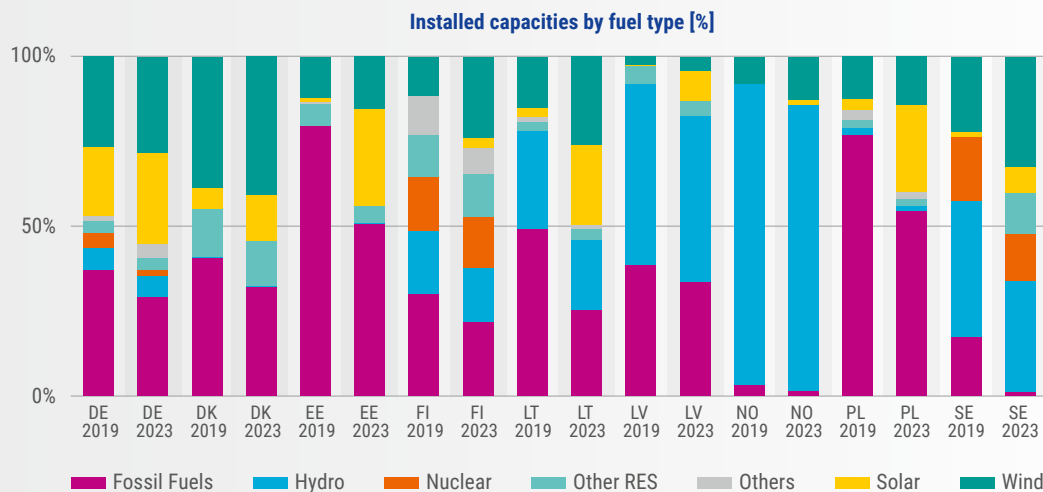


Figure 10: Installed generation capacities by fuel type in the Baltic Sea region in 2019 and 2023

The total annual electricity demand in the Baltic Sea region is approximately 1,100 TWh, of which roughly half is consumed in Germany. The peak load is much higher in winter than in summer due to colder weather conditions during winter periods and the high usage of electric heating in the Nordic and Baltic countries. During the last 10 years, the annual demand in the region has shown only moderate growth, while renewable generation capacity has increased significantly, replacing some fossil generation sources, as shown in Figure 11. The annual electricity demand in the Baltic states is significantly lower than in other countries in the region, at around 10 TWh per country. In all countries except Denmark and Norway, annual electricity declined slightly from 2019 to 2023. This could be due to higher wholesale market prices for electricity across Europe following the onset of the war in Ukraine. The conflict has affected energy prices and energy resource supply costs, leading to reduced consumption in most countries within the Baltic Sea region.

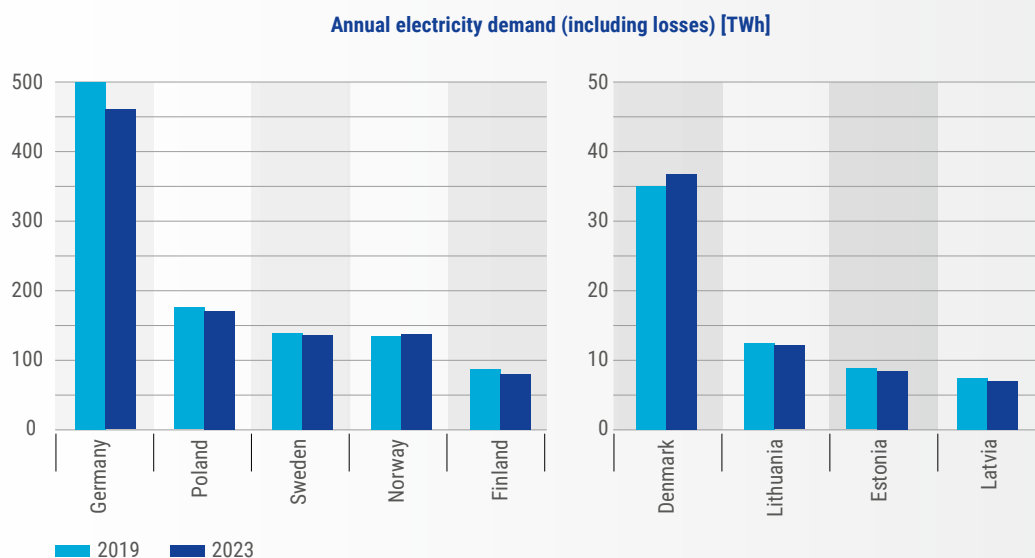


Figure 11: Annual electricity demand, including losses (TWh)

Figure 12 presents the peak demand for Baltic Sea region countries. From 2019 to 2023, peak electricity demand generally increased, except in Latvia, Germany, Finland, and Sweden, where it decreased slightly. In the Baltic Sea region, Germany experienced the highest peak demand, nearing 80 GW, while Latvia had the lowest peak load at approximately 1.3 GW. On average, peak demand across the Baltic Sea region was around 20 GW.

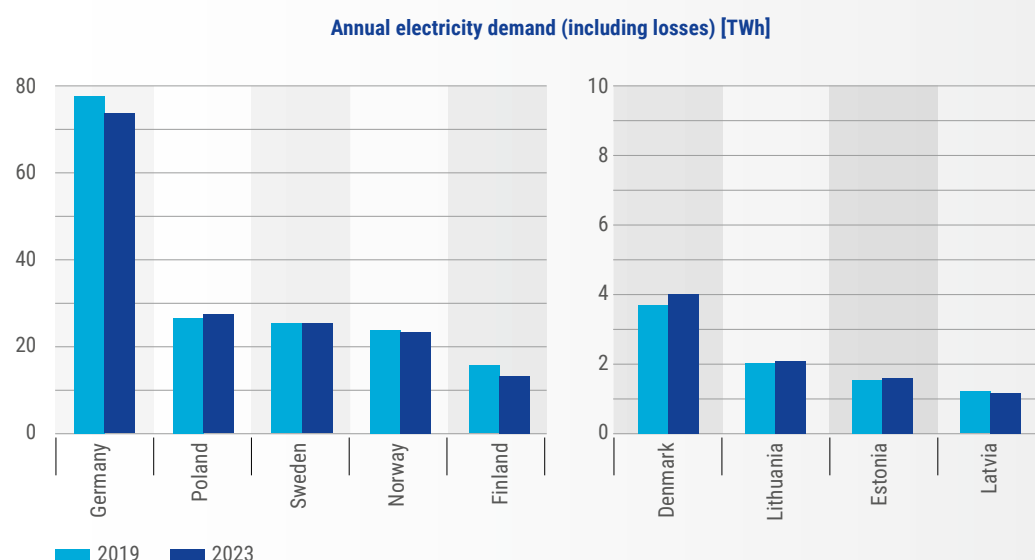


Figure 12: Peak demand without pumping (GW)

The CE and Nordic markets currently have sufficient thermal production capacity to cover demand during periods of low production from variable renewable sources or dry years with low hydro production. Currently, most countries have enough reliably available capacity to cover peak loads without importing from neighbouring countries. However, many countries are trending towards dependency on imports in peak load situations due to the increase in renewable generation capacity. Figure 13 presents the annual generation by fuel type in the Baltic Sea region in 2019 and 2023. Despite the roughly 12% increase in the installed capacity of generation sources from 2019 to 2023, annual production in the Baltic Sea region declined by 36.89 TWh – approximately 3.4% of the total produced in 2019.

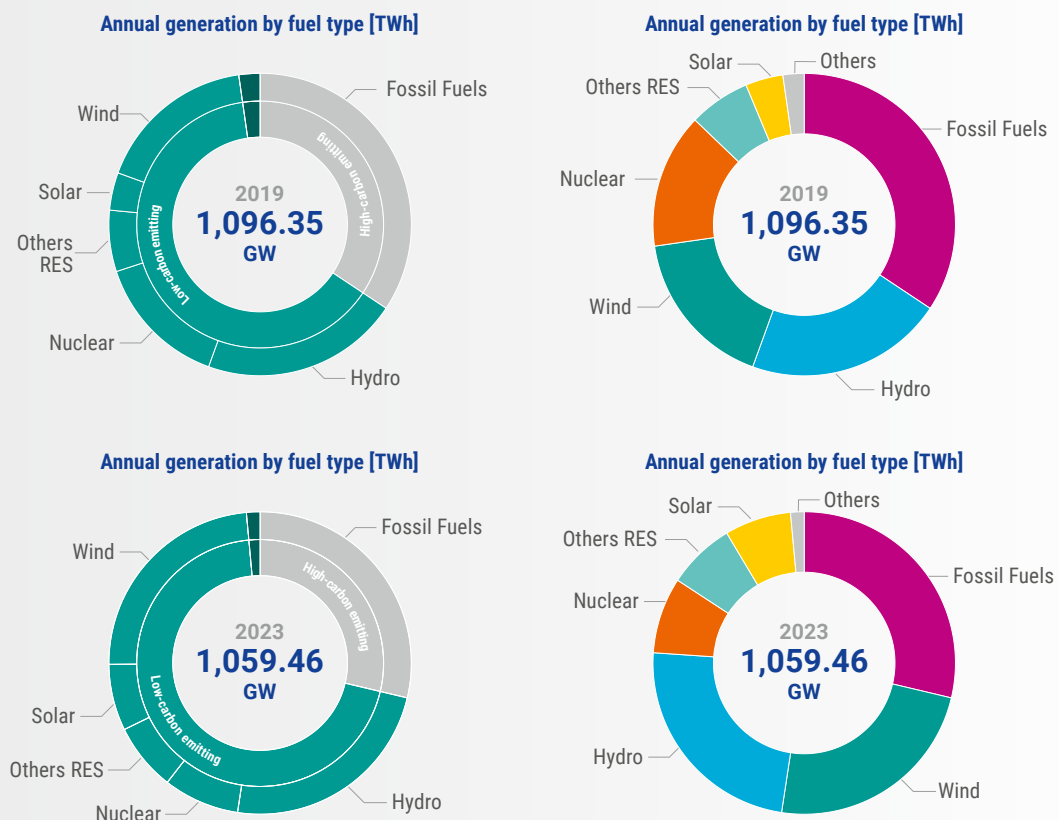


Figure 13: Annual generation by fuel type in 2019 and 2023 (TWh)

Figure 14 shows annual generation by fuel type per country within the Baltic Sea region, comparing 2019 vs 2023. In most countries, the annual generation of fossil fuels decreased, particularly in Latvia due to gas import issues and higher Liquefied Natural Gas (LNG) prices after 2022. The overall variation in annual generation is primarily due to reductions in nuclear and fossil fuel production. The phase out of nuclear energy in Germany has significantly impacted the region, reducing annual production by approximately 70 TWh in the Baltic Sea area.

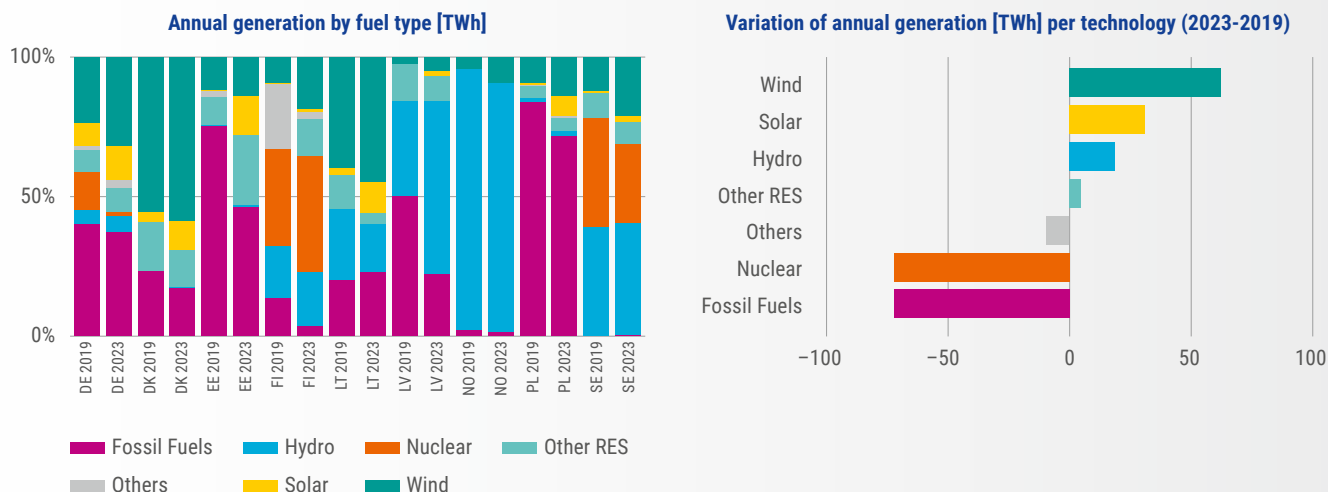


Figure 14: Annual generation by fuel type and variation of annual generation per technology (TWh)

The Nordic power system is dominated by hydropower, followed by nuclear, wind and combined heat and power (CHP) plants. Most hydropower plants are located in Norway and northern Sweden, while nuclear power plants are located in southern Sweden and southern Finland. During a year with normal inflow, hydropower represents approximately 50% of annual electricity generation in the Nordic countries, but variations between wet and dry years are significant. For Norway, the variations can be almost 60–70 TWh between a dry and wet year. Consumption in the Nordic countries is characterised by a high amount of electrical heating and energy-intensive industries. The power balance in the region is positive in a normal year but varies significantly between wet/warm and dry/cold years. The development of generation and demand in the Baltic Sea region is shown in Figure 15.

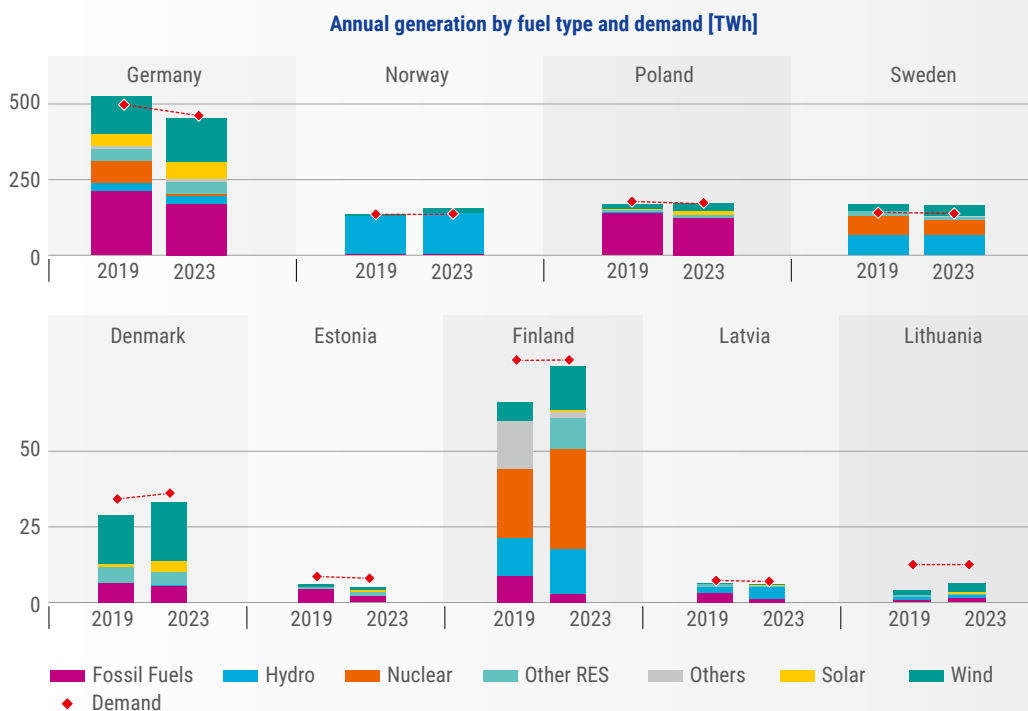


Figure 15: Annual generation by fuel type and demand (TWh)

Power production in the continental part of the Baltic Sea region and the Baltic states area is dominated by thermal power, except in the Danish power system, which is dominated by wind and other RES, which account for more than 60% of consumption in Denmark. Consumption in the area is less temperature-dependent than in the Nordic countries.

Sweden typically has electricity surpluses. Finland has historically had an energy deficit, but electricity consumption and generation in Finland are currently roughly balanced on an annual level. Denmark, Poland, Estonia, and Latvia typically maintain a neutral annual power balance during an average year. In contrast, Germany experienced a yearly surplus in 2019; however, by 2023, following the closure of its nuclear generation facilities, it had shifted to a deficit. Lithuania is currently operating with a large power deficit. The massive increase in RES generation in Germany has replaced nuclear production but only slightly decreased fossil-based generation, while significantly increasing exports.

Cross-border flows in 2023 and 2019 are presented in Figure 16.

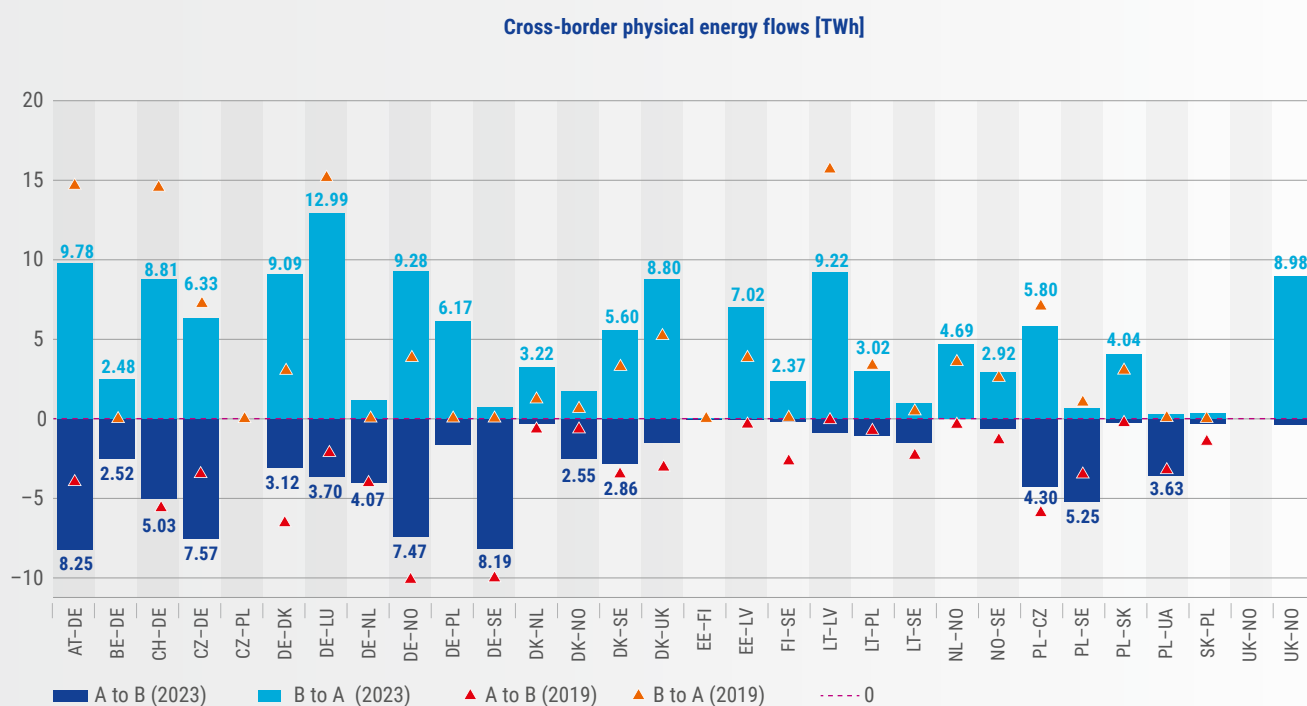


Figure 16: Cross-border physical energy flows (TWh) in the Baltic Sea region in 2023 (bars) and 2019 (triangles)

The largest exchanges were from Germany, Sweden, and Norway to neighbouring countries, while the largest increases in power flow between 2019 and 2023 were from the Netherlands to Germany, Germany to the Czech Republic, Norway to the United Kingdom, and Finland to Sweden. In the Nordic countries, the flow pattern varies greatly from year to year due to variations in hydrological inflow. In wet years, exports from Sweden and Norway are typically much larger than during dry years. Furthermore, the electricity trade between Finland and Russia was suspended in spring 2022 due to Russia's attack on Ukraine and remains suspended at the time of writing.



2.2.2 Evolution compared to RegIP 2022

Climate goals

The EU has agreed to a comprehensive update of its energy policy framework to facilitate the transition from fossil fuels to carbon-neutral energy. The EU has set an ambitious, binding target for long-term achievements and implemented the Fit for 55 package for renewable energy sources implementation in the EU's energy mix by 2050. The development of renewable sources will also lead to greater energy independence and require significantly greater transmission system investments to ensure power exchange among EU Member States. The National Trends (NT) 2030 scenario, used in the analyses performed under the TYNDP System Needs Study 2030 and 2040, assumes a progressive reduction in CO₂ emissions in the Baltic Sea Regional Group compared to the previous edition.

Power to gas

The European Commission's hydrogen strategy, presented in July 2020, outlines how to upscale the demand and supply of renewable hydrogen. It set the strategic objective of installing at least 40 GW of renewable hydrogen electrolyser capacity within the EU (producing about 5 Mton of renewable hydrogen), based on an estimated demand of up to 10 Mton per year of renewable hydrogen in the EU by 2030.

Flexibility

Currently, 20% of all energy in the EU comes from renewable sources. Achieving the Fit for 55 goal would require doubling RES by 2030. For the energy sector, achieving this target will entail shifting from conventional to RES at an increased pace. Most RES, such as wind and solar, are fluctuating and non-dispatchable; that is, they cannot be controlled by grid operators or market needs but instead are weather-dependent. This supply fluctuation can create mismatches between generation and demand, requiring additional flexibility to equilibrate the power system. From the standpoint of the power grid, the installation of battery energy storage is a helpful technological solution. It allows for stabilising the variability of energy production from renewable sources and responding to changing demand.

Moreover, acquiring more RES is much quicker than expanding the grid to transport them. This is creating bottlenecks in transmission systems. To address the congestion, conventional power plants are currently used for preventive redispatch. However, alternative solutions must be implemented, as conventional power plants will become less available or even be phased out, significantly increasing redispatch costs. Two courses of action may help TSOs solve the congestion issue. First, the available grid could be more balanced using controllable devices such as HVDC or phase shift transformers (PST) to bypass the congested areas. Secondly, technical solutions for higher utilisation of the existing grid may be implemented. TSOs have already implemented dynamic line rating (DLR), which is weather-dependent and in certain situations allows for adjusting the rating of the lines for system-wide congestion management.

There are also newly planned and implemented control mechanisms. For example, the Gridbooster offers significantly faster response times to grid events that would otherwise lead to overloads. These faster response times and the free short-term thermal power capacities of the systems and lines make it possible to utilise unused grid potential and improve the coordination of grid operation management. The potential of these approaches was demonstrated in the German research project InnoSys 2030. Concepts were developed and a roadmap for implementation was published. A first Gridbooster pilot project in Germany (Audorf/Süd and Ottenhofen) should begin operation in 2027. It will be used to test these innovative concepts for higher utilisation of the transmission grid.

Influence of Russian–Ukraine conflict on the electricity sector

The outbreak of the war between Russia and Ukraine in 2022 resulted in the imposition of a series of sanctions on the Russian aggressor by the international community. The sanctions imposed on Russia resulted in significant increases in the price of fuels and raw materials, influencing the pace of the manufacturing sector's transition to RES. The greatest threat in this situation was maintaining the continuity of energy supplies, particularly as most gas was imported from Russia, and those supplies were cut off. The rise in gas prices significantly affected the generation sector, increasing overall system costs and causing a shift in the merit order (coal before gas). While most energy supply chains have been diversified and replaced by other suppliers, the impact of this dramatic switch remains.



2.2.3 Current and expected challenges in the region

Two significant changes in the Baltic Sea region are challenging the power system's further development needs. The biggest challenge is how to cope with a significant increase in RES generation. Figure 17 shows the installed capacity per generation type within the Baltic Sea region.

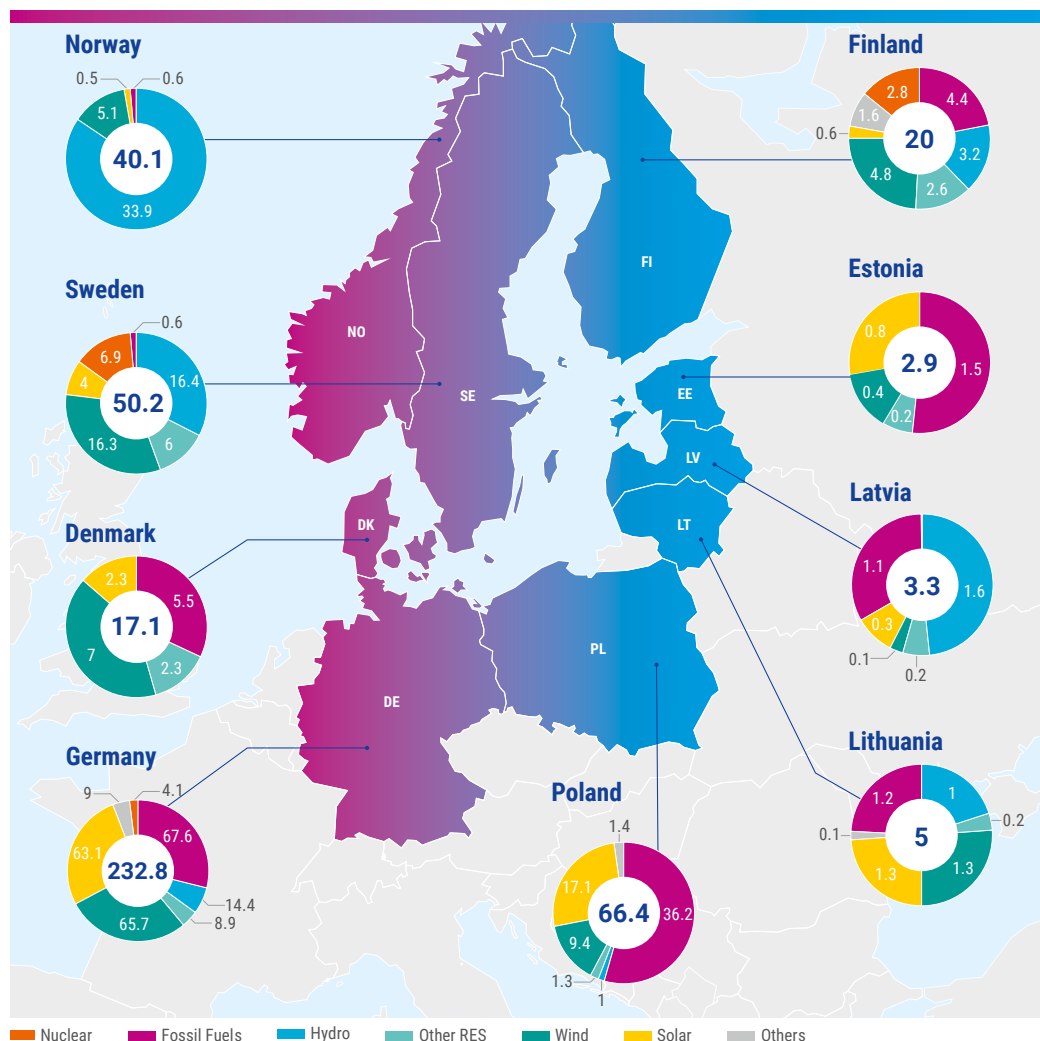


Figure 17: Installed generating capacity in the Baltic Sea region in 2023 (GW)

Most of the future RES increase is coming from solar and onshore and offshore wind. The existing mainland transmission network may not be suitable or sufficient for offshore wind, making offshore grid developments inevitable. The increasing share of RES in the generation portfolio will be connected to the grid as power park modules (PPM).²⁾ This means they will be converter-coupled and therefore will not provide natural short-circuit and inertia support. This technological difference will introduce new challenges related to frequency stability and the ability of some equipment to operate under normal conditions with the required minimum short-circuit power.

2) "A unit or ensemble of units generating electricity, which is either non-synchronously connected to the network, or connected through power electronics, and that also has a single connection point to a transmission system, distribution system including closed distribution system or HVDC system" (NC RfG, [EU 2016/631](#)).

In addition to the change in power system technical characteristics, the change in RES will result in higher price volatility and sudden changes in power flows in different parts of the power system, depending on where the RES source will be available based on weather conditions. It is difficult to plan and predict exact flow patterns, as weather conditions have an indefinite nature. Therefore, the system must develop in two ways: ensuring sufficient transmission capabilities to handle high and varied flows, and addressing risks arising from changing system characteristics, such as inertia and short-circuit power.

The second major technical challenge, which primarily affects the Baltic states, is the synchronisation of their power system with the CE synchronous area. A more specific technical solution and plan is described in the separate synchronisation project in [Chapter 4.3.1](#). Due to the technical design of the future synchronous interconnection between Lithuania and Poland, there remains a small but significant risk that the Baltics could be disconnected from the CE synchronous system and stay in island operation mode if an exceptional contingency were to trip the only double-circuit high-voltage 400 kV overhead line connecting the Baltics with the rest of Europe. While this situation is manageable, it is a significant technical challenge requiring additional technological investment to ensure sufficient system inertia, maintain an acceptable rate of change of frequency (RoCoF), and enable the rapid activation of countermeasures to restore system balance and frequency stability. Technical challenges arising from increases in RES generation, as identified by TSO experts, include:

- › Frequency stability issues due to reduced inertia, increased deviation range and ramp rate of generation, and larger contingencies
- › Voltage stability issues due to longer transmission paths and reduced voltage control near load centres
- › Angular stability issues due to reduced minimum short-circuit current levels

New interconnections and synchronous condensers with increased inertia contribute to system flexibility, while energy and electricity storage and demand-side response can also help balance energy levels. From a dynamic stability perspective, the flexibility needed to keep the power system running when penetration of synchronous machines is reduced can be provided by RES generation units, using flexible AC transmission (FACTS) devices, HVDC link control, DLR, and special system protection schemes. Decreases in inertia, short-circuit power, and voltage regulation near load centres are a few of the main issues that must be solved as the generation portfolio becomes increasingly CO₂-free.



Decreased inertia

One major challenge identified is the decrease in inertia as synchronous generation declines and converter-connected generation increases within the system. Inertia is the kinetic energy stored in the rotating masses of machines. The inertia of a power system resists the change in frequency after a step change in generation or load. Too little inertia can lead to frequency instability, where a sudden change in generation and load balance can cause unacceptable frequency deviation, potentially triggering cascading tripping of system elements and leading to blackouts in worst-case scenarios. The low inertia situation is only expected in the Nordic synchronous system in the medium term, and in the case of island operation, also in the Baltic system. The amount of inertia in future Nordic synchronous power systems has been analysed by the Nordic TSOs. One possibility to compensate for the decrease in system inertia is to provide a temporary, fast-response active power injection from the wind production units, decoupled from the grid with converter technology. The temporary boost of active power support following a sudden decrease in frequency could be achieved by utilising the kinetic energy stored in the wind turbine rotors and generators. Reaction time and control is not instantaneous, but with today's advanced power electronics, it should be fast enough to support the system and avoid sudden frequency drops. The problem with this control could be a slight decrease in power output after utilising the stored kinetic energy of the rotating turbines, as the wind turbine blades are not rotating with the optimal speed necessary to achieve maximum production at certain wind speeds. Maximum output will usually be restored in a very short time (several tens of seconds) after the synthetic inertia has been used. In case of further RES increases, synthetic system inertia as a basic function for rotating RES units decoupled through power electronics could be considered.

Decreased voltage regulation near load centres

Large amounts of planned wind power production are located far from load centres, where conventional units have traditionally been situated. A large extension of reactive power compensation devices is expected due to the longer transmission distances required for power and the decreased dynamic voltage support from conventional units. For example, in the Nordic countries, wind power from the northern areas must be transmitted to load centres close to large cities in southern areas. Similarly, in Germany, wind power from northern areas must be transmitted to load centres in the southern part of the country.

Decreased minimum short circuit power

Directly connected synchronous generators provide short-circuit current and voltage support regulation during faults that are necessary for the normal operation of certain types of converter technologies to avoid commutation failures. Insufficient short-circuit power support might lead to a tripping of the line commutated converters (LCC), which are technology-based converters. Furthermore, when the penetration level of converter-connected power generators is very high, the form of the fault current is determined by the controls of the converters, not by the short-circuit output of rotating machines. This can cause issues with protection devices designed to work in systems based on synchronous machines. When designing future power systems, those technical issues should be studied in more detail, and sufficient countermeasures must be taken into account based on the results. Regional System Needs

3 Regional System Needs

The TYNDP 2024 study identified regional system needs for the Baltic Sea region. The study included NT scenarios for time horizons 2030 and 2040 and the Distributed Energy scenario for 2050. Regional system needs are identified, taking into account offshore system needs based on the ONDP released by ENTSO-E in January 2024.

3.1 Regional results of the identification of system needs

The TYNDP System Needs Study for 2030 shows a substantial need for capacity increases in the Baltic Sea region in Figure 18, especially among Nordic countries, including Finland, Sweden, and Norway. The identified system need is more than 4,000 MW. Within the Baltic states, the identified system need for cross-border capacity expansion ranges from 500 to 1,000 MW. In Central Europe, Germany's system needs for 2030 vary from 1,000 MW to 3,000 MW per cross-border. The identified system needs up to 2030 indicate that almost all cross-border capacity increases are needed to accelerate RES development in the power system. Storage capacity needs for each country are also indicated, with Germany and Poland having the most need for storage capacity to improve flexibility. For the Nordics, the scenarios show a very high and probably unrealistic energy surplus. This means that some of the interconnector needs in and out of the Nordics require further investigation.

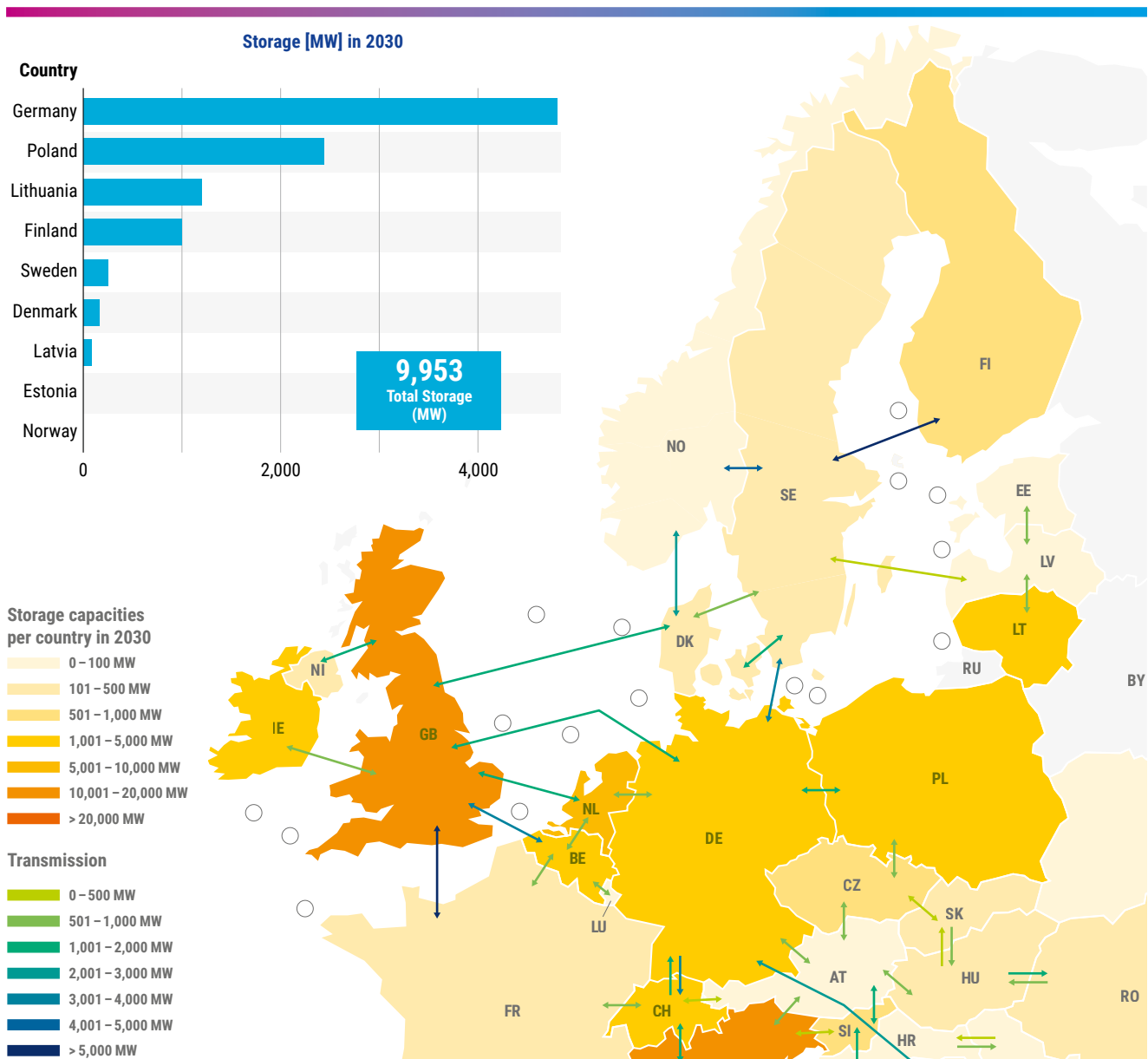


Figure 18: Identified system needs and storage capacity in 2030

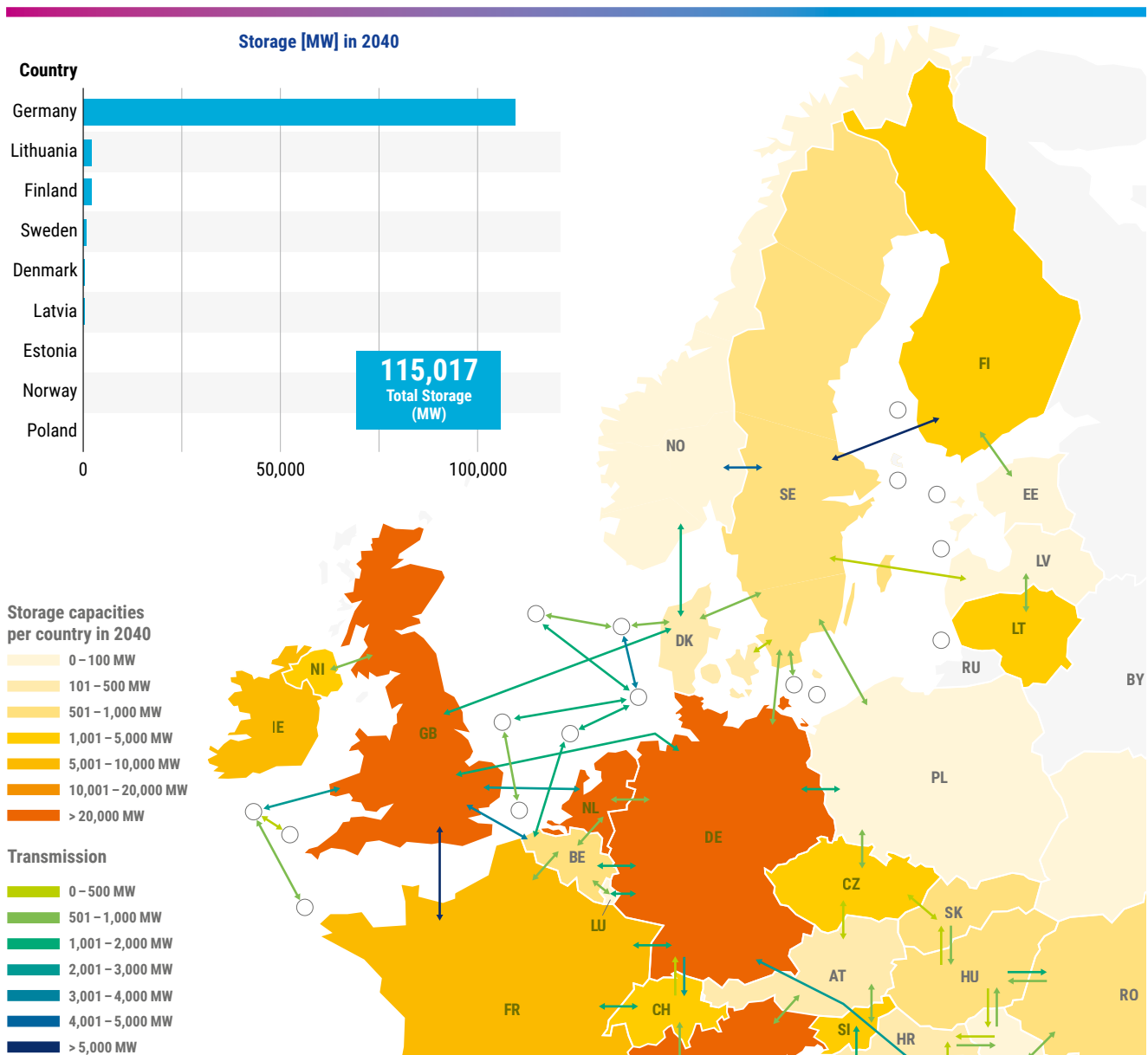


Figure 19: Identified system needs and storage capacity in 2040

System needs for 2040 (Figure 19) indicate that capacity increases in the Baltic Sea region are not as extensive as those in 2030. However, they continue to emphasise the need for constant capacity increases to support the growing demand and integration of RES in the region. The most significant increases in the Baltic region are between Estonia and Finland and Sweden and Poland. In Central Europe, multiple needs for new capacity in and out of the German system are identified, requiring new cross-border capacity to Belgium, France, Austria, and Switzerland. In 2040, there is also a strong need for new storage capacity for flexibility, almost exclusively in Germany, where the need exceeds 100 GW.

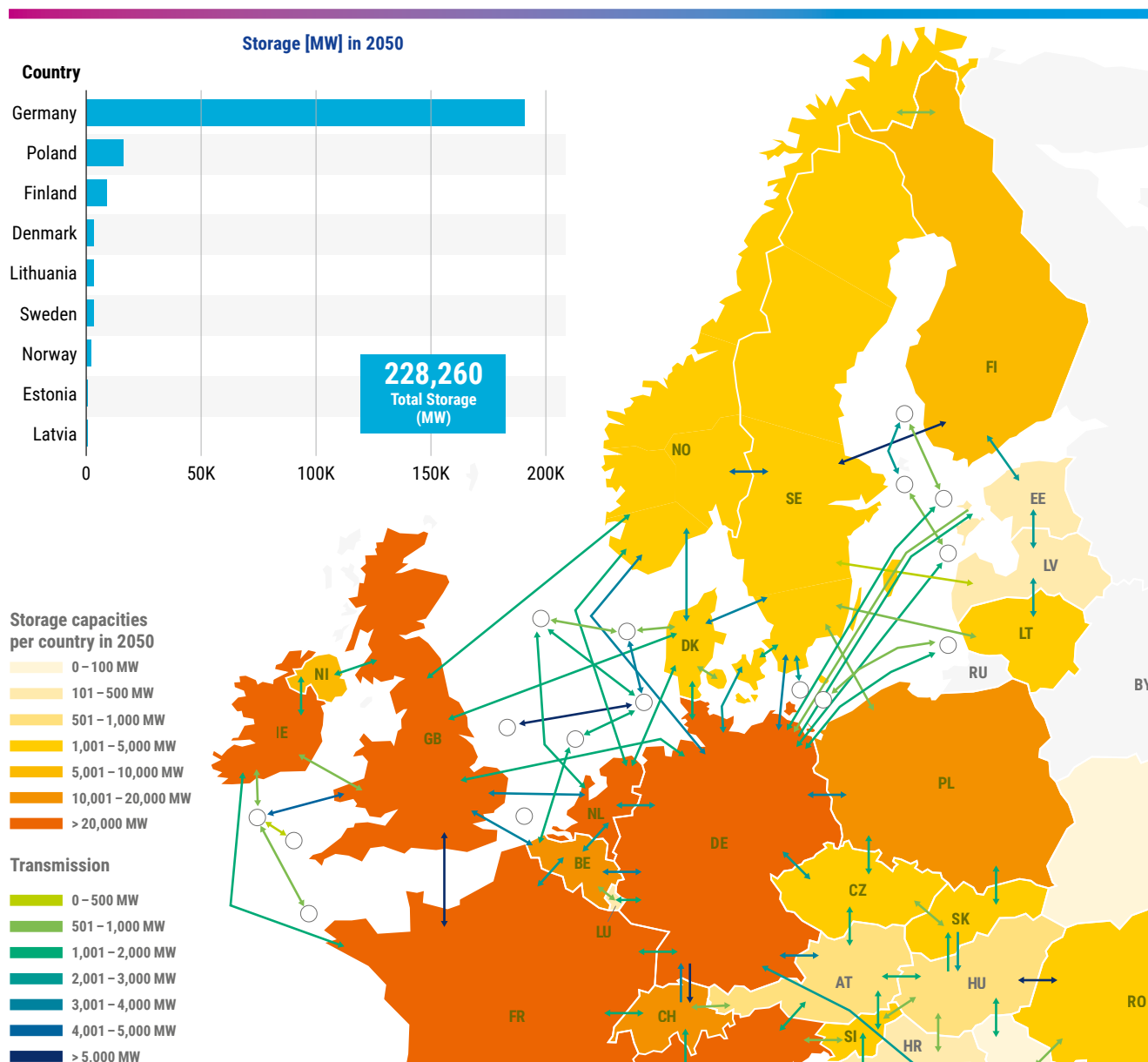


Figure 20: Identified system needs and storage capacity in 2050

System needs for 2050 highlight the development of offshore energy hubs in the Baltic Sea (Figure 20), creating a significant demand for new capacity in the Baltic Sea region, especially in Germany. Germany has identified a need for new interconnector capacity to all its neighbouring countries and the new energy hubs in the Baltic Sea. The Baltic countries also must enhance the already established interconnectors to better integrate their systems. The energy systems in the Baltic countries will also need larger connections to both Sweden and Finland in 2050. The countries bordering the North Sea have an equally large task in developing new interconnector capacity based on the development of wind farms and energy hubs in the North Sea. The need for storage capacity remains almost unchanged from the significant increase in 2040, but countries besides Germany, such as Poland, and to a lesser degree Finland, Denmark, and Sweden, have identified a need to develop storage capacity.

3.2 Market results

The Baltic Sea region's energy system is in constant flux. In recent years, onshore wind capacity has been added at an increasing rate. More recently, in parts of the region, offshore wind generation has been developed in significant quantities. The expansion of renewable generation, alongside existing hydro generation, is providing the region with increased amounts of carbon-free energy. Thermal generation, including fossil fuels and nuclear, may be largely phased out. Finally, nuclear generation is undergoing major restructuring. In Sweden, there is ongoing debate about whether nuclear energy should be maintained for long-term operation or decommissioned due to economic considerations. Some remaining capacity is expected to be available until around 2040, when the units reach the end of their technical lifetimes. All the shifts in generation described above are expected to become more pronounced in the future. In addition, electricity consumption is changing due to increasing electrification in industry and transportation and the entry of consumers into the production system as prosumers. Cross-border capacity increases are expected to have a positive impact on the system in most of the time horizons under the NT scenario and in various climate years. A European overview of these increases is presented in the TYNDP Infrastructure Gaps Report released in January 2024.

The system needs results are very much dependent on the scenario assumptions. Offshore wind goals and development within each country have become more progressive. In addition, internal costs are partially taken into account for several of the investigated borders – for example, Norway–Finland and Sweden–Finland, because actual further power system developments in the region will lead to direct internal grid reinforcements to contribute calculated system needs results. These corridors require further investigation. The potential for increasing transmission capacity on the LT–PL connection lies in unblocking these capacities on the existing LitPol Link connection. This is linked to increasing the resilience and robustness of the Baltic states' grid following synchronisation with the CE system and gradually releasing transmission capacity for trade. The region's needs are partially addressed by projects already assessed in TYNDP 2024.

3.3 Overview per indicator

The market simulations were conducted using the Antares and PLEXOS pan-European market tools, with recently updated input data from all TSOs. The market results show that the identified investments in the 2030, 2040, and 2050 grid will significantly reduce general price levels, the amount of curtailed energy, and the amount of CO₂ emissions, compared to the no grid (no additional investments to the network) scenarios in the 2030, 2040, and 2050 time horizons.

The outcomes of the optimised grid can be compared with those of the starting point grid, which assumes no further extension of the current grid after 2025, and the portfolio grid, in which only the currently planned grid investments are made.

3.3.1 RES energy surplus

In the System Needs Study, the amount of curtailed energy decreases substantially in the optimised grid scenario compared to the no grid scenario. Figure 21 shows the curtailed amounts of energy for the Baltic Sea region countries during the year 2030. The yellow bar represents the amount of curtailed energy without new grid investments or cross-border strengthening projects, while the blue bar indicates the amount of curtailed energy when investment projects proposed by the Baltic Sea Regional Group countries are implemented. Among them, the most significant energy curtailments have been identified in Germany, Lithuania, Denmark, Finland, and Poland, where implementing the planned investment project can reduce RES energy spillage by 13 TWh. For the majority of the Baltic Sea region countries, the anticipated amount of curtailed energy would be insignificant.

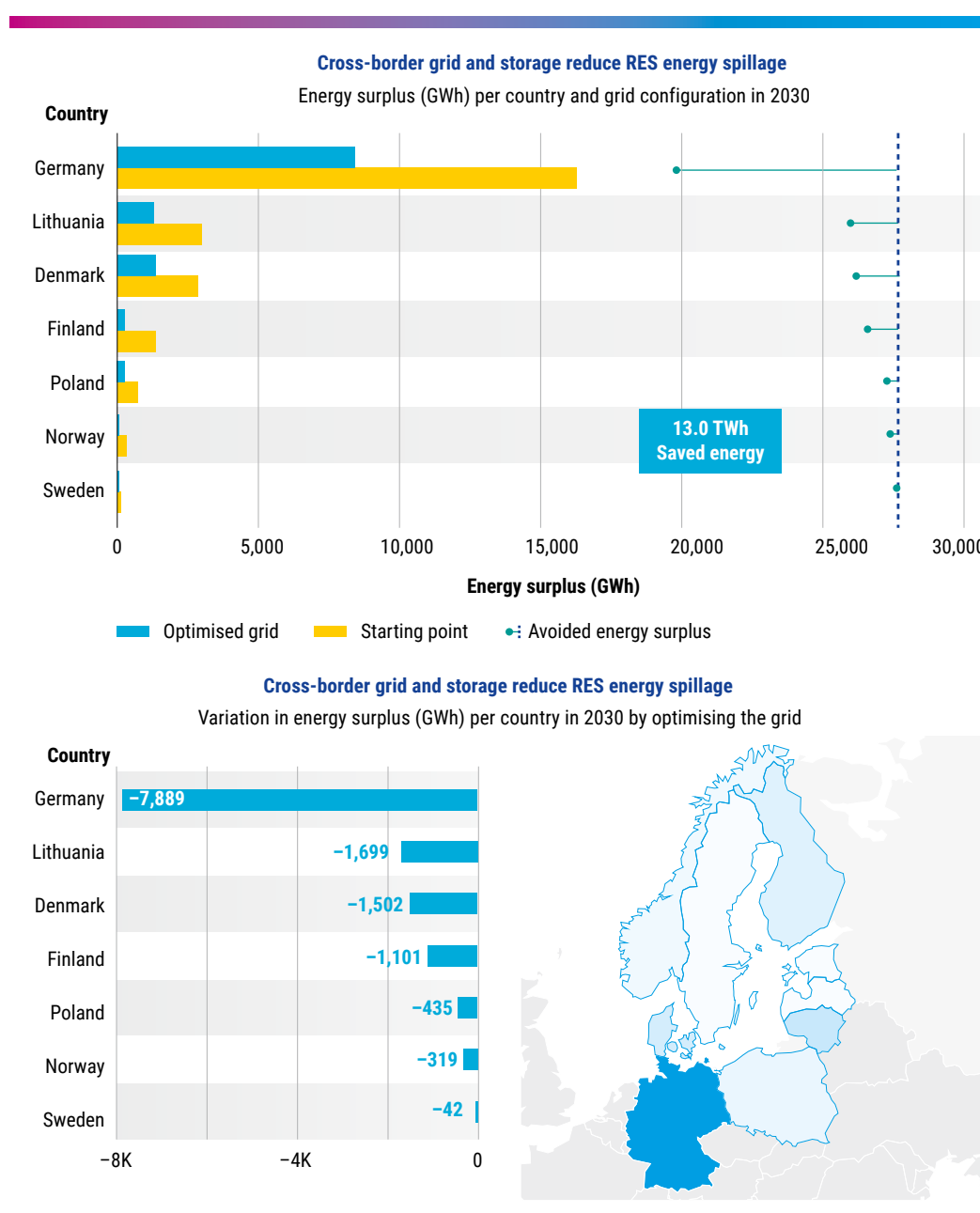


Figure 21: The amount of curtailed energy in the Baltic Sea region with and without identified capacity increases in 2030

New grid capacity up to 2040 helps in situations where the RES share is large and must be curtailed. In surplus situations in Germany and Denmark, as well as in Finland and Sweden, excess energy could be exported and primarily stored in hydro reservoirs and battery storage systems across the EU. In Sweden, curtailed energy can occur when hydro reservoirs are full during renewable energy surplus periods. Therefore, expanding grid capacity to increase exports to other EU Member States can help prevent curtailment and reduce the risk of energy spillage during high renewable generation.

Figure 22 describes RES spillage in 2040. RES spillage increases between 2030 and 2040; however, the implementation of numerous new grid projects will reduce RES spillage by 91.9 TWh in the 2040 time horizon. In the 2040 time horizon, RES energy spillage is identified for all countries within the Baltic Sea region. The highest levels of RES spillage are expected in Germany, Denmark, and Norway, while other countries are expected to see relatively low RES spillage.



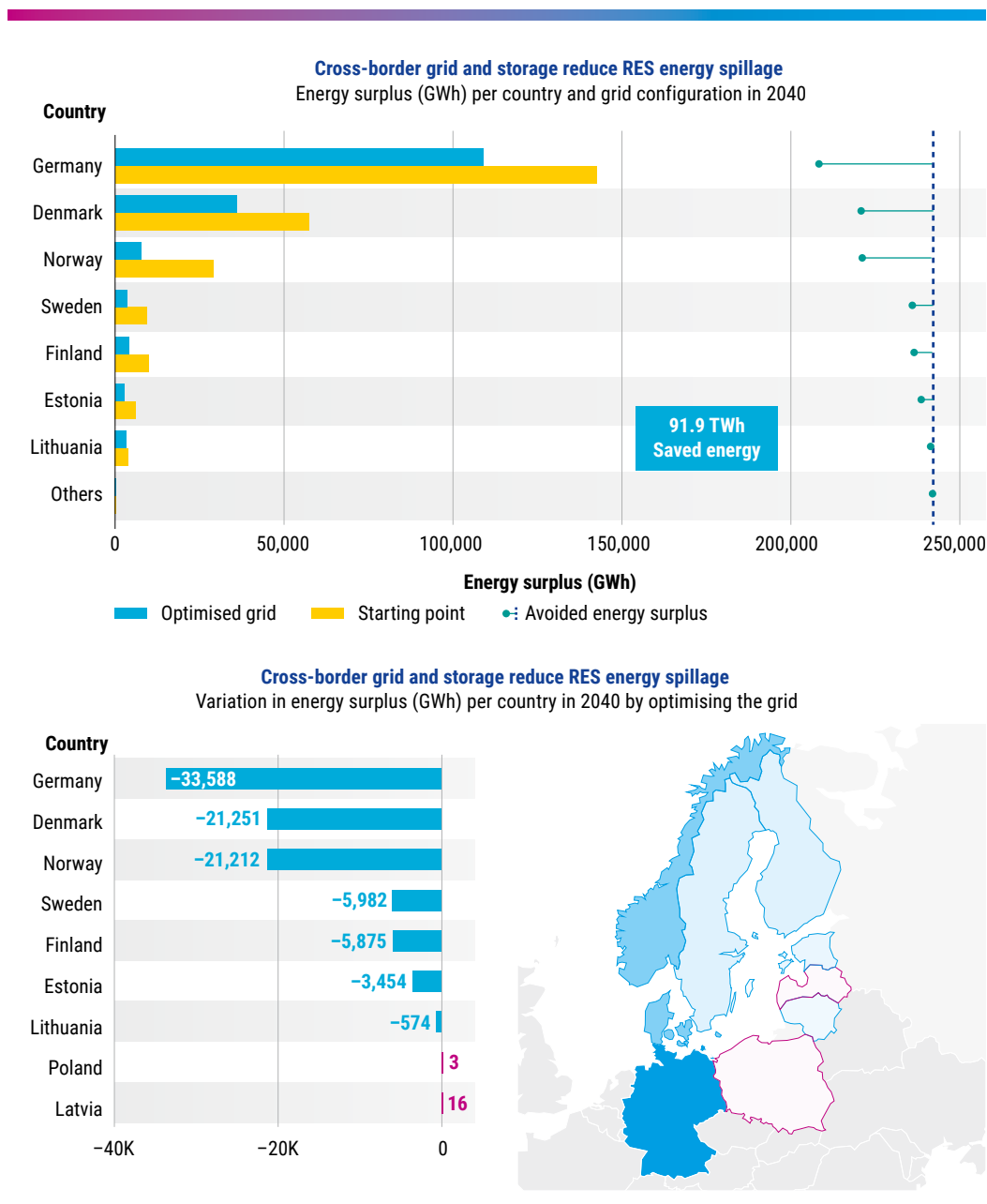


Figure 22: The amount of curtailed energy in the Baltic Sea region with and without identified capacity increases in 2040

In the 2050 time horizon described in Figure 23, the results indicate that there would still be relatively large amounts of energy curtailment or RES spillage under the portfolio and optimised grid scenarios. However, the results likely exaggerate the absolute level of curtailment, since the modelling of wind power, in particular, does not fully consider the expected increase in full load hours, meaning that the same amount of energy can be produced by turbines with lower generation capacity. Even if the results are slightly exaggerated, the message is clear: grid investments are needed to avoid large amounts of wasted renewable energy in the region, and even more capacity than the 2050 grid may be needed, particularly with considerable variable renewable generation. However, in a future power system with a very large amount of variable generation, some curtailment must be accepted, as avoiding curtailment completely would be too costly. By 2050, renewable energy spillage is expected across all countries in the Baltic Sea region.

In some cases, such as Germany, Poland, and Finland, spillage is projected to be higher with an optimised grid compared to the reference grid. By 2050, renewable energy spillage in Finland, Poland, and Germany is expected to be higher even with an optimised grid due to the enormous volume of RES production. The proposed investments are insufficient to fully address the spillage, as the ambitious installed capacities of RES exceed the capabilities of the optimised network to resolve all power system constraints. The annual RES spillage for the Baltic Sea region is projected to be 46 TWh.

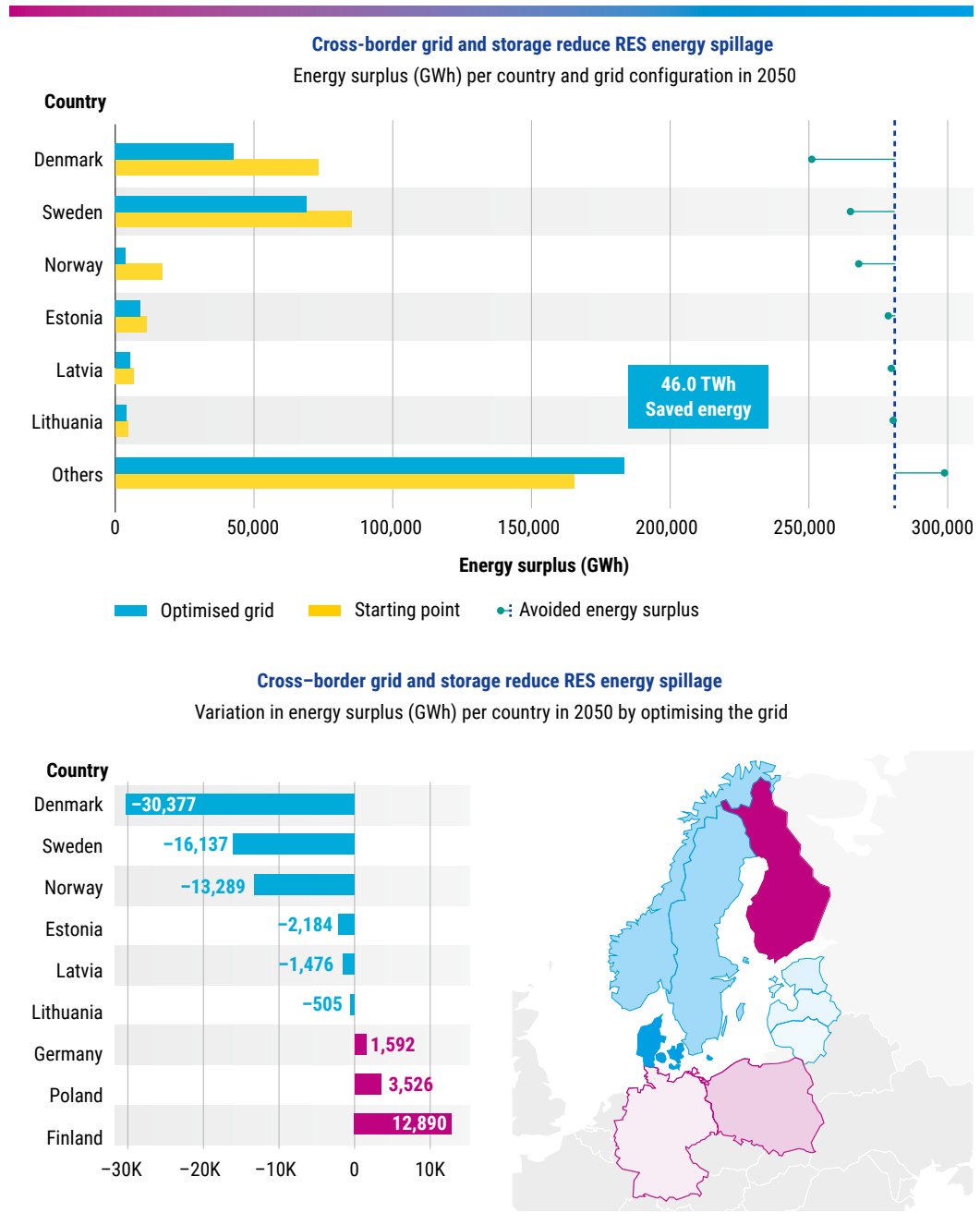


Figure 23: The amount of curtailed energy in the Baltic Sea region with and without identified capacity increases in 2050

3.3.2 Decreased CO₂ emissions

A higher interconnector capacity will also have an impact on CO₂ emissions. This is due to the improved integration of zero-emission renewables and the move towards a carbon-neutral Europe, as well as the increased use of gas in place of coal in thermal generation. Figure 24 presents the most impacted countries with CO₂ reduction, although Germany and Poland will both still have a significant amount of thermal capacity in the 2030 scenario. The deployment of renewables has a greater effect on CO₂ emissions than interconnectors, as can be seen. Implementing the identified system needs in the overall Baltic Sea region transmission system could avoid 9 Mton of CO₂ production.

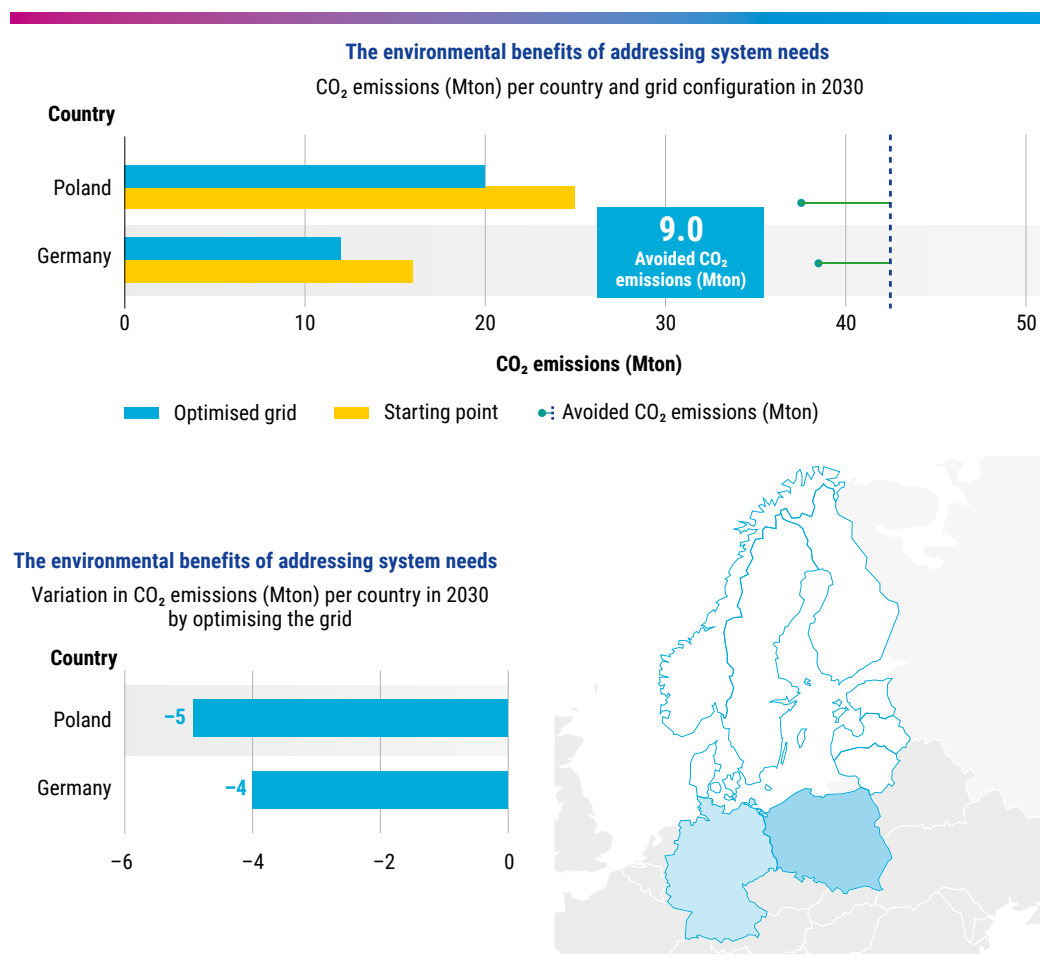


Figure 24: Reduction of CO₂ addressing system needs in 2030, NT scenario

Figure 25 shows the CO₂ reduction in the 2040 time horizon. The most significant CO₂ reduction is identified in Poland, which provides almost the entire CO₂ emissions savings in the Baltic Sea area. The total amount of CO₂ saved is similar to the 2030 time horizon, reaching 15.7 Mton.

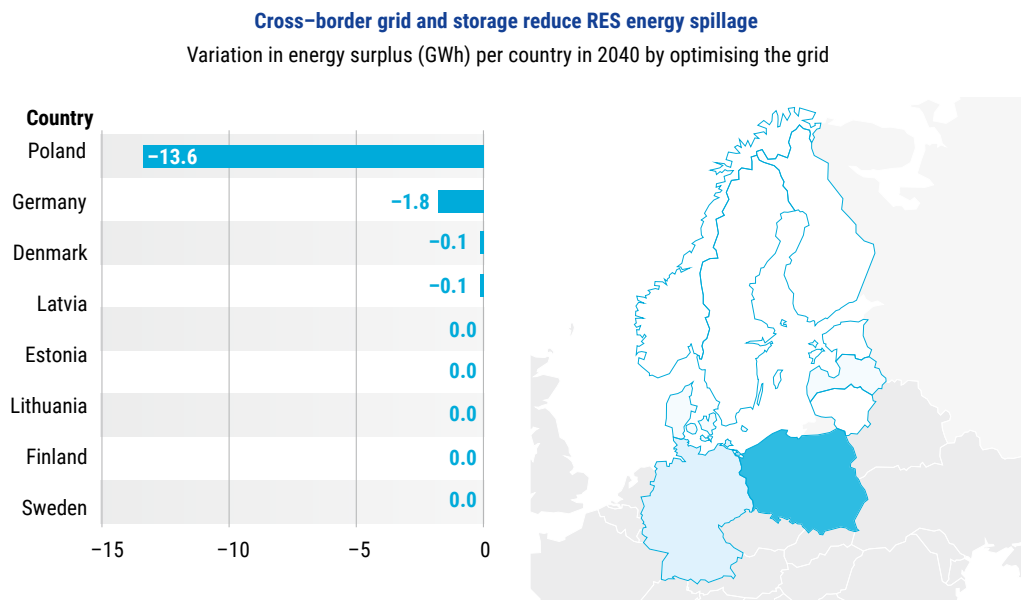
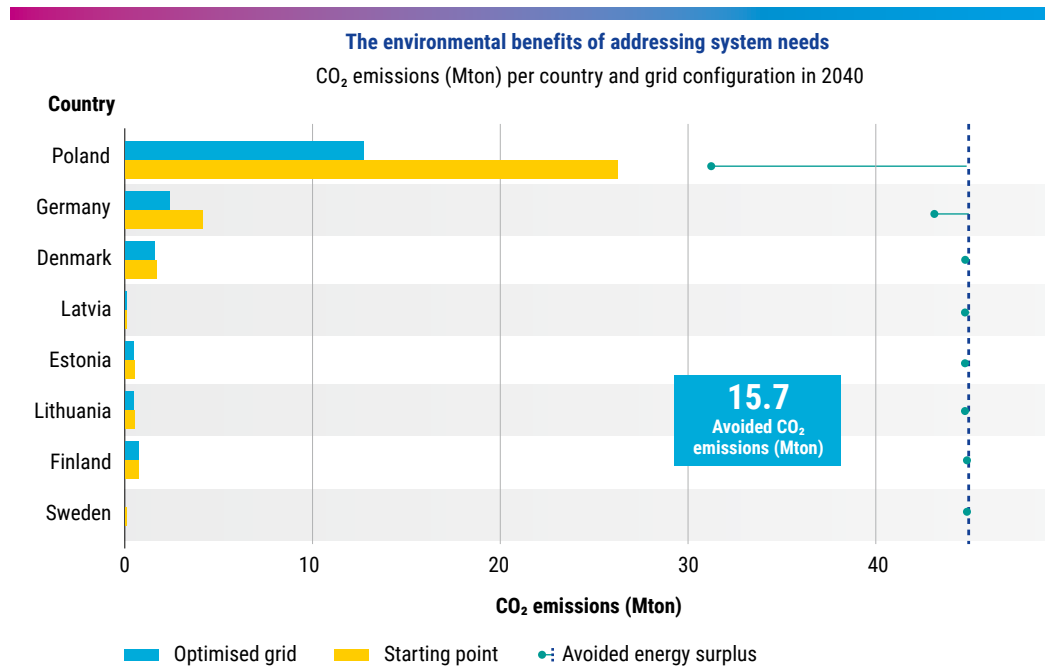


Figure 25: Reduction of CO₂ addressing system needs in 2040, NT scenario

For the long-term time horizon up to 2050, Figure 26 shows the identified CO₂ reduction in the Baltic Sea region. With the proposed investment projects, CO₂ production is reduced significantly, with only Poland showing some remaining production. Overall CO₂ production decreases from 10 Mton in Poland to 6 Mton. On the path towards carbon neutrality, the entire Baltic Sea region is very close to 0 emissions.

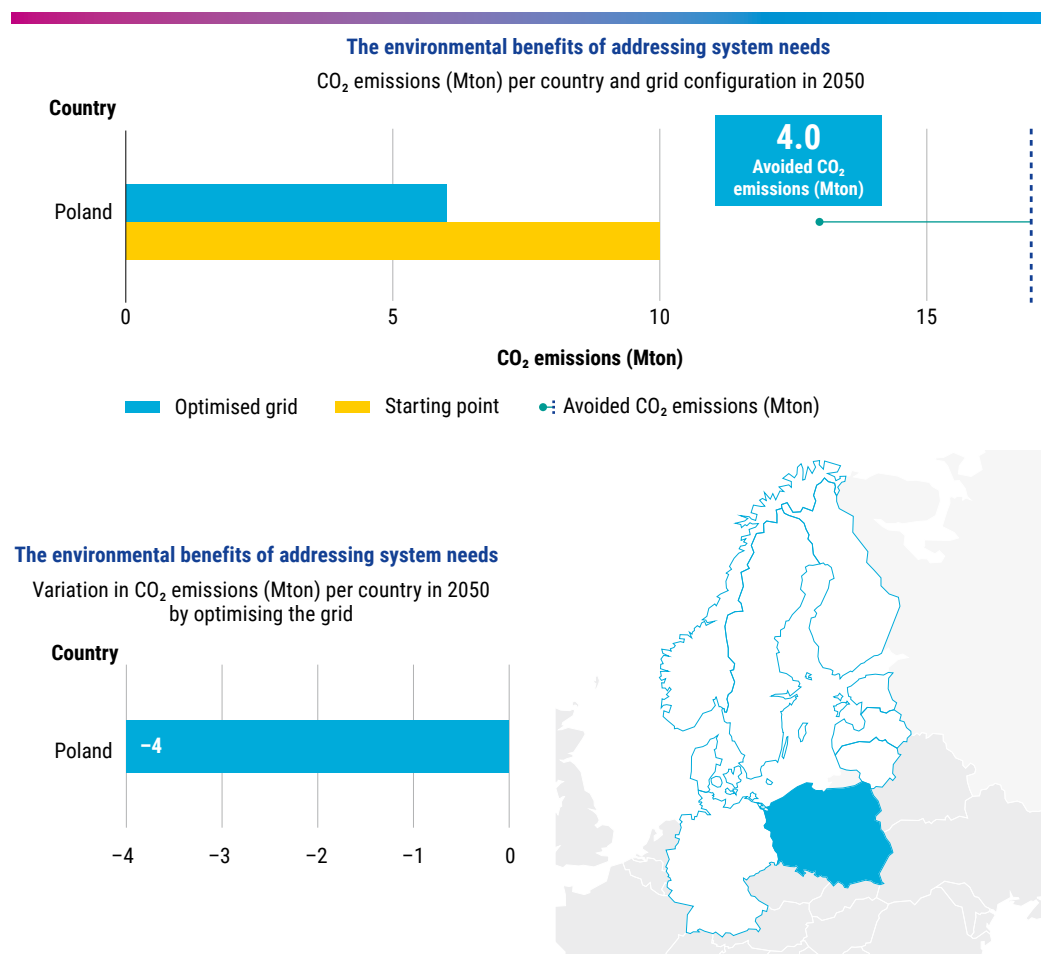


Figure 26: Reduction of CO₂ addressing system needs in 2050, DE scenario

3.3.3 Improved market integration and decreased average prices

As shown in Figure 27, the average price differences decrease when the transmission network is expanded and new cross-border capacities are introduced. More interconnector capacity between countries will reduce price differences and help develop a more effective and integrated market, which also reduces the price in each country. Therefore, it will be possible to import/export more power within a shorter period when price differences are high, such as during dry years with higher prices in the Nordic regions or periods when the variation in renewable production is high. The hydro-based power market in the Nordics will become more integrated than the more thermal-based market in CE, and price variations between wetter and drier years will be lower.

In the 2030 portfolio grid scenario, the average reduction in the wholesale market price would be €4.7/MWh – a significant decrease that reflects the power system’s improved ability to integrate significantly more new RES generation capacity. It should be noted that the results are very sensitive to assumptions about fuel and CO₂ pricing. To integrate electricity markets and harmonise marginal costs between the country groups within the Baltic Sea region, additional capacity increases in the cross-borders will be necessary.

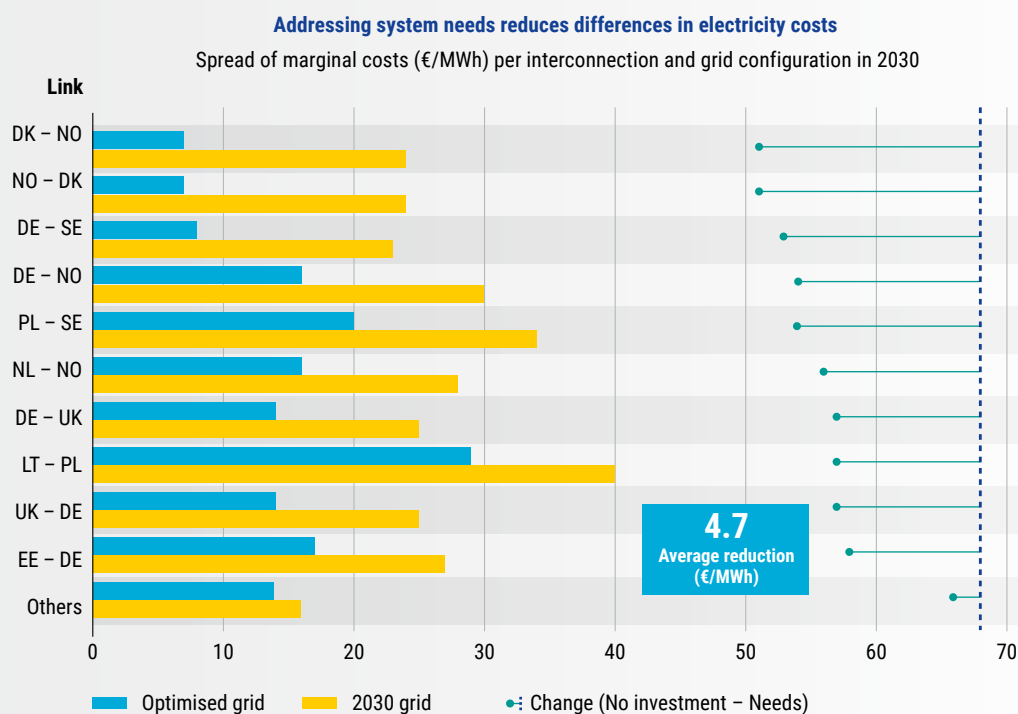


Figure 27: Spread of marginal costs per interconnections and cross-borders in the 2030 time horizon

On average, in the 2040 optimised grid scenario, which is presented in Figure 28, the average marginal cost level could be reduced by € 8.8/MWh, even higher than in the 2030 time horizon. The highest spread of marginal costs in the Baltic Sea region is on the Poland–Sweden border (€ 60/MWh). Implementing a wide range of investment projects could reduce this spread by € 23/MWh. It should be noted that the results are very sensitive to assumptions about fuel and CO₂ pricing. To integrate electricity markets and harmonise marginal costs between the country groups in the Baltic Sea region, additional capacity increases in these groups will be necessary.

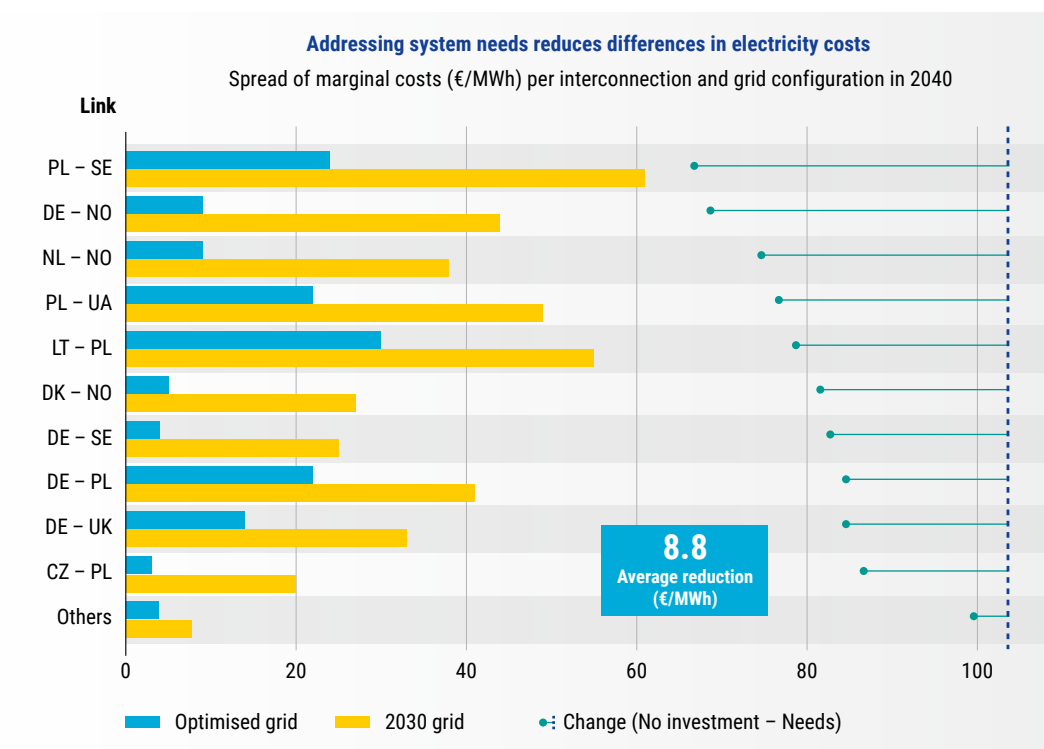


Figure 28: Spread of marginal costs per interconnections and cross-borders in 2040 time horizon

On average, in the 2050 optimised grid in the DE scenario, which is presented in Figure 29, the average marginal cost level in the Baltic Sea Regional Group could be reduced by €16.6/MWh, offering a significant benefit for marginal price harmonisation among EU Member States. In the 2050 time horizon, the highest marginal cost spread is identified in Germany and the cross-border connections in which it is involved. This is due to a significant increase in demand in Germany, highlighting the critical need to strengthen cross-border infrastructure around Germany. The highest marginal cost spreads in the Baltic Sea region are on the Germany–Belgium cross-border (about €95/MWh) and the Germany–Czech Republic (about €96/MWh). Implementing new cross-border projects could reduce these spreads to about €5–7/MWh. It should be noted that the results are very sensitive to assumptions about fuel and CO₂ pricing. To integrate electricity markets and harmonise marginal costs between the country groups within the Baltic Sea region, additional capacity increases will be needed in these countries by 2050.

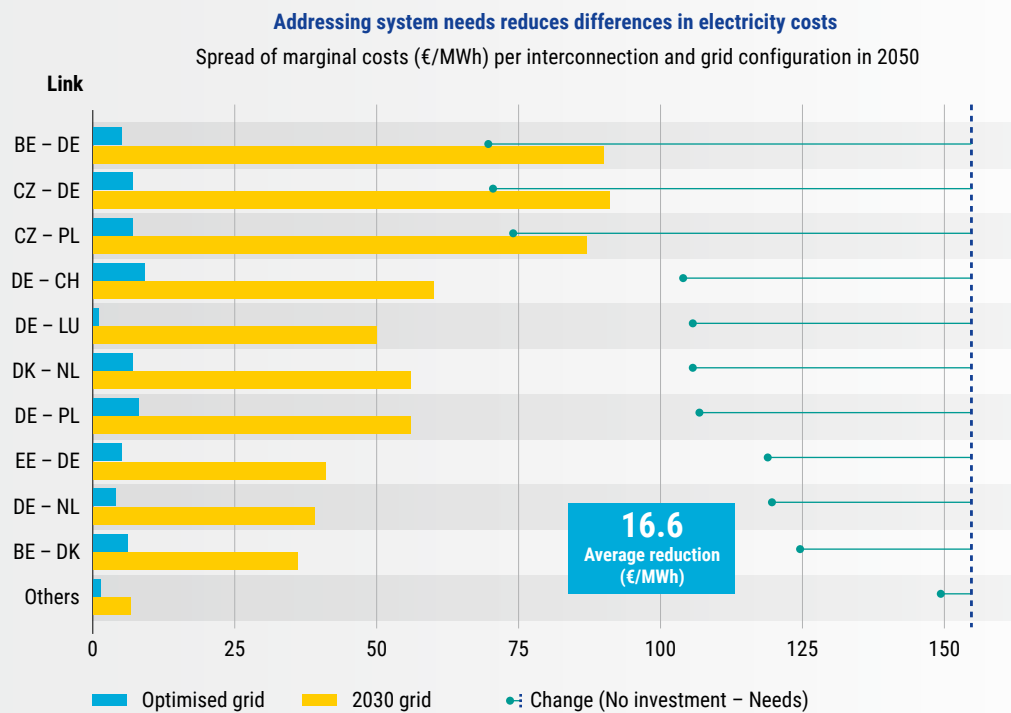


Figure 29: Spread of marginal costs per interconnections and cross-borders in the 2050 time horizon

3.3.4 How technology changes system implementation needs

Figure 30 illustrates the changes in generation technology for each country, reflecting the impact of new power system investments in the 2030 time horizon. The key aspect of Figure 30 is the reduction in non-renewable energy usage through new power system investments, which supports the green transition scenarios developed by ENTSO-E and the EU. The most significant reductions in energy curtailment from enhanced transmission network capacities are observed in Germany, Denmark, and Lithuania. These investments enable more optimal energy generation, shifting towards increased RES production and lower CO₂ emissions. Additional grid projects enhance the exchange of renewable energy among Baltic Sea region countries, further decreasing CO₂ output. In Sweden, a notable amount of power-to-gas (P2G) savings is achieved due to improved renewable energy exchange within the region and energy imports from neighbouring country Finland.

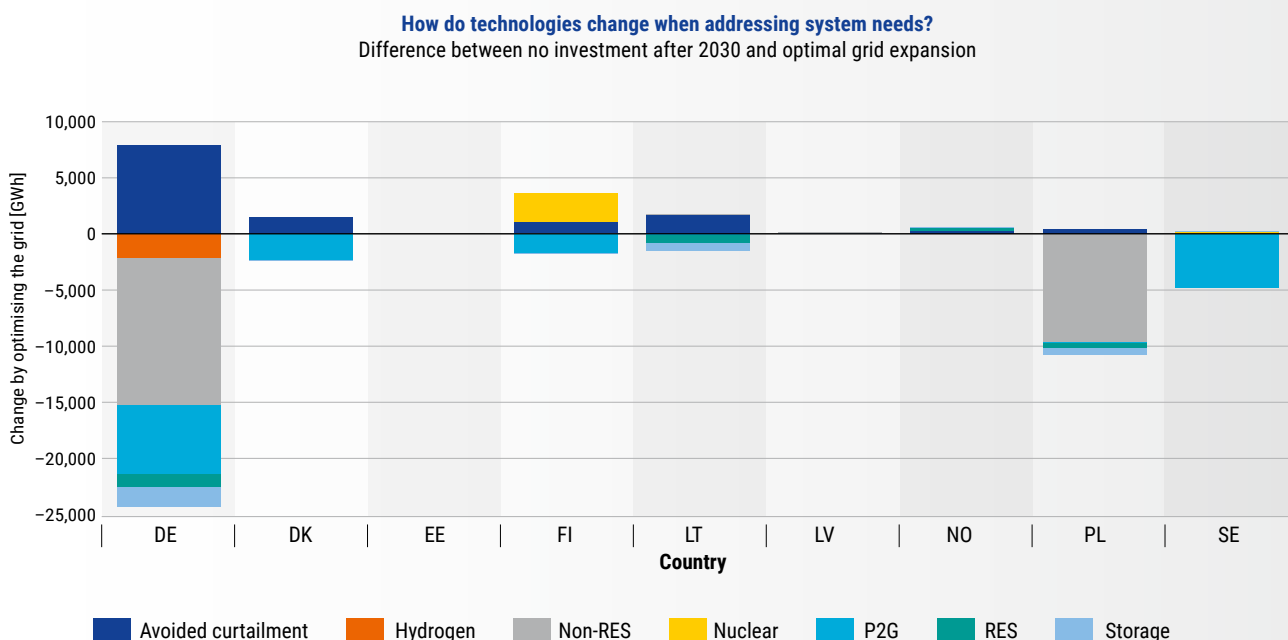


Figure 30: Technological change in the Baltic Sea region addressing system needs in 2030

Figure 31 shows the variation in non-RES generation per country in the 2030 time horizon by optimising the grid. As previously noted, the most significant non-RES generation savings are in Germany and Poland, with the Baltic Sea region countries seeing a very minor impact.

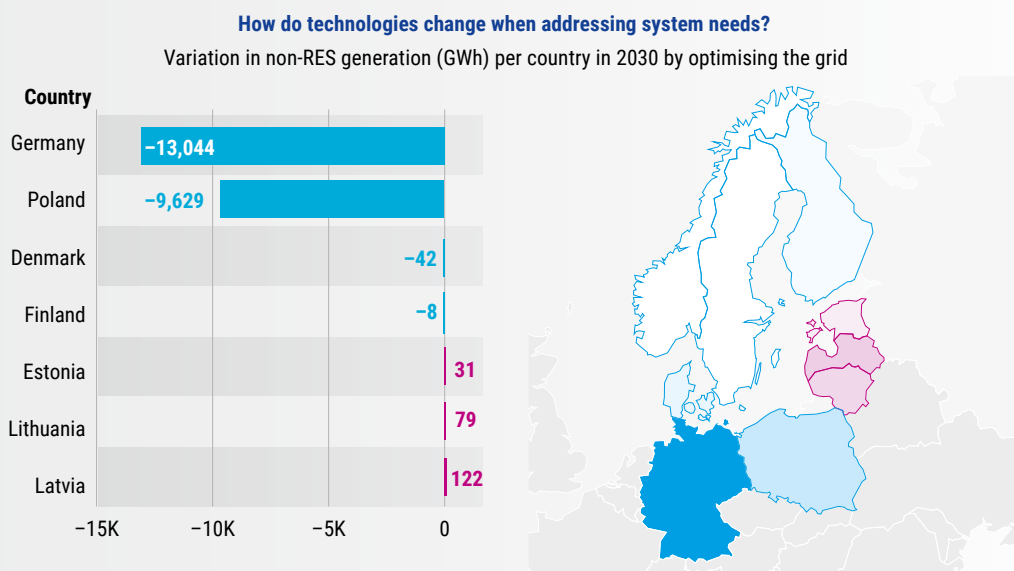


Figure 31: Variation in non-RES generation per country with optimised grid in 2030

Figure 32 shows the generation technology change in each country based on new power system investments projected for the 2040 time horizon. The key aspect of Figure 31 is the reduction in non-renewable energy usage through new power system investments, which supports the green transition scenarios developed by ENTSO-E and the EU. The most significant reductions in energy curtailment from enhanced transmission network capacities are observed in Germany, Denmark, Finland, Norway, Estonia, and Sweden. Power system investments, along with the ability to generate energy elsewhere in the most optimal and efficient way, drive changes in energy production technologies, with the aim of increasing RES production and reducing CO₂ emissions. Additional grid projects improve RES energy exchange among Baltic Sea region countries and reduce overall CO₂ production. By 2040, a significant amount of renewable energy curtailment is anticipated in Germany, Finland, and Norway. Some additional cross-border grid reinforcements could be developed and implemented to reduce RES spillage. In Sweden, a substantial amount of P2G is generated to help maintain energy balance within the country and the Baltic Sea region. In Germany, hydrogen production is constrained by energy supply limitations for production units. Enhancing cross-border capacities to Germany could boost hydrogen production by providing more energy to these units.

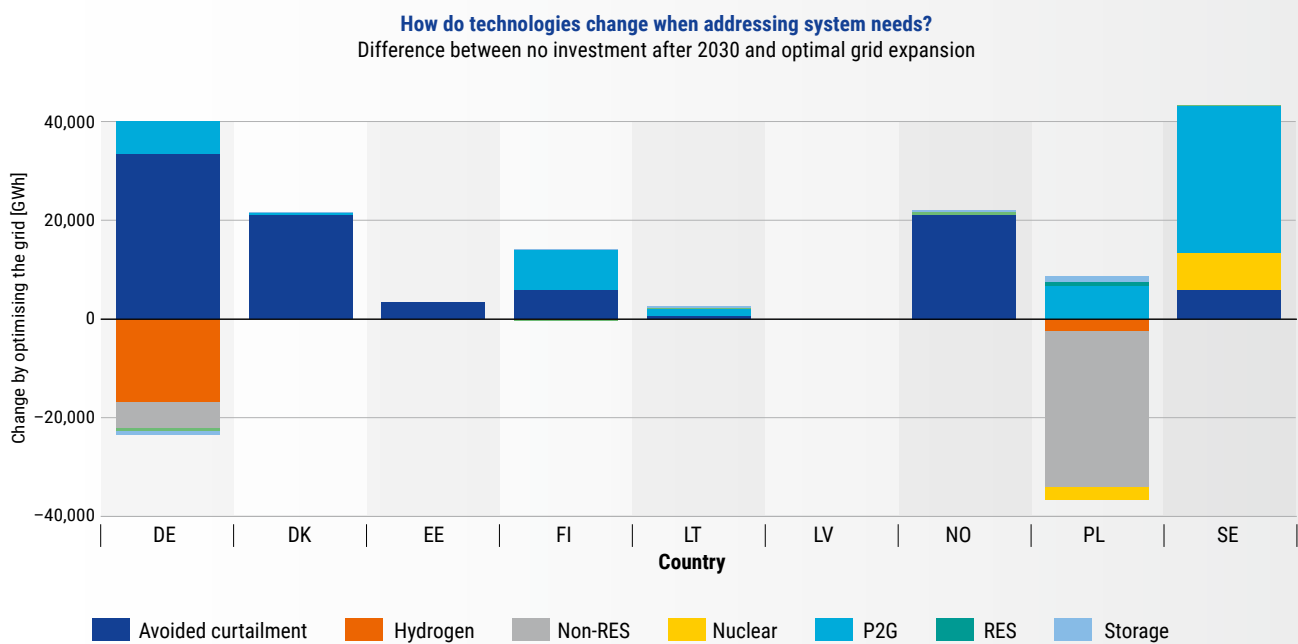


Figure 32: Technological change in the Baltic Sea region addressing system needs in 2040

Figure 33 shows variation in non-RES generation per country in the 2040 time horizon by optimising the grid and introducing new grid investments. As previously noted, the most significant non-RES generation savings are in Poland, followed by Germany. Identified non-RES savings show that the addressed grid investments will reduce non-RES production in Poland and Germany by about 25.2 TWh. The impact on other Baltic Sea region countries is minor.

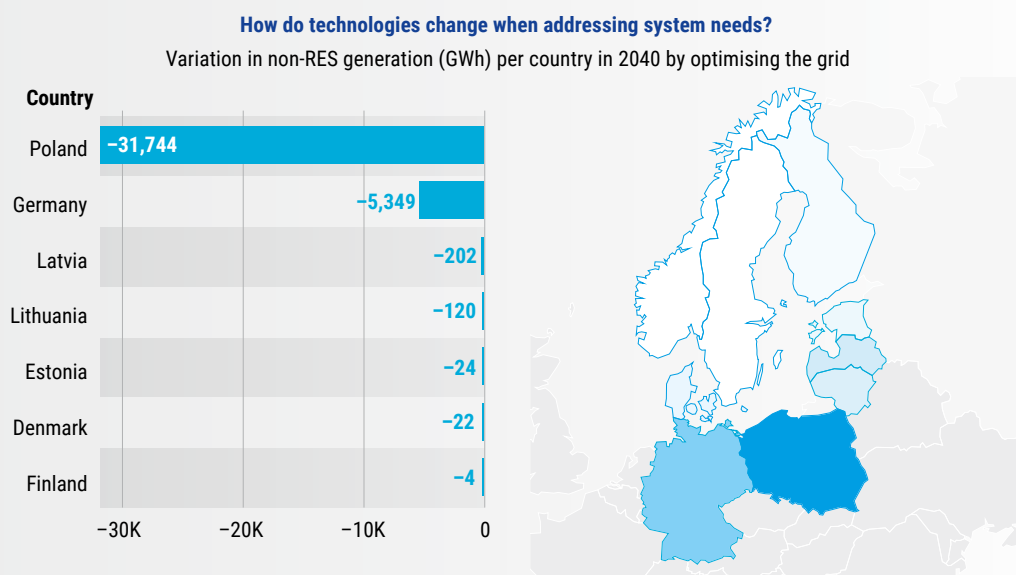


Figure 33: Variation in non-RES generation per country with optimised grid in 2040

Figure 34 shows the generation technology change in each country applying new power system investments up to the 2050 time horizon. Due to substantial investments in the transmission system, RES curtailment is very low in Germany, Finland, and Poland. The greatest reductions in energy curtailments through implementing additional transmission network capacities are observed in Denmark, Norway, Sweden, Estonia, and Latvia. The optimised grid solution will significantly improve RES production in Norway. Storage capacity is effectively applied to ensure energy utilisation in the hours needed for power system balance. Power system investments, along with the ability to generate energy elsewhere in the most optimal and efficient way using storage opportunities, drive changes in energy production technologies, with the aim of increasing RES production and reducing CO₂ emissions. Additional grid projects improve RES energy exchange among Baltic Sea region countries and reduce overall CO₂ production. In Germany, hydrogen production is constrained by energy supply limitations for production units. Enhancing cross-border capacities to Germany could boost hydrogen production by providing more energy to these units.

How do technologies change when addressing system needs?
 Difference between no investment after 2030 and optimal grid expansion

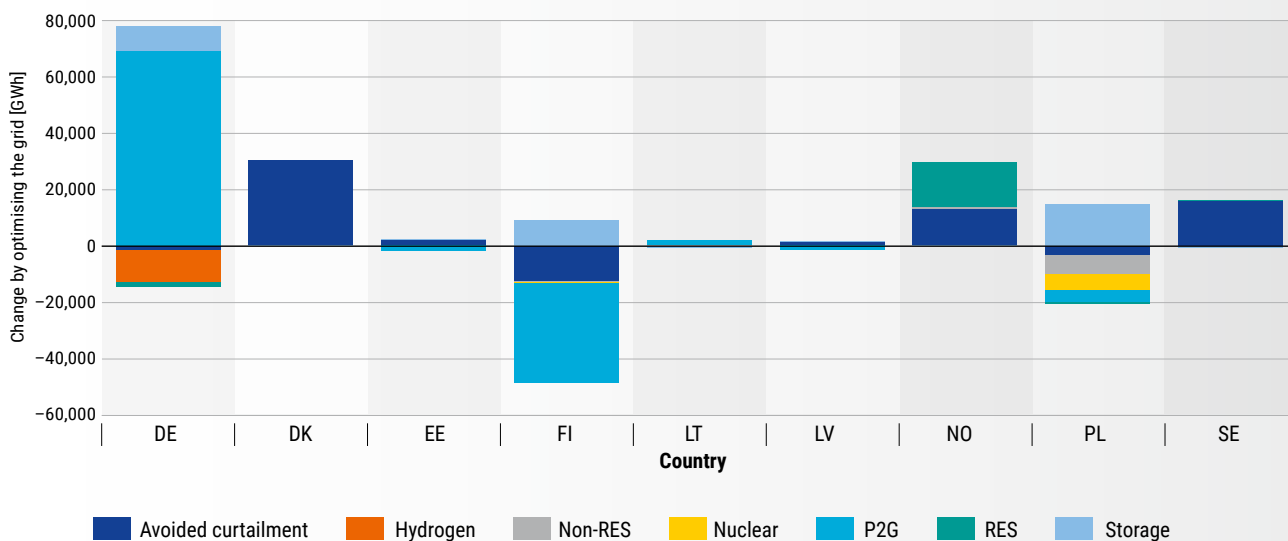


Figure 34: Technological change in the Baltic Sea region addressing system needs in 2050

Figure 35 shows the variation in non-RES generation per country in the 2050 time horizon by optimising the grid and introducing new grid investments. In this distributed energy scenario for 2050, the most significant non-RES generation savings are exclusively in Poland. Identified non-RES savings show that proposed grid investments will reduce non-RES production in Poland by about 6.7 TWh. The impact on the rest of the Baltic Sea region countries is minor. In the Baltic Sea region, Norway has increased non-renewable energy production to help maintain the power system balance across the entire area.

How do technologies change when addressing system needs?
 Variation in non-RES generation (GWh) per country in 2050 by optimising the grid

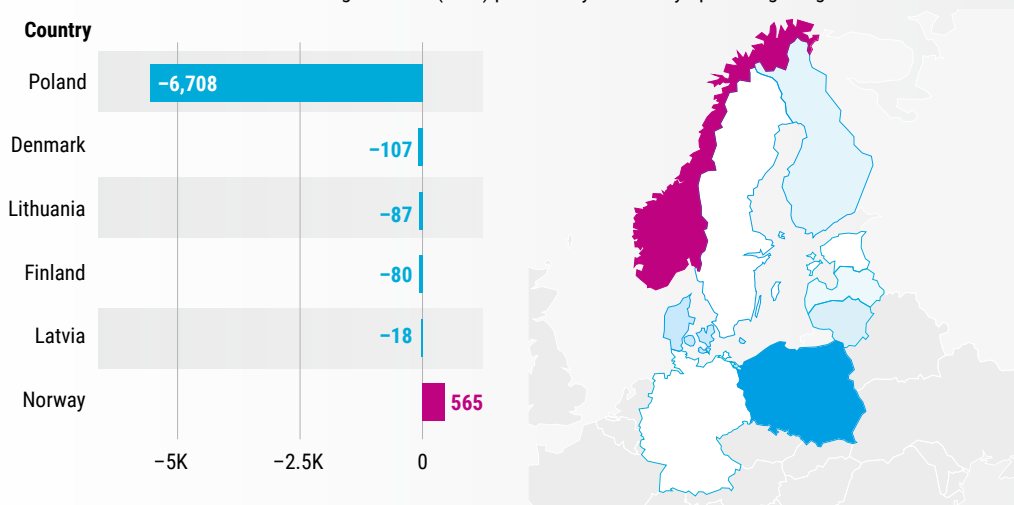


Figure 35: Variation in non-RES generation per country with optimised grid in 2050

3.3.5 Grid extension could reduce system costs

Figure 36 displays all transmission and storage projects included in the pan-European TYNDP 2024. Transmission projects by category reveal that the most significant portion, 31%, is allocated to onshore projects, while offshore hybrid and offshore interconnections each represent 11%. Hydro pumped storage dominates the storage projects category, though the number of power plants – six – is rather small. In the Baltic Sea region, two compressed air storage projects are being developed, located in Germany and Denmark.

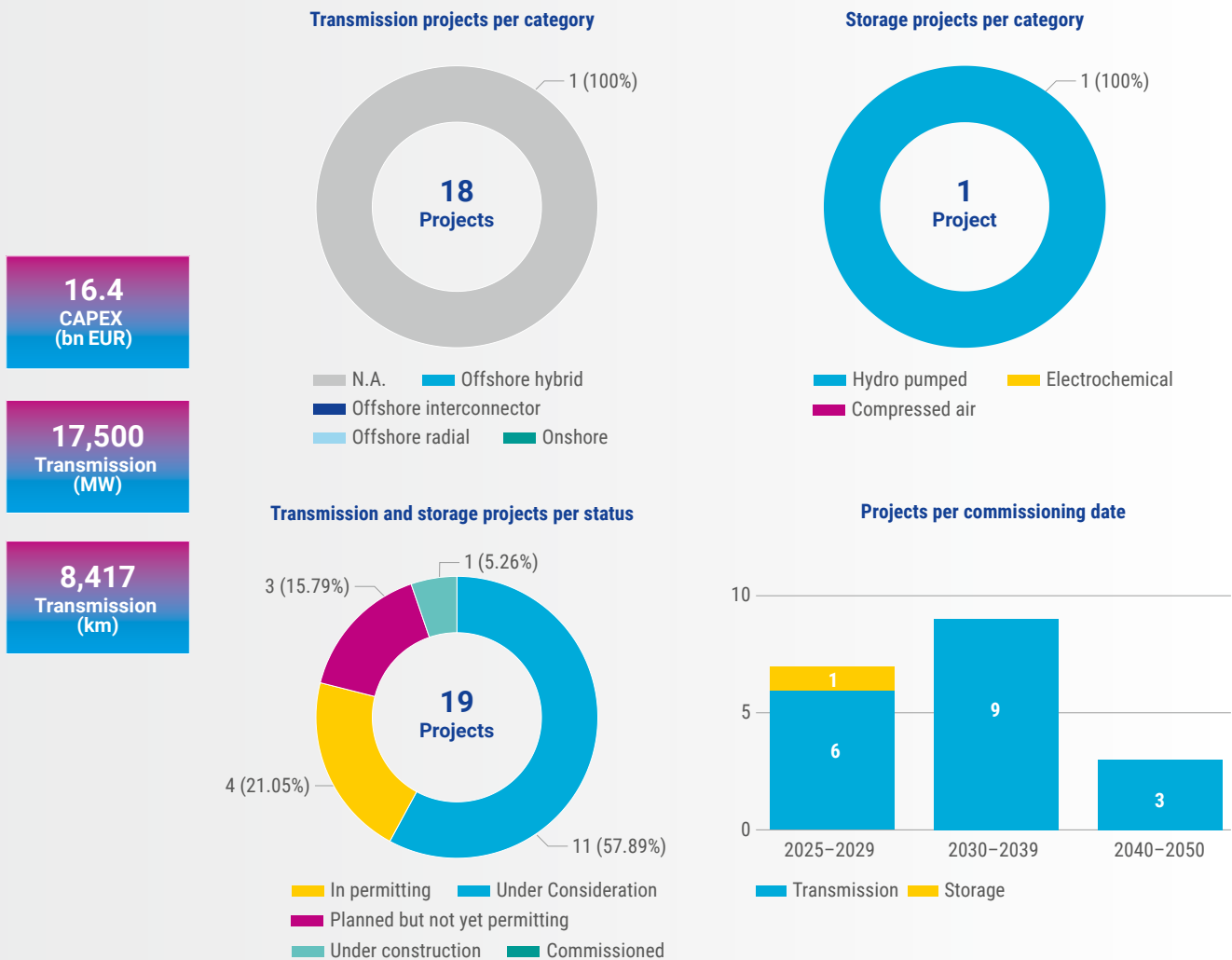


Figure 36: Transmission and storage projects per category and status

In the project status field, a very small percentage (4%) are in the construction phase. Most projects under the TYNDP study are in the “under consideration” and “planned” phases, with long-term goals centred around connecting and integrating renewable energy into the power system. The commissioning dates for these projects vary across different time horizons: short-term (2025–2029), mid-term (2030–2039), and long-term (2040–2050). Most of the proposed transmission projects under TYNDP 2024 are slated for commissioning between 2030 and 2039, with some scheduled for the near future, up to 2029. Very few projects in the Baltic Sea region are scheduled for the long-term time horizon.

4 Roadmap for Addressing System Needs

This chapter presents the roadmap to addressing system needs, including the most important cross-borders and projects to be promoted and developed by the TSOs to meet identified system needs objectives. The infrastructure gaps for 2040 are presented in Figure 37.

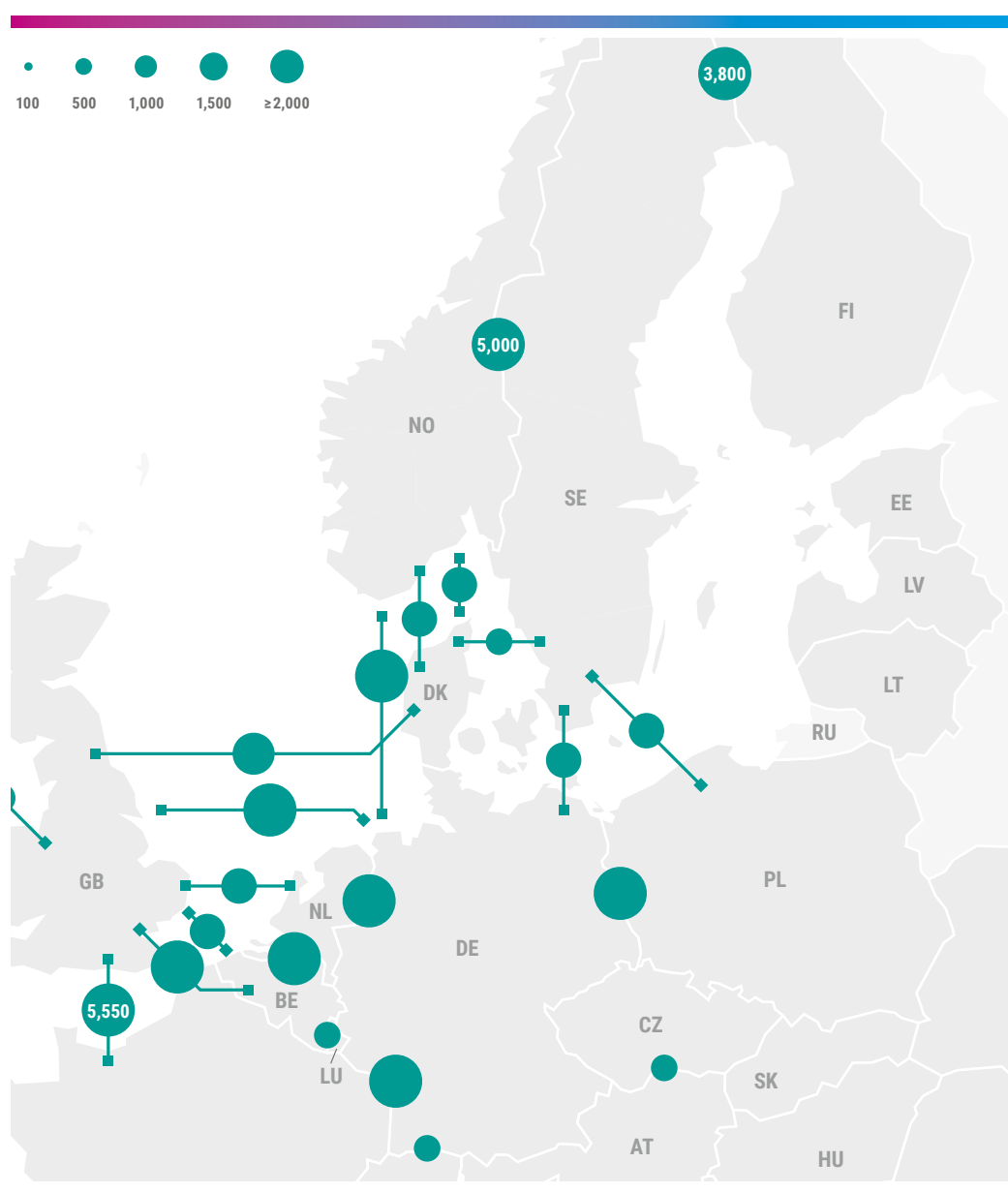


Figure 37: Difference between the cross-border needs identified in 2040 and the cross-border capacity increases expected from transmission projects due to commission by 2040. The bigger the circle, the bigger the opportunity to develop new solutions to increase capacity

4.1 Bridging the gap

To close the gaps between current infrastructure and the system needs identified in Chapter 3, several investment decisions for transmission and storage projects must be made. The projects in the TYNDP 2024 portfolio will help partially bridge the identified gaps, as shown in Figure 38. LaSGo Link – the blue interconnector between Sweden (via Gotland) and Latvia – is not part of the national development plan in Sweden and Latvia.

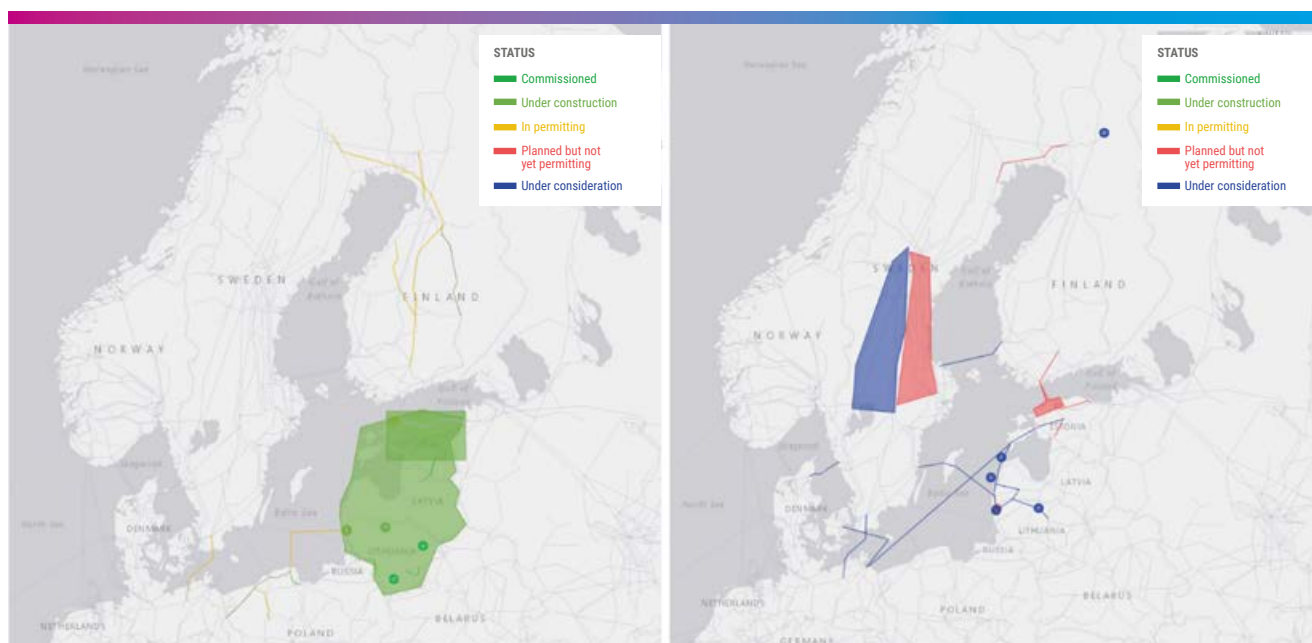


Figure 38: TYNDP 2024 project list, with commissioned, under construction, and in permitting projects (left side) vs planned but not yet permitting and under consideration projects (right side)



Based on the TYNDP 2024 projects, project promoters and TSOs are partially addressing the gap between the current grid and future needs. However, numerous projects still need to be implemented to meet future needs. To cope with this long-term generation mix, the interconnected European power systems will need to solve the following problems through cross-border capacity increases:

Insufficient integration of renewables into power systems, as high amounts of curtailed energy occurred in a couple of power systems

- › Insufficient market integration, including high system costs in certain market areas and significant price differences between market areas
- › High CO₂ emissions
- › Insufficient cross-border capacities

The “future capacity needs” identified in the System Needs Study are primarily driven by anticipated changes in the overall power system, such as shifts in load-flow patterns under future scenarios. Therefore, the transmission system elements that limit cross-border capacity in the 2023 time horizon could change by 2030 and 2040 due to changes in the generation mix – both in terms of installed capacities and power system locations – as well as the partial strengthening of the grid infrastructure.

The theoretical identification of needs for increased capacity, which is based on current assumptions, suggests areas where system development may be necessary. Table 2 describes cross-border projects in various phases – from under consideration to under construction – that will contribute to closing the gaps along the relevant borders.

Project	Commissioning year
DK-NO	The identified capacity increase on the border between Denmark and Norway will be partially covered by the TYNDP project Reinvestment of Skagerrak 1 and 2 . The Norwegian government has decided to postpone the planning of the project to 2029 at the earliest.
DK-SE	The TYNDP project Upgrade to Konti-Skan , a new HVDC connection replacing Konti-Skan 1 and 2, will partially cover the identified gap between Denmark and Sweden.
DK-DE	The TYNDP project Bornholm Energy Island , a new hybrid offshore interconnection, will partially cover the identified gap between Denmark and Germany.
EE-FI	The identified capacity increase between Finland and Estonia will be partially covered by the TYNDP project Estlink 3 , the third HVDC connector.
EE-LV	The identified capacity increase between Estonia and Latvia will be partially covered by the TYNDP project hybrid offshore fourth interconnector between Estonia and Latvia .
FI-NO	The identified capacity increase on the border between Finland and Norway will be partially covered by the TYNDP project Increased capacity Norway–Finland, Back-to-Back .
FI-SE	The TYNDP projects Fenno-Skan 3 (HVDC between SE3 and FI), Aurora line and Aurora line 2 (third and fourth AC line between SE1 and FI) will partially cover the identified capacity increase between Finland and Sweden.

Project	Commissioning year
DE-PL	The identified capacity increase on the border between Germany and Poland is subject to further discussion and analysis, as there is no existing agreement or planned project at this stage. In addition, the new cross-border capacity requires a significant amount of internal network reinforcement in Poland.
DE-SE	The identified capacity increase on the border between Germany and Sweden is subject to further discussion and analysis.
LV-LT	The TYNDP project Latvia and Lithuania cross-border strengthening project , which includes existing interconnection reconstruction to increase the total amount of cross-border capacity up to 1000 MW on the Latvia and Lithuania border, will partially cover the identified gap.
LV-SE	The identified capacity increase on the border between Latvia and Sweden will be partially covered by the TYNDP project LaSGo Link. NB , LasGo-Link is not part of the national development plan in Sweden. The Swedish TSO has previously rejected a grid connection inquiry for the project, but from the long-term perspective, the project would be interesting for RES connection and system flexibility.
LT-PL	The new Harmony Link transmission line will provide a capacity of 700 MW. The potential for increasing transmission capacity on the LT-PL connection relates to the possibility of unblocking these capacities on the existing double-circuit 400 kV LitPol Link connection.
LT-SE	The identified capacity increase on the border between Lithuania and Sweden is subject to further discussion and analysis, as there is no existing agreement or planned project at this stage.
NO-SE	The identified capacity increase on the border between Norway and Sweden is subject to further discussion and analysis, as there is no existing agreement or planned project at this stage.
DE-Baltic states	The Baltic WindConnector (BWC) project is a long-term project with high regional importance. Building on an initial letter of intent, signed by AST, Elering, Litgrid, and 50Hertz in May 2023, all four parties have concluded cost-benefit analyses, grid calculations, and analysis of various topologies for hybrid interconnector projects between the Baltic states and Germany. As an outcome, the Baltic WindConnector project 1211 was submitted to TYNDP 2024 by Elering, AST, and 50Hertz. Germany and all three Baltic states continue to collaborate to further investigate the opportunity for a regional project solution that includes all Baltic countries. Part of the current project phase is therefore to determine the best configuration to maximise the benefits of the project for the Baltic countries and the EU as a whole. At this point, several topologies and configurations are possible, such as a regional solution that includes Germany and all three Baltic states or one to two separate projects that connect the Baltic states with Germany and CE via hybrid interconnectors. Further investigation of the project concept and connection points in the Baltic states and Germany must continue.
PL-SE	The identified capacity increase between Poland and Sweden is subject to further discussion and analysis, as there is no existing agreement or planned project at this stage.

Table 2: The most important cross-border projects to closing the gaps along the regional group Baltic Sea countries

The effects of identified future capacity needs on the cross-border profiles in the Baltic states region could be covered, either fully or partially, by the future transmission projects detailed in the TYNDP 2024 (listed above). It should be noted that all these projects represent *possible* grid development and are subject to change based on assumptions in future scenarios. If these projects are not implemented, system needs will have to be addressed through future grid development, storage solutions, or other, non-infrastructure-based solutions. In addition, the expectations for increased offshore wind may lead to new types of hybrid projects that combine offshore wind with interconnections between countries. Offshore-specific details are provided in the TYNDP ONDP, and further investigation is needed.



4.2. How to address future challenges

For the Baltic Sea region, 2030 and 2040 needs are expected to be met primarily through further integration between countries to reduce high price differences, enhance market integration, and improve the optimisation of RES generation. Another key milestone is the synchronisation of the Baltic system with the CE system, as well as further internal integration within the Baltic region to improve security of supply.

For the Baltic Sea region, 2030 and 2040 needs are expected to be met primarily through:

- › Synchronisation of the Baltic system with the CE power system and further internal integration within the Baltic region to improve security of supply
- › Offshore wind parks – if realised, the energy they generate will need to be transported to the onshore system, increasing the need for additional grid reinforcements
- › Further Sweden–Finland integration to increase market integration and address the negative Finnish energy balance
- › Further integration between Sweden and Germany to address price differences and improve the optimisation of RES generation (hydro/wind)
- › Further integration between Sweden and Denmark to address price differences and improve the optimisation of RES generation (hydro/wind)
- › Further integration between Denmark and Norway to address price differences and improve the optimisation of RES generation (hydro/wind)
- › Further integration between Sweden and Norway to address price differences
- › Further integration between Sweden and Lithuania to address price differences and improve the optimisation of RES generation
- › Further integration between Sweden and Poland to address price differences
- › Further integration between Lithuania and Latvia to address price differences and improve the optimisation of RES generation
- › Further integration between Estonia and Finland to address price differences and improve the optimisation of RES generation

The Nordic power system is well-integrated due to a long history of cross-border cooperation on grid, operations, and market development. The Nordic countries are front-runners in the areas of renewables and sector coupling. Therefore, they have an excellent foundation for addressing new challenges together. The Nordic electricity system is already a strong system, with good possibilities for connecting generation and consumption. In addition, the Nordic TSOs are making significant investments in the power grid to make the connections between electricity production and consumption that will be required in the climate-neutral society of the future. This means that there will be a considerable amount of competitively priced and green electricity available in the Nordics in the future. The TYNDP scenarios indicate an electricity surplus in the Nordics in the future, with average power prices lower than the prices in CE. This, combined with a strong power grid, makes the Nordics an excellent location for power-intensive investments.

Available flexibility will assist in the optimal development and operation of the future system. Flexibility resources, such as demand-side response, P2X, storage, and electric vehicles, will become increasingly important to even out variations in the system and reduce volatility. Due to greater fluctuations in power prices, it is expected that profitable opportunities will emerge for operating these resources in the future system. However, conventional generation, particularly regulated hydropower, will remain important resources in the future system.





4.3 Regional studies and initiatives

Below, we highlight key regional studies and initiatives contributed by TSOs. A crucial aspect is the synchronisation of the Baltic states with the CE power system and the progress of related projects. From an offshore perspective, TSOs in the Baltic Sea region are cooperating in the BOGI group, focusing on key responsibilities and upcoming tasks. The Nordic Grid Development Perspective (NGDP) 2023, released on 25 October 2023, outlines a shared vision for the future power system up to 2050 and presents strategies to tackle emerging challenges within the Nordic system. It also provides a status update on ongoing and planned investments of significant Nordic impact.

4.3.1 Baltic synchronisation

The Baltic states have been operating in synchronous mode with the CE since 9 February 2025. Previously, the Baltic states operated in synchronous mode with Russian and Belarussian electricity systems (IPS/UPS), forming the so-called BRELL ring (Belarus–Russia–Estonia–Latvia–Lithuania). The energy policy of the Baltic states is integrated with the energy strategy of the EU and must comply with major objectives like sustainable development, electricity market competitiveness, and security of supply. In addition to these objectives, the Baltic states must continue developing competitive and fully integrated electricity markets, along with a sufficiently developed energy infrastructure to connect distributed RES (wind, solar, biomass and biogas, etc.) and meet long-term EU energy neutrality targets set for 2050.

Since 2014, many preparatory actions and pre-feasibility studies have been performed to prepare for the Baltic states' synchronisation with CE, and it was successfully accomplished at the beginning of 2025. The project was initiated, a general roadmap was signed, the EU and Baltic states leaders reached a political agreement, various studies and power system upgrades were completed, and others are still in progress to prepare the Baltic states for synchronous operation with CE. The project has received European Union co-financing from CEF funds of around €1.23 billion for its implementation. The Baltic synchronisation project has been divided into two parts:

Phase I

internal transmission network reinforcements in the Baltic states. These investments are necessary to strengthen the internal grid of the Baltic states and prevent bottlenecks in the cross-border connections of the three countries, regardless of the synchronisation scenario with the CE power system.

Phase II

investment recommended by the dynamic and frequency studies conducted by the Baltic and Polish TSOs, as well as for the actions outlined in the Catalogue of Measures of the CFI Agreement – an agreement concluded on 27 May 2019 between the Baltic and European TSOs regarding the conditions for the future interconnections of the Baltic states power system with the CE system.

The Baltic synchronisation cluster is included in the sixth Project of Common Interest (PCI) list with No. 4.8 under the corridor, which includes the Baltic Sea region projects along with the Nordic countries, the Baltic states, Poland, and Germany. Synchronisation Project No. 3.3, along with all relevant investment items, is also included in the latest PCI/PMI list under the Baltic Energy Market Interconnection Plan for electricity, where it is titled “Integration and synchronisation of the Baltic states’ electricity system with the European networks”. The inclusion of synchronisation-related investment items in the updated PCI list highlights the importance of the synchronisation project for both the Baltic Sea region and Europe. The PCI list includes only the most important and beneficial projects for the EU.

In 2021, AST, Litgrid, and Elering signed a service contract with the consortium of transmission system operators of CE (CE TSOs) to prepare synchronisation studies for recommendations on necessary upgrades to Baltic power systems. Five studies were prepared and delivered: a dynamic stability study and an oscillatory stability study, both using a fully dynamic model of the Baltic region and CE; an isolated operation study; a frequency stability assessment system study; and a load-frequency control (LFC) implementation study in Baltic power systems.

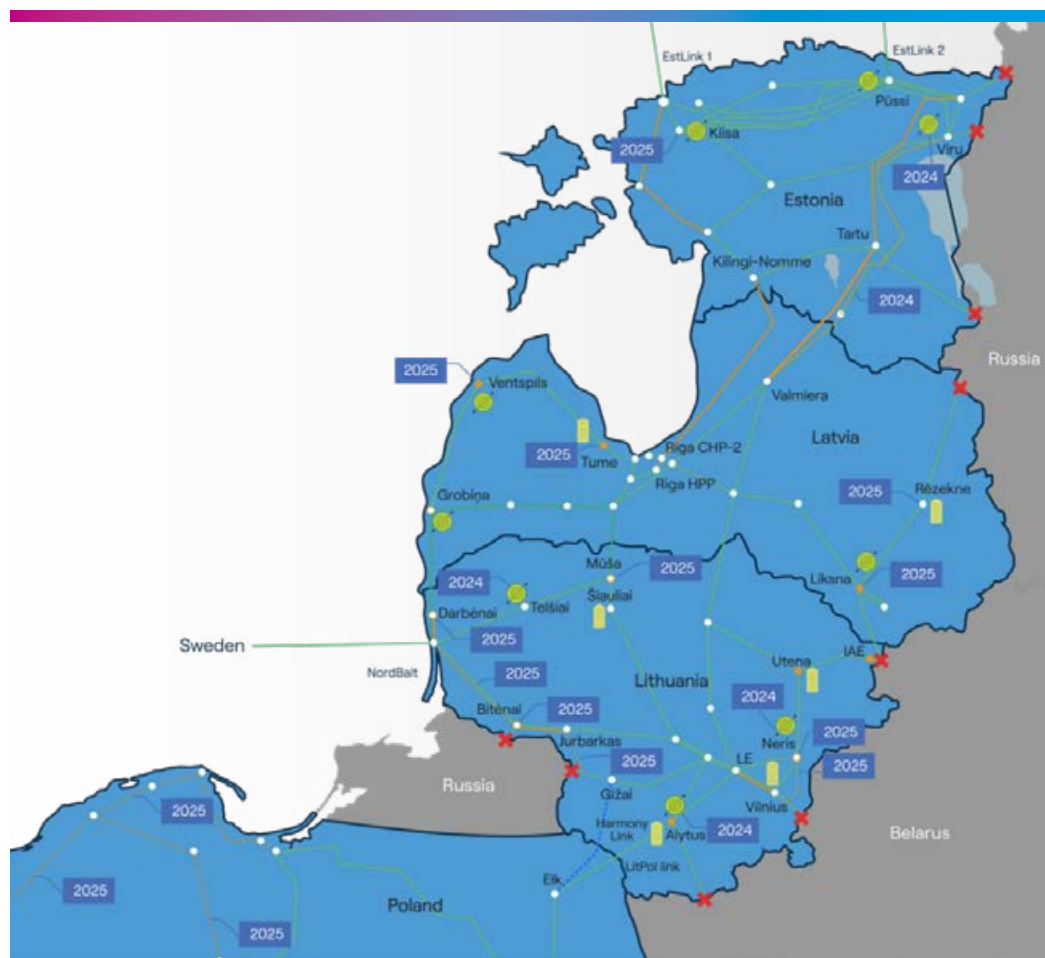


Figure 39: Topology of investments for the Baltic states and Poland, included in the Baltic synchronisation project

In April 2023, Lithuanian TSO Litgrid and Polish TSO PSE cancelled the procurement of the planned offshore Harmony Link HVDC interconnector due to a significant increase in cable and converter station prices. Immediately, the Polish and Lithuanian TSOs began to reconsider various technical solutions to reduce costs and implement the additional interconnection in the shortest possible time. The AC onshore interconnector solution was one proposed solution. According to the Baltic state TSOs (AST, Elering, and Litgrid), along with the Polish TSO, PSE, a power flow and dynamic feasibility study has been commissioned to investigate the option of an AC double-circuit 220 kV AC Harmony Link overland (cable and overhead line) link and its impact on the stability of both the Baltic and CE power systems.

The study found that the Harmony Link in AC onshore concept can be considered a stable interconnected system at least on par with, if not better than, the planned offshore interconnector. At first glance, the HV onshore interconnector would connect the reconstructed substation in Giżai (Lithuania) with the Elk substation in Poland. The overland HV link could partially utilise existing and planned road and rail infrastructure between Poland and Lithuania. A decision on the specific technical approach for implementing the Harmony Link interconnector is expected in 2025.

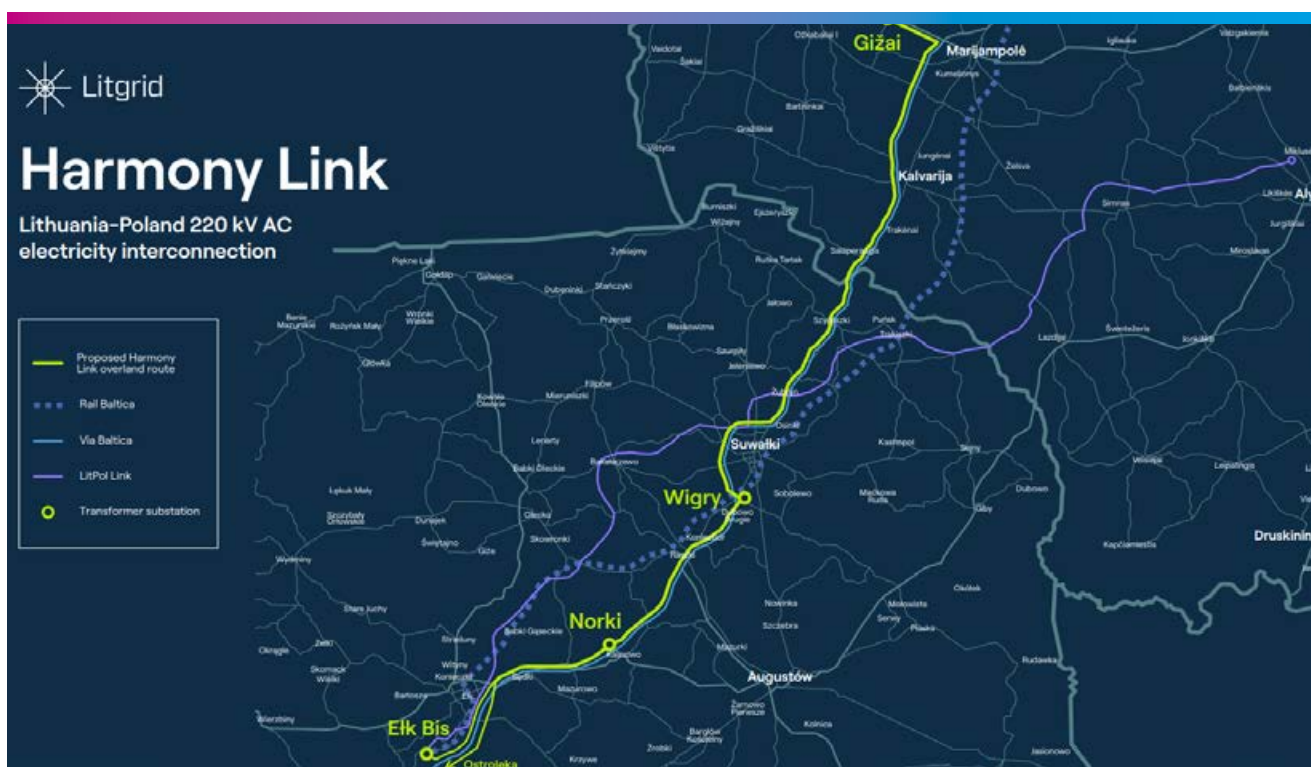


Figure 40: Topology of the investments for the Baltic states and Poland included in the Baltic synchronisation project



4.3.2 Baltic Offshore Grid Initiative – BOGI

The BOGI working group contains members from eight TSOs, including those from the Baltic Sea region – Elering AS (EE), Fingrid Oyj (FI), Affärsverket Svenska Kraftnät (SE), Energinet SOV (DK), 50Hertz Transmission GmbH (DE), AS Augstsprieguma tīkls (LV), Litgrid AB (LT) – and the Polish TSO, PSE Polskie Sieci Elektroenergetyczne. The Norway TSO Statnett was given observer status and does not directly engage in working group activities. The aim of BOGI is to gather strategic inputs at the Baltic Sea basin level for offshore grid development plans. For TSOs to establish all the necessary technical preconditions for offshore grid development, a legal framework must be created and implemented. Establishing an offshore grid is a multi-stage process that requires close cooperation between the countries around the Baltic Sea region. To create a common legal framework, it is necessary to:

- › jointly agree on the roadmap and principles for creating offshore connections
- › prepare mechanisms for costs and income allocation to overcome disproportional financing needs from the offshore grid
- › coordinate the planning and permitting processes

Offshore renewables targets and maritime spatial plans (MSPs) in the Baltic Sea play a vital role in offshore grid development, helping to achieve the long-term (through 2050) climate and energy policy targets set by the EU and individual countries (or sea basins). The BOGI working group has carried out an initial analysis of the current state of grid planning principles and challenges.

The main challenges are:

- › missing legal frameworks or diverse approaches to legal frameworks in MSPs
- › the need for harmonised approaches to hybrid grid planning in the Baltic Sea region
- › an overly lengthy permitting process for offshore grids (or in general)
- › the need for offshore RES targets based on MSPs to provide TSOs with clear guidance on development priorities

The BOGI working group is developing a 2025 expert paper, which will compile information and a grid map of offshore wind projects, focusing on the efficient placement of offshore wind connections in the Baltic Sea region. The document will address cost-sharing among project promoters as well as general funding and financing issues, and provide some historical success stories as examples of cooperation in the region. The work is in progress and the next steps will be defined.



4.3.3 Nordic Grid Development Perspective 2023

The Nordic countries have a long history of cooperation in energy matters. The Nordic electricity system is highly interconnected, and the countries are front-runners in areas such as renewables and sector coupling. Therefore, they have a strong foundation for jointly addressing new challenges – for example, in the NGDP report, which is published every two years. The latest edition, NGDP2023, is available [here](#).

NGDP functions as a complementary bridge between the national planning processes and the ENTSO-E TYNDP. The latest NGDP communicated a common Nordic view on the development of the future power system in climate-neutral societies. The report was structured around two broad topic areas: the rapid pace towards net-zero emissions in the Nordics, and the transition to a PEID (power electronic interfaced device) dominated power system. The key messages in NGDP2023 are as follows.

The Nordic power system is well-integrated due to a long history of cross-border cooperation on grid, operations, and market development. This has been a core prerequisite for the high level of renewable production and will remain essential as the Nordic power system is expected to be carbon-free around 2035–2040.

The path towards a carbon-free system has been set, and the Nordic TSOs are committed to making it a reality. Achieving this goal is complex and requires new solutions and increased collaboration to ensure a favourable investment climate, more renewables, increased electrification, and sustained high levels of security of supply.

A strong and robust Nordic power grid is essential to support the proper pace and evolution of the system. This requires substantial new grid investments. A strong grid, both nationally and across borders, allows for the continued use of national competitive advantages in the Nordic system.

The expected high growth in power demand, combined with the surge in intermittent power production from solar and wind energy, has heightened the need for rapid development of new flexibility within the power system. This is best addressed through collaboration.

A significantly higher proportion of power equipment connected via power electronics presents significant challenges to the future power system. However, through common development and testing of new solutions, we can find innovative solutions for the Nordic power system.

— **Some more detailed insights from NGDP2023 include the following:**

- › Electrification of the transport sector and industrial processes are key factors in achieving net-zero emissions. These sectors are also the main drivers of the massive growth in power demand expected in the near term.
- › Wind and solar power are expected to become the largest sources of power generation. Hydropower is also becoming more important due to its capability to balance fluctuations in weather-dependent generation, although there is little room to expand hydropower capacity.
- › Issues related to permission procedures and the predictability of the business environment (taxation, subsidies, etc.) are crucial to enable investments in new renewable generation capacity, as well as batteries and hydrogen production.
- › One urgent challenge is the growing number of devices connected to the grid via power converters (wind, solar, batteries, HVDC links), which might cause the power system to become unstable in unpredictable ways. PEID-connected generation impacts all aspects of power system stability, including frequency and rotor-angle and voltage stability.
- › Converter-connected generation is becoming increasingly common: last year, more than half of the power fed to the Nordic grid was generated via converters during the maximum penetration hour. Price areas where converter-connected generation is expected to be the highest are DK2, SE4, and FI.
- › Simulations show that during the hour with the highest share of converter-connected generation, wind power accounts for 50% of the generation mix. In contrast, during the hour with the lowest converter-connected generation, hydro-power accounts for nearly 75% of the generation mix.
- › A new frequency control product, Fast Frequency Reserve (FFR), has been added to the Nordic portfolio to address the stability challenges caused by PEID-connected generation. In addition to market-based solutions, TSOs have addressed stability challenges by adding grid code requirements to power plants and strengthening the grid itself.



NGDP2023 also provided updated information on bilateral connections from the previous plan and presented grid development projects in greater detail:

- › Norway and Sweden have identified greater benefits in increasing NTC along the NO4–SE1 corridor compared to other corridors. However, expanding capacity in this corridor requires internal grid reinforcements in both countries.
- › Joint feasibility studies identified benefits in maintaining or perhaps increasing capacities between Sweden and Denmark (DK1–SE3 and DK2–SE4).
- › Between Finland and Sweden, a new connection called Aurora Line will be completed in 2025, increasing NTC between Finland and the SE1 price area to 2,000 MW in both directions. Moreover, national TSOs have conducted a technical assessment of the Fenno–Skan 1 link (FI–SE3) and concluded that with extended monitoring of technical equipment, the link, which was commissioned in 1989, can remain operational until 2040. In addition, Fingrid and SvK are continuing to explore the potential for Aurora Line 2 (by 2035) and a new HVDC link between Finland and SE3 (by 2040) as part of the European TYNDP process.
- › Norway and Denmark conducted technical assessments of the Skagerrak 1 and 2 links (known as SK12) in 2020–2021 and concluded that renewing SK12 could have high socioeconomic benefits, as indicated by the large price differences between Norway and Denmark.
- › Statnett and Fingrid are in discussions to establish a memorandum of understanding (MoU) to formalise a project exploring a potential back-to-back HVDC connection between Northern Norway (NO4) and Finland.

5 Conclusions

The European power system began a major transformation in the last 10–15 years. One of the main drivers of this transformation was the change in the power generation mix, replacing conventional power generation (thermal and partial nuclear decommissioning) with renewables (on/offshore wind, solar, and water generation in several countries). This will lead to more climate-dependent power generation, with a high fluctuating power infeed into the grid. As a result, an increased number of flexible solutions will be needed. Part of the solution could involve increasing interconnection capacities between countries and synchronous systems, such as those between Nordic countries and CE. Other drivers for grid development could include system enlargement projects, such as the continued integration of the Baltic states into the CE power system.

To address gaps between the current and future system needs identified in the system needs analyses, investment decisions for several transmission projects should be made in this or subsequent decades.

It is important to emphasise that the projects discussed earlier are currently potential grid development options aimed at addressing future capacity increases and system needs. These projects are subject to change as future scenarios evolve. Any future capacity increases not covered by projects in TYNDP 2024 will require bilateral analysis by the TSOs. Following these analyses, TSOs may propose new projects for inclusion in future TYNDPs.



6 Appendix

Appendix I: TYNDP Projects

Transmission Projects				
ID	Project name	Commissioning year	Status	Included in TYNDP 2022
111	Aurora line (3 rd AC Finland–Sweden north)	2025	Under construction	Yes
1095	Aurora line 2 (4 th AC Finland–Sweden north)	2032	Planned but not yet permitting	Yes
170	Baltic states Synchronisation with CE	2030	Under construction	Yes
1211	Baltic Wind Connector (BWC)	2037	Under consideration	Yes
1106	Bornholm Energy Island (BEI)	2030	Under consideration	Yes
124	Ekhyddan–Nybro–Hemsjö	2027	In permitting	Yes
1094	Estlink 3			
1086	Estonia internal grid reinforcement to increase RES connection capability (RRF project)			
239	Fenno–Skan 3	2038	Under consideration	Yes
1046	Finnish North–South reinforcement			
1202	Increased capacity Norway–Finland, Back-to-Back			
1068	LaSGo Link	2040	Under consideration	Yes
1088	Latvia and Estonia Hybrid Offshore interconnector	2035	Planning, not permitting yet	Yes
1209	Latvia and Lithuania cross-border strengthening project	2035	Planning, not permitting yet	Yes
123	LitPol Link Stage 2			Not included in TYNDP 2024
1098	Offshore Wind LT 2			
1039	SE North–south long-term reinforcements	2040	Planned but not yet permitting	Yes
126	SE North–south short-term reinforcements	2035	Planned but not yet permitting	Yes
1097	Upgrade to Konti–Skan	2036	Planned but not yet permitting	Yes
40	Belgium–Luxembourg–Germany: long-term perspective	2040	Under consideration	Yes
47	Westtirol (AT)–Vöhringen (DE)	2030	In planning but not permitting	Yes
94	GerPol Improvements	2025	Under construction	Yes
130	HVDC SuedOstLink Wolmirstedt to area Isar	2027	In permitting	Yes



Transmission Projects

ID	Project name	Commissioning year	Status	Included in TYNDP 2022
132	HVDC Line A-North	2027	In permitting	Yes
176	Hansa PowerBridge I	2029	In permitting	Yes
187	St. Peter (AT)–Pleinting (DE)	2030	In permitting	Yes
225	Second interconnector Belgium–Germany	2037	Under consideration	Yes
228	Muhlbach–Eichstetten	12–2027	In permitting	Yes
231	Beznau–Tiengen	2035	In planning but not permitting	Yes
235	HVDC SuedLink Brunsbüttel/Wilster to Großgartach/Bergrheinfeld West	2028	In permitting	Yes
267	Hansa PowerBridge II	2040	Under consideration	Yes
309	NeuConnect	2027	Under construction	Yes
313	Isar/Altheim/Ottenhofen (DE)–St. Peter (AT)	2027	In permitting	Yes
328	Interconnector DE–LUX	2028	In planning but not permitting	Yes
335	North Sea Wind Power Hub	2035	Under consideration	Yes
1034	HVDC corridor from Northern Germany to Western Germany	2032	In planning but not permitting	Yes
1058	HVDC Interconnector DE–CH	2037	Under consideration	Yes
1104	Bauler–Roost	2025	In planning but not permitting	Yes
1106	Bornholm Energy Island (BEI)	2030	Under consideration	Yes
1192	Germany–UK Hybrid Interconnector – Phase 1	2033	Under consideration	No
1193	Germany–UK Hybrid Interconnector – Phase 2	2035	Under consideration	No
1200	Hybrid interconnector Norway–Sørvest F Windfarm–Continent (DK, DE, or BE)	2035	Under consideration	No
1207	380 kV Niederstedem–Bertrange/Bofferdange	2037	In planning but not permitting	No
1211	Baltic WindConnector (BWC)	2037	Under consideration	No
1213	Offshore hybrid Interconnector (DE–NL)	2035	Under consideration	No
1214	Hybrid Interconnector Denmark–Germany	2036	Under consideration	No
1215	Xlinks Morocco – Germany	2032	Under consideration	No

Storage Projects

1004	Estonian PHES (pumped-hydro energy storage)			
1048	WSK PLUS (PHES)	2034	Planned but not yet permitting	No
1066	Kemijoki PSP	2032	Under consideration	No
1070	Hydro Pumped Electricity Storage in Estonia Mine			

Appendix II: Regional projects

Country	Project name	Investment		Expected commissioning year
		From	To	
Poland	Construction of the 400/220/110 kV Baczyzna substation	Baczyzna (PL)		2025
Poland	Construction of the 400 kV Baczyzna-Plewiska line	Baczyzna (PL)	Plewiska (PL)	2023
Poland	Construction of the 400 kV Mikułowa-Świebodzice line	Mikułowa (PL)	Świebodzice (PL)	2025-2026
Poland	Expansion of the 400/220/110 kV Pątnów substation	Pątnów (PL)		2025
Poland	Modernisation of the 220 kV Łagisza-Jamki line	Łagisza (PL)	Jamki (PL)	2026
Poland	Modernisation of the 400 kV Rzeszów-Krosno Iskrzynia line	Rzeszow (PL)	Krosno-Iskrzynia (PL)	2025
Poland	Construction of a 400 kV line between Dobrzeń and the Pasikowice-Ostrów line cut	Dobrzeń (PL)	Pasikowice-Ostrów (PL)	2027
Poland	Construction of a 400 kV line between Trębaczew and the Joachimów (Rokitnica)-Wielopole line cut	Trębaczewo (PL)	Joachimów (Rokitnica)-Wielopole (PL)	2027
Poland	Expansion and modernisation of the 400/220 kV Joachimów substation	Joachimów (PL)		2031
Poland	Expansion of the 400 kV Gdańsk Przyjaźń substation and the 400 (220)/110 kV Żydowo substation	Gdańsk Przyjaźń and Żydowo Kierzkowo (PL)		2025-2028
Poland	Modernisation (reconstruction) of the 400 kV Rogowiec-Joachimów, Rogowiec-Tuczawa (Joachimów) lines	Rogowiec (PL)	Joachimów/Tuczawa (PL)	2028
Poland	Modernisation of the 220 kV Świebodzice-Ząbkowice line	Świebodzice (PL)	Ząbkowice (PL)	2026
Poland	Modernisation (reconstruction) of the 220 kV Groszowice-Ząbkowice line	Groszowice (PL)	Ząbkowice (PL)	2028
Poland	Construction of the 400/220/110 kV Podborze substation along with the introduction of 220 and 400 kV lines	Podborze (PL)	Kopanina (PL)-Liskovec (CZ), Bujaków (PL)-Liskovec (CZ), Bieruń (PL)-Komorowice (PL), Czeczott (PL)-Moszczenica (PL), Nosovice (CZ)-Wielopole (PL), Dobrzeń (PL)-Detmarovice (CZ)	2030



	Description	Main drivers	Included in RegIP 2022	Status
	Construction of the 400/220/110 kV Baczyzna substation along with the connection of the 400 kV Krajnik–Plewiska line and the 220 kV Krajnik–Gorzów line	Cross-border exchange with Germany, RES integration	No	Under construction
	Construction of the 400 kV Baczyzna–Plewiska line	Cross-border exchange with Germany, RES integration	No	Commissioned
	Construction of the 400 kV Mikułowa–Świebodzice line along with the expansion of the 400/220/110 kV Świebodzice substation and the 400/220/110 kV Mikułowa substation	Cross-border exchange with Germany	No	Under construction
	Expansion of the 400/220/110 kV Pątnów substation along with the connection of the 400 kV Kromolice– Pątnów line	Cross-border exchange with Germany	No	Under construction
	Modernisation of the 220 kV Łagisza–Jamki line	Elimination of transmission constraints for cross-borders exchange	No	Planned
	Modernisation of the 400 kV Rzeszów–Krosno Iskrzynia line	Cross-border exchange with Slovakia	Yes	Under construction
	Construction of a 400 kV line between Dobrzeń and the Pasikurowice–Ostrów line cut	Elimination of transmission constraints for cross-borders exchange	Yes	Under construction
	Construction of a 400 kV line between Trębaczew and the Joachimów (Rokitnica)–Wielopole line cut	Elimination of transmission constraints for cross-borders exchange	Yes	Tender
	Expansion and modernisation of the 400/220 kV Joachimów substation	Elimination of transmission constraints for cross-borders exchange	No	Planned
	Expansion of the 400 kV Gdańsk Przyjaźń substation and the 400 (220)/110 kV Żydowo Kierzkowo substation together with the installation of reactive power compensation equipment and adaptation of the 400/220/110 kV Gdańsk I substation to switch the 400 kV Dunowo–Żydowo Kierzkowo–Gdańsk I and Piła Krzewina–Żydowo Kierzkowo lines to 400 kV	Elimination of transmission constraints for cross-borders exchange	No	Under construction
	Modernisation (reconstruction) of the 400 kV Rogowiec–Joachimów, Rogowiec–Tuczawa (Joachimów) lines	Elimination of transmission constraints for cross-borders exchange	No	Planned
	Modernisation of the 220 kV Świebodzice–Ząbkowice line	Elimination of transmission constraints for cross-borders exchange	No	Under construction
	Modernisation (reconstruction) of the 220 kV Groszowice–Ząbkowice line	Elimination of transmission constraints for cross-borders exchange	No	Planned
	Construction of the 220 kV Podborze – Kopanina–Liskovec, Podborze – Bujaków–Liskovec, Podborze – Bieruń–Komorowice, Podborze – Czeczott–Moszczenica sections and the 400 kV Podborze – Nosowice–Wielopole and Podborze – Dobrzeń–Detmarowice section along with the construction of the 400/220/110 kV Podborze substation	Elimination of transmission constraints for cross-borders exchange	No	Planned

Country	Project name	Investment		Expected commissioning year
		From	To	
Poland	Modernisation of the AC/DC converter station in Słupsk	Słupsk (PL)		2025
Poland	Modernisation (reconstruction) of the 220 kV Joachimów–Łośnice line	Joachimów (PL)	Łośnice (PL)	2028
Poland	Switching of the 400 kV Ostrołęka–Wyszków–Stanisławów line circuit operating at 220 kV to 400 kV	Ostrołęka (PL)	Wyszków-Stanisławów (PL)	2023–2027
Germany	DC20	Klein Rogahn/ Stralendorf/Warsow/ Holthusen/Schossin	Isar	2030
Germany	AMP-P21/TTG-P21	Conneforde	Merzen/Neuenkirchen	2026
Germany	TTG-P24	Stade	Landesbergen	2026
Germany	P33	Wolmirstedt	Wahle	2032
Germany	TTG-P37/50HzT-P37	Vieselbach	Mecklar	2027
Germany	50HzT-P38	Pulgar	Vieselbach	2025
Germany	50HzT-P39	Röhrsdorf	Remptendorf	2025
Germany	AMP-P41	Punkt Metternich	Niederstedem	2026
Germany	P43	Mecklar	Bergheinfeld West	2031
Germany	TTG-P46	Redwitz	Schwandorf	2026
Germany	AMP-P47/TNG-P47	Urberach	Daxlanden	2031
Germany	TTG-P48/TNG-P48	Grafenheinfeld	Großgartach	2026
Germany	TNG-P49	Daxlanden	Eichstetten	2029
Germany	P51	Großgartach	Endersbach	2030
Germany	P206	Herbertingen	Waldshut/Tiengen	2032
Germany	TNG-P70	Birkenfeld	Ötisheim (Mast 115A)	2025
Germany	P23	Dollern	Elsfleth West	2028
Germany	50HzT-P34	Güstrow	Wolmirstedt	2027
Germany	P53	Raitersaich	Altheim	2031
Germany	TTG-P72	Kreis Segeberg	Siems	2027
Germany	50HzT-P150	Schraplau/Obhausen	Vieselbach	2028
Germany	P222	Oberbachern	Ottenhofen	2029
Germany	P26	Brunsbüttel	Amt Geest/Marsch Südholstein	2030
Germany	P84	Hamburg Nord	Ämter Büchen/Breitenfelde/ Schwarzenbek-Land	2031



	Description	Main drivers	Included in RegIP 2022	Status
	Modernisation of the AC/DC converter station in Słupsk	Cross-border exchange with Sweden	No	Under construction
	Modernisation (reconstruction) of the 220 kV Joachimów–Łośnice line	Elimination of transmission constraints for cross-borders exchange	No	Planned
	Switching of the 400 kV Ostrołęka–Wyszków–Stanisławów line circuit operating at 220 kV to 400 kV along with replacement of the 220/110 kV transformer at the Wyszków substation with a 400/110 kV unit	Cross-border exchange with Lithuania	No	Planned
	New HVDC Line; detailed information provided in Germany's grid development plan	RES integration	Yes	In permitting
	New 380 kV OHL, Replacement of existing 220 kV OHL	RES integration	Yes	Under construction
	New 380 kV OHL in existing corridor	RES integration	Yes	Under construction
	Reinforcement and new construction of 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	Under construction
	Replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	Yes	Under construction
	Replacement of existing OHL with new 380 kV OHL	Security of supply	Yes	Under construction
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	Under construction
	New 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	Under construction
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	Under construction
	New 380 kV OHL, partially in existing corridor	RES integration	Yes	In permitting
	New 380 kV OHL	Security of supply	Yes	In planning but not yet permitting
	New 380 kV OHL, partially in existing corridor	Security of supply	Yes	In planning but not yet permitting
	New 380 kV OHL	RES integration	Yes	Under construction
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL, replacement of existing 220 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In planning but not yet permitting
	Reinforcement of existing OHL, new 380 kV OHL	RES integration	Yes	In permitting

Country	Project name	Investment		Expected commissioning year
		From	To	
Germany	P215	Güstrow	Sanitz/Gnewitz/Dettmannsdorf/Marlow	2029
Germany	P216	Güstrow	Pasewalk	2031
Germany	P22	Conneforde	Unterweser	2028
Germany	P22	Elsfleth West	Ganderkesee	2029
Germany	P119	Conneforde	Samtgemeinde Sottrum	2031
Germany	P116/P135	Dollern	Bechterdissen	2033
Germany	P113	Ämter Büchen/ Breitenfelde/ Schwarzenbek-Land	Wahle	2029
Germany	P228	Landesbergen	Salzgitter	2032
Germany	P124/P359/450	Siedenbrünzow	Lauchstädt	2034
Germany	P315	Hanekenfähr	Gronau	2033
Germany	P403	Hattingen	Bezirk Ronsdorf	2033
Germany	P133/P211	Borken	Karben	2029
Germany	P161	Großkrotzenburg	Urberach	2028
Germany	AMP-P159	Bürstadt	BASF (Ludwigshafen am Rhein)	2029
Germany	P302	Höpfingen	Hüffenhardt	2030
Germany	P175	Wilhelmshaven/ Landkreis Friesland	Conneforde	2029
Germany	P200	Punkt Blatzheim	Oberzier	2027
Germany	P462	Siersdorf	Verlautenheide	2034
Germany	P225	Isar	Altheim	2029
Germany	DC31	Hemmingstedt/Lieth/ Lohe-Rickelshof/ Wöhrden	Klein Rogahn/Stralendorf/Warsow/ Holthusen/Schossin	2032
Germany	DC32	Pöschendorf/ Hadenfeld/Kaisbors- tel/Agethorst/ Mehlbek	Klein Rogahn/Stralendorf/Warsow/ Holthusen/Schossin	2034
Germany	P227	Lübeck	Ämter Büchen/Breitenfelde/ Schwarzenbek-Land	2029
Germany	P223	Güstrow	Ämter Büchen/Breitenfelde/ Schwarzenbek-Land	2034
Germany	P367	Emden-Ost	Emden-West	2034
Germany	50HzT-P180/P252/P531	Wulheide/Thyrow/ Teufelsbruch	Marzahn/Berlin Mitte/Malchow/ Schönefeld	2038



	Description	Main drivers	Included in RegIP 2022	Status
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Upgrade from 220 kV to 380 kV	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL, reinforcement of existing OHL	RES integration	Yes	In planning but not yet permitting
	New 380 kV OHL in existing corridor	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In planning but not yet permitting
	New 380 kV OHL in existing corridor	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL in existing corridor, upgrade from 220 kV to 380 kV	RES integration, security of supply	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In planning but not yet permitting
	New 380 kV OHL in existing corridor	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL	RES integration, security of supply	No	In permitting
	New HVDC line; detailed information provided in Germany's grid development plan	RES integration	Yes	In permitting
	New HVDC line; detailed information provided in Germany's grid development plan	RES integration	No	In permitting
	New 380 kV OHL	RES integration	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL	RES integration, security of supply	No	In planning but not yet permitting
	New 380 kV lines, reinforcement of existing lines and substations	Security of supply	Yes	In planning but not yet permitting/In Permitting

Country	Project name	Investment		Expected commissioning year
		From	To	
Germany	P212	Landesbergen	Borken	2030
Germany	P402	Westerkappeln	Gersteinwerk	2033
Germany	P501	Gersteinwerk	Mengede	2038
Germany	P408	Emscherbruch	Hattingen	2037
Germany	P502	Walsum	Beek	2030
Germany	P528	Lauchstädt	Pulgar	2033
Germany	P504	Sechtem	Weißenthurm	2030
Germany	P500	Aschaffenburg	Urberach	2035
Germany	P464	Punkt Fraulautern	Diefflen	2032
Germany	AMP-009/TTG-007	Dörpen West	Niederrhein	2025
Germany	AMP-014/AMP-032	Niederrhein	Osterath	2030
Germany	AMP-014/AMP-015	Osterath	Weißenthurm	2025
Germany	AMP-010	Wehrendorf	Gütersloh	2028
Germany	AMP-022	Keuckel	Dauersberg	2026
Finland	Huittinen–Forssa transmission line	Huittinen	Forssa	2025
Finland	Helsinki cable link	Vanhakaupunki (Helsinki)	Länsisalmi (Vantaa)	2026
Finland	Svartby–Keminmaa reinforcement	Svartby (Sweden)	Keminmaa	2028
Finland	Kristinestad–Nokia transmission line	Kristinestad	Nokia	2028
Finland	Nuojuankangas–Seitenjärvi transmission line	Nuojuankangas	Seitenjärvi	2030
Finland	Hausjärvi–Anttila transmission line	Hausjärvi	Anttila	2030
Finland	Anttila–Länsisalmi transmission line	Anttila	Länsisalmi	2030
Finland	Lieto–Raisio transmission line	Lieto	Raisio	2031
Finland	Ridge Line	Höyttikangas	Pysäysperä	2032
Finland	Seitenjärvi–Pontema–Pyhäselkä	Seitejärvi	Pyhäselkä	2032
Finland	Compensation solutions	Several locations	–	
Sweden	Norrlandskusten package			2028–2031



	Description	Main drivers	Included in RegIP 2022	Status
	Reinforcement of existing 380 kV OHL	RES integration	Yes	Under construction
	New 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In planning but not yet permitting
	New 380 kV OHL, reinforcement of existing OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration	Yes	In permitting
	Replacement of existing OHL with new 380 kV OHL	Security of supply	Yes	In permitting
	Reinforcement of existing 380 kV OHL	RES integration	Yes	Under construction
	New 380 kV OHL	RES integration	Yes	In permitting
	New 380 kV OHL in existing corridor, upgrade from 220 kV to 380 kV	Security of supply	Yes	In planning but not yet permitting
	New 380 kV OHL, partially in existing corridor	RES integration	Yes	Under construction
	New 380 kV OHL, reinforcement of existing OHL	RES integration, security of supply	No	In permitting
	Replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	No	Under construction
	Replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	No	Under construction
	New 380 kV OHL, replacement of existing OHL with new 380 kV OHL	RES integration, security of supply	No	Under construction
	New 400 kV + 110 kV OHLs	RES integration, security of supply, export capability	Yes	Under construction
	New 400 kV underground DC cable, new substation (Vanhakaupunki)	Growing demand in the capital region	Yes	Under construction
	New conductors for an existing 400 kV cross-border connection	Electricity production and consumption trends in Sweden	No	In planning
	New 400 kV + 110 kV OHLs	RES integration	No	In planning
	New 400 kV + 110 kV OHLs	Replacement of an old 220 kV transmission line	Yes	EIA procedure/ preliminary planning
	New 400 kV OHL	Growing demand in the capital region	No	EIA procedure/ preliminary planning
	New 400 kV OHL	Growing demand in the capital region	No	EIA procedure/ preliminary planning
	New 400 kV OHL	Growing demand in Turku region	Yes	EIA procedure/ preliminary planning
	New 400 kV OHL	RES integration	No	EIA procedure/ preliminary planning
	New 400 kV OHL, new substation (Pontema)	RES integration	No	EIA procedure/ preliminary planning
	Several compensation solutions, such as synchronous compensator, if required	Grid stability	No	-
	4 new 400 kV OHL, 3 new substations, and reinforcement of OHL	Connection of new demand, system reinforcement	Yes	Preparatory phase

Country	Project name	Investment		Expected commissioning year
		From	To	
Sweden	Malmfälten package			2026–2027
Sweden	Malmfälten pt. 2			2030–
Sweden	The coastal investment package			2031–2035
Sweden	Sollefteå investment package			2026–2030
Sweden	Uppsala investment package			2028–2033
Sweden	Inland investment package			2032–2035
Sweden	Laforsen investment package			2030–2033
Sweden	Ockelbo investment package			2029–2032
Sweden	Västerås investment package			2028–2032
Sweden	The Hallsberg leg			2037–2041
Sweden	The Karlstad leg			2033–2035
Sweden	Stockholm ström			2024–2031
Sweden	Storstockholm väst			2025–2030
Sweden	Väst kust investment package			2024–2031
Sweden	Göteborg norr			2026–2038
Sweden	Series compensation projects			2026–2029



	Description	Main drivers	Included in RegIP 2022	Status
	New 400 kV OHL, new substation	Connection of new demand	Yes	Preparatory phase
	6 new 400 kV OHL, new substation	Connection of new demand	Yes	Under consideration
	3 new 400 kV OHL, 3 new substations, decommissioning of old OHL and substations	Growing demand	Yes	Preparatory phase
	New OHL, substation and capacity upgrade	Growing demand	Yes	Preparatory phase
	4 new OHL, 2 new substations, decommissioning of old OHLs	Growing demand	Yes	Preparatory phase
	2 new OHL, new substation, decommissioning of old OHLs	Growing demand	Yes	Preparatory phase
	New substation, decommissioning of OHL	Growing demand	Yes	Preparatory phase
	3 new OHL, 3 new substations	Growing demand	Yes	Preparatory phase
	2 new OHL, decommissioning of old OHL	Growing demand	Yes	Preparatory phase
	New OHL	Growing demand	Yes	Under consideration
	New OHL	Growing demand	Yes	In permitting
	New cable, 2 new substations	System reinforcement	Yes	Construction phase/ contracting phase
	4 new OHL, 3 new substations, renewals	System reinforcement	Yes	Construction phase/ contracting phase
	Reinvestment of 6 OHL	Reinvestment	Yes	Contracting phase
	2 new OHL, 2 new substations, OHL renewals	New connection, system reinforcement	Yes	Contracting phase/ under consideration
	6 new series compensation	System reinforcements	Yes	Contracting phase/ preparatory phase/ under consideration

Appendix III: Links to national development plans

Country	TSO	Link
Latvia	AS Augstsprieguma tīkls	Latvian National Development Plan
Estonia	Elering	Estonian National Development Plan 2025 – 2034
Sweden	Svenska Kraftnät	Grid development plan 2024–2033
Lithuania	Litgrid	400 – 110 kV Transmission Network Development Plan of Lithuanian electricity system 2024 – 2033
Denmark	Energinet	Energinets long-term development Plan 2024
Finland	Fingrid	Main Grid Development Plan 2024 – 2033
Norway	Statnett	Statnett's System Development Plan
Germany	50Hertz Transmission GmbH TenneT TSO GmbH Amprion GmbH TransnetBW GmbH	Grid Development Plan Electricity | Grid Development Plan (netzentwicklungsplan.de)
Poland	PSE	Development Plan for meeting the current and future electricity demand for 2025 – 2034



Appendix IV: Glossary

Acronym	Term	Definition
AC	Alternating Current	An electric current that periodically reverses direction and changes its magnitude continuously with time, in contrast to direct current (DC), which flows only in one direction. Alternating current is the form in which electric power is delivered to businesses and residences.
ACER	Agency for the Cooperation of Energy Regulators	EU agency established in 2011 by the Third Energy Package legislation as an independent body to foster the integration and completion of the European Internal Energy Market for both electricity and natural gas.
BEMIP Electricity	Baltic Energy Market Interconnection Plan in electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Supports interconnections between Member States in the Baltic region and strengthening the internal grid infrastructure to end the energy isolation of the Baltic states and foster market integration; this includes working towards the integration of renewable energy in the region.
BOGI	Baltic Offshore Grid Initiative	A working group established by Baltic Sea region TSOs focused on TSO cooperation in planning hybrid connections, with an emphasis on short-term (2–3 year) actions and timelines.
	Bottom-up	This approach of the scenario-building process collects supply and demand data from gas and electricity TSOs.
	Carbon budget	The amount of carbon dioxide the world can emit while still having a likely chance of limiting average global temperature rise to 1.5 °C above pre-industrial levels, an internationally agreed-upon target.
CAPEX	Capital Expenditure	The funds used by a company to acquire, upgrade, or maintain physical assets like buildings, equipment, or infrastructure.
CBA	Cost–Benefit Analysis	A method used to evaluate the economic pros and cons of a project or decision by comparing its costs with its expected benefits.
CBAM	Carbon Border Adjustment Mechanism	An EU policy that imposes a carbon price on certain imported goods to match the costs EU producers face under the Emissions Trading System (ETS). It aims to prevent carbon leakage and promote cleaner industrial production globally.
CCE	Continental Central East	Region of Europe comprising Austria, Croatia, Czechia, Germany, Hungary, Poland, Romania, Slovakia, Slovenia, and Ukraine.
CCS	Carbon Capture and Storage	Process of sequestering CO ₂ and storing it in a way that prevents it from entering the atmosphere.
CCS	Continental Central South	Region of Europe comprising Austria (AT), France (FR), Germany (DE), Italy (IT), Slovenia (SI), and Switzerland (CH).

Acronym	Term	Definition
CCU	Carbon Capture and Usage	Captured CO ₂ that instead of being stored in geological formations is used to create other products, such as plastic.
CE	Continental Europe	The continent of Europe is situated in the Northern Hemisphere and bordered to the south by the Mediterranean Sea, the north by the Arctic Ocean, and the west by the Atlantic Ocean. It is separated from the continent of Asia by the Caucasus Mountains and the watershed divide of the Ural Mountains.
CEF	Connecting Europe Facility	A key EU funding instrument to promote growth, jobs, and competitiveness through targeted infrastructure investment at the European level.
CEN/CESA	Continental Europe Network/ Continental Europe Synchronous Area	Formerly known as the UCTE grid, it is one of the largest synchronous electrical grids in the world, primarily operating in Europe. It is interconnected as a single phase-locked 50 Hz main frequency electricity grid that supplies over 400 million customers in 32 countries, including most of the European Union.
CFI	Agreement on the conditions of the future interconnection of the power system of the Baltic states and the power system of Continental Europe	The specific rules and requirements issued by the TSOs of the CE Network to Baltic state TSOs for successful Baltic state synchronisation and connection to the CE power system.
CHP	Combined Heat and Power	A technology that produces electricity and thermal energy at high efficiencies using a range of technologies and fuels. With onsite power production, losses are minimised and heat that would otherwise be wasted is applied to facility loads in the form of process heating, steam, hot water, or even chilled water.
CNEC	Critical Network Element with Contingency	A transmission grid component, such as a line or transformer, that becomes critically loaded under specific system conditions, including the failure of another element (the contingency). It is used in grid planning and capacity calculations to identify and manage potential congestion risks in the electricity network.
CO₂	Carbon Dioxide	An important heat-trapping gas, also known as a greenhouse gas, that comes from the extraction and burning of fossil fuels (such as coal, oil, and natural gas), wildfires, and natural processes like volcanic eruptions.
	Congestion revenue/rent	The revenue derived by interconnector owners from the sale of 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	A situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants due to insufficient capacity in the interconnectors and/or the relevant national transmission systems.
COP21		21 st Conference of the Parties to the United Nations Framework Convention on Climate Change, organised in 2015, where participating states reached the Paris Agreement.



Acronym	Term	Definition
CSE	Continental South East	Region of Europe comprising Albania (AL), Bosnia and Herzegovina (BA), Bulgaria (BG), Croatia (HR), Cyprus (CY), Greece (GR), Hungary (HU), Italy (IT), Montenegro (ME), North Macedonia (MK), Romania (RO), Serbia (RS), and Slovenia (SI).
CSW	Continental South West	Region of Europe comprising France, Portugal, and Spain.
	Curtailed electricity	Curtailement is a reduction in the output of a generator from otherwise available resources (e. g. wind or sunlight), typically on an unintentional basis. Curtailments can result when operators or utilities control wind and solar generators to reduce output to minimise transmission congestion or otherwise manage the system or achieve the optimal mix of resources.
DC	Direct Current	An electric current that flows steadily in one direction, maintaining a constant magnitude over time, unlike alternating current (AC), which periodically reverses direction. DC is commonly used in batteries, electronics, and some power transmission systems.
DE	Distributed Energy	One of the TYNDP 2024 assessment scenarios.
DLR	Dynamic Line Rating	A technology and technique that uses the environmental conditions or a set of conditions to calculate the ampacity of the conductor. The calculation of DLR relies on some degree of physical technology to implement the solution.
DSR	Demand Side Response	Consumers play an active role in softening peaks in energy demand by changing their energy consumption based on energy price and availability.
EC	European Commission	The executive branch of the European Union, responsible for proposing legislation, implementing decisions, managing EU policies, and upholding EU treaties. It acts in the interest of the EU as a whole, independently of national governments.
ENS	Energy Not Supplied	The volume of energy to customers that is lost as a result of faults or failures on the network, measured in megawatt hours (MWh).
ENTSO-E	The European Network of Transmission System Operators for Electricity	An association representing 40 electricity transmission system operators (TSOs) from 36 countries across Europe, thus extending beyond EU borders. It manages the CE Synchronous Area (CESA). ENTSO-E was established and given legal mandates by the EU's Third Package for the Internal Energy Market in 2009, which aims at further liberalising the gas and electricity markets in the EU. Ukrainian Ukrenergo became the 40 th member of the association on 1 January 2024.
ERAA	European Resource Adequacy Assessment	A pan-European monitoring assessment of power system resource adequacy up to 10 years ahead. Building on the work done with the Mid-term Adequacy Forecast (MAF), the ERAA is a leap forward in system modelling. It is based on state-of-the-art methodologies and probabilistic assessments, aiming to model and analyse possible events that can adversely impact the balance between the supply and demand of electric power. It will be an important element for supporting qualified decisions by policymakers on strategic matters, such as the introduction of capacity mechanisms (CMs).

Acronym	Term	Definition
EU	European Union	A supranational political and economic union of 27 Member States located primarily in Europe. The EU has a total area of 4,233,255 km ² (1,634,469 sq mi) and an estimated total population of over 449 million. The EU has often been described as a sui generis political entity combining the characteristics of both a federation and a confederation.
EVA	Economic Viability Assessment	A crucial but complex analysis that enables the assessment of the economic viability (under certain conditions) of existing or new generation, storage, and demand response capacity in the electricity market. The ERAA methodology indicates that the EVA shall either assess the viability for each capacity iteratively or by minimising the overall system costs, where all capacities are optimised at once.
FACTS	Flexible Alternating Current Transmission System	A family of power electronic-based devices designed for use on an AC transmission system to improve and control power flow and support voltage. FACT devices are alternatives to traditional electric grid solutions and improvements, where building additional transmission lines or substations is not economically or logistically viable.
FFR	Fast Frequency Reserve	Procured to handle low-inertia situations. Inertia means the ability of the kinetic energy stored in the rotating masses in the electricity system to resist changes in frequency.
GTC	Grid Transfer Capacity	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.
GW	Gigawatt	A unit of power. Power measures the rate at which energy is generated, used, or transferred. Watts are the standard unit of power. A gigawatt is a much larger unit, equivalent to 1 billion watts.
HVAC	High Voltage Alternating Current	HVAC transmission refers to the transmission of electrical power using supply voltages ranging from 33 kV AC to 230 kV AC. In HVAC transmission, the power generated is stepped up to high voltages and transmitted through transmission lines. It requires at least three line conductors to transmit three-phase electrical power.
HTLS	High-Temperature-Low-Sag	A type of conductor capable of maintaining transmission capacity without physically deteriorating at higher temperatures than conventional conductors.
HVDC	High Voltage Direct Current	A type of high voltage transmission system where power is transmitted in the form of DC at voltages between 100 kV and 800 kV. In this system, electrical power produced in the form of AC is first converted into DC using rectifiers and then transmitted through HVDC lines. At the receiving end, the DC is converted back to AC. The major advantage of HVDC is that it requires only two conductors for transmission and has comparatively low power losses over long distances.



Acronym	Term	Definition
IEM	Internal Energy Market	The main objectives of the EU IEM are to strengthen and expand the rights of individual consumers and energy communities; address energy poverty; clarify the roles and responsibilities of market participants and regulators; address security of supply for electricity, gas, and oil; and develop trans-European networks for gas and electricity.
IGBT	Insulated Gate Bipolar Transistors	Semiconductor devices that efficiently switch and control high voltages and currents. They are commonly used in power electronics such as inverters, electric vehicles, and renewable energy systems.
	Investment (in the TYNDP)	Individual equipment or facility, such as a transmission line, a cable, or a substation.
ITEG	Interconnection Targets Expert Group	A European Commission expert group that advises on achieving electricity interconnection targets to enhance energy market integration and security of supply in the EU.
IPS/UPS	Integrated Power System/ Unified Power System	The IPS/UPS (Russian: ЕЭС/ОЭС), also widely known as the Russian grid or the post-Soviet grid, is a wide area synchronous transmission grid, the Unified Power System (UPS; Единая энергетическая система России [ЕЭС]) being the Russian grid, and the Integrated Power System (IPS; Объединенная энергетическая система [ОЭС]) portion of the network being the national networks of Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, and Uzbekistan.
LCC	Line Commutated Converters	The conventional, mature, and well-established technology used to convert electric power from AC to DC or vice versa. The term "line-commutated" indicates that the conversion process relies on a stable line voltage, with clear zero-crossings of the AC system to which the converter is connected to enable a flow commutation from one switching element to another.
LFC	Load Frequency Control	The mechanism that regulates the power flow between the different regions of an interconnected system to keep frequency constant.
LNG	Liquefied Natural Gas	Natural gas that has been cooled to liquid form for ease and safety of non-pressurised storage or transport.
LOLE	Loss of Load Expectation	The expected number of hours per year that a country's electricity production park fails to meet its demand.
MIBEL	Mercado Ibérico de Electricidad	The integrated electricity market of Spain and Portugal, enabling cross-border electricity trading to promote competition and price convergence. It is a key step towards aligning the Iberian market with the broader European energy market.
MoU	Memorandum of Understanding	An agreement between two (bilateral) or more (multilateral) parties that expresses a convergence of will between the parties, indicating an intended common line of action. It is often used either in cases where parties do not imply a legal commitment or in situations where the parties cannot create a legally enforceable agreement. It is a more formal alternative to a gentlemen's agreement.

Acronym	Term	Definition
MS	Member State	
MSP	Maritime Spatial Plan	A tool to coordinate the use of seas and oceans to ensure human activities occur efficiently, safely, and sustainably.
Mton	Million ton	Measurement unit.
MW	Megawatt	The standard term of measurement for bulk electricity. One megawatt is 1 million watts.
	N-1 criterion	The rule according to which elements remaining in operation within a 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.
NDP	National Development Plan	In the context of EU electricity development, a strategic plan created by individual EU Member States to outline investments, infrastructure upgrades, and policies aimed at achieving national energy and electricity goals. It supports EU-wide initiatives, such as decarbonisation and grid integration, ensuring alignment with broader energy objectives.
NECP	National Energy and Climate Plans	The new framework within which EU Member States must plan, in an integrated manner, their climate and energy objectives, targets, policies, and measures for the European Commission. Countries must develop NECPs on a 10-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 must ensure that the EU's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency, and electricity interconnection are met.
NGDP	Nordic Grid Development Perspective	The purpose of this report is to present a unified perspective on the development of the Nordic electricity grid. Released biennially, it is prepared collaboratively by the four Nordic transmission system operators (TSOs): Energinet, Fingrid, Statnett, and Svenska kraftnät. It is intended for everyone who has an interest in the development of the Nordic grid and the challenges related to managing this increasingly complex and evolving system.
NSEC	North Seas Energy Cooperations	A regional collaboration among nine European countries to develop offshore renewable energy, particularly wind power, and improve cross-border energy infrastructure. Its goal is to enhance energy security, reduce emissions, and support the transition to a greener energy system in the North Seas region.
NSOG	North Seas Offshore Grid	One of the four priority corridors for electricity identified by the TEN-E Regulation. Integrated offshore electricity grid development and related interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea, and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage and increase cross-border electricity exchange.
NSI East Electricity	North-south electricity interconnections in central eastern and southeastern Europe	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections and internal lines in the north-south and east-west directions to complete the EU internal energy market and integrate renewable energy sources.



Acronym	Term	Definition
NSI West Electricity	North-south electricity interconnections in western Europe	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between EU countries in this region and with the Mediterranean area including the Iberian Peninsula, to integrate electricity from RES and reinforce internal grid infrastructures to promote market integration in the region.
NT	National Trend	One of the TYNDP 2024 assessment scenarios.
NTC	Net Transfer Capacity	The expected maximum volume of generation that can be transferred between two power systems without causing network constraints in either system, while accounting for technical uncertainties in future network conditions.
ONDP	Offshore Network Development Plan	A new component of the TYNDP focused on offshore transmission infrastructure needs. It translates the EU Member States' non-binding agreements on offshore goals from January 2023 into offshore transmission corridors, transmission equipment needs, and related costs. ONDP is mandated by the TEN-E Regulation (2022/869 EU Reg Art. 14.2).
OTC	Offshore TSO Collaboration	The OTC was established in 2022 and consists of TSOs from the Northern Seas working together to develop a sustainable offshore network infrastructure.
P2G	Power-to-Gas	The process of converting surplus renewable energy into hydrogen gas through PEM electrolysis technology. The hydrogen can then be injected into the natural gas grid to displace natural gas, reduce greenhouse gas emissions, and lower reliance on high-carbon fuels.
P2X	Power-to-X	Conversion technologies that allow the decoupling of power from the electricity sector for use in other sectors (such as transport or chemicals), possibly using power provided by additional investments in generation.
PCI	Projects of Common Interests	A category of projects launched in 2013, which the European Commission has identified as essential for interconnecting the energy infrastructure in the European Union. These projects are eligible to receive public funds.
PINT	Put IN one at the Time	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.
PMI	Project of Mutual Interest	Analogous to Projects of Common Interest, Projects of Mutual Interest are between the EU and non-EU countries, which contribute to the energy and climate policy objectives of the Union.
PEID	Power Electronic Interface Devices	Essential components of contemporary power systems that permit the efficient conversion and control of electrical energy. They are the vital link between electrical power sources and the loads that use them, allowing for the necessary power conversions (DC/AC, AC/DC, AC/AC, and DC/DC).

Acronym	Term	Definition
PPM	Power Park Module	A unit or group of units that generate electricity and are connected to the network either non-synchronously or via power electronics. They share a single connection point to a transmission system, distribution system (including closed distribution systems), or HVDC system (defined in Article 2(17) of the Network Code on Requirements for Grid Connection of Generators (NC RfG)).
	Project (in the TYNDP)	Either a single investment or a set of investments, clustered together to form a project to achieve a common goal.
PST	Phase Shifting Transformer	A specialised type of transformer typically used to control the flow of active power on three-phase electric transmission networks. It does this by regulating the voltage phase angle difference between two system nodes. The principle relies on a phase-shifted voltage source injection into the line by a series-connected transformer, which is fed by a shunt transformer. The configuration of the shunt and series transformer unit induces the phase shift.
PV	Photovoltaics	Refers to the technology that converts sunlight directly into electricity using semiconductor materials, typically in solar panels. It is a key renewable energy source widely used in residential, commercial, and utility-scale power generation.
	Reference grid	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.
RegIP	Regional Investment Plan	The investment plan for specific regions, which outlines 10 years of infrastructure development projects from a regional perspective. Based on joint planning studies among Member States – a core added value of the TYNDP – they provide details on the regional constraints and needs of the high-voltage grid. Infrastructure projects resulting from these studies are part of the final list of projects.
REPowerEU	REPowerEU plan	An ambitious plan launched by the EU to reduce its dependence on fossil-fuel imports and accelerate the green transition. In October 2022, the EIB announced it is substantially increasing its commitment to supporting the goals of the REPowerEU plan by providing € 30 billion in additional financing over the next 5 years to businesses and public authorities for clean energy.
RES	Renewable Energy Sources	Also called renewables, energy sources that replenish (or renew) themselves naturally. Typical examples are solar energy, wind, and biomass.
RfG	Requirement for Generators	The Network Code on Requirements for Generators is harmonising standards that generators must respect to connect to the grid. These harmonised standards across Europe will boost the market of generation technology and increase competitiveness.
RG	Regional Group	A collaboration of TSOs from a specific area to coordinate cross-border grid investments.

Acronym	Term	Definition
RGBS	Regional Group Baltic Sea	Region comprising Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, and Sweden.
RGNS	Regional Group Northern Seas	Region of Europe comprising Belgium, Denmark, France, Germany, Great Britain, Ireland, Luxembourg, Netherlands, Northern Ireland, and Norway.
RoCoF	Rate of Change of Frequency	The time derivative of the power system frequency (df/dt). This quantity was traditionally of minor relevance for systems dominated by synchronous generators because the inertia of these generators naturally counteracts load imbalances and limits RoCoF.
	Scenario	A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding electricity and gas demand and supply, infrastructures, fuel prices, and global context occur.
SEW	Socioeconomic Welfare	Refers to the overall economic and social benefits to society, including consumer and producer surplus, typically used as a key metric to assess the value of energy market decisions or infrastructure projects.
SMR	Steam Methane Reforming	A process used to produce hydrogen by reacting methane with steam over a catalyst, typically producing hydrogen and carbon monoxide as the primary products.
SoS	Security of Supply	Signifies that a supply of energy is guaranteed at all times, now and in the future. A secure supply of energy, not only electricity but also other final and primary energy sources, is vital both economically and socially.
SSI	Smart Sector Integration	An energy system approach that addresses all value chains of the energy sectors while supporting energy transition and decarbonisation goals. It links various energy resources and networks to consumption sectors in an optimal way. This leads to a "system of systems" vision, where electricity becomes the leading energy carrier and power grids form the backbone for decarbonising all energy sectors. In this context, smart sector integration is expected to deliver a scalable solution that improves overall system efficiency and resilience, allows greater integration of renewables, enables flexible consumption, and supports deeper consumer empowerment.
SSSC	Static Synchronous Series Compensator	A type of FACTS device used in power systems to control power flow and improve stability by injecting a controllable voltage in series with a transmission line.
SVC	Static Var Compensator	A device used in power systems to regulate voltage and improve stability by providing reactive power compensation.
t	ton	Measurement unit.
TEN-E	Trans-European Networks for Energy	A long-standing EU instrument for connecting the energy networks of EU countries, strengthening cohesion, and developing solidarity and cooperation across the EU.

Acronym	Term	Definition
TSO	Transmission System Operator	An organisation responsible for efficient and reliable transmission of electricity from generation plants via the power grid to regional or local electricity distribution operators. In Europe, transmission grids usually have voltage levels of 220 kilovolts (kV) to 380 kV.
TOOT	Take Out One at the Time	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 evaluate the load flows over the lines with and without the examined network reinforcement.
	Top-down	The “top-down carbon budget” scenario-building process is an approach that uses “bottom-up” model information gathered from gas and electricity TSOs. The methodologies are developed in line with the carbon budget approach.
TWh	Terawatt hour	A unit of energy representing 1 trillion watt hours. A kilowatt hour is equivalent to a steady power of 1 kilowatt running for 1 hour and is equivalent to 3.6 million joules or 3.6 megajoules.
TYNDP	10-Year Network Development Plan	Prepared by ENTSO-E and published every 2 years, it plays a central role in the development of electricity transmission infrastructure in Europe, which is needed to achieve European policy goals. It builds on national investment plans prepared by TSOs and takes into account regional investment plans.

Acknowledgements

To be
update

Regional Group Team

Katerina Macos (Convener)	..... IPTO
Anca Antemir	..... TRANSELECTRICA
Dilyana Bolashikova	..... ESO EAD
Edina Aganovic	..... NOSBiH
Elena Achkoska	..... MEPSO
Elgi Haxhiraj	..... OST
Francesca Ferretti	..... TERNA
Giorgiana Giosanu	..... TRANSELECTRICA
Gyorgy Ovari	..... MAVIR
Irena Basanovic	..... CGES
Ivan Simunic	..... HOPS
Nikola Rebic	..... ELES
Stefanos Kosma	..... TSOC
Tatyana Kirova	..... ESO EAD
Vladan Ristic	..... JSC EMS

Special thanks to

Gokhan Yasin UYSAL TEIAS
--------------------	-------------

Design

DreiDreizehn GmbH, Berlin . www.313.de

Images

Cover: © iStockphoto.com/imagean

pages 11, 36: courtesy of PSE

page 26: courtesy of Amprion

page 56: courtesy of Fingrid

pages 60–61: courtesy of Statnett

page 65: courtesy of Svenska Kraftnät

Publication date

June 2025