Grid development plan 2024–2033

Svenska kraftnät

Svenska kraftnät

Svenska kraftnät is a system responsible authority, tasked with commercially managing, operating and developing a cost effective, reliable and environmentally sound power transmission system. This includes 400 kV and 220 kV power lines with substations and interconnectors. Svenska kraftnät is responsible for developing the transmission grid and the electricity market so as to meet society's need for a secure, sustainable and economic electricity supply. This means that Svenska kraftnät also plays a key role in climate policy.

Abbreviations

Concept	Meaning
ACCEL	Accelerated Power Grid Capacity in Västra Götaland
AGON	Accelerated Green Transition in Norrbotten
DLR	Dynamic Line Rating
ENTSO-E	European Network of Transmission System Operators
FÖN	Fossilfritt Övre Norrland
KMA	Short-term market analysis
LMA	Long-term market analysis
LOLE	Loss of Load Expectation (number of hours with a power shortfall per year)
PRA	Probabilistic Risk Assessment
SOGL	System Operation Guideline (EU Regulation on electricity transmission system operation)
TSO	Transmission System Operator

Foreword

Svenska kraftnät has released three versions of its system development plan to provide a comprehensive overview of the future development of the power system. The system development plan outlines the necessary changes that need to be effectively managed in order to maintain a strong and dependable power system, while also facilitating the transition towards cleaner and more sustainable energy sources. To address the need for a more proactive and transparent approach to planning the transmission grid, we have made the decision that going forward we will release a dedicated grid development plan. This plan will specifically concentrate on the expansion and enhancement of the transmission grid.

The grid development plan for the years 2024–2033 outlines the civil engineering investment projects currently underway, as well as an assessment of current needs. In addition to this, we are currently moving forward with a more regional approach to presenting these plans in the future. We are actively working on creating long-term target systems and capacity escalation specific to each region. By doing so, we establish better opportunities for a dialogue regarding the optimal placement of high-consumption centres within the power system, to ensure swift access to available capacity. We also consider the most efficient utilisation of the system and where and when new installations can best be integrated into the power system. Our goal is to create regional clarity and predictability at the same time as we concentrate our efforts to ensure a reliable power system with good capacity in line with needs. While the grid development plan provides a detailed account of the next ten years' progress, our ultimate goal is to establish target grids with a perspective spanning twenty-five years.

The 2024–2033 grid development plan contains a first taste of what the future reports with a regional focus will look like. Although the plan is more comprehensive for certain regions than others at present, our objective is to progressively create regional plans for all areas. Our objective is to consistently communicate updates and progress in the regional plans, ensuring that the grid development plan in its entirety is summarised every two years.

We respond to feedback and are happy to receive suggestions for further development. Dialogue and cooperation are key elements in achieving the energy transition. Everyone can contribute to this.

Lotta Medelius-Bredhe
Director General, Svenska kraftnät

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1. Introduction

The energy transition has created major challenges for the power system and it requires major investment. Several major industries in Sweden are planning to transition towards electric power. At the same time, electricity consumption is increasing in the metropolitan regions and new industries want to establish themselves in Sweden. Furthermore, the extensive connection of new electricity generation is expected in the coming years. To enable these changes and meet existing needs, Svenska kraftnät must invest in new infrastructure. This new investment coincides with the need for the renewal of large parts of the transmission grid. At Svenska kraftnät, we are working to implement this investment as effectively as possible. So our grid development strategy is based on coordinating measures so that, in as far as it is possible, new power lines are built in a way that both increases capacity and replaces old power lines.

Consequently, over the next decade, Svenska kraftnät's plans include a combination of new investment and reinvestment. As a result of this we will construct approximately 1,500 km of new transmission power line and approximately 30 new substations. In addition, we are renewing over 2,500 km of power line and about half of our nearly 200 substations. The complete list of all measures affecting the ten-year period 2024–2033 can be found in the section “Ten-year plan for grid investment” at the end of the grid development plan.

The grid development plan provides comprehensive information about Svenska kraftnät's significant grid development initiatives and ongoing investigations over the next decade. The grid development plan must be capable of providing insight into ongoing projects and investment, and the benefits they bring. It is worth noting that the material presented in this publication is founded on current requirements that have been thoroughly researched. As new needs arise, plans may be modified or extended.

Apart from detailing ongoing investigations and projects, the grid development plan encompasses data on various aspects, such as the factors that drive grid development, the correlation between society and the expansion of the power grid, and a comprehensive analysis of the potential supplements that can be employed to tackle the power system's challenges. The grid development plan highlights the importance of a large degree of flexibility in the power system to cope with increased electricity consumption in combination with a major expansion of weather-dependent electricity generation.

In recent years, the grid development plan has been part of the Svenska kraftnät publication “System development plan”, however, the grid development plan is now published as a separate report. Previous publications of the system development plan can be found on the website: www.svk.se. More information about our operations and ongoing projects not detailed in this report, is also available there.

2. Drivers of grid development

Svenska kraftnät develops the national transmission grid to meet many different needs as effectively as possible. For many years, we have chosen to group and present our activities based on their main drivers, although many of the initiatives we take meet several different needs. The drivers we use are: reinvestment, connection, system reinforcement and market integration.

Reinvestment: Large parts of the transmission grid are close to the end of their service life, meaning that the need for reinvestment remains high. In order to continue to have a safe and reliable transmission grid and to be able to transmit the amount of electricity that society requires, we need to renew a large number of power lines and substations before they reach the end of their service life.

Connection: These drivers include initiatives linked to external applications for new or additional connections, as well as consumption and generation. That electricity demand in Sweden is expected to increase sharply in the coming years is supported by the steady increase in the number of applications for connection to Svenska kraftnät. For example, in some parts of the country if all the applications for connection were to be realised, the total power demand would greatly exceed present consumption.

System reinforcement: System reinforcement mainly includes investment in the transmission grid undertaken to increase capacity within an area. As generation and consumption rates continue to rise rapidly, often in new areas, the demand for system reinforcement initiatives will inevitably grow.

Market integration: Market integration aims to increase or maintain trading capacity within Sweden and between Sweden and our neighbours. These initiatives enable increased transmission from areas with a surplus to deficit areas. This contributes to increased security of supply and more efficient utilisation of generation resources.

Figure 1 shows the number of substations commissioned during the period 2020–2033 by year, summarised by driver. Over the next decade, we plan to renew almost 50 of our current substations and to construct approximately 30 new substations.

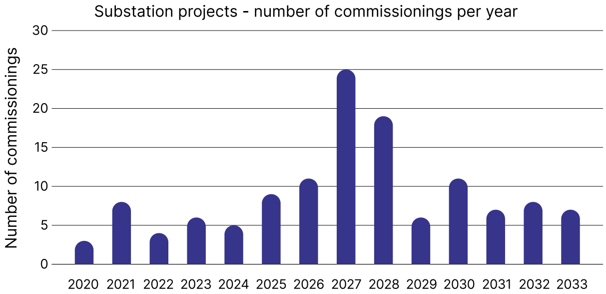


Figure 1. Number of substations commissioned each year during the period 2020–2033.

Figure 2 illustrates the annual construction rate in terms of line kilometres from 2020 to 2033, aggregated by year and summarised for all drivers.

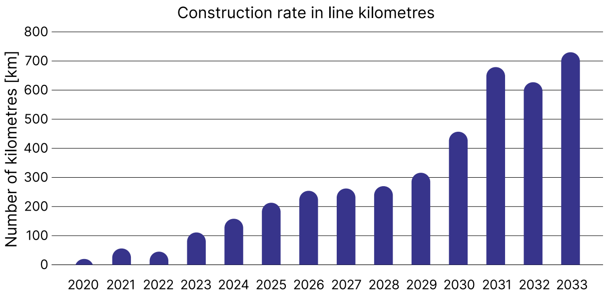


Figure 2. Construction rate in line kilometres per year during the period 2020–2033.

2.1 Reinvestment

There is a clear interplay between the need for maintenance, with the ongoing inspection of equipment, the replacement of individual components, and the rate of reinvestment. The goal is to prevent failures because this risks the availability of the power system, has a negative impact on the environment and, at worst, impacts safety. At the same time, it is crucial to avoid replacing properly functioning infrastructure components prematurely, as this will result in increased costs. The active and systematic maintenance of existing infrastructure creates favourable conditions for the maximum possible service life. This, in turn, enables a lower reinvestment rate and an increase in the intervals between costly replacement.

Svenska kraftnät's asset management policy is based on a number of basic principles. Decisions regarding infrastructure are made based on a comprehensive analysis of its entire life cycle, taking into account the characteristics of the specific infrastructure and the risks associated with it. To effectively manage our infrastructure, all remedial measures implemented during its service life need to be coordinated as part of our management strategy. This includes both maintenance and reinvestment activities, how infrastructure is operated and how we utilise and manage all information regarding it. At the same time, we must consistently develop and improve our infrastructure management operations.

Continuous operational development must take place in order to manage the high rate of reinvestment ahead of us in the 2020s. The aim of operational development is to find a balance between the technical status of infrastructure, the potential for outages, safety, environmental impact and cost. To comply with its newly adopted management policy, Svenska kraftnät has made the decision to pursue certification in accordance with the international asset management standard, ISO 55001, in 2024

Future needs govern the renewal of our existing infrastructure

Over the next decade, Svenska kraftnät anticipates that reinvestment will make up the largest portion of its construction investment. Most of our infrastructure was constructed in the 1950s, 60s, and 70s, and the oldest are now approaching the end of their service life. These power lines and substations were designed primarily for the requirements and demands of the day. However, today, there are completely new requirements for future transmission grid design.

Svenska kraftnät acknowledges that reinvestment should be an integral component of grid development. Consequently, when replacing outdated equipment, we must ensure that it is tailored to meet society's future electricity demand. For instance, we may opt to construct more robust power lines with a higher voltage capacity, and substations that can accommodate additional generation and consumption. One such example is the NordSyd investment package. In that package, several of our existing power lines will be renewed by constructing completely new lines, both along new routes and with greater capacity. In conjunction with the connection of new generation or consumption, we will also renew many of our substations. Most of our substation projects involve other parties, such as grid owners and generators that must be taken into account. We coordinate the need for reinvestment with them.

Extended service life of our infrastructure

Renewal while focussing on meeting future needs poses several new challenges. One such is that renewal through new investment often takes longer to investigate and implement than the direct renovation of existing infrastructure. Sometimes this means that we must keep our existing infrastructure in operation for several years longer than originally planned. This cannot be achieved without remedial measures.

To continue operating the infrastructure with sufficiently high degrees of operational and personal safety until it can be replaced, all or parts of it need to be repaired to extend its technical service life. Svenska kraftnät is therefore increasingly implementing what we call life extension measures. These require both internal and external resources and the cost is not negligible. The remedial measures are primarily linked to the major new NordSyd and Storstockholm investment packages. However, the alternative, not implementing new and reinvestment in a coordinated manner, would lead to significantly higher total costs.

Historically high renewal rate

Most of the transmission grid's substations are from the 1970s and 80s and need to be renewed within a 20-year period. Because these substations were built over a short period of time, many are the same age, with a similar service life and thus need to be renewed within the same time frame. This has resulted in the need for a historically high rate of renewal over the next ten-year period. A status and renewal needs assessment was recently carried out. It focussed on new investment, capacity-enhancing initiatives and the connection of wind power, reinforcing our view that the rate of reinvestment needs to be greater than it has been over the past decade.

Over the next ten-year period, approximately half of our almost 200 substations will therefore be renewed. Almost 50 of them will be completely renewed. Additionally, a large number of individual components, such as control systems, perimeter protection and switchgear, will be renewed in another 50 or so substations. As is the case for substations, many power lines also need to be renewed. Around half of the existing power line grid for 220 kV and 400 kV was built during the 1950s and 1960s, its need for renewal has been limited until now. Over the next decade, about 50 power lines, covering over 2,500 km, will be completely renewed. This reinvestment will make up an increasingly large proportion of planned power line activities.

Safeguarding the operation of power lines during their service life

For many decades, we have carried out power line maintenance based on inspections of each individual line. For some years, we have carried out power line audits more systematically. This means that after approximately half of their service life, we audit the power line to verify its status and take remedial action to ensure that all components will last for its remaining life span. At the same time, we are able to follow up and adjust our assessment regarding the technical service life of the infrastructure components. Over the next ten years, nearly 6,000 km of power line, in more than 100 different installations and several packages, will be audited. This covers over a third of our power line grid. Given that scope and against the background of fewer power lines being built in recent decades, we see a reduced need for power line audits after this ten-year period.

Automated condition monitoring of infrastructure and more efficient decision support

The ongoing energy transition places higher demands on increased digitalisation and information exchange. Digitalisation affects all parts of our operational activities and can, for example, enable improved understanding and management of our reinvestment needs, including through the improved collection and management of digital information. vA concrete example of Svenska kraftnät's ongoing work on increased digitalisation is automated condition monitoring of our infrastructure. The automated condition monitoring of infrastructure aims to make better use of valuable information from infrastructure, enabling faster and more accurate decision making in order to maintain a high level of availability for the infrastructure. By coordinating our need for information from infrastructure, we can manage information more efficiently and increase the quality of data, as well as reducing manual data management.

Over time, this will lead to fewer substation inspections being required because more information will be available centrally, making it easier to make the correct decisions. The concept is based on the automated collection and centralised storage and processing of information about our infrastructure, including tools for analysing and visualising information.

2.2 Connection

In order to be able to connect new, or increase existing, generation or consumption, varying degrees of modification of the transmission grid will need to be carried out in many cases. This principle is applicable to various scenarios, including the integration of new wind power generation and the electrification of significant electricity consumers such as industrial facilities, server halls, or conventional electricity-intensive industries. The adaptations that must be made vary from case to case, but can consist of anything from new power lines and substations to the expansion of an existing substation.

Connection application drivers can be the connection of large generation facilities or the demand for increased consumption as a result of industrial establishment or the restructuring of the existing grid. Connections are mainly made from the grids of other grid owners to the transmission grid and not by connecting consumption or generation directly to the transmission grid. These grid owners take out subscriptions for the transmission and/or withdrawal of electricity based on the generation and consumption that they wish to connect.

More and larger connection applications

The number of applications for new connections to the transmission grid is steadily increasing, both numerically and, above all, in terms of overall power. The increasing number of applications for connection are both for generation, for example new onshore and offshore wind farms, and new consumption or increased power demand at existing connection points.

In recent years, several major industries in Sweden have started to transition from using fossil raw materials in their processes to direct or indirect electrification. This is a contributing factor to many of the significant consumption applications that have been received recently. The connection of large individual electricity consumers has become particularly relevant, and as the power demands have increased, it has become difficult to connect them without undertaking grid reinforcement. Often the capacity of the power lines in the local area is not adequate, this means that it can take a long time to satisfy the desired grid capacity.

The applications for withdrawal from the transmission grid mainly pertain to industries located in northern Sweden, specifically in bidding zone SE1. The total number of consumption applications in this region is approximately 12,500 MW, of which around 11,700 MW has been requested for between 2024 and 2033. However, interest in the electrification of industrial operations applies throughout Sweden, and it is anticipated that requests will continue be made to connect very large volumes of consumption. We currently have consumption applications for a total of approximately 20,500 MW throughout the country, of which approximately 17,800 MW is for connection in the period 2024–2033. This can be compared to the maximum power consumption during the peak load hour in Sweden in 2022, which was just under 24,000 MW.

Table 1 presents the total volume of applications for consumption to Svenska kraftnät, by bidding zone.

Bidding zone	Applications for consumption, total volume [MW]
SE1	12,500
SE2	3,700
SE 3	4,300
SE4	0
Total	**20,500**

Connection of wind power generation

The interest in constructing wind power remains substantial, and Svenska kraftnät presently has applications for wind power injection totalling approximately 134,000 MW. Offshore wind power constitutes approximately 117,000 MW and onshore wind power approximately 17,000 MW of the total volume of wind power generation applied for. The volume of offshore wind power injection applied for does not take into account physically overlapping project proposals, which is a unique circumstance for offshore electricity generation. This means that several different applications can cover the same geographical area. In practice, this means that not all of these applications can be fulfilled.

In the past, it has often been possible to connect wind power through relatively small interventions in the grid, for example by building new substations, adapting existing substations, and in some cases by installing automatic generation shedding to manage overloading in the transmission grid. However, in recent years capacity in the transmission grid has increasingly been utilised by installed generation and connections that have already been granted. This means that it is becoming increasingly difficult to connect more generation to the existing grid, which in turn means that further interventions, such as new

power lines, become necessary to manage new capacity requirements.

2.3 System reinforcement

System reinforcement mainly includes investment in the transmission grid undertaken to increase capacity within an area. This could, for example, be measures that involve the adaptation of the transmission grid to increase the ability to transfer more electricity generation from a large area, with several different connections, out into the grid. These may also be the measures that need to be taken to allow an increase in consumption in metropolitan regions.

As generation and consumption rates continue to rise rapidly, often in new areas, the demand for system reinforcement initiatives will inevitably grow. As a result of the installation and continuing installation of large amounts of new wind power, total generation capacity in individual areas has increased, leading to an increasing need to adapt the transmission grid. We therefore need to ensure that individual parts of the power grid do not limit the ability to reliably transmit this increased electricity generation.

In addition to the anticipated increase in electricity generation and consumption, flows through the power grid have also changed in recent years, presenting a challenge for the operation and planning of the transmission grid. The typical North-South flow through Sweden in the past has changed and an East-West flow through the country has become more common in certain operating situations.
In the long term, if offshore wind is built in southern Sweden, a more South-North flow may also become applicable. An increasing and more variable flow makes greater demands on the transmission grid and means that it may be more difficult to predict future flows and likely scenarios, which is important as a basis for long-term grid planning. Svenska kraftnät is working to improve its ability to better use the results of long-term market analysis (LMA) in grid planning. This will contribute to Svenska kraftnät's LMA results being transferred to the grid planning programs in a more automated manner, and will make it easier to take all scenarios and operating cases that may arise into consideration. Read more about Svenska kraftnät's LMA in Section 3.2.

In recent years, several large generation facilities have been closed in southern Sweden, which has had negative consequences for system stability and transmission capacity in the area. Measures to compensate for this deterioration have already been introduced, but investigations have been started to analyse the long-term need for voltage regulation measures for example. To ensure the system's overall ability to maintain voltage and transmission capacity dynamically, we are also implementing a number of stability improvement measures. In several cases, these consist of reactive power compensation infrastructure based on power electronics, for example STATCOM. Read more about the voltage regulation measures that Svenska kraftnät is taking in section 3.5.5.

2.4 Market integration

Market integration aims to increase or maintain trading capacity, both within Sweden and between Sweden and our neighbours. These activities allow and increased transfer from surplus to deficit areas. This contributes to increased security of supply and a more efficient utilisation of generation resources, resulting in lower price differentials.

We analyse the need for transmission capacity using electricity market models based on long-term scenarios for the Northern European power system, as described in section 3.2. Investigations carried out within the European and Nordic collaboration on planning programme are often an important basis for decisions about grid investment resulting in increased market integration. In order to maintain trading capacity with our neighbours, replacement of several of the existing direct current connections needs to be investigated.

Svenska kraftnät has received many applications for the connection of electricity intensive industry in northern Sweden. Several of these installations plan to be commissioned in the period 2025–2030 and we expect North-South flows to decrease by 2027[1]. There will also be periods of northbound flows from bidding zones SE2 to SE1 from 2026. This is due to greatly increased electricity consumption in northern Sweden, and despite the significant expansion of wind power, generation will not increase at the same rate as demand. Changes in flows, generation and consumption are also taking place in central Sweden. Imports from Finland to SE3 vary within the analysis period (2023–2027) but are higher at the end of the period than at its start. This can also be explained by increased electricity consumption in Sweden, as well as the increase in trading capacity and Finland's electricity generation capacity. The flow in the AC connections from SE1 to Finland will switch from export to import in 2027. There are also factors that can contribute to long-term changes to flows in the Swedish transmission grid, including:

> Greater demand response and energy storage can contribute to improving power adequacy.

> The establishment of large amounts of offshore wind power in southern Sweden.

> More electricity intensive industry in northern Sweden. In the longer term, electricity consumption may increase sharply in northern Sweden, mainly due to the electrification of the steel and mining industries. The large northbound flows expected with such a development would entail a need for increased trading capacity, primarily in our domestic interfaces between bidding zones SE1 and SE2 and between bidding zones SE3 and SE4, but also with Finland and Norway. Interconnectors with neighbouring countries, enabling the export of electricity during periods of surplus and imports during deficit periods, are becoming increasingly important with the growth of intermittent electricity generation. Increased trading capacity also contributes to reducing the price difference between bidding zones.

1. Svenska kraftnät 2022: Short-term market analysis 2022 – Power system analysis 2023-2027

3. Changes in the operating environment and future prospects

The future development of the transmission grid will be influenced by a variety of factors, for example the development of technology, future demands for power, energy and transmission capacity, other societal interests and political decisions. This chapter describes some of these factors, including how Svenska kraftnät will work to streamline the expansion of the transmission grid through increased cooperation with other actors and an abbreviated permit process.

This chapter also contains an in-depth look at various technical solutions that can potentially complement the construction of new power lines and substations to meet the challenges of the power system. This includes dynamic line rating, energy storage and controllable power flow. Moreover, it provides an account of solar power and hydrogen, which should be able to play a significant role in the future energy system.

3.1 The interplay between society and infrastructure

The long-term design of the power system, in other words how different generation facilities, power grids, demand response and storage are together to meet society's needs, will be influenced by political decisions, the development of technology and market conditions. Svenska kraftnät has two main responsibilities in that respect:

> To secure a robust and reliable power system with sufficient transmission capacity over the transmission grid.

> To develop the transmission grid by finding a balance between social benefit and the impact on our environment.

Our initiatives will not only affect the power system itself, but also the society we live in: we build power lines and substations that affect both the environment and neighbouring residents; renewable electricity generation contributes to reduced climate impact; increased transmission capacity has an impact on electricity prices and enables the growth of society and a transition from fossil fuels to electricity. All of these factors have a role to play in deciding which initiatives we want to implement in developing the transmission grid. Our goal must always be to implement the most socioeconomically effective measures.

3.1.1 Initiatives for the future supply of electricity

The transmission grid in Sweden consists predominantly of substations and overhead power lines for alternating current operating at voltages of 400 kV and 220 kV. At the same time as we are meeting new needs in the transmission grid (increased capacity for new connections or increased consumption for example), we need to maintain operational security and electricity quality. Reinforcing the grid by upgrading existing power lines or by constructing new overhead power lines, has therefore been a reliable and cost-effective way to meet existing demand.

Sometimes, when an end-to-end solution improves, or circumstances require it, we use other technologies or opt for other measures. A very common question regarding power line design is whether they should be built using overhead lines or underground cables. Overhead power line technology is robust, reliable and cost-effective, while the advantage of underground cable is reduced intrusion. However, overhead power line technology is still the alternative of choice, mainly thanks to its advantages related to technology and operational security, but also due to its longer service life and lower costs.

Together with a number of regional grid owners, Svenska kraftnät submitted a letter to the Government in 2021 with a number of proposals to ensure the expansion of the power grid[2]. The consensus of the signatories had as its starting point that overhead power lines constituted the best possible technology for high voltages and, by making clear the requirements of the Swedish Electricity Act [*Ellagen*] for example, the government could clarify the criteria for the expansion of transmission and regional grids. This was also highlighted as a proposal in the 2022 Climate Law Inquiry [*Klimaträttsutredningen*][3].

In many cases, Svenska kraftnät also uses other measures when developing the transmission grid. One such example is high-temperature conductors that can increase transmission capacity by replacing conductors on existing pylons. Other types of measure are those that, in some cases, can remedy capacity shortfall in urban areas through regionally increased generation or reduced consumption. Using remedial measures such as these during critical hours, the demand for electricity from existing or new customers can be met. However, in order to be able to use this type of resource, long-term guaranteed availability may be required, and in some cases direct control in the operating phase when measures need to be taken.

2. Svenska kraftnät 2021: Press release 29/01/2021 - Proposed initiatives to streamline the expansion of the electricity grid submitted to government

3. Climate law, SOU 2022:2021

Svenska kraftnät believes that all of these measures will be needed to solve the challenges we face. However, the continued expansion of grid infrastructure is important to allow a robust grid that can handle requirements from a total defence perspective, as well as the various requirements imposed by the future development of electricity generation and consumption.

3.1.2 Socioeconomic cost-benefit assessment and impacts

Part of our mission is to develop a cost-effective transmission grid, which we will achieve by building socioeconomically viable infrastructure. By that we mean that the benefits to society, through for example a better functioning electricity market and increased opportunities for connection, outweigh the costs and the negative impact arising. Socioeconomic analyses contribute to this by showing the impacts of our planned initiatives, so that we can make decisions based on relevant data, and that the grounds of the assessment are transparent. Thus, the socioeconomic analysis is an important part of the decision-making process for our planned investment. The analysis includes a description of impact on the electricity market, security of supply, transmission losses, climate change and the local environment, as well as intrusion and investment costs. Thus, decisions can be made based on a socioeconomic cost-benefit assessment.

Depending on the type and magnitude of grid initiative, the scope of the socioeconomic cost-benefit assessment can vary. However, regardless of the level of detail of the analysis, the investigation and preparation phases must always confirm that the planned initiatives are appropriate and cost-effective in relation to the impact they will have.

Not all impacts can be priced, that is described in monetary terms, but are to be included as qualitatively assessed impacts in the cost-benefit assessment. This makes Svenska kraftnät's socioeconomic analyses similar to the decision-making basis of many other public actors, such as the Swedish Transport Administration for example. The socioeconomic analysis makes the impact of the planned initiatives clear. When there are several alternative initiatives that meet the criteria, Svenska kraftnät can choose the option that is most socioeconomically viable. Work is underway internally to develop the methods forming the basis of our socioeconomic analyses. As part of this this work, we also follow the development of analysis methods used in the European Network of Transmission System Operators, ENTSO-E, adapting our methodology to the normative requirements and directives of the Energy Markets Inspectorate and the government.

3.1.3 Grid development and conflicts of interest

The requirements placed on delivery performance, robustness and cost effectiveness mean that, together with technical limitations, the power lines Svenska kraftnät builds in the future will generally continue to be in the form of overhead power lines. With this as a starting point, we can expect that the conflicts of interest we see today, between the need for electricity infrastructure and society's acceptance of it, may persist or increase.

However, there are several trends in the strategic analysis that could form the basis for changes in attitude. The most obvious being that the commitment to counteract climate change is increasing. This commitment ranges from individual action, such as choosing electric vehicles, to a slowly increasing acceptance of the electrical infrastructure needed for industry to transition from fossil fuels to electricity. Correspondingly, an increased focus on the security and vulnerability of society can also lead to a greater understanding of the power grid as infrastructure that needs to be developed.

Complexity in the development of the transmission grid

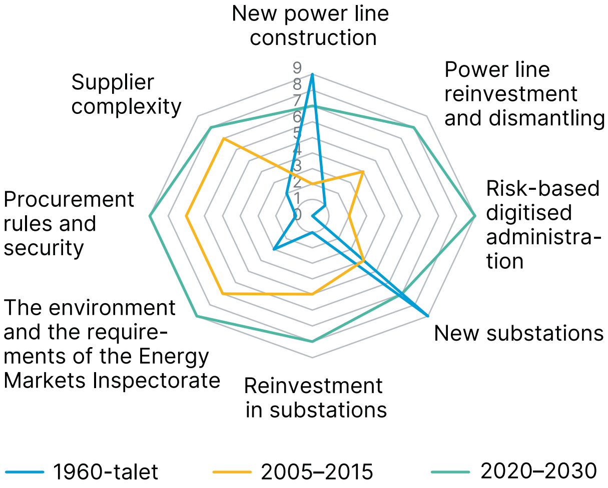


Figure 3. As it has grown the development of the transmission grid has become more complex.

To illustrate the challenges we face, we can look back to the 1960s when the transmission grid was also facing extensive expansion. Figure 3 illustrates, without being based on direct key indicators, how the challenge has progressed over time with the growth of the transmission grid. In the early years, technical development meant that a lot of new things were being built, but with no significant demands on environmental considerations, safety or procurement rules. Greater formal requirements were introduced in the early 2000s, but the demand for construction was limited. We are now in a situation with a great need for investment, both to renew the older components in the power grid and to increase transmission capacity, at the same time as legislation in several areas is more stringent. This means, among other things, that the conflict between electricity infrastructure and other societal interests is clearer, the safety requirements are greater and the procurement regulations are more complex.

Svenska kraftnät has an important role in reducing potential conflicts of interest and we will work on improving specific consultations related to individual measures. We will also contribute to the more general dissemination of the understanding that increased electricity consumption is a key to a climate neutral future, but that this entails a need for more electricity infrastructure.

3.1.4 Regional cooperation and new approaches

To speed up the energy transition and contribute to more rapidly meeting the increasing demand for electricity, new forms of regional cooperation have emerged in recent years. Municipalities, business, regional grid owners and Svenska kraftnät are included in these collaborative forums. New approaches can be developed to speed up the energy transition by these actors meeting and defining a common vision. For example, this collaboration can create solutions that make the permit process for new electricity generation and grid expansion more efficient, thus reducing lead times.

Two of the clearest examples of this form of regional collaboration on energy transition, in which Svenska kraftnät participates, are in Norrbotten and Västra Götaland. In Norrbotten the forum AGON (Accelerated Green Transition in Norrbotten), started in 2021, operates under the auspices of the county administrative board. In Västra Götaland the forum ACCEL (Accelerated Electricity Capacity in Västra Götaland), started in 2022, is led by Region Västra Götaland together with the County administrative board and Svenska kraftnät. Skåne, Västmanland and Uppsala are other examples of locations in Sweden where there are regional collaborative forums.

By expanding cooperation in various forums across the country with the regional grid owners (the actors that usually have direct contact with major electricity users and electricity generators), we can undertake more proactive work on long-term grid development plans. This is important so that we can better meet some of the major challenges we face today; managing the increasing number of applications that are also tending to become increasingly large in terms of power for both injection and withdrawal. In turn this implies conducting comprehensive local system inquiries that adopt a holistic approach and that consider all needs. Having proactive dialogue with the regional grid owners increases the opportunity to identify needs linked to the development of local electricity consumption and generation. These needs can be included in long-term grid planning in this way. Regional cooperation increases a level of acceptance for the rapid expansion of the transmission grid for the electrification of Sweden.

For some time now, Svenska kraftnät and the regional grid owners have collaborated on forecasting. The purpose of this is to forecast additional consumption and generation in the power grid up to about 2040. Joint forecasting by civil society actors is key to the success of electrification. This is because joint long-term forecasts can be used to streamline the time from identified need to solution. Well-substantiated forecasts create the conditions for the better delivery of power grids in the right place, at the right time and with the right capacity - regardless of whether this relates to local, regional or transmission grids. Joint forecasting by Svenska kraftnät and the regional grid owners also creates improved opportunities for the joint planning of regional grids and transmission grids using shared assumptions. Because the external environment is changing, continuous cooperation between Svenska kraftnät and the regional grid owners is required in order to further develop the methodology and assumptions for producing these forecasts.

Another example of regional collaboration and a new approach enabling the energy transition is Svenska kraftnät's investment programme Fossilfritt Övre Norrland (FÖN). The programme started in 2022 and brings together investment linked to the industrial energy transition in northern Sweden, including the expansion of both power lines and substations. The programme is also part of a pilot project to significantly reduce lead times in the expansion of the electricity grid. Close cooperation between authorities in the AGON collaboration forum is a necessary condition for the success of FÖN. See section 4.1.1 to read more about FÖN and the packages that are part of the investment programme.

3.1.5 Consultation and the permit process

The process, from the need for a power line being identified to it being taken into service, is long. Building and operating power grids requires a permit, a concession, which is issued by the Energy Markets Inspectorate [*Energimarknadsinspektionen*]. In addition to grid concessions, a number of other permits may also be required. This is an extensive and time-consuming process, that requires undertaking investigations and consulting, as well as drafting the documents required to make a concession application. On top of this there is the work of designing, procuring and building the power line. Previously, the process from starting work to a completed transmission grid line could take about 15 years.

In order to make it possible for Svenska kraftnät to expand the transmission grid at the pace expected by society, intensive work is being carried out to reduce lead times. For example, Svenska kraftnät has started an initiative to halve lead times for overhead power line projects by the end of 2024. To reach that goal, wide-ranging partnerships in civil society are needed to achieve internal and external efficiencies. The pace of construction needs to be improved, both in terms of increased volume (number of kilometres of line/number of substations per year) and the time it takes from identified need to commissioned infrastructure. A central part of the work to reduce lead times is reviewing internal procedures. One major change that has been implemented is that work on permits and land access begins earlier than it did before. This means that more activities can be carried out in parallel instead of sequentially, which will reduce lead times.

In addition to reviewing internal approaches, Svenska kraftnät has also taken part in the Government commission, along with the Energy Markets Inspectorate, the Mapping, Cadastral and Land Registration Authority [*Landmäteriet*] and County Administrative Boards [*Länsstyrelse*] to develop new coordinated procedures to try to reduce lead times for power grid expansion. New approaches can be developed though further and more extensive collaboration. This can contribute to finding solutions to streamline the permit process for new energy generation and expansion of the transmission grid.

Between 2000 and 2020, Svenska kraftnät built 600 km of transmission grid. Now, in a similar number of years, we are to build upwards of 7,000 km of transmission grid. To make this possible, legislative change is needed. The Climate Law Inquiry has presented several well-substantiated proposals aimed at facilitating power grid expansion. As the inquiry states, it is difficult to quantify the time savings of the various proposals. However, it is Svenska kraftnät's assessment that these proposals can reduce lead times by 6–12 months on average, meaning time savings of several years for some important projects.

3.2 Long-term transmission needs and power adequacy

Svenska kraftnät publishes a long-term market analysis (LMA) every two years. LMA2023 will be published at year-end 2023, and this chapter is therefore mainly based on LMA2021[4].

Investments in the transmission grid are often large, complex projects that take many years to complete from identified need to commissioned infrastructure. To meet the challenges of the future using the right measures at the right time, it is important to identify the needs that could arise in the long term at an early stage. To achieve this, Svenska kraftnät uses future scenarios simulated using models of the power system. By analysing the results of simulations such as prices, flows, electricity generation and electricity consumption, a clearer picture of the future need for power, energy and transmission capacity can be created. The scenarios also play an important role in comparing different alternatives for action and finding the best solutions for meeting needs from a socioeconomic perspective.

Analyses that stretch many years into the future are fraught with uncertainty, and there are many paths that development could take. In LMA2021, four scenarios were developed to identify different possible development paths for the power system along with the different needs that these could entail. Among other things these scenarios vary with regard to electricity consumption and the electricity generating mix. Electricity use is expected to increase from approximately 140 TWh/year today to almost 300 TWh/year by 2045. Since LMA2021 was published, we estimate that future consumption may be even higher. On the generation side, there is a scenario in which the life of nuclear power is extended, and even expanded somewhat, and another where it is completely phased out by 2045, with the substantial development of wind power, particularly offshore.

In this section, long-term transmission needs and power adequacy are highlighted, because they are the focus of the grid development plan. See LMA2021[4] for analyses linked to the scenarios.

Long-term transmission needs

These scenarios depict a power system greatly transformed in comparison to the present day. The major electrification of industry in northern Sweden means that the trading flow across Interface 1 will go north from bidding zone SE2 to SE1 on an annual net basis. In the scenario with a steep expansion of offshore wind power along Sweden's southern coast, the northbound trading flow across Interface 4 (between bidding zones SE3 and SE4) will also be great for much of the year.

It is assumed that transmission capacity will increase in Interface 2 (between bidding zones SE2 and SE3) as the investment in the NordSyd programme is put in place. Despite the investment, and despite a large part of generation in bidding zone SE2 being needed to meet the electricity demand in bidding zone SE1, in the 2045 scenarios there will be restrictions across Interface 2 southbound for more than ten per cent of the time. The exception is the scenario in which nuclear power remains in place in 2045, where the corresponding figure is approximately three per cent of the time. This is as a result of factors such as an improved annual electrical energy balance in bidding zone SE3 because, given that scenario, large amounts of nuclear power will still be in place. The analyses show that in the future there will also be a significant need for the transfer of electricity from the North to the South of Sweden.

The analyses generally indicate the increased benefit of transmission capacity between Sweden and its neighbours. This benefit applies with continental Europe, the Baltic states, Finland and Norway. The service life of several interconnectors will be reached before 2045, and it may be socioeconomically viable to upgrade the capacity of some of these through reinvestment.

To maintain operational security today, and on the basis of existing regulations, Svenska kraftnät regularly needs to reduce the transmission capacity at the domestic Swedish interfaces and to operate interconnectors below their nominal capacity as a result of changing flows in the grid. Long-term scenarios show that major variations in net balances and flows will occur more often. The challenges we see today will therefore also be a factor in the long-term.

4. Svenska kraftnät 2021: Long-term market analysis 2021 - Scenarios for the development of the electricity system to 2050

Power adequacy

The entire Northern European power system is simulated in the power adequacy analysis. The simulation is carried out for a large number of weather years (correlating historical temperature, inflow, wind and solar radiation). Outages in generation facilities and on transmission connections are randomly generated for each simulated hour according to assumed outage numbers that are to reflect real availability. When generation and imports are inadequate, there is a risk of a power shortfall, which is expressed as the key indicator Loss of Load Expectation (LOLE).

The results of the model show that flexibility is crucial for a functioning power system, where weather-dependent electricity generation accounts for a large portion of electricity generation, even given the continued development of various types of predictable electricity generation.

Analyses of power adequacy in Sweden show that increased electricity consumption without a significant volume of flexibility in the power system, could lead to a high risk of power shortfalls as soon as 2035, particularly when increased electricity consumption is combined with a major expansion of weather-dependent electricity generation. Without a significant volume of flexibility, the situation will become unsustainable by 2045, with a large number of power shortfall hours in most scenarios.

In the long-term scenarios studied, Sweden becomes completely dependent during peak hours on a large volume of flexibility in the power system and on imports from its neighbours. However, it is uncertain at what rate such large volumes of flexibility in electricity consumption could be implemented. Flexibility in the electricity system can also be created through energy storage or flexible electricity generation. Flexible electricity generation could involve wind power in combination with storage or new and predictable electricity generation.

3.3 Hydrogen as an energy carrier

The ongoing energy transition has highlighted the importance of hydrogen in the future energy system. Hydrogen has a variety of uses in industry and in the energy system, either directly or as a medium for the relatively cost-effective storage and transport of energy.

There are many ways to produce hydrogen from fossil sources, but fossil-free hydrogen is produced in electrolysers, using electricity produced from fossil-free sources. Its waste products are oxygen and heat that can be recovered and used for increased efficiency. Given the significant volumes of hydrogen use now planned, electrolysers are expected to account for a considerable proportion of the additional electricity consumption in the future.

The hydrogen produced can be used directly, but there are significant advantages for the energy system if there are also storage possibilities that allow flexibility in production. Since energy storage capacity is independent of the size of the electrolysers and often has relatively low investment and operating costs, hydrogen storage is well suited for long-term storage.

Hydrogen usage

Much of the Swedish primary sector could use hydrogen directly in their processes when they switch to fossil-free production. In the steel industry, hydrogen will be used instead of coal to remove oxygen from iron ore, and corresponding developments are also taking place in other large industrial sectors.

Stored hydrogen can also be used to produce electricity, either in fuel cells or in hydrogen turbines. However, it is likely that this will not be particularly extensive as a result of the large losses it currently entails. Nevertheless, applications such as backup power units generating electricity from hydrogen could play an important role. There may also be some use of hydrogen in the transport sector, and there are examples today of hydrogen filling stations, but this is likely to be limited in comparison with battery technology.

Hydrogen transport

There are essentially two options for supplying industry with the hydrogen it needs. Either the hydrogen is produced in electrolysers located directly adjacent to the industrial installation and supplied with electricity transmitted over the power grid, or the hydrogen is produced elsewhere, such as next to electricity generation facilities, and piped to industry. The initial steps in the large-scale transition to hydrogen in industry have been based on hydrogen being produced and stored close to industrial locations, resulting in a need to extensively expand the power grid. In step with an increase in the planned use of hydrogen, the potential for a supplementary system for transporting hydrogen in pipelines has become increasingly relevant.

A direct comparison between pipelines and power lines is influenced by a number of factors, including how hydrogen and electricity will be used by customers, and the design of local energy systems. The transfer of large amounts of energy by hydrogen pipeline should be technically and economically feasible, but will not be without its challenges. Many different studies into future hydrogen pipeline systems are being undertaken.

The potential of producing hydrogen in direct connection to electricity generation facilities, such as offshore wind power, has also become increasingly interesting for actors in the field. There could be several reasons for this, but limits on the ability to connect to the electricity system could be one factor, higher overall efficiency another. The production of hydrogen close to primary electricity generation or where there are already the conditions to satisfy significant electricity withdrawals, rather than at the consumer, would lead to the development of pipelines for transporting hydrogen to storage and end users, in many cases parallel to the existing power grid.

To achieve socioeconomically efficient development of an integrated energy transmission system for electricity and hydrogen, the two systems must be planned taking each other into consideration. In the autumn of 2023, the Government charged the Swedish Energy Agency [*Energimyndigheten*] with tasks including the analysis of how hydrogen infrastructure could be developed in concert with electricity infrastructure, as well as an assessment of the need for a state transmission system operator and a system responsible authority. Svenska kraftnät is taking part in this work and sees a clear need for proper joint planning of the electricity and hydrogen transmission systems in order to make the energy transition as socioeconomically efficient as possible.

3.4 Solar power and battery storage

Since the middle of 2022, Svenska kraftnät has received applications for large-scale solar parks, some of which have a capacity of more than 1,000 MW. Most of the applications to connect solar power also include battery storage. Table 2 presents the total volume of solar power injection applied for, broken down by bidding zone.

Table 2. Total volume of solar power generation connection applied for by bidding zone.

Bidding zone	Total injection applied for [MW]
SE1	600
SE2	400
SE 3	3,700
SE4	1,300
Total	**6,000**

We can see that solar parks combined with battery storage will play a major role in the transmission grid in the near future. It is therefore important to investigate how these resources can be connected to the power system appropriately, and to analyse their impact on the transmission grid.

Since large-scale solar parks and battery storage are relatively new phenomena in the Swedish power system, they will create both new challenges and opportunities. Solar power is an intermittent energy source, leading to uncertainty in electricity generation, which in turn creates challenges regarding the management of the combined storage of solar and wind power, when assessing applications for the connection of generation for example. The management of this storage has a direct impact on capacity allocation in the grid, especially if there are many applications for generation in a congested area.

The most suitable subscription should be investigated when connecting a solar park. A comparison should be made between traditional fixed subscriptions and other types of subscriptions, for example temporary, flexible and conditional. The technical and legal solar park requirements also need to be investigated. This also applies to battery storage installed in combination with a solar park.

Svenska kraftnät is actively investigating the impact of large-scale solar parks and battery storage on the power system. One example is an ongoing investigation into energy storage requirements in general and battery storage in particular. This investigation is being carried out as a result of the increased interest in combining the connection of large-scale solar parks with battery storage. At a Nordic level there is ongoing cooperation and a sharing of experience, including on the impact on the power system of solar power and how both solar and wind power can participate in the ancillary service markets.

3.5 Technical solutions to meet the challenges of the power system

The energy transition has created major challenges for the power system and it requires major investment. Reinvestment and building new power lines and substations are an important part of this work, but involve long lead times and Svenska kraftnät sees an increased need to find additional solutions to meeting the challenges facing the power system.

This chapter presents some examples of various initiatives and technical solutions linked to innovation, research and development that can complement the construction of new power lines and substations. To make the technical solutions described in this section possible, and to contribute to the effective implementation of the energy transition, many initiatives linked to increased digitalisation and greater requirements related to information exchange are needed.

3.5.1 Dynamic line rating

Dynamic Line Rating (DLR) is a technique to more accurately assess the thermal transmission capacity of an overhead power line based on current weather conditions, and in this way be able to increase the transmission capacity of a line for much of the year.

An overhead power line's ability to transmit power is limited by factors such as its thermal limit, which indicates how hot a power line can be allowed to become. When the overhead line conductors get hot, the metal expands and they sag closer to the ground. Regulations specify how low the conductors can sag, if the distance to the ground is too small this can lead to an increased risk of personal injury or property damage. Furthermore, an overhead power line ages faster if it is stretched a lot, and may then need to be replaced earlier than planned.

The current through an overhead power line gives rise to electrical losses that heat the conductor. In addition to heating due to current, the temperature of the overhead power line is affected by a number of environmental factors, mainly wind strength, wind direction, ambient temperature and solar radiation. Since the exact ambient conditions of an overhead power line are not usually known, limits are set with sufficient margins to ensure that the conductor does not become too hot and that its height off the ground does not become too low, even in adverse conditions. These margins mean that a power line usually, but not always, has a higher transmission capacity than that Svenska kraftnät uses as a limit. Svenska kraftnät estimates that these safety margins mean that potential transmission capacity may be systematically underestimated by about 20–30 per cent, and in certain conditions significantly more.

The hope is, that with increased use of DLR we can set more precise transmission limits, in order to utilise the transmission grid more optimally. Eventually, it may be possible to connect more customers more rapidly and cheaply and to allocate more capacity to the electricity market, while waiting for new power lines to be built. There are several different suppliers of DLR systems, some measure weather data directly, some use external weather data from other sources and others do not use weather data at all, but only measure conductor sag or temperature. Some systems can forecast transmission capacity up to several days in advance, and all systems have different IT solutions.

In 2023, Svenska Kraftnät is to carry out a preliminary study to examine the terms of reference for the eventual introduction of DLR on a large scale across the transmission grid.

3.5.2 Energy storage for increased capacity

The increasingly variable power flow in the Swedish transmission grid has given rise to unforeseen bottlenecks resulting in reduced transmission capacity. To increase allocated transmission capacity to the market, investment in new power lines is necessary, however, the lead time for the construction of new power lines is long.

Many grid owners, both in Sweden and internationally, face similar challenges. In several European countries, as well as in Swedish local and regional grids, projects are underway to deal with a lack of transmission capacity with the help of energy storage. Energy storage, such as battery storage, has an installation period time of 1–2 years, this does not include the time it takes to get permits to build energy storage, which is however, a significantly shorter lead time than for new transmission grid lines. Svenska kraftnät has also studied whether it is effective to increase the transmission capacity in the Swedish transmission grid quickly using energy storage. In 2022, a research and development project undertook to investigated this issue, focusing on managing east-west flows.

Svenska kraftnät has identified several options for locating energy storage to relieve the thermal overloads that limit transmission capacity between bidding zones. Corresponding energy storge facilities, based on two energy storage facilities working together (Virtual Power Lines, where one is discharged at the same rate as the other is charged) and individual non-corresponding energy storage facilities have been evaluated. Corresponding energy storage has better efficiency in relieving thermally overloaded grid elements than non-corresponding energy storage. The disadvantage is that it is more expensive, in that two energy storage facilities are required instead of one.

To make it possible to increase transmission capacity allocated to the market, all limits that affect capacity need to be addressed. Our analysis showed that for the Swedish transmission grid there was often more than one area with thermal overload limiting transmission capacity. Svenska kraftnät investigated whether it was possible to locate an individual energy storage facility or corresponding energy storage facility in such a way that it would reduce the load in all areas at the same time. No such solution has so far been identified. This means that although energy storage effectively relieves one of the thermal overloads with a limiting effect, it only provides a marginal increase in transmission capacity.

Since Svenska kraftnät has not found a system solution where energy storage provides a clear benefit, no concrete initiatives are currently being taken in this area. However, we are continuously monitoring the suitability of technical developments and their possible application in the Swedish transmission grid. Currently, there are more interesting solutions for increasing allocated transmission capacity, technology for controllable power flow on AC power lines for example.

3.5.3 Controllable power flow on AC power lines

The ability to control power flows today in the Swedish transmission grid using grid measures is relatively limited, even if there is some potential. For example, by bypassing series capacitor installations on the power lines in Interface 2, the power flow over the interface can be better distributed and the margin to maximum current limits increased, whereupon a higher transmission capacity between bidding zones SE2 and SE3 can be achieved.

There are several different technical options that can be used to influence the flow in the alternating current system, one of them being direct current connections located electrically in parallel with alternating current power lines. However, direct current connections are substantial and resource-intensive infrastructure, so other types of modern flow control equipment that can be mounted on existing AC power lines are an alternative. Svenska kraftnät has carried out a preliminary study which has shown that flow control equipment can be used in the transmission grid to control and redistribute power flows in the existing 400 kV power line grid. The redistribution of power can provide for better utilisation of the grid and increase capacity for existing bottlenecks.

A specific type of equipment was investigated in the preliminary study. This can be used to control flow to a limited extent, but is significantly less substantial than installations of HVDC solutions with converter substations. The equipment can therefore be installed relatively quickly in existing switchgear or along a power line. As a result, the equipment can also be moved when needs change, reinforcing different parts of the grid and removing bottlenecks.

The preliminary study has shown that a greater ability to control the power across Interface 2 results in significant benefits. Other conceivable areas of use, where the control of power flows between power lines may be desirable, are the injection into metropolitan regions or large local consumers. An unbalanced load between power lines can limit the total injection, even though there may be a large margin to the maximum current limit on the other power lines. If the flow on one or more power lines can be increased or decreased individually, then a higher transfer limit for the total flow to the area can be permitted.

Since the preliminary study has shown a positive benefit, the goal now is to start a project for the implementation of a pilot installation on one of the interface power lines where the impact of such equipment can be of greatest benefit.

3.5.4 Probabilistic risk assessment

Historically, the deterministic N-1 criterion has been used to assess the reliability of the transmission grid. This means that the power system is to be designed to withstand the failure of an arbitrary system component during the worst possible operating case, peak load hour for example. In a power system with increasingly intermittent consumption and generation, it is difficult to know what the worst possible operating case would be. It is therefore interesting to use complementary probabilistic tools.

Probabilistic risk assessment complements the traditional N-1 criterion in operational security analyses. In conjunction with establishing operational safety limits this is a method for assessing both the probability of a failure in the power system, as well as the consequences of this failure. Hence, using the PRA method, TSOs have more results on which to base their reliability assessments, and thus can better monitor the status of the power system. The results obtained from the risk assessment can also serve as a supplementary basis for decisions on future initiatives in the power system.

Svenska kraftnät is part of the European cooperation organisation ENTSO-E and has a legal mandate to work in accordance with the Probabilistic Risk Assessment (PRA) method. This requires Svenska kraftnät to transition to a more probabilistic attitude with regard to the planning, operation and safety assessment of the transmission grid, and to collate and manage data that is missing for this purpose.

This work has its background in the EU regulation on the operation of electricity transmission systems (SOGL, Article 75[5]) and more specifically Article 44[6] in the Coordinated Security Assessment Methodology (CSAM) on the use of the probabilistic risk method when assessing operational security. The regulation has placed clear requirements on Svenska kraftnät and other TSOs within ENTSO-E to develop a method to implement PRA by 31 December 2027 at the latest.

The main goal of the PRA approach is to achieve a transmission grid with high availability and the right capacity by complying with legislation and optimised capacity while maintaining operational security. The goal is for Svenska kraftnät to use PRA for both operation and planning, which means that the probabilistic consequences of N-1 failure can be predicted. This means that the risk of N-1 failure and possibly an arbitrary number of simultaneous outages can be assessed using PRA.

5. Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

6. ACER Decision on CSAM: Annex I – Methodology for coordinating operational security analysis, in accordance with Article 75 of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

3.5.5 New infrastructure for voltage regulation

It is important for a well-functioning power system that the voltages can be maintained within specified limits in all parts of the grid. The voltage can be locally regulated by increasing or decreasing the flow of reactive power. Historically, Svenska kraftnät has mainly invested in breaker-connected devices with the stepped regulation of reactive power, shunt reactors for withdrawing reactive power and power capacitor banks for the injection of reactive power, which are connected from our area control centres. In line with the ongoing changes to the power system, Svenska kraftnät now also needs to invest in more components capable of automatic and stepless regulation of voltage. In recent years, we have taken into service a STATCOM facility, and further such facilities will be taken into operation in the future.

Svenska kraftnät is implementing several different initiatives to improve voltage stability and thus maintain a satisfactory voltage within specified limits. The map in Figure 4, gives a summary by electricity price zone and voltage level of the planned investment in reactive power in the transmission grid.

Synchronous compensators

The ongoing change in the power system, with a reduced proportion of synchronously connected generation and a sharp increase in wind power and other unpredictable generation connected to power electronics, means that synchronous compensators are once again to be installed in the transmission grid. A synchronous compensator contributes synchronously connected rotational energy, fault current injection and dynamic voltage regulation, stabilising the system and leading, among other things, to the possibility of further increasing the proportion of generation connected to power electronics.

Svenska kraftnät has carried out a system study with the aim of investigating the usefulness of a synchronous compensator at Hallsberg. The investigation shows that the installation contributes to improved system stability and increased transmission capacity.

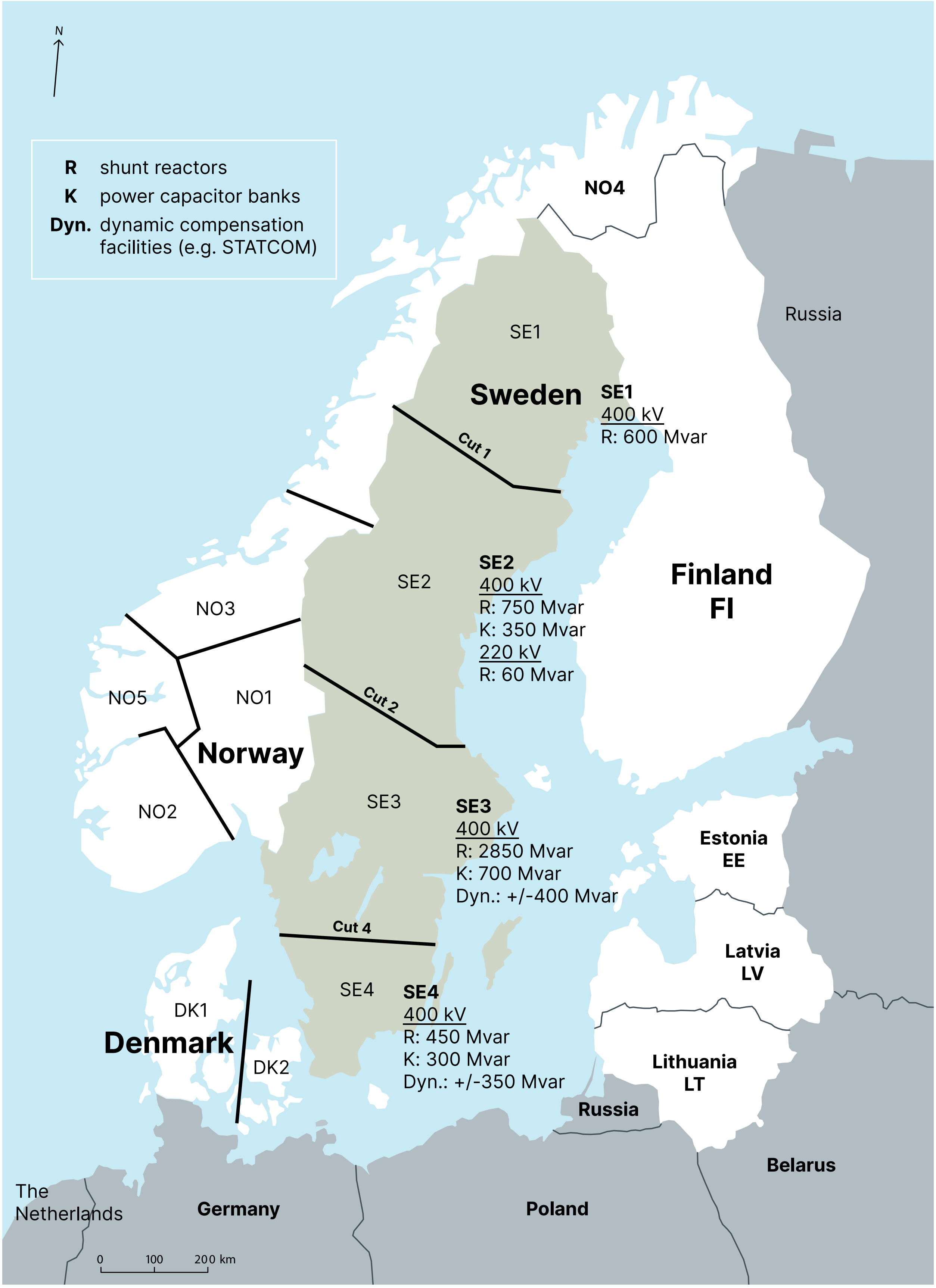


Figure 4. Planned investment in facilities for the compensation of reactive power (voltage regulating devices) in the transmission grid.

4. Ongoing investigations and projects

Svenska kraftnät has a large number of ongoing investigations and projects linked to the expansion and development of the transmission grid. This chapter describes some of those major ongoing investigations and projects. Many of these investigations are being carried out so that we can provide responses to applications for the connection of new generation or consumption that have been received. However, we are also working on several investigations into how transmission capacity can be increased in various parts of the transmission grid.

This chapter is divided into six different sections, the first four of which describe investigations and projects in Sweden's four bidding zones - a section for each bidding zone. At the beginning of each of these four sections, there is a brief description of the changes, linked to the development of the transmission grid, that are expected in the bidding zone. Some investigations and projects, such as NordSyd, concern more than one bidding zone so have been put in the section for one of the bidding zones that they affect.

This chapter describes some of the major ongoing investigations and where we believe it likely that major grid initiatives will be the result. In the case of ongoing projects, for example, the background, purpose and measures to be taken for a selection of the more significant investments are described.

The complete list of measures relating to the ten-year period 2024–2033 can be found in the section “Ten year plan for grid investment” at the end of the grid development plan. The ten-year plan includes information on the planned commissioning date and geographical location of each project.

The last two sections of this chapter detail projects and ongoing work that are not linked to a specific bidding zone, but which affect the whole country. This includes Svenska kraftnät's ongoing work on the connection of offshore wind power and the development of regional plans.

4.1 Investigations and projects in bidding zone SE1

Bidding zone SE1: includes the Norrbotten region and some of Västerbotten. From here there are connections to northern Finland and northern Norway. The Luleälven and Skellefteälven rivers flow through bidding zone SE1 into the sea at Luleå and Skellefteå respectively.

New industry and the transition of existing industry is expected to greatly increase power demand in the area. It is expected that when this takes place, transmission capacity for the area will need to increase and that new generation will be added.

This section details some of the ongoing investigations and projects in bidding zone SE1.

4.1.1 Fossilfritt Övre Norrland (FÖN)

To meet the large power requirement of industry in bidding zone SE1, Svenska kraftnät has created a programme called Fossilfritt Övre Norrland (FÖN). This programme currently includes two investment packages called Norrlandkusten and Malmfälten respectively, but it also contains a number of pilot projects seen as necessary to successfully meet the needs of industry in a timely manner. Normally, the reinforcement of the transmission grid takes over ten years to complete, but this needs to move faster in order to meet industry's timetable. FÖN will eventually include additional measures as demand is investigated. Figure 5 shows a map with the initiatives included in the Norrlandskusten and Malmfälten packages.

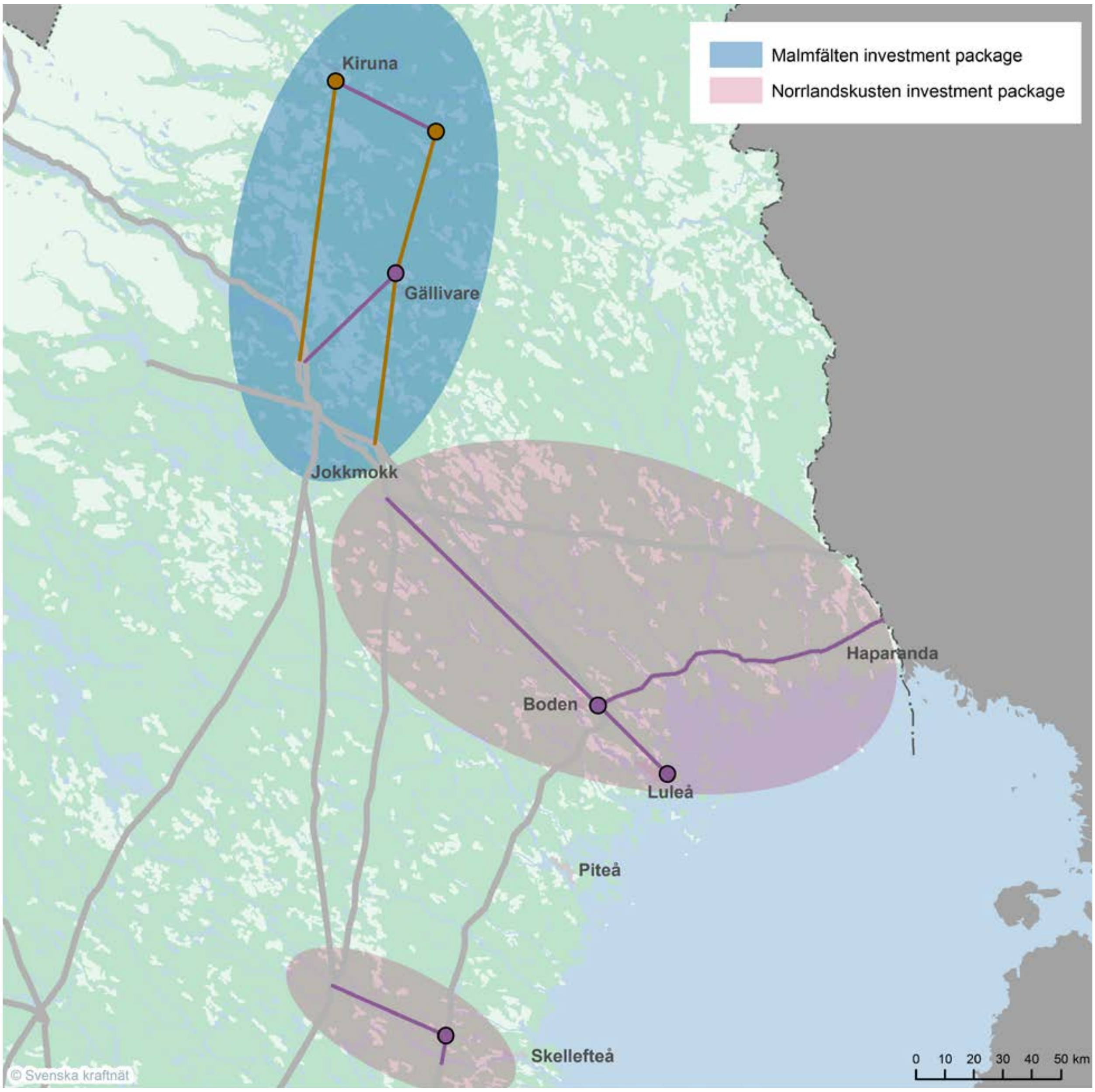


Figure 5. Overview map illustrating the initiatives included in the investment packages Malmfälten and Norrlandkusten. For the complete map including legend, refer to the section Ten-year plan for grid investment.

Norrlandskusten

Grid capacity today is not sufficient to meet current plans for large-scale and electricity-intensive industries along the northern Norrland coast, that is, around the cities of Boden, Kalix, Luleå, Piteå and Skellefteå. In addition, these industries want connections considerably sooner than it has been possible to build 400 kV power lines historically. Svenska kraftnät has therefore started a pilot aimed to halve lead times for new 400 kV power lines.

The Norrlandskusten investment package is expected to allow an increased withdrawal of approximately 2,500 MW by the 2031. This includes three new system reinforcing 400 kV power lines, three new 400 kV substations and a number of 400 kV connection lines. However, the investment package does not cover the entire withdrawal requirement applied for, which is several thousand MW more. Svenska kraftnät therefore continues to investigate the additional investment required.

Current capacity for connecting generation is already booked up by future wind power generation in the area around Piteå and Skellefteå, but the potential to connect additional generation will increase with the reinforcement of the transmission grid mentioned above, and as more consumption can be connected.

Malmfälten

There are currently several initiatives to electrify the iron and steel industry in Sweden. Significant new power withdrawal is planned in the Malmfälten area. This power withdrawal is linked to Hybrit's demonstration facility near Vitåfors in Gällivare municipality and LKAB's continued electrification of mining and iron ore processing at its industrial facilities outside Gällivare, Svappavaara and Kiruna. The total energy requirement for LKAB's transition has been forecast to be in the order of 70 TWh per year before 2050[7].

The transmission grid in bidding zone SE1 has been built to collect electricity generation from the hydropower plants along the rivers for onward transmission southwards. There is therefore currently no transmission grid in the vicinity of the new area of consumption north of the Luleälven river. These new electricity-intensive industries are so large that regional grid power lines are not the most efficient way to connect them. It is therefore necessary to expand the transmission grid northwards.

7. LKAB 2022: Press release 26/04/2022 - A faster pace and higher targets in LKAB's transition towards a sustainable future

Preparatory work has begun on a first power line from an area near Vitåfors in Gällivare municipality to the Porjusberget substation in Jokkmokk municipality. The plan is for a 400 kV overhead power line for alternating current. Svenska kraftnät also plans to build a new substation near the demonstration plant.

In addition to this power line and the new substation outside Vitåfors, it is expected that at least two more substations will be required, one outside Svappavaara and one outside Kiruna. There will also be a need for at least two more 400 kV power lines from Svenska kraftnät's current substations along the Luleälven river to Kiruna. The number of power lines required will depend on the potential to expand the hydrogen infrastructure. In addition to these initiatives, action will also be required in the existing grid to manage changes to flows resulting from increased electricity consumption in the Malmfälten.

The electrification of the iron and steel industry

The electrification of the iron and steel industry includes changes to the iron ore reduction process. In traditional blast furnace reduction, carbon in the form of coke is used as a reducing agent, resulting in carbon dioxide as a by-product. Many industrial actors are now working to reduce carbon dioxide emissions in steel production. An alternative to the traditional reduction process is direct reduction, where iron ore in the form of iron ore pellets uses hydrogen as a reducing agent, resulting in water as a by-product rather than carbon dioxide. This process is electricity intensive mainly because the production of hydrogen takes place through electrolysis. Electrolysis involves splitting water to produce oxygen and hydrogen.

4.1.2 Long-term needs in bidding zone SE1

There are currently plans to connect new consumption capacity at several locations in addition to those mentioned above in bidding zone SE1. All applications here have significantly greater power requirements than before. The increase in consumption is largely due to various industrial projects with electrified manufacturing processes. Since the existing transmission grid in SE1 is not designed for the planned power increases, there is a substantial need for system reinforcement in the area to enable the energy transition. With the greatly increased power withdrawal in SE1, South-North power flows in the transmission grid are becoming more relevant, this means that transmission between SE1 and SE2 needs to be reviewed. A number of large wind farms are expected to be connected to the transmission grid, which will also impact the need for transmission capacity.

A long-term investigation of bidding zone SE1 has therefore been started. This aims to draw up a proposal for an overall development plan for the development of the transmission grid in SE1 up to 2050. This extension plan also covers the boundary to SE2 across Interface 1. The investigation consists of several different delimited investigations, together taking into account the increased need for the potential for injection, withdrawal and increased transmission capacity. Together, these investigations highlight the four drivers of grid expansion.

4.1.3 Interconnectors

Capacity between Sweden and Finland

In the Aurora Line project, a third 400 kV alternating current power line is planned for construction between northern Sweden and Finland. The power line will connect the transmission grid substations Messaure in Sweden and Viitajärvi in Finland, and the plan is for the power line to be taken into operation in 2025–2026. The power line includes the electricity trading capacity between bidding zone SE1 and Finland being able to increase to 2,000 MW (an 800 MW increase), which will contribute to evening out electricity prices between Finland and the rest of the Nordic region. The power line will also improve the potential to exchange regulatory resources since the bottleneck periods between Sweden and Finland will be reduced. It will also contribute to increased security of supply through the improved integration of Finland into the rest of the Nordic power system. Figure 6 shows a map of the route of the Aurora Line.

Figure 6. Map illustrating the route of the Aurora Line.

Svenska kraftnät and Fingrid are also working together to review the long-term need for electricity trading capacity between Sweden and Finland and the measures that could be relevant to meet this need. It has already been decided to extend the life of Fenno-Skan 1, the oldest of the two direct current interconnectors between Sweden and Finland. This is so that capacity need not be reduced after 2030 when it is estimated that the connection will reach the end of its service life unless remedial measures are taken. These life extension measures are expected to increase its service life to at least 2040. A joint study is underway in which Svenska kraftnät and Fingrid are jointly investigating the need for an additional 400 kV connection between the two countries. This investigation is expected to be completed by the second quarter of 2024.

Transmission capacity to bidding zone SE1

In Svenska kraftnät's long-term market scenarios, there is a general need to reinforce the trading capacity of SE1. Work is underway to determine how transmission capacity for SE1 needs to be reinforced and how transmissions between Sweden and Norway, Sweden and Finland and between bidding zones SE1 and SE2 are interdependent. As previously mentioned, there is an ongoing study into transmission capacity between bidding zone SE1 and Finland that Svenska kraftnät is carrying out together with Fingrid. Corresponding study will be undertaken on transmission capacity with Norway together with Statnett. In the long-term investigation for SE1, a review of Interface 1 is already underway.

It should be observed that there are plans for the construction of hydrogen infrastructure stretching around both the Swedish and Finnish sides of the Gulf of Bothnia. This also affects the need for electricity infrastructure and transmission capacity between the countries.

4.2 Investigations and projects in bidding zone SE2

Bidding zone SE2 covers the regions of Jämtland, Västernorrland and parts of Dalarna, Gävleborg and Västerbotten. The rivers Umeälven, Ångermanälven, Indalsälven and others flow through these regions. There are two interconnectors from SE2 to Norway in the west.

In SE2, wind power generation has increased steadily in recent years but not as much connection is expected in the future. Several larger cities such as Östersund, Sollefteå, Sundsvall and Umeå are expected to increase their consumption for new industry.

This chapter details some of the ongoing investigations and projects in bidding zone SE2.

4.2.1 Grid capacity around Östersund

Just North of Östersund, a 220 kV power line runs between the Midskog and Järpströmmen substations. This is beginning to approach the end of its service life and a total renewal of the power line needs to be carried out. Along the power line is a connection point for the regional grid that is important for the supply of Östersund. In the next five-year period, there are plans in the area around Östersund for the establishment of both large industrial facilities and wind farms, meaning that with the existing grid structure increased subscription to the transmission grid is very limited.

A system investigation is underway for the area taking into account both future capacity needs and the need for reinvestment in this 220 kV power line. As conditions in the area have changed significantly in recent years, a major change to the grid may become relevant. The investigation also considers the need for increased import capacity from Norway via the 400 kV Nea–Järpströmmen line.

4.2.2 The 220 kV grid between Krångede and Sundsvall

The 220 kV grid in the area between Krångede and Sundsvall was largely built in the 1930s and 1940s and is in need of reinvestment. There are initiatives that are relied upon in the NordSyd programme that to some extent affect the changes necessary for grid structure and local needs for injection and withdrawal. Both grid structure and local needs are therefore reviewed in a system investigation entitled Indalsringen. The grid in the area is to be reinforced, and although the measures to be taken are generally of a long-term nature and are expected to last for a long time, some are already underway while other investigations have only recently started.

4.2.3 Series compensated Interface 2 power lines

The series compensation of long power lines is a well-known method for reducing the electrical length of power lines, thereby improving their transmission capacity in an extended grid. In Sweden, series compensation is used on the 400 kV power lines that are part of Interface 2, which forms the boundary between bidding zones SE2 and SE3, as well as on the power lines to Finland. It can be technically difficult to connect new substations along an existing series-compensated power line. One of the challenges is that series compensation has an impact on the voltage along the power line, which can make it challenging to maintain the voltage at the new substations. As there have been several applications to connect wind power to these lines in recent years, and because there is a need to renew the series compensation infrastructure, Svenska kraftnät plans to carry out extensive measures on these lines.

The planned initiatives will be carried out in the coming years and five of today's eight series-compensated power lines in Interface 2 will be affected in various ways. On several of the power lines, the existing series capacitor substation will be replaced by two new series capacitor substations at other locations along the power line. These will be designed to handle higher currents so as not to limit transmission. On other power lines the existing series capacitor substation will be renewed with a modified design and increased current tolerance, and in some cases supplemented with additional new series capacitor substations along the power line. Because the power distribution between the power lines is currently good, the total compensation ratio per line will be maintained at today's level for most power lines.

The measures on the series-compensated power lines will contribute to better voltage stability and are a necessary condition for meeting the need for increased transmission capacity from North to South. The planned initiatives, in combination with the construction of some new AC substations along some of the power lines, will allow the connection of more electricity generation. The plan is for the measures on the series-compensated Interface 2 power lines to be completed in 2026–2029. In the longer term, it is planned that the series capacitor substations will be decommissioned as the series-compensated power lines are renewed as 400 kV double power lines as part of the planned NordSyd initiative.

4.2.4 NordSyd

During 2016–2018, Svenska kraftnät carried out an extensive investigation into the transmission grid that connects northern Sweden's large generation surplus with the southern parts of the country where there is a large generation deficit. Interface 2 runs through this part of the grid, forming the boundary between bidding zones SE2 and SE3. The transmission grid around Interface 2 is geographically long and today consists of three old 220 kV power lines and eight 400 kV power lines of varying ages, with the oldest being the world's first 400 kV power line from 1952. The oldest power lines will soon be too old to continue in operation, at the same time as there is a clear need to increase transmission capacity through the area.

The NordSyd initiative must resolve the need for both renewal and capacity in a coordinated manner. Through the structural change that is planned as part of NordSyd, the outdated 220 kV grid through Interface 2 will be completely replaced with a 400 kV grid, constructed largely as double power lines. The voltage increase will provide an opportunity to rationalise both the transmission grid and the regional grid in the area by moving and reinforcing connection points. The changes planned as part of NordSyd also mean that the old series-compensated 400 kV power lines through Interface 2 will in due course be replaced with new 400 kV double power lines.

Double 400 kV lines will provide increased capacity, lower losses, improved outage conditions and greater robustness in comparison with today's grid solution. At the same time, they will keep down the land requirement for the power line corridor through Interface 2. Figure 7 shows a map that illustrates the initiatives included in NordSyd.

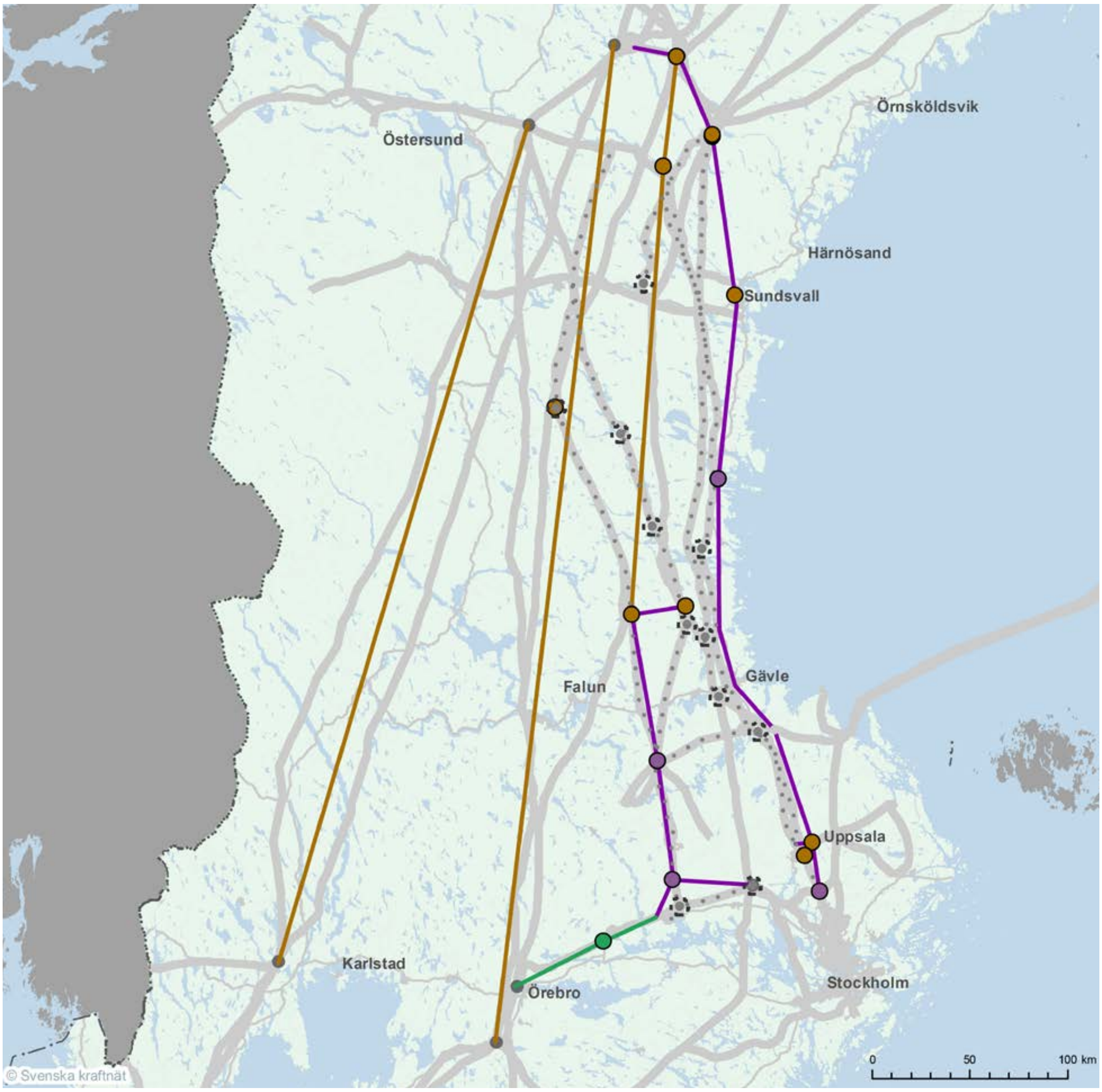


Figure 7. General map illustrating the initiatives included in NordSyd. For the complete map including legend, refer to the section Ten-year plan for grid investment.

The drivers behind the increased need for transmission between northern and southern Sweden are the same as those behind many of Svenska kraftnät's other initiatives. Despite the large increase in consumption expected in bidding zone SE1, a large expansion of wind power in the North; the decommissioning of nuclear power and other generation in the South; and increasing electricity consumption, greatly increases expected transmission through the interface. Limits in the capacity in Interface 2 will have a large detrimental impact on the electricity market, as well as on the security of supply in southern Sweden.

Thus, there are clear motives for reinforcing capacity in connection with the implementation of the necessary renewal measures.

Another driver that has been added is the relatively large volume of offshore wind power planned for southern Norrland. This presupposes that new power lines with sufficient capacity are to be built, because existing power lines will not able to take the additional power.

NordSyd is Svenska kraftnät's largest ever investment package and means that large parts of the transmission grid in central Sweden will be renewed and reinforced through a series of initiatives over the next 20 years. The result will be a more robust and flexible transmission grid that is prepared for changes to the Swedish power system. The main part of NordSyd deals with long-term initiatives that will be gradually taken into operation until about 2040. However, the package also includes adjacent measures to enable an earlier capacity increase across Interface 2.

Overall, this means that approximately 2,000 km of new line and around 30 substations must be built or rebuilt as part of the NordSyd package. All in all, these measures will lead to a capacity increase between bidding zones SE2 and SE3 from 7,300 MW today to over 10,000 MW.

From September 2020 to May 2023, policy decisions relating to NordSyd have been reached costing approximately SEK 40 billion. The total cost for NordSyd is currently estimated at approximately SEK 75 billion, of which approximately two-thirds are costs largely linked to the renewal of the older power lines.

Adjacent measures to increase capacity in Interface 2

To meet the need for increased north-south capacity faster, initiatives with a shorter implementation time are planned. These initiatives are linked to the installation of voltage regulation equipment in central Sweden. It is planned that these resources will be largely static, although there will also be some that are controllable. In addition to increasing capacity, the initiatives will also contribute to better voltage stability in the grid.

According to the present schedule, adjacent measures will provide a north-south capacity increase of approximately 800 MW, which will be available in about 2027-2028. A number of wind farms are to be connected to the series-compensated power lines between bidding zones SE2 and SE3. To make this possible, extensive measures are required to the series-compensated power lines, including the partitioning of series compensation.

Initiatives in the next 20-year period

The long-term initiatives consist of the establishment of four north-south 400 kV double power line connections, in other words two 400 kV power lines in parallel, which will contribute to an increase in capacity across Interface 2. These will replace the 220 kV power lines and the three oldest 400 kV power lines across that interface. The first projects started in 2020 with a focus on reinforcing the transmission grid, improving the power shortfall situation and decommissioning older grids in the Uppsala and Mälardal regions. Between 2021–2023, projects were started to reinforce Interface 2 with two 400 kV double power lines between Västerås and the river Ångermanälven and between Sollefteå and the river Dalälven (connected onwards to Uppsala). Continued investigations for the Karlstad leg, between Midskog and Borgvik, were also started in 2023. The Karlstad leg and Hallsberg leg projects will start in 2023–2024. Svenska kraftnät's board will make a policy decision when the investigations have been completed.

Figure 8 presents a graph of planned transmission capacity development for Interface 2 for the period 2023–2042.

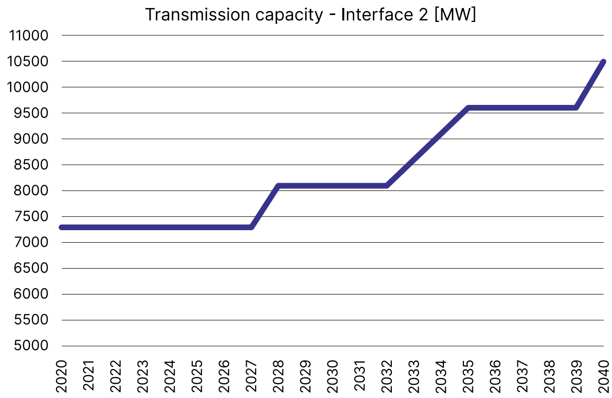


Figure 8. Planned capacity development for Interface 2, the boundary between bidding zones SE2 and SE3.

The Uppsala leg

The Uppsala leg will establish a double 400 kV connection across Interface 2 from Sigtuna municipality in Uppland to the river Ångermanälven and will replace old power lines on the corresponding section. Transmission grid substations will be established to connect the Uppsala leg to the existing power grid, creating the conditions for increased injection and withdrawal along the route. Completion of the Uppsala leg is estimated to be in 2034.

The Västerås leg

The Västerås leg will establish a double 400 kV connection over Interface 2 from Mälardalen to Ångermanälven and will replace old 220 kV power lines on corresponding stretches. Transmission grid substations will be established along the Västerås leg to connect the existing power grid creating the conditions for increased injection and withdrawal along the route. Completion of the Västerås leg is estimated to be by 2035.

The Hallsberg leg

The Hallsberg leg will establish a new double 400 kV connection across Interface 2 from Hallsberg to Storfinnforsen by the river Faxälven and will replace an old series-compensated 400 kV line on the corresponding section. The line will create the necessary conditions for increased injection and withdrawal along the route, including the potential to establish new substations. Completion of the Hallsberg leg is estimated to be in the late 2030s.

The Karlstad leg

The Karlstad leg establishes a new double 400 kV connection over Interface 2 from Karlstad to Midskog by the river Indalsälven and replaces an old series-compensated 400 kV power line on the corresponding section. The line will create the necessary conditions for increased injection and withdrawal along the route, including the potential to establish new substations. Completion of the Karlstad leg is estimated to be in 2033–2035.

4.3 Investigations and projects in bidding zone SE3

Bidding zone SE3, includes most of central Sweden. This includes the regions of Stockholm, Uppsala, Västmanland, Örebro, Södermanland, Östergötland, Värmland, Gotland and Västra Götaland, and parts of Dalarna, Gävleborg, Halland, Jönköping, Kronoberg and Kalmar. SE3 contains eight of the country's ten largest cities: Stockholm, Gothenburg, Uppsala, Västerås, Örebro, Linköping, Jönköping and Norrköping. All three Swedish nuclear power plants are also located in SE3.

The two direct current interconnectors Fenno-Skan 1 and 2 to Finland, two alternating current interconnectors over the Hasle interface to Norway (NO1) and the two direct current interconnectors Konti-Skan 1 and 2 to Jutland (DK1) originate in SE3.

During this period, onshore wind power and solar power are expected to increase in the area. Along the coast, connecting offshore wind power may become applicable in the longer term.

This chapter details some of the ongoing investigations and projects in bidding zone SE3.

4.3.1 System reinforcement Stockholm

The initiatives to meet the long-term need for electricity supply to the Stockholm region are contained in an investment programme and are divided into two investment packages: Stockholms Ström and Storstockholm Väst. With both initiative packages Stockholms Ström and Storstockholm Väst in place, the ability of the transmission grid to deliver electricity to the withdrawal points around Stockholm will be sufficient to cover future needs based on current forecasts. However, it is important that the regional grid in the area is also adapted and reinforced in order ultimately to be able to meet the needs of end customers.

Stockholms Ström and Storstockholm Väst rely on many initiatives that Ellevio and Vattenfall Eldistribution are carrying out. This is also the case for the municipalities with plans for land being released for development, making implementation very complex. The construction of new substations and power lines, as well as the refurbishment of existing substations and power lines, must be coordinated to achieve objectives. At the same time, the technical system requirements for each phase of implementation must be met, placing great demands on cooperation with regard to outage planning between the various parties. Figure 9 presents the initiatives to be carried out in the Stockholm area.

Figure 9. General map illustrating the initiatives to be carried out in the Stockholm area. For the complete map including legend, refer to the section Ten-year plan for grid investment.

Stockholms Ström

Stockholms Ström comprises about 50 sub-projects and, in addition to Svenska kraftnät, involves the region's other grid owners Vattenfall Eldistribution and Ellevio, and 21 municipalities in the Stockholm region. The background to grid renewal in Stockholms Ström is a Government commission from 2004. This commissioned Svenska kraftnät to draw up a proposal for the design of the future power grid in the Stockholm region. Together with the regional grid owners, Svenska kraftnät prepared a proposal for a new grid structure that would fulfil future requirements regarding availability and operational security with a minimal impact on the environment. The proposal was presented in an interim report in 2005 and a final report in 2008.

The new grid structure means that part of today's relatively intricately meshed 220 kV grid will be phased out. In other parts of the grid, the voltage level is being raised from 220 kV to 400 kV. A new, partially underground 400 kV power line is being constructed between Upplands Väsby in the North and Haninge in the South. The Hagby–Anneberg section is complete and has been taken into operation. A section under the inner city between Anneberg and Skanstull is being laid in a drilled tunnel. Large parts of City Link are now under construction and work on the tunnel began in the autumn of 2019. At the end of May 2023, half the length of the tunnel, which will be approximately 13.4 km long, had been drilled. It is planned that the Skanstull–Snösätra and Snösätra–Ekudden sections will be taken into service in 2023–2025. The entire City Link is expected to be ready for operation in 2030.

In conjunction with the implementation of Stockholms Ström, about 150 km of overhead power lines will be dismantled. Municipalities and other land owners are co-financing Stockholms Ström in proportion to the value of the land that will be released for other use. The large-scale use of 400 kV cable technology in the Stockholm area results in many substantial technical challenges, mainly in terms of operation, electricity quality and voltage control. Shunt reactors will largely compensate for the reactive power generation of the cables. In some substations, however, dynamic control resources are being considered for voltage regulation.

Storstockholm Väst

The demand for electricity in the Stockholm region has increased faster than that predicted when the new grid structure was developed just over a decade ago. Population growth, reduced regional electricity generation, new electricity-dependent infrastructure such as charging posts for electric cars and the appetite for server farms are the main reasons for the increased demand. We have already reached a level of consumption that means that further increases cannot be granted given the current transmission grid. At the same time, the initiatives implemented as part of the Stockholms Ström programme are not adequate for future needs.

To meet this sharply increased demand for electricity, and to ensure long-term operational security in the Stockholm region, Svenska kraftnät is planning further reinforcement in the form of a new north-south 400 kV connection, Storstockholm Väst, through the west of the region. This is intended to replace the present 220 kV connections on the Hamra–Överby–Beckomberga–Bredäng–Botkyrka–Kolbotten section. These initiatives also include a new 400 kV power line between Odensala and Överby, as well as a series of new transformer substations. The connection will be built in phases during the period 2024–2030.

4.3.2 System reinforcement Västra Götaland

In Västra Götaland, several actors in the automotive industry, chemical and petrochemical industry, manufacturing industry and the transport sector are planning to move towards a fossil-free future. This will result in a greatly increased demand for electricity and thus a need for increased transmission capacity to and within the region.

In May 2023, Svenska kraftnät presented its initiatives for meeting the sharply increased demand for withdrawal in Västra Götaland based on the application by the regional grid owner, Vattenfall Eldistribution, for 1,200 MW for the period 2026–2030. The initiatives presented include the earlier reinvestment in a 400 kV power line north of Gothenburg as well as the previously adopted 400 kV power line Skogsäter–Stenungsund–Ingelkärr–Stenkullen. The initiatives also include reinforcing of the 400 kV grid in Skaraborg and one of the Interface 2 power lines in western Sweden. Given the present grid structure, withdrawal in the region can increase by around 400 MW, after which further increases in withdrawal will be possible in 2026, 2031 and 2035. The initiatives presented here are expected to satisfy the applied for withdrawal of 1,200 MW in phases until 2035, which is later than Vattenfall Eldistribution stated in its application. To meet the withdrawal demands before all grid reinforcement is in place, Svenska kraftnät is therefore also investigating other initiatives, such as flexibility solutions and dynamic subscription agreements.

Figure 10 presents a map of upcoming initiatives in Västra Götaland and South-west Sweden.

Figure 10. General map illustrating the initiatives to be carried out in Västra Götaland and South-west Sweden. For the complete map including legend, refer to the section Ten-year plan for grid investment.

Since Vattenfall Eldistribution applied for increased withdrawal of 1,200 MW, it has submitted a new application for an additional 1,300 MW in the early 2030s, corresponding to a total increase of 2,500 MW relative to today's level. It is both time-consuming and costly to resolve the total withdrawal demand using grid reinforcement alone. Investment in new regional electricity generation is therefore also required, as the degree of self-sufficiency in Västra Götaland is currently very low. Svenska kraftnät is currently investigating the potential for connecting onshore wind and solar power in Skaraborg, as well as offshore wind power in the northern North Sea. These investigations are expected to be finalised in the spring of 2024.

Skogssäter–Stenungsund–Ingelkärr–Stenkullen

The new 400 kV power lines Skogssäter—Stenungsund, Stenungsund—Ingelkärr and Ingelkärr—Stenkullen will contribute to increased transmission capacity throughout the region. The Skogsäter—Stenungsund—Ingelkärr power line, with its comparatively coastal location, is also important for allowing the connection of offshore wind power in the area. The new substations at Stenungsund and Ingelkärr will provide the regional grid greater withdrawal capacity and create withdrawal potential closer to connecting customers.

Hallsberg–Timmersdala–Stenkullen

A need to reinforce the 400 kV grid in Skaraborg has arisen following Vattenfall Eldistribution's connection application for increased withdrawal in the area, which is primarily driven by planned industrial development. To enable increased withdrawal in the region, Svenska kraftnät plans to bring forward reinvestment in the 400 kV power lines between Hallsberg-Timmersdala and Timmersdala-Stenkullen. In addition, the possibility of building a new transformer substation and a new 400 kV power line between Hallsberg and Timmersdala is also being investigated.

Increased consumption is not the only factor driving the need for grid reinforcement in Skaraborg. The need for additional capacity also occurs when the nuclear power plant on the West coast shuts down for its annual scheduled maintenance outage. This leads to an increase in the east-west transit flow through SE3. In other words, imports from Finland go through SE3 and are exported onwards to Norway and Denmark. The east-west flow creates a bottleneck between Hallsberg and Timmersdala that Svenska kraftnät needs to resolve in the long term.

New regional electricity generation and flexibility solutions

New regional generation in the area will be required to enable the energy transition in Västra Götaland. The region already has a high electricity consumption today, while there is a generation deficit in the area. Currently, only a third of the electricity consumption is produced within the region. This means that electricity needs to be transferred from other parts of the country or abroad. When industries and the transport sector are electrified and electricity consumption increases in the coming years, it is therefore not enough just to build new power lines. Svenska kraftnät sees the potential to manage capacity in the area in the long term, given the applications that have come in for new nuclear power from Ringhals and the large offshore wind farms in the area. However, the timetable for these generation sources is uncertain and alternative solutions to satisfy an increased demand for withdrawal will need to be investigated in the meantime.

To enable connections and the allocation of increased capacity, work is underway to develop flexibility solutions that can mitigate the shortfall while Svenska kraftnät reinforces the transmission grid. Flexibility solutions will consist of a collaboration between Svenska kraftnät, the regional grid owners and major electricity-intensive industries in the area.

4.3.3 Roslagstriangeln in Östra Uppland

The 400 kV substation Tuna is located outside Uppsala. From Tuna, a 220 kV power line runs to the Gråska substation North west of Hallstavik, and onwards to the Malsta substation just west of Norrtälje and then back to Tuna.

Sections of this loop will need to be renewed over the next twenty years as they begin to reach the end of their service life. At the same time, there is a need for increased capacity and a potential need for more powerful interconnectors and for the connection of offshore wind power.

An investigation into various future solutions is underway, this should clarify the optimum grid structure for the loop at Norrtälje. In addition to other considerations, it may be appropriate to construct new substations and power lines, as well as to modify voltage levels. This investigation is expected to be finalised in the first quarter of 2024.

4.3.4 Gotlandsförbindelsen

In the 2020 regulatory letter, Svenska kraftnät was tasked with analysing whether Gotland had a safe and secure electricity supply in the short and long terms. A needs assessment was carried out in the winter of 2021 and the results showed a clear need for another transmission connection to Gotland by around 2030. Even if electricity consumption does not increase, a new connection will be needed to replace the current connections in phases between 2030 and 2040. In the regulation letter for the budget year 2023, Svenska kraftnät has been tasked with expanding the transmission grid to include Gotland. This expansion is to secure a transmission grid point on Gotland in good time before the current supply is phased out due to age. In 2022–2023, an investigation was carried out with regard to future development in the area, including the development of the grid on the mainland and the expansion of wind power.

A collaboration with Vattenfall Eldistribution AB and Gotlands Elnät AB has been undertaken in parallel with the investigation in order to identify the best solution for connecting Gotland to the mainland. The Gotland power balance shows a deficit from 2030 using current forecasts. This is why Svenska kraftnät's ambition is to have a new connection in operation by the early 2030s.

As a result, in May 2023 Svenska kraftnät decided on a new transmission connection to Gotland. This will consist of two submarine 220 kV AC cables with a transmission capacity of 220 MW each and is expected to be operational in 2031.

4.3.5 The eastern corridor along the South-east coast

In 2022, Svenska kraftnät investigated the need for increased transmission capacity along the Swedish Baltic coast from Norrköping in the North to Kristianstad in the South. The need for this investigation was partly prompted by the large amount of renewable electricity generation planned for the area, but also aimed to identify initiatives to eliminate existing and future electricity transmission bottlenecks between bidding zones SE3 and SE4.

The current 400 kV power line between Norrköping and Kristianstad was built in the 1960s and has a transmission capacity corresponding to less than half of a modern 400 kV power line. By renewing and upgrading the capacity of the existing power line, a good capacity exchange is achieved at a price of limited new physical intrusions.

The conclusion of this investigation was that an early renewal of the 400 kV power line along the Baltic Sea coast, from the late 2040s to the beginning or mid-2030s, is justified in order to prevent new costly internal bottlenecks from arising. The measure is also deemed necessary in order to utilise the full capacity of the new Gotland connection and to prevent the rejection of new applications for the connection of new generation in the area from 2026.
A final decision on the accelerated timetable for renewing the 400 kV Östra corridor power line has not been made at this time.

4.3.6 Interconnectors

Konti-Skan

The existing HVDC interconnectors Konti-Skan 1 and 2 between Sweden and Denmark will reach the end of their service life in the period 2030–2036. If they are not replaced with new interconnectors, there will be a decrease in transmission capacity between the two countries and some electricity market benefit will be lost. It would also make it more difficult to maintain operational security and will impair the security of supply in both the Danish and the Swedish transmission grids. In the event of a failure in the power grid, the interconnectors can support the grid through emergency power interventions.

This ability would be lost in the event of a non-renewal of Konti-Skan. The potential for replacing the existing HVDC interconnector (Konti-Skan 1 and 2) with a new interconnector (Konti-Skan 3) with greater capacity and new technology are therefore being investigated. A suitable location for the converter substation on the Swedish side is also currently being investigated by Svenska kraftnät. Commissioning of the new interconnector is planned for the first half of the 2030s.

4.4 Investigations and projects in bidding zone SE4

Bidding zone SE4 covers the regions of Skåne, Blekinge and parts of Kalmar, Kronoberg and Halland. Much of the consumption takes place in the region around Malmö and Lund and in the cities along the coast: Helsingborg, Ystad, Trelleborg, Karlskrona and Kalmar. In the North, Interface 4 consists of five 400 kV power lines. The interface runs in a line from South of Oskarshamn on the East coast to South of Varberg on the West coast. Four interconnectors originate in SE4. There are two 400 kV alternating current cables to Zealand (DK2), the Baltic Cable HVDC interconnector to Germany, the SwePol Link HVDC interconnector to Poland and the NordBalt HVDC interconnector to Lithuania.

In subsequent years, a significant addition of renewable generation in the form of onshore wind power and solar power is anticipated. In the slightly longer term, a substantial amount of offshore wind power can be connected in the area.

This chapter details some of the ongoing investigations and projects in bidding zone SE4.

4.4.1 Renewal of power lines on the West coast and in Skåne

Nine 400 kV power lines between Trollhättan and Malmö are now more than 60 years old and in great need of renovation. Foundations and pylons as well as phase conductors have corroded at a faster rate than in the rest of the country due to the salt-saturated winds in the area. Work to replace approximately 400 km of these power lines will continue throughout the 2020s. This is due in part to the long permit process, and in part to limits to the coordination of outages necessary to construct new power lines along an existing power line corridor.

The transmission capacity of a modern 400 kV power line constructed according to today's standards is significantly greater than the capacity of the power lines constructed in the 1950s and 1960s. Thus, the renewal programme on the west coast and in Skåne will also mean an increase in transmission capacity in the area. The power line renewals in Skåne, driven mainly by the lines reaching the end of their service life, have now also become key to meeting the power requirements in South-west Skåne. The current capacity requirement in the Malmö region is being resolved with the Hurva–Sege line, renewed in 2021, and Sege–Barsebäck line, renewed and upgraded in 2023.

4.4.2 Long-term plan for the transmission grid in bidding zone SE4

Svenska kraftnät and E.ON Energidistribution (E.ON) have been working on an investigation since 2021 that aims to draw up a long-term joint development plan for the transmission and regional power grids in the current bidding zone SE4. The long-term plan must ensure that southern Sweden gets an efficient, coordinated electricity grid structure with regard to operational security, functionality and intrusion that can meet the area's long-term need for transmission capacity. Ultimately, this work aims to identify appropriate initiatives to manage new electricity trading patterns and satisfy new capacity needs linked to the electrification of regional industry and the transport sector and the connection of new fossil-free electricity generation.

Close planning with the regional grid owner E.ON is key to this joint analysis work. In addition to other factors, the examination and assessment of replacing certain 130 kV power lines with new co-built 400 kV and 130 kV power lines, along with the location and design of new connections between the transmission and regional grid, are currently underway. The long-term planning horizon also creates the conditions necessary for an early involvement of public actors such as municipalities and county administrative boards with the various coordination and permit issues.

It is anticipated that based on the results and recommendations from the ongoing investigation in bidding zone SE4, a decision on a first investment package with system reinforcement measures focused on the area around Malmö and Trelleborg can be made in 2024.

4.4.3 Ekhyddan–Nybro–Hemsjö

As a component in ensuring operational security in the transmission grid in South-eastern Sweden, Svenska kraftnät needs to build a new 400 kV transmission grid line between Ekhyddan and Nybro, and onward from Nybro to Hemsjö. This project is divided into two parts due to its size; Ekhyddan–Nybro and Nybro–Hemsjö.

Following the connection of the NordBalt to Nybro interconnector, the need for power transmission through the area has increased. The new power line is needed for the long-term secure operation of NordBalt and so that the parallel regional grid in Småland is not overloaded in the event of a failure in the 400 kV grid. Figure 11 shows a map of the route of the new power line from Ekhyddan, via Nybro, to Hemsjö.

Figure 11. Map illustrating the route of the power line Ekhyddan–Nybro–Hemsjö. For the complete map including legend, refer to the section Ten-year plan for grid investment.

The power line improves the ability of the one remaining nuclear power block, Block 3 at the Oskarshamn nuclear power plant, to better withstand outages in the surrounding grid. This is particularly important following the closure of the two oldest blocks 1 and 2, since Oskarshamn 3 now has an even more important role in regional voltage stability and supply capacity. Investigations have shown that this power line is of central importance to connecting the offshore wind power off the coast of Småland. The power line is also deemed as important to the development of the common electricity market in Europe because it contributes to the secure operation of NordBalt.

In 2021, the Government granted a grid concession for the Nybro–Hemsjö section and in December 2022, the Energy Markets Inspectorate granted a grid concession for the Ekhyddan–Nybro section. The delay in the concession decision process has resulted in the bringing forward of the planned commissioning of both routes to 2027–2028.

4.4.4 Interconnectors

Hansa PowerBridge

Hansa PowerBridge is a planned direct current connection between southern Sweden and Germany with a transmission capacity of 700 MW. It is being developed in collaboration with the German TSO 50Hertz.

The interconnector will connect to the transmission grid in Hurva outside Hörby in Skåne. The direct current connection SydVästlänken connects to the same substation from the north. This allows some of the power that comes via the SydVästlänken to be transmitted onwards to Germany, or vice versa from Germany and onwards to the SydVästlänken without subjecting the surrounding alternating current grid to load.

The increased potential for import from Germany will also be important when the combined electricity generation in Sweden and the other Nordic countries is not sufficient to meet demand.

Work is currently underway with 50Hertz, to produce technical and legal procurement documents to start the tender process for suppliers to construct the link. Svenska kraftnät is also working on a renewed socioeconomic analysis. Figure 12 shows part of the Hansa PowerBridge route from Hurva to Ystad and onwards to Germany.

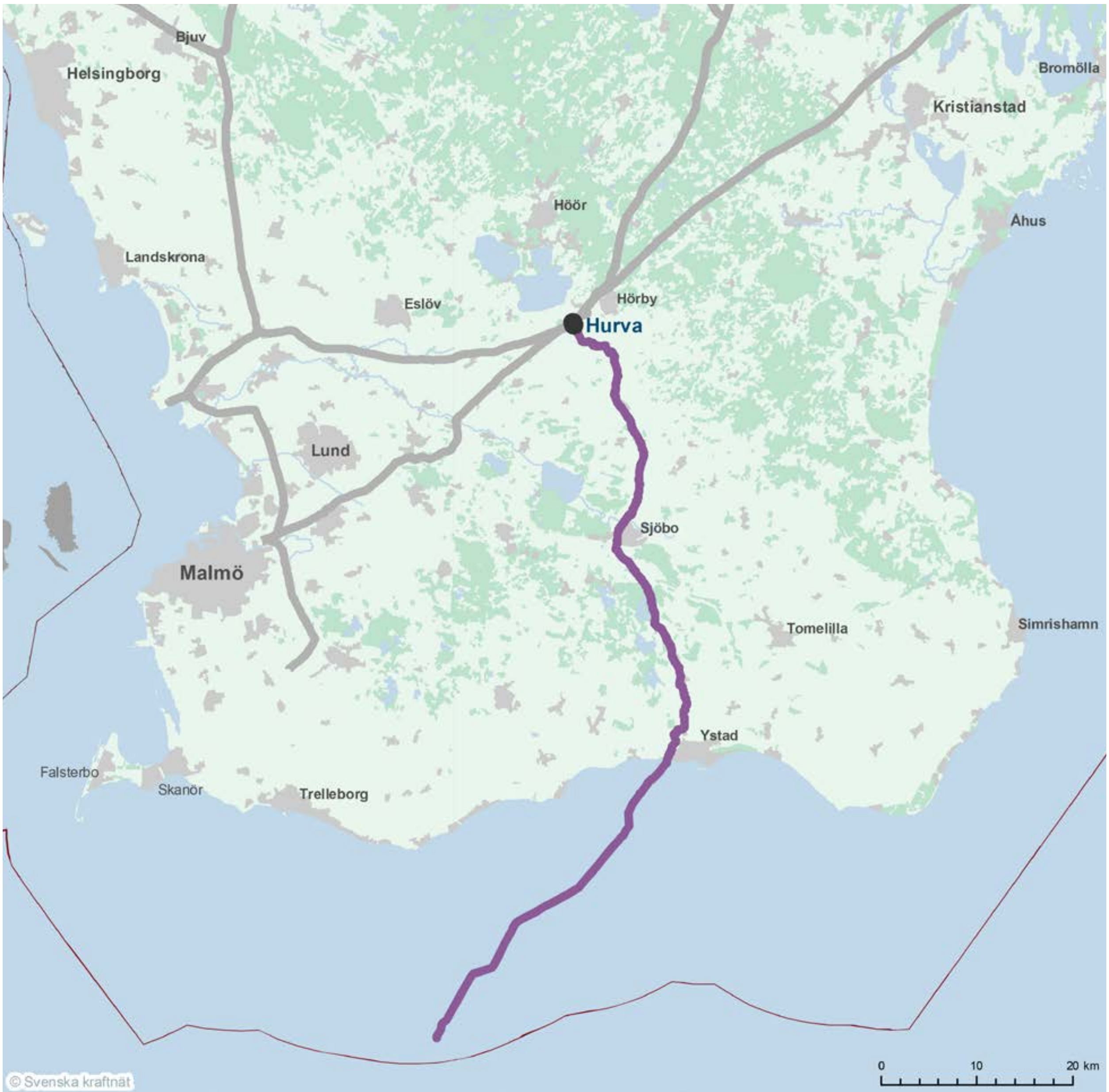


Figure 12. Map of the Hansa PowerBridge route from Hurva to Ystad and onwards to Germany. For the complete map including legend, refer to the section Ten-year plan for grid investment.

4.5 Other projects and ongoing work

4.5.1 The shunt reactor investment package

To manage the challenges related to high voltages, an investigation was carried out in 2020 to draw up proposals for suitable initiatives to deal with them. One such proposal was to investigate the deployment of shunt reactors.

If the voltage in the transmission grid is higher than its components are designed for, this poses a risk to personal safety. Voltages that are too high can also result in damage to components and their premature aging. Shunt reactors can be used to lower the voltage in the transmission grid by consuming reactive power. Shunt reactors are a cost-effective solution for this purpose.

The investigation into the deployment of shunt reactors will make a recommendation on the substations in which new shunt reactors should be deployed, and their appropriate size. This will reduce the current issue with high voltages. In this investigation, we have taken a collective approach to the issue and, instead of dealing with each case individually, are investing in several shunt reactors at once. The expected result is that about ten shunt reactors will be located in the transmission grid at the applicable voltage level (400 kV and 220 kV).

4.5.2 Connection of offshore wind power

Financial support for grid connection and streamlined permit application review - current status

Interest in the connection of offshore wind power to the Swedish transmission grid has increased significantly over the past five years. The increased involvement of offshore wind power companies in Sweden is partly a consequence of the wording of the 2016 energy agreement that *the connection cost of this energy source should be scrapped*. However, a concrete commitment linked to the pledge to scrap connection costs for offshore wind power only came into force in February 2021, when the then government submitted the memorandum "Reduced connection costs for offshore electricity generation"[8].

8. Ministry of Infrastructure [*Infrastrukturdepartementet*] 2021: Memorandum 02/02/2021 – Reduced connection costs for offshore electricity generation

This memorandum described a proposed new task for Svenska kraftnät; to expand the transmission grid to areas in Sweden's territorial waters where the conditions for connecting several electricity generation facilities exist.

This new assignment to expand the transmission grid offshore was then formalised and written into an amended instruction to Svenska kraftnät. This instruction came into force on 1 January 2022. In the autumn of 2022, a new government came into power in Sweden. The new government's position is that the connection cost for offshore wind power must be paid in its entirety by the wind power companies themselves. On June 21, 2023, a new memorandum was sent, "Amendment to Ordinance (2007:1119) with instructions for Affärsverket Svenska kraftnät"[9]. This communication proposed that changes to the instructions introduced on 1 January 2022 should be withdrawn on 1 October 2023. Svenska kraftnät submitted its comments to the memorandum in August 2023. The written comments to the report can be read in their entirety at svk.se[10].

In parallel with the proposal to withdraw support for grid connection by changing Svenska kraftnät's remit, the government decided in May 2023 that a special investigator should analyse how the overall regulatory framework for reviewing permits for offshore wind power can be improved[11]. This assignment includes analysing the possible design of a referral system similar to that used in other European countries. Svenska kraftnät has expressed its support and recommended a gradual transition to a referral system as this creates better conditions for predictable grid expansion and the development of the power system as a whole.

The government's new commission also includes analysing whether connection agreements should be a criterion to be observed in order to maintain the exclusive right to an area. An important condition in the investigation is that submitted proposals must not affect Svenska kraftnät's ability to control the principles of connection.

9. Ministry of Climate and Enterprise [*Klimat- och näringslivsdepartementet*] 2023: Circulation for comment of Amendment to Ordinance (2007:1119) with instructions for Affärsverket Svenska kraftnät

10. Svenska kraftnät 2023: Opinions on circulation for comment regarding Amendment to Ordinance (2007:1119) with instructions for Affärsverket Svenska kraftnät

11. Committee directive 2023:61 – A review of offshore wind power, Decision at cabinet meeting on 4 May 2023

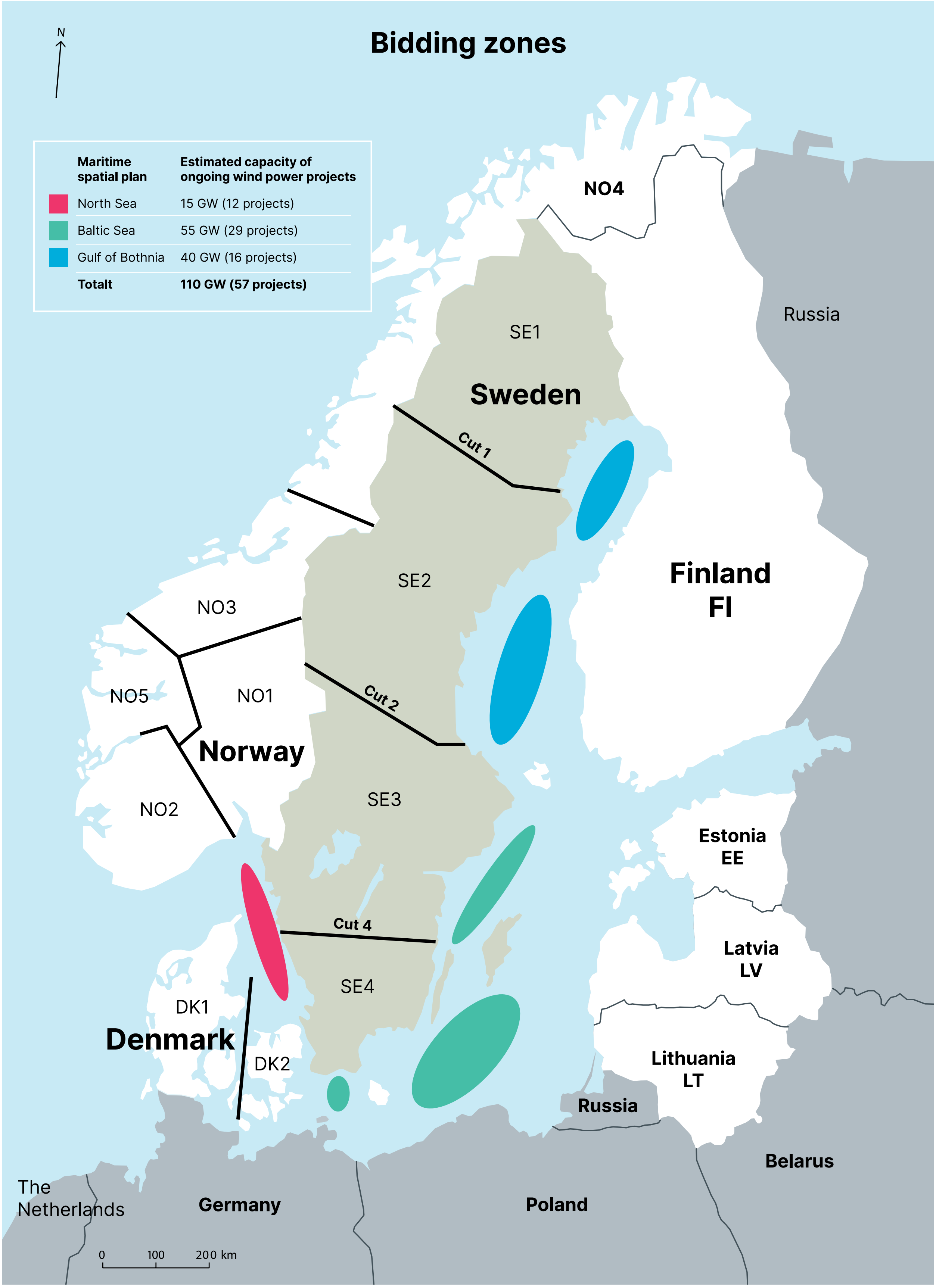


Figure 13. Estimated capacity per maritime spatial plan area and each maritime spatial plan area's geographic location.

Planned offshore wind power in Sweden

In the wake of the previous political signals about financial support for offshore wind power, Svenska kraftnät received applications for the connection of approximately 84,000 MW of offshore wind power in 2021 alone. The large volume of applications is due to Sweden, in contrast to most other European countries, having an open establishment system for offshore wind power.

In Sweden, the wind power companies themselves choose potential maritime areas for installing offshore wind power. Several companies can investigate the same maritime area at the same time, which can result in duplicated projects or partially overlapping applications in Svenska kraftnät's connection queue. The wind power companies have different methods for assessing the potential for construction in individual maritime areas. Combined with project overlap, it is therefore difficult to know exactly how much theoretical offshore electricity generation capacity is planned in Sweden.

A survey undertaken by Svenska kraftnät shows that there are currently at least 57 major Swedish offshore wind power projects. The total theoretical capacity of these projects, when qualitative deductions have been made for overlapping development areas, is estimated to be approximately 110 GW. Of this generation capacity, 15 GW is located in the North Sea, 55 GW in the Baltic Sea and 40 GW in the Gulf of Bothnia maritime spatial plan areas. In Figure 13, estimated capacity is presented for each maritime spatial plan area and the location of the maritime spatial plan areas is illustrated on a map.

Ongoing investigations and projects

Open investigations of onshore connection points

In 2021, Svenska kraftnät was commissioned to carry out a preparatory investigation into the expansion of the transmission grid into Swedish territorial waters. This investigation reported in June 2022[12] and contained, in addition to a description of prioritised areas for grid expansion, proposals for the modification and rationalisation of the connection process for the Swedish offshore wind power open establishment system.

The most important change to the processing of connection applications for offshore wind power is that the traditional approach, in which the potential for connection for individual actors is investigated in the order in which the actors submitted their applications, be abandoned. Instead, Svenska kraftnät has started to work on open, geographically delimited investigations into the potential for connection to the transmission grid onshore. These investigations are not initially linked to a specific wind farm. Offshore wind actors who wish to join are offered access to the results of the investigation by way of public notification to a stakeholder pool.

In 2023, Svenska kraftnät started preliminary investigations of onshore connection points for offshore wind power located in the central Baltic Sea, the Bothnian Sea and the Gulf of Bothnia. In parallel with this work, a special connection process for offshore wind power is also being drawn up. Detailed status reports on these activities were published in October 2023.

Project-specific investigations on the grid connection of offshore wind power

The new principles of investigation mean that the current administrative process is waived for agreements of intent regarding connection signed early in the connection process. However, at the time of Svenska kraftnät's decision to depart from this arrangement, there were signed agreements of intent linked to six wind farms:

Gotlands havsvindpark, Kattegatt Syd, Kriegers Flak, Skåne havsvindpark, Stora Middelgrund and Södra Victoria. According to these agreements, Svenska kraftnät is obliged to carry out investigations regarding the specific connection of these projects.

Two investigations into connection – those for Skåne havsvindpark och Stora Middelgrund – were completed in Q2 of 2023. A potential connection in Barsebäck, Kävlinge municipality, has been investigated for Skånes havsvindpark. In the case of Stora Middelgrund, the investigation has identified a potential connection point in Kårarp, about 10 km east of Laholm. In July, the government rejected the application to change the permit for Stora Middelgrund pursuant to the Act on Sweden's exclusive economic zone (1992:1140). Since there is now no opportunity to build this wind farm, Svenska kraftnät is also closing this matter.

The investigation into the connection of Southern Victoria has also been completed, slightly later in Q2 2023. The connection point for this wind farm is about 10 km west of Nybro.

12. Svenska kraftnät 2022: Commission to prepare for the expansion of transmission grids into areas in Sweden's territorial waters - Connecting offshore electricity generation

As part of the investigation into the connection of Kattegatt Syd, a notice of connection point was issued to the stakeholder in Q2 2023. The aim is for Kattegatt Syd to be connected to the transmission grid at a new substation in the municipality of Varberg some 10 km east of the Ringhals nuclear power plant.

For Kriegers Flak, the connection is to be implemented through the expansion of an existing substation in Svedala municipality in the Skåne region.

Gotlands havsvindpark will have a connection point about 10 km north east of the Ekhyddan substation, in Oskarshamn municipality.

4.6 Regional plans

The ongoing electrification of society means that interest in Svenska kraftnät's activities has grown. In turn, this has led to an increase in the need for information and communication in relation to the planned development of the transmission grid.

Public regional planning documents for grid development could be a transparent way for Svenska kraftnät to provide interested parties with an overview of the needs that Svenska kraftnät has to deal with in its analyses. The main purpose of the regional planning documents could be to illustrate the needs and drivers of grid development in an easily accessible and visual manner. While the geographical demarcation between different regional plans may probably vary somewhat, the regional level is a generally suitable geographical scope. The regional planning documents for grid development, or simply regional plans, can also conceivably contain certain information linked to the availability of transmission capacity. The idea is that the regional plans should be a living documentary basis, ensuring that public and private actors operating within or affected by the energy transition, are provided with one and the same picture of the regional conditions for continued power grid expansion.

The concept of public regional plans is still evolving. The section below presents some conceptual examples that briefly illustrate what regional plan documentation could look like for the Norrbotten, Västerbotten and Jämtland regions.

As has been pointed out above, the grid development plan and the regional plans are snapshots. Actors who are interested in a connection are asked in the first instance to contact the regional grid companies that connect to each connection point to get up-to-date information.

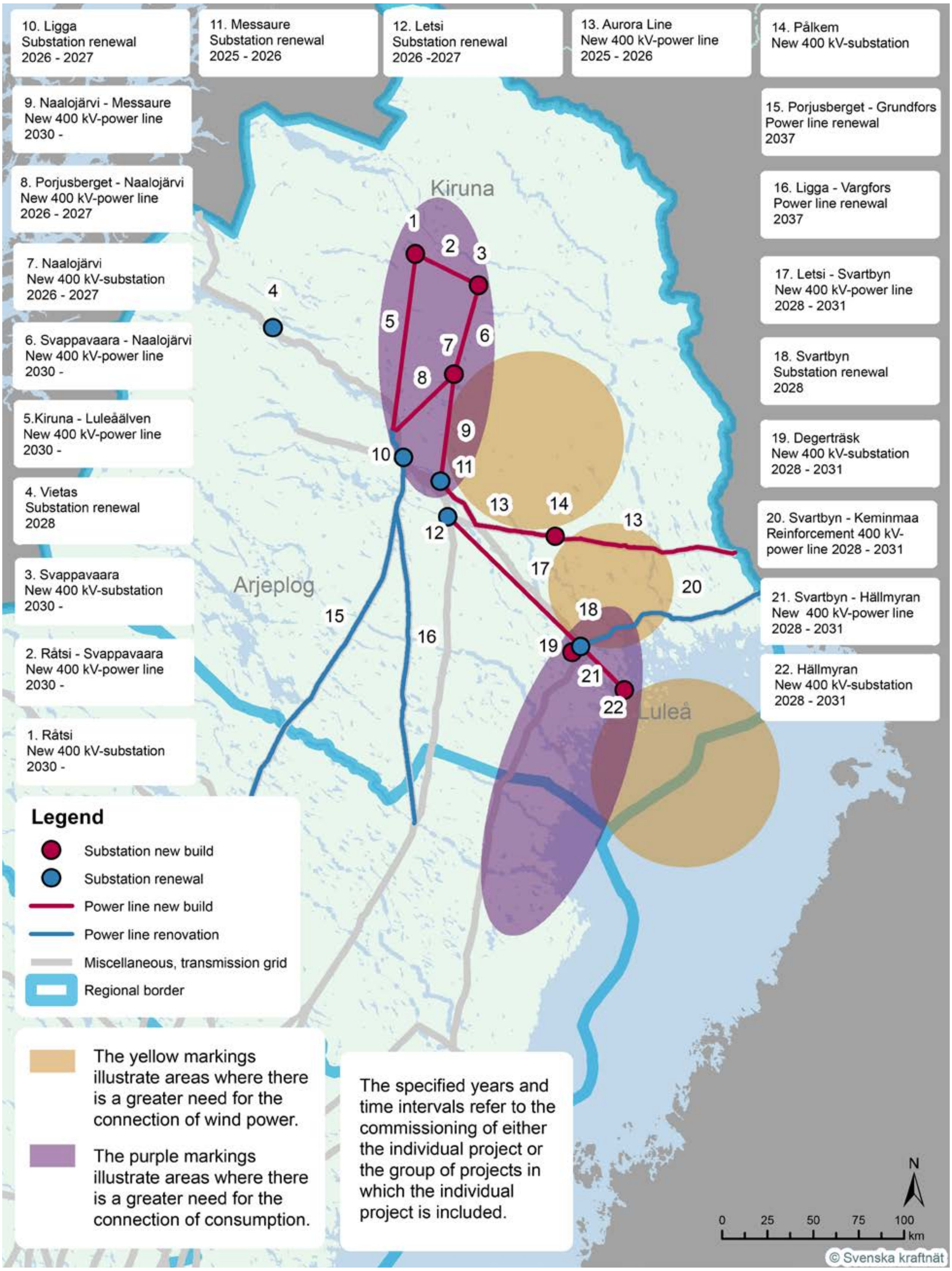


Figure 14. Regional plan for Norrbotten.

4.6.1 Regional plan for Norrbotten

Expansion of the transmission grid in Norrbotten started in the 1930s, collecting hydropower along the Luleälven river for onward transmission south. In recent years, a substantial amount of wind power has been connected to the grid, the largest wind farm being Markbygden outside Piteå. There have also been smaller consumers, especially in the cities along the coast. In general, the area has a large generation surplus with relatively little consumption.

As of 2020, the number of consumption applications increased sharply in the area, and the total power demand in the area is expected to greatly exceed current consumption id all of these are realised. The background to this is a number of initiatives relating to the electrification of new or existing operations by LKAB, SSAB, Vattenfall AB, H2GS, Fertiberia and others with energy-intensive processes. Svenska kraftnät is undertaking projects and investigations to meet this demand, see Figure 14, but there is more to be processed. Thus, capacity in the area is already largely booked, and only after major grid investment can new consumers be connected.

Without additional generation in the area it will have a significant deficit, so reinforcing transmission capacity into SE1 must be investigated in parallel. Svenska kraftnät also sees a need for supplementary grid reinforcement along the Luleälven river. Furthermore, the first power lines commissioned in the area are getting old and must therefore be renewed in the near future.

Based on the early indicative applications received by Svenska kraftnät, a number of areas have been identified as very interesting for the connection of wind power. Svenska kraftnät sees this as important information for overall grid planning in the region and aims to prepare connection points for connections in the order of 1,400 MW in these areas. The capacity at each point ultimately depends on the evolution of withdrawal demand in the Norrbotten region.

Regional plan for Norrbotten in relation to hydrogen demand

The greatest power demand comes from facilities that intend to produce hydrogen using electrolysis. Hydrogen can then be used to produce steel, ammonia and methane. The significant demand power means that there are plans for a parallel hydrogen infrastructure around the Gulf of Bothnia and up towards Kiruna. Svenska kraftnät believes that the situation in bidding zone SE1 is a unique one and that a parallel hydrogen infrastructure will affect the structure of energy supply as a whole in the region. In the same way that the household demand for heat can be met through district heating and as electricity for heat pumps, the demand for hydrogen can be met through hydrogen infrastructure and through the power grid supplying electrolysers located at the end user.

Given that new hydrogen infrastructure is being constructed that can supply some of the demand for hydrogen, Svenska kraftnät believes that the energy system in general must be designed to make it socioeconomically efficient. Parallel energy infrastructure does not necessarily mean an inefficient solution, on the contrary it can be a good solution to increase robustness and resource utilisation. Svenska kraftnät wishes to highlight the importance of the joint planning of energy infrastructure and society working towards a common goal.

Investigations are underway to establish both hydrogen pipelines and electricity infrastructure. However, the structure of the energy system in the region in the future is still uncertain. One thing is clear however, and that is that the Luleälven will play an important role, and that it is likely that infrastructure will be constructed along the river and out towards the coast. The construction of transmission grids has no intrinsic value, so to conserve society's resources the short-term plan is to concentrate consumption and generation as close to each other as possible. This means that Svenska kraftnät will focus generation and consumption at points where demands can, to a great extent, be combined. These points are also expected interface with any future hydrogen pipeline network.

Svenska kraftnät also wants to make clear that the withdrawal demand in bidding zone SE1 is substantial and, according to current planning, if this is realised it will exceed regional generation capacity. See, for example, Svenska kraftnät's short-term electricity market analysis (KMA2022)[13]. The bidding zone becomes a deficit area and the situation becomes unsustainable. Any withdrawal flexibility will improve the situation.

13. Svenska kraftnät 2022: Short Term Market Analysis 2022 – Power System Analysis 2023-2027

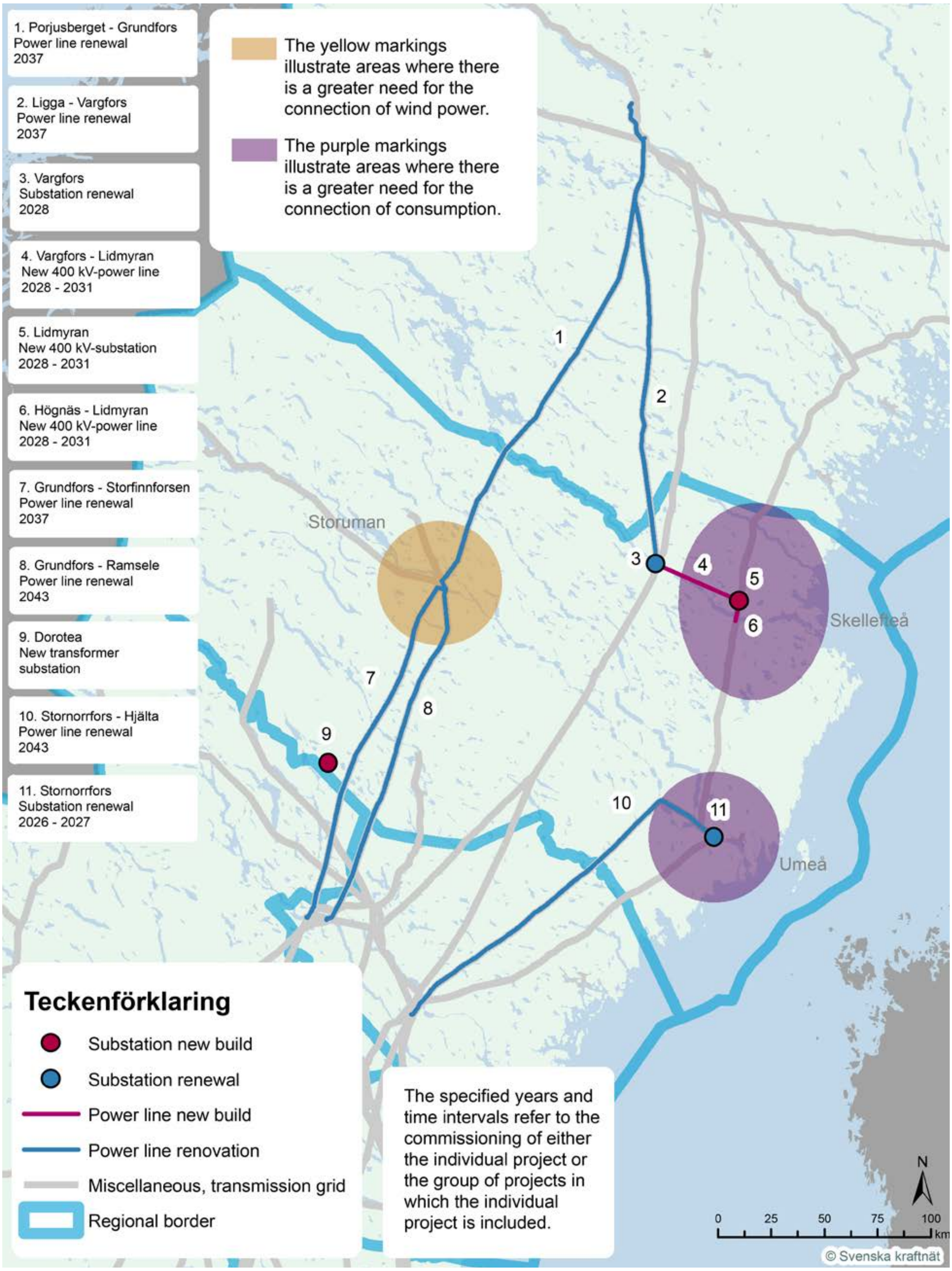


Figure 15. Regional plan for Västerbotten.

4.6.2 Regional plan for Västerbotten

The transmission grid in Västerbotten mainly consists of long power lines between the Luleälven in the north and the Ångermanälven in the south. The Umeälven and Skellefteälven power plants are essentially connected to the underlying regional grid. As in Norrbotten, the largest consumers are located along the coast. A large amount of wind power has been connected in Västerbotten in recent years, primarily in inland areas, and more is being constructed. This has led to the entire region being by and large fully booked, and connecting new generation will be challenging. Only when new consumers have established themselves within or to the north of the region, or when the transmission grid has been reinforced, is the connection of additional generation expected to be possible.

Skellefteå has expanded considerably in recent years and similar growth is taking place in Umeå. While limitations have been identified in the area around Skellefteå, in the rest of the region the conditions for connecting consumers are still considered to be good.

Svenska kraftnät has received several applications and early indicative applications in the area surrounding Grundfors in western Västerbotten. This is important information for the overall grid planning in the area and Svenska kraftnät aims to prepare for the connection of new generation in the area. However, the grid is crowded at present and it is anticipated that major connections will only be possible when system reinforcement has been effected or older power lines have been upgraded. In Västerbotten, several transmission grid power lines are old and must be renewed in the near future. Figure 15 shows the regional plan for Västerbotten.

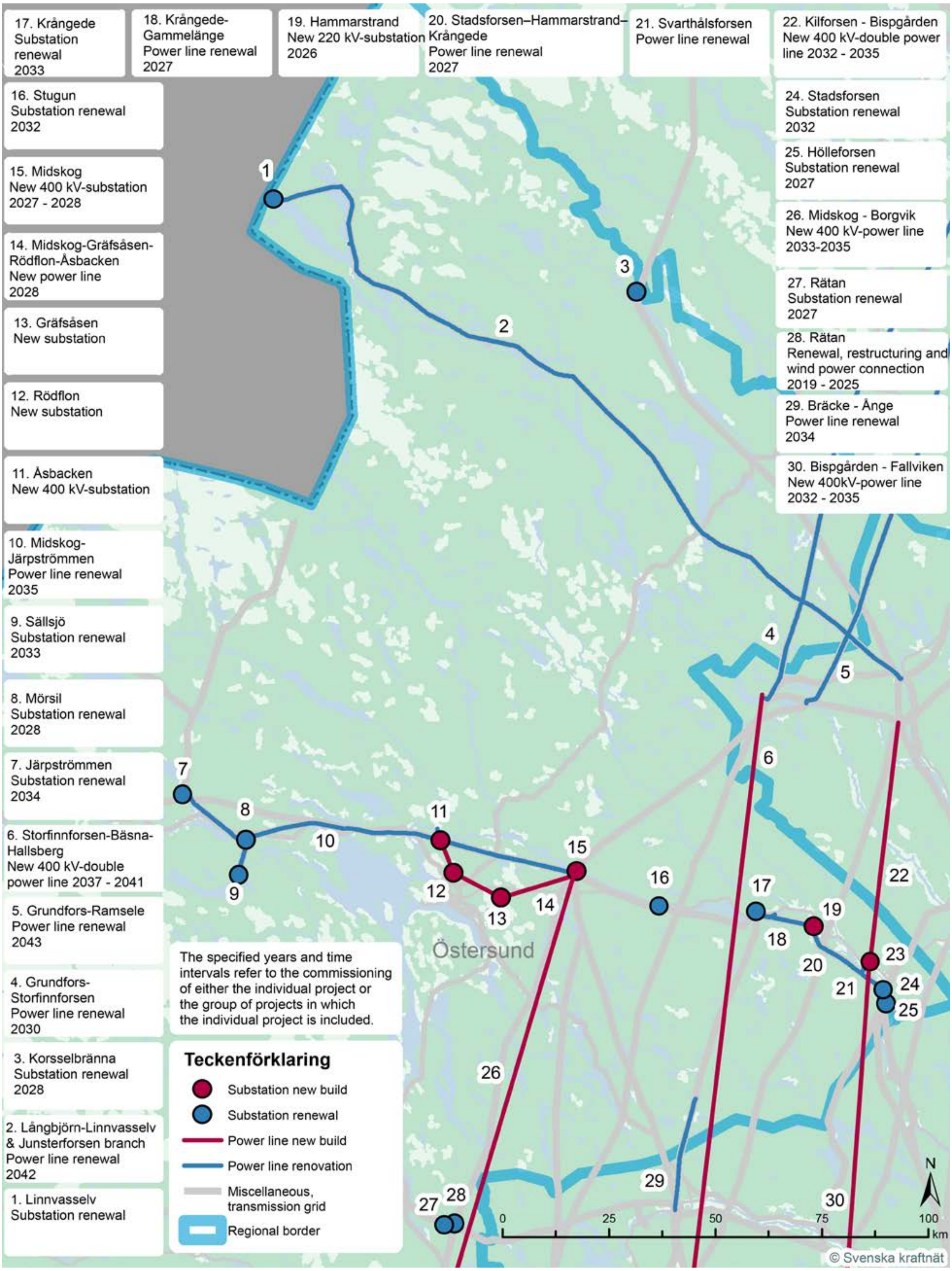


Figure 16. Regional plan for Jämtland.

4.6.3 Regional plan for Jämtland

The transmission grid in Jämtland connects several power lines between bidding zones SE2 and SE3 as well as an interconnector to Norway. The area is to a great degree affected by the reinforcement initiatives planned within the NordSyd programme. In addition to planned renewal in the NordSyd programme, there is also a need to renew the section between Järpströmmen and Midskog.

Östersund is expected to grow considerably due to new electricity-intensive industry, and the power grid remains crowded until planned reinforcement initiatives are in place. In Jämtland, a large amount of wind power has been connected and further projects are about to be connected. Because of this, capacity is poor on the north-south power lines in the west until NordSyd reinforces this section. Other areas have better potential for connecting new generation. Figure 16 shows the regional plan for Jämtland.

Ten-year plan for grid investment

As has been mentioned above, Svenska kraftnät is facing major challenges. Figure 17 shows the outcome of Svenska kraftnät's grid investment over the past decade together with the likely outcome of grid investment over the next ten years. The latter is given as an estimated range (shaded area). We can see that while the rate of investment has been fairly flat over the past decade, it will increase sharply over the next ten years.

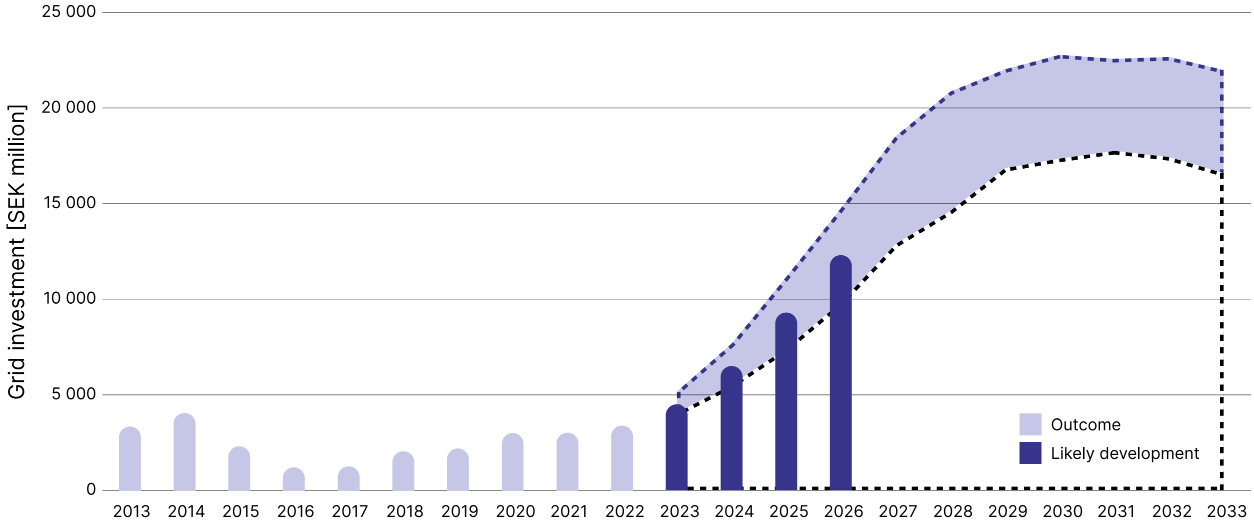


Figure 17. Outcome of grid investment for the period 2013–2022, as well as the likely growth of grid investment over the period 2023–2026. The shaded area provides an estimate of grid investment in the future based on the plans in 2023.

This chapter details the investment in the transmission grid currently deemed applicable in the decade 2024–2033[14] and which forms the basis of Figure 17. The projects reported in the plan constitute today's best assessment. New projects will gradually be added while others will be withdrawn or modified as to their and scope. This is an inevitable consequence of the large number of parameters that affect the conditions and drivers of investment. There is also ongoing work on the development of basic assumptions for the investment plan. For example, the potential for outages, resource utilisation and the statutory requirements regarding connection obligations and priorities.

An overview of the various investments can be seen in Figure 18. The following sections present these investments in more detail in separate maps. Investments are primarily grouped so that the projects listed under each heading are connected to one another. Other projects are sorted by bidding zone and phase.

14. Information refers to investment forecast for the second quarter of 2022. Investments made by the subsidiary Svensk Kraftreserv AB are not included.

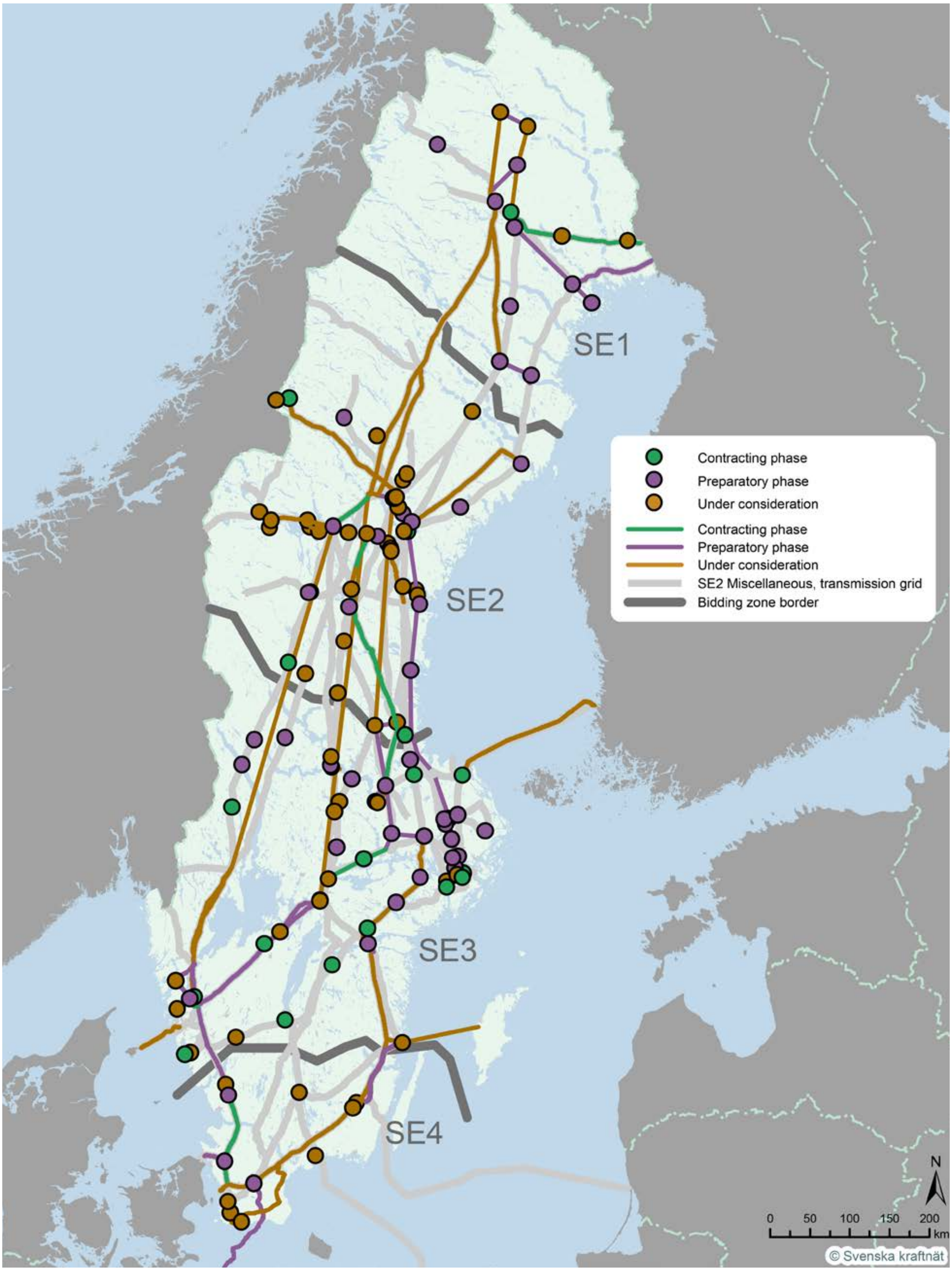


Figure 18. Large construction projects starting before 2034.

The projects are divided into the three phases: under consideration, preparatory and construction.

Projects under consideration

A project is classified as being under consideration when there is an ongoing investigation as to whether the conditions are right for an investment to be made. This category also includes projects for which such an investigation has not yet been started but for which a clear need has been identified to start initiatives within the next ten years. The majority of the latter type apply to reinvestment in infrastructure that is nearing the end of its service life which needs to be initiated within the ten-year period. Projects that relate to the connection of external parties are not included in the appendix where the conditions have not yet been investigated.

A project moves into the preparatory phase when a decision to start preparatory work has been made. This decision corresponds to policy decisions in accordance with Svenska kraftnät's decision making procedures.

Projects in the preparatory phase

A project is considered to be in the preparatory phase when it is in the stage between the investigation phase and the ultimate decision being made on whether or not to proceed with implementation. At this point in-depth technical design is undertaken. All consultation and authorisation work related to power lines is also carried out in this phase. In addition, the works contract is procured in the preparatory phase.

In some cases, projects in the preparatory phase are not implemented. This may be because the rationale for the initiative is no longer adequate, but more often it is projects related to the connection of external parties that are cancelled. In these cases, Svenska kraftnät is not solely responsible for decision making. Implementation of the project may be dependent on a wind-power developer obtaining financing for their project in order to enable them to sign a connection agreement with Svenska kraftnät.

Projects in the contracting phase

A project enters the contracting phase when Svenska kraftnät has resolved to start implementation and signed a general contract. This corresponds to an investment decision being made in accordance with Svenska kraftnät's current decision making procedures. Only in exceptional cases will ongoing projects be cancelled, but changes to timetables or cost estimates may be made.

Explanatory notes to the tables

The tables for each bidding zone and phase contain the following information:

Map no.: Serial number shown on the map.

Project description: Short description of the activities included in the project.

Phase: Specifies in which of the three phases, under consideration, preparatory phase and contracting phase, the project finds itself.

Planned commissioning: Planned date for taking the facility into service.

Driver: The drivers of the project can be divided into connection, market integration, system reinforcement and reinvestment. The drivers are described in the section Drivers of grid development. The tables indicate each project's main driver.

Fossilfritt Övre Norrland

All projects linked to the Fossilfritt Övre Norrland initiative are brought together here, see Section 4.1.1. Other projects in SE1 can be found on the map "Other projects in bidding zone SE1".

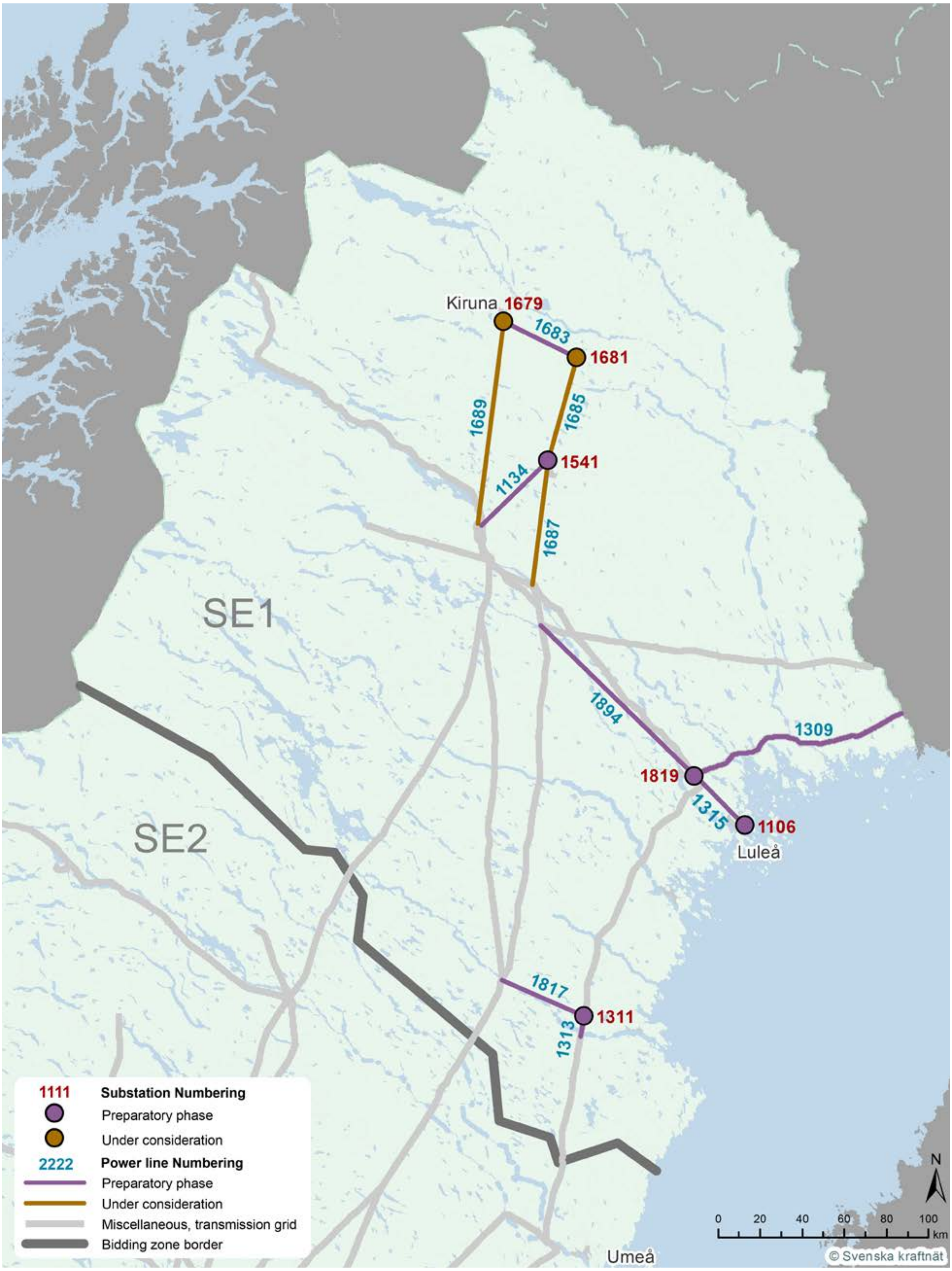
NORRLANDSKUSTEN

Map no.	Project description	Phase	Planned commissioning	Driver
		Preparatory phase	**2028–2031**	
1819	Degerträsk new 400 kV substation	Preparatory phase		Connection
1313	Högnäs–Lidmyran new 400 kV power line	Preparatory phase		Connection
1309	Svartbyn–Keminmaa reinforcement	Preparatory phase		System reinforcement
1315	Svartbyn–Hällmyran new 400 kV power line	Preparatory phase		Connection
1106	Hällmyran new 400 kV substation	Preparatory phase		Connection
1894	Letsi–Svartbyn new 400 kV power line	Preparatory phase		System reinforcement
1311	Lidmyran new 400 kV substation	Preparatory phase		Connection
1817	Vargfors–Lidmyran new 400 kV power line	Preparatory phase		System reinforcement

MALMFÄLTEN

Map no.	Project description	Phase	Planned commissioning	Driver
	Part 1	**Preparatory phase**	**2026–2027**	**Connection**
1134	Porjusberget–Naalojärvi new 400 kV power line			
1541	Naalojärvi new 400 kV substation			
	Part 2	**Under consideration**	**2030–**	**Connection**
1687	Naalojärvi–Messaure new 400 kV power line			
1683	Råtsi–Svappavaara new 400 kV power line			
1679	Råtsi new 400 kV power line			
1685	Svappavaara–Naalojärvi new 400 kV power line			
1681	Svappavaara new 400 kV power line			
1689	Kiruna–Luleälven new 400 kV power line			

Fossilfritt Övre Norrland – map



NordSyd

This is where all projects linked to the NordSyd initiative are brought together, see Section 4.2.4. Other projects in SE2–SE3 can be found in the maps "Other projects in bidding zone SE2" and "Other projects in bidding zone SE3".

THE UPPSALA LEG – COASTAL INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
	Construction project	**Preparatory phase**	**2031–2035**
2914	Njutånger new 400 kV substation[15]		
2903	Hjälta/Nässe–Vattjom, new 400 kV double power line		
2690	Hjälta/Nasse substation extension and connection to Odensala		
2920	Vattjom–Njutånger new 400 kV double power line		
2923	Nesse connection to Jälla		
2917	Vattjom new 400 kV substation		
2924	Njutänger–Mehedeby new 400 kV power line		
	Decommissioning project		**2031–2037**
2904	Forsse–Stadsforsen power line decommissioning[16]		
2907	Hällsjö–Söderala power line decommissioning		
3882	Stackbo substation decommissioning and Valbo substation decommissioning		
2905	Stadsforsen–Hällsjö power line decommissioning		
2925	Söderala–Valbo substation decommissioning		
3886	Untra 220 kV new connection and substation decommissioning		
3927	Valbo–Untra power line decommissioning		
3926	Stackbo–Valbo power line decommissioning		
2929	Söderala substation decommissioning		
3928	Untra–Horndal power line decommissioning		
2908	Hjälta–Nysäter–Ängsberg power line decommissioning		

15. Planned commissioning in 2026

16. Planned decommissioning in 2027

THE UPPSALA LEG – SOLLEFTEÅ INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
		Preparatory phase	**2026–2030**
2910	Kilforsen–Ramsele - capacity upgrade		
2911	Nesse - new substation[17]		
2909	Betåsen–Nasse - new 400 kV power line		
2974	Nesse - power line initiatives		

THE UPPSALA LEG – UPPSALA INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
		Preparatory phase	**2028–2033**
3880	Odensala substation station refurbishment and extension[18]		
3881	Plenninge new 400 kV substation		
3879	Jälla new 400 kV substation		
3895	Plenninge–Odensala power line decommissioning		
3884	Bredåker–Jälla power line renewal		
3890	Bredåker–Jälla new 220 kV power line		
3892	Bredåker–Plenninge power line decommissioning		
3897	Jälla–Plenninge new 400 kV power line		
3889	Plenninge–Odensala new 400 kV power line		
3883	Mehedeby–Jälla new 400 kV power line		
3894	Untra–Bredåker power line decommissioning		

17. Projects in the contracting phase

18. Projects in the contracting phase

THE VÄSTERÅS LEG – INLAND INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
		Preparatory phase	**2032–2035**
2918	Bispgården new 400 kV substation		
3872	Kilforsen substation expansion		
2937	Kilforsen–Bispgården new 400 kV power line		
2861	Ockelbo 220 kV decommissioning		
2951	Bispgården–Fallviken new 400 kV power line		
2869	Dönje substation decommissioning		
2027	Järvissle branch–Hällsjö power line decommissioning		
2962	Ljusdal substation decommissioning		
2900	Stadsforsen–Torpshammar power line decommissioning		
2956	Dönje–Ockelbo power line decommissioning		
2939	Ljusdal–Dönje power line decommissioning		
2957	Ockelbo–Horndal power line decommissioning		
2960	Ånge–Ljusdal power line decommissioning		
2938	Krångede–Bräcke decommissioning		

THE VÄSTERÅS LEG – LAFORSEN INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
		Preparatory phase	**2030–2033**
2948	Laforsen 220 kV decommissioning		
2857	Laforsen new 400 kV substation		
2959	Laforsen–Horndal power line decommissioning		
2863	Ånge–Laforsen power line decommissioning		

THE VÄSTERÅS LEG – OCKELBO INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
		Preparatory phase	**2029–2032**
3735	Horndal substation renewal		
3852	Munga new 400 kV substation		
3874	Fallviken new 400 kV substation		
2853	Grönviken substation expansion		
3873	Grönviken–Fallviken new 400 kV power line		
3856	Horndal new 400 kV substation		
3858	Fallviken–Horndal new 400 kV double power line		
3876	Horndal–Munga new 400 kV double power line		

THE VÄSTERÅS LEG – VÄSTERÅS INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning
	Västerås investment package, part 1	**Preparatory phase**	**2029–2032**
3855	Himmeta renewal and voltage increase[19] [20]		
3868	Horndal–Finnslätten power line decommissioning		
3860	Munga–Bysingsberg new 400 kV power line		
3859	Munga–Hamra new 400 kV power line		
	Västerås investment package, part 2	**Preparatory phase**	**2028–2032**
3899	Arosverket substation decommissioning and branching 220 kV power line		
3005	Finnslätten substation decommissioning		
3004	Finnslätten–Hamra power line decommissioning		
3867	Hamra substation decommissioning		

19. Planned commissioning in 2025

20. The project is in the contracting phase

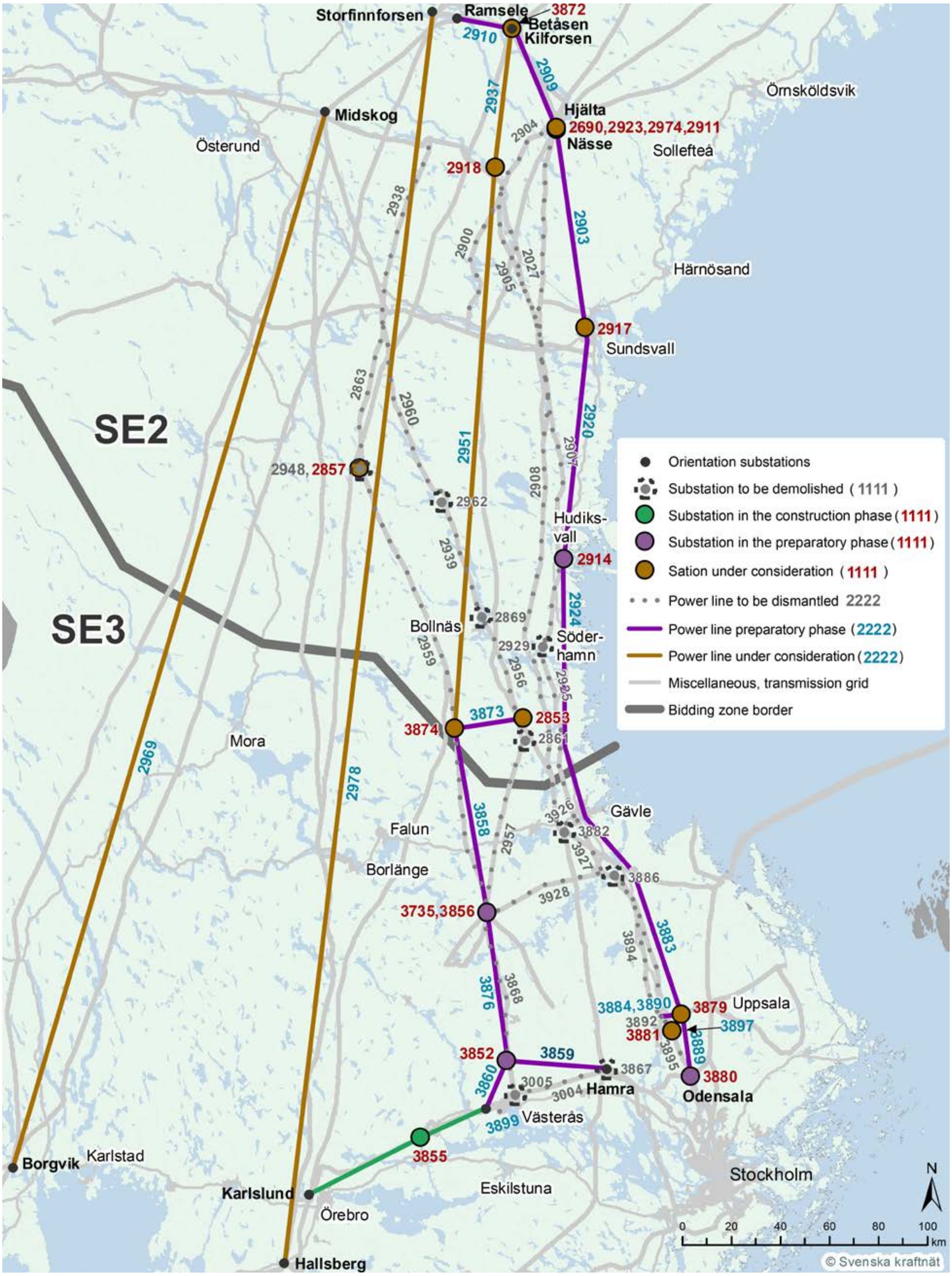
THE HALLSBERG LEG

Map no.	Project description	Phase	Planned commissioning
2978	The project is in the contracting phase	Under consideration	2037–2041

THE KARLSTAD LEG

Map no.	Project description	Phase	Planned commissioning
2969	Karlstad investment package	Under consideration	2033–2035

NordSyd – map



Storfinnforsen
Ramsele
3872
Betåsen
Kilforsen
2910
2909
2937
Örnsköldsvik
Midskog
Hjälta
2690,2923,2974,2911
Nässe
Österund
Sollefteå
2904
2918
2938
2903
2900
2027
2905
Härnösand
2917
Sundsvall
2863
2960
2920
SE2
2951
2907
2948, 2857
2908
2962
Hudiks-
vall
2914
2939
SE3
2924
2869
Bollnäs
2929
Söder-
hamn
2959
2956
2925
3873
3874
2853
2861
Mora
2969
2978
3858
3926
Gävle
Falun
2957
3882
3927
Borlänge
3886
3928
3735,3856
3894
3883
3876
3868
3884,3890
3879
Uppsala
3892
3881
3897
3895
3889
3852
3859
3867
3880
3860
3005
3004
Hamra
Odensala
Västerås
3899
3855
Borgvik
Karlstad
Stockholm
Karlslund
Eskilstuna
Örebro
Hallsberg
N
0 20 40 60 80 100 km
© Svenska kraftnät
Orientation substations
Substation to be demolished (1111)
Substation in the construction phase (1111)
Substation in the preparatory phase (1111)
Sation under consideration (1111)
Power line to be dismantled 2222
Power line preparatory phase (2222)
Power line under consideration (2222)
Miscellaneous, transmission grid
Bidding zone border

Stockholms Ström and Storstockholm Väst

Här samlas alla projekt kopplade till investeringspaketen Stockholms Ström och Storstockholm Väst, se avsnitt 4.3.1.

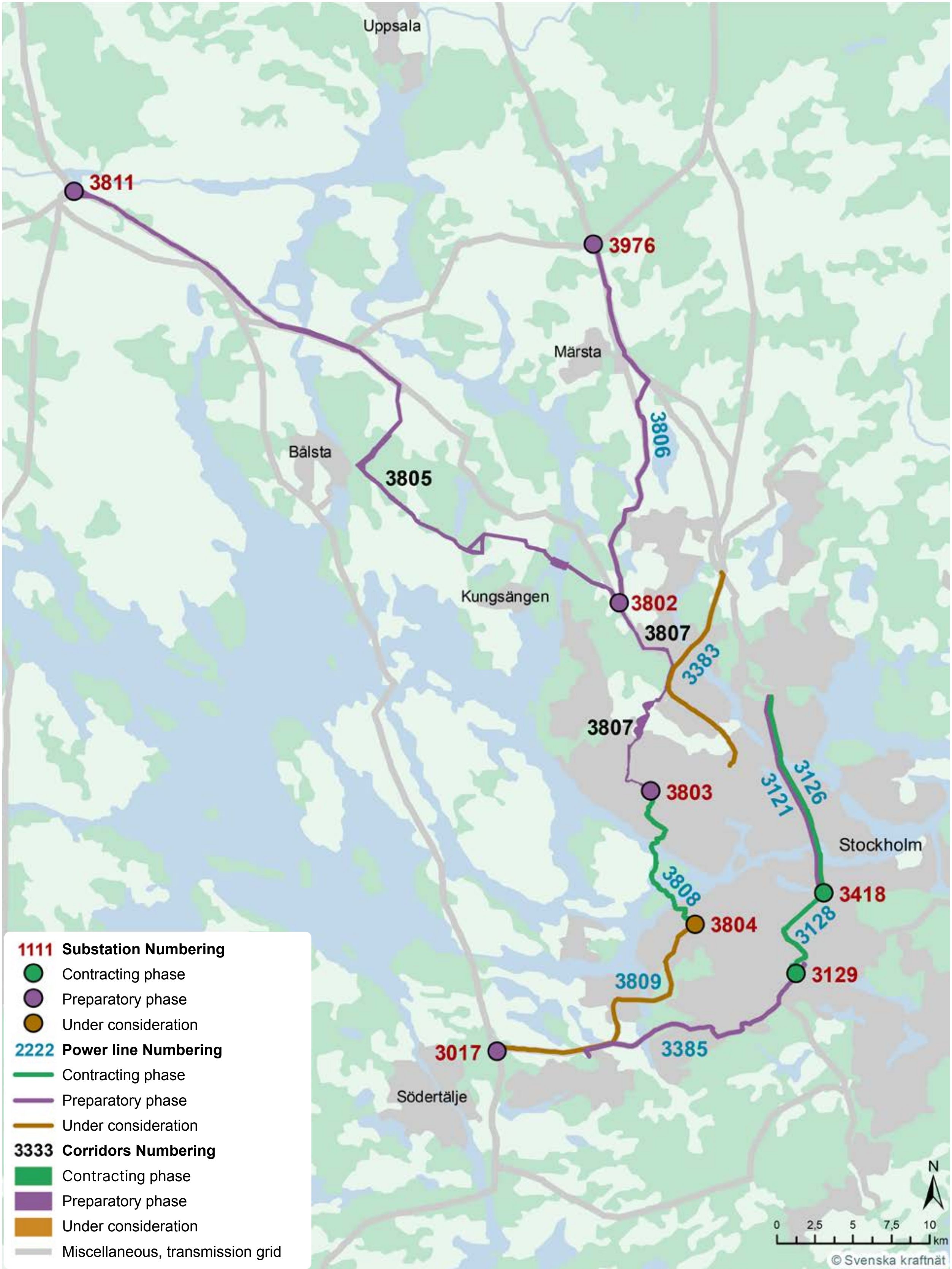
STOCKHOLM STRÖM

Map no.	Project description	Phase	Planned commissioning	Driver
3418	Skanstull new 400 kV substation	Contracting phase	2024	System reinforcement
3129	Snösätra Substation	Contracting phase	2024	System reinforcement
3128	Örby-Snösätra and Snösätra Högdalen new underground cable	Contracting phase	2024	System reinforcement
3126	Anneberg-Skanstull tunnel	Contracting phase	2028	System reinforcement
3385	Lindhov-Högdalen dismantling and diverting Hågelby	Preparatory phase	2026	Reinvestment
3121	Anneberg-Skanstull 400 kV cable system	Preparatory phase	2030	System reinforcement
3383	Hagby–Järva power line dismantling	Under consideration	2031	Reinvestment

STORSTOCKHOLM VÄST

Map no.	Project description	Phase	Planned commissioning	Driver
3976	Odensala new connection	Contracting phase	2025	Connection
3811	Hamra substation renewal with expansion	Preparatory phase	2028–2030	System reinforcement
3807	Kappetorp–Råcksta new 400 kV power line	Preparatory phase	2030	System reinforcement
3802	Kappetorp's new 400 kV substation	Preparatory phase	2030	System reinforcement
3808	Beckomberga–Bredäng new 400 kV power line (Ellevio)	Contracting phase	2030	System reinforcement
3804	Björksätra new 400 kV substation	Preparation phase	2030	System reinforcement
3809	Björksätra–Kolbotten power line renewal	Preparatory phase	2030	System reinforcement
3805	Hamra–Kappetorp new 400 kV line	Preparatory phase	2030	System reinforcement
3017	Kolbotten substation renewal	Preparatory phase	2030	Reinvestment
3806	Odensala–Kappetorp new 400 kV power line	Preparatory phase	2030	System reinforcement
3803	Råcksta new 400 kV substation	Preparatory phase	2030	System reinforcement

Stockholms Ström and Storstockholm Väst – map



South-west Sweden

All projects linked to the investment packages Västkust, Göteborg Norr and interconnectors from the west coast are brought together here, see Section 4.3.2. Other projects in SE3–SE4 can be found on the maps "Other projects in bidding zone SE3" and "Other projects in bidding zone SE4".

VÄSTKUST INVESTMENT PACKAGE

Map no.	Project description	Phase	Planned commissioning	Driver
3739	Kilanda substation renewal	Contracting phase	2024	Reinvestment
4653	Söderåsen-Barsebäck power line renewal	Contracting phase	2024	Reinvestment
4652	Breared-Söderåsen power line renewal	Contracting phase	2026	Reinvestment
3619	Skogssäter-Kilanda power line renewal	Preparatory phase	2026	Reinvestment
3640	Horred-Breared power line renewal	Preparatory phase	2028	Reinvestment
3634	Stenkullen-Horred power line renewal	Preparatory phase	2029–2030	Reinvestment
3647	Kilanda–Stenkullen power line renewal	Preparatory phase	2031	Reinvestment

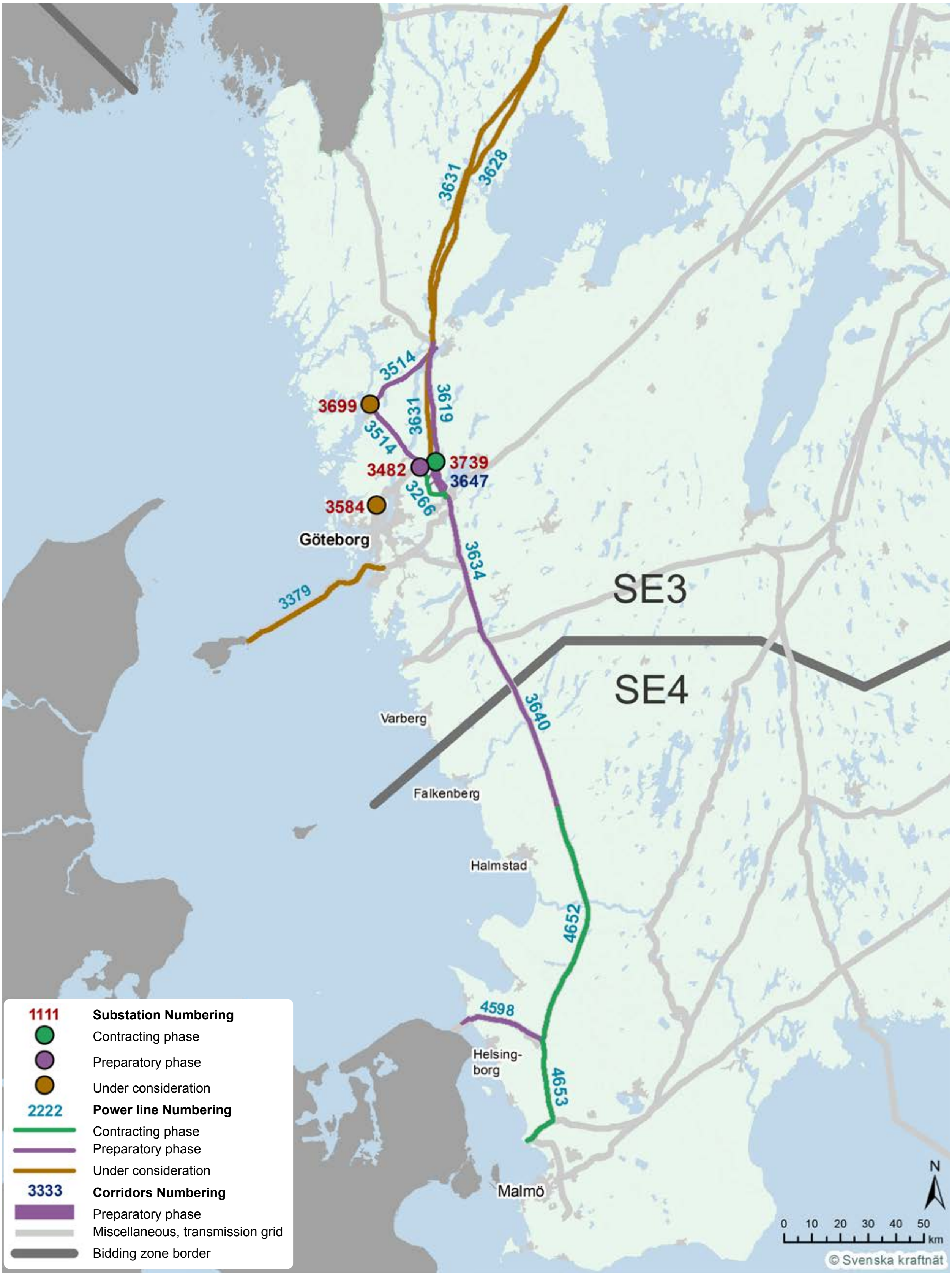
GÖTEBORG NORR

Map no.	Project description	Phase	Planned commissioning	Driver
3266	Ingelkärr–Stenkullen new 400 kV power line	Contracting phase	2026	System reinforcement
3482	Ingelkärr new 400 kV substation	Preparatory phase	2026	System reinforcement
3584	Hisingen, new 400/130 kV transformer	Under consideration	2027	Connection
3514	Skogsäter–Ingelkärr new 400 kV power line	Preparatory phase	2029–2031	System reinforcement
3699	Stenungsund new 400 kV substation	Under consideration	2029	Connection
3628	Borgvik–Skogsäter power line renewal	Under consideration	2034	Reinvestment
3631	Skogsäter–Kilanda power line renewal part 2	Under consideration	2038	Reinvestment

INTERCONNECTORS

Kartnr	Projektbeskrivning	Fas	Planerad idrifttagning	Driver
4598	Denmark–Sweden Cable connections renewal	Preparatory phase	2026	Reinvestment
3379	Total renewal of the entire Konti-Skan link	Under consideration	2036	Reinvestment

South-west Sweden - map

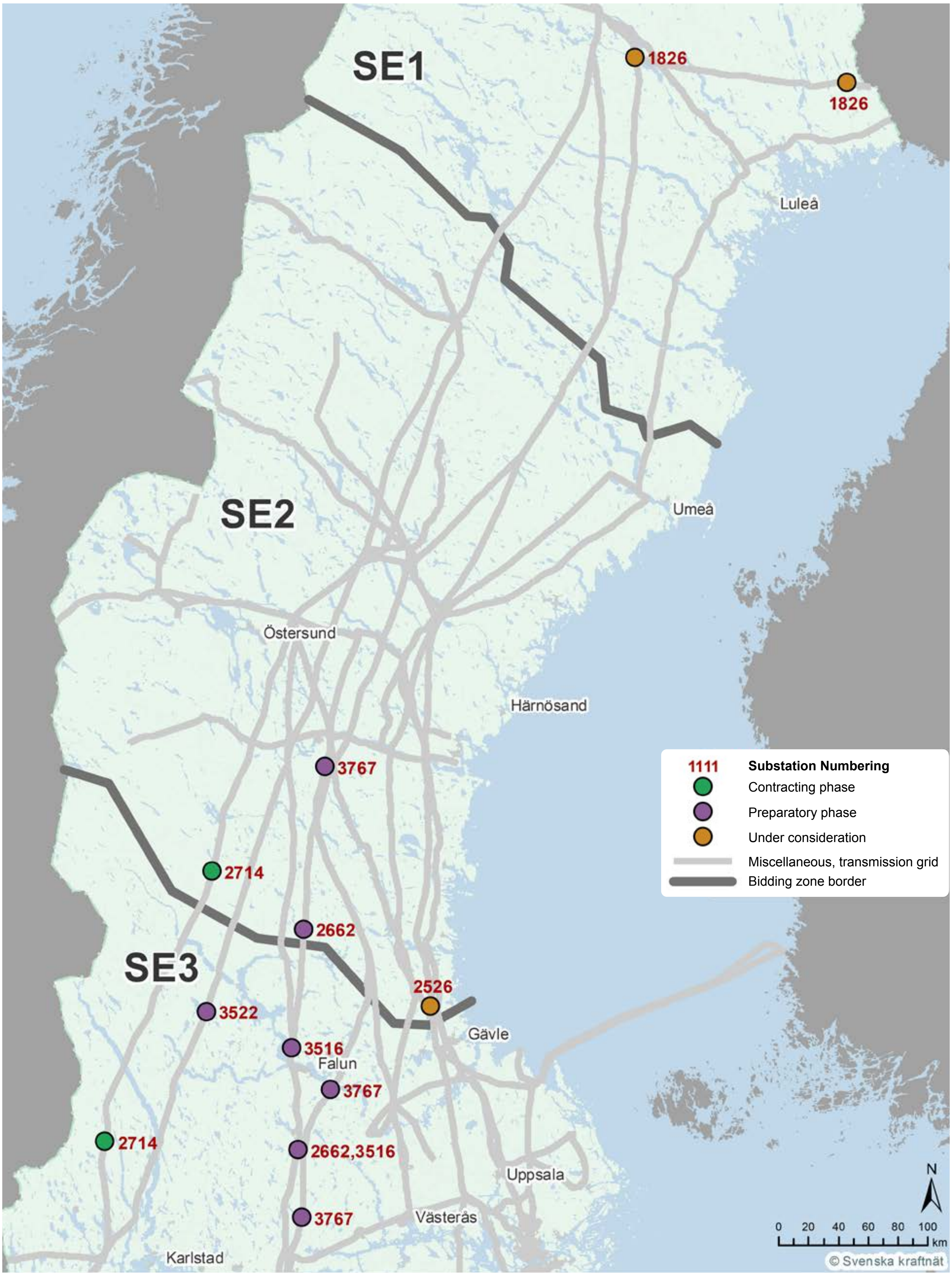


Series compensation project

The series compensation projects described in section 4.2.3 are listed here.

Map no.	Project description	Phase	Planned commissioning	Driver
2714	Olingan and Gräsmark series compensation	Contracting phase	2026	System reinforcement
2662	Gäddtjärn and Snösjön series compensation	Preparatory phase	2027–2028	System reinforcement
3522	Kättbo substation renewal of series compensation	Preparatory phase	2027	System reinforcement
3516	Helgbo and Snösjön series compensation	Preparatory phase	2028	System reinforcement
3767	Tovåsen, Gustafs and Tränmossen series compensation	Preparatory phase	2028	System reinforcement
2526	Vittersjö substation renewal	Under consideration	2028	Reinvestment
1826	Isovaara substation renewal and Letsi new series compensation substation	Under consideration	2029	System reinforcement

Series compensation project - map



Connections under consideration

Här listas anslutningsprojekt som är under övervägande. De anslutningsprojekt där inriktningsbeslut har tagits finns under respektive elområdeskarta.

CONSUMPTION

Map no.	Project description	Electricity Area
2108	Midskog–Gräfsåsen–Rödflon–Åsbacken new 220 kV power line	SE2
2818	Bandsjö station expansion	SE2
2016	Bandsjö–Nysäter new 400 kV power line	SE2
2816	Åsbacken, new 400 kV substation	SE2
2109	Gräfsåsen and Rödflon, new 220 kV substations	SE2

ONSHORE WIND POWER

Map no.	Project description	Electricity Area
2582	Helgum wind power connection	SE2
2283	Storfinnforsen wind power connection	SE2
1989	Pålkem (Hällberget) wind power connection	SE1
2260	Bodriset wind power connection	SE2
2553	Orsa Finnmark wind power connection	SE2

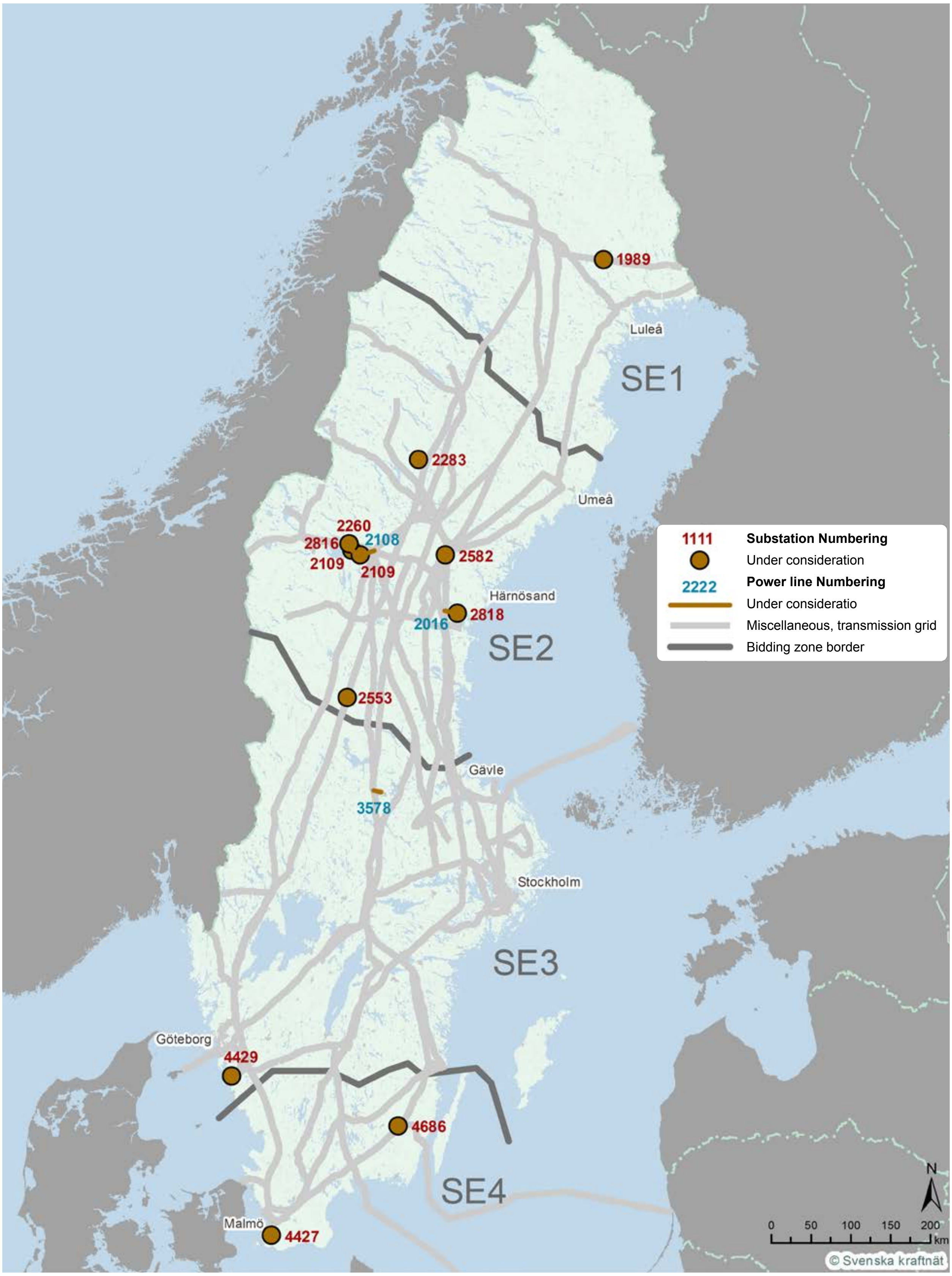
OFFSHORE WIND POWER

Map no.	Project description	Electricity Area
4427	Arrie connection of offshore wind power	SE4
4686	Vackamo connection of substation for offshore wind power	SE4
4429	Nordvära connection of substation for offshore wind power	SE4

MISCALEANEOUS CONNECTION

Map no.	Project description	Electricity Area
3578	Bäsna–Repbäcken new 400 kV power line and new switchgear bay in Bäsna	SE3

Connections under consideration – map



Other projects in bidding zone SE1

The projects in bidding zone SE1 that are not on the maps for Fossilfritt Övre Norrland, series compensation projects or connections under consideration are listed here.

PROJECTS IN THE CONSTRUCTION PHASE

Map no.	Project description	Planned commissioning	Driver
1072	Aurora Line	2025–2026	Market integration
1133	Messaure substation renewal	2025–2026	Reinvestment

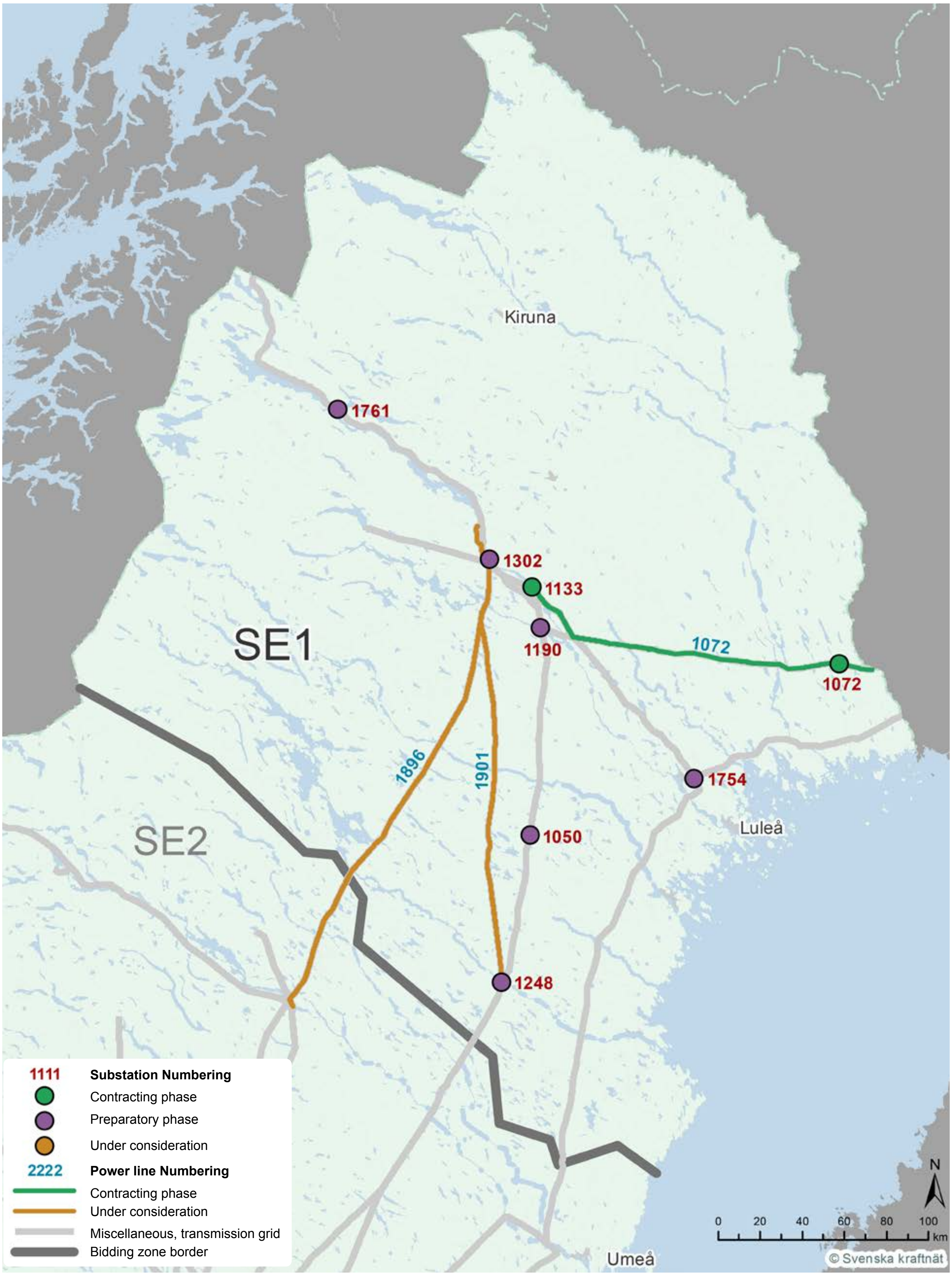
PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
1190	Letsi substation renewal	2026–2027	Reinvestment
1302	Ligga substation renewal	2026–2027	Reinvestment
1050	Trolltjärn new transformer	2026	Connection
1754	Svartbyn substation renewal	2028	Reinvestment
1248	Vargfors substation renewal	2028	Reinvestment
1761	Vietas substation renewal	2028	Reinvestment

PROJECTS UNDER CONSIDERATION

Map no.	Project description	Planned commissioning	Driver
1901	Ligga-Vargfors power line renewal	2037	Reinvestment
1896	Porjus-Grundfors power line renewal	2037	Reinvestment

Other projects in SE1 - map



Other projects in bidding zone SE2

The projects in bidding zone SE2 that are not on the maps for NordSyd, series compensation projects or connections under consideration are listed here. Note that there are two maps in this section. One for projects in the contract and preparatory phases and one for projects under consideration.

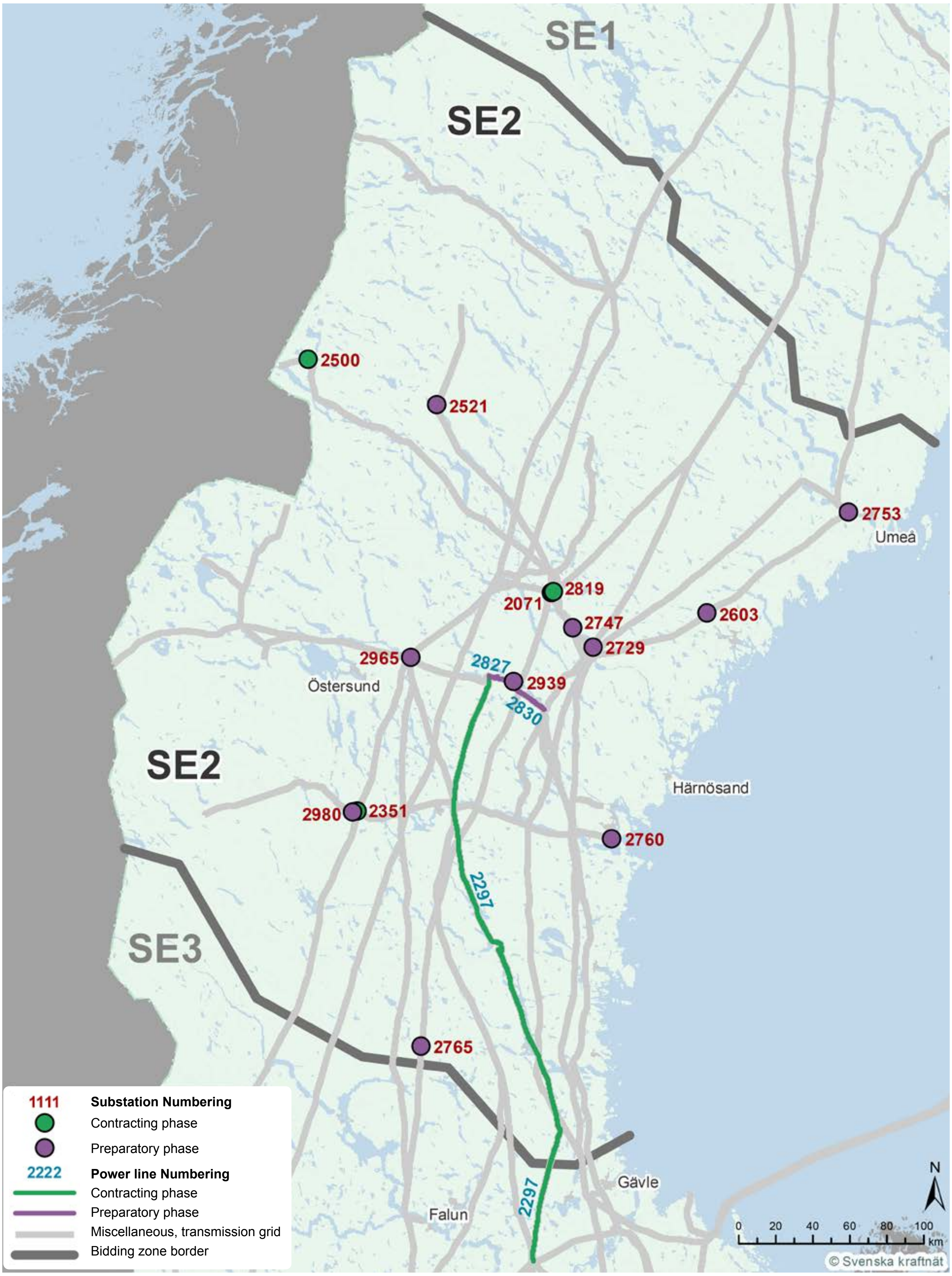
PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
2351	Rätan renewal, restructuring and wind power connection	2019–2025	Reinvestment
2819	Betåsen connection Krange Wind cluster	2023–2024	Connection
2297	Krångede–Horndal life extension	2025–2026	Reinvestment
2500	Linnvasselv additional shunt reactor	2025	System reinforcement

PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
2603	Moliden partial renewal	2025	Reinvestment
2939	Hammarstrand new substation	2026	Connection
2753	Stornorrfors substation renewal	2026–2027	Reinvestment
2765	Gäddtjärn new 400 kV substation	2027	Connection
2071	Kilforsen substation renewal	2027	Reinvestment
2827	Krångede-Gammelänge power line renewal	2027	Reinvestment
2965	Midskog industry connection	2027	Connection
2747	Moforsen substation renewal	2027	Reinvestment
2980	Rätan substation renewal	2027	Reinvestment
2830	Stadsforsen–Krångede power line renewal	2027	Reinvestment
2760	Vaple substation renewal	2027–2028	Reinvestment
2729	Forsmo substation renewal	2028	Reinvestment
2521	Korsselbränna substation renewal and expansion	2028	Reinvestment

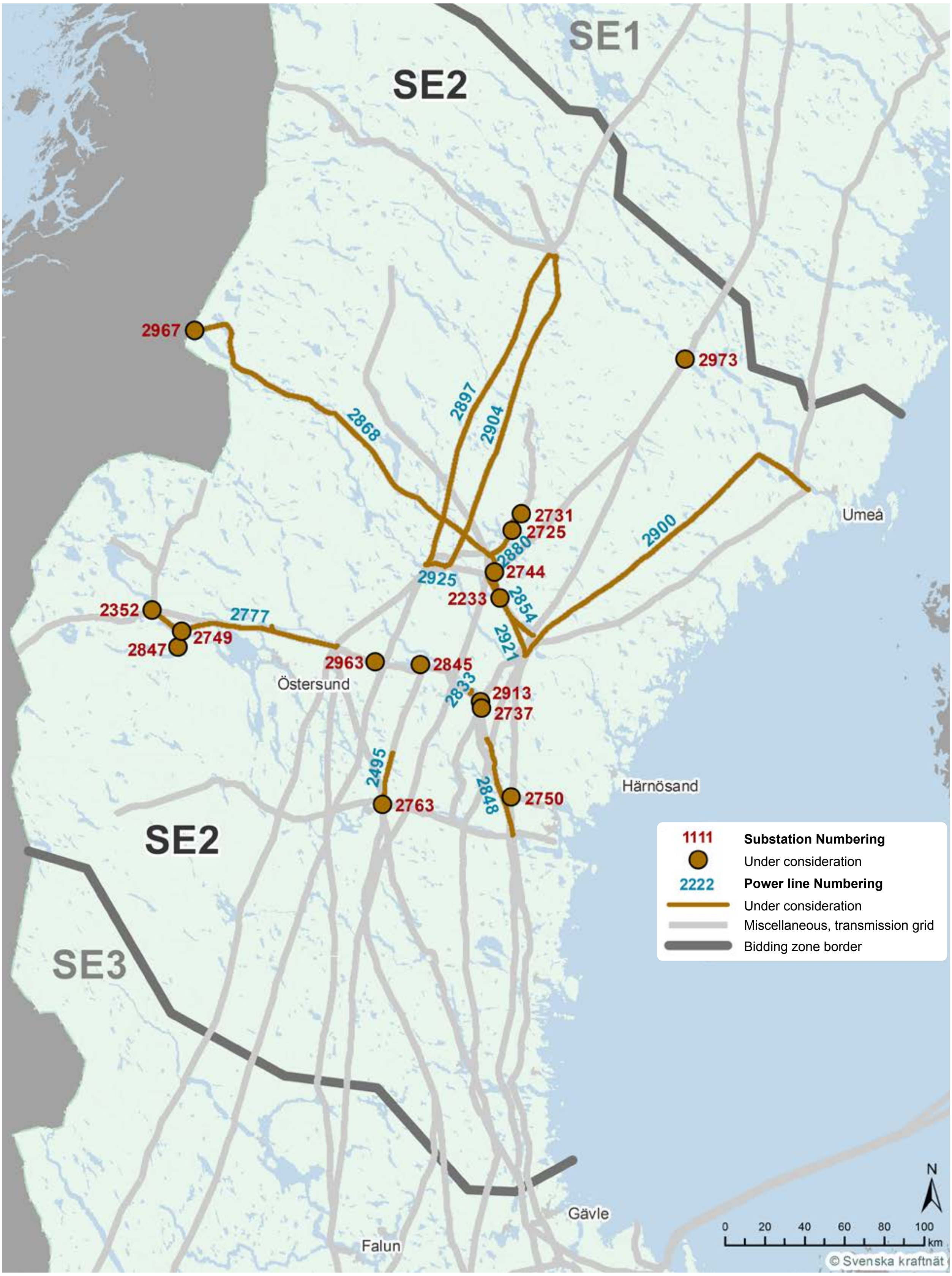
Other projects in SE2 - map



PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
2737	Hölleforsen substation renewal	2027	Reinvestment
2744	Lasele substation renewal	2027	Reinvestment
2749	Mörsil substation renewal	2028	Reinvestment
2731	Gulsele substation renewal	2029	Reinvestment
2725	Degerforsen substation renewal	2030	Reinvestment
2967	Linnvasselv substation renewal	2030	Reinvestment
2233	Nämforsen substation renewal	2031	Reinvestment
2973	Chew substation renewal	2031	Reinvestment
2913	Stadsforsen substation renewal	2032	System reinforcement
2963	Stugun substation renewal	2032	Reinvestment
2763	Cancel substation renewal	2032	Reinvestment
2854	Forsmo–Lasele–Långbjörn power line renewal	2033	Reinvestment
2845	Troubled substation renewal	2033	Reinvestment
2750	New seats substation renewal	2033	Reinvestment
2848	Stadsforsen Hällsjö power line renewal	2033–2034	Reinvestment
2847	Sällsjö substation renewal	2033	Reinvestment
2495	Bräcke–Ånge power line renewal	2034	Reinvestment
2352	Järpströmmen substation renewal	2034	Reinvestment
2777	Midskog–Järpströmmen 220 kV upgrade to 400 kV	2035	System reinforcement
2897	Grundfors-Storfinnforsen power line renewal	2037	Reinvestment
2921	Kilforsen–Hjälta power line renewal	2038	Reinvestment
2925	Ramsele–Storfinnforsen power line renewal	2038	Reinvestment
2833	Svarthålsforsen branching power line renewal	2038	Reinvestment
2880	Långbjörn–Degerforsen branching power line renewal	2040	Reinvestment
2868	Långbjörn–Linnvasselv and Junsterforsen branching power line renewal	2042	Reinvestment
2904	Grundfors–Ramsele power line renewal	2043	Reinvestment
2900	Stornorrfors–Hjälta power line renewal	2043	Reinvestment

Other projects in SE2 - map



Other projects in bidding zone SE3

The projects in bidding zone SE3 that are not on the maps for NordSyd, Stockholm, south-west Sweden, series compensation projects or connections under consideration are listed here. Note that there are two maps in this section. One for projects in the contract and preparatory phases and one for projects under consideration.

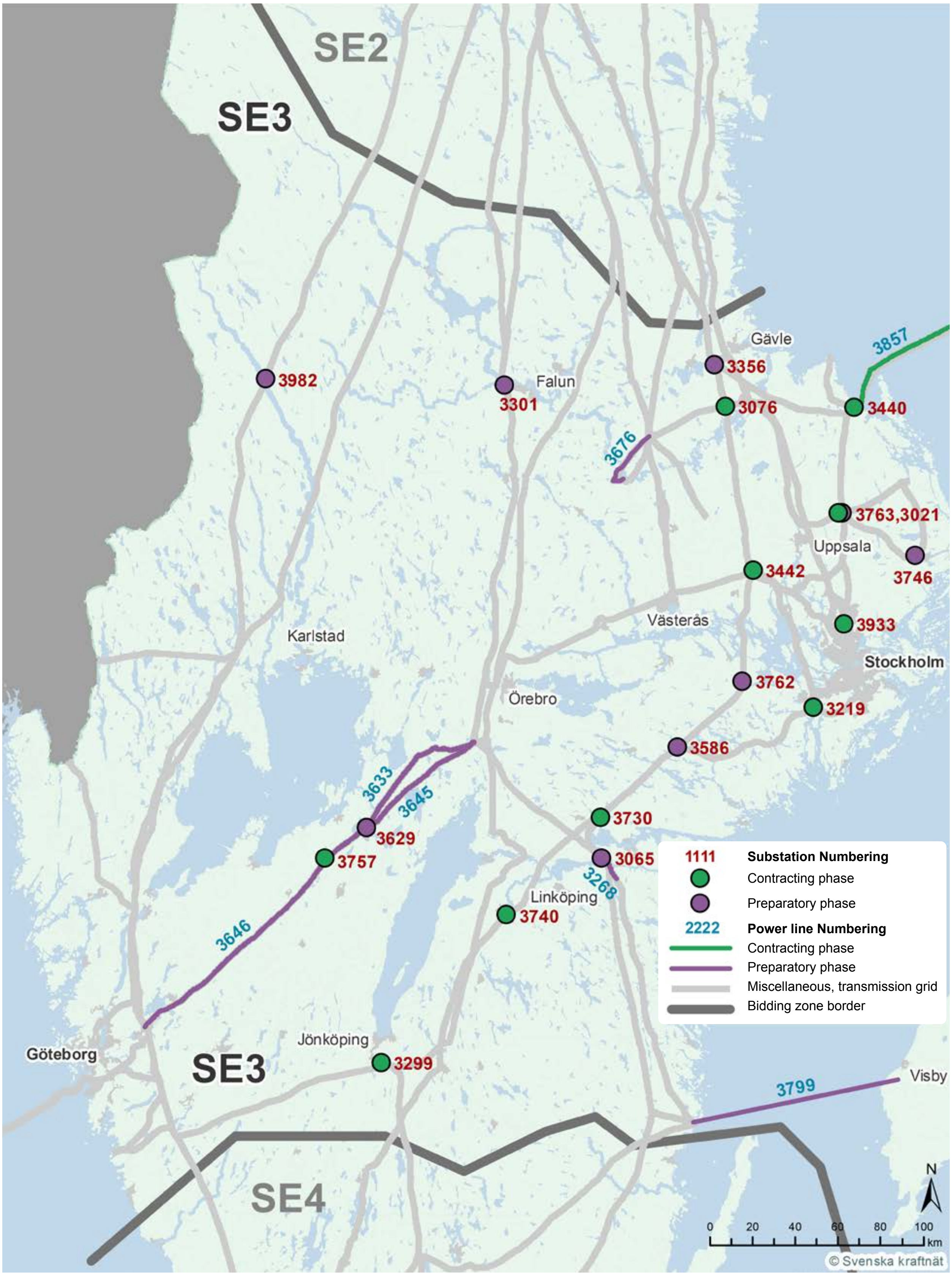
PROJECTS IN THE CONSTRUCTION PHASE

Map no.	Project description	Planned commissioning	Driver
3757	Timmersdala substation renewal	2025	Reinvestment
3076	Fenno-Skan 2 SCM replacement	2024–2025	Reinvestment
3740	Kolstad substation renewal	2024	Reinvestment
3763	Tuna new transformer	2024–2025	System reinforcement
3857	Fenno-Skan 1 life extension	2024–2035	Reinvestment
3440	Forsmark substation renewal	2025	Reinvestment
3933	Hagby connection	2025	Connection
3730	Glan substation renewal and new reactor	2025	Reinvestment
3219	Hall new STATCOM installation	2025–2026	System reinforcement
3442	Hamra renewal SVS installation	2025–2026	Reinvestment
3299	Tenhult substation renewal	2025	Reinvestment

PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
3586	Hedenlunda new connection	2025–2026	Connection
3356	Ängsberg new connection	2025–2026	Connection
3676	Horndal–Avesta power line renewal	2026–2027	Reinvestment
3982	Tandö new 400 kV substation wind power connection	2026	Connection
3762	Åker substation renewal	2026	Reinvestment
3301	Bäsna substation renewal	2027–2028	Reinvestment
3065	Kimstad substation renewal	2027	Reinvestment
3746	Malsta substation renewal	2027	Reinvestment
3021	Tuna 220 kV substation renewal	2027	Reinvestment
3629	Töreboda new 400 kV substation	2028	Connection
3268	Kimstad adaptation of power lines at the Göta canal	2029	Reinvestment
3633	Hallsberg–Timmersdala new 400 kV power line	2030–2032	Connection
3799	Gotlandsförbindelsen	2031–2032	System reinforcement
3645	Hallsberg-Timmersdala power line renewal	2031–2033	Reinvestment
3646	Timmersdala-Stenkullen power line renewal	2031–2033	Reinvestment

Other projects in bidding zone SE3



PROJECTS UNDER CONSIDERATION

Map no.	Project description	Planned commissioning	Driver
3000	Lindbacka partial renewal	2026	Reinvestment
3404	Hallsberg new dynamic shunt compensation	2027	System reinforcement
3434	Ekhyddan new dynamic shunt compensation	2028	System reinforcement
3969	Krylbo substation renewal	2030	Reinvestment
3850	Avesta substation renewal	2031	Reinvestment
3234	Uddebo substation renewal	2032	Reinvestment
3971	Morgårdshammar substation renewal	2033	Reinvestment
3636	Glan-Ekhyddan power line renewal	2035	Reinvestment
3690	Forssjön–Krylbo power line renewal	2038	Reinvestment
3632	Glan–Kimstad power line renewal	2039	Reinvestment
3946	Konti-Skan 1 HVDC link renewal	2040	Market integration
3458	Hamra–Åker power line renewal	2041	Reinvestment
3669	Hedenlunda–Glan power line renewal	2041	Reinvestment
3668	Åker–Hedenlunda power line renewal	2041	Reinvestment

Other projects in bidding zone SE3

Other projects in bidding zone SE4

The projects in bidding zone SE4 that are not on the maps for south-west Sweden or connections under consideration are listed here.

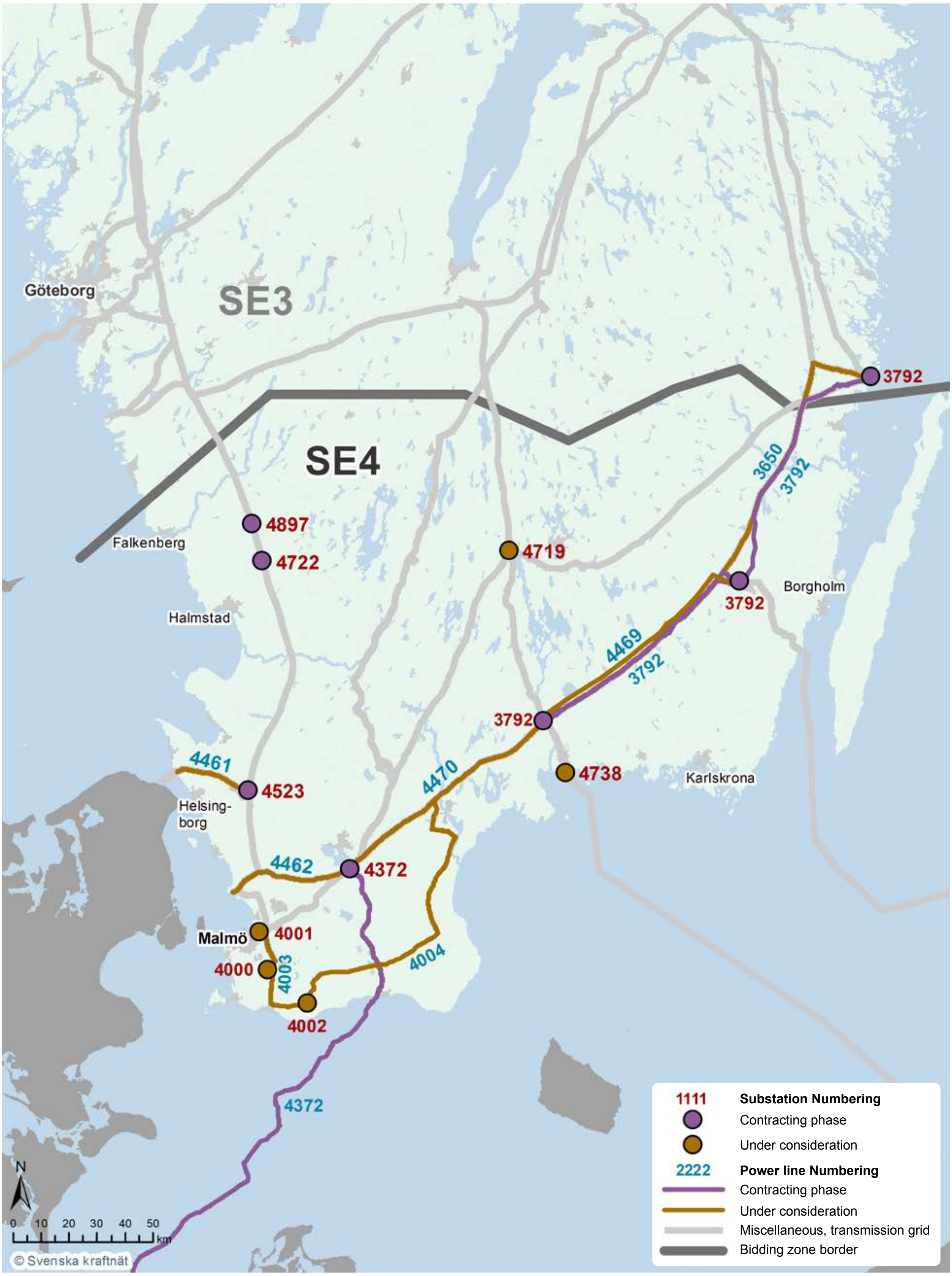
PROJECTS IN THE PREPARATORY PHASE

Map no.	Project description	Planned commissioning	Driver
4523	Söderåsen new system transformer	2024	Connection
4897	Häradsbo new shunt capacitor	2025	System reinforcement
3792	Ekhyddan-Nybro-Hemsjö new 400 kV power line	2027–2028	Market integration
4722	Breared substation renewal	2027	Reinvestment
4372	Hansa Powerbridge	2028–2029	Market integration

PROJECTS UNDER CONSIDERATION

Map no.	Project description	Planned commissioning	Driver
4738	Karlshamn substation renewal	2028	Reinvestment
3650	Ekhyddan–Nybro power line renewal	2033	System reinforcement
4469	Nybro–Hemsjö power line renewal	2033	Reinvestment
4719	Eleventh substation renewal	2035	Reinvestment
4470	Hemsjö–Hurva power line renewal	2037	Reinvestment
4462	Hurva–Barsebäck power line renewal	2043	Reinvestment
4461	Söderåsen–Kristinelund	2043	Reinvestment
	Trelleborg investment package part 1	**2029–2035**	**System reinforcement**
4000	Arrie substation renewal		
4001	Sege substation expansion		
4002	Trelleborg East new 400 kV substation		
4003	Sege–Arrie–Trelleborg new 400 kV power line		
	Trelleborg investment package part 2	**2036–2040**	
4004	Hemsjö–Trelleborg		

Other projects in bidding zone SE4



Overhaul of power lines and other projects

OVERHAUL OF POWER LINES

Project description	Planned commissioning	Driver
Power line overhaul investment package 0	2022–2024	Reinvestment
Power line overhaul package 1	2020–2025	Reinvestment
Power line overhaul package 2	2027	Reinvestment
Power line overhaul package 3	2029	Reinvestment
Power line overhaul package 4	2031	Reinvestment

Other projects in bidding zone SE1–SE4

Project description	Planned commissioning	Driver
Life extension substation measures investment package 1	2024–2025	Reinvestment
Replacement of composite cap and pin insulators	2026	Reinvestment
Installation of reactors in the transmission grid	2028	System reinforcement
Step and touch project	2019–2025	Reinvestment
Replacement of bypass switches in several substations	2024	Reinvestment
Renewal of control infrastructure	2019–2047	Reinvestment
Aviation obstruction lighting on pylons, 60 metres and higher	2025–2026	Reinvestment
Package procurement - Telecommunications equipment	2030	
Sydvästlänken - installation of potential lines	2026	Reinvestment
Nordbalt - installation of potential lines	2026	Reinvestment

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