Nordic Grid Development Perspective 2025

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SVENSKA KRAFTNÄT ENERGINET FINGRID Statnett

About the report

The Nordic Grid Development Perspective (NGDP) is prepared by the Nordic TSOs biennially to present our perspective on the overall trajectory of the Nordic power system. The NGDP is intended to complement the national planning processes and network development plans, and the regional and European plans developed within ENTSO-E.

Initially requested by the Nordic Council of Ministers, this report is intended for everyone who has an interest in the development of the Nordic transmission grid and the challenges related to managing an increasingly complex and evolving system.

The report communicates our shared perspective on key development trends in the power system and strategies to address emerging challenges. It also provides a status update on ongoing and planned grid investments of significant Nordic impact.

Executive summary

We are in the middle of a radical transformation of the Nordic power system, and strong Nordic TSO cooperation is more important than ever. The transition to emission-free energy is necessary to reach climate goals and large volumes of new electricity production is needed to enable new industries. The development will continue to bring significant changes to all parts of our power system. At the same time, there is a lot of uncertainty driven by geopolitical changes, global competition and high costs for key technologies. The willingness to pay and technology costs will be decisive for how much and how fast the power system can expand.

Although circumstances are challenging, we remain firm in our belief that they also hold the potential to drive transformation and innovation. A successful transition to emission-free energy is key to a secure and competitive Nordic power system with affordable electricity prices and also a prerequisite for achieving climate goals. The Nordic TSOs remain committed to do what we can to enable a successful transformation towards a sustainable future.

Russia's war in Ukraine and profound changes in the international order have brought new challenges in terms of preparedness, safety and security. Since the last NGDP 2023 was published, Finland and Sweden have joined NATO, and the Nordic TSOs have intensified and formalized our cooperation on security and preparedness. With hybrid warfare as a threat, we must also prepare for attempts to undermine our integration, trust and societal cohesion through disinformation campaigns and other measures.

All the participating countries benefit from an integrated Nordic power system

The Nordic countries have a unique and long-standing cooperation in the energy field, and our power system is among one of the most integrated in the world. The sum of our different energy resources and comparative advantages constitutes a diversified and resilient Nordic system and makes our system stronger. Through cross-border connections each of the Nordic countries can access a broader spectrum of energy resources, enhancing security of supply beyond what we could achieve independently. An integrated Nordic market ensures that we use our energy resources efficiently, lowering the overall system costs.

We expect significant growth in electricity consumption – how much depends on production

Electrification, more activity in industry, and data centres are strong drivers for increased electricity consumption in all the Nordic countries. Consumption growth has progressed more slowly than anticipated, and more uncertainty has increased the range of scenarios for consumption growth towards 2050. The costs of key technologies are still high, and profound changes in the international order and more global competition are likely to affect goals and measures in energy, climate and industrial policy. Consumption growth assumes low enough electricity prices and without new electricity production, high electricity prices will limit consumption growth.

The Nordic capacity balance will be tighter – we need more flexibility

High growth in electricity consumption and a surge in intermittent power production will make it more challenging to balance the system during hours with little solar and wind power. A tighter Nordic capacity balance will affect the whole Nordic region and lead to more frequent high price peaks. Batteries and more flexible consumption will be important sources of flexibility, but sufficient dispatchable power plants must also be in place to ensure system adequacy. The Nordic TSOs are monitoring the development closely. Flexibility and energy storage will also play a key role for harnessing the potential surplus when there is a lot of production from solar and wind power.

Fundamental change in system characteristics calls for common solutions

The technical performance of the Nordic power system will inevitably change as the system shifts from one dominated by large power plants with inherently stabilizing characteristics (hydro and thermal) to one increasingly reliant on wind, solar, and battery-based generation connecting to the grid via converters. Large-scale introduction of converter-interfaced loads will accelerate this shift. The operational security of the system could be at risk if the resulting changes in dynamic behavior are not adequately addressed.

While converter-interfaced resources introduce new challenges, they also offer advanced functionalities which can help enhance and support grid stability. It is important to find solutions to exploit this potential and to ensure that grid users support the system. The topic was thoroughly addressed in the NGDP 2023, and the Nordic TSOs remain committed to develop and implement effective strategies and solutions together and in partnership with external stakeholders.

Substantial grid investments are essential

The Nordic TSOs are planning massive investments to reinforce and expand the transmission grid to enable a significantly larger and well-connected Nordic power system. As the share of renewable and fluctuating generation increases, a strong Nordic grid will have a key role in balancing geographical variations in flexible (hydro, nuclear and thermal) and non-flexible (wind and solar) power sources across the region and facilitate efficient use of the power resources. A strong grid is also important for handling short-term imbalances in production and consumption across the Nordic countries. The Nordic TSOs will build on our strong cooperation and continue to explore relevant cross-border projects.

We are investigating all possibilities to use the grid more efficiently

Surging costs and prices make the green transition more challenging in terms of lead times, grid expansion, development cost and public acceptance. With high investment costs, long lead times and growing connection queues it is more important than ever to optimize the use of existing and new assets through more efficient grid utilization. The Nordic TSOs also strive to unleash time and cost reduction potential through transparency on our grid development plans and working together to identify upsides from increasing standardization on components and technical requirements.

We need active participation from grid customers

Active participation from customers is key to enable flexibility and ensure system stability and efficient use of the power grid. This is imperative to the system and with efficient market solutions it is also profitable for grid users. Nordic TSOs are committed to working together to contribute to this development.

The energy transition is a joint effort

Achieving climate goals will require a joint effort where policymakers, industry, businesses and society move in the same direction. A strong and resilient transmission grid is the backbone of the energy transition, and the Nordic TSOs remain committed to do what we can to expand grid capacity in the right pace and magnitude, while we also ensure safe and efficient system operation. To succeed with our ambition, we need effective governance and a supportive regulatory framework, including a more efficient permitting process and a regime that enables anticipatory investments.

Lengthy permitting procedures constitute a key barrier for timely grid development in all the Nordic countries, and all possibilities to reduce lead times must be investigated. More efficient permitting procedures must not come at the expense of thorough processes and assessment of grid projects. All the Nordic TSOs remain committed to developing sustainable solutions with acceptable consequences for nature. We also work to ensure early, regular and meaningful stakeholder engagement in our projects, in line with the European Commission's Pact of Engagement.

Content

1. Development trends for the Nordic power system

KEY TAKEAWAYS

- We expect that the electricity consumption in the Nordic region will increase in the coming decades, but it is highly uncertain how much, where it will be placed and how fast it will increase.
- Most of the new electricity production will come from wind and solar.
- The total energy balance of the Nordic region shows a moderate but decreasing energy surplus, but there are variations across the region.
- The Nordic TSOs plan for substantial grid investments to connect grid users, to transport electricity from areas with production to areas with consumption and to efficiently utilize production across a wider area.
- Flexibility in production and consumption is needed to ensure efficient use of energy resources and maintain a high security of supply.

As a foundation for planning of the transmission grid the TSOs establish scenarios of the development trends of the Nordic power system. In this chapter, we present Nordic power system projections and key development trends based on the most recent national projections[1] and analyses of the projections performed in joint Nordic flow-based analyses[2]. Projections are compared to realized values for 2023[3]. The national projections are not output values of an analysis from a consistent, common dataset, but are based on each TSO's individual input.

The consumption of electricity is increasing to uncertain levels

Among the Nordic TSOs there is a consensus that electricity consumption in the Nordic region will increase in the coming decades. Figure 1 presents projections of the electricity consumption in the Nordic countries, but exactly where, how fast and how much the consumption will develop is highly uncertain. Figure 2 presents the aggregated electricity consumption for the Nordic region illustrating how consumption could more than double from 2023 to 2050 in our scenario.

Today, electricity consumption is mainly in households and industries. In the shorter term, electrification of existing demands in industries, transport and heating will increase demand. In the longer term, we expect that the increase in electricity consumption will come from mainly new electrified industries in the Nordic region including data centres, new industrial facilities and hydrogen production based on electrolysis. Production and use of green hydrogen will be central to reduce emissions in parts of the industry and transport sector. The development in usage of hydrogen and production is simultaneously one of the most central uncertainties for electricity prices, climate targets, and the industrial need for energy.

1. Data set for national energy system projections are based on for Denmark: Analyseforudsætninger til Energinet 2024 updated based on recent development on Danish offshore wind tenders, for Finland: Prospects for future electricity production and consumption Q3 2024 and ENTSO-E TYNDP long-term power system projection, for Norway: Langsiktig Markedsanalyse (LMA) 2024-2050 and for Sweden: Kortsiktig marknadsanalys (KMA) 2024 and Långsiktig marknadsanalys (LMA) 2024, the FM scenario.

2. The Nordic flow-based analyses investigate the target years 2028, 2030, 2033 and 2035 in the Samnett model. The analyses serve as input for the European Resource Adequacy Assessment 2025 in generating flow-based domains for the Nordic region, and do not present any adequacy results themselves.

3. Historical values for 2023, that is the latest year with available data for energy system statistics, are based on for Denmark: Analyseforudsætninger til Energinet and Miljøredegørelse 2023 for Finland: Statistics Finland for Norway: elhub and for Sweden: Energiläget I siffror. As it was not possible to find the same consumption subcategories for the realized consumption in 2023 compared to the projected demand, only total consumption in 2023 is presented.

The long-term development of electricity consumption will depend on multiple factors including the competitiveness of electricity prices in the Nordics as well as the maturation of the electrolyser technology.

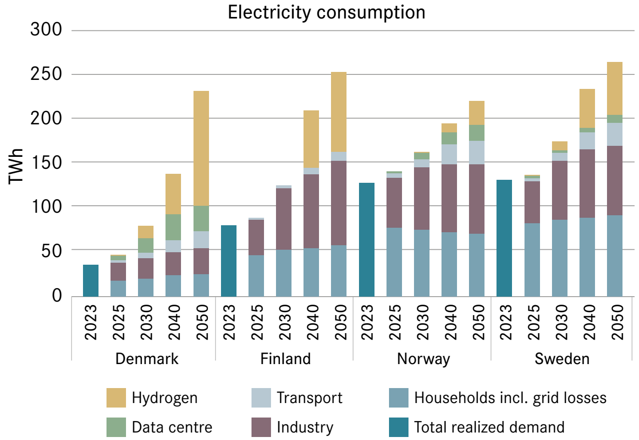

Figure 1: Projection of electricity consumption for Denmark, Finland, Norway and Sweden.

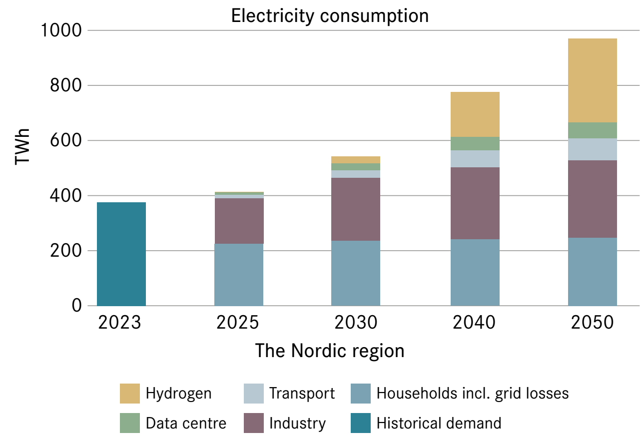

Figure 2: Projection of electricity consumption for the Nordic region.

Note 1: The "Industry" electricity consumption in Finland includes data centres. Before target year 2040 the category also includes consumption for hydrogen production. From 2040, consumption for hydrogen production is registered separately. Note 2: Electricity consumption for heating is included in "Households incl. grid losses".

Most of the new energy comes from variable wind and solar power

Across most scenarios, we expect that the production needed to meet the increasing consumption will come from wind and solar power. Figure 3 and Figure 4 show projections of how the electricity capacity in the Nordic countries can develop towards 2050. From 2023 to 2050 the capacity in the Nordic region is more than doubled, and the share of capacity from wind and solar compared to the total capacity increases from ⅓ to ¾. However, the rapidly changing political climate and the momentum for investment in new electricity production highlight the uncertainty related to the expected development.

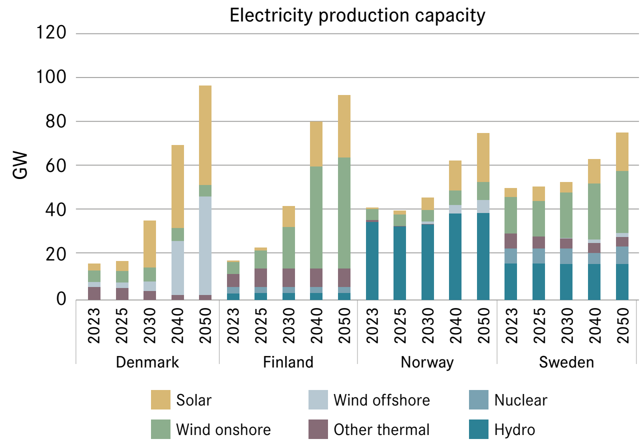

Figure 3: Projection of electricity production capacity for Denmark, Finland, Norway and Sweden.

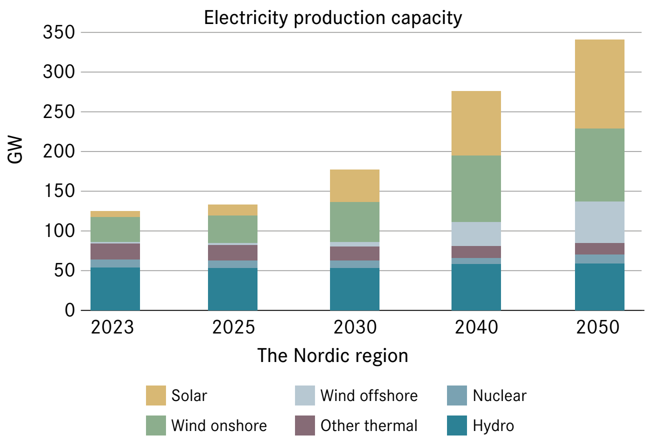

Figure 4: Projection of electricity production capacity for the Nordic region.

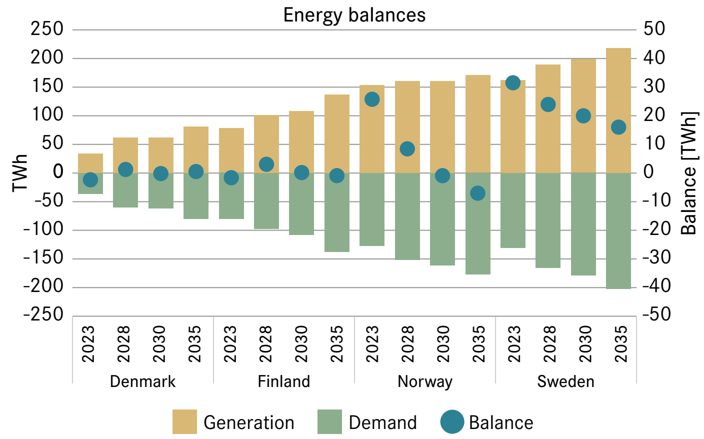

Figure 5: Development in energy balance for the Nordic countries.

The Nordic area is likely to keep a moderate energy surplus – with exceptions

Based on market-grid analyses of the Nordic power system, we expect energy balances to vary across the Nordic countries, as shown in Figure 5. In 2023, energy balances in Denmark and Finland are roughly neutral, whereas there is significant energy surplus in Norway and Sweden. Towards 2035, the overall trend in the Nordic region is a decreasing energy surplus, driven by the increasing electricity consumption, see Figure 6. Energy balances in Denmark and Finland remain around zero, while energy balances in Norway and Sweden decrease significantly. The yearly energy balance in the Nordic region remains positive in 2035.

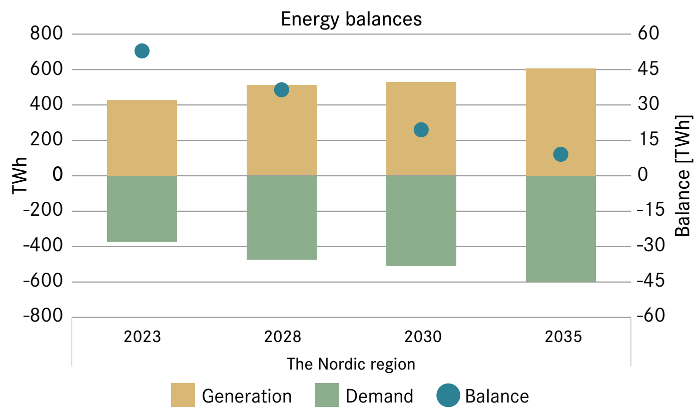

Figure 6: Development in energy balance for the Nordic region.

Yearly energy balances are also calculated for the northern and southern parts of the Nordic region, respectively. Figure 7 shows how the Nordic region is divided in a northern and southern part, and Figure 8 shows that there is a positive energy balance in the northern part and a negative energy balance in the southern part. The currently large surplus in the northern part of this area is likely to be reduced as new consumption is established. Still, we expect that it will remain as an area of surplus for many years ahead. In the south, a greater increase in demand compared to the development in production results in an increasing negative balance towards 2035.

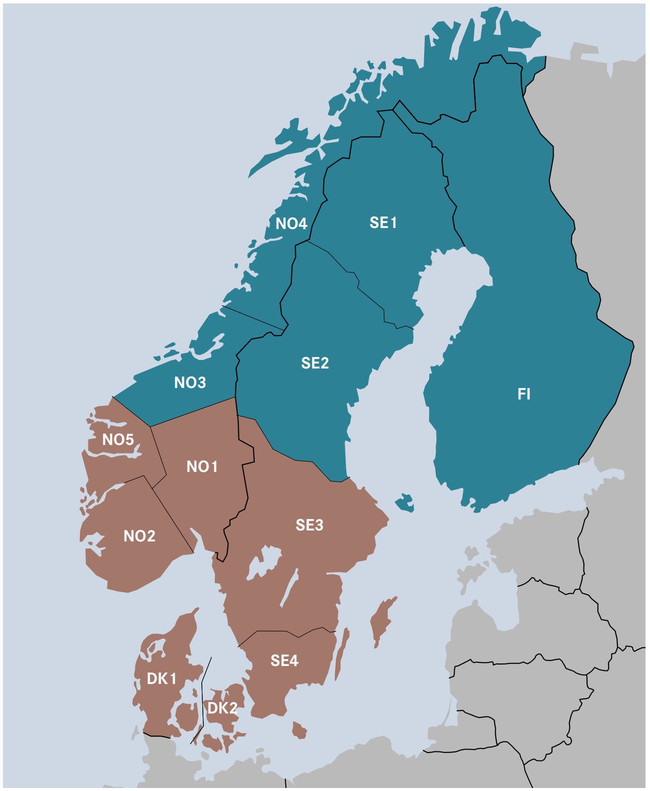

Figure 7: Map showing northern (blue) and southern (red) areas of the Nordic region. Simplified representation of bidding zones.

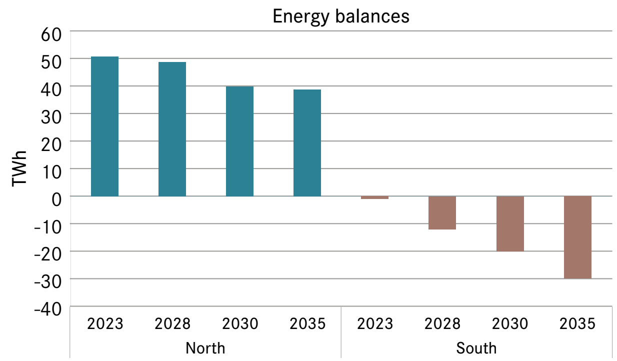

Figure 8: Development in energy balance in the north (NO3, NO4, SE1, SE2 and FI) and the south (NO1, NO2, NO5, SE3, SE4, DK1 and DK2) of the Nordics towards 2035.

Increased need for grid capacity in all scenarios

Nordic TSOs are planning large investments in the transmission grid in the coming years – see also chapter 4 regarding Nordic grid projects. Investments are partly driven by grid components that have reached end of life and need to be replaced and partly by the many requests for grid connection from new consumers and producers. Besides that, grid expansion is also needed to enable an economically efficient utilization of energy resources across regions and countries by facilitating transport of power from areas of production to areas of consumption. In the Nordic region there is a significant variation in electricity production sources. Figure 9 presents the electricity production capacity mix in each bidding zone in 2023 and how it develops towards our 2035 scenario. In Norway and northern Sweden, the production is dominated by hydro, whereas wind and solar constitute a significant share of the production capacity mix in Denmark, Finland and southern Sweden.

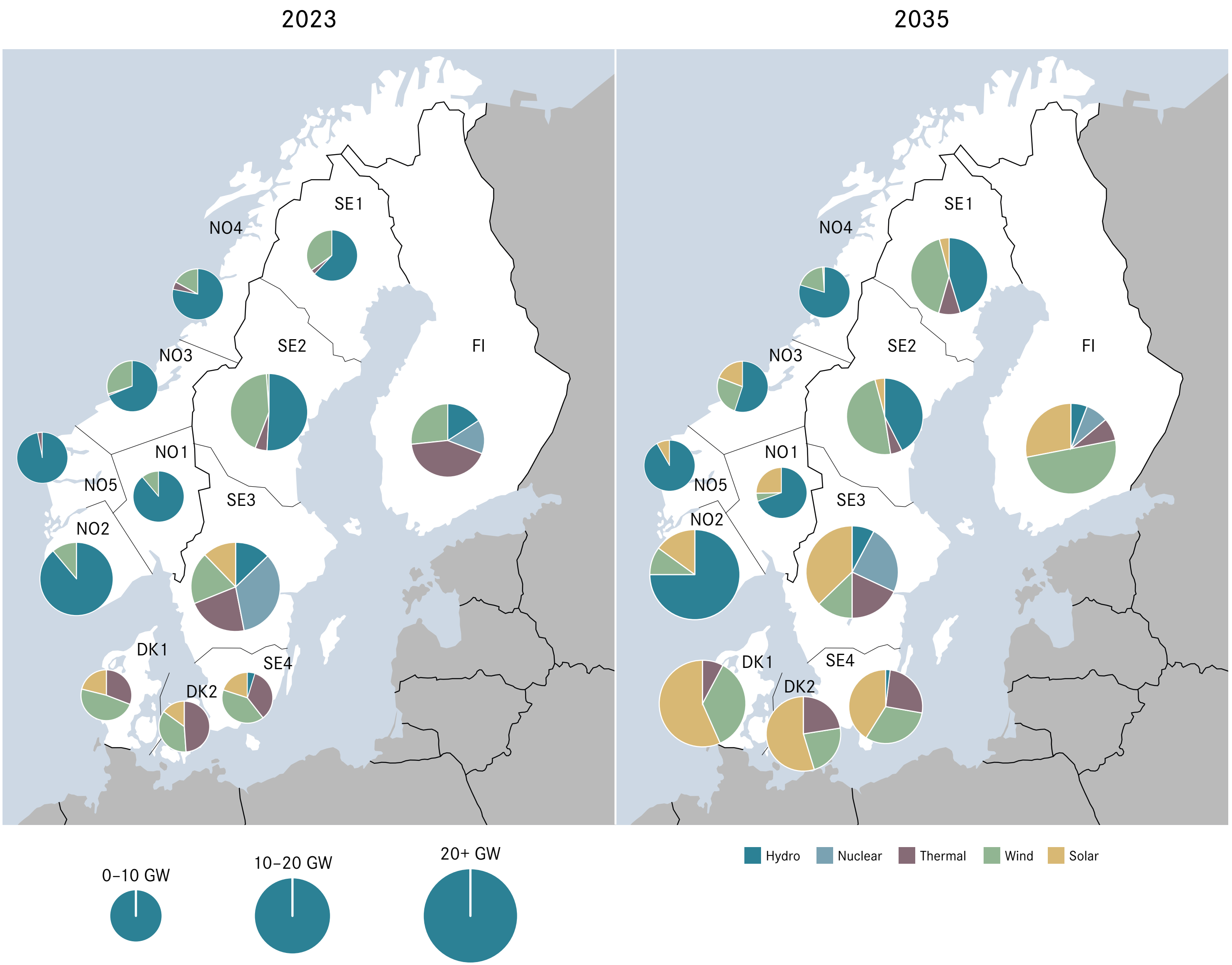

Figure 9: Electricity production capacity mix in Nordic bidding zones in 2023 and 2035. Simplified representation of bidding zones.

The possibility for power exchange between bidding zones and across borders is fundamental to achieve efficient utilization of the power sources. Without the possibility of electricity trade, each bidding zone would need to rely solely on its own production capacity at all times, leading to inefficient overinvestments to meet the local demand. Figure 10, as one example, shows how cross-border exchange is used to optimize the value of flexible hydropower production in NO2 and wind production in DK1. This is done by storing the water and importing power when there is a lot of wind in DK1, while DK1 imports when the wind production is low, for the mutual benefit in both areas.

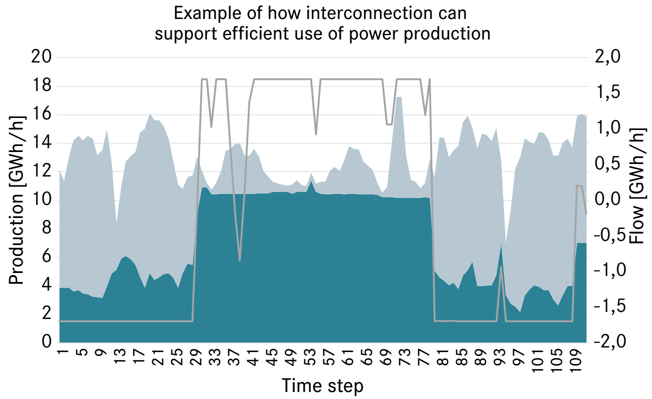

Figure 10: Wind production in DK1, hydro power production in NO2 and cross border exchange between DK1 and NO2. The figure shows a two-week period in 2035 where modelling is done with three-hour time steps.

Figure 11 illustrates how the net flows between bidding zones in the Nordic countries develop. Following the increasing number of producers and consumers and to efficiently utilize the electricity production with an increasing share from wind and solar, our analyses show that the total yearly power flow within the Nordic region will increase from year 2023 to 2035. Also, the power flow, in general, shifts from being mainly from north to south to being more bidirectional and in accordance with the decreasing Nordic energy balance presented in the previous section, the net export flow from the Nordic area is decreasing.

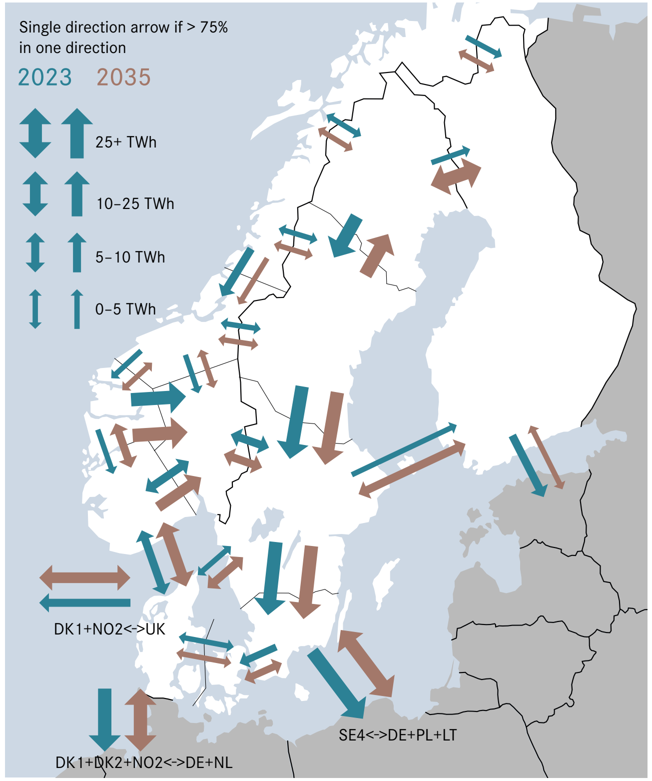

Figure 11: Yearly power flows within and across borders in the Nordic countries and between the Nordic countries and Baltics, Continental Europa and UK in 2023 and 2035. Simplified representation of bidding zones.

Exemplifying how power flow changes, Figure 12 shows how the flow from SE2 to SE3 decreases towards 2035, with fewer hours with high north-south flow and more flow towards SE2. This is due to the assumption of a large increase in industry demand in the north of Sweden. On the other hand, Figure 13 shows the opposite in Finland. A large development in wind and solar capacity especially in northern Finland, combined with a substantial increase in demand mainly in the south, will lead to a greater need for north-to-south power flow within Finland.

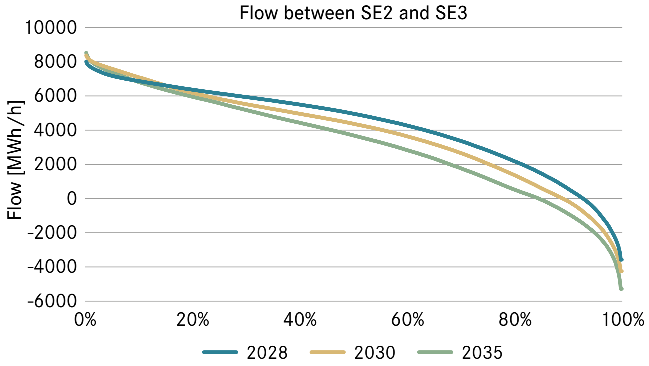

Figure 12: Development in the flow duration curve of the power flow between SE2 and SE3. Positive flow is from SE2 to SE3. Negative flow is from SE3 to SE2.

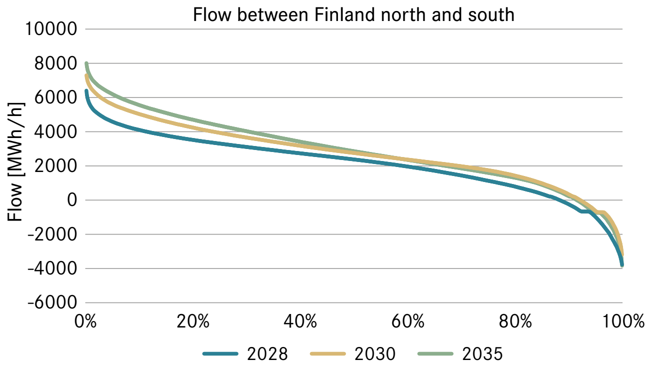

Figure 13: Development in the flow duration curve of the power flow between Finland north and south. Positive flow is from north to south. Negative flow is from south to north.

Flexibility is needed to keep the system secure and efficient

The growing consumption of electricity towards 2035 is expected to be met primarily by production from wind and solar power plants. Unflexible wind and solar power production varies with weather conditions and cannot always meet the seasonal or daily variations in demand.

Figure 14 shows the development in residual demand[4] in the Nordic region. The trend shows that residual demand is increasing towards 2035, indicating a need for an increased amount of flexible production capacity from e.g. hydropower, nuclear or gas power plants to cover the demand in these hours. Flexibility can also be provided through flexible consumption e.g. in the transport and the heating sectors, or by storing electricity at times of surplus and producing electricity at times of deficit.

High availability of existing flexible production and import possibilities will be necessary in the hours with high residual demand. However, the total installed capacity of flexible production is unlikely to be available at the same time due to maintenance and revision periods. In addition, investments in new flexible production units are challenged due to a limited economic viability from a low number of operational hours, which is also what is found in the economic viability assessment (EVA)[5] in the European Resource Adequacy Assessment 2024 (ERAA24)[6]. Additional measures to secure enough available flexibility could be needed to avoid adequacy issues, both in the day-ahead market, and in the operational hour. In that sense, some of the Nordic TSOs are investigating the need for capacity mechanisms.

4. Residual demand is calculated as total electricity demand subtracted production from wind and solar.

5. The EVA step assesses the viability of capacity resources participating in the energy-only market (from ERAA methodology)

6. ERAA 2024 Edition: https://www.entsoe.eu/eraa/2024/

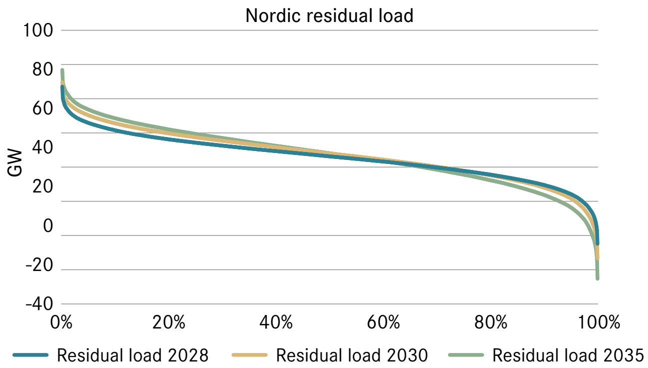

Figure 14: Development in residual demand in the Nordics.

On the other hand, the negative residual demand is expected to further increase towards 2035, and there will be more hours where the intermittent production more than covers the demand. This results in low prices and an excess of power that is either exported or goes to waste. This highlights a growing need for demand flexibility from off takers such as hydrogen production with storage opportunities or batteries. Depending on the development in technology costs, these technologies could have a central role in the energy transition towards 2050.

In the map in Figure 15, the power balance in each Nordic bidding zone is presented for a tight winter hour with a high Nordic residual demand in our 2035 scenario. In this specific hour, the total availability of flexible production resources is lower than the residual load, and the Nordic region is dependent on net imports from the continent. The map shows that in an hour with high residual demand, the need for flexibility applies to a larger geographical area in the Nordics. Recent occurrences of “dunkelflaute” in Europe, with low wind and solar availability over a consecutive period, indicate that it is also rising as a common European issue. This will also affect the Nordic region due to our close integration with the continent. In this case, higher grid capacity cannot alone eliminate the issue.

Similarly, times of high negative residual demand will often be a common challenge over a large geographical area as well, where flexibility will be needed to make sure that energy, besides what can be exported, does not go to waste.

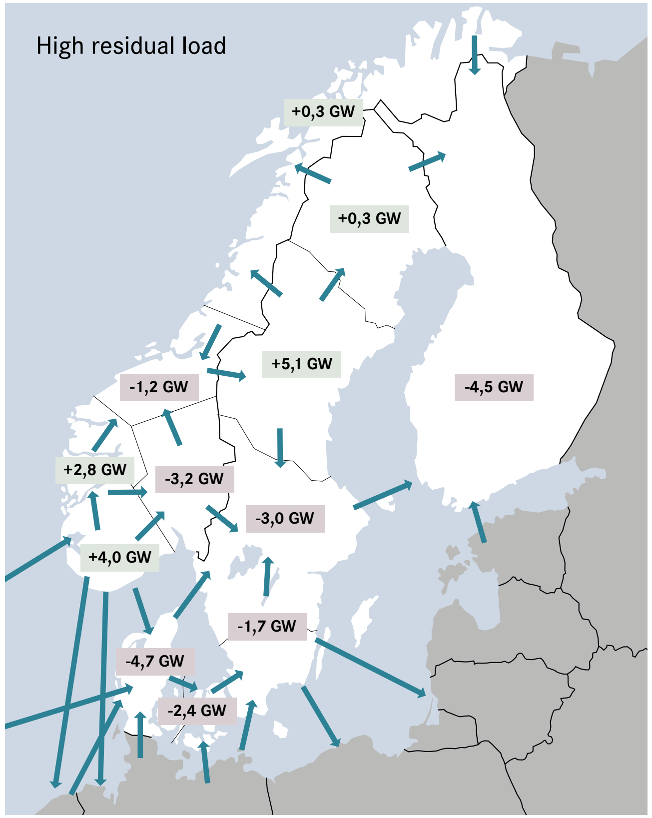

Figure 15: Zonal power balances and flow directions in a winter hour with high residual demand in 2035. Simplified representation of bidding zones.

2. Emerging technical challenges need a joint Nordic effort

2.

KEY TAKEAWAYS

- As more Power Electronic Interfaced Devices are introduced, the technical characteristics of the Nordic power system change rapidly, affecting system stability, reliability and resilience.
- Grid stability and other technical aspects also set limits for how the grid can be utilized, in addition to thermal constraints.
- The fundamental change in system characteristics calls for new solutions.
- The Nordic TSOs are working together on common guidelines and monitoring practices for managing converter stability issues related to the fast dynamics of converter controls.
- We are developing a joint guideline for grid-forming functionality to ensure a harmonized implementation of grid-forming capabilities within the Nordics.
- We are taking measures to safely integrate large demand facilities

The previous NGDP publication from 2023[7] extensively discussed the transition towards a Nordic power system dominated by Power Electronic Interfaced Devices (PEID). The technical fundamentals behind the changing system characteristics and associated challenges were also discussed. This chapter provides an update on the expected development of converter-connected facilities in the Nordic power system as well as the work carried out by the Nordic TSOs since last NGDP publication.

The transition towards a decarbonized society will change the energy landscape and technical abilities of the Nordic power system. Besides thermal constraints, grid stability and other technical aspects also set limits for how to utilize the grid.

A significant and ever-increasing share of generation in the Nordic power system comes from wind and solar power, which connect to the grid using converters. These devices do not inherently have the same stabilizing characteristics as the traditional synchronous units. In addition, batteries and large demand facilities such as data centers and electrolyzers connect to the grid via converters.

As more PEIDs are introduced, the technical characteristics of the Nordic power system change rapidly, affecting system stability, reliability and resilience. This fundamental shift calls for joint efforts among the Nordic TSOs to, in close collaboration with external stakeholders, develop and implement strategies to maintain a robust and secure system as the share of PEIDs continues to grow.

The converter-based generation has become significant in Nordic synchronous area. Figure 16 presents how the share of converter-based generation varied throughout 2024, showing that there were already around 200 hours during which the share of converter-based generation was over 40 % of the

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total generation in the power system[8]. Also HVDC links are connected to the power system via converters, and thus the power transmitted towards Nordic synchronous area via HVDC links will add on to the total share of converter connected power within the system.

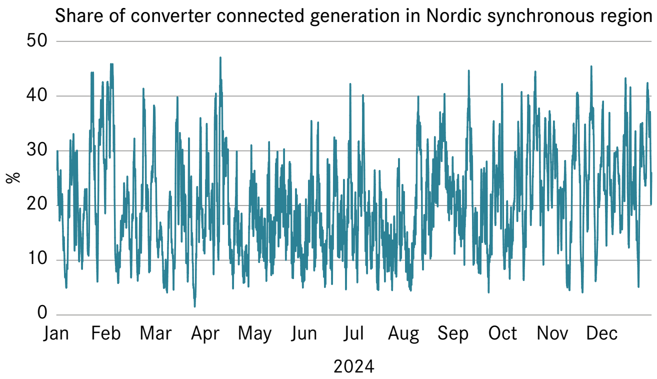


Figure 16: Variations in the share of converter-based generation of total generation during year 2024 in the Nordic synchronous region[9].

The capacity of converter-interfaced facilities is expected to triple on the generation side during the next ten years, and the development is expected to continue in the years after, as shown in Figure 4 in Chapter 1.

While there is an increasing trend with converter-based generation, similarly, there is a fundamental change in the development of consumption. Data centers, electrolyzers as well as other power intensive industry devices connect to the grid via converters, and the size of these new facilities can be very large in terms of consumed instantaneous power.

As the installed capacity of converter-interfaced facilities increases, this will lead to increasing number of events with a high share of PEIDs in operation in the coming years. Figure 17 represent the average share of PEID in each modelling region in the Nordic region and the hour with the highest share is presented in Figure 18.

8. There is no strict limit on how large portion of the power in the power system can be generated by grid following PEIDs, but for instance in the EU funded pan-European R&D project MIGRATE it was found that an instantaneous share higher than 65% requires new considerations and mitigation actions. More information from MIGRATE project can be found from here: https://cordis.europa.eu/project/id/691800/results.

9. Data source: Entso-E transparency platform

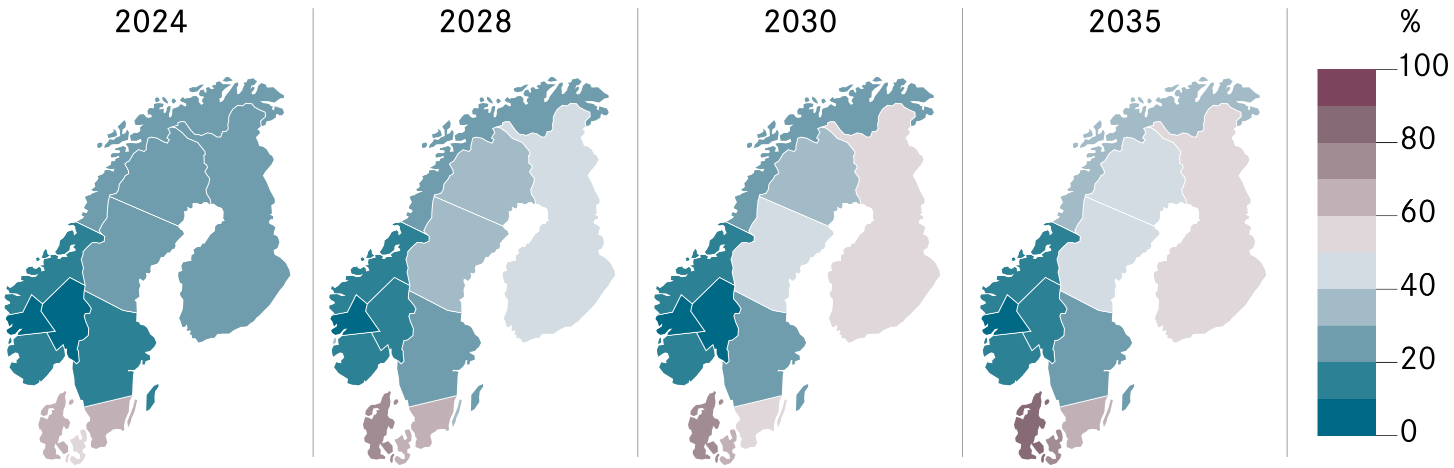


Figure 17: Average share of converter connected wind and solar generation during all the hours of the simulated year per bidding zone with weather conditions from average Weather year 1999. Darker red colour indicates higher share of converter connected wind and solar generation of total production. Higher share causes stability risk if no mitigating measures are introduced.[10] Simplified representation of bidding zones.

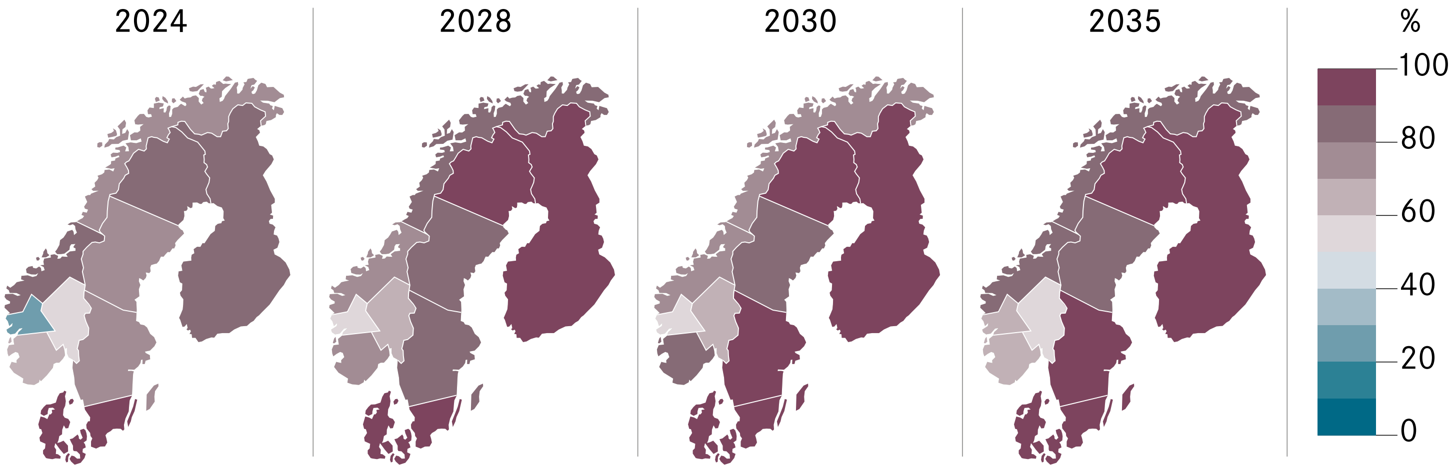


Figure 18: Share of converter connected wind and solar generation per bidding zone during system level maximum penetration hour. Darker red colour indicates higher share of converter connected wind and solar generation of total production. High share causes stability risk if no mitigating measures are introduced[11]. Simplified representation of bidding zones.

10. Data source: data for 2024 from Nordic TSOs, data for expected development for years 2028, 2030 and 2035 from [ENTSO-E ERAA2024](#)

11. Data source: data for 2024 from Nordic TSOs, data for expected development for years 2028, 2030 and 2035 from [ENTSO-E ERAA2024](#)

The fundamental change in system characteristics calls for new solutions

Traditional sources of system strength, inertia, and fault current are declining, while the demand for a secure and reliable electricity supply remains unchanged. This creates significant challenges for the technical performance of the system. On the other hand, while converter-interfaced resources introduce new challenges, they also offer advanced functionalities which can help enhance and support grid stability. The challenges need to be handled in a sufficient and timely manner, otherwise the risk of serious and even critical system incidents will increase considerably.

To tackle these new challenges, the Nordic TSOs established the Converter Dominated Nordic Grid (ConDoN) group in 2022, in which the Nordic TSOs have been collaborating to identify and solve technical challenges introduced to the Nordic synchronous system due to massive integration of PEIDs. The work is structured in multiple working packages aiming to study the new challenges and to assess possible measures. The work also aims to create harmonized Nordic guidelines and aligned requirements to ensure cross-border interoperability and to manage system level needs to ensure stability in the future, converter-dominated Nordics. In the following chapters, three critical topics that ConDoN has been working on since the last NGDP publication are highlighted: the need for implementing grid forming capabilities, challenges with managing system response during fault and recovery following the introduction of large-scale demand facilities, and measures to address converter-driven stability issues as the share of PEIDs increases.

We are developing a joint guideline for grid-forming functionality

Grid-forming control has emerged as a key technology to ensure that PEIDs can contribute to system stability in the same way traditional synchronous machines do. Grid forming is becoming a new technical foundation for secure operation in a converter-dominated future.

Grid-following inverters, which dominate today's renewable installations, synchronize to the grid voltage to operate. In contrast, grid-forming inverters can establish voltage and frequency on their own. This makes them capable of operating in weak grid areas[12], supporting black-start capability[13], and contributing to inertia and damping of oscillations.

Introducing grid-forming capabilities enhances the system's ability to:

- Regulate voltage and frequency under normal and disturbed conditions,
- Maintain synchronism and support the system during faults,
- Operate in low-inertia environments or even islanded grids,
- Improve resilience and dynamic stability.

To ensure a harmonized and future-proof approach, the Nordic TSOs are developing a joint guideline for grid-forming functionality. The purpose is to:

- Define consistent performance requirements for grid-forming capable inverters,
- Provide clarity for developers and manufacturers on expectations,
- Enable TSO coordination in planning, grid connection and operation,
- Support pilot projects and real-world validation of grid-forming behavior in the Nordic context.

12. In this context, a weak grid refers to an area with a high share of converters relative to the system strength.

13. Black-start capability refers to the ability to start the system following a partial or complete blackout.

2.

This work builds on European experiences and ongoing research but is tailored to the specific operational needs of the Nordic power system—characterized by long transmission distances, low short-circuit levels, and high system sensitivity to disturbances.

Recognizing the need for action, grid-forming requirements are already being introduced for key technologies such as HVDC links, Static Synchronous Compensators (STATCOMs)[14], and battery energy storage systems (BESS)[15]. These early implementations serve as a foundation for extending requirements to other technologies over time.

Grid-forming functionality is not a stand-alone solution, but it is a critical building block in securing the stability of the Nordic grid as we move towards a carbon-neutral energy system. By introducing grid-forming requirements now—before they become critical—we ensure that new investments in generation and storage can actively support the system, not just connect to it.

We are taking measures to safely integrate large demand facilities

One key aspect of power system stability is the system response during fault and fault recovery. In the Nordic power system, voltage dips, caused for example by lightning strikes, can propagate over rather large areas, as shown in Figure 19, due to the meshed nature of the high voltage network. When new transmission lines are built to connect new facilities, the meshed system gets denser, which is expected to increase the propagation of voltage dips.

14. A STATic synchronous COMpensator (STATCOM) is a fast-acting device capable of providing or absorbing reactive current and thereby regulating the voltage at the point of connection to a power grid (definition by ENTSO-E). If the STATCOM is supplemented with some form of energy storage (e.g. batteries or supercapacitors) it is also possible to provide and absorb active power, supporting the grid under frequency disturbances.

15. The progress may differ nationally between Nordic TSOs

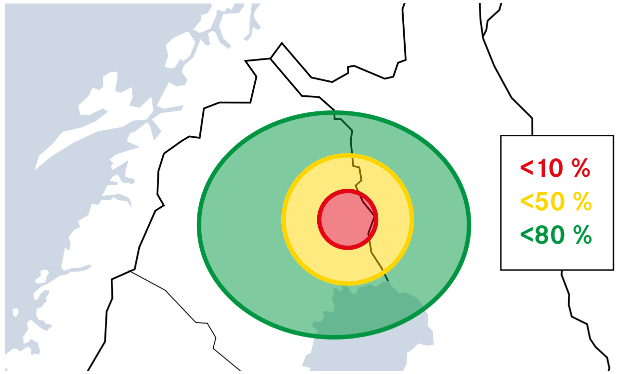


Figure 19: Example of a voltage dip propagating due to a fault in power system. The colours represent the residual voltage.

One of the key differences between PEIDs and synchronous machines is the active power recovery period. In synchronous generation and conventional demand facilities connected to the power system, the active power recovery is governed by electromechanical and electromagnetic dynamics. In converter-based generation and converter-interfaced demand facilities, however, the active power recovery is governed by the converter and the underlying process, for example hydrogen production. In converter-interfaced generation and load the active power recovery may take up to several seconds, which in turn may have a huge cross-border impact by affecting voltage stability, frequency stability and rotor angle stability. The impact of low voltage ride through capability and active power recovery time of the demand facilities to power system stability are visualized in Figure 20. The ConDoN work aims to find techno-economically feasible measures to limit the above-mentioned stability impacts.

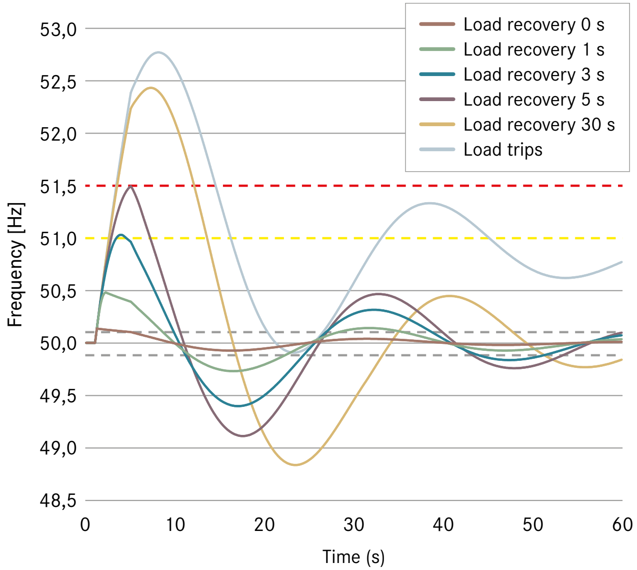


Figure 20: Example of impact of fault recovery period of 3 GW load concentration to the Nordic power system frequency.

All Nordic countries have low-voltage-ride-through requirements in place for both synchronous and converter-based generation units in the event of faults. At present, not all Nordic countries have requirements in place regarding demand facilities. However, in the Nordic power system, a significant number of demand facilities are expected to be located close to each other, and the number of facilities that may experience a voltage dip is expected to significantly exceed the dimensional fault of the Nordic power system. Thus, low-voltage-ride-through requirements for demand facilities are essential. Considering the possibility of system-wide consequences when integrating large demand facilities, it is deemed critical to ensure that these requirements are coordinated within the Nordics.

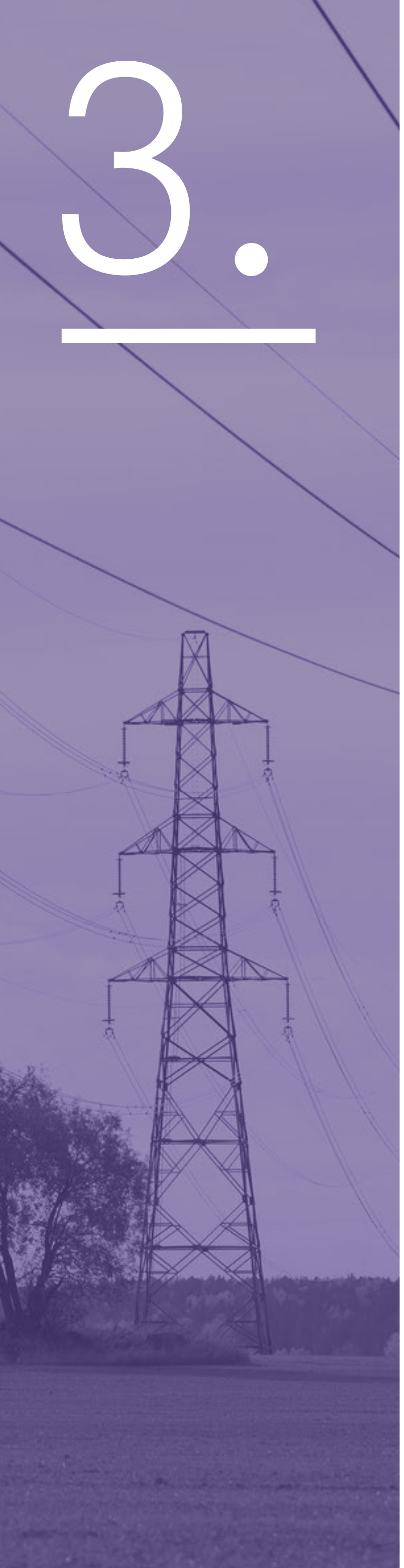
We coordinate technical requirements and methods for managing converter stability

As the Nordic grid sees increasing proportions of PEIDs, including wind, solar, HVDC/FACTS, and large converter-interfaced loads, new stability challenges are emerging. These phenomena, often referred to as “converter-driven stability issues,” extend beyond traditional concerns like rotor-angle, voltage, or frequency stability.

The fast dynamics of converter controls can give rise to unwanted oscillations in a broad frequency range, with possible consequences including equipment damage, plant disconnections, or even wider disturbances. Traditional analysis tools alone are no longer sufficient to capture these complex interactions. Therefore, more advanced methods, including frequency-domain and electromagnetic transient (EMT) tools, are being adopted. These methods help to assess the risk of unwanted interactions, enabling plant owners and TSOs to implement stability-preserving design choices early in the project lifecycle, or to assess and implement measures following a disturbance.

Through the ConDoN project, the Nordic TSOs are working together on common guidelines for managing converter stability, including requirements and processes when integrating plants into the grid. Another focus is on improved monitoring practices, so that problems can be quickly detected and addressed. By actively coordinating technical requirements and methods for managing converter stability, the Nordic TSOs aim to reduce the risk of unwanted interactions and support a smooth transition to a converter-dominated Nordic grid.

3. Efficient utilization and timely development of grid capacity



KEY TAKEAWAYS

- Surging costs, long lead times and many requests for grid connection stress the need to unlock the full potential of the existing transmission grid.
- We are working with a broad range of measures to use the grid more efficiently and will continue this work in joint TSO working groups and stakeholder collaboration.
- We must reduce the lead times for network expansion and will scrutinize internal and external processes for optimization. A faster permitting process is key but can only be achieved through broad collaboration.

The Nordic power system is undergoing a significant development and in the coming decades the ambitions for the transition will not diminish. The future will bring various challenges that the Nordic TSOs must tackle in broad collaboration. Efficient use and timely development of the transmission grid are important for all the Nordic TSOs to succeed. We continue to find strategies to address these challenges, learn from each other and identify best practices.

We are working with a broad range of measures to use the grid more efficiently

Connection queues are growing in all the Nordic countries, while network expansion entails long lead times and high investment costs. The Nordic TSOs are therefore working dedicatedly to unlock the full potential of the existing transmission grid through increased capacity in existing grid assets and better utilization of the power grid. Since the Nordic transmission grid is already highly utilized, this approach alone will not be sufficient to meet expected future grid needs.

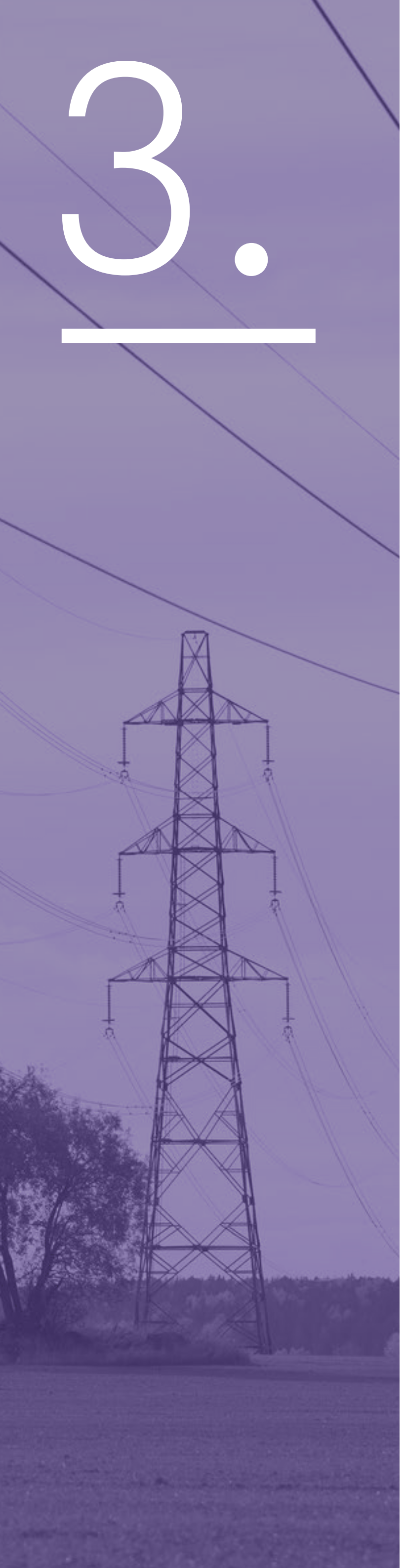
In the short term, however, it is our most important tool to connect more consumers and producers to the grid. In the long term, increased utilization is crucial to ensure that we do not build more transmission infrastructure than necessary.

Measures in existing grid components can increase transmission capacity

Minor measures in existing grid assets can significantly increase transmission capacity, particularly in power lines. Temperature upgrades for existing power lines may be a low-hanging fruit that can increase thermal capacity at a low cost. This can be achieved by controlling the minimum clearance, increasing tower height, or removing obstacles below the power line to increase clearance.

Traditionally, the capacity rating of power lines has been defined by fixed values for various temperature intervals. Dynamic Line Rating (DLR), which measures line temperature and sagging as well as local weather conditions (air temperature, wind speed and solar radiation), allows for increased capacity by bringing it closer to the physical limit. The line capacity is determined dynamically based on actual weather conditions and line sagging rather than conservative capacity ratings using worst-case weather assumptions. Equally, the capacity of power cables and transformers can be rated dynamically. All the Nordic TSOs see DLR as an important tool to increase capacity but are at different stages in development and implementation.

Replacing limiting network components, such as current transformers, which involve low costs and lead times, is another measure that can be implemented in the existing grid to increase capacity.



We use market solutions that meet system needs

The Nordic TSOs have introduced different measures and solutions to enable better utilization of the grid while maintaining a secure operation.

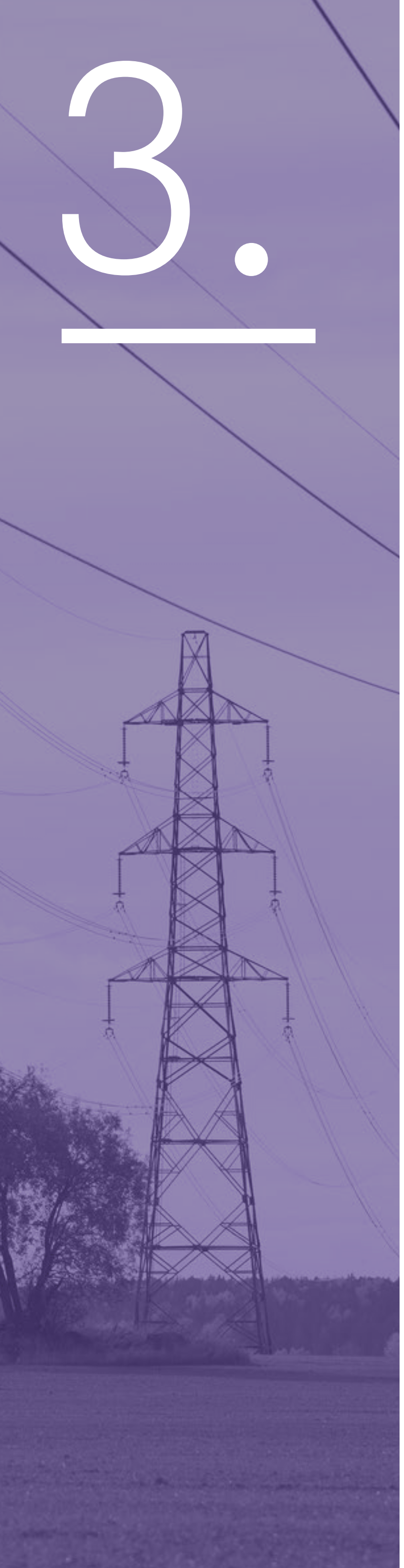
Traditionally, the available capacity of transmission grid has been defined by a fixed value based on the physical characteristics of the grid and with a safety margin to prevent overloading. To obtain a higher utilization of the grid, the available capacity must be closer to the operational boundaries without compromising safe operation.

The Nordic flow-based market coupling is a core example of a project where the Nordic TSOs have developed a robust and well-tested methodology to use the transmission grid more efficiently. The physical characteristics of the power grid are taken into account, and available capacity is dynamically assessed based on real-time grid constraints and power flows. As a result, the available capacity of the grid moves closer to its operational boundaries. Automated and digitalized solutions have been crucial to ensure an efficient and safe system operation with flow-based market coupling.

The flow-based project shows what can be achieved through close collaboration between TSOs, market participants and regulatory authorities, with a strong focus on using the technological developments to enable new solutions. An introduction to flow-based capacity calculation in the Nordic day-ahead market and experiences so far are found in Text Box 1.

The use of bidding zones is also a way to ensure that the power market better reflects the physical grid limitations. Finland constitutes a single bidding zone, whereas the other Nordic countries are divided into multiple bidding zones. Svenska kraftnät recently announced that a new bidding zone configuration in Sweden might be needed and will carry out a study, which also includes upcoming changes in the electricity system. The Swedish government has specified possible configurations and solutions to be investigated. Statnett is on a regular basis assessing the bidding zone configuration in Norway and will continue to analyze possible configurations that might improve grid efficiency. There are no plans to change the bidding zone configuration in Finland or in Denmark with the exception of a new bidding zone at the Danish Energy Island Bornholm[16] where a structural congestion has been identified.

16. See description of Energy Island Bornholm as cross-border project CB12 in chapter 4.



Text Box 1: Nordic flow-based market coupling as a case study of efficient use of grid

CASE STUDY: NORDIC FLOW-BASED MARKET COUPLING

Flow-based (FB) capacity calculation is a methodology for determining cross-border electricity transmission capacity based on the physical characteristics of the power grid. Unlike the traditional net transfer capacity (NTC) method, which sets predefined limits for exchanges between bidding zones, the FB approach dynamically assesses available capacity based on real-time grid constraints and power flows. The implementation of FB aims to optimize grid infrastructure use while ensuring system security. By analyzing numerous scenarios, the FB algorithm enables a more precise and data-driven assessment of grid capacity, complementing operational experience and leading to a more efficient utilization of the infrastructure compared to the NTC method. This is particularly critical as the Nordic region undergoes a transition towards a more volatile power system.

Also, FB has been a prerequisite for the introduction of the new Nordic Balancing Model (NBM). The NBM represents a major change in how the Nordic power system is operated with the introduction of automation and new markets. In this way system balancing is adapted to a changing energy landscape, with increasing shares of intermittent power production and more trading closer to real-time. The NBM is another core example of important Nordic TSO collaboration.

Following years of joint efforts in the FB-project, extensive testing, and stakeholder engagement, FB was introduced in the day-ahead market on October 29, 2024, marking a significant step in modernizing the Nordic electricity market. This milestone underscores how regional cooperation enables smarter and more efficient grid management, which is essential for accommodating increasing volumes of renewable energy.

The benefits of FB are already evident. One key example is the increased east-west electricity flow from Finland to SE3, see Figure 21. Under the previous NTC system, the maximum recorded flow in 2024 was 1000 MW for just 11 hours. After FB go-live, flows reached 1200 MW in 154 hours, demonstrating a significant improvement in cross-border capacity utilization. Other key transmission corridors have also seen notable improvements. In the Central and South Cuts maximum flows rose by 9% and 7%, respectively. In South Norway, the maximum flow rose by 23%, reflecting the improved transmission capability in the region.

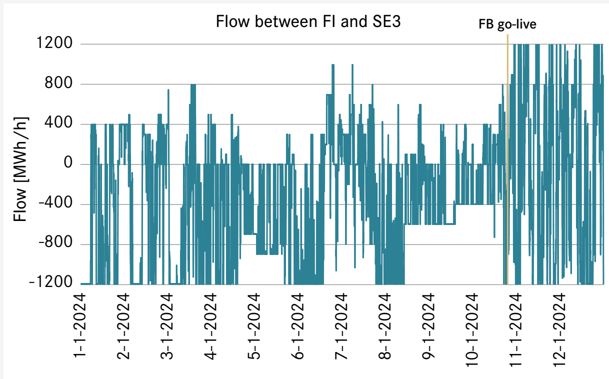
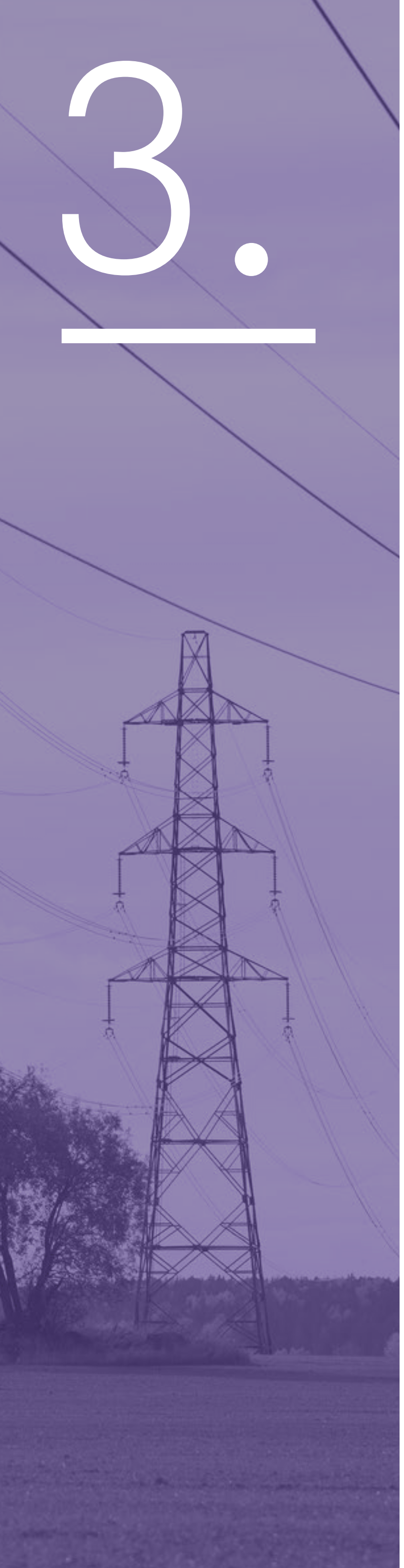


Figure 21: Power flow between Finland and Sweden (SE03) before and after FB go-live. Positive values represent westbound flow[17].

17. Reference: https://www.skmenergy.com/syspower/overview

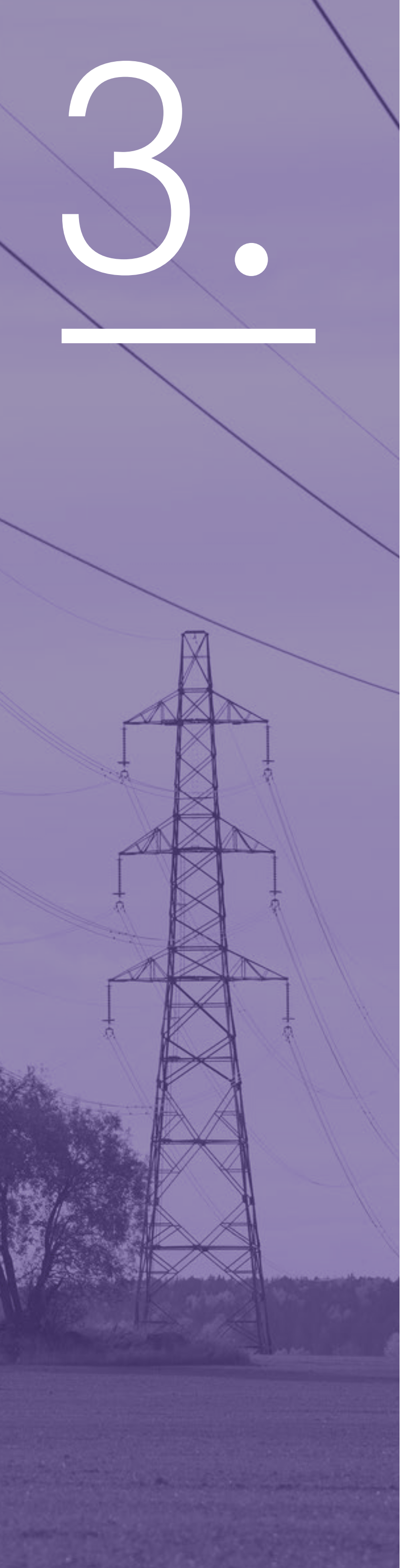


The introduction of flow-based also resulted in major changes in the power flow patterns on Nordic transmission corridors, as illustrated in Figure 22. The North Cut experienced a shift with reduced southbound flows and increased northbound flows. In the Central and South Cuts, average flows from north to south increased by 22%. The most significant impact was observed in South Norway, where average flows into the region surged by 173%.

The go-live of FB in the day-ahead market has been a significant milestone for the project, but does not mark the ending, as it will be an iterative process to continuously improve and adjust the method. The results demonstrate how the FB methodology effectively optimizes the use of existing infrastructure, ensuring electricity flows where it delivers the most value. This ongoing development is key to balancing efficiency with security, reinforcing a resilient and well-functioning electricity grid for the future.

In addition to improving the input data and the day-ahead model itself, there are also significant improvements planned in the years to come with the introduction of FB to the intraday market and the balancing market. Today, the consequent markets after the day-ahead-market still operate with the NTC-method, and there is currently a process to translate the FB domain back to NTC-domains for these markets. The capacities provided by this translation are much lower than what was given before FB go-live, which also impacts on the balancing markets, as the remaining capacities after intraday are given to the Nordic Balancing Model (NBM) algorithm. Thus, improving the translation method and eventually replacing the capacities with FB capacities will provide large value for the market.

Figure 22: Power flow (yearly average) changes on Nordic key transmission corridors from FB implementation. Simplified representation of bidding zones.



We strive to unlock flexibility in different ways

The European regulation aims to ensure that grid tariffs promote efficient use of the grid and integration of renewable energy sources. Tariffs can for instance be designed to give an economic incentive for consumers and producers to locate in places with sufficient transmission grid capacity. Grid tariffs can also be designed to provide a time-differentiated price signal indicating when there is scarcity of grid capacity, thus incentivizing grid users to reduce loads during these periods. In that way, more grid users can potentially connect to the existing grid.

If regulated properly, energy sharing and behind the meter solutions can also be means to enable more consumption and production. These solutions are enabled to various degrees across the Nordic countries. In Denmark it is, for instance, possible to apply for a direct connection between power production and demand facilities, which gives the possibility for simultaneous production and consumption behind the meter with no or reduced connection capacity to the collective transmission grid.

Agreements on non-firm connection - also called limited grid access or flexible connections – are another mean used by the Nordic TSOs to utilize existing grid better. These agreements enable users that have some flexibility to connect to the grid with lower reliability than the default regime. In return, grid users can have a faster grid connection and, in some instances, a reduced grid fee. The rationale behind and variations of non-firm connections are further described in the case study in Text Box 2.

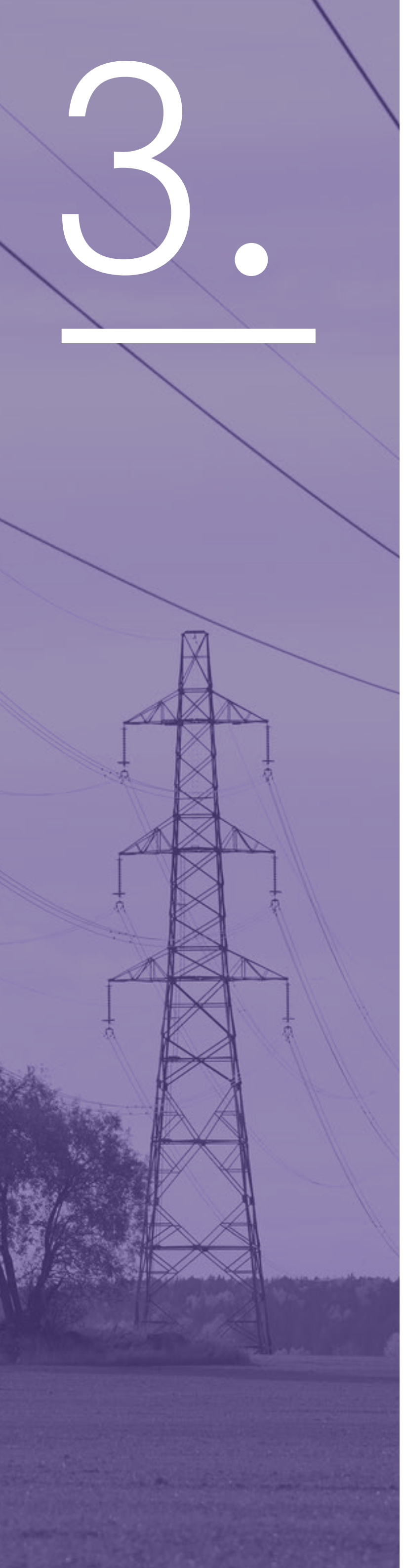
We also see that the demand for electricity from the heating and transport sectors increasingly reacts to electricity prices in the day-ahead market, thereby acting more flexibly. Going forward, this flexibility should be integrated into the organized markets. We also expect new forms of potentially flexible electricity consumption to develop. Particularly the production of hydrogen from electrolysis can have a significant potential, but how fast it will develop and how flexible it will be, is highly uncertain.

Text Box 2: Non-firm grid connections as a case study of efficient use of grid

CASE STUDY: NON-FIRM GRID CONNECTIONS

With a sharp increase in the requests for grid connection in the Nordic countries, more flexible network access is a key solution that can enable more customers to connect and with a higher pace than what would be possible with traditional agreements on firm connection.

Agreements on firm connection, the default regime in the Nordics and in Europe, enable the customer to use all of the contracted capacity of their connection at any time. The Nordic power system is already highly utilised, and in many areas, it is not possible to connect new loads or generation with a firm connection without having to reinforce the grid. The grid constraints that hinder firm connection are strongly dependent on local conditions and vary from case to case. While grid constraints may occur for a small percentage of the time some places, there may be significant restrictions to the available capacity other places. If new or existing grid users can accept reduced access to the grid, it is possible to connect more new customers with non-firm connections and thereby use the existing grid closer to the grid capacity limit while still ensuring safe system operation.



Unlike firm connections, non-firm connections do not give the same certainty of full-time access and enable grid companies to reduce consumption or generation in periods when grid capacity is limited.

In general, there is two types of non-firm connections:

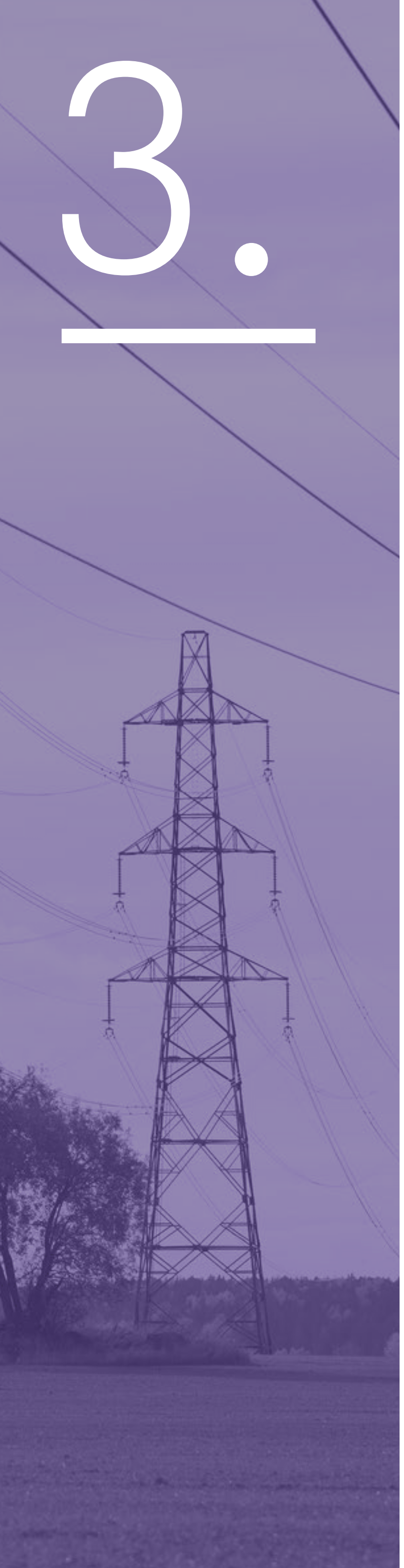
- As a *temporary solution*, non-firm connections can facilitate earlier connection for new generation or loads, where the alternative is to wait for grid expansions that allow for firm connection.
- As a *permanent solution* non-firm connections may increase the utilisation of existing grid and can reduce or postpone the need for grid investments. This is suitable for grid users who have no problem in being flexible e.g. due to being able to store energy.

The extent of non-firm connections varies across the Nordic countries. In Finland, legislative changes to enable these agreements are being implemented. In Sweden, a pilot study was conducted last year that examined what was needed to introduce non-firm grid connections. In Norway, it has been possible for grid companies and customers to voluntarily and bilaterally agree on non-firm connections since 2021. Norwegian grid companies have experienced a high interest in these agreements. Some agreements are in operation and many are in pipeline. Similar trends are found in Denmark, where there has been great interest in the concept the last few years, and projects are expected to come in operation under the conditions of non-firm connections within this year.

The importance of non-firm connections was also recognized in the European electricity market reform (2024). The legislation establishes that network users requesting grid connection in areas where electricity grids have limited or no network capacity should be able to benefit from establishing a non-firm, flexible connection agreement. The regulatory authorities in the Member States shall develop a framework to this end.

Agreements on non-firm connection may be designed in a variety of ways, depending on the grid constraints in question. A connection for a limited period, until future restrictions are expected to occur, may be relevant for construction projects and industries with back-up. Recurring periodic disconnection can be a solution for charging stations for public transport that typically charge overnight and as a source of energy for the cruise ship industry that primarily is active during the summer.

Although non-firm connection is an important tool for efficient use of the grid, it can be challenging for system operation. Clear agreements and technical solutions to ensure safe system operation must be in place. Furthermore, it may be a suitable option when the grid constraints are specific and not recur too often, but less suitable when the grid constraints are complex.



We work proactively to ensure timely grid development

More efficient use of the grid is a key priority but will not be sufficient to meet the need for increased grid capacity. Currently, the number of projects waiting for grid connection is high, and significant reinforcement and expansion of the transmission grid is also needed.

All the Nordic TSOs are planning historically high investments to enable new customers to connect and accommodate power flows across the integrated systems. At the same time, there is uncertainty about the pace, magnitude and location of new consumption and production, and a broad range of scenarios must be taken into account in our grid planning. Furthermore, lead times for new transmission capacity are very long, particularly due to complex and lengthy permitting processes. A strained supply chain makes procurement more challenging and adds pressure to the situation. In sum, this makes it challenging to develop the grid in the right pace and scale.

To ensure timely development, the TSOs must be forward-looking and investigate the consequences of high growth scenarios that go beyond confirmed generation and demand needs, despite the uncertainty. We also need a supportive regulatory framework that enables us to commit to long-term grid investments and anticipatory investment, although there is a risk that consumption and production may evolve differently than our initial expectations.

A faster permitting process is a key priority for us

We must fully explore the potential to reduce lead times in grid development, and a faster permitting process is of high importance.

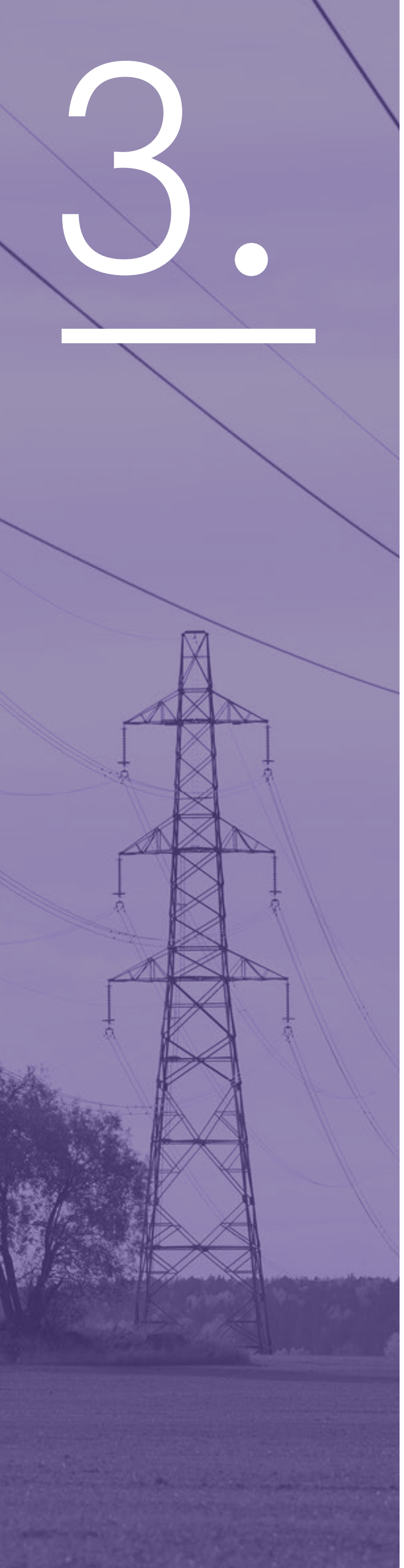
In all the Nordic countries, slow and complex permitting processes remain a large barrier for timely grid development. The topic is also high on the European agenda, which is driving momentum for discussions on potential improvements, see Text Box 3. Possibilities to reduce lead times without compromising the quality or the involvement of stakeholders are therefore being investigated thoroughly.

The time it takes from planning to the commissioning of new transmission grid lines vary across the Nordic countries but can take up to 14 years. To gain insight and learn from each other, the Nordic TSOs have investigated differences across our countries.

A faster permitting process is an explicit goal in all the Nordic countries, and several steps have been taken in the right direction. In Norway, the permitting authority has adopted a fast track for the permitting process of simple and well-prepared applications that have minimal impacts on public and private interests, and where affected stakeholders do not have objections to the measure. In Sweden, pilot studies have been carried out for a coordinated process for permits when developing new transmission grid lines. In Finland, permitting authorities have allocated additional resources to address the backlog of projects awaiting permits. In Denmark, three specific areas have been designated as dedicated grid zones as part of the implementation of the Renewables Energy Directive (RED)III aiming to speed up the permitting process.

Although steps are taken in the right direction, the Nordic TSOs will continue to work together and with the energy authorities to identify good solutions.

In addition, the Nordic TSOs also strive to improve our internal work streams and processes and ensure that our applications



are solid and well-prepared. With transparency on grid development, we aim to involve stakeholders at an early stage and establish a shared understanding of the need for grid expansion and possible solutions.

At TSO level we are also scrutinizing our internal processes to identify possible reductions in the planning and construction phase. We work together to identify sourcing optimums for critical infrastructure components and upsides from increasing standardization on components and technical requirements.

Text Box 3: About the European momentum for building energy infrastructure

THE EUROPEAN MOMENTUM FOR BUILDING ENERGY INFRASTRUCTURE IS HIGH

Although legislation passed after Russia's invasion of Ukraine has underscored the importance of energy infrastructure, achieving a significantly faster permitting process remains a challenge. The 2023 revision of the Renewable Energy Directive introduced "renewables acceleration areas", marking a step in the right direction for renewable electricity production. However, to truly ensure the necessary pace, more comprehensive measures are still needed. This is emphasized in the Draghi report[18] that highlights the central role of energy infrastructure in driving Europe's energy transition and competitiveness. Based on the Draghi report, on February 26th 2025, the Commission presented its Clean Industrial Deal - a plan on how to turn decarbonization into a driver of growth for European industries. To support the Clean Industrial Deal the EC also presented its Affordable Energy Action Plan that lays out actions to secure affordable clean energy. Action 2 'Bring down the cost of electricity supply' emphasizes the need to accelerate permitting procedures for energy infrastructure at both EU, national, regional and local level. Expectations are that the EC will present concrete proposals on how to deliver on this action as parts of its European Grids Package before the end of 2025.

18. https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

4. Nordic grid projects

There are several ongoing grid development projects in the Nordics, both cross-border and national. Figure 23 presents the most significant Nordic grid projects that are under consideration, in planning phase, under construction or have been commissioned since NGDP 2023 and are now in operation. The cross-border and national projects will be presented in more detail in the following subchapters.

Text Box 4: About the need for massive investments in the Nordic region

THE NORDIC TSOS EXPECT MASSIVE GRID INVESTMENTS

The continuing electrification requires a significant build-out of the Nordic transmission grid. Throughout the Nordic region, large investments are expected.

- Energinet expects to invest around 40 billion DKK (~5.4 billion EUR) in the Danish transmission grid[19] from 2025 to 2028, of which approximately 20% is for reinvestments and the remaining 80% for reinforcements.
- Fingrid expects to build 6100 km of new transmission lines in 2024–2033 and to invest approximately 400 million euros per year.
- Statnett expects to invest more than 150 billion NOK (~12.5 billion EUR) in the Norwegian transmission grid and digitalization in the next decade, where many of the grid measures are reinvestments where transmission capacity is increased by upgrading the existing 300 kV network to 420 kV.
- Svenska kraftnät expects to build approximately 1500 km of new transmission lines and renew 2500 km of current transmission lines in 2024–2033. Between 2026 and 2028 the investments in the transmission grid are expected to reach 57 billion SEK (5,2 billion EUR)[20] and for the years 2029-2033 investments are expected to reach between 17 and 22 billion SEK per year (~1.6 and 2 billion EUR)[21].

19. Energinets Investerings- og Finansieringsplan 2025-2028

20. Ökade investeringar i stamnätet och en plan för flaskhalsinkomsterna

21. Nätutvecklingsplan 2024–2033

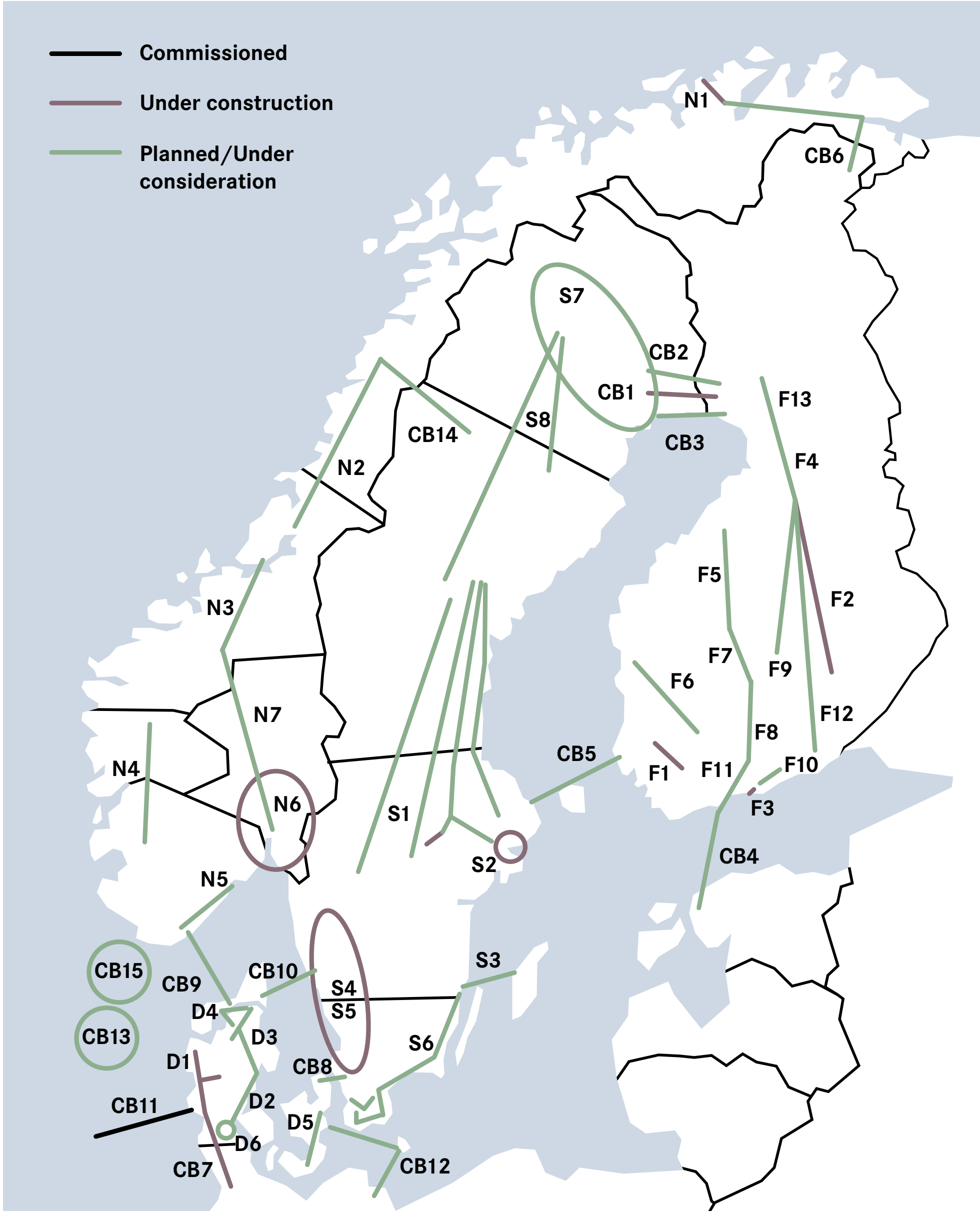


Figure 23: A graphical representation of the major Nordic grid development projects presented in this chapter. Black markings indicate projects commissioned since the last NGDP report was published, purple markings indicate projects currently under construction and green markings indicate projects that are currently in planning stage or under consideration. Several of the mapped projects consist of more projects and the status of these can differ. Simplified representation of bidding zones.

Cross-border projects

Below, the Nordic TSOs give a status on cross-border projects in the corridors between the Nordic countries including expected next steps. Following that, a complete overview of the current cross-border projects between and to/from the Nordic countries is given.

Norway-Sweden

Today, there are four Norwegian-Swedish corridors: (1) the power line between Ofoten in Norway and Ritsem in Sweden (400 kV) connecting the northern bidding areas NO4 and SE1; (2) Rössåga-Ajaure (220 kV) connecting NO4 and SE2; (3) Nea-Järpströmmen (400 kV) connecting NO3 in Mid-Norway with SE2; and (4) two 400 kV power lines connecting the southern bidding areas NO1 and SE3, the Hasle-corridor. All power lines between Norway and Sweden are AC overhead power lines.

Development in the corridor since NGDP 2023

Svenska Kraftnät has investigated and implemented several grid reinforcements to handle internal east-west congestions, enabling better utilization of the existing transmission capacity between NO1 and SE3.

Our analyses still indicate that grid reinforcements on the Norwegian - Swedish corridors will have benefits. More short-term price variation in Sweden results in large price differences hour by hour on the connections between Norway and Sweden. However, the results vary with different scenarios. A higher consumption growth in the north of Sweden leads to more frequent congestions into SE1 because of the large need of import.

Particularly in the northern corridors, our recent market and grid studies show many hours with bottlenecks and increasing price differences. Increasing transmission capacity by upgrading the current line from Nedre Røssåga (NO4) to Grundfors (SE2) from 220 kV to 420 kV, has significant benefits in all the scenarios we have investigated, and Statnett and Svenska Kraftnät will continue to conduct bilateral studies on a possible upgrade of the line.

Next steps

Both TSOs recognize the benefits of having a closer collaboration on joint market and grid studies. Collaboration related to maintaining the capacities on the existing cross-border corridors between the countries is still important in a short-term perspective. Svenska Kraftnät and Statnett will continue to conduct studies on a possible upgrade of Nedre Røssåga - Grundfors and evaluate relevant cross-border interconnections between Sweden and Norway as well as internal grid reinforcements when necessary.

Denmark-Sweden

Today Denmark and Sweden are connected between several bidding zones. Konti-Skan 1 and 2 that are connecting Jutland in Denmark (DK1) to Sweden (SE3) with a net transfer capacity of 715 MW, and Øresund cables that are connecting Zealand in Denmark (DK2) to the southern part of Sweden (SE4) with a total net transfer capacity of 1300 MW import to Denmark and 1700 MW export from Denmark. Konti-Skan 1 and 2 has an estimated end of life in the mid-2030s, and the northern Øresund cable has an estimated end of life around 2030. The corridor between Denmark and Sweden is important as it links areas with hydropower with areas with high dependencies on wind and solar power.

Development in the corridor since NGDP 2023

The preparations for the reinvestment of Øresund cables (System 2) is progressing as planned, and the construction

work is expected to begin in start 2026 with project commissioning end 2026.

As part of the ongoing joint studies between Energinet and Svenska kraftnät, a feasibility study examining the renewal of Konti-Skan 1 and 2 was started in fall 2022. Based on the result of joint studies, Svenska kraftnät and Energinet are planning to renew the HVDC-cables Konti-Skan 1 and 2 with a new modern cable, Konti-Skan Connect REI with a capacity of 1000 MW. The existing connections are expected to reach their technical lifespan in the mid-2030s and to maintain a reliable electricity transmission between Denmark and Sweden (SE3 and DK1), a renewal is necessary.

Next steps

Svenska kraftnät and Energinet are in the process of designing the Konti-Skan project, preparing for route studies and determining expected costs of the connection. Prior to entering into contracts for converters and cables, a joint Final Investment Decision, expected in 2026/2027, will be agreed upon by the two TSOs.

Finland-Sweden

Finland and Sweden are currently connected in the European electricity market via AC overhead lines in the north and subsea DC cables Fenno-Skan 1 and 2 across the Gulf of Bothnia. Overhead lines connect bidding zones SE1 and FI, while Fenno-Skan cables connect bidding zones SE3 and FI.

Development in the corridor since NGDP 2023

Svenska Kraftnät and Fingrid are finalizing the construction works of the Aurora Line, located between bidding zones SE1 and FI. When Aurora Line enters operation in late 2025 it will be the 3rd AC interconnector between the countries.

Next steps

Fingrid and Svenska Kraftnät continue investigating new possibilities through bilateral studies and as part of European network planning processes. Aurora Line 2 between SE1 and Finland (first part of 2030's) and a new HVDC connection, Fenno-Skan 3, between SE3 and Finland (latter part of 2030's) will be investigated in the European TYNDP process to replace Fenno-Skan 1 that is nearing the end of its lifetime. Currently, Fingrid and Svenska Kraftnät are conducting bilateral studies on Aurora Line 2 and Fenno-Skan 3. The estimated commissioning of Aurora Line 2 will take place in the first half of 2030, and the possibility of building a 400 kV double circuit (2 x 400 kV on same towers) is also being investigated. In the case of Fenno-Skan 3, the estimated commissioning will be by the end of 2030s. The companies have applied for Project of Common Interest (PCI) status for both Aurora Line 2 and Fenno-Skan 3.

Norway-Denmark

Today, the net transfer capacity between Norway and Denmark is 1700 MW distributed on four interconnectors, Skagerrak 1, 2, 3 and 4. Skagerrak 1 and 2, with a total capacity of 500 MW, are beginning to reach the end of their expected technical lifetime.

Development in the corridor since NGDP 2023

Statnett and Energinet are currently investigating minor measures to prolong the operation of Skagerrak 1 and 2 and thus postpone the decommissioning of the interconnectors.

At the same time Statnett and Energinet are investigating a possible reinvestment of the interconnectors. Our studies show that a reinvestment would be of mutual benefit, and Energinet and Statnett are working on the technical details of a possible reinvestment, the necessary joint agreements and material needed for approval of the project internally and

externally. Statnett sent a notification to the Norwegian Energy and Water Resources Directorate (NVE) in September 2024 with a proposed program for the Environmental Impact Assessment. Statnett's proposal has been on a public consultation, and NVE has established a final study program.

Next steps

More detailed analysis of environmental impact, technical details and costs and benefits must be carried out prior to a possible license application. A possible reinvestment will require approval from the energy authorities in both countries.

Norway-Finland

The flow on the current 220 kV-line between Finland (Ivalo) and Norway (Varangerbotn) is challenging to control and limit in today's power system due to long, radial connections with limited capacity in both countries. Enhancing this connection would enable better control over the flow by matching physical and market flows when the cross-section becomes a market border. Additionally, improved connection would provide market advantages as well as increase security of supply and enable more consumption and possible new wind power in Finnmark.

Development in the corridor since NGDP 2023

Statnett and Fingrid have signed a memorandum of understanding, and both parties recognize the need to improve the connection to enable better control over power flows. Based on the preliminary studies carried out in 2022, Fingrid and Statnett have done further investigations of different technical solutions to better control power flows, in order to enhance the connection and increase the cross-border capacity. Possible solutions include a BtB (HVDC) or a phase-shifting transformer. These solutions have different technical characteristics and benefits, and investment costs differ. More detailed analysis will be carried out to identify the most appropriate technical solution.

Next steps

Statnett and Fingrid will continue to work closely on identifying the appropriate solution through more detailed analysis.

Cross-border projects

	Project	Status	Description
CB1	**Aurora Line**	Planned/Under construction Expected in operation 2025	Third 400 kV AC connection between Finland and Sweden. Has PCI-status[22] and will be series compensated. The line will increase trading capacity and the possibility to exchange system services. In addition, Aurora Line will support power adequacy in Finland.
CB2	**Aurora Line 2**	Planning/Under consideration Expected in operation 2034	Fourth AC connection between Finland and Sweden.
CB3	**Svartbyn - Keminmaa reinforcement**	Planning	Other solutions are under consideration.
CB4	**EstLink 3**	Planning/Under consideration Expected in operation in the latter part of 2030's.	Third DC link between Finland and Estonia. The project also includes 400 kV transmission network upgrade and extension to the landing point to connect Estlink 3 converter station to the rest of the transmissions system.
CB5	**Fenno-Skan 3**	Planning/Under consideration	Renewal of Fenno-Skan 1.
CB6	**Increased capacity Norway-Finland**	Planning/Under consideration	Statnett and Fingrid have signed a memorandum of understanding and are looking into different technical solutions to better control the flow on the existing power line and increase the cross-border capacity.
CB7	**The West Coast project**	Under construction. Expected to be in operation in 2026.	The West Coast project is a project of a new 400 kV AC double circuit line (OHL[23], partly UGC[24]) from Endrup to the Danish/German border (close to Klixbüll in Germany) where it is planned to connect with the double 400 kV line, which has been built along the German western coastline in Schleswig-Holstein. This project increases the possibility of exporting and importing electricity on the border from 2,500 MW to 3,500 MW.
CB8	**Reinvestment of Øresund (System 2)**	Planned/Under construction from 2026.	Energinet and Svenska kraftnät owns and operates four Øresund connections that connect Zealand and southern Sweden in the form of two 400 kV connections and two 132 kV connections. The reinvestment of the 400 kV connection (System 2) which is owned by Energinet, has been approved in 2023. Construction is planned to start early 2026 and commissioning in late 2026.
CB9	**Reinvestment Skagerrak 12**	Planning / Under Consideration	Statnett and Energinet are currently investigating a possible reinvestment of Skagerrak 1 and 2. Our preliminary studies show that a reinvestment would be of mutual benefit. Statnett and Energinet are working on specifying the reinvestment project in detail. Statnett's proposal for a study program has been on public consultation, and the Norwegian Water and Resourced and Energy Directorate (NVE) has established a final study program. A possible reinvestment will require approval from the energy authorities in both countries.

22. A Project of Common Interest (PCI) must have a significant impact on energy marets and market integration in at least two EU countries. It should boost competition on energy markets and help the EU's energy security by diversifying sources, as well as contribute to the EU's climate and energy goals by integrating renewables (EC description: https://energy.ec.europa.eu/infrastructure/projects-common-interest-and-projects-mutual-interest/pci-and-pmi-selection-process_en).

23. Overhead line (OHL)

24. Underground cable (UGC)

	Project	Status	Description
CB10	**Reinvestment Konti-Skan**	Planning/Under consideration	Svenska kraftnät and Energinet are in the process of designing the project, preparing for route studies and determining expected costs of the connection. Prior to entering into contracts for converters and cables, a joint Final Investment Decision expected in 2026/2027 will be agreed upon by the two TSOs.
CB11	**Viking Link**	In operation from ultimo 2023	The Viking Link project went in operation from ultimo 2023 connecting DK and UK with a 1400 MW HVDC subsea cable. The project is closely connected to an expansion of the internal western Danish grid and additional interconnection to Germany in the so-called West Coast Project, which has been delayed. Thus, Viking Link has been operated on limited capacity since commissioning and full capacity will be available when the grid in western Denmark is sufficiently reinforced.
CB12	**Bornholm Energy Island**	Under consideration	Bornholm Energy Island is a joint hybrid offshore project with 50Hertz, one of the German TSOs. The aim of the project is to connect 3 GW offshore wind in the Baltic Sea to both the Danish and German markets. In the end of January 2025, it was announced that the necessary legal framework is not in place to launch the next phase of Bornholm Energy Island. Therefore, the potential continuation of the project awaits a further dialogue between the Danish government and the newly established German government on Bornholm Energy Island, the necessary legal framework and how Denmark can contribute to the German demand for green electricity.
CB13	**North Sea Energy Island**	Under consideration	In 2020 it was agreed by a broad coalition in the Danish Parliament ("Folketinget") to start planning an energy island in the North Sea with the potential for expansion up to 10 GW offshore wind. The deployment of offshore wind will be done for the benefit of assisting in the transition to renewable energy in Europe. The hub in the North Sea is planned as a series of transformers and platforms for 2 GW offshore wind with 2 GW connections to Denmark and other countries. The various proposed projects have no firm commissioning dates yet.
CB14	**Upgrade power line NO - SE**	Under consideration	Svenska kraftnät and Statnett are investigating the possibility of upgrading the existing 220 kV line between Nedre Røssåga (NO4) to Grundfors (SE2) to 420 kV.
CB15	**Hybrid connections**	Under consideration	On request by the Norwegian Ministry of Energy, Statnett has investigated possible grid solutions for the next development phase of offshore wind in the Southern part of the North Sea, including hybrid connections. The analyses show that it is likely possible to connect 2.8 GW of offshore wind connections to southern Norway with the planned onshore grid reinforcements.

National projects

In the following, the Nordic TSOs share an overview of the most significant national infrastructure projects in addition to connecting a large number of new grid users. The overview consists mainly of 400 kV projects, but also other projects are included.

Sweden

The Swedish transmission grid needs to meet the future development of renewable energy generation and the increased demand for electricity all throughout Sweden and at the same time do the necessary reinvestments. According to the latest grid development plan, published in 2024 and covering projects up to 2033, this will include 1500 km new transmission lines and around 30 substations along with reinvestments for approximately 2500 km transmission lines and 100 substations. To meet such a task, the grid development strategy is to coordinate the different needs to invest in the transmission grid to increase the capacity and replace old lines at the same time.

	Project	Status	Description
S1	**Nord-Syd**	In planning. Seeking permission. Under construction. Expected in operation between 2027-2040	A set of 50 different projects that both reinvest and increase the capacity between SE2 and SE3. Replacing old 220 kV with new 400 kV lines. The capacity between bidding zones will increase from 7300 MW to over 10 000 MW. This includes 2000 km OHL and 35 substations.
S2	**Stockholms Ström & Stockholm Väst**	In planning. Under construction	A series of projects to reinforce and reinvest the larger Stockholm area. 220 kV lines are replaced with 400 kV lines. Projects will come online in continuity up to 2031
S3	**Gotlandsförbindelsen**	Seeking permission	220 kV double circuit AC lines to be built between mainland Sweden (Misterhult) and Gotland (Stenkumla). Expected in operation 2031-2032.
S4	**Göteborg Norr**	Under consideration. In planning. Under construction.	Reinvestment and reinforcement. 400 kV AC lines that will increase capacity to the west of Sweden in SE3. In operation 2026-2038.
S5	**Västkustpaketet**	In planning. Under construction	Includes connection to new sources of production and remedy limits on power flows going east-west. In operation 2025-2031.
S6	**Skåne**	In planning	Three large investment packages to increase connection of intermittend production in northern Skåne. These packages will also increase redundancy around Malmö, increase capacity in southern Sweden. This will also help with interconnectivity to the continent. In operation 2038
S7	**SE1**	Seeking permission	Internal reinforcements in SE1 to connect industrial consumers
S8	**SE1-SE2**	Under consideration	Reinvestment and reinforcement of 250 km double circuit 400 kV OHL. Expected in operation 2035.

Finland

Transmission lines are reinforced in Finland to facilitate integration of new renewable energy generation, power transmission from surplus areas to deficit areas, and allow further integration with Sweden. New transmission lines between Finland and Sweden are built to northern Finland where renewable capacity is also increasing besides the western part of the country, while consumption is mostly increasing in southern Finland, leading to the necessity for an increase in north-south and west-south transmission capacities.

	Project	Status	Description
F1	**Huittinen - Forssa**	Planned/Under construction Expected in operation 2025	New 400 kV OHL between Huittinen and Forssa. Improves reliability and transmission capacity of the grid in the western part of Finland.
F2	**Reinforcement of Lake Line**	Planned/Under construction Expected in operation 2026	New 400 kV AC single circuit OHL of 300 km between Nuojuankangas and Huutokoski substations. The line will be series compensated.
F3	**Helsinki 400 kV cable**	Planned/Under construction Expected in operation 2026	New 400 kV AC cable connection. Improves reliability and transmission capacity of the grid in the southern part of Finland.
F4	**Herva - Nuojuankangas**	Planned/Under consideration Expected in operation 2027	New 400 kV AC OHL between Herva and Nuojuankangas (over the P0 cut in northern Finland). The line will be series compensated.
F5	**Jylkkä - Alajärvi**	Planning/Under consideration Seeking permission Expected in operation 2028	New 400 kV double circuit AC OHL of 150 km from the western coast to Central Finland. The line will be partly series compensated.
F6	**Kristiinankaupunki - Nokia**	Planning/Under consideration Seeking permission Expected in operation 2029	New 400 kV connection between Kristiinankaupunki and Nokia. Wind power is increasing on the western coast and power consumption increases in capital area.
F7	**Alajärvi - Toivila**	Planning/Under consideration Seeking permission Expected in operation 2028	New 400 kV single circuit AC OHL of 150 km between Alajärvi and Toivila substations. Power line is extension to Jylkkä - Alajärvi power line. The line will be partly series compensated.
F8	**Toivila - Hikiä**	Planning/Under consideration Seeking permission Expected in operation 2028	400 kV double circuit AC OHL of 130 km from Toivila substation to Hikiä substation.
F9	**Reinforcement of Forest**	Planning/Under consideration Seeking permission Expected in operation 2030	New 400 kV AC single circuit OHL of 300 km next to the existing Forest Line. The line will be series compensated.
F10	**Hikiä - Anttila - Länsisalmi**	Planning/Under consideration Seeking permission Expected in operation 2030	New 400 kV AC OHL connection. Improves reliability and transmission capacity of the grid in the southern part of Finland.
F11	**Hikiä - Kynnar - Inkoo**	Planning/Under consideration Seeking permission Expected in operation 2031	New 400 kV AC single circuit OHL of 100 km to reinforce transmission capacity for EstLink 3 and possible new industrial green investments.
F12	**Ridge Line**	Planning/Under consideration Seeking permission Expected in operation 2032	New 400 kV AC double circuit OHL of 450 km from Kainuu region to southern Finland.
F13	**Petäjäskoski - Herva**	Planned/Under consideration Expected in operation 2032	New 400 kV AC OHL between Petäjäskoski and Herva (over the P0 cut in northern Finland).

Norway

Statnett is planning significant investments to increase security of supply, the capacity to contract new consumption and generation to the grid, and the transmission capacity between regions. Several projects are reinvestments where capacity is increased by upgrading the existing 300 kV grid. Many of these reinvestments are necessary regardless of the future growth in consumption.

	Project	Status	Description
N1	**Finnmark**	Skillemoen-Skaidi built and operated temporarily at 132 kV. Permission received for Skaidi-Hammerfest, which is currently under construction. Statnett has applied for permission to build Skaidi-Lebesby and Lebesby-Seidafjellet (Varangerbotn).	Extending the 420 kV grid from Skillemoen to Skaidi, and from Skaidi futher to Hammerfest and to Varangerbotn in the eastern part of Finnmark. The new lines will improve reliability and increase capacity for new consumption and power production.
N2	**Namos/Tunnsjødal - Nedre Røssåga**	Planned / under consideration	Statnett is planning to replace the current 300 kV line between Verdal and Tunnsjødal with a new 420 kV line between Namsos (NO4) to Nedre Røssåga (NO3). This will increase the north south capacity.
N3	**Through Mid-Norway**	Åfjord-Snilldal and Surna-Viklandet (under planning)	New 420 kV lines in Mid Norway (Fosen) in order to facilitate new wind production and increased consumption.
N4	**Western Norway**	Several sub-projects in different phases.	Voltage upgrades (420 kV) from Sogndal to Sauda in western Norway. Increases the north-south capacity in general and enables higher utilisation of other parts of the grid in southern Norway. Facilitates increased consumption in the Bergen and Haugesund areas.
N5	**South (Eastern corridor)**	Planned / under consideration	New 420 kV line from the Kristiansand/Arendal-area in the south to the Grenland-area further north-east, increasing the transmission capacity between southern and eastern Norway.
N6	**Greater Oslo**	Several sub-projects in different phases (planning and under construction).	Renewal and voltage upgrade of transmission lines/cables and stations in the Greater Oslo area. Improves reliability and increases capacity to both consumption in the area and transmission through the area.
N7	**Mid-Norway - Oslo**	Planned/under consideration	Several sub-projects. Renewal and voltage upgrade (420 kV) from Sunndalsøra in Mid-Norway to the Oslo-area. Increases the transmission capacity north-south as well as the capacity for new consumption and production locally.

Denmark

The Danish transmission grid is expected to undergo significant expansion in the coming years across the entire country. The expansion is driven by the expectation that a large number of wind turbines and solar panels will be installed in the coming decades, along with a significant increase in electricity consumption. However, it is not the growth in renewable energy production and consumption itself, but rather the geographical and temporal imbalance between production and consumption that is the primary driver for the expansion. From Energinets long-term development plan 2024 (LUP24), Energinet has estimated the need of 2700 km of power grid in 2030. Additionally, a further 3000-4000 km of power grid is expected by 2050.

	Project	Status	Description
D1	**Idomlund – Endrup and Midt- og Vestjylland Kabel NUP**	Under construction Expected in operation in 2026 (400 kV line) and in 2028 (150 kV grid reinforcement)	New 400 kV AC double circuit line (OHL, partly UGC) from Idomlund to Endrup and 150 kV grid reinforcement in Western and Mid Jutland. The project is important to collect the expected expansion of renewable production in Western Jutland and transport it to demand nationally or outside Danish borders.
D2	**Nyt Elnet Aarhus-Aabenraa**	Planning/Under consideration Expected in operation in 2033	Upgrade of existing 400 kV AC OHL to double circuit OHL between Kassø and Trige. The project has been appointed as a grid acceleration area and will be important to connect areas of renewable excess production with areas of high demand.
D3	**Nyt Elnet Midtjylland-Vendsyssel**	Planning/Under consideration Expected in operation 2036	Upgrade of existing 400 kV AC single circuit OHL to double circuit OHL between Tjele and Ferslev and between Trige and Ferslev. New 400 kV AC OHL between Ferslev and Vendsysselværket. The project will be important to transport production from renewables in Northern Jutland to demand and interconnectors further south.
D4	**Ny Netstruktur i Nordjylland**	Planning/Under consideration Expected in operation 2031	More projects reinforcing the 150 kV grid in the northwest Jutland. The project is appointed as a grid acceleration area and will be important to transport production from renewables in Northern Jutland to demand and interconnectors further south.
D5	**Grønt net Sjælland-Lolland/Falster**	Planning/Under consideration Expected in operation start/mid-2030s	More projects upgrading and expanding the 400 kV grid between Copenhagen area and Lolland-Falster. The project is appointed as a grid acceleration area and will be important to transport renewable production from Lolland-Falster and Southern Zealand to demand in the Copenhagen area and in Sweden.
D6	**Substations Kassø, Tjele, Revsing**	Planned/Under consideration Expected in operation start/mid-2030s	Reinvestments and upgrading of larger substations on various locations in the Danish transmission grid to meet requirements from renewable production connections.