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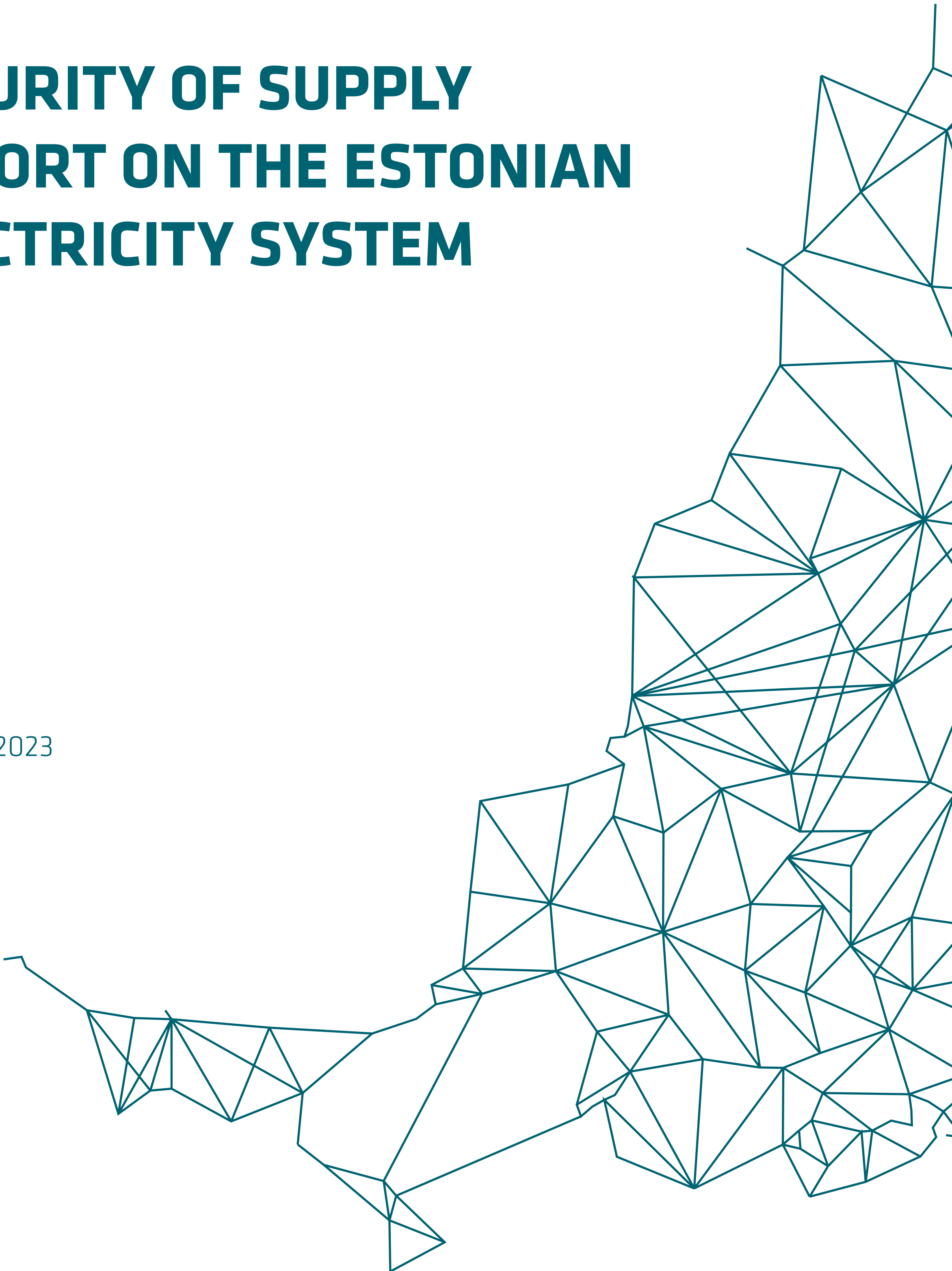
SECURITY OF SUPPLY REPORT ON THE ESTONIAN ELECTRICITY SYSTEM

TALLINN 2023



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Elering is an independent and autonomous operator of a combined gas and power transmission system, the main goal of which is to ensure the high-quality supply of energy to Estonian consumers. To this end, the company administers and develops domestic and cross-border energy infrastructure. With its activities, Elering ensures the conditions for the functioning of the energy market and for the development of the economy.

To accomplish these functions, Elering submits a report on the security of supply pursuant to the Electricity Market Act (subsections 39 (7) and (8); subsections 66 (2), (3) and (4)). The assessment of the system adequacy reserve was conducted pursuant to sections 14 and 141 of the Grid Code on the functioning of the electricity system.

CONTENTS

Security of supply plan

A plan is in place to ensure Estonia's security of electricity supply. This plan also has a contingency plan and the contingency plan has a contingency plan.

The energy crisis of 2021-2022 and the geopolitically tense situation have left many worried about whether we will have enough electricity and whether it will be affordable, both for the coming winter and for the years to come. The anxious environment around us has added a palpable amount of emotion and subjective cognition to the social discussions, making it more difficult to make reasoned judgements and explain conclusions. This is probably also the reason for the doubts that are still being raised, that perhaps Estonia has been late in making major and important energy decisions and that security of supply will therefore be poor in the near future.

Affordable electricity will reach consumers at any time through the connection of more and more power plants generating electricity from low-cost renewable sources. By 2030, Estonia should have enough renewable electricity to cover local consumption on an annual basis. However, there will certainly be many hours when local wind and solar power plants are not able to produce enough electricity. During these hours, large amounts of electricity can be imported from power plants in other countries. The capacity of the international connections of Estonia today already exceeds our own peak consumption and we are preparing additional connections with both Finland and Latvia.

If there are not enough cheap generation resources in the rest of the region either, or if there is insufficient interconnection capacity between countries, there must also be a sufficient amount of locally controlled generation capacity. The more renewable power plants there are in the system, the fewer hours the controlled plants need to be operated for, but their usable capacity for Estonia still needs to be in the order of 1,000 MW, or somewhat more if consumption increases significantly in the future.

TSOs base their security of supply assessments on science-based analyses and existing regulations. The TSOs are thereby more conservative than average in their approach to all kinds of future assumptions and forecasts, precisely in order not to find themselves in a situation where a positive future trend or event that they had hoped for did not materialise in reality, thus creating a security of supply problem. The security of supply assessment takes into account major power system failures, fluctuations in generating capacity caused by to climatic variability, higher than normal electricity consumption due to cold spells and other complex situations that may arise due to a combination of random factors. An analysis carried out in this way could give a sufficient degree of certainty that the reality will be less complex than the forecast made by the analysis.

In the short term, the security of supply picture is quite clear – we are much more confident going into this winter than a year ago. In the region's point of view, new generation capacity has been added, hydropower reserves are clearly larger and, perhaps most critically, the risk of a winter shortage of natural gas, which is an important energy source in Europe, has been significantly reduced.

The Estonian transmission network is operating at an exemplary level – customers continue to receive more than 99.99 percent of energy. Irrespective of the difficult circumstances, we have been able to keep the projects for developing the network that are required for separation from the Russian power grid and connection to the power grid of Continental Europe on schedule as initially planned, or have even adopted an accelerated schedule. Considering the ambitious goal for renewable energy in Estonia for 2030, we are making preparations for reinforcing the Estonian electricity transmission network at a rapid pace in order to add new power plants, the addition of which is still gaining momentum and will peak only a couple of years before the arrival of 2030. This way, we can avoid the risk that the time- and resource-intensive process of merging power plants will become an obstacle to the start-up of new generation capacity at the end of this decade.

Speaking of the risks associated with managing the grid, we have mitigated one of the biggest, which is the potential need to keep the grid functioning in a situation where our aggressive eastern neighbour might try to use energy as a weapon against us. We have confidence that if Russia were to unilaterally separate the Baltic states from the electricity system we are still sharing, we will be able to guarantee the stability of our system and join the Continental European system without delay. This is the case despite the fact that all the investments and activities planned for the scheduled merger have not yet been completed. We have also reached an agreement with our Latvian and Lithuanian partners to bring forward the regular connection to the European power grid by almost a year to further reduce the geopolitical risks emerging from an aggressive Russia.

In order to ensure autonomous control of the electricity system, in particular to maintain a balance between generation and consumption after the Russian system is desynchronised, a market for fast reserves is being set up to be ready to manage changes in the system in a matter of seconds. There are enough reserves for this together with the new battery stations in Latvia and Lithuania and emergency reserve power plants at Elering's disposal. Reserves are also important in another respect – greater flexibility is needed to manage the electricity system, especially in the light of the growing share of renewable energy, as the unpredictability and forecasting error in the system increase. The goal of the Baltic countries is to have the possibility under EU law to build up fast reserves for years in advance, which would give potential investors greater certainty for building new, flexible power plants.

While there is no risk of electricity shortages this winter, changes in the electricity system, including an expected increase in consumption and the expected closure of obsolete power plants, will add tension to the situation in the second half of this decade, especially between 2027 and 2030. In order to ensure system adequacy, i.e. the availability of power plants necessary to cover consumption, it is necessary to be ready to implement capacity mechanisms. In Estonia, a scenario where the level of controlled capacity operating in the market falls below 1,000 MW is rather likely. Over the past five years, Elering has been preparing for the implementation of a strategic reserve, which will ensure that sufficient dispatchable capacity is available even on a particularly cold winter day, should renewable energy not be sufficient to cover peak demand. If consumption will grow as expected and the increasing consumption is mostly covered by renewable electricity, Estonia's electricity system will need a new, dispatchable power plant capable of providing reserve capacity that can be started up quickly to ensure a stable frequency.

Following the damage to Balticconnector on 8 October, the question of whether our infrastructure is sufficiently protected has also come under the spotlight. Should we not be doing something much more effective than we have done so far, especially to protect cables and pipes under the sea? But the reality is that we are always aware of the potential damage and failure of infrastructure, and the system is built in such a way that in the event of an unexpected loss of a key element, security of supply is not disrupted. However, it must also be clearly understood that infrastructure is scattered over a large territory, both in the sea and on land, that it is not realistic to defend it to the end and that simultaneous targeted attacks in many places can damage infrastructure to the point of disrupting its comprehensive functioning. Here, we have to use the tactic, which has proven itself in the Ukrainian war, of being ever better prepared in order to remedy any intentionally caused or accidental failure as quickly as possible. Following Russia's invasion of Ukraine, we have thoroughly assessed the risks of physically securing the infrastructure and have significantly increased the amount of reserves as well as deployed new types of back-up solutions that can put damaged infrastructure back into operation more quickly.

The challenging geopolitical environment, as well as organic changes in the energy sector – the rise of smart and renewable energy and the rapid addition of complex business processes, combined with the explosion of data volumes – require increasingly bigger digital 'muscle'. The digital muscle needs to be trained and resilient to attack, i.e. more vital data, systems and processes place high demands on cyber security. Systematic risk assessment, improvement of protection solutions, coordinated cooperation and the development of digital skills of staff are increasingly critical in the day-to-day work of the modern TSO.

The following report provides a comprehensive overview of these and many other issues. I would like to thank the Elering colleagues and partners who participated in the preparation of the report and wish everyone who is interested in energy a pleasant read!

Kalle Kilk
Chairman of the Elering Management Board

1 Summary

1. SUMMARY

1.1 Operation capacity

- ***The Baltic electricity systems are ready for emergency synchronisation with Continental Europe if Russia unilaterally cuts us off from its electricity system.***
- ***According to current plans, everything needed to manage the electricity system in a secure way will be ready for synchronisation in February 2025.***
- ***The addition of renewable energy in the Estonian and Baltic electricity systems will increase the need for fast frequency reserves and new investments in flexible resources must be made.***
- ***In order to ensure that Estonia has sufficient frequency reserves, Estonia is requesting a derogation from the European Commission for the long-term acquisition of reserves.***

The existence of the capability to manage the electricity system means that the electricity system withstands possible disruptions, the functioning of the system is planned in detail for the next day, the real-time management process is in place and there are sufficient reserve capacities. The capacity to manage the Estonian electricity system has been very good so far and there have been no interruptions to consumers due to management capacity.

A major change in the management of the electricity system is linked to the connection of the Baltic states with the Continental European Synchronous Area (CESA). Currently Estonia and the other Baltic states are part of the frequency area controlled by Russia and the 50 Hz frequency is the key parameter of the electricity system. In order to reduce Russia's influence, it is essential to connect to the CESA in time, a plan which has been accelerated by the Baltic countries to February 2025.

The probability that the Baltic electricity system may be unilaterally cut off from the Russian electricity system has grown substantially. Elering, together with the Baltic TSOs, has been working on mitigating this risk, and an agreement has been reached with the Continental European TSOs to make it possible to extraordinarily connect to the Continental European system, even if all investments are not yet ready. This will ensure security of supply even in the event of a unilateral disconnection of the Baltic states by Russia but will mean significantly higher costs for managing the system than today.

After synchronisation with the Continental European frequency area, Elering will use inertia as well as both automatic and manually activated reserve capacities – in other words, fast reserves. The local power plants must be capable of changing their production within seconds in order to ensure the balance of production and consumption in the system. For this purpose, the market of fast reserves will be created where market participants will be able to provide services to the system operators. According to analyses, there are sufficient units in the Baltic electricity system to provide the necessary reserves, taking into account the new battery installations in Latvia and Lithuania and Elering's Kiisa emergency reserve power plant. According to proposed design the TSO costs of acquiring the reserves are included in the balance providers balancing cost.

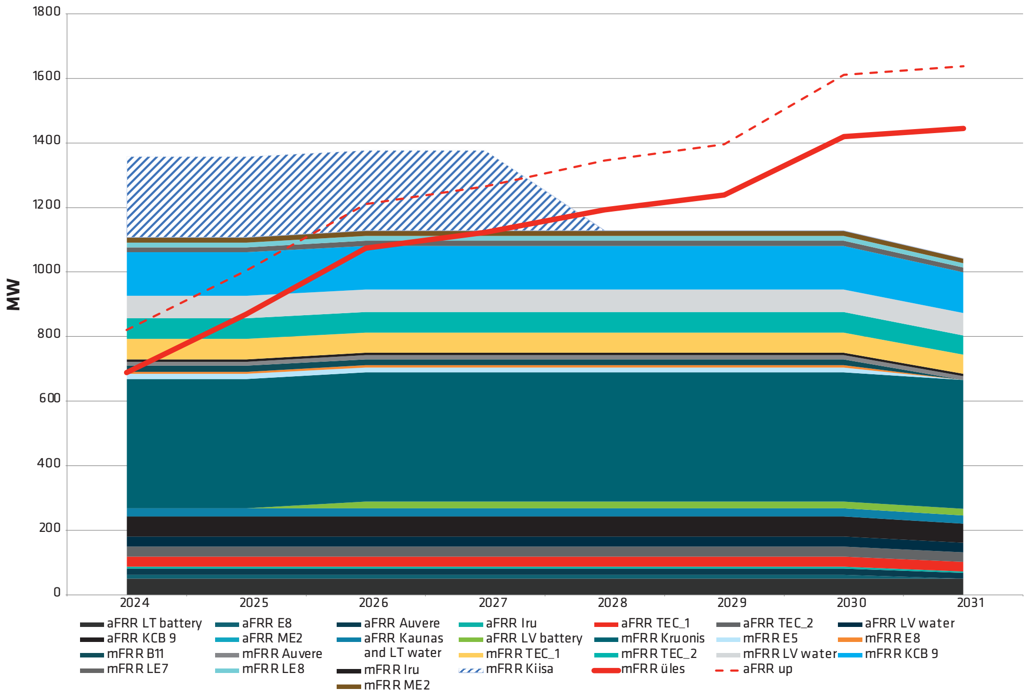

Figure 1.1 The need to upregulate the Baltics and the capacity of existing resources

The increase in renewable energy production will lead to an increase in the demand for fast reserves (Figure 1.1). This is due to an expected increase in generation forecast errors. As old dispatchable power plants are closed in the region, it means that investments in flexible resources providing frequency reserves are needed. In order to ensure the necessary investment in resources that provide the frequency reserves, which can cover emergencies over a longer period, the Baltic states are applying to the European Commission for a derogation that would allow them to acquire fast reserve capacity on a long-term basis. Such a solution would give investors greater investment certainty and ensure that frequency reserves are available in the future. Giving the Baltic states such an option is under discussion as part of the EU's electricity market reform. Preliminary estimates suggest that in the long term, there is a need to procure upwards of 250-400 MW of frequency reserves (aFRR and mFRR combined).

1.2 Network capacity

- ***The reliability of Estonia's power grid is very high – over 99.99%.***
- ***The investment projects required for synchronisation with Continental Europe are on schedule.***
- ***A lot of new generation will need to be added to meet Estonia's renewable electricity generation target for 2030. In order to ensure that the investments are made at the right time, Elering has proposed to amend the grid development principles to allow Elering to make the investments in advance. The implementation of the new development principles requires amendment of the Electricity Market Act.***
- ***Elering, in cooperation with the neighbouring TSOs, is assessing the feasibility of new international connections Estlink 3 and the fourth Estonia-Latvia line. The earliest completion time for both connections is in 2035.***

From the standpoint of security of supply, it is important that the capacity and reliability of the transmission grid be sufficient for energy to be transmitted to the area's substations. The Estonian transmission grid has been designed to ensure that, should a line be switched off, the electricity supply of regional Estonian production and consumption centres will still remain functional with the support of other lines.

The reliability of Elering's network has been very good, which has enabled energy to reach consumers without disruptions.

Elering's largest network investments that will be made in the years ahead are related to the Continental Europe synchronisation programme and ensuring additional connection capacity for new producers. Pre-planning of additional connections has also started with Finland and Latvia. The major network investments required for synchronisation with Continental Europe are the reconstruction of the Baltic-Tartu-Valmiera and Viru-Tsirguliina 330 kV high-voltage line, the synchronous compensators to be established at strategic points in the network, which are necessary for ensuring the stability of the electricity system, and schunt reactors to be installed to help maintain the electricity system's voltage in the allowed parameters.

After synchronisation, Elering's higgest focus will be on grid investments that will enable Estonia to meet its renewable electricity generation target for 2030. The Estonian government has set the goal of generating enough renewable energy to cover the entire yearly consumption in Estonia. In order to meet this target, several thousand megawatts of renewable energy generation capacity will be added to the Estonian power grid, and Elering estimates that, together with the controlled generation capacity, around 5,500 MW of generation capacity should be connected to the grid.

In order to ensure the timely and cost-effective completion of the transmission investments, Elering proposes to change the current concept of new connections. According to the new concept, Elering would not make network investments for generators solely on the basis of a connection application, but would make some investments in a forward-looking manner under the so-called 'development obligation'. In addition, it is proposed to fix the connection fee, which, today, is based on the direct costs of connection. The new concept would allow grid investments to be completed in time, as the realisation time of grid investments can be significantly longer than the realisation time of investments in renewable generation capacity. A fixed connection fee ensures that the cost of connecting to the network is not too high for anyone who wants to get connected and provides clarity on the size of this cost component when planning the investment. It is important to clarify here that Elering uses the money of electricity consumers to fulfil the development obligation and that the development obligation must be laid down in the Electricity Market Act. Until the amendment enters into force, Elering will not take the development obligation into account in the preparation of the Estonian Electricity Transmission Network Development Plan 2024-2033.

Elering and the Finnish TSO Fingrid have initiated a cooperation process for the construction of a third electricity interconnection between Estonia and Finland (EstLink 3), and Elering and the Latvian system operator AST have started a survey of the construction of a fourth link between Estonia and Latvia. Under the cooperation agreements, joint activities will cover technical questions, the necessary investments and relevant time schedule. The earliest expected completion date for both EstLink 3 and the fourth Estonia-Latvia line is 2035.

1.3 System adequacy

- ***The security of supply for the coming winter is significantly better than that of last winter, as several risks have been mitigated.***
- ***The electrification of different sectors has led to an increase in electricity consumption in Estonia and across Europe. Over the next 10 years, Estonia's annual electricity consumption will increase by nearly 2 TWh, and peak demand will grow by nearly 450 MW.***
- ***Capacity mechanisms may need to be put in place in the medium term to ensure system adequacy in the region. The 2027-2030 period will be particularly critical for the region, with consumption and demand for reserves growing rapidly but old power plants exiting the market.***
- ***Estonia's reliability standard is fulfilled until 2027 by 1,000 MW of oil shale units kept in Narva. Analyses estimate that it is economically sustainable to keep four oil shale units on the market from 2027-2030. In 2030, only four blocks will no longer be enough and a capacity mechanism in the form of a strategic reserve will be needed. In 2033, the reliability standard will be exceeded, as Auvere is the only oil shale unit that will be left and, above all, there will be a shortage of automatic Frequency Restoration Reserve (aFRR) capacities.***
- ***If the level of dispatchabledispatchablecapacity in Estonia falls significantly below 1,000 MW, a strategic reserve will beintroduced. Fast-ramping capacities that can provide automatic Frequency Restoration Reserve (aFRR) will be needed as of 2030.***

We consider electricity system adequacy to constitute a situation where the expected electricity consumption is covered with the local generation, imports and consumption management possibilities.

Before last winter, there were a number of risks to the security of supply of the electricity system, many of which are much lower this winter. This allows us to face the coming winter with much more confidence. Last year, the main risks were European and regional gas supply, the reliability of nuclear power plants (including the completion of Olkiluoto 3), hydropower conditions across Europe and the possibility of intentional damage to energy infrastructure. This year, European gas storage facilities are almost at full capacity in the run-up to winter, as is the case for the Incukalns gas storage facility in Latvia in our region. The outage of Balticconnector has reduced the number of supply channels but still makes it possible to cover consumption in the Baltic states as well as in Finland. Nuclear power plants across Europe are in better working order than last year. The new Olkiluoto 3 nuclear power plant, which is a very important element for our region, is now operating. Compared to last year, which was characterised by drought, the fill of reservoirs is better in the lead up to this winter. For example, the level of reservoirs in Nordic countries is about 10% better, which is more than Estonia's annual consumption. As a result of the better overall security of supply situation, we are also better prepared for a variety of possible events that may damage the infrastructure.

As in the previous year, Elering's long-term power system adequacy analyses show that there is a risk of not meeting Estonia's Loss of Load Expectation (LOLE) from 2027 onwards. This means that after expiry of the owner's expectation in 2026, a further closure of the Narva oil shale units could lead to a shortfall in generation capacity or frequency reserves. In order to mitigate this risk, the establishment of the Estonian Strategic Reserve, for which a start was made regarding application for a state aid permit on the basis of last year's report, needs to be completed. Figure 1.2 illustrates LOLE in Estonia in a situation where uneconomic capacity has been closed in the Baltic states and investment in flexible consumption has increased. According to analyses, the Narva oil shale units – Estonian 5, Estonian 8, Balti 11 and Auvere – will remain on the market in Estonia in 2028 and 2030, ensuring security of supply in 2028. Estonia's reliability standard will be exceeded with current market-based resources also in 2030 and a strategic reserve will be needed. In the 2030+ perspective, as the Narva oil shale units reach the end of their technical lifetime, it will be important to add additional secure generation capacity capable of providing automatic frequency restoration reserves. Notably, despite the opening of trade at the Lithuania-Poland border in 2032, the capacity of the Estonian system remains below the standard. If such capacities are not added on a market basis, state aid measures must be taken to help create new capacities. In this case, it is also important to ensure that the capacities are future-proof, i.e. that certain capacities must be ready to use climate-neutral fuels.

Figure 1.2
Analysis of Estonia's security of supply adequacy in 2028, 2030 and 2033

1.4 Digital capability

- ***Digitalisation is a key factor in the ever-increasing complexity and distributed generation environment of energy systems, requiring real-time management of critical systems and increasing volumes of data analytics.***
- ***Cybersecurity is of critical importance, especially given our complex geopolitical environment. Cyber risk assessment, the continuous development of protection measures and coordinated cooperation are an integral part of our solutions and activities to ensure systems run smoothly and are resilient to external threats.***
- ***Digital and secure solutions are only effective if they are supported by capable people and smoothly running business processes. This is why developing the digital skills of our team and optimising business processes is essential to ensure the efficiency and security of supply of the energy system.***

Digital capability is defined as a company's resources that make it possible to automate business processes and ensure day-to-day system management and security of supply. The need to increase this capacity is linked to the growth of electrification and the share of renewable energy, which make the management of the energy system more complex and increase data volumes.

Increasing demands of data volumes have created the need to adapt Elering's key systems and technology, while also emphasising the importance of cyber security. Elering has responded to this challenge by introducing changes to its key systems, technical architecture and data models. The use of cloud-based technologies is also considered to support the growing digital ecosystem.

Investing in cybersecurity is necessary to ensure security of supply and to implement the European Union Network Code on Cybersecurity and the amendments to the Estonian Cybersecurity Act.

In addition, Elering focuses on developing the digital skills of its team and optimising business processes in order to increase digital capabilities and ensure the smooth running of the organisation and high-quality services.

2 Operation capacity

2.1 ENSURING OPERATIONAL RELIABILITY OF THE ELECTRICITY SYSTEM AND ADMINISTRATION IN REAL TIME

2.1.1 Organisation of management of Estonian electricity system

The management of the real-time operation of the Estonian electricity system is organised by the Elering control centre. The planning of the operation of the electricity system is followed by real-time management process, which takes place around the clock. The function of planning the operation is to conduct coordinated checks of the permissibility of the functioning of the electricity system and, if necessary, to bring it within the allowable limits and prepare plans and forecasts for the operational management phase. In planning the operation, the requirements specified in the Grid Code on the Functioning of the Electricity System and Commission Regulation (EU) 2017/1485i are followed and the plans and forecasts prepared in its course must meet the established reliability and security of supply requirements, ensure that losses are at the optimum level and allow the maximum possible cross-border transmission capacity.

The electricity system management process is carried out by energy system dispatchers who have received the relevant training and whose knowledge is checked periodically and updated in emergency drills and at training courses. The energy system dispatchers are responsible for correcting deviations from the balancing plan occurring in real time, ensuring high-quality supply of electricity to transmission system clients, managing the process of scheduling transmission system equipment for maintenance, operation and reserve status, identifying and clearing interruption and emergency mode, organising cooperation with clients and neighbouring countries' TSOs and keeping control centres and market participants informed of changes in cross-border transmission capacities.

The SCADA real-time monitoring and control system is in use for real-time management of the system. This control system allows energy system dispatchers to monitor transmission system equipment's location, status and measuring data and control their operation. Partner and client data needed for managing the operation of the electricity system are also sent to this control system. The most important real-time operational management processes that require several parties to work in concert are coordinated by telephone as an additional level.

Transmission of electricity being a vital service, it is extremely important to minimise the possibility of an interruption in the supply of electricity taking place in the transmission system. Thus, the control centre provides for the redundancy of all of the most important equipment and employees. Energy system dispatchers engaged in real-time management of the electricity system's operation must be capable of standing in for other energy system dispatchers in the same shift, a SCADA backup server is in use, reserve communication channels and the technical functions of the management centre are redundant.

The control centre engages in close international cooperation with the European association of TSOs, the ENTSO-E system operations committee and the Baltic regional working group formed at the SOC. Since the Estonian electricity system will be in the IPS/UPS synchronous area until synchronisation with the Continental Europe synchronous area, it is necessary to cooperate in the field of control with Russian and Belarusian TSOs, and this cooperation has been organised through the BRELL organisation, founded in 2001 (Belarus, Russia, Estonia, Latvia and Lithuania).

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1 https://eur-lex.europa.eu/legal-content/ET/TXT/PDF/?uri=CELEX:32017R1485

2.1.2 Ensuring operational reliability of the electricity system in ordinary situations

The Estonian electricity system is currently part of the synchronously operating combined system, IPS/UPS. The Estonian electricity system is connected to IPS/UPS via cross-border 330 kV AC lines. The Estonian electricity system is connected to Latvia via three 330 kV transmission lines and to Russia via three 330 kV transmission lines (Figure 2.1).

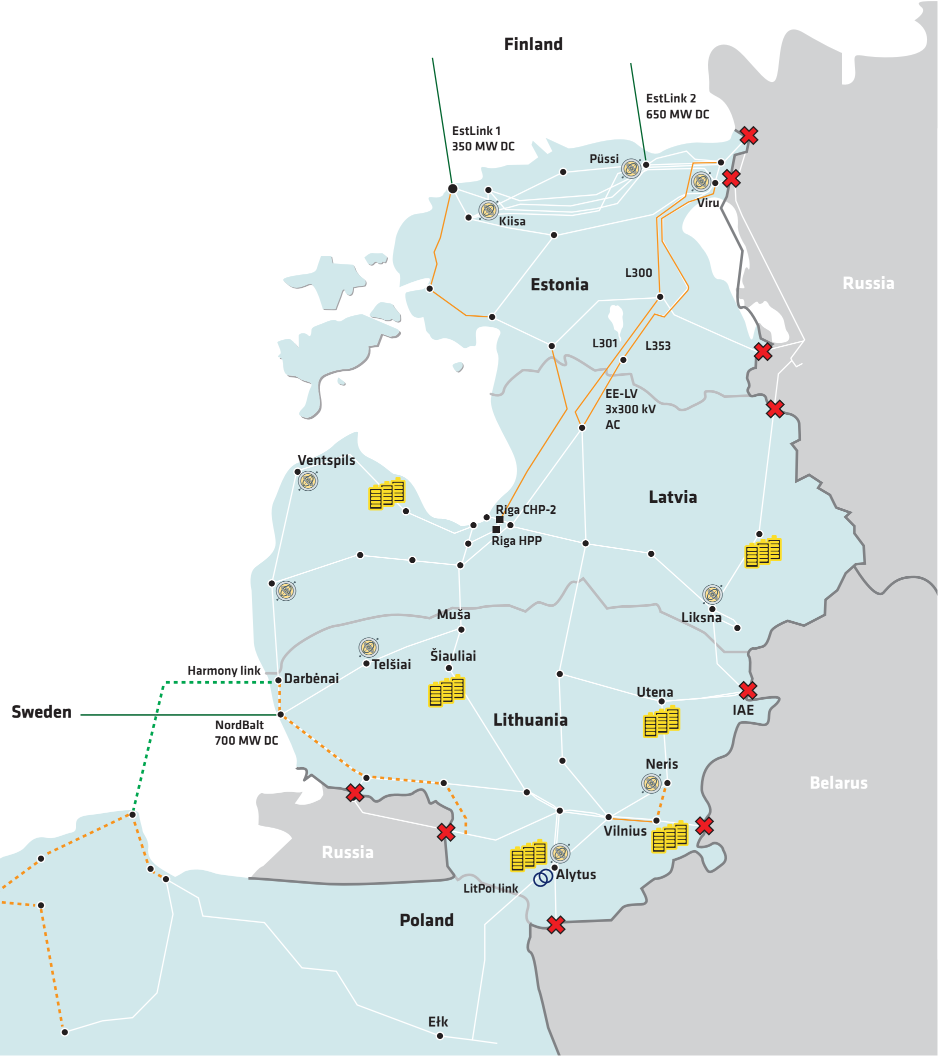

Figure 2.1 Baltic transmission network with international connections

The Russian TSO provides automatic frequency regulation. The role of the Estonian electricity system in regulating frequency in the synchronous area is maintaining the AC balance (the sum of cross-border supplies of energy planned via the AC lines) within the necessary limits in cooperation with the Latvian and Lithuanian TSOs. The Baltic AC balance is managed under an energy-based approach from an operational hour perspective, using manual activation of the manual frequency restoration reserve (mFRR) from the Baltic regulation market. Baltic TSOs have agreements in place on exchanging regulation reserves with Finnish and Swedish TSOs that allow the use of regulation reserves from the Nordics as well for balancing the Baltic system. Data on activated quantities on the Baltic regulation market and the Baltic AC balance can be found on the Baltic Transparency Dashboard [2]website.

In the operation of the electricity system, it is also important to assess the system's capability to continue normal operations after system problems, i.e. to maintain system stability. Stability can be divided into three parts:

1. Voltage stability – Voltage stability is ensured if, as a result of a system interruption, the allowed voltage level is maintained and there are no oscillations in voltage. Voltage depends on the operation of equipment that generate or consume reactive power.

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2 https://baltic.transparency-dashboard.eu/

2. Rotor angle stability – Rotor angle stability means the synchronous operation of generators. In the case of rotor angle instability, some generators start revolving at a different speed to other generators. In addition, loss of rotor angle stability can cause loss of frequency stability.

3. Frequency stability – Frequency stability occurs when there is a noteworthy imbalance between generation and consumption. Following interruptions, system stability may not rise or fall faster than the allowable range.

For the purposes of assessing the stability of the electricity system, static and dynamic stability are also distinguished, namely the examination of minor and major interruptions on the functioning of the electricity system. In the case of minor interruptions, there may be smooth, aperiodic or periodic changes in system parameters. Major interruptions may impact damped and undamped oscillations of generators operating in the system[33].

In the Estonian electricity system, voltage stability is ensured in the real-time management phase, where the balance of the system's reactive energy is regulated so that the limits of voltage stability are not exceeded after system interruptions. All revolving generators support rotor angle stability in that they must withstand more severe interruptions than the ones normally present in the system without losing rotor angle stability. Frequency stability is ensured regionally with the existence sufficient inertia and short-circuit power in the system.

2.1.3 Ensuring operational reliability of the electricity system in emergency situations

When planning the operation of the electricity system, it must ensured that the more frequent disturbances N-1 and N-1-1 do not cause deviations of voltage or frequency or other quantities from the specified limits, major power cuts or loss of system stability. During a disturbance and in the situation resulting from the disturbance, the electricity system and its components may operate with lower than normal operational and supply reliability if this is necessary to localise or eliminate the disturbance or to restore the electricity supply to consumers.

In the case of emergency operation, one or several parameters that characterise the operation of the system may be outside the permitted limits, there is the threat that the emergency automation system starts operating or that this system has started operating, and full required consumption capacity may not be guaranteed. A serious failure of the computer systems on which the technical management of the electricity system depends can also lead to emergency operation.

The management of the emergency operation depends on the specific disturbance or situation that led to the emergency. In different cases, different tools and activities are used to manage the emergency operation. The basic rules for managing emergency operation are as follows: immediately eliminate the risk to people and equipment not affected by the emergency; isolate the damaged equipment or part of the electrical network from the rest of the electrical network; prevent the emergency from spreading; restore electricity supply to consumers in the shortest possible time; and bring the parameters of the electrical system within the prescribed limits.

The energy system dispatchers on duty at the control centre are responsible for organising emergency operation. In order to ensure the necessary knowhow to manage emergency operation, all power system operators must participate in emergency drills. At Elering, emergency drills are organised on several levels. Both individual emergency drills and emergency drills involving several parties, such as service providers or distribution system operators, are organised. In addition, joint emergency drills are carried out with the control centres of neighbouring system operators. Each year, the three Baltic TSOs conduct joint emergency drills at the respective training centre in Germany, which allows the drills to be as similar as possible to the real situation, and the Baltic TSOs and the Polish TSO conduct joint emergency training.

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[3] *M.Meldorf, J.Kilter, "Elektrisüsteemi stabiilsus", 2011*

2.1.3.1 Imposing constraints on consumption

Consumption is limited only in the case of very serious emergencies. This option is used if there is a risk of permanent damage to the operation of the electricity system or important electrical equipment that cannot be eliminated by other means. In such cases, the dispatchers of the Elering control centre organise the limitation of the distribution networks and major clients pursuant to the consumption limitation plan developed in advance.

Should a need to limit consumption arise, Elering's dispatcher notifies Elektrilevi of the consumption amount that needs to be restricted. Elektrilevi limits consumption pursuant to the agreement between Elering and Elektrilevi on technical cooperation and ensuring security of supply. Elektrilevi in turn chooses which consumers are to be switched off in a manner that prevents interruption of service to critical consumers (such as vital service providers and general interest service providers). If it is not possible to quickly restore a situation that allows power to be restored to all consumers, the consumers to be disconnected will be rotated by two-hour time periods, if possible.

Restricting consumption is the last resort to ensure the functioning of the electricity system. Before curtailing consumption, all other means will be used, such as activating back-up capacity, requesting assistance from neighbouring system operators, modifying network topology, interrupting maintenance, etc.

2.1.3.2 Island mode of the Baltic electricity system

The island mode of the Baltic electricity system occurs when all the electricity transmission lines connecting the Baltic electricity system to the Russian and Belarusian electricity systems either switch off or are switched off. In the case of the Baltic electricity system being in island mode, frequency regulation will need to be organised in cooperation between the Baltic TSOs, using the resources available to the Baltic TSOs. From Estonia's perspective, all new power plants that join the Estonian electricity system have technical capacity for regulating frequency, and this also applies to wind farms.

The capacity of local power plants is also used to regulate frequency in the Baltic electricity system, and in addition to power plants, both DC connections between Estonia and Finland possess automatic frequency regulation capability (Estlink 1 and Estlink 2). Through these DC connections, the Nordics' reserve capacities can be used for automatic regulation of the frequency of the Baltic and Estonian electricity system. The NordBalt connection between Lithuania and Sweden has similar capability, as does the Lithuania-Poland connection LitPol Link.

In addition, there is a need to ensure the stability of the Baltic electricity system, given that the Baltic electricity system operates as an island and no longer receives stability support from a large frequency area. In order to ensure stability in island mode, it is necessary to reduce transmission capacities with the Nordic countries, to reduce transnational power flows within the Baltic States and to ensure the necessary level of inertia and short-circuit power by local means.

The Baltic TSOs are constantly carrying out actions for increasing the Baltic island mode capability, taking into consideration the fact that due to geopolitical risks there is a possibility of the Baltics being disconnected from the Russian and Belarusian electricity system without forewarning.

2.1.3.3 Island mode of the Estonian electricity system

The island mode of the Estonian electricity system is a situation where all the electricity transmission lines connecting the Baltic electricity system to the Russian, Belarusian and Latvian electricity systems either switch off or are switched off. Presumably, the emergence of island mode in Estonia would mean that the Baltic electricity system would already be isolated from the Russian and Belarusian electricity systems, and then for some reason the AC connections between Estonia and Latvia would switch off.

In the case of the Estonian electricity system being in island mode, frequency regulation will need to be organised in Elering, using the resources available to Elering. The capacity of local power plants is also used to regulate frequency in the Estonian electricity system, and in addition to power plants, the DC connections between Estonia and Finland can be used for automatic frequency regulation (Estlink 1 and Estlink 2). Through these DC connections, the Nordics' reserve capacities can be used for automatic regulation of the frequency of the Estonian electricity system.

In addition, there is a need to ensure the stability of the Estonian electricity system, given that the Estonian electricity system operates as an island, which is considerably smaller than, for example, the Baltic electricity system and thereby considerably more sensitive to the impact of various possible disturbances because it no longer receives stability support from a large frequency area. In order to ensure stability in island mode, it is necessary to reduce the commercial transmission capacities with the Nordic countries even more than in the case of the Baltic island mode, and only resources located in Estonia must be used to ensure the necessary level of inertia and short-circuit power.

2.1.3.4 Re-electrification of the Estonian electricity system

Should various circumstances coincide, and more than one electrical installation with a bearing on the functioning of the electricity system as a whole is switched off, the entire or a large part of the electricity system may shut off. Estonia and its vicinity have not seen such a wide-scale outage in recent decades. The last outage of this scope in the vicinity of the Estonian electricity system took place in summer 1984. As a result of this malfunction, the Latvian, Lithuanian and Belarusian electricity systems went out. The outage started on a line connecting the Belarusian and Russian electricity system and a faulty failure prevention apparatus aggravated the situation. In addition, the cross-border power grid was operating with a lower reliability reserve than usual, since immediately before the outage, maintenance took place on one of the lines connecting Soviet-occupied Estonia and Latvia. A number of the power plants went dark and consumers were left without power for several hours.

In such cases, in order to re-electrify the electricity system, Elering control centre has developed the relevant restoration plans. On the basis of these plans, it is possible to do the following to electrify and restart the Estonian electricity system:

- use the Estlink 1 black start
- electrify the Estonian electricity system via lines between countries connecting neighbouring electricity systems
- use Elering's emergency reserve power plants at Kiisa

2.1.3.5 Ensuring inertia

Inertia is the ability of the electricity system to maintain a stable operating point even in major interruptions – until fast reserves respond, thus preventing major frequency changes. In order to ensure the frequency stability of the Baltic electricity system during accession to the Continental European synchronous area, at least 17,100 MWs of inertia must be present, this being able to ensure a frequency change speed of under 1 Hz/s.

Estonia must provide 5700 MWs of the required inertia – one-third of the Baltic total. In a situation where the Estonian power system is in the same synchronous area as the Russian power system, inertia is ensured by conventional power plants in this synchronous area. Until now, the Estonian electricity system has not had a specific obligation to store a certain amount of inertia. In order to be sure of the existence of the necessary quantity of inertia after synchronisation with the Continental European synchronous area, even if conventional power plants are non-operational or do not operate at the sufficient level, three synchronous compensators will be added to meet the system's need for inertia at Püssi, Viru and Kiisa substations; these will cover most of the inertia need. One synchronous compensator must provide at least 1,750 MWs of inertia, have the capability to regulate reactive energy in the range of ±50 MVAr and support the system with 900 MVA short-circuit power. The first of the three synchronous compensators at the Püssi substation has been completed and is ready to operate when needed and contribute to the operation of the Estonian electricity system.

2.1.4 Essential technical tools to ensure the reliability of the Estonian electricity system

2.1.4.1 Emergency reserve power plants

Based on the TSO's duty to ensure security of supply and balance at all times in the system, the system must have a sufficient reserve capacity. In order to fulfil this obligation, Elering uses the emergency reserve power plants I (110 MW) and II (140 MW) located in Kiisa. The total capacity of the two emergency reserve power plants is 250 MW, ensuring that Elering has the emergency reserve capacity needed to cope with a shutdown of the element of the Estonian electricity system with the greatest possible capacity, which is the second DC connection between Estonia and Finland, Estlink 2.

Electricity in emergency reserve power plants is generated when the generation capacity or transmission capacity of the system or of another country's electricity system electrically connected to the system, is unexpectedly switched off or if the system's security of supply is at risk. For the abovementioned reasons, activation of the emergency reserve power plant can also be ordered by other TSOs of the united system and by the Finnish TSO. The emergency reserve power plants' capacity does not participate in the power exchange and these plants do not generate electricity for balancing inaccuracies in balance administrators' consumption and generation forecasts. To keep power plants in constant readiness for use, Elering regularly tests their capability. Full-capacity test start-ups take place once a month (if it was not necessary to start up the power plant to ensure security of supply before that) and the power plant operates for one hour during the test.

Another very important function of the emergency reserve power plants is to ensure the re-electrification capability of the Estonian electricity system if due to some serious system disruption, the electricity system has shut down partially or completely. That means the emergency reserve plants must be capable of starting up autonomously; they have to be capable of regulating frequency and voltage levels and allow activities to be conducted to incrementally electrify the Estonian electricity system, synchronising other power plants with the electricity system and restoring consumption.

2.1.4.2 Synchronous compensators

In the course of the realisation of the synchronisation programme with the Continental European electricity system, Elering is building three synchronous compensators at the Püssi, Kiisa and Viru substations. A synchronous compensator is a device whose main function is to slow down the change in frequency so that other devices, which have to take care of frequency maintenance, have time to make their corrections. In addition to the inertia that brakes the frequency changes, synchronous compensators make it possible to ensure short-circuit power in the power system and to consume or produce reactive power if needed.

In order to join Continental Europe, Estonia is obliged to provide 5,700 MWs of inertia. Three synchronous compensators must ensure that this objective is met.

2.2 SYNCHRONISATION WITH THE CONTINENTAL EUROPEAN FREQUENCY AREA

2.2.1 Principles of joining the continental European synchronous area

Connection of the Baltic electricity system to the Continental European synchronous area was planned for the end of 2025. By that time, the necessary investments for connection must be completed and the electricity system must be managed in line with the principles that apply in Continental Europe. In order to join the Continental European synchronous area, Elering and the other Baltic TSOs must comply with the terms and conditions stipulated in the Synchronous Area Framework Agreement – SAFA. The SAFA can be read in detail on the ENTSO-E website .

The SAFA has six annexes that describe the six areas of electricity system operation management, i.e. policies, and contain the precise requirements and conditions on how to ensure that the respective area operates as required. Listed below are the six annexes to the SAFA that are mandatory for all system operators in the Continental Europe synchronous area:

- Load Frequency Control and Reserves. This annex describes the requirements and principles that the TSOs operating in the Continental European frequency area must adhere to. The main requirements of this annex cover:
    - ► TSOs' obligations in frequency control processes;
    - ► agreements between TSOs on operating and sharing/exchanging frequency control reserves;
    - ► etermination of the reserve capacities needed for frequency control;
    - ► technical requirements for frequency load systems.
- Scheduling of cross-border supply plans, which describes the principles of cooperation between TSOs for coordinating state electricity system supply plans. This annex describes the content of the supply plans to be coordinated, the frequency of transmission and the data transmission standards.
- Accounting and Settlement, which establishes the rules and principles for the coordination of border measurement data and the process of maintaining frequency in the frequency control area, the ramping period and the methodology for calculating and determining quantities and the prices of energy exchange arising as a result of unplanned energy exchange.
- Coordinated Operational Planning, which describes how cooperation between TSOs proceeds for coordinating state operational data to carry out regional reliability analyses and ensure the capability of managing the system.
- Emergency and Restoration, which describes the requirements of the TSO in ensuring the operation of the system in a state of emergency, what kinds of principles should be followed to restore the system and what requirements this poses for the system.
- Data Exchange, which describes the TSO data exchange principles nationally and between TSOs.

The Baltic TSOs have agreed on an action plan to ensure that all six of these areas are covered and thus compliant with the SAFA. According to this action plan, all the necessary conditions must be met by the Baltic TSOs before synchronisation with the Continental European electricity system in February 2025.

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[4] https://www.entsoe.eu/publications/system-operations-reports/

2.2.2 Reorganisation of frequency management in the Baltic electricity system

2.2.2.1 How frequency control in the continental European electricity system is carried out

Upon joining the Continental European synchronous area, the Baltic states' TSOs will have the obligation to start managing the Baltic AC balance in real time based on capacity, which would also take into account the balancing impact of different electricity systems. In addition, the Baltics will have to start supporting the frequency area and regional frequency with two types of reserves – Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (FRR). The FCR is activated when the system frequency deviates from the nominal frequency, and the purpose of the reserve is to slow change in frequency across the frequency area. The FRR can be divided into automatically and manually activated reserves, aimed at freeing up the FCR and restoring system frequency to the nominal frequency. The technical requirements and quantities needed regionally are determined pursuant to the principle of European regulations. Figure 2.2 depicts the general sequence of activation of frequency control reserves and general technical principles.

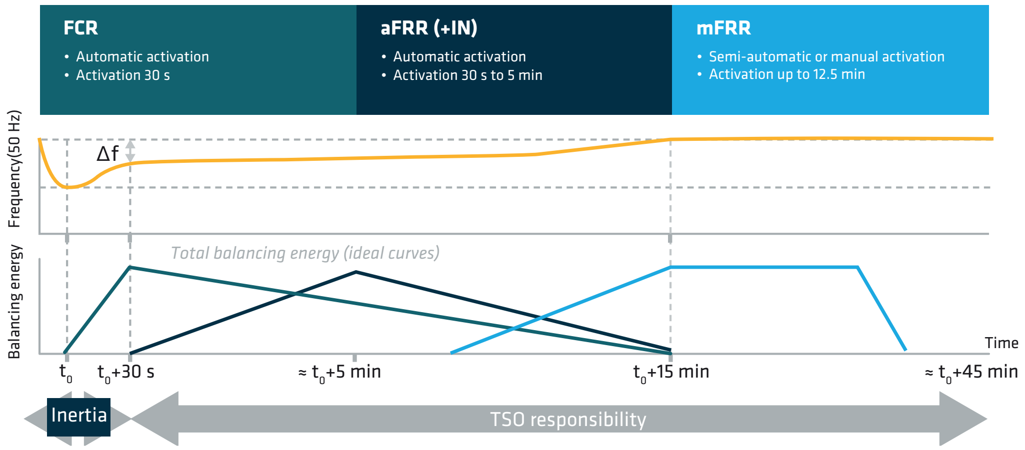

Figure 2.2
Europe-wide principles for frequency control reserves

The activation of FCRs takes place pursuant to changes in frequency automatically thanks to relay devices that monitor the frequency. In the case of FRRs, the bids are gathered from market platforms and the activation takes place through the control system, which assesses the amount of reserves needed for activation and sends out an activation order to the relevant reserves on the basis of the information received. The Baltic TSOs have developed a frequency control concept document describing the general Frequency control principles and needs for reserves in the Baltics after synchronisation with the continental European frequency area. The document describes the principles used to assess the need for different types of frequency management reserves, and based on these principles, the Baltics and Estonia need frequency control reserves based on the values shown in Figure 2.3.

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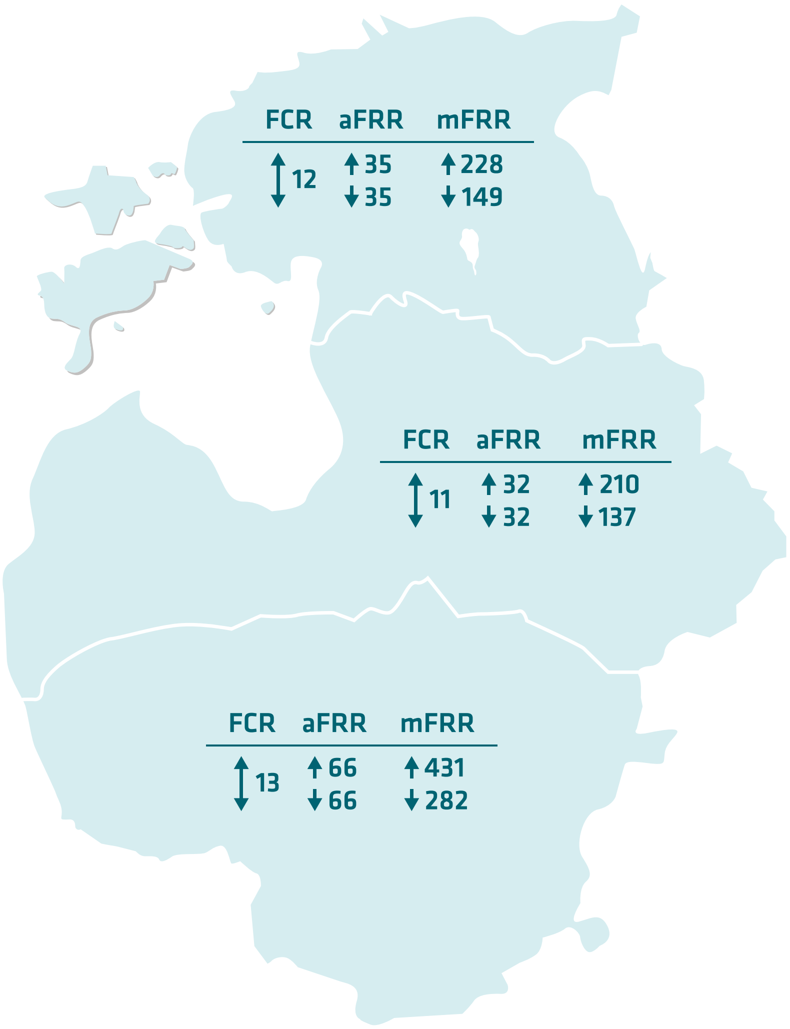
[5] https://elering.ee/sites/default/files/2021-01/Baltic%20Load-Frequency%20Control%20concept%20document.pdf

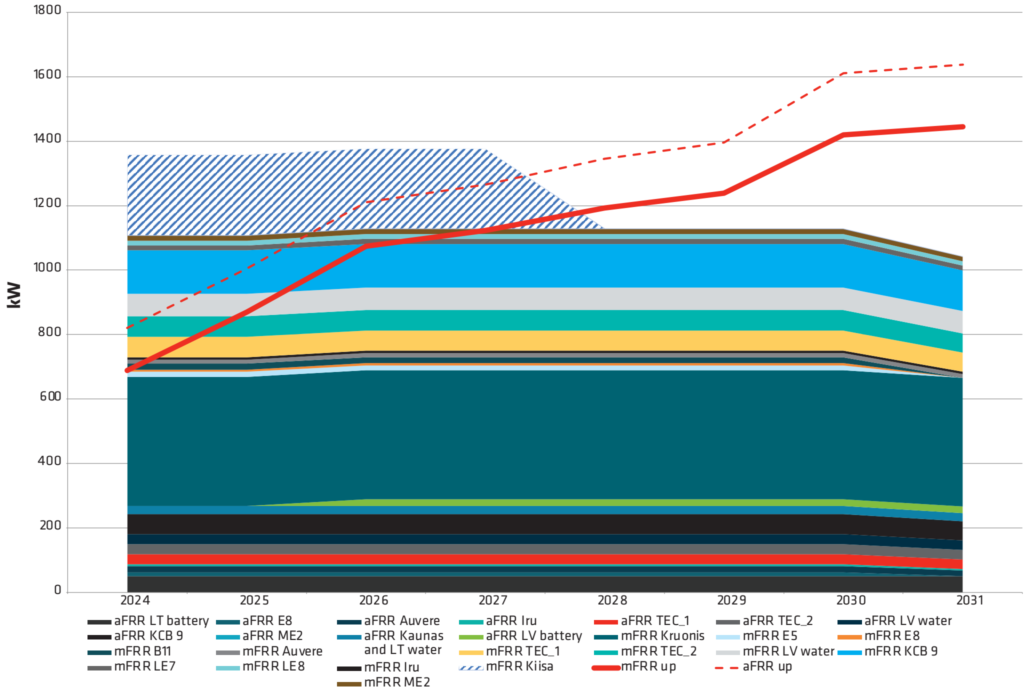
Figure 2.3
Assessed needs for frequency control capacities for 2025



Due to the increase in renewable energy production to meet the TE100 targets, the Baltic TSOs expect an increase in demand for frequency reserves. The main reason for this is the increase in the absolute value of the forecast error for renewable energy, despite the expected improvement in forecasts. This means that investment in flexible resources providing frequency reserves will be needed over the next decade. As far as is known to Elering, many market participants have such investments (especially storage devices) underway. In order to ensure the necessary investment in resources, which can cover emergencies of power plants, for example, over a longer period, the Baltic states are applying to acquire frequency reserves on a long-term basis. Such a solution would give investors greater investment certainty and ensure that frequency reserves are available in the future.

The Baltic TSOs regularly assess the adequacy of the resources available in the frequency reserve compared to forecast demand. According to the TSOs, the frequency reserve resources, together with those of the Latvian, Lithuanian (accumulators) and Estonian TSOs (Kiisa AREJ), are sufficient for synchronisation with Continental Europe. Figure 2.4 shows the quantities of aFRR and mFRR for upregulation and the capacity of resources in the Baltic states to supply these products (taking into account the reduction in reserve supply due to power plant malfunctions). In the Baltic states, there are sufficient resources to provide frequency reserves according to current knowledge, but there are many risks involved. In order to provide fast reserves, most power plants must be operational during activation, but their competitiveness on the market may not allow this and their hours of operation will decrease with the growth of renewable energy. In addition, supply is very low during periods of scheduled maintenance, increasing the likelihood that the need for reserves cannot be met at that time. From 2028 onwards, there will be a shortage of capacity to upregulate mFRR, and from 2029 onwards, additional investment in resources providing frequency reserves will be needed if today's TE100 renewable energy investment plans materialise. It is important to add that the same power plant cannot simultaneously provide frequency reserves and generate electricity on the day-ahead market with the same megawatts. There are also regular maintenance operations at power plants that can create moments where several important reserve providers are down at the same time. Therefore, resource adequacy needs to be analysed in conjunction with the adequacy of frequency reserves and the capacity to cover electricity consumption. Such an analysis can be found in the chapter on the capacity of the electricity system.

Figure 2.4 The need to upregulate the Baltics and the capacity of existing resources



The main challenge for making investments in resources providing frequency reserves today is the lack of investment certainty. The frequency reserve markets of the Baltic states will open in 2025 and even then market prices will become clear every day for the next day. This means volatility in the market prices of the frequency reserves, which makes it difficult to make investments. In order to mitigate this risk during the initial period of the frequency reserve market, the Baltic states are applying for permission to purchase reserves for a longer period at a time within the scope of the European electricity market reform. Such a measure would provide certainty on the market price of frequency reserves for the initial period of the investment. At the time of writing, trilogues are being held between the European Commission, the European Parliament and the European Council to discuss the grant of this derogation. Based on the best knowledge available today, we could expect a decision in Q1 2024. On the basis of the document on the dimensioning of reserve quantities prepared by the three Baltic TSOs, the total amount of frequency reserves (aFRR and mFRR) to be procured in the long term remains at around 250-400 MW in the upwards direction.

2.2.2.2 Baltic Load Frequency Control Block (LFC Block)

When joining the Continental European synchronous area, the Baltic states will have to follow the structural distribution of load frequency control obligations in the synchronous area. Specific obligations are laid down for the load frequency area, load frequency control blocks and load frequency control areas. The Baltic TSOs are planning to create a common load frequency control block that covers three load frequency control areas. For this purpose, a contract for the operation of the load frequency control block is being developed, setting out the obligations of the load frequency control block and the load frequency control areas and the methodologies to be applied. The TSOs are planning to submit the contract for operation of the frequency control block to the Baltic regulators for approval in Q4 2023.

The main task of the load frequency control area (LFC area) is set to detect and balance current system faults by activating aFRR and mFRR reserves. Each Baltic TSO will start assessing the system faults of its region and make activations against them.

The main task of the LFC block is to dimension FRR capacities for the block to provide a sufficient quantity of aFRR and mFRR powers so that the LFC block can cover system faults 99% of the time or at least

[6] https://elering.ee/sites/default/files/2022-10/FRR_dimensioning_forecast_2024-2031_0.pdf

cover the largest event failure in both surplus and deficit of energy. In the synchronous area, the specific system fault limits have been set for the LFC block on the basis of which the adequacy of reserves is assessed. If several LFC areas belong to an LFC block, the LFC block must also provide for coordinated actions to ensure that joint actions result in a minimal system fault in the LFC block.

Joint FRR reserve dimensioning of the Baltics

The Baltic TSOs have jointly developed and publicly consulted on the methodology for the dimensioning of FRR reserves in the LFC block[7]. The FRR dimensioning methodology is based on the aggregation of deterministic and probabilistic system imbalances and estimates the need for reserves to cover 99% of system control faults in accordance with Article 157 of the System Operation Rules. In addition, the methodology sets out the principles for assessing aFRR and mFRR.

Coordinated activities to minimise load frequency control errors in the Baltics

The Baltic LFC block provides for the aggregated balance of the block to be ensured through the separate control of each LFC area. Each LFC area balances itself through the activation of reserves, using the reserves available on the market. If there are disturbances in the standard process, the coordinated actions to minimise the frequency restoration control error, as described in the methodology, are specified in the LFC operation contract[8]. This methodology describes the additional measures available to the Baltic TSOs and the process for their implementation.

2.2.2.3 Pan-European MARI and PICASSO energy platforms

Elering and other Baltic TSOs are joining the MARI and PICASSO platforms, which consolidate energy bids on European regulation markets and are aimed at operating mFRR and aFRR energy bids, respectively. Market platforms collect all bids and optimise the activation of reserves to achieve the greatest socioeconomic benefit. Baltic TSOs received an exception to join the MARI platform at the same time as Nordic TSOs and no later than 24 July 2024. The Baltic TSOs are planning to become official PICASSO members in Q1 2024, in order to gain access to the technical systems and to start the technical preparations and implementation of the PICASSO system. The implementation of the PICASSO platform for the Baltic electricity system is planned for Q1 2025.

Implementation of the MARI platform

The MARI platform will consolidate mFRR energy bids from all TSOs that have implemented MARI. The MFRR bids submitted to the MARI platform must comply with the MARI standard product[9]. Elering consolidates the bids of Estonian mFRR service providers and forwards a consolidated list of mFRR energy bids to MARI. The activation of the mFRR bids will be based on the demands of TSOs submitted to the MARI platform and the available transmission capacities.

The standard mFRR product differs from today's Baltic CoBa mFRR product and obliges Estonian mFRR service providers to change the message standards of their bids. In addition, with the implementation of MARI, the activation of mFRR bids will be message-based.

Implementation of the PICASSO platform

The PICASSO platform will consolidate aFRR energy bids from all TSOs that have implemented PICASSO. The aFRR energy bids submitted to the PICASSO platform must comply with the PICASSO standard product. Elering consolidates the bids of Estonian aFRR service providers and forwards a consolidated list of aFRR energy bids to PICASSO. The activation of the aFRR bids will be based on the demands of TSOs submitted to the PICASSO platform and the available transmission capacities.

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[7] https://elering.ee/sites/default/files/2023-06/Baltic_FRR_methodology_clean_after_PC.pdf

[8] https://elering.ee/sites/default/files/202306/Coordinated%20actions%20to%20reduce%20FRCE_final.pdf

[9] https://elering.ee/sites/default/files/2021-09/Baltic%20balancing%20market%20rules%2020201230_0.pdf

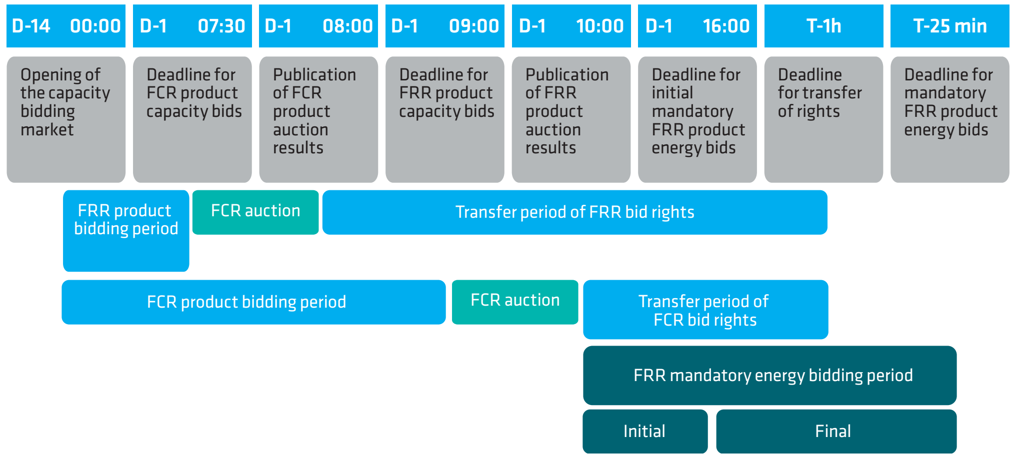
2.2.2.4 Baltic capacity market for frequency control reserves

The Baltic TSOs are planning to start a common Baltic LFC capacity market from early 2025, with the procurement of reserve capacities on a day-ahead basis. Unlike the MARI and PICASSO platforms, this process will be only based on the Baltics and will be carried out independently of the merger process of the aforementioned pan-European platforms. The Baltic TSOs consider it necessary to carry out a capacity market test period before synchronisation with Continental Europe. The quantities to be procured during the capacity market testing period range up to the capacities dimensioned for synchronisation and depend on the needs of the system.

The Baltic LFC capacity market consists of two stages – FCR and FRR capacity procurement. The FCR procurement will be carried out first and the results of the FCR capacity market will be published before the period when the bid gate of the FRR capacity market is closed. The FRR capacity procurement will then be carried out, selecting the most efficient bids on socio-economic grounds to meet the demands of both the Baltic LFC block and each LFC area. The Baltic TSOs also see a need for sharing and swapping reserves between LFC areas to cover the Baltic reserve requirements. For this purpose, intra-Baltic transmission capacities will need to be allocated in the capacity market process so that the corresponding FRR reserves are available for the LFC areas in the operation of the energy markets. Based on the results of the auction, the transmission capacities between the Baltic states to be placed at the disposal of the day-ahead market will decrease.

Figure 2.5 gives a more detailed overview of the steps and timings of the capacity market.

Figure 2.5
Schedule of Baltic LFC reserve markets



2.2.2.5 Promotion of Estonia's aFRR market

Elering and Fingrid have developed a technical pilot solution that allows Estonian market participants to take part in the Nordic aFRR market. To ensure that the influence of aFRR activated at Estonian-based power plants reaches Finland, the capacity transmitted on Estonia-Finland connections must also automatically change simultaneously. The DC connection Estlink 1 situated between Harku and Espoo substations is in use for this purpose. Channelling reserves to Finland will take place only if electricity connections have available capacity. The pilot is open to all Estonian market participants who would like to offer the reserve service to the Finnish TSO. Additional information for joining the project is available on the Elering website.

The Elering and Fingrid pilot has pre-qualified 40 MW upregulation and 65 MW downregulation aFRR capacities. The reserve equipment that took part in the aFRR pilot can be pre-qualified under a simplified procedure for use of the Baltics and PICASSO aFRR markets.

Elering has channelled 45 GW of aFRR upregulation capacity to Fingrid in 2022 for a total value of €5.3 million within the scope of the aFRR pilot, and Fingrid has activated 12 GWh of aFRR upregulation energy for a total value of €1.9 million[10].

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[10] https://elering.ee/afrr-turu-dokumentatsioon

2.2.2.6 Promotion of Estonia's FCR market

Elering and Fingrid have identified the capacity to further extend the cooperation between the system operators on the FCR-N service.

In addition to channelling aFRR, Elering and Fingrid have agreed on the channelling of the FCR-N service. FCR-N is a frequency-based reserve that regulates active capacity in order to balance sudden changes in the electricity system balance and to slow down changes in system frequency. The pilot tests the technical solution of the FCR-N frequency reserve on a 10 MW symmetric product. The physical exchange takes place on the Estlink1 connection. The operation of the FCR-N reserve is based on free capacity between Estonia and Finland, taking into account the results of the day-ahead market, and subject to additional technical constraints. Estonian market participants will be paid for FCR-N service for successful capacity on the Finnish FCR-N market and for FCR-N energy according to the Finnish mFRR market price or the day-ahead market price like the Finnish service providers. Elering and Fingrid reserve the right to suspend the pilot in the unlikely event that the pilot has a negative impact on the reliability of the system.

The TSOs plan to have the technical capacity to launch the pilot by the end of Q3 2023; until then, service providers will be able to configure and pre-qualify their reserve unit to provide the service.

2.2.2.7 Pre-qualification of frequency control reserves

A detailed overview of the existence of reserve capacities will be available after technical pre-qualification of the existing frequency management reserves. Elering verifies that the frequency reserve providers have the capability to offer the service. Technical pre-qualification is both a precondition for participating in the markets of future European energy platforms MARI and PICASSO and also gives the right to take part in the Baltic FCR, aFRR and mFRR capacity markets to be set up in the future. The Baltic TSOs have developed common requirements for the pre-qualification of frequency management reserves[11], based on which the TSO prepares state pre-qualification test plans.

The state documents on the pre-qualification of frequency reserves at Elering can be found on the Elering website[12], based on which frequency control service providers can pre-qualify their assets for future frequency control energy and capacity markets. The data exchange requirements and service agreements needed by the markets are created upon the launch of the relevant markets.

2.2.3 Upgrading the technical tools for the operational planning and management of the electricity system

2.2.3.1. Updating the SCADA/EMS real-time monitoring and management system

After joining the Continental European frequency area, the Baltic states will be subject to the technical requirements for the operation of the grid and the assessment of grid stability, which will create the need to extend the SCADA/EMS capacities of the technical control system of the electricity system. In order to join the Continental European synchronous area, SCADA/EMS must include the following additional functionalities, among others:

- Frequency Restoration Controller for controlling aFRR reserves
- Dynamic Security Assessment System for the automatic monitoring of performance at a time close to real time (online).

In order to add these functions to the real-time control system, Elering has launched a SCADA/EMS update project. The project started in Q4 2021, where SCADA bidders were pre-qualified. The public contract was awarded to the supplier of SCADA/EMS (GE Digital) in December 2022. The expected deadline for the completion of the new SCADA/EMS is Q4 2024.

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[11] https://elering.ee/sites/default/files/2022-03/Harmonised%20principles%20for%20Baltic%20LFC%20reserve%20prequalification__updated_version.pdf

[12] https://elering.ee/sagedusreservid

2.2.3.2 Frequency Restoration Controller for controlling aFRR reserves

Automatic Frequency Restoration Reserves (aFRR) are activated according to the required amount of aFRR transmitted by the frequency restoration controller, i.e. the activation signal. The activation signal is calculated by a high-performance proportional-integral controller, taking into account the system control error of the area to be controlled and the system frequency deviation. Every few seconds, the controller assesses the status of the system and finds the new amount of aFRR needed.

The Frequency Restoration Controller collects the energy offers of the aFRR service providers in Elering's control area and activates them on a marginal price basis according to the quantity of the activation signal. Marginal price-based activation means that bids are activated by price in ascending order, i.e. the cheaper bid is activated in full before the higher bid is activated. All aFRR service providers whose energy offers are activated in a given market period will receive the marginal price for that market period. As a fallback solution, it is also possible to activate all bids proportionally to ensure performance.

In order to optimise the activation of aFRR energy offers, the Frequency Restoration Controller is connected to the PICASSO energy market platform, which helps TSOs to carry out netting with each other in case of system control errors and to find the most favourable aFRR bids to activate among the bids available in PICASSO. From the PICASSO platform, a correction signal is sent to the Frequency Restoration Controller, which reflects possible imbalance settlements, activations in other areas for the respective TSO as well as additional activations for other TSOs.

Technical testing of the Frequency Restoration Controller can start (within the scope of the SCADA/EMS project) in Q2 2024 when the service provider delivers the system to Elering. The Frequency Restoration Controller will be tested and configured to activate aFRR reserves by the end of Q4 2024. This schedule will allow the activation of aFRR capacity to start from Q1 2025.

2.2.3.3 Updating the wide area monitoring system WAMS

Pursuant to the Continental European synchronous area accession agreement, we must be able to monitor and analyse the rapid processes taking place in the grid. Various dynamic processes in the electricity system progress at a speed that makes it impossible to use SCADA/EMS real-time measurement for monitoring and real-time analysis. To ensure the necessary data quality, a wide area monitoring system (WAMS) is used, which measures and saves electricity system parameters at a frequency of 10 kHz and is capable of analysing and visualising them in real time. The wide area monitoring system can:

1. analyse disturbances;
2. validate data models;
3. alert on events;
4. monitor phase angles and rotor angle stability;
5. monitor voltage stability;
6. monitor the damping of oscillations within and between regions.

The measurement data from the WAMS can be used to replace missing measurement data from the SCADA system to make the SCADA/EMS grid model more accurate and the SCADA/EMS real-time operational status assessment process more reliable. The wide area monitoring system gives the automatic control information systems more detailed measuring data on frequency and active power, which allows the requirements of synchronisation with Continental Europe to be fulfilled.

Elering started updating the capability of the WAMS in Q4 2021 and the upgrade was completed in Q4 2022.

2.2.3.4 Frequency automation upgrade

As a result of the accession agreement with the Continental European synchronous area, Elering and the other Baltic TSOs have to bring their underfrequency automation into line with the requirements in Continental Europe. Underfrequency automation is equipment that shuts off the necessary amount of consumption automatically when the frequency falls below a critical level, without human intervention, to keep the electricity system running. Underfrequency automation is the last line of defence in the electricity system, which must prevent blackouts of the electricity system.

At present, underfrequency automation in Estonia and the other Baltic states is configured according to the requirements set in BRELL. The main differences compared to the current BRELL requirements are a smaller frequency range for the operation of underfrequency automation, a smaller number of underfrequency automation operating steps as well as different technical parameters for underfrequency automation.

As the underfrequency automation is physically located in the transmission networks, the practical implementation of the adaptation of underfrequency automation to Continental European conditions is the responsibility of the transmission networks. On the basis of the corresponding action plan, the compliance of the underfrequency automation in Estonia with the requirements of the Continental European synchronous area is planned by the end of 2024.

2.3 UNEXPECTED SYNCHRONISATION WITH THE CONTINENTAL EUROPE SYNCHRONOUS AREA

An unexpected synchronisation of the Baltic electricity system with the Continental European synchronous area will take place in the event of a prior unilateral disconnection of the Baltic electricity system from the current synchronous area by the Russian and Belarusian TSOs and, after this event, the Baltic TSOs will start the agreed actions with the aim to connect the Baltic electricity system to the Continental European synchronous area as soon as possible.

Eight 330 kV lines currently connect the Baltic electricity system to the Russian and Belarusian systems, and there are three 330 kV lines between Lithuania and the Kaliningrad region. The likelihood of all these lines being switched off more or less at the same time for some technical reason is very small. However, Russia's aggression against Ukraine and the resulting changes in the geopolitical situation have increased the likelihood that Russia and Belarus might take such a unilateral step. This in turn means that the Baltic TSOs have taken such a possibility into account and have planned their own contingency actions.

2.3.1 Emergency desynchronisation

In the event of an unexpected desynchronisation of the Baltic electricity system, the Russian and Belarusian system operators will switch off all lines connecting the Baltic electricity system to Russia and Belarus as well as the lines between Kaliningrad and Lithuania. The Baltic States will remain in operation as a separate synchronous area, connected to the Nordic countries and Poland by four DC connections.

The Baltic TSOs will launch the agreed action plan to ensure the stable operation of the Baltic electricity system in island mode. The agreement also covers the assignment of different operational responsibilities between the Baltic TSOs and activities to ensure frequency control and the stability of the electricity system.

When the Baltic electricity system is in island mode, the capacity of local power plants will be used to regulate the frequency and, in addition to the power plants, the direct current connections between Estonia and Finland (EstLink 1 and EstLink 2) and the direct current connection between Lithuania and Sweden (NordBalt) will be put into automatic frequency regulation mode. Through these DC connections, the reserve capacities of the Nordic countries can be used for automatic regulation of the frequency of the Baltic electricity system.

In addition, there is a need to ensure the stability of the Baltic electricity system, given that the Baltic electricity system operates as an island and no longer receives stability support from a large frequency area. In order to ensure stability in island mode, it is necessary to reduce transmission capacities with the Nordic countries, to reduce transnational power flows within the Baltic States and to ensure the necessary level of inertia and short-circuit power by local means.

Meeting all the needs listed above also means putting the emergency reserve capacity in the Baltic States into use and launching the generation equipment that is in reserve (for example, launching the Narva power plant units). It must also be taken into account that ensuring the stable operation of the Baltic synchronous area is considerably more complex than it would be in a situation where the Baltic electricity system were a part of a large synchronous area. The impact of a possible disturbance that may occur in the electricity system on stability is bigger than it would be in a large synchronous area. Therefore, in some situations, it is necessary to also be prepared for the possible operation of underfrequency automation or limitation of consumption. Elering has signed contracts with Enefit Power (for launching generation capacity in Narva and participation in frequency regulation) and Elektrilevi (for limiting consumption, if necessary) for such cases. In addition, Elering has the right, under subsections 40 (2) and (3) of the Electricity Market Act, to issue mandatory orders to producers to increase or reduce generation, the right to issue mandatory orders to consumers to reduce consumption and the right to increase or reduce generation or consumption, regardless of whether a contract has been entered into with the system operator for the purchase of regulating capacity, provided that the issue of such orders or the increase or reduction of generation or consumption is necessary for technical reasons or in order to ensure security of supply.

2.3.2. Unexpected synchronisation

Following the unexpected desynchronisation of the Baltic electricity system by the Russian and Belarusian TSOs, the Baltic TSOs will start preparations for the unexpected synchronisation of the Baltic electricity system with the Continental European synchronous area. Technical capacity for this has been built at the Alytus substation in Lithuania. On the practical side, this would mean that the DC connection between Poland and Lithuania at the Alytus substation would be switched off and the existing DC connection would be replaced by an AC connection between Poland and Lithuania and the Baltic electricity system would be synchronised with the Continental European synchronous area through this AC connection. It is estimated that the extraordinary synchronisation of the Baltic electricity system with the mainland European synchronous area would take 6-12 hours.

An agreement has been concluded between Poland and the Baltic TSOs that addresses the practical connection to the Continental European synchronous area and the conditions to be met by the Baltic TSOs when operating in the Continental European synchronous area. The agreement is based on the assumption that the need for extraordinary synchronisation may arise at any time before the scheduled synchronisation deadline and therefore the Baltic electricity system will be connected to the Continental European synchronous area as it is at that moment. Therefore, compliance with the terms and conditions of the connection agreement with the Continental European synchronous area is not required in the case of extraordinary synchronisation. In the event of an unexpected synchronisation, the Baltic TSOs will have to ensure that their imbalance with Poland would be within certain limits in terms of hourly energy and the instant value of capacity. In order to keep the imbalance within limits, the Baltic TSOs may use the mFRR reserve capacities at their disposal in the same way as they currently do in the BRELL framework. The costs incurred by Continental European TSOs for balancing the Baltic electricity system will be covered by the Baltic TSOs.

2.3.3 Need for 1,000 MW of dispatchable capacity in Estonia

Elering as the TSO must be prepared for the occurrence of low-probability events, such as the emergence of island mode in the Baltics or Estonia ending up in island mode as a result of unilateral action by Russia and Belarus. Starting from synchronisation with Continental Europe, this would mean eliminating the cause of being disconnected from the Continental European synchronous area (for example, remedying a technical fault in the Lithuania-Poland lines or substation equipment), and after that, restoring connections to the Continental European synchronous area. Since the speed of reconnecting the Baltic electricity systems with the larger frequency area depends specifically on the situation as it shapes up and may take time, there must be readiness for the Baltic electricity systems to operate separately for a longer time. This in turn means that there should be readiness to ensure the supply of electricity to all Estonian power consumers during peak consumption periods. In recent years, peak consumption in Estonia has been around 1500-1550 MW.

For the Baltic electricity system to function in island mode, all Baltic TSOs must be capable of ensuring their electricity system balance, i.e. the balance between generation, consumption and cross-border power flows. An additional condition for the functioning of the Baltic frequency area is the use of DC connections to a reduced extent. This in turn is caused by the fact that a small synchronous area cannot cope with overly rapid changes in large loads and can shut off as a consequence. Based on the current assessment, DC connections of up to 400 MW can be used. This 400 MW also includes reserves that support frequency stability and that can be obtained from the Nordics and Poland. The 400 MW constraint also applies to large generation equipment in the Baltic electricity systems. In addition, it should be considered that Estonian and Baltic peak consumption as a whole coincides in a time when the renewable energy output may be low. This means that solar plant output cannot always be counted on to cover peak consumption in the Estonian electricity system and wind output may be quite low.

Based on the above, Estonia must have sufficiently firm generation capacities, which, coupled with Estlink 1 and Estlink 2, are capable of covering peak consumption in the Estonian electricity system. In Elering's estimation, an additional approx. 1000 MW of generation capacity will be needed locally in Estonia in addition to the energy from the two EstLinks (see also Chapter 4.4.3). If any events occur in the Baltic synchronous area that have a significant impact on the balance of the electricity system (e.g. disconnections of generation equipment or DC connections), the emergency reserve capacities at the disposal of Baltic TSOs will be used to ride out such situations. In this regard, Elering contributes the Kiisa emergency reserve power plant output (250 MW). These emergency reserve capacities are kept in addition to the 1000 MW of firm generation capacity. In addition to the Baltics being in island mode, the existence of 1,000 MW of certain generation capacities in Estonia will ensure electricity supply to Estonian consumers for most of the time when Estonia is in island mode.

2.4 SYNCHRONISATION WITH THE CONTINENTAL EUROPEAN FREQUENCY AREA ACCORDING TO ELECTRICITY SYSTEM MANAGEMENT

Synchronisation with the Continental European synchronous system was originally planned for the end of 2025. In view of the risks to the Baltic electricity system arising from Russia's aggression against Ukraine, the Baltic states have agreed to accelerated synchronisation with the Continental European Synchronous Area in August 2023. Synchronisation with the Continental European synchronous area must take place in February 2025. In the case of accelerated synchronisation, it is important to ensure the minimum conditions for the operation of the electricity system that would allow the operation of the Estonian electricity system to be organised in a reliable manner and without taking excessive risks. In line with the new deadline for synchronisation, activities are planned to meet the requirements of the infrastructure, IT systems and the terms and conditions of the connection agreement (i.e. the requirements set forth in the SAFA).

The implementation of accelerated synchronisation requires the completion of essential infrastructure. The completion of the third 330 kV line between Estonia and Latvia, scheduled for the end of 2024, is particularly important. This would allow mitigation of the risk of Estonia's electricity system falling into island mode (a risk that exists in the case of two lines between Estonia and Latvia). The completion of synchronous compensators is also important, as it will significantly contribute to ensuring the stability of the Estonian electricity system. The last synchronous compensator on the territory of the Viru substation will be completed in June 2024.

As for IT systems, updating the SCADA/EMS real-time monitoring and management system is the most important. This system is scheduled to be completed by the end of 2024. It is a system through which all the functions of the Estonian electricity system and all Elering's objects are centrally controlled. The new system also has additional functionalities specifically ordered for synchronisation with Continental Europe, including a Frequency Restoration Controller to trigger aFRR reserves.

In addition to the completion of major infrastructure objects and IT systems, Baltic regional reserve capacity markets need to be developed, otherwise there may not be sufficient fast reserve capacities (FCR, aFRR). If we are unable to meet the Load Frequency Control and Reserves annex of the SAFA, it would mean that for some time we would have to rebalance our system in a similar way to the current situation. All in all, this means that by the beginning of 2025, we will not fully meet the conditions of the connection agreement.

An additional factor to be taken into account is the implementation of the Baltic electricity system separation test. According to the terms and conditions of the connection agreement, such a test (or tests) must be carried out before synchronisation with Continental Europe and, after this test (or tests), the Baltic electricity system should reconnect to the BRELL system for a period of time. As the preparation of such a test is a very time-consuming process and requires the existence of the necessary technical conditions, carrying out such a test in 2024 involves risks. From a practical point of view, it would make sense in such a case to carry out this test immediately before synchronisation with the Continental European synchronous area and immediately after the test to synchronise the Baltic electricity system with the Continental European synchronous area once and for all.

2.5. BALTIC RCC

2.5.1 What is Baltic RCC?

Starting in 2016, regional security coordination is organised at the European level in the context of an RSC, a regional security coordinator. In the Baltics, a Baltic RSC was founded in 2016. The Baltic RSC was formed as a joint cooperative unit of the three Baltic TSOs, the main area of responsibility of which was coordination of the Baltic regional operational reliability across TSOs.

In 2019, the European Parliament and Council adopted a package of regulations called the Clean Energy Package (CEP), consisting of eight regulatory acts: The package's directive 2019/944 and regulation 2019/943 covered, among other things, the creation of regional coordination centres, RCCs, by June 2022. On the basis of the aforementioned directive and regulation, the existing RSCs were transformed into RCCs – new organisations legally separate from the TSOs were created. The main goal of the amendment is to ensure the independence of the RCCs from the TSOs and state interests, ensuring a neutral view with regard to the entire region.

In cooperation with Latvian and Lithuanian TSOs, a Baltic RCC in the ownership of the TSOs was established upon the signing of the foundation agreement on 3 May. Pursuant to the agreement, the Baltic RCC is legally seated in Estonia. Balti RCC OÜ was registered in the Estonian Commercial Register on 20 June 2022. The Baltic RCC shareholders are the Baltic TSOs, each of which holds one-third. The establishment of the Baltic RCC proceeded from the principle that the three Baltic states would be as equally weighted as possible in RCC activities as well as employees to ensure joint cooperation and broad-based knowledge in all fields.

2.5.2 Functions of Baltic RCC

The purpose of the Regional Control Centre is to organise coordination of regional activities between TSOs as needed for the functioning of the electricity system. To achieve the coordination, the RCC provides the TSOs services necessary for increasing the system's reliability. In effect, it means that the RCC performs certain operational planning functions that until this point had been performed by the TSOs. At the current time, the Baltic RCC provides the Baltic TSOs five main services, which were taken over from the Baltic RSC portfolio. The services are as follows:

- Creation of joint network models. The main objective is to harmonise the principles for compiling network models and their everyday validation and consolidation into central network models that could be used in various system reliability processes and calculations.

- Calculation of cross-border transmission capacities. Unified calculation of transmission capacities in the Baltic Nordic transmission capacity calculation region (CCR).

- Coordinated operational reliability analysis, including assessment of corrective actions (such as with regard to countertrading). Using a single network model to model network states, potential malfunction situations are found, where the normal operation of the network could be disrupted, and thereby the corrective actions to be taken for eliminating the situations will be determined.

- Coordinated regional planning of interruptions of electricity system equipment. Planning and assessing system interruptions to ensure reliability of the system in the case of possible malfunctions.

- Preparing system adequacy forecasts for regional, week-ahead market until at least the day-ahead market and preparing risk mitigation measures.

- Supporting assessment of TSOs' protection plans and restoration plans in the course of periodic reviews.

- Analysis of the electricity system after failures and preparation of action plans to mitigate risks in the future.

The list of services to be provided by Baltic RCC in the future will expand, since the electricity internal market regulation 2019/943 sets forth up to 16 services that RCCs must or may provide to TSOs. The development of service content and requirements is at different stages for different services, but the addition of services is planned until 2026. Currently, the implementation of the services is planned according to the roadmap shown in Figure 2.6.

Figure 2.6
Roadmap for implementation of Baltic RCC services

2022	2023	2024	2025	2026
• Creation of joint network models • System adequacy • Outage scheduling • Post-disturbance analysis	• Coordinated performance analysis • Supporting the assessment of onsistency between protection and recovery plans	• Calculation of cross-border capacity used by reserve capacity mechanisms • Training and certification of regional coordination centre staff	• Coordinated capacity calculation • Supporting regional restoration activities • Facilitating regional acquisition of balancing capacity • Assisting TSOs in upgrading regional transmission capacities	• Regional determination of reserve capacity levels

2.5.3 Baltic RCC from the standpoint of regional functioning of the electricity system

The main goal of regional coordination is to ensure a single picture for assessing operational reliability in the Baltic region as well as in Europe in general in order to see the countries' cross-border influences that may cause problems in the functioning of the energy system. Regional coordination will help the TSOs make better decisions in the electricity system's operational planning phase, providing corresponding assessments at the regional level. For example, to better decide which activities are the most effective for ensuring cross-border transmission capacities, which equipment to perform maintenance on or which equipment maintenance should be postponed so that it would have a positive regional impact on both reliability and functioning of the markets.

Last winter, the focus was on the latter service (coordination of interruptions in equipment), as the reserve capacity of the electricity system was lower than usual, resulting in higher electricity prices and the need to constantly assess the availability of generation equipment when controlling the system. In cooperation with the TSOs, the reserve of generation equipment and interruptions in generation equipment were reviewed on a daily basis in order to hedge against potential capacity shortfalls.

RCC-side coordination increases the efficiency of managing the electricity system, reduces risk of major accidents arising and reduces the costs for consumers by ensuring maximum cross-border transmission capacity.

2.6. OVERVIEW OF ELECTRICITY SYSTEM MANAGEMENT CAPABILITY

2.6.1 Winter period 2022/2023 (November to February)

The actual temperatures in the 2022/2023 winter period proved much warmer than the multi-year average. Only December was cooler. On the other hand, in November and the first months of the year, the air temperature was an average of 1.7 degrees warmer.

Average net consumption decreased by 2% in the 2022/2023 winter period compared to the winter period the year before to 1063 MW, and 1391 MW was recorded as peak consumption, which was 10% less than the year before. Average electricity production fell by 7% to 804 MW. Maximum and minimum output were measured at 1,408 MW and 331 MW, respectively. Maximum generation in wind farms connected to the Elering network was measured at 282 MW.

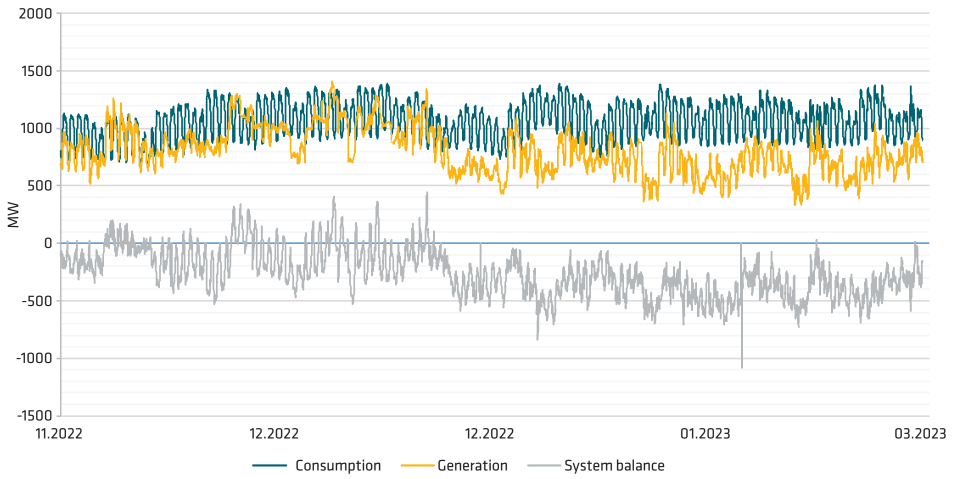
Throughout the period under review, Estonia's domestic generation covered domestic consumption in 11% of the hours, compared to 14% in the previous year, and on average the Estonian electricity system was a net importer to the extent of 259 MW.

Summary of the Estonian electricity system operational parameters in the 2022/2023 winter period (01.11.2022–1.03.2023) is set forth in the following table (Table 2.1) and figure (Figure 2.7).

Table 2.1
Operational parameters of the Estonian electricity system in 2022/2023 winter period

	Value, MW	***Period***
Estonian maximum net consumption	1391	*09.01.2023 11:25*
Estonian minimum net consumption	673	*13.11.2022 04:30*
Estonian average net consumption	1063	*1.11.2022 00:00 – 1.03.2023 00:00*
Estonian maximum net generation	1408	*08.12.2022 20:35*
Estonian minimum net generation	331	*12.02.2023 03:10*
Estonian average net generation	804	*1.11.2022 00:00 – 1.03.2023 00:00*
Maximum generation of wind farms connected to the Elering network	282	*09.02.2023 12:30*
Estonian maximum export	447	*22.12.2022 00:55*
Estonian maximum import	-1082	*3.02.2023 22:20*
Estonian average export/import	-259	*1.11.2022 00:00 – 1.03.2023 00:00*

Joonis 2.7
Eesti elektrisüsteemi tarbimine, tootmine ja import/eksport 2022.-2023. aasta talveperioodil



2.6.2 2022/2023 summer period (May to August)

The air temperature in the 2023 summer period proved warmer than the multi-year average in May, June and August, and cooler than average in July. The temperature measured in July was 1.2 degrees cooler than the multi-year average, while June was 1.7 degrees warmer. The Estonian average and minimum net consumption were at the same level as in the summer period the year before. The maximum net consumption was measured at 1,328 MW, 10% higher than last year.

The electricity generation indicators fell significantly compared to the past period. On average, 499 MW of electricity was generated and the maximum generation was 1089 MW. Compared to the previous year's summer period, these indicators proved 40 and 34 percent lower, respectively. The maximum production capacities of solar and wind power plants increased in the current period. The maximum solar energy output was 526 MW and the maximum output from wind farms supplied to the Elering grid was recorded as 336 MW. The increase on the previous period is 37 and 66 percent, respectively.

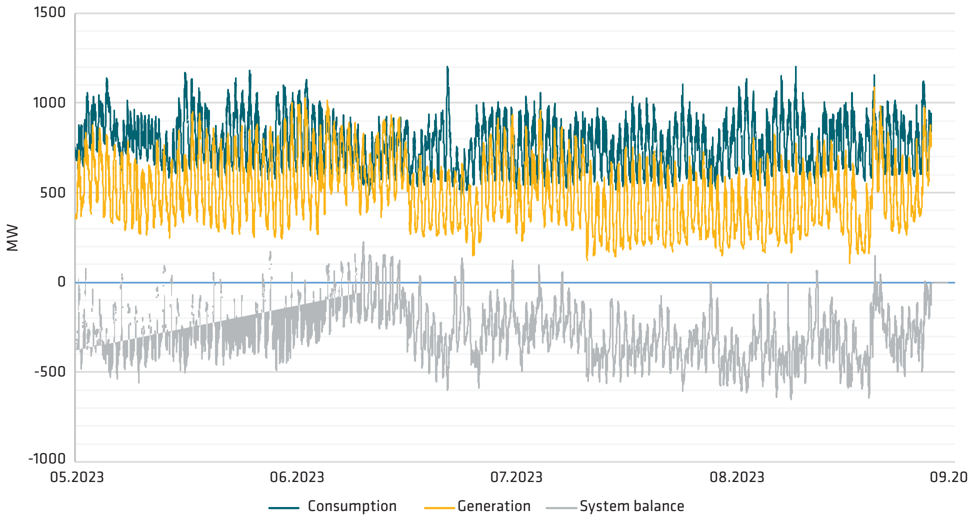
While last year's summer period saw the Estonian electricity system cover consumption with local generation as much as 46% of the time, in the 2023 summer period, local generation covered demand in only 5% of hours. The maximum export in the summer period was 229 MW and maximum import was 655 MW. On average, the Estonian electricity system was a net importer by 272 MWh.

A summary of the Estonian electricity system's operational parameters in the 2023 summer period (01.05.2023–31.08.2023) is set forth in the following table (Table 2.2) and figure (Figure 2.6).

Table 2.2
Operational parameters of the Estonian electricity system in 2023 summer period

	Value, MW	***Period***
Estonian maximum net consumption	1206	*22.06.2023 11:30*
Estonian minimum net consumption	456	*24.06.2023 10:00*
Estonian average net consumption	776	*1.05.2023 – 1.09.2023*
Estonian maximum net generation	1089	*21.08.2023 13:30*
Estonian minimum net generation	105	*18.08.2023 02:00*
Estonian average net generation	499	*1.05.2023 – 1.09.2023*
Maximum generation of wind farms connected to the Elering network	336	*03.07.2023 14:05*
Maximum generation of solar plants	526	*09.06.2023 13:00*
Estonian maximum export	229	*10.06.2023 14:05*
Estonian maximum import	-655	*09.08.2023 21:45*
Estonian average export/import	-272	*1.05.2023 – 1.09.2023*

Figure 2.8
Consumption, generation and import/export, Estonian electricity system in summer period 2023



2.6.3 Cross-border maximum transmission capacities and flows in the 2022/2023 winter period

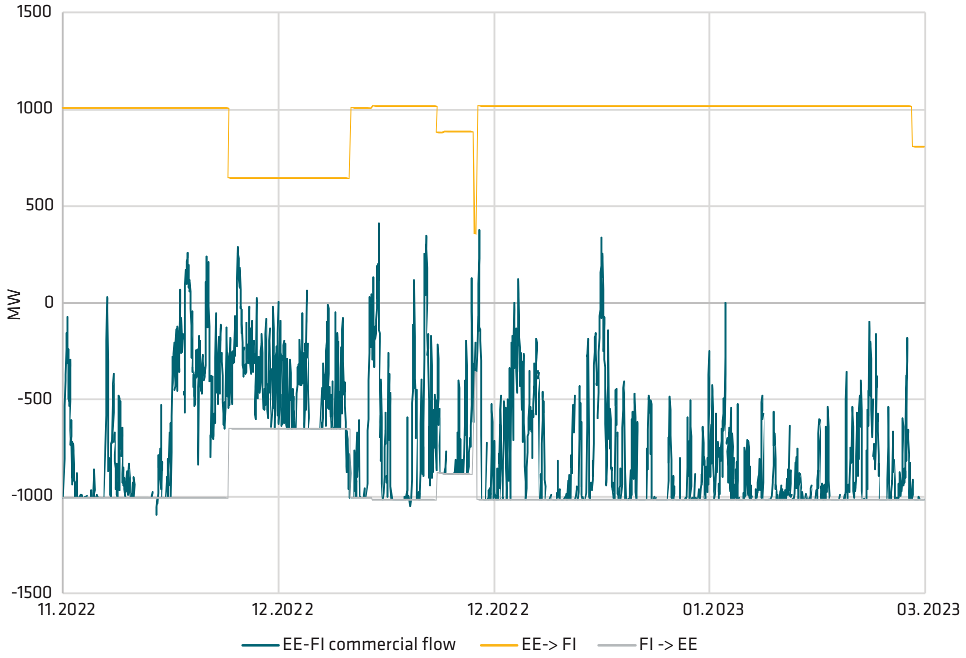
In the 2022/2023 winter period, electricity transport flowed from Finland to the Baltics 97% of the time, achieving the maximum transmission capacity limit 33% of the time.

In the Estonia-Finland cross-section, transmission capacities were limited for 11 hours on 28.12.2022 in both directions at a maximum of 658 MW, which was applied for the purpose of maintenance of the Estlink 2 submarine cable[13]. Between 22.11.2022 and 10.12.2022, the entire Estlink 1 connection[14] was interrupted, resulting in 368 MW less transmission capacity during the maintenance works.

Between 22 and 24 December, capacity on the Estlink 2 cross section was reduced by 138 MW, and between 24 and 28 December by 130 MW, due to a fault in a high-voltage equipment[15]. Between 27 February and 2 March, limitations were applied to the extent of 208 MW in connection with maintenance work[16] at Kiisa substation. Cross-section transmission capacities and physical energy flows are listed in Figure 2.9.

The average flow on the Estonia-Finland cross-section decreased by 8% compared to the same period last year, being an average of 730 MW (last winter period, the average flow was 795 MW).

Figure 2.9
Power flows in the Estonia-Finland cross-section in 2022/2023 winter period



The average flow between Estonia and Latvia shrank significantly compared with the same period last year, being an average of 460 MW (last winter period, the average flow was 570 MW). The number of hours during which the transmission capacity from Estonia to Latvia was in maximum use was 93. Power flowed from Estonia to Latvia 91% of the time, and 9% of the time in the other direction. The maximum transmission capacity in the winter period in the Latvian direction was 1016 MW and in the Estonian direction 969 MW. The minimum transmission capacity in the Latvian direction was 616 MW and in the Estonian direction 629 MW.

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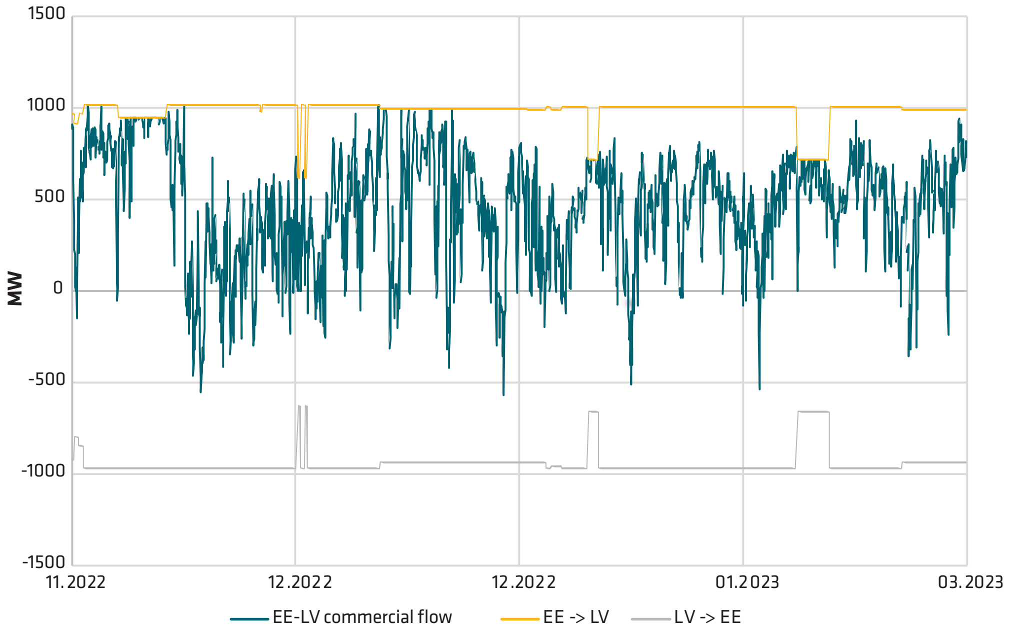
[13] https://umm.nordpoolgroup.com/#/messages/c58aebdb-deca-4e8b-88a1-7161a5796409/1
[14] https://umm.nordpoolgroup.com/#/messages/2dde7e69-1d78-4a2d-863f-5aee3c58acd1/17
[15] https://umm.nordpoolgroup.com/#/messages/c68d8275-9f36-4581-a987-ed4ad0fba64e/11
[16] https://umm.nordpoolgroup.com/#/messages/d11c3a56-66af-498e-96ba-97ba15754127/3

The transmission capacities for 2022/2023 in the Estonia-Latvia direction and total power served during the winter period are shown in Figure 2.10.

Figure 2.10
Power flows in the Estonia-Latvia cross-section in 2022/2023 winter period



In a situation where the physical energy flows exceed the network's through-capacity and there is a risk to system control capability, countertrading must occur to remove the physical congestion. Countertrading takes place only during the hour of operation itself; it is not performed preventively (such as eight hours ahead). To perform countertrading, generation is increased in the region into which the active power flow enters and generation is reduced in the region from which the active power flow exits (exited). In order to ensure that electricity systems' power balances remain balanced, the increase and decrease in generation must be equivalent. Primarily, countertrading has to take place between Estonia and Latvia (AC connection) in the summer period, but in addition to Latvian and Lithuanian import, the lines' transmission capacity will decrease due to an increase in ambient air temperature. Major power flows in the Latvia to Estonia direction can cause situations where the cross-border lines' cross-sections are congested and there is a risk of a transmission cut. To avoid this, countertrading is used in cooperation between TSOs. During the previous winter period, a total of one hour of countertrading was carried out on the Estonia-Latvia cross section. The maximum technical transmission capacities in winter and summer are shown on Table 2.3

Table 2.3
Maximum technical transmission capacity in Estonian cross-sections in winter and summer

Maximum technical transmission capacity(TTC)	**EE→LV**	**LV->EE**	**EE<->FI**	**EE->RU**	**RU->EE**	
winter 0°C	1610	1600	1016	910	910	
summer +25°C	820	920	1016	350	360	

2.7. OPERATIONAL RELIABILITY OF THE POWER GRIDS

In terms of the number of outages, 2022 was the best result in the last three years and the third best result in the last 10 years. In terms of the energy not supplied, 2022 was the worst in the last three years. In terms of the last 10 years, the indicators were even higher than in 2022 in the years 2013, 2016 and 2019. In terms of the number of outages, however, it was the best result in the last three years and the third best result in the last 10 years. The transmission reliability indicators of the ratio of actual to calculated energy transmitted can be seen in the graphs below for each year. The graph below shows that in 2022, the 6-month transmission reliability was 100%. The graph for 2023 shows that in the first half of the year, transmission reliability was 100% in January and June. The overall transmission reliability indicator for the whole year was brought down by the incident at Kunda substation, which will be discussed later.

The figures for the first half of 2023 were worsened by one event, but the energy not supplied because of it was still less than in 2022. Overall, the performance of the Elering AC grid has been good with the exception of the two events in 2022 and 2023.

The actual temperatures in the 2022/2023 winter period proved much warmer than the multi-year average. Only December was cooler. On the other hand, in November and the first months of the year, the air temperature was an average of 1.7 degrees warmer.

Figure 2.11
Availability by year for the period 2010-2023 (6 months)

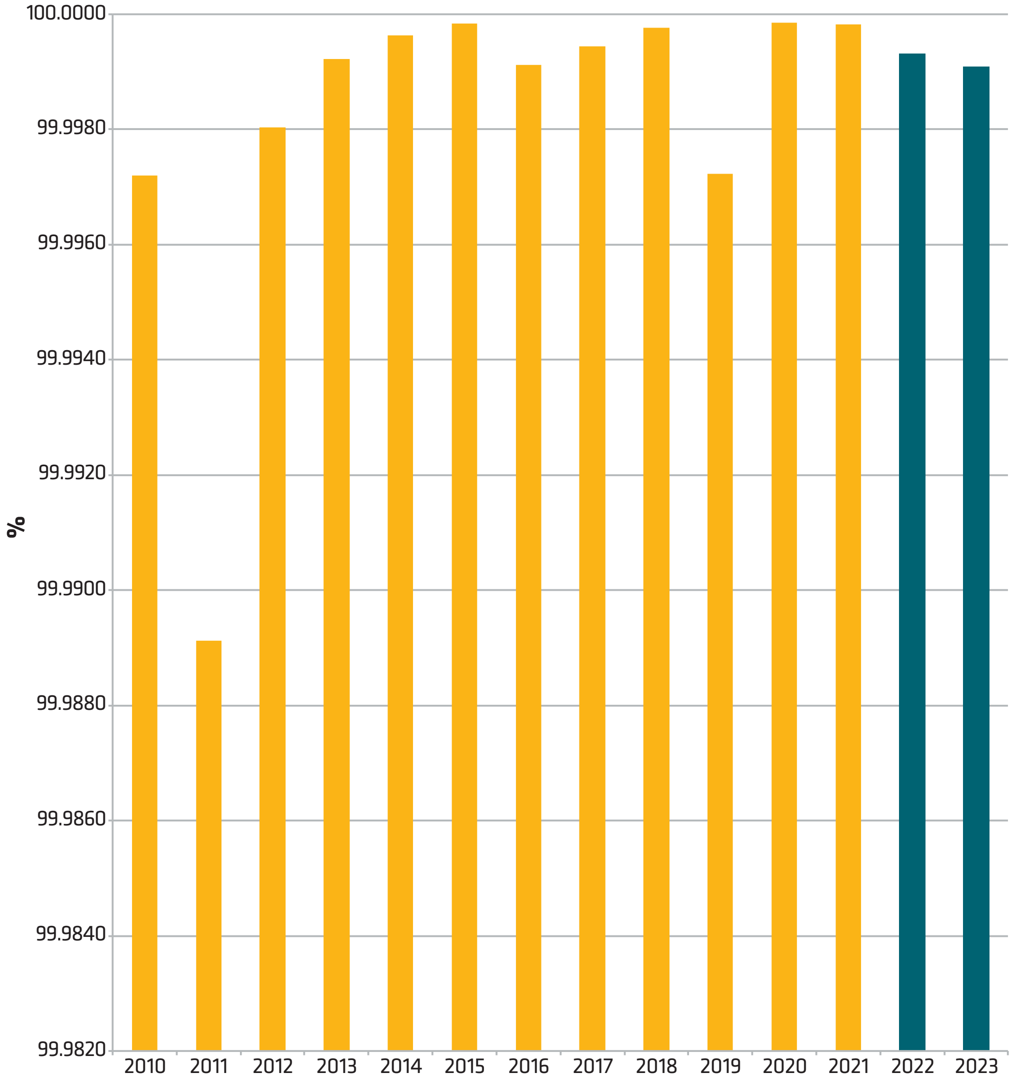


Figure 2.12
Availability in 2022 by month

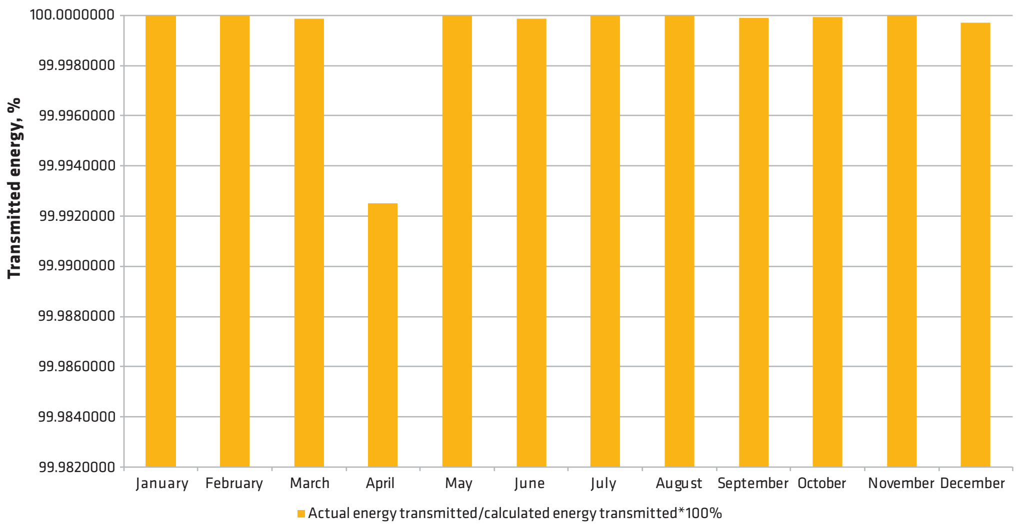
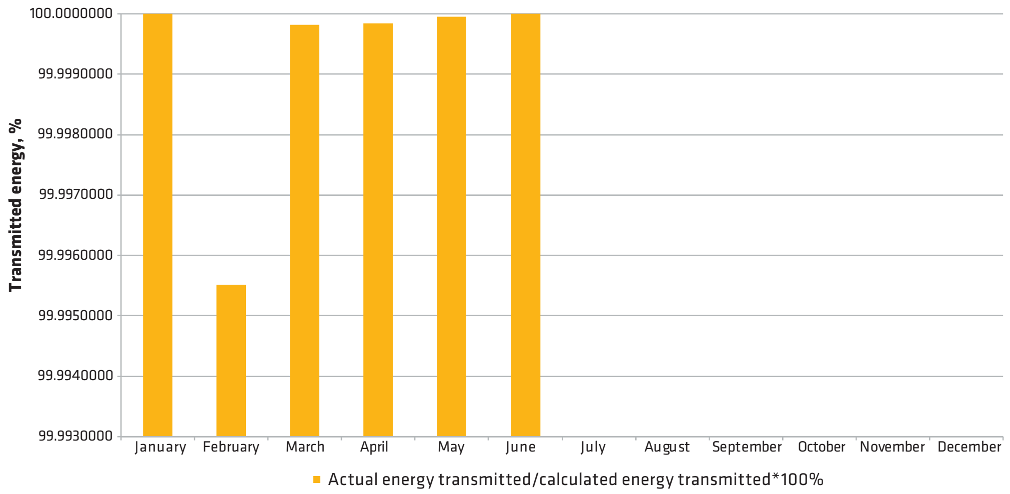


Figure 2.13
Availability in 2023 by month



There have been outages caused by human error (for example, machinery hitting overhead lines) over the years. Such situations are not directly dependent on the actions of Elering, but in order to ensure safety and increase reliability, Elering issues information material to prevent outages caused by third parties. Most of these failures occur due to activities immediately next to lines that have not been approved by Elering or about which Elering has not been informed. The good impact of Elering's outreach activities is demonstrated by the reduction in outages caused by third parties over time.

While birds have been a major cause of outages in previous years, the installation of bird barriers has been successful and the number of outages caused by birds has decreased.

In addition to the above, it is important to consistently invest in improving the technical condition of lines and substations and thereby improve the reliability and constant periodic maintenance of overhead line corridors. Investments in large hub substations due to equipment depreciation, i.e. age, have mostly been made and improvements are made on an ongoing basis in accordance with the maintenance plan. This mainly concerns the high-voltage equipment, which is directly necessary for the transmission of electricity. The systems that assist and support the transmission of electricity, such as relay protection, automation, communication telemechanics, control, signalling and other equipment, have a significantly shorter life cycle, which causes new investment needs, while high-voltage equipment will be able to continue operating for some time. Low-voltage equipment represents a small proportion of the total investment in a substation, but it is still rather considerable. The equipment of smaller substations, which are not operating at full load, is assessed and maintained as necessary. In the case of the latter, the lifetime of the substation can initially be extended by replacing individual components.

The principle behind the maintenance of Elering's power grid, including both substations and lines, is to prevent faults. Most of the maintenance of substation equipment is schedule-based, which is carried out to the extent of 98%. The works are planned according to the factory requirements of the equipment and the intended use specified by the manufacturer. In regard to non-electrical equipment, the same principle applies: they must have good durability and be in working order. Individual extraordinary jobs can also be added to this list. Maintenance of line equipment is carried out in line with a maintenance plan prepared on the basis of annual periodic inspections. In addition to keeping the equipment in order, the line corridors are regularly maintained.

In 2022, the performance quality of the high-voltage DC connections between Estonia and Finland was very good in spite of the fact that the usage of Estlink 1 and Estlink 2 was the highest of the past years and the number of interruptions caused by failures was relatively big. Although there were a total of 10 emergency outages or load limitation events on EstLink 1 and 2 connections in 2022, they were quickly repaired and most of them were short in duration and had a minor impact. The exception, and the most prominent failure in 2022, was the breakdown of the EstLink 1 phase reactor in November. In order to repair this failure, it was necessary to replace the broken device in its entirety, and the works also required a large amount of construction work, including the removal of the roof and ceilings of the building to lift out the defective device and install a back-up device in its place. The total duration of the outage required for the replacement of the reactor was around 414 hours. All other emergency outages of EstLink 1 (3) were short, with a total duration of around seven hours. All four emergency outages on EstLink 2, with a total outage time of 17 hours, were also quickly repaired. In addition, there were two temporary load limitations on EstLink 2 last year, with an equivalent duration of around 32 hours. Scheduled maintenance interruptions were carried out in 2022 on a significantly smaller scale than originally planned.

Including planned maintenance, the technical reliability of the Estonia-Finland DC connections in 2022 was very good: The figure for Estlink 1 was 94.81% and for Estlink 2 99.33%.

During the first half of 2023, there was one emergency shutdown of EstLink 1 due to the incorrect operation of fire detection systems at the Harku converter station. It was possible to put EstLink 1 into operation in around four hours. In terms of EstLink 2, there was one event in the first half of 2023 that reduced the transmission capacity of EstLink 2 to around 60% for a short time (one minute). There were also planned shutdowns for preventive maintenance on both EstLink 1 and EstLink 2 in the first half of 2023. Figure 2.14 depicts the full capacity of the availability of DC cables, i.e. the % of availability in full capacity in 2022. Constraints, disruptions, planned and unplanned outages are taken into account

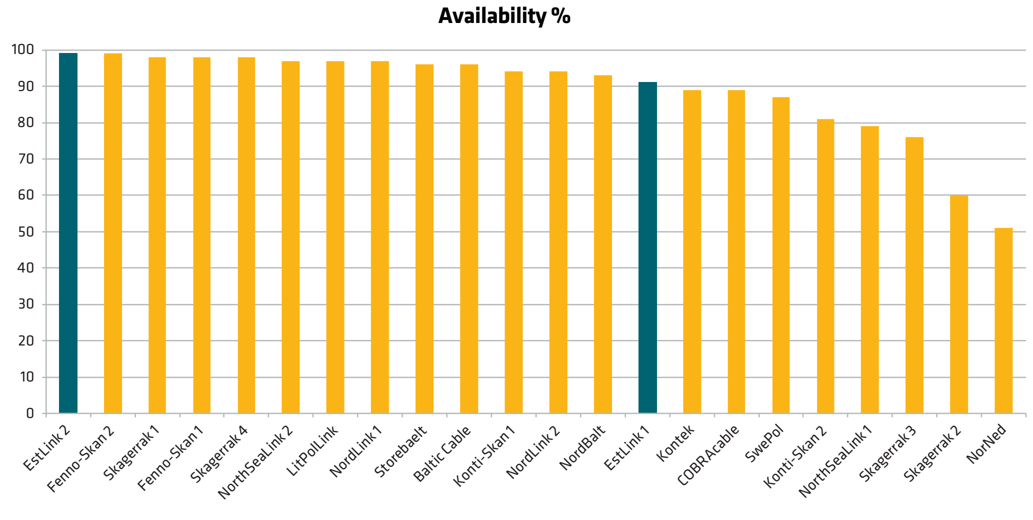


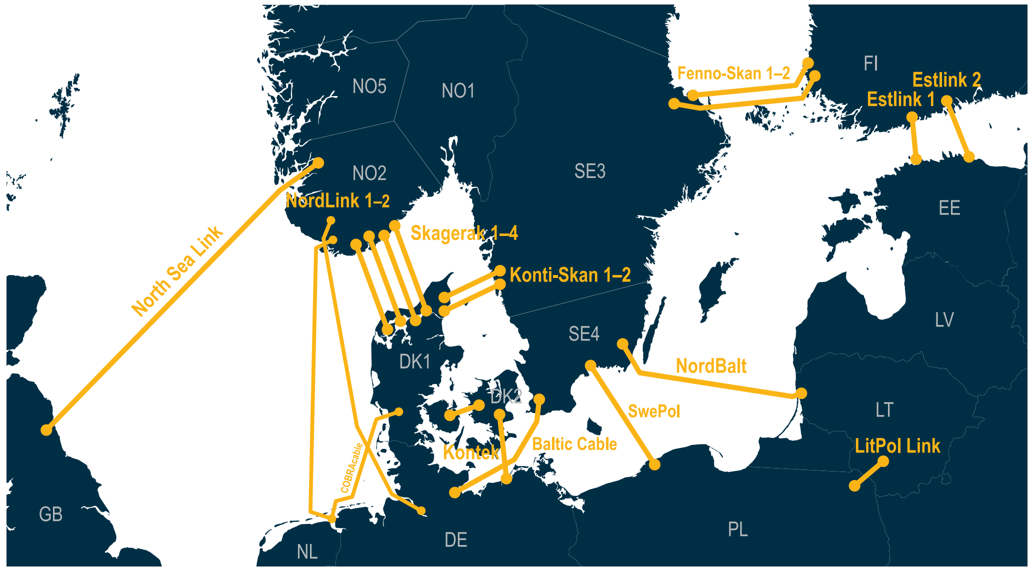
Figure 2.14 Percentage of the capacity of availability of Nordic and Baltic direct current cables in 2022

On the energy market, the connection between Estonia and Finland is among the most used (see Figure 2.15).

A total of 3,442 bottleneck hours emerged on the Estonia-Finland cross-section in 2022 – 39.29% of the hours in the year, of which:

- he total installed transmission capacity was used (i.e. the Estlink cables were used at full capacity without constraints): 2596 hours, which is 29.63% of the year;
- transmission capacity was limited owing to the Elering or Fingrid network (including due to constraints on GVDC connections) during 843 hours, which is around 9.26% of the year. There were a total of 397 hours, i.e. 4.53% of the hours of the year, in which less than 1,000 MW of the Estonia-Finland transmission capacity was at the disposal of the electricity market. Due to HVDC links, the Estonia-Finland cross-section was limited to less than 1,000 MW for a total of 199 hours, or around 2.27% of hours in the year.
- Constraints caused by the speed of change in Nordic capacity occurred in three hours, i.e. 0.03% of the year.

Figure 2.15 Geographic locations of 20 HVDC connections in 2022



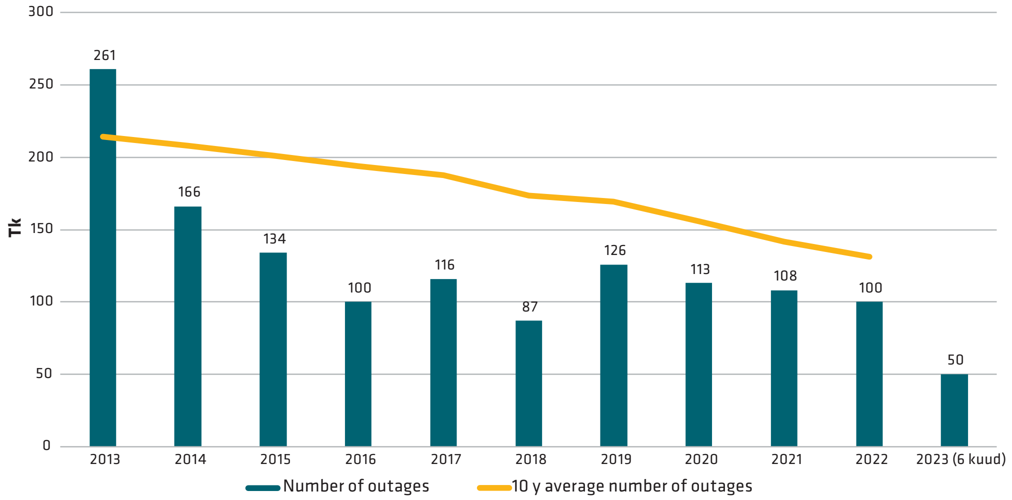
2.7.1 Outages and electricity not supplied

Fault disconnections of network devices/elements take place by way of automated equipment for the protection of humans or equipment or equipment if the device is in a hazardous or non-operational state. Disconnections of equipment do not generally mean only an outage for consumption point since all systems are redundant or can be reserved. Statistics on disconnections are held on high-voltage equipment that transmit electric energy, disconnection via automated equipment when power transmission is interrupted, such as a high-voltage line or high-voltage transformer. Statistics of disconnections is not held on low-voltage, i.e. auxiliary equipment such as supply of relay protection or automation equipment, lighting, heating etc. if they don´t cause an outage for high voltage equipment, . If a fault of any of these does result in a powertransmission cut, the event is included in statistics.

The number of outages in 2022 was 100, which is lower than the year before – 108 pc, which is 92.6% of the 2021 figure and 88% of the figure of 2020. The lowest number of outages of all time was in 2018 (86). The number of outages in 2022 was significantly lower than the 10-year average, which is 117. The company has a limit of 180 disconnections per year.

The year 2022 saw 47 disconnections due to line equipment, 41 due to substation equipment, 12 due to DC equipment and none due to energy reserve emergency plants, which amounts to 47%, 41% and 12% of the 2022 total, which was 100, respectively.

Figure 2.16
Number of outages by year



The number of outages in the first half of 2023 is 58. Compared to the first half-year figures for the last 10 years, we see it is slightly higher than the 10-year average – 47 – and the five-year average – 50. Compared to recent years, the first half of 2022 had 41 outages; 2018 with the fewest number had 36 in the first half-year.

In the first half of 2023, there were 27 disconnections due to line equipment, 18 due to substation equipment, eight due to DC equipment, one due to emergency reserve plants and four due to synchronous compensators, so 47%, 31% 14%, 2% and 7% of the total number of outages in the first half of 2023, respectively.

In addition to faults that cause outages, there are also faults where an outage has been incidentally prevented before the equipment lost its ability to operate during inspections, the switching process or in another manner. These are potential outages where the equipment has not yet caused a fault but is dangerous to the continued operation of the equipment and can no longer function normally. These are basically preventive forced interruptions, where the device must be immediately swiched off to prevent the device from spontaneously tripped. There were 56 of them in 2022, of which 41 were in substations and 15 on lines. There were no outages of DC equipment. The average for the last five full years was 36. There were 34 forced interruptions in the first half of 2023, of which 26 were at substations, 12 on lines, one on DC equipment and one on synchronous compensators.

As regards the reliability of the grid, we keep separate track of poutages of Elering equipment that were not caused by faults in Elering equipment but in the equipment of clients or neighbouring grids, but the device protecting Elering equipment, which depending on the scheme belongs either to Elering or to the client, has started operating to protect the equipment and ensure safety by switching off the Elering equipment. There were 38 such disconnections in 2022. Thirty-three of them were caused by clients and five by neighbouring grids – 87% and 13%, respectively. Such disconnections occurred on five occasions during the first half of 2023 and all of them were caused by clients.

The outages caused by clients and neighbouring grids amounted to 27% of all disconnections in 2022. In the first half of 2023, the figure was 8%.

The number of outages for consumption points that lasted less than three minutes, the majority of which are transient short circuits when the operation time of the automation asts only for a few seconds, was 25 in 2022 compared to 15 in 2021 and 19 in the first half of 2023.

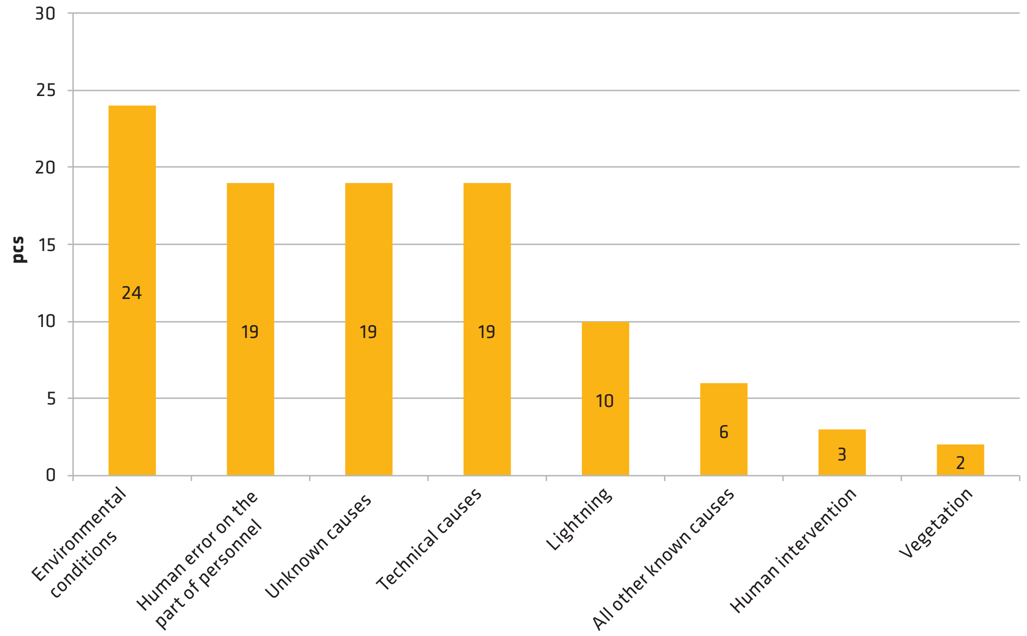
If outages are grouped by category, the largest number of causes category of outages in 2022 was environmental conditions, with a total of 24 occurrences. In turn, unlike in many previous years, the majority of environmental conditions were not related to birds, but icy rain. The number of outages caused by icy rain in 2022 was 17. Unfortunately, this is not avoidable in our climate. Of these, eight occurred in February and nine in December. In previous years, equipment has not tripped so intensively for this reason, where the live wires and lightening wire of overhead lines stretch down under the weight of ice causing outages by wires 'dancing' in the wind or coming into contact with each other, support structure or something else. In addition to outages, icy rain also caused four hazardous situations where an outage fortunately did not occur. In comparison, there were seven outages caused by ice in the first half of 2023. Of course, the grouping of causes is in some ways arbitrary, so if we add to the group of environmental conditions the number of outages caused by thunderstorms, which occurred 10 times and are listed as a separate cause, the number of outages caused by environmental conditions would be as high as 34. Lightning is listed as a separate category because it is still a fairly common cause of outages, but we have little control over outages caused by lightning. Lightning is a force of nature, but we can install bird barriers to protect against birds.

There were an equal number of 19 outages in each category due to staff errors, unknown and technical reasons. The largest number of errors made by staff were construction and installation errors, which caused seven out of 19 outages, while the remaining events were very marginal for various reasons.

In the case of unknown causes, which amounted to 19, it was not possible to identify the cause, as no visible sign of an outage was found during the inspection of the equipment, and the equipment has continued to operate smoothly after being switched back on manually or due to automation. These include, for example, transient short-circuits on power lines caused by bird activity (fouling) or wind-borne objects such a branch or plastic film, or a protection device has activated in a substation and tripped the device but an inspection of the device did not turn up anything amiss. In other cases, the device was so damaged, in some cases irreparably, that it was impossible to identify the exact cause. There have been faults where after the issue, the cause disappeared and it was impossible to ascertain whether it was in Elering or the client's equipment or due to a combined effect, since there was no physical boundary between the equipment. Such faults can only be eliminated using trial and error. Among the technical reasons, the largest number was due to manufacturing faults (13), while four outages were caused by ageing equipment. Thus, in 2022, environmental conditions were the cause in 24 cases, or around 24% of all cases, and together with thunderstorms, environmental conditions accounted for 33% of the total number of outages, while the second, third and fourth categories of reasons for the number of outages were staff errors with 19 or 33%, unknown with 19 or 33% and technical reasons with 19 or 33% of the total number of outages caused by Elering.

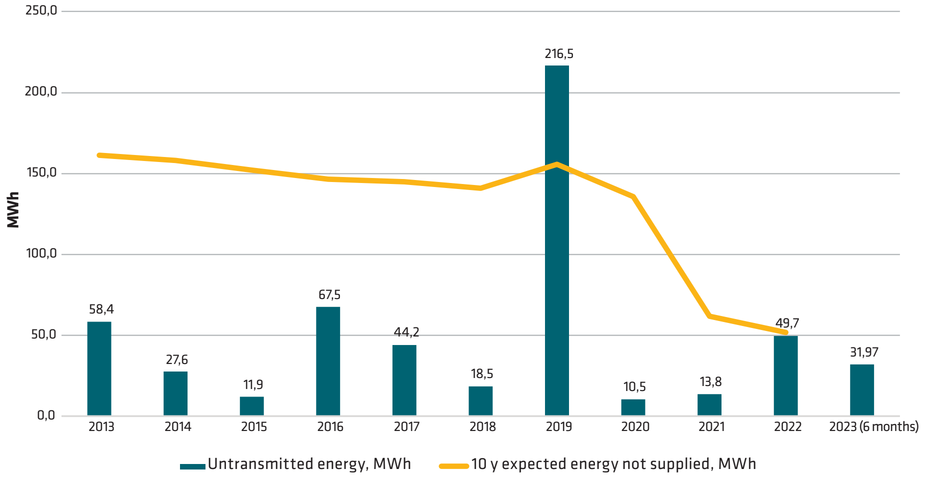
The number of outages caused by machines hitting the overhead lines was two last year, compared to four in 2021.

Figure 2.17
Outages in 2022 by cause



In the first half of 2023, various staff errors were the largest category of outages with 15 times out of 47, i.e. essentially 33% of the total number of outages when faults caused by clients are excluded. Unfortunately, errors in the configuration of automatic equipment were the biggest precise cause this year, as they caused unnecessary outages on eight occasions. The second biggest cause of staff error was poor quality or unnoticed construction or installation errors, which only became apparent once the equipment was operational – their number was six.

Figure 2.18
Electricity not served by year



The amount of energy not supplied due to the faults in the Elering grid in 2022 was 49.66 MWh (Figure 2.18). If we break down the causes of energy not supplied, the biggest cause of energy not supplied was external factors, namely vandalism 45.18 MWh. The remaining events resulted in a total of 4.49 MWh of energy not supplied during the whole year.

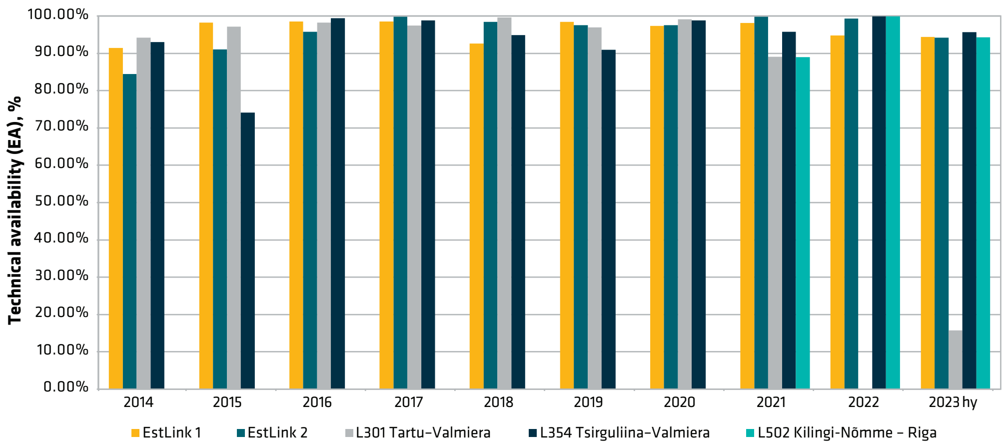
The second category was the ageing of equipment with 2.65 MWh. The outages caused by the allowed non-selectivity, as previously discussed, resulted in 0.9 MWh of energy not supplied. There were 0.59 MWh of outages whose causes were not identified and 0.38 MWh of energy not supplied due to trees falling on the line. The remaining quantities of MWh not served were very marginal. Elering was unable to serve 6.19 MWh of electricity due to faults in the equipment of clients. The amount of energy not supplied due to the faults in the Elering grid in the first half of 2023 was 32.96 MWh. If we break down the causes of energy not supplied, the biggest cause of energy not supplied was external factors, like in 2022, but this time it was objects thrown on the line 29.75 MWh. The second category was 2.4 MWh of energy not supllied as a result of substandard construction and installation activities. The cause of 0.01 MWh of outages could not be identified. The remaining quantities of MWh not served were very marginal. Elering was unable to serve 2.03 MWh of electricity due to faults in the equipment of clients.

2.7.2 Events that caused major disturbances from 2022-2023 (first half)

2.7.2.1 Cross-border connections

The reliability of Estonia's cross-border connections has been good over the years (see Figure 2.19, Figure 2.20, Figure 2.21, Table 2.4)

Figure 2.19
Reliability of international connections by year



Outages of Estlink 1

In early April, EstLink 1 was tripped three times at the Harku converter station due to the activation of fire detection systems (high sensitivity aspiration system). The total duration of the outages was 7.35 hours. The fire system had been temporarily taken out of service. During the maintenance carried out in July, signs of heating were found on one defective IGBT in the converter, which caused the aspiration system to go off in April. The defective device has been replaced and the fire detection system has been put back into operation on 7 July 2022.

At 10:41 on 22 November 2022, the HVDC connection at the Harku converter station failed due to damage to the phase reactor in phase L1. The defective device has been replaced with a back-up device, the ceiling of the building was additionally insulated and the waterproofing of the roof was improved. EstLink 1 was put back into operation on 9 December 2022 at 16:31. The duration of the outage was about 414 hours (17.25 days). The root cause of the fault could not be identified.

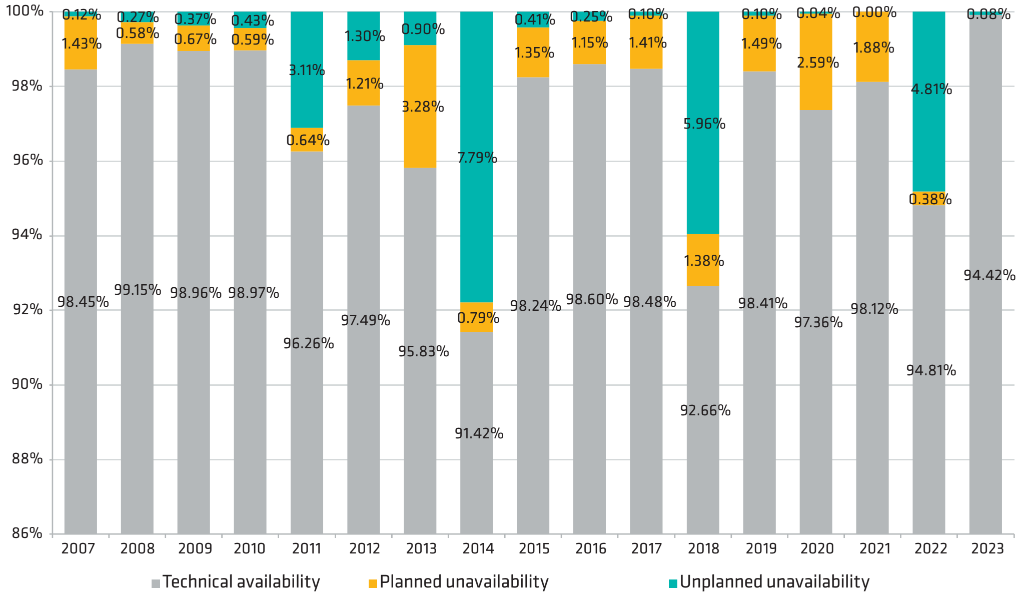
Outages of Estlink 2

From April to December 2022, there were a total of five outages or events that required the limitation of capacity. All of these were caused by various technical failures, either in the interconnector's own converter stations or by external factors.

Table 2.4
Statistics of Estonia-Finland electricity interconnection in 2022

Description	EstLink 1	EstLink 2
Use of electricity	**57,96%** (ca **1777** GWh) EE->FI: **14** GWh FI->EE: **1763** GWh	**87,74%** (ca **4996** GWh) EE->FI: **53** GWh FI->EE: **4943** GWh
Technical availability	**98,12%** (0.75% higher than in 2020)	**99,79%** (2,3% higher than 2020)
Planned unavailability	1,88% (164,5 h)	0,02% (1,7 h)
Unplanned unavailability	0,0% (0 h)	0,19% (16,74 h)
Total number of outages	2	7
Number of planned outages	2 (1 FIN, 0 EST, 1 common)	1 (1 FIN, 0 EST, 0 common)
Number of unplanned outages	0 (0 FIN, 0 EST)	6 (3 FIN, 3 EST) Transmission limitation: 4 transmission interruption: 2

Figure 2.20
Reliability of Estlink 1 by year



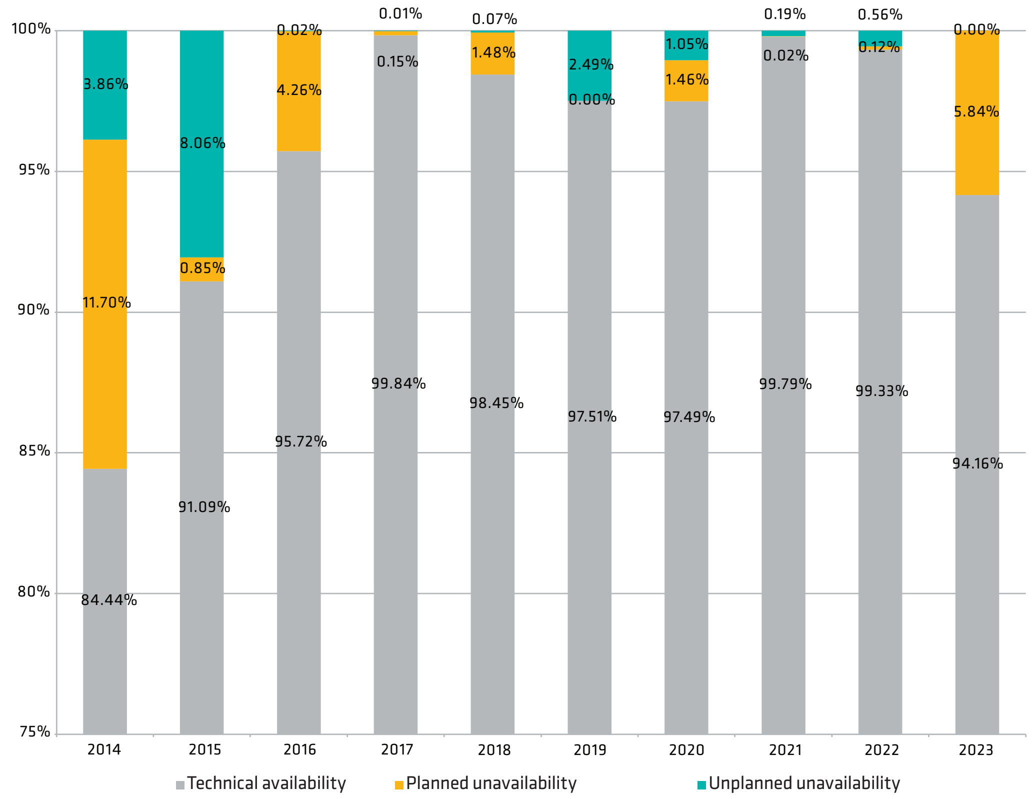


Figure 2.21
Reliability of Estlink 2 by year

2.7.2.2 Selection of major events in the grid:

10.04.2022 Circuit breakers switched off at Kunda substation

On 10 April 2022 at 20:41, an unknown person, who got into the substation, switched off the the 110 kV overhead lines feeding Kunda town and its surroundings. There was an outage for L8060, Estonian Cell and all of Kunda substation's 6 kV consumers . The remote control by telemechanics was blocked as well. Powersupply was restored when the switching staff reached the substation. At 22:05 the substation was restored to normal. The event was handed over to the security authorities for investigation. Elering is introducing changes at its substations and procedures to prevent such incidents in the future. This event remained the largest contributor to energy not supplied in 2022 with 45.18 MWh.

29.07.2022 330 kV circuit breakers of Viru substations

On 29 July 2022 at 00:36, the 330 kV circuit breakers were tripped at Viru substation. The outage was caused by the auxiliary equipment of the Eesti power station.

02.12.2022 L677/L677H outage

On 2 December 2022 at 05:22, the 110 kV overhead line L677 Tsirguliina–Valka and L677H Valga branch were tripped with an unsuccessful autoreclose. The outage was caused by a broken wire of the overhead line the L677 during reconstruction work.

16.02.2023 L183/L184 outage

On 16 Febryary, at 11:37, the wire of 220 kV former overhead line L206 that was being dismantled crashed onto the operating 110 kV lines L183 and L184 with an unsuccessful the autoreclose . The anchoring of the wire came loose during the dismantling. As both lines run in parallel on common towers and both supplied the consumers of the Topi 110 kV substation in parallel, the possibility of reservering power was also interrupted, leaving the whole substation without energy. EU2 automatically reduced the load by 350 MW as a result of the short circuit. At 14:20, lines L183 and L184 were switched on and energy supply of the Topi substation was restored. Interruption at the place of consumption 163.3 min. The energy not supplied amounted to 29.75 MWh.

2.7.3 Fulfilment of the tree trimming and grid reliability programmes

A programme for improving grid reliability was developed in 2013, aimed at widening the line corridors to prevent trees from falling and being felled on lines. Line corridors were widened so that trees at the margins would no longer reach the lines. Since the bulk of the projects in this programme have been completed, the programme for boosting reliability and safety for the next five years was developed in 2016 – Reliable grid 2016-2021. The uncompleted parts of the abovementioned programme are the clearing of protection zones around power lines. The corresponding actions and goals have been updated in this plan. The goal of the Reliable grid plan is to improve the quality of maintenance, including the maintenance of protection zones to reduce outages for clients and constraints on international connections and maximising the lifespan of power lines and gas pipelines, as a result of which future investment costs will drop. An important aspect that has been added is increasing the safety of the power grid and gas network, considering the major negative coverage of potential incidents, reducing risks in Elering's grid to human life and health as well as to property and the environment. The actions related to boosting safety also serve the goal of reducing outages and increasing safety, since most of the power grid malfunctions are related to short-circuits in publicly accessible line protection zones, and much of the energy not supplied due to outages is related to human activity in electrical installations. This plan encompasses actions whose goal is to:

1. reduce the number of outages and faults and in that connection, energy not supplied;

2. maximise the lifespan of equipment in that connection, to reduce the need for investments in future;;

3. 3. increase equipment safety.

Compared to the above, the determination of priorities has changed in the maintenance principles, based on risk assessment pursuant to the significance of the equipment and its condition (product of the latter factors). Significance in this context refers to the potential amount of energy not supplied, the impact on the cross-border transmission capacities, and safety aspects. The total area of protection zones around overhead and cable lines in September 2022 was 32,018 hectares, around 54% of which was in forested areas; the remaining part in protection zones is located either on arable land or in densely populated areas where forest does not grow. At the start of the Make Lines Free of Trees programme in 2011, there was around 1,800 ha of uncleared forest area, and by the end of 2022, around 200 ha was still not cleared. Around 200 hectares of the forested areas is uncleared forest and the rest is brushy.

Uncleared areas are mostly either areas with nature conservation restrictions or areas where no agreement has been reached with landowners to fell trees (mainly yard areas). We spend around €1.8 million per year on the maintenance of protection zones; 56.65 ha was cleared and 2,592.19 ha of scrub was cut.

3. Electricity network capability

The network's capability is part of security of supply and impacts the electricity not served and the performance covered in the previous chapter. The capability of joining the network ensures that new generating equipment is connected to the grid for generating the necessary electricity and that the grid could be attractive to new generation equipment. According to § 66 of the Electricity Market Act, the network operator must prepare a 10-year network development plan at least every two years.

This chapter has been prepared on the basis of Elering's Estonian Electricity Transmission Network Development Plan 2024-2033, which was submitted for public consultation but does not include the amendments received during the public consultation.

The investments to be made over the next 10 years are discussed in chapters 3.2 and 3.5. Chapter 3.2 describes the projects (synchronisation with the Continental European network, external connections with Latvia and Finland, reinforcement of the electricity network in Western Estonia and the islands) included in the 10-year development plan for the European electricity transmission network that is updated every two years, TYNDP 2022[17] and the soon to be published TYNDP 2024. A lot of new generation will need to be added to meet Estonia's renewable electricity generation target for 2030. In order to ensure that the investments are made at the right time, Elering has proposed to amend the grid development principles to allow Elering to make the investments in advance. It is important to clarify here that Elering uses the money of electricity consumers to fulfil the development obligation and that the development obligation must be laid down in the Electricity Market Act. Until the amendment enters into force, Elering will not take the development obligation into account in preparation of the Estonian Electricity Transmission Network Development Plan 2024-2033.

3.1 NETWORK NEEDED TO MEET RENEWABLE ENERGY TARGETS

In order to meet the European Union's green targets, Estonia needs to change its electricity production and switch to green ways of energy production. The target set by Estonia for 2030 is to generate 100% of its annual electricity consumption from renewable sources[18]. Elering's role in meeting this target is to ensure a network with sufficient capacity. Elering updates its annual electricity network investment budget and long-term 10-year investment plan. This chapter gives an overview of the projects Elering is planning over the next 10 years. The chapter includes both the investments budgeted for the next five years and those planned for the 10-year horizon, which, in addition to ensuring security of supply, support the transition to renewable energy production. As 100% of the electricity generated in Estonia will have to come from renewable energy sources in the future, we need a more accurate projection of where renewable energy sources will be connected in the near future so that the additional investment needs of the network can be assessed more accurately and built in time. This chapter also gives an overview of the generation capacities at different stages of the connection process.

Among the major investments Elering is already making today to support the connection of renewable energy are the synchronisation with Central Europe and the network reinforcements from the RRF. The planned investments with the biggest impact are Estlink 3, the Saaremaa 330 kV connection, the fourth Estonia-Latvia connection and the investments related to the reinforcement of the network of larger consumption centres.

The energy system will become much more flexible than it is today rather quickly. A new type of energy system with a lot of distributed generation needs consumption and time management. This requires the creation of the capacity to shift consumption during the day to hours when the price is more favourable. For example, electric vehicles should be charged smartly, heating systems should be run with heat storage devices or accumulation, and batteries or a pump hydro plant should be introduced. Such energy consumption creates lower costs for the consumer, a more even load on the energy system and stability. The energy system of the future also needs short-term flexibility and electricity imports in the day view. This creates the possibility to cover consumption on days when prices are higher through the flexibility of energy-intensive industry, hydrogen production or energy imports, which play an important role in the efficient use of the renewable energy produced. In addition to the above, there is a need for long-term flexibility in the weekly view and for dispatchable capacities that would cover consumption during periods when renewable energy generation is very low and the price very high. For this purpose, we need dispatchable power plants for the Estonian power grid to ensure security of supply in Estonia. Electricity consumption is growing significantly, but the new nature of electricity consumption also increases the flexibility of electricity consumption, i.e. the ability to schedule consumption according to production and to store it. A lot of distributed generation in the form of solar panels will be added to consumption, so the profile of consumption will change – when the sun is shining, consumption will decrease or change into generation in respect of the grid.

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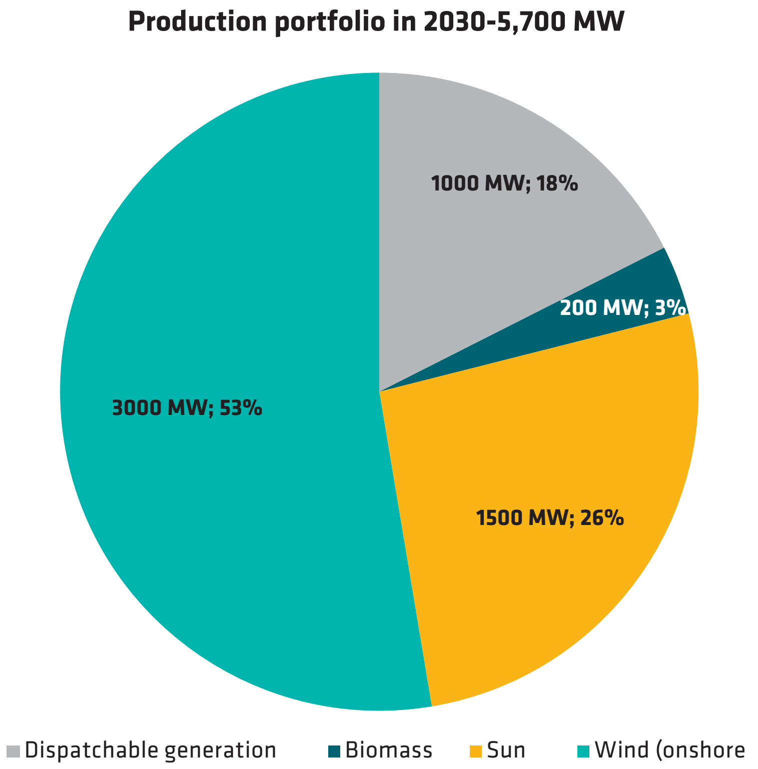
[17] https://2022.entsos-tyndp-scenarios.eu/
[18] https://kliimaministeerium.ee/media/9407/download

In order to meet the renewable energy 100 target in 2030, annual renewable energy production of around 10 TWh is needed. A possible generation portfolio view for meeting this target is a mix of different types of generation capacities of around 5.7 GW and additionally around 0.5 GW of storage capacity. The majority of the need would be covered by wind energy and to a lesser extent by solar energy and biomass. 1,000 MW of dispatchable generation is needed to ensure security of supply at times when renewable energy production is very low and the capacity of international connections is limited.

Figure 3.1
2030 production portfolio



Today's connection contracts do not guarantee this capacity, and additional large-scale renewable energy must be added.

Large-scale connection of renewable electricity to the grid means connecting new power plants in many cases in areas of the grid where there were historically no generation capacities. Renewable energy generation is of a random nature, and compared to the past, there will be many more possible paths for the transmission of capacity flows. In order to ensure the uninterrupted transport of electricity from renewable electricity generation to consumers, the capacity of the grid in these areas must be increased. Since covering 100% of annual electricity consumption also means that the nominal generation capacity of renewable electricity has to be over-covered, i.e. a few times higher than the consumption capacity of the Estonian electricity system, there will often be times in the future when renewable electricity generation will significantly exceed consumption capacity and this electricity will have to be either exported or stored locally. This requires further increases in grid capacity, especially in those areas where additional renewable electricity generation will be connected. Typically, this means upgrading the entire 110 kV grid in the region and reinforcing 110/330 substations and adding transformers. The investments outlined below will cover a large part of the known grid reinforcement needs, but additional investments will be needed to cover the planned 100% renewable electricity, which will be ascertained according to the overall portfolio of future renewable electricity plants and the regions in which the new generation capacities will be located. In order to ensure that the grid will be ready for the connection of the generation portfolio needed to meet the renewable energy 100 targets by 2030, some investments may need to be made upfront before a producer starts the connection process. Otherwise, the planning and construction activities related to the grid reinforcement will not be completed on time. One option is to ensure grid reinforcements for prospective generation connection as part of the network development obligation and to use fixed megawatt-based connection fees to speed up the connection process.

3.2 INVESTMENTS INTO THE TRANSMISSION GRID

The map below gives an overview of investments made in the Estonian transmission network in 2023-2035. The map shows only large-scale investments such as the construction of new lines/substations, the reconstruction or replacement of existing lines with cable lines, and some major line renovation works. A more detailed investment plan can be found on the Elering AS website. In addition to the approved investments of Elering, the map below summarises the major potential development prospects, which are discussed in more detail in the following subsections. The investments shown on the map fall into the following categories:

- **Synchronisation with the Continental Europe frequency area**

  The construction of the third Estonia-Latvia 330 kV connection has been completed and the renovation of the north-south 330 kV overhead lines is now in progress. The investments made for synchronisation are discussed in more detail in chapter 3.2.1.

- **Cross-border network investments**

  The third Estonia-Finland and fourth Estonia-Latvia connection are in the planning phase, as is the Baltic Sea offshore grid development project. The investments are described in chapter 3.2.3.

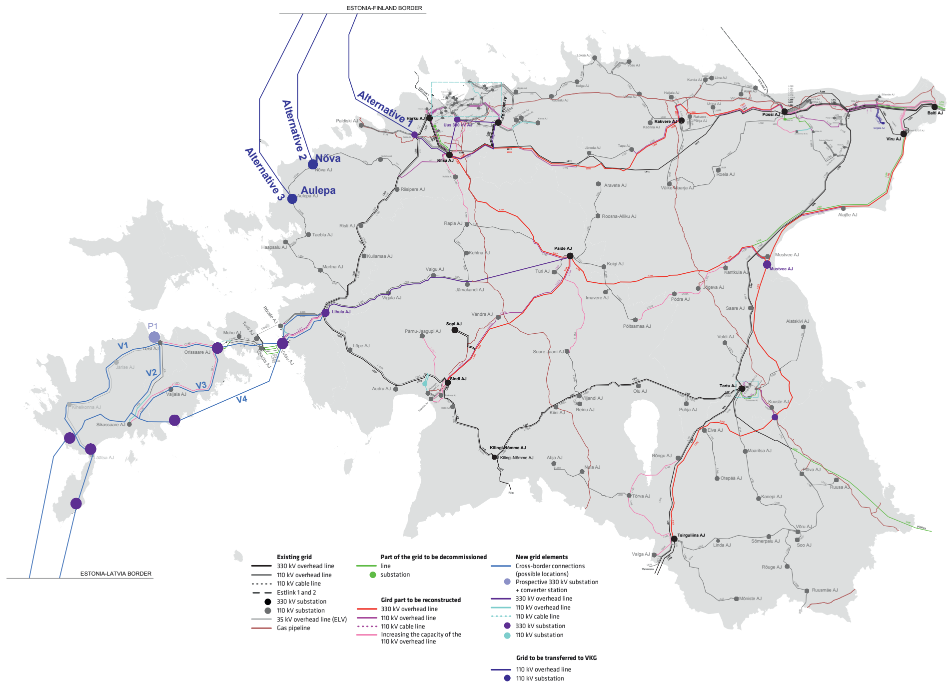
- **Reinforcements of the Western Estonia and islands' power grid – investments made through European Commission's Recovery and Resilience Facility funding**

  Reinforcements of 110 and 330 kV power grid in Western Estonia for enabling higher renewable energy volumes are described in chapter 3.2.2.

- **Domestic Estonian grid developments**

  These are investments made to ensure the reliability, capacity and efficiency of the power grid and halt the obsolescence of the grid. They are described in chapter 3.5.

Figure 3.2
Investment in Estonian electricity system



3.2.1. Synchronisation with continental Europe frequency area

The precondition for synchronisation is the reinforcement of the Estonian north-south 330 kV grid, the existing Estonia-Latvia 330 kV overhead lines and the third Estonia-Latvia 330 kV overhead line between Tallinn and Riga to improve capacity between Estonia and Latvia and improve security of supply in Estonia and Latvia alike.

Another significant precondition is ensuring the minimum necessary inertia and short-circuit power that guarantees the frequency, voltage and angle stability of the electricity system in both normal situations and during disturbances. Three synchronous condensers must be installed in the electricity system for this purpose. A synchronous condenser is a device connected to the grid to help the inertia necessary for system functioning to be ensured, i.e. mechanically turning mass, and the synchronous condenser also provides support to the system by way of a reserve of short-circuit power and, where necessary, reactive power. The synchronous condensers will be located at Püssi, Viru and Kiisa 330 kV substations. In connection with changes in the topography and configuration of the transmission system arising from the synchronisation project, more reactive energy will be generated in the transmission system and the number of devices that enable contribution to voltage control will decrease. The gradual decrease in generation capacities in Northeastern Estonia and the decommissioning of lines leading to Russia will result in a situation where the system will have to cope in certain periods with increased reactive energy flows. As a result, reactive energy compensation equipment will be added to network nodes that are strategically important (Viru, Balti, Paide and Mustvee 330 kV substations).

The more detailed order in which the lines will be renovated and locations of synchronous compensators and voltage control equipment are shown in Figure 3.3 below.

3.2.1.1 Investments to be made

The third Estonia-Latvia connection and the 330 kV Balti-Tartu and Tartu-Valmiera overhead lines have been completed, and the first synchronous compensator has been installed at the Püssi substation and variable shunt reactors at the Paide and Balti substations.

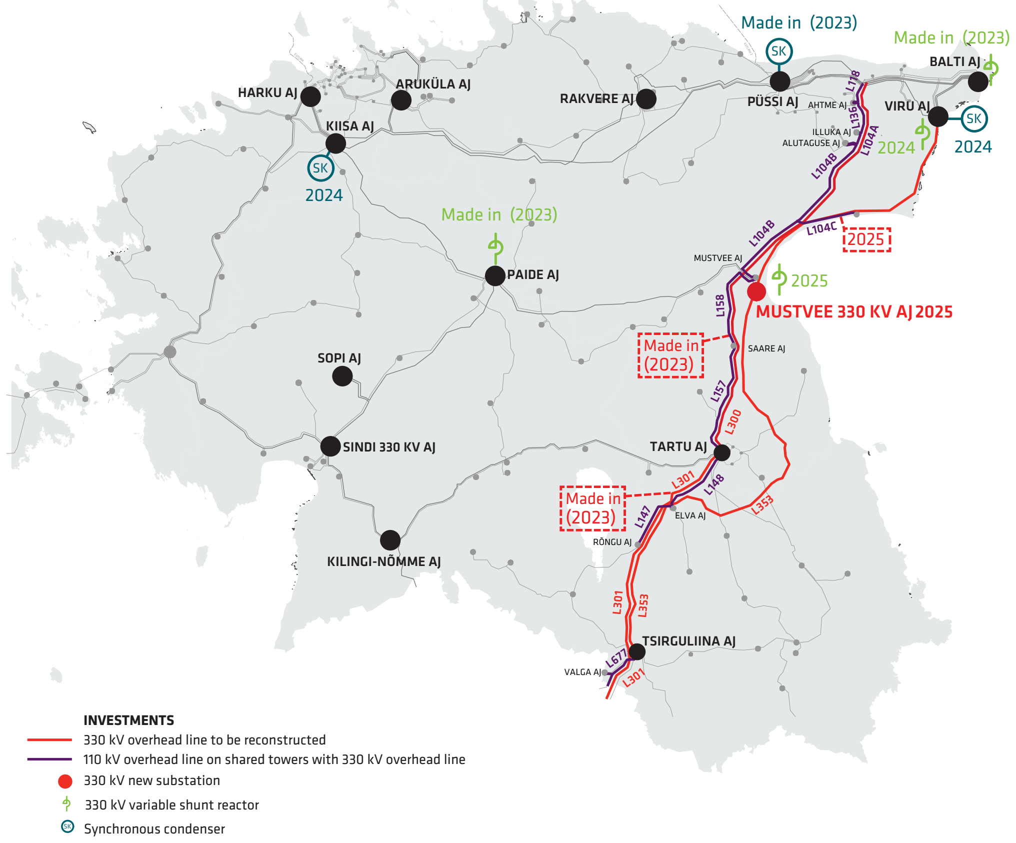
The plan is to reconstruct the entire length of the Viru-Tsirguliina 330 kV overhead line and to build a new 330 kV substation in Mustvee (to be completed in 2025). The Viru-Tsirguliina and Viru-Paide 330 kV overhead line will be connected to the Mustvee 330 kV substation, as a result of which a line with three ends will be created: Viru-Tsirguliina-Paide.

It is planned to install synchronous condenser in Viru (to be completed by the end of 2023) and Kiisa 330 kV substations (to be completed in 2024) and to install variable speed shunt reactors in Viru 330 kV substation and in Mustvee 330 kV substation.

3.2.1.2 Upgrading the EstLink 1 control system

Synchronisation with the Continental Europe combined system through the Lithuania-Poland AC link will place greater demands on the operation of the electricity system than before, in particular in terms of frequency control. Therefore, it is necessary to upgrade the control system for the DC link between Estonia and Finland by adding the additional functionality needed for frequency control. Due to the age of EUL1, the existing control system is obsolete, so the entire existing control system on both the Estonian and the Finnish side will be replaced and the necessary functionality will be added, which will improve the capacity to support market services and frequencies provided via the DC link. According to the initial schedule, the project is due to start in 2024 and be completed in 2027.

Figure 3.3
Investments to be made within the scope of the synchronisation project



3.2.2 Reinforcement of the Western Estonian and islands' power grid – investments made from the RRF

The package of investments described in the chapter is co-financed by the European Union recovery package (RRF[19]).

Historically, generation of electricity has been centred in one region of Estonia – Ida-Viru County. The suitable locations for renewable energy generation equipment (wind farms, solar plants) are located all over Estonia, above all in Western Estonia, which has the weakest grid in terms of connecting to the renewable energy generation equipment. To improve connection possibilities, investments must be made to increase the capacity of existing overhead lines in the 110-330 kV grid, and the 110 kV grid will have to be more strongly integrated with the 330 kV transit grid to decrease the impact of cross-border flows of power through the local 110 kV power grid. The capacity and reliability of the network will increase as a result of the investments, the old network will be upgraded and bottlenecks will be eliminated. The ability to withstand climate change will also rise – weatherproofing. It is planned to complete the investments in July 2026.

In August, Elering signed a contract for the reconstruction of the Paide-Kiisa 330 kV high-voltage line (cost €24.7 million, Connecto Eesti AS). The construction of the line will, among other things, increase the potential for renewable energy development in Western Estonia, including on the islands. The existing masts and wires will be demolished during the work. The route of the line will not change and the new line masts will be erected in the locations of the existing masts. The line upgrade must be completed in summer 2026. The 110 kV Paide-Rapla power line, which currently runs on separate masts, will also be partly installed on the masts of the upgraded Paide-Kiisa line. The construction of the Paide-Kiisa high-voltage line will be financed by Elering from the surplus congestion charge received from the Nord Pool power exchange. The work is co-funded by the EU Recovery and Resilience Facility (RRF). The upgrade of the line will not affect the network tariff for Estonian power consumers.

[19] https://www.consilium.europa.eu/et/policies/the-eu-budget/long-term-eu-budget-2021-2027/

The tower sharing option with the 110 kV lines will be used when the Mustvee-Paide 330 kV line is reconstructed. The 110 kV Mustvee-Kantküla line will be immediately moved to the same towers as the 330 kV Mustvee-Paide line. The Paide-Koigi 110 kV line and part of the Jõgeva-Kantküla 110 kV line will be moved to the same towers as the Mustvee-Paide line once they have become obsolete. 330/110 kV towerss will be used proactively in the reconstruction of the Mustvee-Paide line in the sections of the planned future tower sharing between Paide-Koigi and Jõgeva-Kantküla.

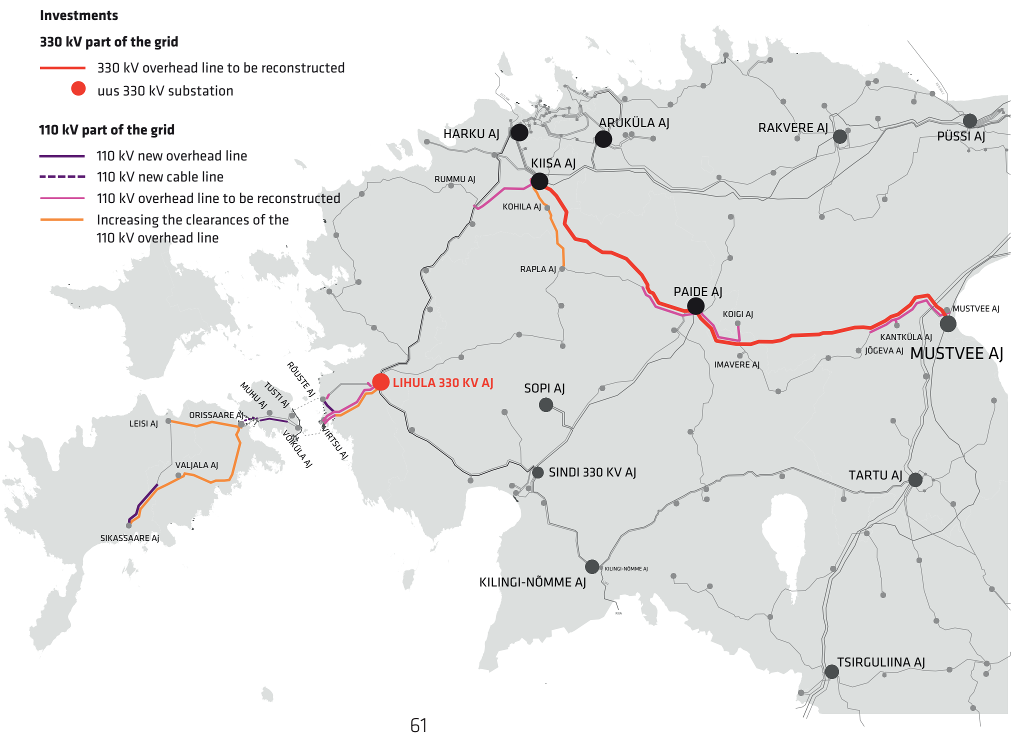
In May 2023, Elering signed a contract as part of which a new 330/110 kV substation will be built in Lihula (cost €34 million, Connecto Eesti AS). The Lihula 330 kV substation will significantly improve the options for connecting renewable energy generation capacities in Western Estonia, the lengths of the 110 kV lines will decrease in the western region, and as a result, the negative impacts caused by voltage drop will ease, security of supply will increase and the integration between 330 and 110 kV will improve. The new 330 kV substation will decrease the impact of north-south transit flows through the 110 kV Western Estonian grid. In addition, it is possible to create disconnection points using the planned substation in order to completely eliminate transit flows, especially on weaker lines. The new Lihula substation will be completed in the first half of 2026.

In order to increase security of supply in the islands, the Lihula-Virtsu 110 kV lines feeding the islands from the mainland will be reconstructed and a new 110 kV line will be built from the Rõuste substation, which will be connected to the Lihula-Virtsu L170 110 kV line. A 110 kV Lihula-Virtsu-Rõuste line with three ends will be created. The transfer of the Võiküla-Orissaare 110 kV line to separate masts from the Rõuste-Muhu-Leisi 110 kV line has been completed on Muhu. This has eliminated the risk that Saaremaa, Hiiumaa and partly Muhu would remain without power if the tower of the previously double-circuit line had broken. In order to increase security of supply in the Sikassaare area, the double-circuit line section to the Sikassaare substation will also be built on separate masts.

In order to reduce environmental impacts and increase weather resilience, a contract has been signed for the construction of a second high-voltage submarine cable in the Väike Strait (€7.3 million, Connecto Eesti AS). The overall length of the second 110-kilovolt submarine cable in the Väike Strait is approximately seven kilometres, five of which are located specifically in the sea. The cable connects the overhead line ending on the west coast of Muhu with the Orissaare substation in Saaremaa. The construction work will be completed in autumn 2024. To increase the capacity, the existing external dimensions of the 110 kV lines in the Western Estonia and islands region will be improved – the distance between ground and phase wire will be increased.

The investments to be made in the context of the programme are depicted on the figure below.

Figure 3.4
Investments to increase the capacity of distributed and renewable electricity in Western Estonia and the islands



3.2.3 International connections to Finland and Latvia

Estonia needs to establish additional connections with Latvia and Finland in order to meet green targets, integrate the electricity market and ensure security of supply and energy security. The additional connection with Finland will reduce the commercial congestion between Estonia and Finland, thereby reducing the price difference on the electricity exchange. The additional connection with Latvia will help to transfer the energy produced by the Baltic Sea wind farms and will also help to avoid commercial congestion between Estonia and Latvia after the completion of EstLink 3.

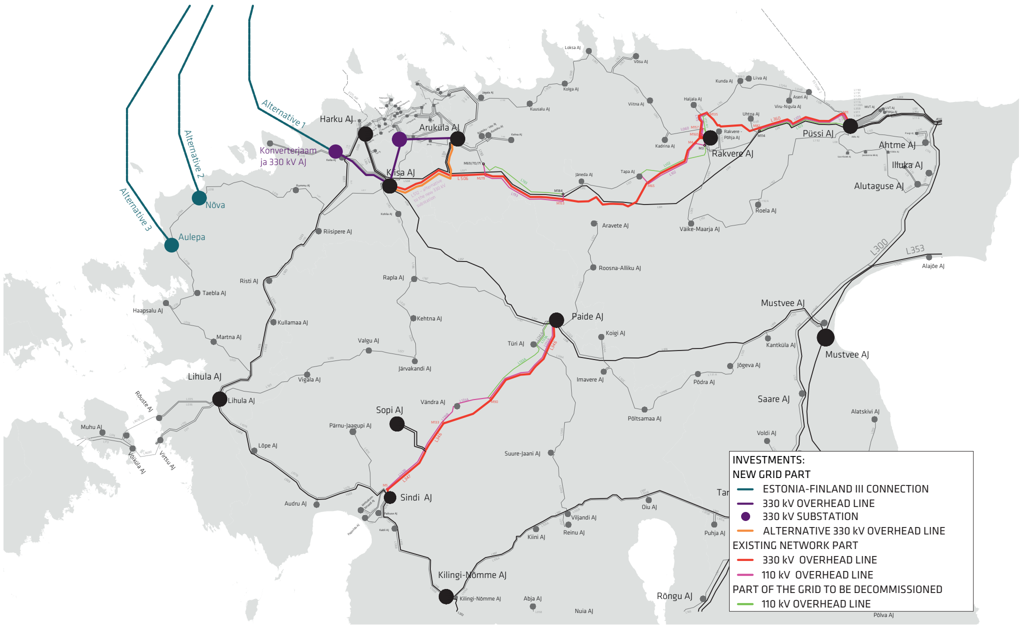
Today, no investment decision has been made on either project. The planned decision period could be 2027, after the planning procedures have been completed. The duration of the national special plan for the new line routes is expected to be up to four years.

3.2.3.1 Estonia-Finland third connection

In June 2022, the Estonian and Finish TSOs Elering and FinGrid signed a Memorandum of Understanding (MoU) in which they agreed on launching a joint work process for establishing a third electricity connection between the two countries (EstLink 3). Under the agreement, joint activities will cover the technical questions, the necessary investments and the relevant time schedule. The planned DC connection capacity of EstLink 3 is 700 MW at a rated voltage of 450 kV or 320 kV. The new connection could be up and running in 2035. EstLink 3 consists of a HVDC cable link connecting Estonia and Finland and converter stations at the ends of the cable. The converter station on the Estonian side will be connected to the 330 kV grid through a new 330 kV substation. A study is currently underway to analyse the most suitable cable landing and converter station location and the connection of the 330 kV grid to the converter station. On the basis of the study, a more detailed cost analysis and project schedule can be prepared. Possible line corridors are shown in Figure 3.5.

The existing grid must be reinforced when EstLink 3 is built. This requires the construction of a new 110 kV/330 kV substation in Tallinn, which will be connected to the 330 kV substations in Aruküla and Kiisa via new 330 kV lines. As an alternative to the new substation, the construction of a 330 kV overhead line between the Aruküla and Kiisa 330 kV substations is being considered. In addition to the construction of new lines, the existing 330 kV overhead lines Kiisa – Rakvere, Rakvere – Püssi, Paide – Sopi and Sopi – Sindi will be reconstructed. When these lines are reconstructed, the 110 kV lines running parallel will be lifted to common masts. The tower sharing allows the environmental impact to be reduced and creates savings on the maintenance costs of corridors and lines.

Figure 3.5
Estlink 3 investments



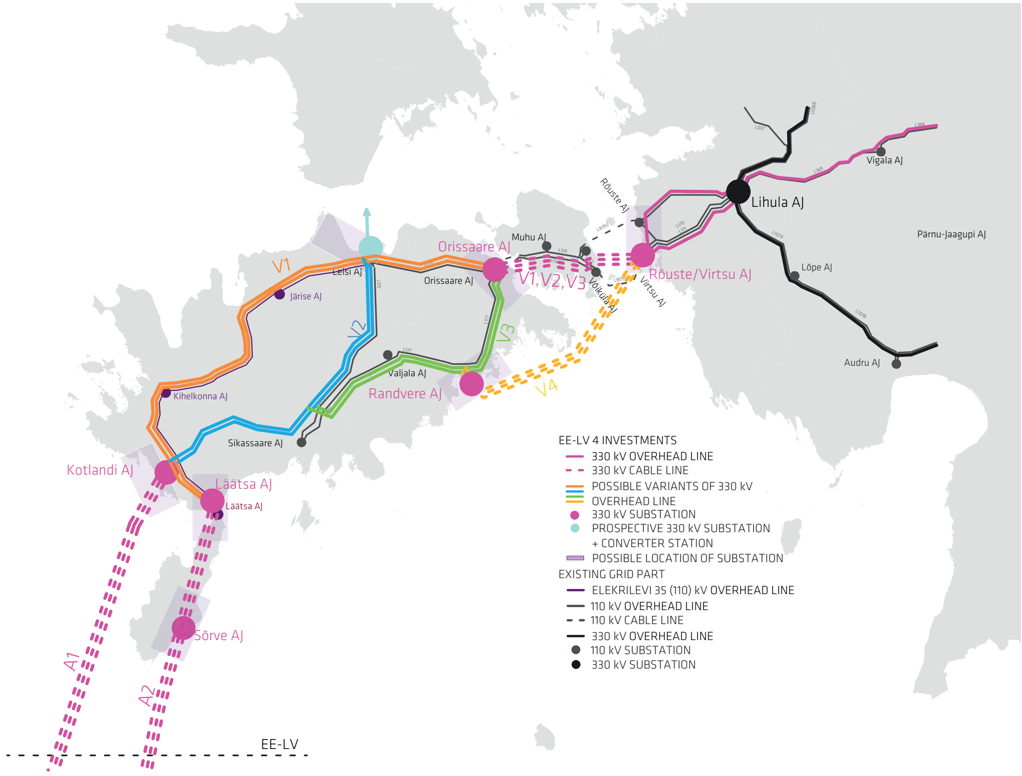
3.2.3.2 Estonia-Latvia fourth connection

Elering is developing an additional cross-border connection with Latvia (also known as the Estonian south-oriented offshore grid). In addition to the memorandum of joint intent signed in 2020 between Estonia and Latvia for developing wind energy[20], the companies from both country's TSOs (the Latvian TSO is AS Augstsprieguma tīkls) signed an agreement in 2021 under which the best possible solutions will be explored for establishing additional 700-1000 MW transmission capacity. The project foresees the construction of a fourth 330 kV connection between Estonia and Latvia, to which renewable energy generation can be connected. Elering and AST will not start constructing additional generation capacities themselves, but rather assume responsibility for constructing a grid suitable for meeting the renewable energy targets and connecting it to the overland network.

In 2021-2022, a preliminary analysis of potential corridors for the 4th Estonia-Latvia connection was conducted by Elering; it showed that the most suitable starting point for ensuring additional transmission capacity was on Estonia's west coast toward the western coast of Latvia (Pavilosta region). This means the construction of a new 330 kV grid from the Lihula region across Muhu and Saaremaa (figure below). The line corridor of the Estonia-Latvia 4th transmission line and the exact technical solution are not yet in place as of now, as it depends on the national special plan, the environmental impact assessment carried out within its scope and the design. According to plans, the environmental impact assessment programme will be prepared in 2024 and the implementation of the programme is planned for 2025-2027. The design is expected to be completed between 2025 and 2026. The whole project should be completed in 2035.

The figure below depicts the options for the 4th connection and possible locations of substations in the existing transmission system and the new Lihula-Paide 330 kV overhead line.

Figure 3.6
Possible routes for the fourth EE-LV connection



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[20] https://www.mkm.ee/et/uudised/eesti-ja-lati-solmisid-uhise-meretuulepargi-eelarendamise-leppe

3.2.3.3 European Union projects of common interest

The fourth Estonia-Latvia and the third Estonia-Finland connection projects have been approved as projects of common interest by the European Union. Projects of common interest (PCI) are projects of European public interest that have a cross-border impact and contribute to the development of a single European energy system, improve competition in energy markets and enhance Europe's energy security.

The authorisation procedures and planning of the PCI are carried out in accordance with Regulation (EU) No. 347/2013, in consultation and with the involvement of all relevant stakeholders. Projects can apply to the PCI list under specific categories each year. Approved projects on the PCI list will also be eligible to apply for funding from the Connecting Europe Facility (CEF) later on.

3.3. LONG-TERM VISION FOR THE GRID

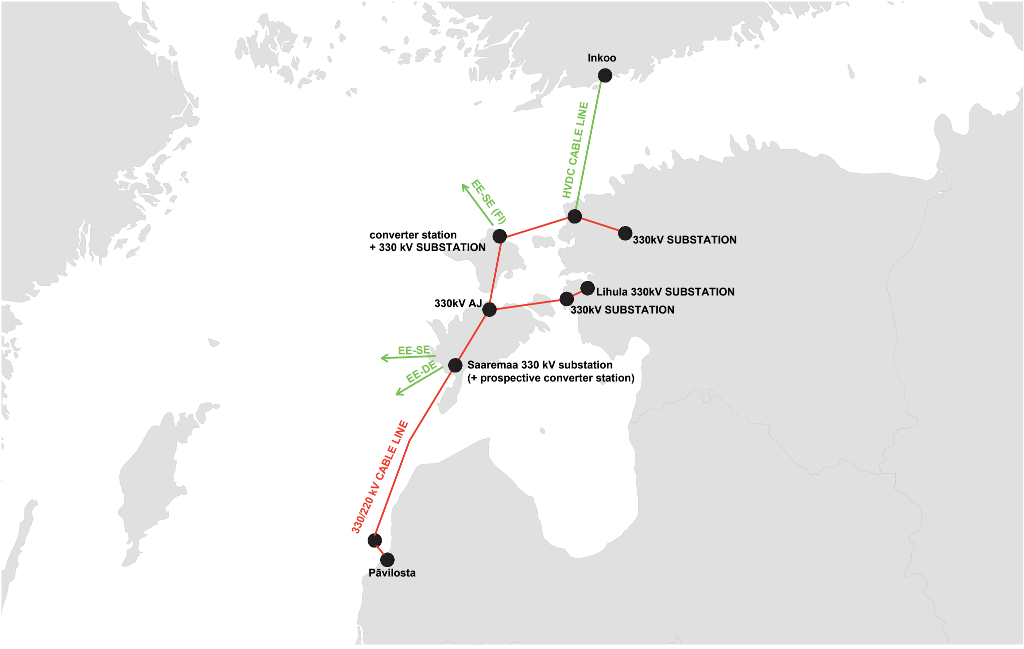
According to the electricity increase forecast of Estonia, consumption will grow to 15 TWh per year by 2050. Large wind farms can only be interconnected to high-capacity grids. In the case of Estonia, this means extending the 330 kV grid and building substations close to wind farms to make connecting wind farms to the grid feasible at reasonable costs. As the wind potential exceeds Estonia's energy needs many times over and the need for renewable energy in Central Europe is expected to increase, additional international connections will be needed. That is why it is reasonable to build international connections from sites of large-scale renewable energy generation.

In the context of the development of the offshore grid, the establishment of the Estonia-Finland third connection via Aulepa/Nõva is also being considered as an alternative (figure below). Such an approach would form a circular connection with Saaremaa, Hiiumaa and mainland Estonia. This solution will connect the wind areas around Hiiumaa and Saaremaa, EstLink 3 and the Estonia-Latvia fourth connection. However, higher investment costs and the time associated with various planning needs are challenges. Although the initial cost is significantly higher, this solution may be more optimal in the long run. Notably, it can be assumed that the potential of wind power will be exploited in the future in any case, which means that there is a high likelihood of future offshore capacity requiring transmission grids. The various alternatives and connections will be further explored and implemented when better solutions are identified. The Offshore Network Development Plan (ONDP), coordinated by ENTSO-E, will be completed in early 2024, showing the longer-term potential and possible generation capacities of renewable energy in the Baltic Sea as well as the need for additional connections, which could provide an initial view on the need for additional connections. On the basis of this, Estonia's renewable energy import portfolio and onshore or offshore park solutions can be further planned and analysed.

The long-term vision outlined below envisages the development of a 330 kV AC grid in the vicinity of potential wind areas on the large Estonian islands of Hiiumaa and Saaremaa. The prospective solution includes substations built close to the wind areas, where large-scale renewable electricity capacity can be connected as well as new international connections to neighbouring grids. Connections must be built with two-way power supply to ensure security of supply and transmission capacity even in the N-1 situation. For this purpose, the extended transmission network in Hiiumaa and Saaremaa will be connected by an additional 330 kV line. The two-way power supply for the 330 kV substation in Saaremaa will be guaranteed the high-voltage AC cable line to be built in the direction of Latvia. A minimum connection capacity of 1,000 MW must be considered for the extension of the transmission network to the islands. The exact capacity will depend on the volumes of renewable energy that are to be connected to the various points and also on how much transmission capacity Estonia wants to guarantee with neighbouring countries. The year of completion of the Estonia-Latvia fourth connection (2035) will not be affected by this solution.

On 9 May 2023, Elering and the German TSO 50Hertz signed a Memorandum of Understanding aimed at exploring the technical feasibility and cost-effectiveness of building an electricity interconnection of up to 2,000 MW between the two countries. If the joint impact assessments demonstrate the technical feasibility and cost-effectiveness of the Estonian-German Baltic WindConnector, Elering and 50Hertz will submit the project to the 10-year grid development plan to be prepared in cooperation with the European system operators, after which the project's financing model and the sources of external financing can be identified[21].

Figure 3.7
2030+ grid outlook



3.4 OFFSHORE AND ONSHORE WIND FARMS

As increasingly more renewable energy sources, including wind energy, are being used to generate electricity, all EU countries are working together to create a pan-European energy market. Most of the countries in the Baltic Sea region are meeting their green targets[22] using different energy sources. The renewable energy targets that are part of the green objectives can be met with both onshore and offshore wind. Elering is responsible for the readiness of the grid for the connection of both offshore and onshore wind farms.

3.4.1 Green targets of the European Union

As an EU member state, Estonia participates in achieving the joint climate goals associated with the environment goals and implementing the energy policy. Estonia's national target[23] is to increase the share of renewable energy in total final energy consumption to 42% by 2030. An amendment to the Energy Sector Organisation Act has also been prepared, which raised the share of renewable energy to 65% of total energy consumption by 2030 and the goal of renewable electricity generation to 100% by 2030.

In theFit for 55 package, the European Commission made proposals for raising the pan-European renewable energy goals in power generation, transport sector, industry and energy end consumption to fulfil climate neutrality goals by 2050. The package proposed how to increase renewable energy-based generation and replace fossil energy sources, raise energy performance and the flexibility of energy use and integrate electricity, gas, transport and thermal energy use into one whole. After Russia's invasion of Ukraine, the European Commission proposed the package RePower EU, introducing alleviatory measures for resolving the security of supply and energy security problem in the short term and, in the medium term, higher renewable energy ambitions were set, including speeding up the introduction of hydrogen. The energy policy proposals described above and today's high energy prices will in all likelihood speed up the move to renewable energy and reduce Estonian and European dependence on imported fossil energy. As a result, countries' subsidies and guarantees for energy producers will increase and investor interest

[21] https://elering.ee/elering-ja-50hertz-uurivad-voimalusi-ehitada-eesti-ja-saksamaa-vahele-elektri-merekaabel
[22] https://valitsus.ee/valitsuse-eesmargid-ja-tegevused/rohepoliitika
[23] https://kliimaministeerium.ee/media/9407/download

in finding innovative solutions will be stimulated. All this will bring new energy generation to the market, improve system capability, reduce GHG emissions and reduce Estonian and European dependence on third countries[24].

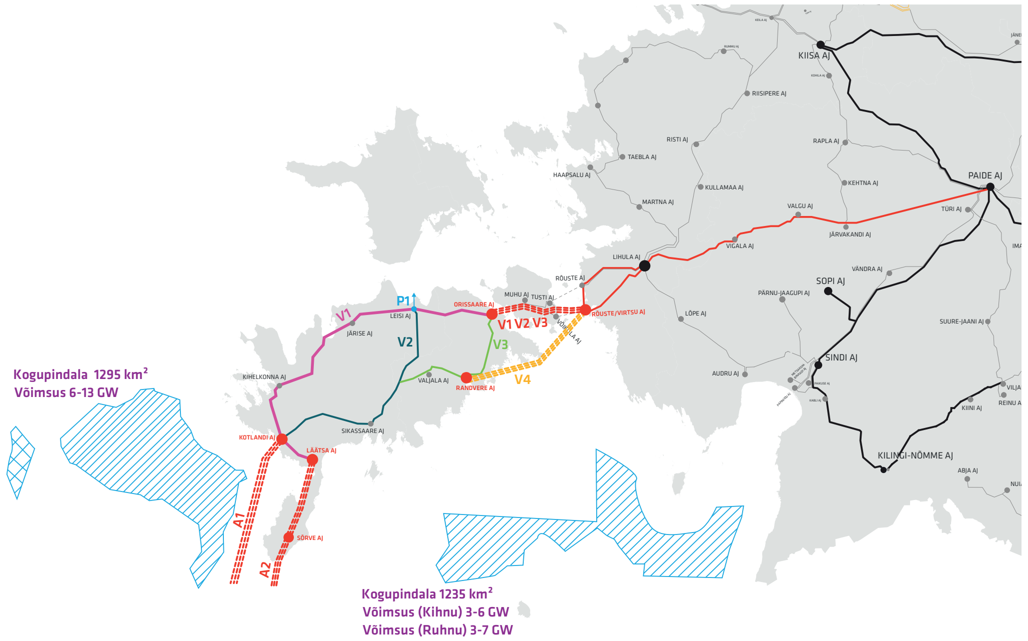
3.4.2 Offshore wind potential of the Baltic Sea and Estonia

Estonia is working closely with other European Union countries to together reach the set targets.. Development plans will be set up within the different offshore areas to ensure that planning is successful. Elering, together with the Latvian, Lithuanian, Polish, German, Danish, Swedish and Finnish TSOs, is responsible for the completion of the Baltic Sea ONDP (Offshore Network Development Plan), which aims to show how the offshore network will develop and grow over the years, and to analyse and resolve the different views that arise in society.

According to the Marienborg Declaration, 1 GW of offshore wind farms will be connected to the Estonian grid by 2030, 3.5 GW by 2040 and 7 GW by 2050.[25] The potential of Estonia's offshore wind areas is about 10 times higher than Estonia needs for its own consumption. Areas suitable for the development of wind energy have been established by the Estonian Maritime Spatial Plan[26] and are located in the Gulf of Riga and on the coasts of Saaremaa and Hiiumaa. The wind potential of different areas is as follows:

- Saaremaa 6-13 GW
- Kihnu 3-6 GW
- Ruhnu 3-7 GW

Figure 3.8
Offshore wind farm areas



Connecting all of Estonia's offshore wind potential to the Estonian power grid is neither reasonable nor necessary, so solutions must be found to channel energy where it is needed through the offshore grid. Requests for building permits for a total area of 2,439 km2, which of 1,300 km2 overlap, have been submitted to the Consumer Protection and Technical Regulatory Authority and a competition will be declared for distributing them. The requests that do not overlap cover 20 GW and, depending on the outcome of the final site designation, the requested capacity is 30-40 GW, with the average wind farm capacity density of 10-13.4 MW/km2. According to the European Maritime Spatial Planning Platform[27], the average capacity density of offshore wind farms installed in the Baltic Sea is 5.5 MW/km2, which means that the volumes of the requests submitted to the Consumer Protection and Technical Regulatory Authority are rather overestimated. However, as wind technologies develop, the capacity density of offshore wind farms can also be increased, as there are already offshore wind farms with a capacity density of more than 10 MW/km2 in the North Sea, for example.

The total wind energy potential of the Baltic Sea is 93.5 GW, while the total capacity of real projects currently stands at a maximum of 50 GW. The capacity targets for offshore wind farms in Baltic Sea countries for 2030, 2040 and 2050 are given in Table 3.1. The North Sea countries have the following targets for 2030: Belgium 6 GW, Denmark (North Sea part) 12.9 GW, France 4.4 GW, Germany (North Sea part) 30 GW, Ireland 7 GW, Norway 0 GW, and the Netherlands 16 GW.

Table 3.1. Capacity targets for offshore wind farms in Baltic Sea countries[28]

Country	2030 [GW]	2040 [GW]	2050 [GW]
Denmark	7.9	7.9	7.9
Germany (Baltic Sea part)	4.1	4.1	4.1
Estonia	1.0	3.5	7.0
Latvia	0.4	0.4	0.4
Lithuania	1.4	2.8	4.5
Poland	5.9	10.9	10.9
Finland	1.0	5.0	12.0
Sweden	0.7		
Total in Baltic Sea	22.4	34.6	46.8

Figure 3.8 shows the offshore wind farm areas, which are marked in purple on the map. Information on potential offshore renewable energy development projects can be found here: https://xgis.maaamet.ee/xgis2/page/app/TTJAhoonestusload

3.4.3 Options for using energy generated from wind farms in Estonia

Estonia's annual electricity consumption is projected to increase from the current 8.5 TWh to about 9.9 TWh by 2030 (see chapter 4.4 Consumption Forecast for more details). In order to cover electricity consumption, 3 GW of wind farms are needed in addition to solar energy, which would certainly ensure that the renewable energy targets are met. The additional wind farm capacity in the 2030 generation forecast of Estonia is up to 2 GW. Today, the necessary reinforcements to connect to the grid are made during the connection process, but by 2030, the network capacity to accommodate additional connections will need to be built and included in the development obligations. It may therefore be necessary to prepare the grid, as is currently done to meet the future needs of existing network customers.

The offshore wind potential in Estonia is several times higher than the onshore wind potential. As the offshore wind potential exceeds Estonia's renewable energy needs by far, it will also be necessary to create additional international interconnections as it is developed, so that any surplus electricity can be channelled outside Estonia. There are several ways for Estonia to make easy use of surplus electricity from renewable energy sources. Firstly, local consumption could be increased through industries, for example by setting up methanol or ammonia production plants in Estonia that would use the surplus electricity. In addition, it is possible to export surplus electricity from the country in the form of electricity or hydrogen. In order to transport electricity or hydrogen, cross-border connections and systems are needed. One option is to export electricity through the Estonia-Germany 2,000 MW offshore connection[29], whose possibilities are currently being explored and which is planned for 2040. In addition, there is the potential to build additional connections with Finland and Sweden in the future, which would increase the transmission capacities between the countries.

The forecast for 2050 envisions that consumption will increase to ca 15 TWh. Estonia lacks the onshore wind capacity to cover this amount of energy, which means that other renewable energy sources such as offshore wind will need to be added to the grid (see Chapter 3.3 for a long-term vision).

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[24] https://kliimaministeerium.ee/energeetika-maavarad/taastuvenergia/taastuvenergia
[25] https://valitsus.ee/media/5288/download
[26] Mereala planeering | Rahandusministeerium (fin.ee)
[27] Capacity Densities of European Offshore Wind Farms | The European Maritime Spatial Planning Platform (europa.eu)
[28] Microsoft Word - Offshore agreement BEMIP_final draft_updated rev (europa.eu)
[29] https://elering.ee/elering-ja-50hertz-uurivad-voimalusi-ehitada-eesti-ja-saksamaa-vahele-elektri-merekaabel

The potential for hydrogen use and production varies from region to region in the Baltic Sea. Significant hydrogen demand and supply is expected in the Nordic countries (Finland, Sweden, Denmark). The rapid growth of wind power means that supply is exceeding demand, which means that the Nordic countries are in a position to export large volumes of hydrogen or attract energy-intensive industry. The demand for hydrogen in the Baltic states, Estonia and Latvia, is low, but their capacity to produce it is high due to their large renewable energy potential. In the future, Estonia and Latvia will be able to export their renewable energy, or, like the Nordic countries, valorise it. Lithuania has a high demand for hydrogen in Baltic terms due to the refining and fertiliser industries. Lithuania, however, will probably not be able to meet its own hydrogen demand and will need to import hydrogen. Germany and Poland (together with other Central European countries) remain energy importers. These countries have a large number of industries that need to replace fossil fuels with clean energy. Given the current situation, Estonia needs to decide how to exploit its good potential. The figure below shows the planned Nordic-Baltic Hydrogen Corridor, a cross-border hydrogen infrastructure project from Finland to Germany, through the Baltic states and Poland, which will connect regional supply, demand and storage along the infrastructure. The length of its main corridor is around 2,500 km and its north-south capacity is 200 GWh/day[30].

Figure 3.9
Nordic-Baltic
Hydrogen Corridor

3.4.4 Local developers

There is great interest in the development of offshore wind farms in Estonia. Offshore wind farms are under development in Western Saaremaa and Northern Hiiumaa. The first phase of the development in the Gulf of Riga, 10 km west of Kihnu, which has a planned capacity of 1,200 MW and a total annual production of around 5 TWh, will be completed by 2028. The second offshore wind farm in the Gulf of Riga is located around 10 kilometres south of the island of Kihnu, and the area covered by the requested building permit is 183 km2. The planned capacity of this offshore wind farm in the Gulf of Riga is 1,000 MW and the forecast productivity is around 4 TWh per year. There are also plans to complete an offshore wind farm with a capacity of up to 1,400 MW in the western part of Saaremaa by late 2028. In addition to the abovementioned developments, ELWIND[31], a joint Estonian-Latvian project located in the sea area of Western Saaremaa, is ready to generate electricity after 2030. This wind area is capable of supplying around 3 TWh of electricity per year.

Today, there are 13 contracts for the construction of onshore wind farm in force, two of which are hybrid farms and 11 are wind farms. There are two pending connection contracts to add wind farms to the grid. The effective contracts also include the capacities that, due to other restrictions, prevent wind farms from connecting in certain areas[32].

3.5 INVESTMENTS IN INTERNAL NETWORK REGIONS

3.5.1 Tallinn and its vicinity

The area in Estonia with the greatest demand is Tallinn region and demand there is expected to grow faster than average compared to other Estonian regions.

Overhead lines are being replaced with cable lines in Tallinn:

- L011 Harku-Veskimetsa cable and overhead line (cable part is ready)
- L012 Harku-Kadaka cable and overhead line (cable part is ready)
- L001 Harku-Veskimetsa partial cable and overhead line
- L002 Harku-Veskimetsa partial cable and overhead line
- L8108 Construction of Iru-Viimsi 110 kV cable line
- L087 Replacement of Harku-Tabasalu overhead line with cable line

The Veskimetsa-Kadaka L8023, Veskimetsa-Kopli L8017 and Veskimetsa-Volta L8025 cable lines are completed and L009 Kopli-Paljassaare and L010 Paljassaare-Volta have been partly replaced with cable lines.

110 kV overhead line works:

- Among 110 kV overhead lines, the Aruküla-Lasnamäe 110 kV overhead lines will be reconstructed.
- The Kehra-Aruküla lines will be established on separate towers so that the supply of Kehra substation would be ensured with two single-circuit lines. On the Aruküla side of the remaining section of the Aruküla-Kehra L195 line, the clearances will be raised to 45C.

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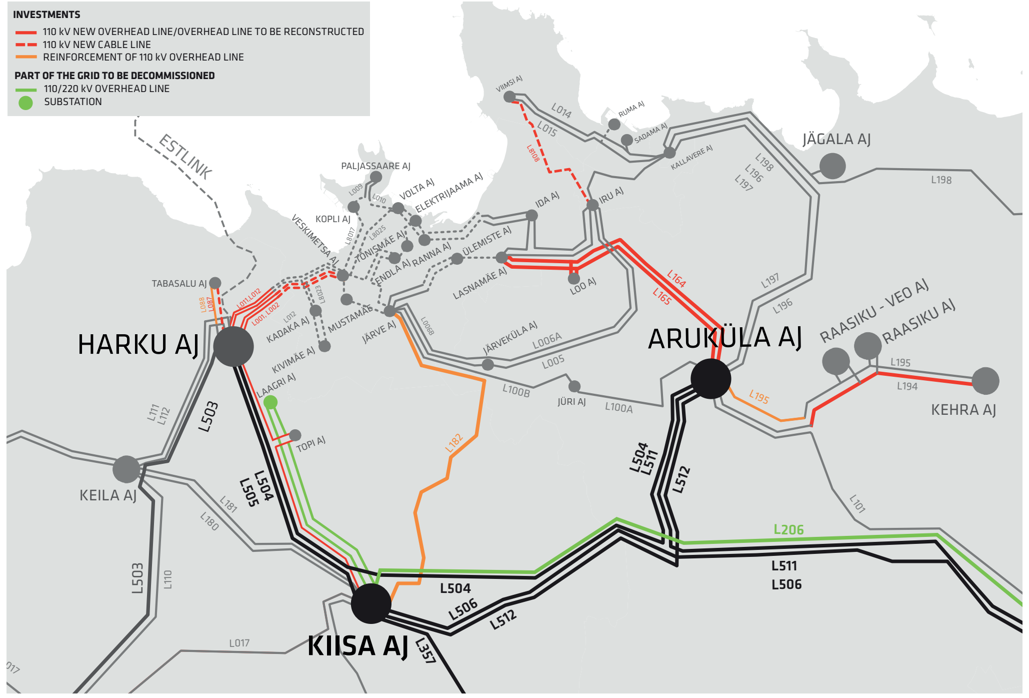
[30] ehb-report-220428-17h00-interactive-1.pdf

[31] Elwind (elwindoffshore.eu)

[32] https://elering.ee/pohivorguga-liitumine

- The Kiisa-Harku 110 kV overhead lines are being renovated into Kiisa-Topi and Topi-Harku lines and Laagri 110 kV substation and Kiisa-Laagri 110 kV overhead lines will be dismantled.
- On the Kiisa-Järve 110 kV overhead line, the plan is to replace the cable and individual masts and to streamline the clearances at cable temperature +60C.
- The plan is to take the Tabasalu-Harku L087 overhead line to a cable and replace the cable on the second Tabasalu-Harku L088 overhead line.
- The only 220 kV line in the Estonian electricity system, L206 Püssi-Kiisa, is being dismantled.

Figure 3.10
Grid developments in Tallinn grid region



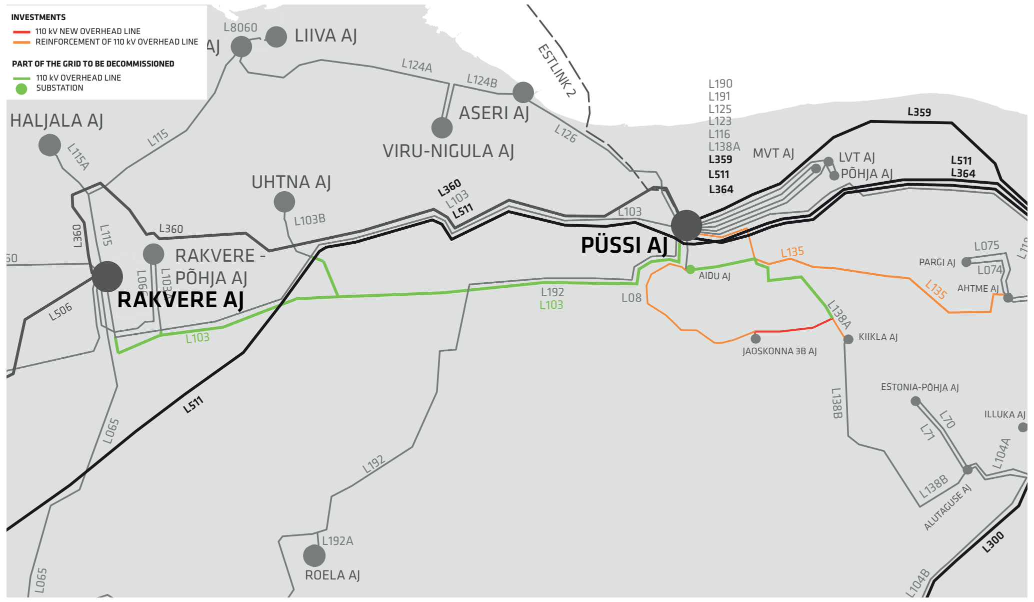
3.5.2 North-eastern Estonia

Power flows will change in the north-eastern Estonian region, since after Estonia's synchronisation with the Continental European grid, the transmission lines between Estonia and Russia will no longer be necessary. A number of investments for optimising the power grid in the region are planned for this reason.

Redistribution of loads and network configuration will take place in the Püssi-Ahtme 110 kV grid region: The Püssi-Kiikla and Aidu-Ahtme 110 kV overhead lines will be connected to form a Püssi-Ahtme line and a new 110 kV overhead line from the Jaoskonna 3B substation to Kiikla substation. External dimensions will be increased on the existing Aidu-Jaoskonna 3B and Ahtme-Püssi 110 kV lines. In future, the Aidu 110 kV substation will be decommissioned.

The 110 kV line L103 Rakvere-Püssi has been reconstructed by now in the line corridor of the 220 kV Rakvere-Püssi overhead line that will be dismantled; the old L103 line is being dismantled (marked in green on the figure).

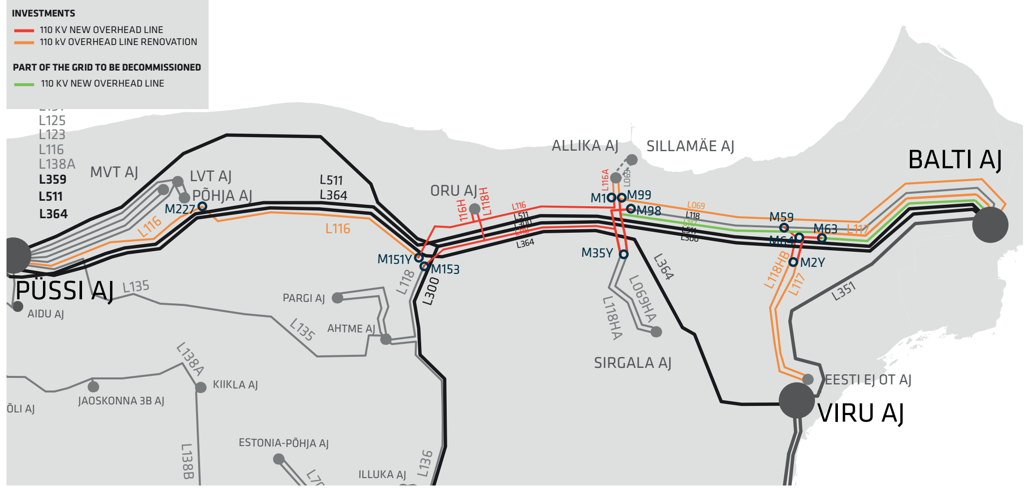
Figure 3.11
Grid developments in Püssi-Ahtme-Jaoskonna 3B grid region



The configuration of 110 kV lines directed to the Baltic substation is also planned to be optimised (figure below). For L118, a new 110 kV overhead line section will be built on the line corridor vacated by the dismantling of L300, starting from the L118 mast 153 up to the existing L116 mast 98 in Balti-Püssi. From mast 98, the new L118 section and the existing L116 will be joined to form the line L118 Ahtme-Balti. The double-circuit section of L116 and L118 from 151Y to 102Z will be upgraded to a new single-circuit line, and from 102Z a new connection will be built from the existing line L116A (Allika branch) to mast 1. Line L116 Püssi-Allika will be formed. The Sirgala substation will remain connected as a branch – one branch on the L069 Allika-Balti line and the other branch on the L118 Ahtme-Balti line. The first supply of the Eesti Power Plant OT will be connected as a branch to the line L118 Ahtme-Baltic, for the second feeder the parallel lines L117 and L119 from the Balti substation will be connected to the lines up to mast 63 from the Balti substation (see the figure below). The first supply of Oru substation will be connected as a branch to the L116 Allika-Balti line and the second power supply as a branch to the L118 Ahtme-Balti line.

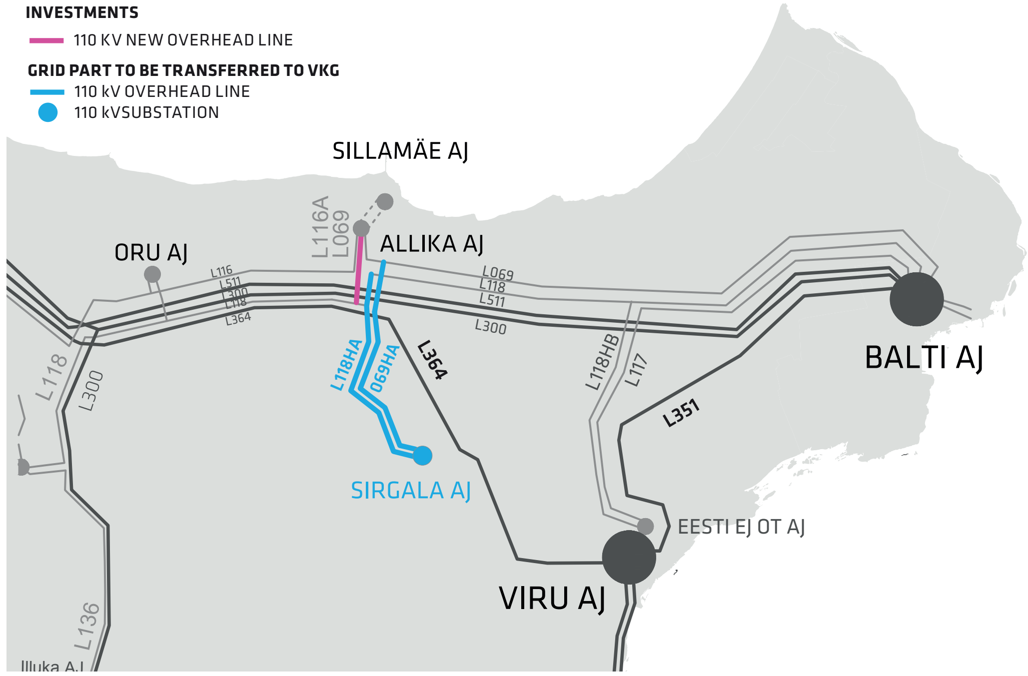
The renovation works of the existing section of Püssi-Allika will include replacement of the wire and the dilapidated masts on the section from mast 227 to 151Y, clearances from Püssi substation to M151Y will be streamline at wire temperature +60C. The clearances of L069 Allika-Balti will also be streamlined at wire temperature +60C. The wire and obsolete masts on the connection lines of Eesti Power Plant OT will be replaced and the clearances will be streamline at the temperature +35C.

Figure 3.12
Reconfiguration of Baltic-Püssi 110 kV lines



In addition to the reconfiguration of the power grid planned for the region, it is possible to reduce the 110 kV grid if VKG abandons its consumption location in Sirgala substation and the Sirgala 110 kV switchgear is decommissioned. The lines connecting Sirgala substation will be transferred to VKG. VKG will change over to 110 kV connections at Allika substation and build at Allika substation new medium-voltage switchgear in addition to transformers. To ensure conditions of the connection agreement between VKG Elektrivõrgud and customers, a third 110 kV power line will be built to Allika substation as a branch of the Ahtme-Balti line. The third 110 kV connection to Allika substation can be built as a separate line or one of the existing lines can be renovated into a two-circuit line. At the moment, the third connection is provided from Sirgala substation, which in the optimised solution is no longer a transmission grid substation. In connection with the renovation of Allika substation, the Elektrilevi OÜ 10 kV connection point at Allika substation will be removed and Elering will build a new 10 kV cable line to Oru substation.

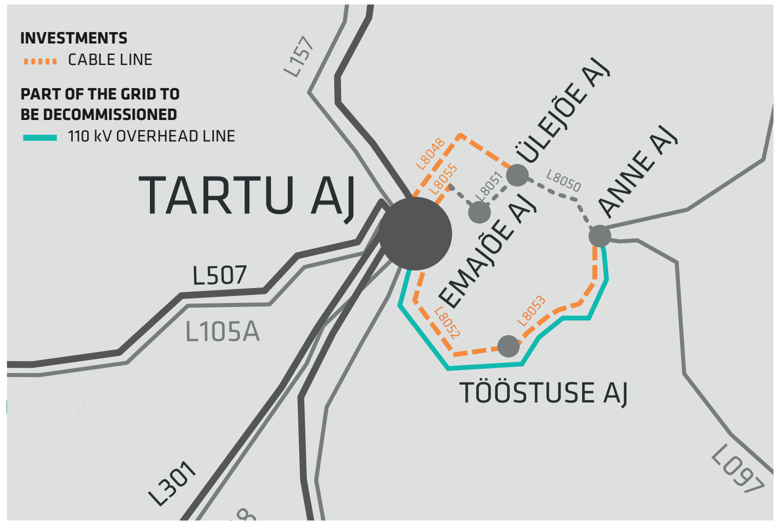
Figure 3.13
Optimised scenario of the Allika-Sirgala grid region



3.5.3. Tartu region

Estonia's second largest city in Estonia, Tartu, and its vicinity has the greatest concentration of demand and the continuing growth of demand can be foreseen here. The Tartu-Tööstuse-Anne 110 kV overhead lines located in inner Tartu are in poor technical condition and run in the immediate vicinity of residential buildings, due to which the overhead lines will be replaced with cable lines. In addition, it is planned to establish a new 110 kV Tartu-Ülejõe cable line and replace the Emajõe-Tartu overhead line part with a cable line.

Figure 3.14
Developments in Tartu grid region



3.5.4

The 330 kV and 110 kV lines take part in parallel in the transmission of power flows. In situations where some lines are in maintenance or switched off due to malfunctions, part of the switched-off Line's power flow will be transferred to 110 kV lines and these may be congested or the power flows may approach the maximum permissible limit. One way of reducing power flows on 110 kV lines is the use of disconnection points. Available connection capacities of substations also depend on loads on the lines. Greater available connection capacities encourage electricity producers and consumers to join the Estonian transmission system. In addition, greater available connection capacities enable the amount of electricity generated from renewable sources to be increased, which in turn will help Estonia to fulfil its climate goals.

A study conducted by Elering AS[33] showed that the disconnection points used in the 110 kV grid do not increase overall 110 kV substations' available connection capacities and do not generate direct economic value-added. In addition, the location of separation points must continuously be optimised. The optimal locations of separation points may change in time and with non-optimal disconnection points the losses of active energy in the electricity system may increase. Use of separation points also means decreased security of supply in the Estonian electricity system, which is caused by short-term interruptions resulting from lag times in reserve switching automation equipment.

Use of 110 kV disconnection points significantly increases the available connection capacities of 330 kV substations, which may provide indirect economic value-added. The study concluded that use of 110 kV separation points is not expedient and the use of dynamic separation points should be studied. Dynamic separation points are created pursuant to network element congestion and it presupposes development of an additional automated system.

Historically, the largest production capacity was concentrated in Eastern Estonia, but the trend of connections shows an increasing share of other regions, notably Western Estonia. With the addition of large capacities of the offshore wind farms in the Lihula area, 110 kV congestion may occur when 330 kV lines are switched off. The network calculations of offshore wind farm connections show that the highest congestion will occur on the lines in the direction of Lihula-Risti-Keila and Rapla-Kohila-Kiisa. The calculations were based on the completion of the Lihula 330 kV substation and the new Lihula-Paide 330 kV overhead line. Major congestions on 110 kV lines occur due to transit when the L503 Harku-Lihula-Sindi or L510 Kilingi-Nõmme-Sindi lines switch off. Dynamic interconnection points, e.g. at Haapsalu or Lihula and Rapla substations, would improve the situation, and according to a preliminary analysis, would be around €20 million cheaper than upgrading congested lines.

3.5.5 Consumption forecast

The values in the table below are the set of statistics for the last 10 years and forecast for the next 15 years. The forecast of consumption provides average peak consumption values for various years.

The forecasts in the table were made for the ENTSO-E system capability assessment based on modelling results and the Elering-commissioned study on Estonian electricity consumption scenarios. As of 2030, the findings of the study of Estonian electricity consumption scenarios commissioned by Elering[34] have been used, which take into account various development directions in Estonian and EU climate and energy policy, the aim of which is to reduce the use of fossil energy and the gradual electrification of the energy sector.[35]

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[33] https://digikogu.taltech.ee/et/Download/06533504-c9d4-4322-9833-1bf519845627
[34] https://elering.ee/sites/default/files/2022-10/Study - Electricity demand scenarios.pdf
[35] Study of Estonian electricity consumption scenarios

Table 3.2 Consumption forecast up to 2038

Consumption forecast		
Year	Annual consumption, TWh	Peak load, MW
2023	8.6	1514
2024	9	1591
2025	9.2	1668
2026	9.3	1705
2027	9.5	1742
2028	9.7	1779
2029	9.9	1800
2030	10.3	1829
2031	10.3	1870
2032	10.5	1910
2033	10.8	1950
2034	11.1	1984
2035	11.3	2018
2036	11.7	2075
2037	11.9	2131
2038	12.3	2187

The electrification of energy consumption is expected to lead to an increase in consumption in the coming years. As can be seen from the table, the projected peak demand will increase by an average of 45 MW over the next 15 years, with a total annual demand of 9.9 TWh per year from 2030 to 12.3 TWh by 2038.

Overall electrification increases, in particular, the annual consumption of the end consumer. The volume of consumption of grid power will grow at a slower pace due to the increase in distributed consumption. Together with electrification and introduction of electric transport, the flexibility of electricity consumption will grow (the capability to control, time and store electricity), which will support the transition to renewable energy sources, general reduction in GHG emissions and price volatility and prevent peak consumption from becoming concentrated at the same time. Diversion of consumption to a non-peak hour is supported by the adoption of smart technology, such as smart chargers for electric cars, heat pump accumulation tanks, heat storage devices in central heating areas, battery storage and bidirectional charging of EVs. The higher price formed at peak hours and the increase in flexibility of consumption will to a certain extent slow the speed of growth in peak consumption. The growth in the share of renewable energy in energy generation will create volatility in the grid consumption profile and electricity prices, which favours the introduction of energy capture technology such as batteries and pump hydro accumulation plants, and active participation on the electricity market, which, in turn, will equalise the grid consumption profile and reduce volatility of electricity prices.

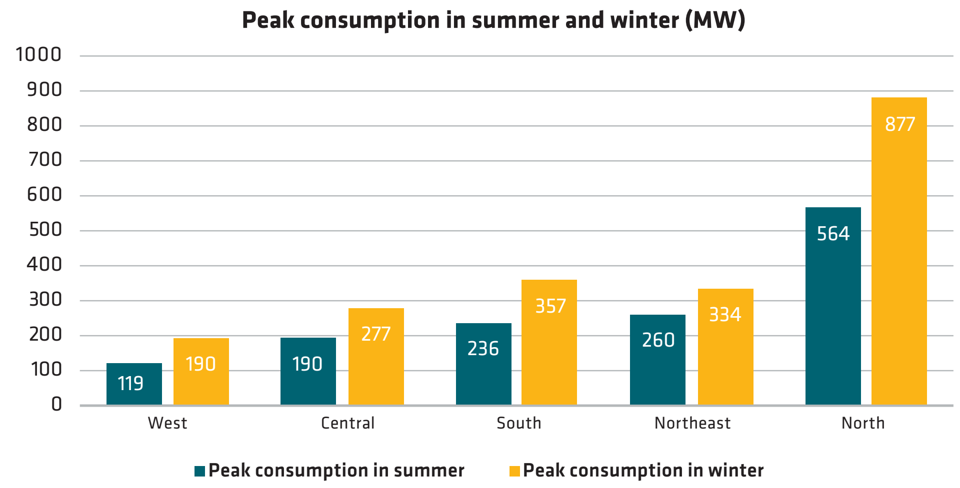
The consumption forecast is discussed in more detail in Chapter 4.5.

3.5.6 Developments of and investments in load centres

The investment plan prepared to ensure security of supply must take into account the growth in consumption in the load centres (Tallinn, Tartu, Pärnu) due to the accelerating electrification of energy consumption. What will future growth in consumption be like, how will it affect the grid, and what additional investments will we need to ensure security of supply and the reliability of the electricity system? These are the questions that were posed in the framework of the aforementioned study on electricity consumption scenarios in Estonia.

For the analysis, two baseline models were prepared (winter and summer peak consumption), where the results of the study of electricity consumption scenarios in Estonia (average climate year /ACY/ and baseline scenario) were used as input data for the forecasted consumption per substation for 2035. According to the study, electricity consumption in Estonia is on an upward trend, mainly due to the accelerating electrification of the service, industrial and transport sectors. The total peak consumption in Estonia reached 1,370 MW in summer and 2,035 MW in winter. As the hourly consumption forecast for each substation in the study was made only for 2030, the consumption data for all substations in the 2035 model was increased uniformly by 20%, which according to the forecast in the study is the increase in total consumption in Estonia by 2035 compared to 2030.

Figure 3.15 Regional distribution of PSSE baseline model's summer and winter peak demand 2035

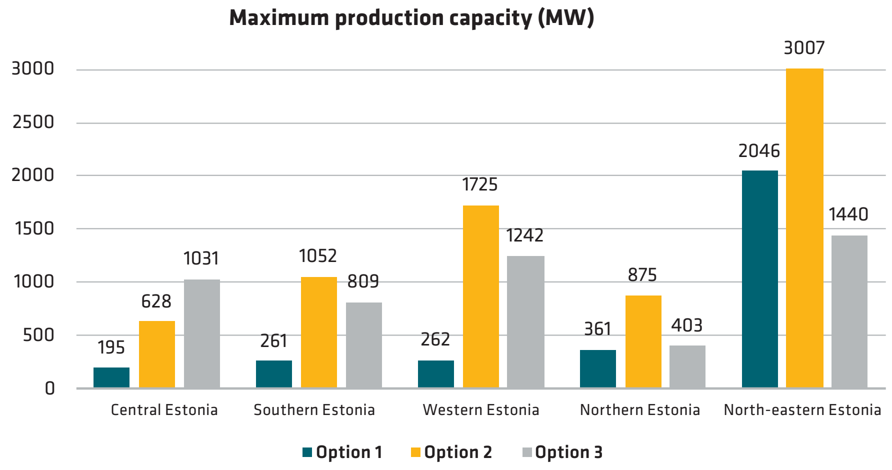


Three variants were used to create the capacity pattern of the baseline model, with each variant in turn using scenarios with a different regional generation profile. This means that in at least one scenario, the predefined maximum capacity was reached for each region.

Description of the variants:

- Option 1 – Existing generation, using only production units with a valid network contract and a built connection point. Historically, most generation is located in Eastern Estonia. The total maximum generation capacity in Estonia is 3 GW.
- Variant 2 – Generation capacities of the first variant plus generation-oriented capacities in the connection process. Although the bigger share of generation is once again located in Eastern Estonia, this time the share of other regions is increasing, with Western Estonia coming in second. The total maximum generation in Estonia is 7 GW.
- Variant 3 – The third variant is based on the assumption that 10 TWh of consumption in the Estonian electricity system is guaranteed from renewable energy sources. The regional pattern of generation capacities takes into account the wind farm development areas of local authorities and the current regional share of solar power plants. The capacities of fossil fuel power plants have been reduced by two-thirds. The top three in terms of generation-oriented capacities are North-eastern, Western and Central Estonia. The total generation capacity in Estonia is 5 GW.

Figure 3.16 Regional distribution of PSSE baseline model's summer and winter peak demand 2035



3.5.6.1 Load growth in Tallinn region

According to the study, the impact of electrification will be the biggest in the Tallinn region, where consumption amounts to 43% of peak consumption in Estonia. Compared to the current forecasted increase in consumption, the load of most lines in the Tallinn area is starting to grow and at least one of the variant considered is over 90% congested. Tallinn an area with one of the biggest loads, where a faster increase in the load is foreseen in the future compared to the rest of Estonia. Electrification of electric transport and technologies will lead to additional load growth on top of normal capacity growth. The Tallinn grid is currently not sufficient to transmit increasing capacities and therefore an additional 330/110 kV substation must be established in the region, which will be connected by 330 kV cable or overhead lines to the Kiisa and Aruküla substations. The 110 kV lines to the substation will be determined in the course of further study. In addition to the new 330 kV substation, the 110 kV grid must be reinforced by upgrading about 25 km of overhead lines to cable lines.

Figure 3.17
Average increase in load on overhead and cable lines and transformers connected to the Tallinn region by 2035 in situation N-1

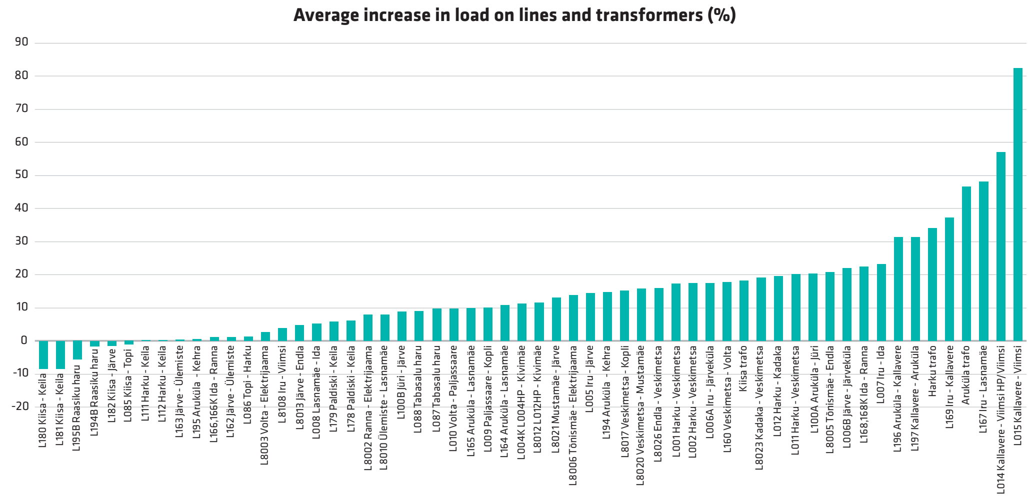
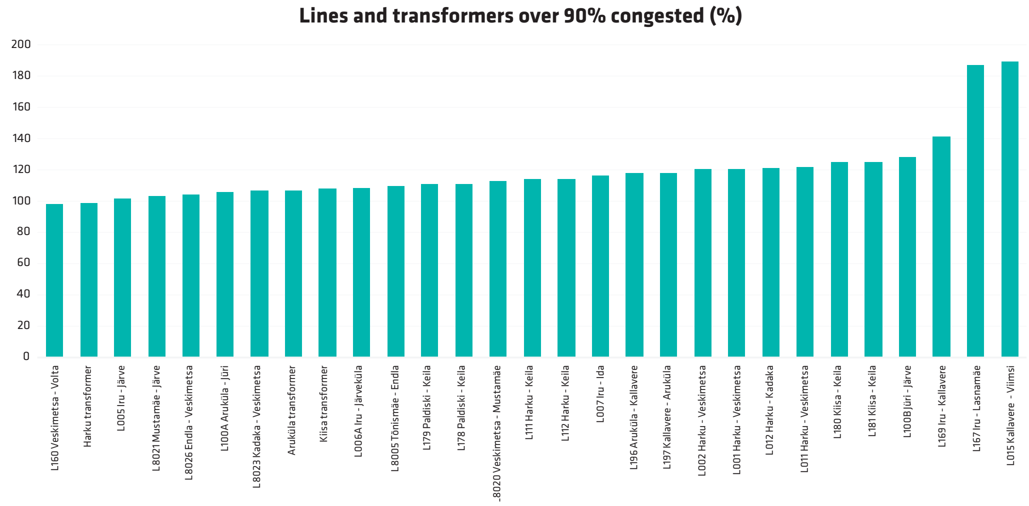


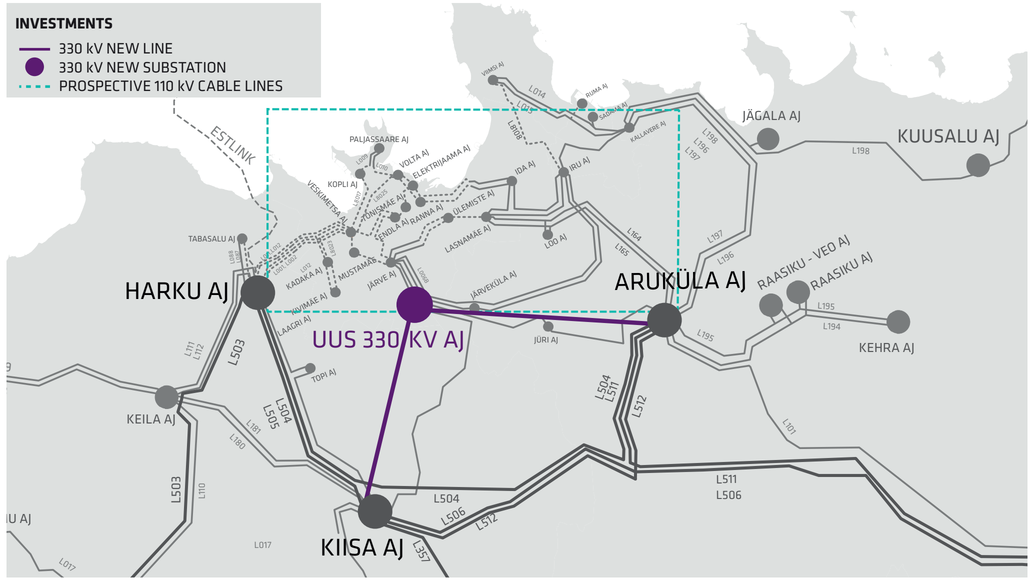
Figure 3.18
Increased load of several variants of overhead and cable lines and transformers connected to the Tallinn region in situation N-1 (the figure presents the elements where the load comprised more than 90%)



Prospective investments in the Tallinn region and modelling results

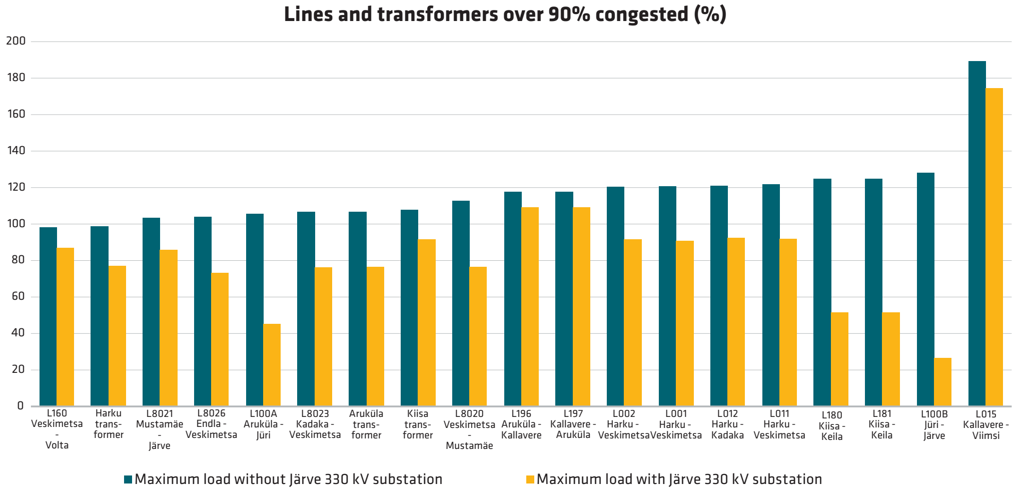
The new 330 kV substation will have the greatest positive effect if it is as close as possible to the existing 110 kV cable grid. In such a case, the new substation will take on the majority of the power flows and will reduce power flows from the directions that are likely to be congested. The substations with two 200 MVA 330 kV power transformers will be connected with new 330 kV lines to the Kiisa and Aruküla 330 kV substations. In the model, the new 330 kV substation was connected to the existing Järve 110 kV substation.

Figure 3.19
New Järve 330 kV substation in Tallinn region



The investment will have a positive impact on lines and transformers in the Tallinn region. The average decrease in the load of overhead and cable lines is 27%, while the load of power transformers will drop by 23% on average.

Figure 3.20
Increased congestion of several variants of overhead and cable lines and transformers connected to the Tallinn region in situation N-1, with and without investment (the figure presents the elements where the load decrease with Järve 330 kV substation was more than 1%)



Despite the positive impact of the investment on most of the cable lines, the load on cable lines L8005, L8006 on the section Endla-Tõnismäe-Elektrijaama will increase by 8% on average. Both cable lines show congestion or are operating while borderline congested.

In order to ensure better transmission on cable lines, the following options need to be modelled and analysed to update prospective investments:

1. replacement of L162/L163 overhead line section with cable
2. L168 (M14)-Lasnamäe new cable line
3. Endal-Veerenni new cable line
4. Järve-Endla-Volta new cable line
5. Four corners: Endla-Veerenni-Lasnamäe – L168 M14-Tõnismäe-Elektrijaama
6. Endla-Tõnismäe-Elektrijaama new cable line

3.5.6.2 Load growth in Tartu region

After Tallinn, the Tartu area is an area with one of the biggest loads, where a faster increase in the load is foreseen in the future compared to the rest of Estonia. Electrification of electric transport and technologies will lead to additional load growth on top of normal capacity growth. Modelling showed an average increase of 11% in load on network elements (lines, transformers, cables) in the Tartu region. On average, the increase in the load of the 330 kV power transformers in Tsirguliina and Tartu is 23%.

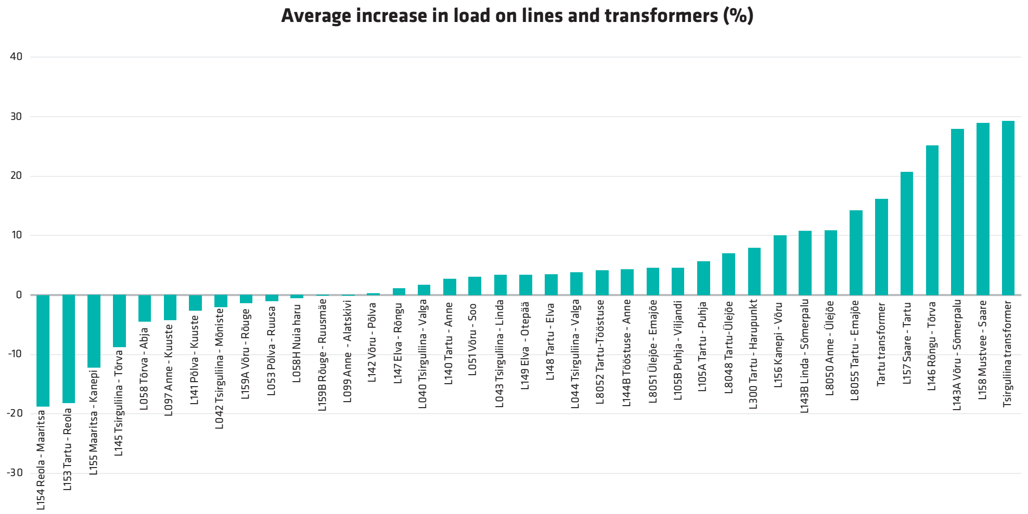


Figure 3.21
Average increase/ decrease in several variants of the load on overhead and cable lines and transformers connected to the Tartu region by 2035 in situation N-1

The congestions were the biggest in the third variant, mainly because of the large potential capacities of large wind turbines are added in the Southern and Central regions. For example, on lines L157 and L158, the most severe N-1 situation is the L132A Paide-Koigi outage, which results in all capacity on the Paide-Jõgeva-Mustvee section being diverted towards Tartu. The Tartu power transformer showed congestion in all variants.

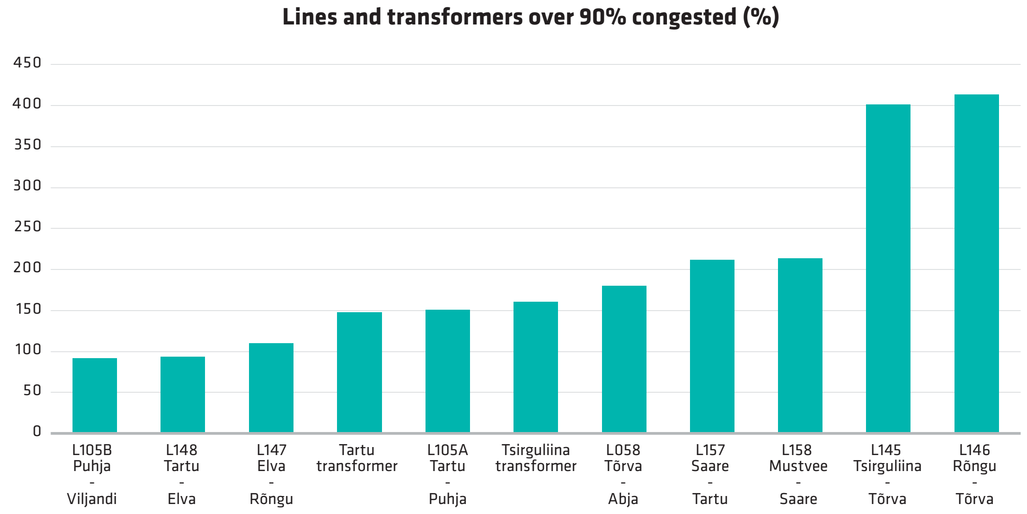


Figure 3.22
Increased load of several variants of overhead and cable lines and transformers connected to the Tallinn region in situation N-1 (the figure presents the elements where the load was more than 90%)

Prospective investments in the Tartu region and modelling results

Tartu's security of supply is currently guaranteed by just one 330 kV substation. To eliminate the risk, it is planned to build an additional 330 kV substation that will ensure Tartu city's power supply if there is an outage in the Tartu substation.

Modelled investments:

- New 330 kV substation with a single transformer in Uniküla
- Reconstruction of Anne-Kuuste-Uniküla 110 kV overhead lines

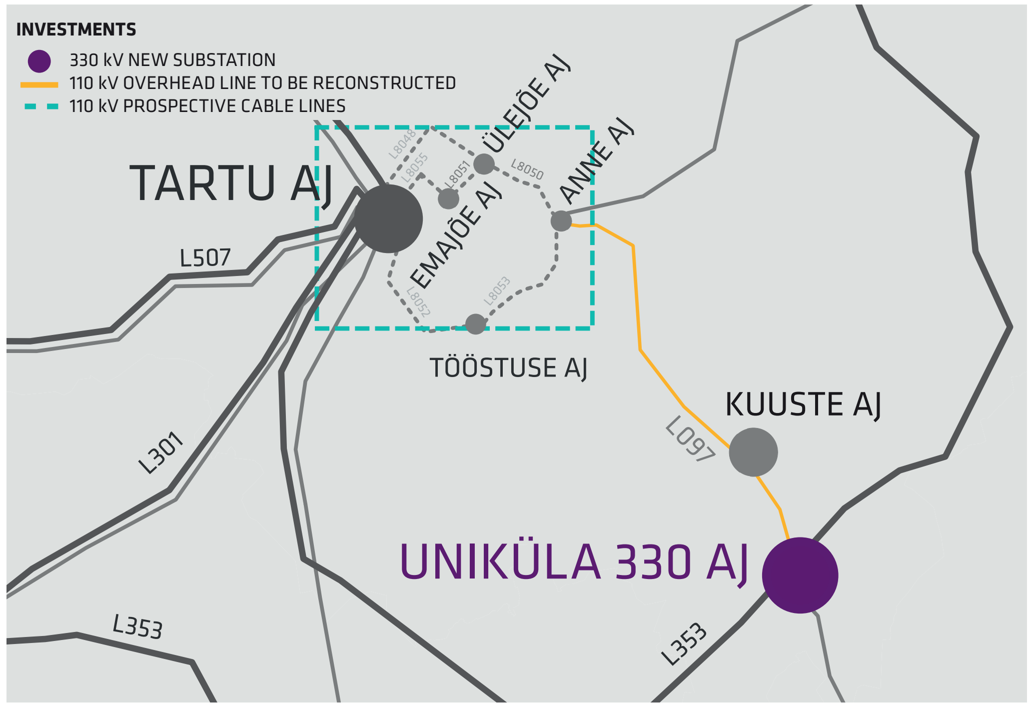


Figure 3.23
New Uniküla 330 kV substation in Tartu region

The model shows that the Uniküla 330 kV substation will have a positive impact in particular on the line in the direction of Tartu substation – Võru substation – Anne substation – Emajõe substation. The congestion of the Tartu power transformer drops by 33% but remains higher than 100%. High congestion on lines L157 and L158 will also persist in the third variant. This may be due to the large production capacities moving from Paide and Sindi towards Tartu. The addition of large capacities at Tsirguliina substation will create congestion of the Tsirguliina power transformer, where additional grid reinforcements need to be analysed. The scenarios of the first and third variants show that the load on the Tartu substation – Ülejõe substation – Anne substation cable line will increase with the new substation and exceed 100%.

The results show that the construction of Uniküla alone will not solve the congestion of the different possible development scenarios. The following variants need to be modelled and analysed in order to update the investment:

1. Additional cable line in Tartu region
2. Connection of Mustvee 110 kV to Mustvee 330 kV substation

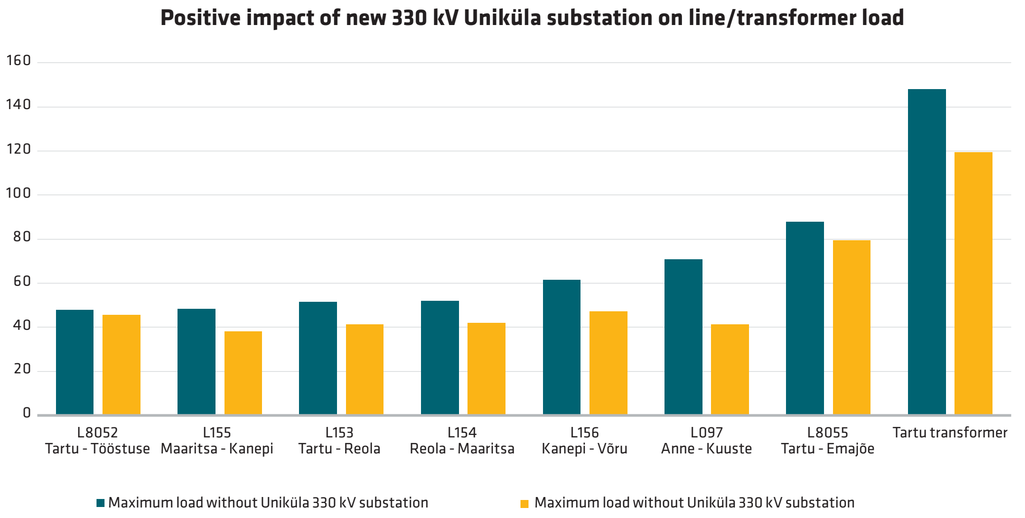


Figure 3.24
Increased congestion of several variants of overhead and cable lines and transformers connected to the Tartu region in situation N-1, with and without investment (the figure presents the elements where the load decrease was more than 5%)

3.5.6.3 Load growth in Pärnu region

In addition to Tallinn and Tartu, Pärnu is one of the regions with the highest load in Estonia. Besides normal growth of capacities, we expect an additional increase in loads due to electrification of electrical transport and technologies and the existing grid is not sufficient for this growth. Another problem is security of supply – the Pärnu power supply is ensured from Sindi 330 kV substation. Lines in the Sindi-Viljandi-Paide region have been considered during the modelling of the Pärnu region. The biggest increase in load will be on the Sindi-Metsakombinaat-Papiniidu lines. In addition, at least one of the variants showed congestion on these lines.

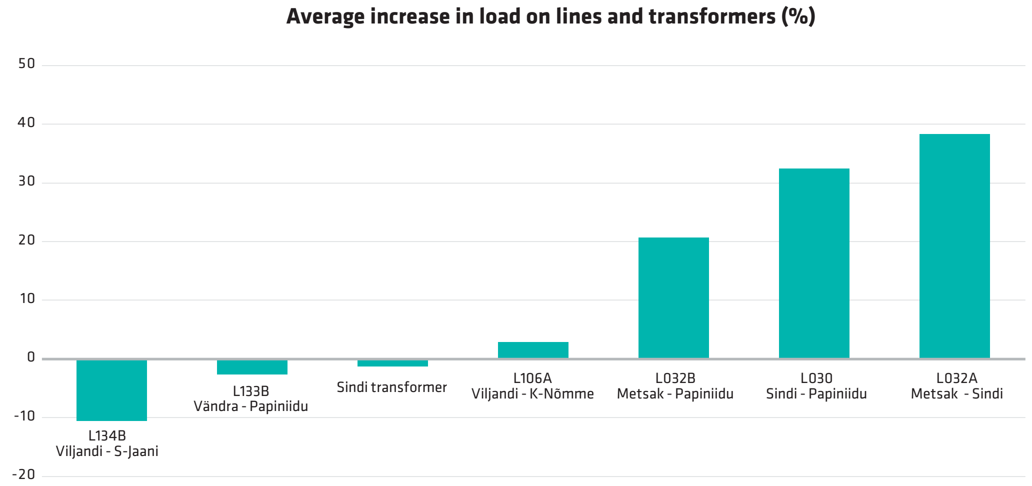


Figure 3.25
Average increase in load on overhead and cable lines and transformers connected to the Pärnu region by 2035 in situation N-1

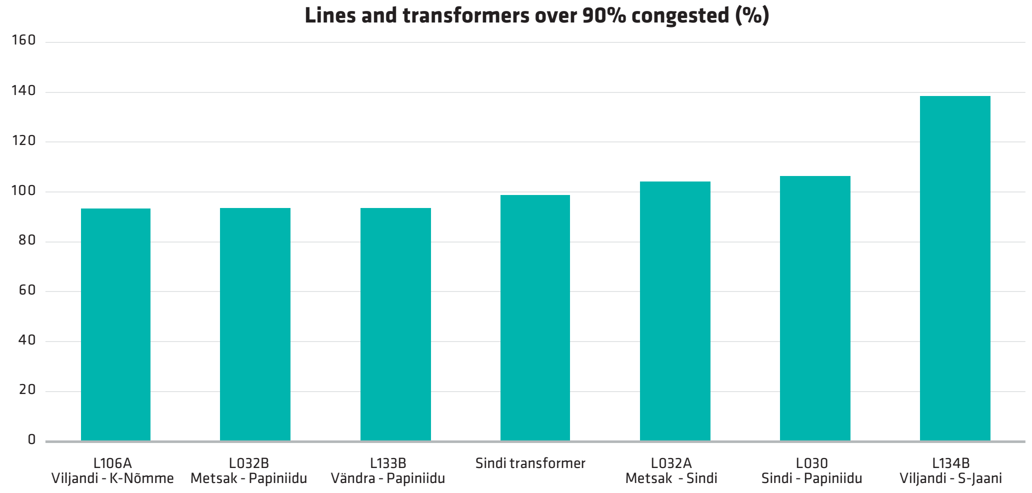


Figure 3.26
Increased load of several variants of overhead and cable lines and transformers connected to the Pärnu region in situation N-1 (the figure presents the elements where the load was more than 90%)

Prospective investments in the Pärnu region and modelling results

The new Sauga 110 kV substation can be used to provide electricity supply from Lihula substation if Sindi substation should be switched off. The new Sauga 110 kV substation will be established on the line L033 Sindi-Audru and connected to the Metsakombinaat substation via the new 110 kV cable lines.

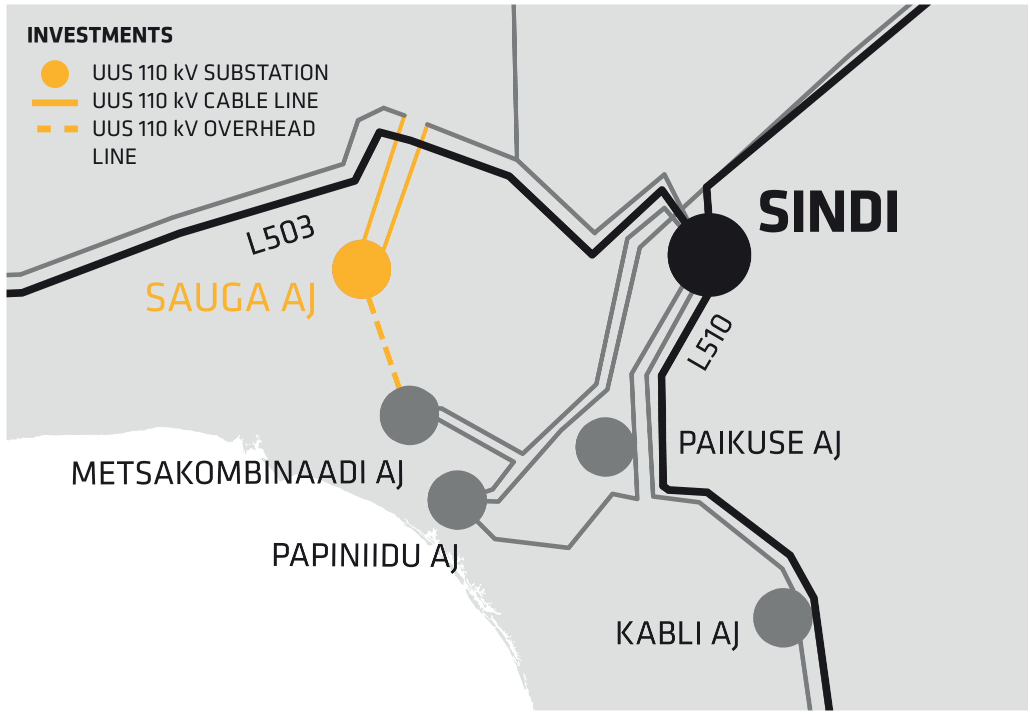


Figure 3.27
Sauga new 110 kV substation in Pärnu grid region

The following additional investments were modelled for the Pärnu region:

1. Uus Sauga 110 kV substation
2. 2. Metsakombinaadi – Sauga 110 kV cable line

Whilst ensuring better security of supply, the Sauga 110 kV substation creates a new N-1 situation at the same time, where in the case of an outage on the Sauga-Sindi line section, congestion will emerge on the new cable line Sauga-Metsakombinaadi and on the lines L032A Metsakombinaadi-Sindi and L032B Metsakombinaadi-Papiniidu. One of the solutions is to install an additional cable from Sauga to Metsakombinaadi and to raise the clearance on line L032A to +60C and reconstruct line L032B.

3.6 NETWORK CONNECTION CAPABILITY

3.6.1 Investments associated with connections

An important part of the connection process is the determination of the investment needed to connect the new module to the grid. The volume of investments will be determined by grid calculations using a computer simulation method. During the simulation, the module to be connected is integrated into the existing network model and the N-1 calculation is done. Calculations are done with different generation and consumption patterns, resulting in a list of network elements with insufficient capacity. The volume of necessary investments will depend on the capacity of the module to be connected, the strength and density of the existing grid and the capacity of modules previously connected to the grid.

The main limitation of overhead lines is thermal resistance, which is a direct consequence of the cross-section and clearance of the wire. In the case of insufficient capacity, it will first be investigated whether the congestion can be eliminated by raising the clearance of the existing wires to the temperature of +60 °C. If the cross-section of the existing wires is insufficient, the construction of a new line in the existing line corridor will be considered. The standard cross-section in the company is 1x240 mm2 or 2x240 mm2 for new 110 kV lines and 3x400 mm2 for 330 kV lines. New lines are designed with a clearance of +80 °C. In order to save land that will go under a protection zone, it is preferable to place the parallel running circuits of 110 kV and 330 kV lines on joint masks and use exiting line corridors when lines are built.

Grid calculations for new connections also include congestion of substation equipment. One solution in the case of power transformer congestion is to connect an additional transformer in parallel with the existing one. The cost of building power transformers and new lines is currently the main constraint for customers to connect new generation modules. When the connection of a power plant to the main grid is planned, it must be taken into account that no more than 400 MW may leave the grid as a result of a N-1 fault. The minimal number of necessary lines and the substation solution are based on this. Larger capacities need to be shared between several connection points. The final solution will be determined during the grid calculations, with some differences for nuclear power plants and offshore wind farms.

Additional requirements are introduced for nuclear power plants in terms of the reliability of the connection to the grid. Regardless of the capacity, at least two 330 kV lines are needed to connect a nuclear power plant, and one 110 kV line is necessary for own consumption. From a security of supply point of view, it is preferable to build a nuclear power plant close to strong 330 kV substations and power plants with black start capability. The 330 kV lines and the 110 kV own consumption line must be located on separate towers in relation to each other, and tower sharing is not allowed. The capacity of the lines must be sufficient to carry all the generation capacity to the grid or to obtain the capacity needed for own consumption from the grid under all possible regimes.

Compared to onshore connections, the construction of grid connections for offshore wind farms is more expensive due to the need to install offshore cables. Cable lines have a high capacity, which in an AC grid leads to the generation of additional reactive power, which in turn can cause overvoltages. The higher the nominal voltage and the total length of the cable lines to be connected, the more significant the impact. Shunt reactors must be installed at the start and end substations of cable lines to keep the voltage within the permitted limits. In order to increase the length of the cable lines, it is possible to plan the connection of offshore wind farms at 220 kV, but in this case there will be additional investment costs for the installation of 330/220 kV power transformers. In the case of a DC connection, the length of the submarine cable can be somewhat longer. The cost of the converter stations, which is added to the price of the cable, must also be taken into account.

3.6.2 Overview of the status of connections

Estonia has set a target of covering at least 100% of its total final electricity consumption with renewable energy by 2030. This requires the generation of ca 9.5-10 TWh of renewable energy per year, which can be supplemented by connecting ca 6,000 MW of capacity to the grid.

More volatile electricity prices on the exchange have led to a surge in interest in connecting to the generation-oriented grid.

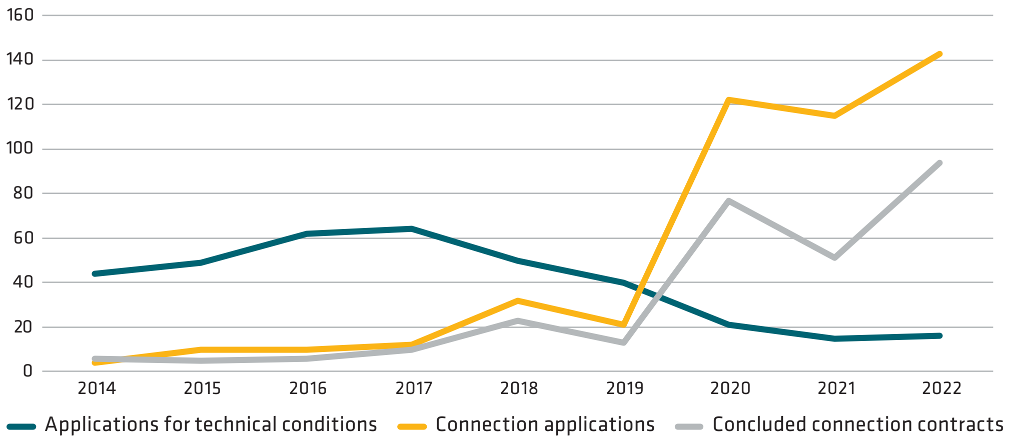


Figure 3.28 Applications for technical conditions, connection applications and concluded connection contracts from 2014-2022

As of the beginning of September 2023, Elering has:

- approximately **3,000 MW** of existing grid contracts with generators for the operation of generating equipment on the grid;
- completed connection contracts with generators, where we expect ca **1,000 MW** of generating capacity to be connected by generators;
- connection contracts of generators, which are performed by Elering to the extent of ca **3,000 MW**.

Among the power plants with grid contracts are:

- **2,655 MW** of conventional thermal power plants with synchronous generators or cogeneration plants;
- **349 MW** of wind farms;
- **25 MW** of solar power plants.

Among the planned power plants are:

- **1,087 MW** of storage devices (batteries);
- **1,196 MW** of onshore wind farms;
- **1,721 MW** of solar power plants.

In order to bridge the gap between potential and needed generation capacities, it is important that generators receive a signal from the state, either through reverse auctions of renewable energy or similar measures, to rapidly develop additional generation projects. For Elering, this will bring about the need to be ready for fast processing of connections and the construction of grid connections, including grid reinforcements.

At the same time, Elering is in a situation where the sanctions imposed due to the war initiated by Russia, the economic downturn and the already increased interest in the construction of power plants and other electricity infrastructure where the contractors operating in the field are overburdened and, as a result, construction prices have increased significantly and construction deadlines have been extended. Today, the existing transmission network is dimensioned to transmit around 3,000 MW of capacity – on average 1,000 MW for local consumption and 2,000 MW for inter-state electricity trade to the south and the north. Therefore, the time and money needed to increase the capacity of the grid must be taken into account, as each subsequent connecting party causes the need for more and more extensive grid reconstruction and the size of the connection fee. One option is to release network operators of their obligations to guarantee to power plants not using the grid and/or connection contracts generation-oriented transmission capacities under existing contracts.

The Electricity Market Act was amended for this purpose, which, alongside the amendment that entered into force on 17 March 2023, gives network operators the right to charge a justified fee for non-use of reserved power grid resources. The purpose of such a fee is to encourage connecting parties to actually install generation equipment and connect to the grid within one to two years. The fee for non-use of the reserved power grid resource will also apply to old and dismantled power plants that were previously in operation to free up capacities on their grid connections.

3.6.3 Available connection capacities

Available connection capacities are the capacities in the case of which it is not necessary to increase the capacities of the transmission lines upon connection to Elering. Available connection capacities depend on the strength of the Estonian transmission system. The main limiting factor is the thermal constraint of transmission lines, which depends on the current passing through the line. Available connection capacities decrease with new connections and with increases in the existing connection capacity and increase with investments into the electricity system. The grid connection capacity is increased by the investments made in the ensuing 10 years, described in the previous chapter, into synchronisation, the offshore grid and the Western Estonia and islands network investments programme.

The best overview of changes in available connection capacities can be found in the available connection capacity app on Elering's website (https://vla.elering.ee/)The following figures compare the available connection capacities now and after five years, when the investments provided for in the Elering investment budget have been made.

From the second half of 2021, the number of electricity producers joining the grid has increased significantly. By autumn 2022, Elering had constructed a total of about 5000 MW of network connections and there is an additional 6000 MW of connection capacity in the connection supply or contract performance phase. Compared to Estonian electricity demand, which ranges between 500-1600 MW, and the capacity of international connections, which is up to 2000 MW, we see that it would be possible to add to the Estonian power grid significantly greater capacity than the market can accommodate at any given point in time. It follows that the possibilities for connecting to the grid in Estonia are good.

The key question is undoubtedly whether all of the network connections built or to be built will also be actually utilised or whether they will block plans for market participants who have the actual intent for building new generating installations.

The interest in connections in 2021 and 2022 also generated a large number of 'phantom' connections, which have not been put into operation (peak interest on 1 March 2022 was 12,218 MVA). Partly in order to rectify this situation, a security of €38,000 per megawatt-ampere (MVA) was introduced for those wishing to join the transmission network as of 17 March 2023 – Electricity Market Act §871. It is used to cover connection costs when building capacity. This security fee will provide an incentive to release capacities removed from the grid and new reserved but unused capacities or to put them into operation as planned.

The total generation capacity has decreased (existing grid and connection contracts, connection contract offers and connection requests accepted). There was 11,424 MVA on 1 March 2023 and 8,490 MVA on 1 September 2023.

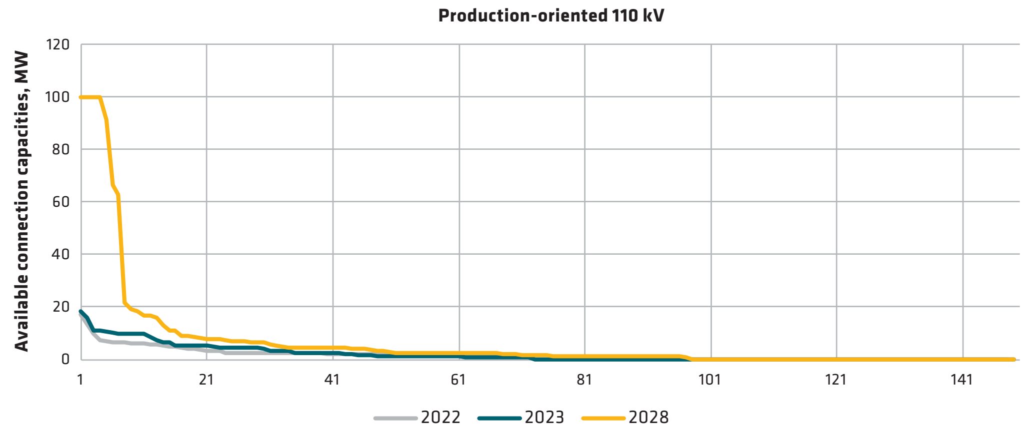


Figure 3.29
Distribution of available production-oriented connection capacities of 110 kV substations

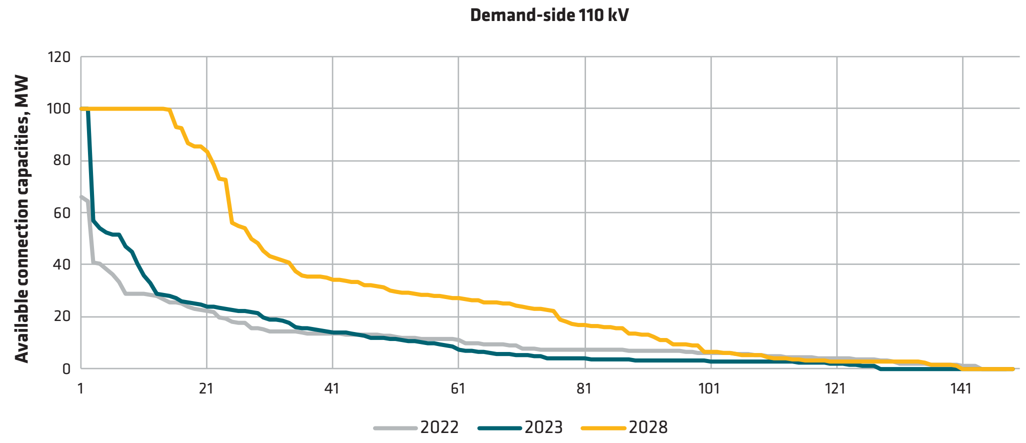


Figure 3.30
Distribution of available demand-side connection capacities of 110 kV substations

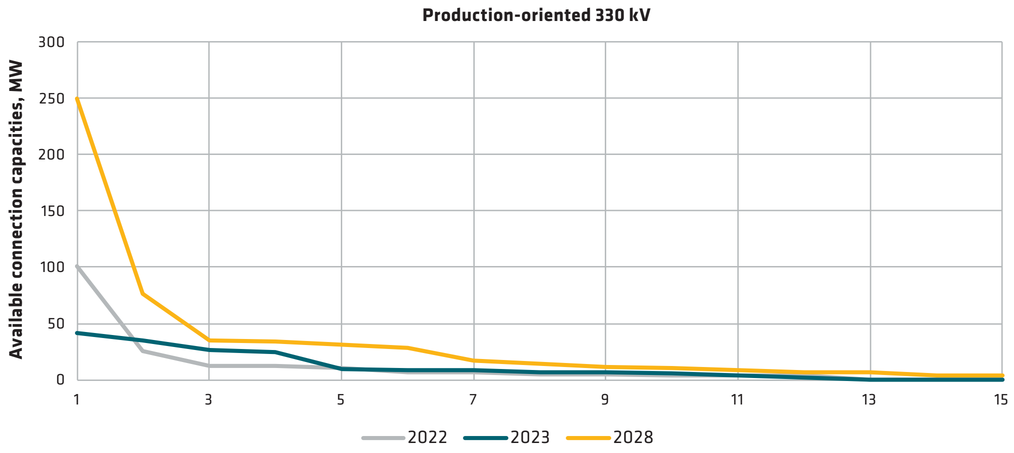


Figure 3.31
Distribution of available production-oriented connection capacities of 330 kV substations

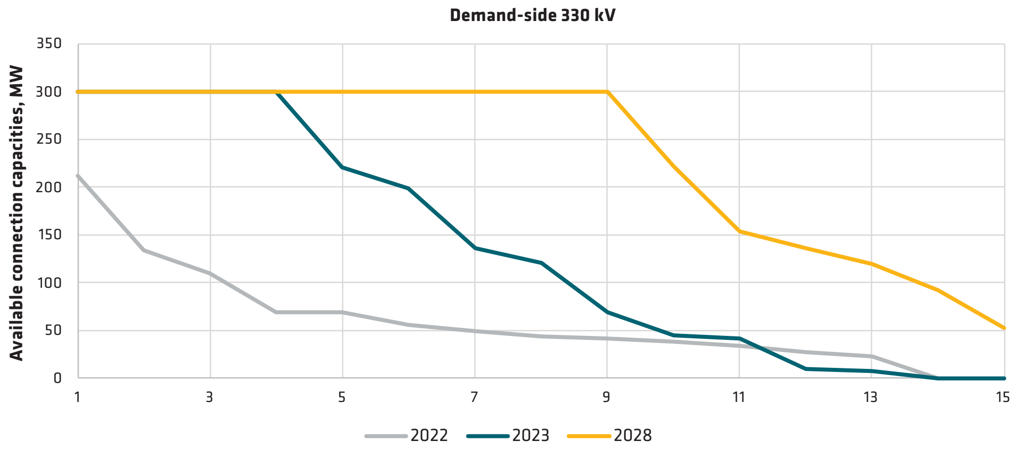


Figure 3.32
Distribution of available demand-side connection capacities of 330 kV substations

Due to the legislative amendment and grid investments, the situation of available connection capacities has improved. Elering's long-term power grid development plan also includes the Estonia-Finland and Estonia-Latvia connections that will definitely increase the system's capacity both domestically and internationally. The total export capacity of the Estonian electricity system would increase with these projects. The exact impact related to connection capacity has not been evaluated and these potential developments are not taken into account in current connection offers, as only binding investments are taken into account.

3.6.4 Flexible connection

For new connections to the power grid where any network element is congested due to transmission of the power desired by the client and where the client should pay for network reinforcement to prevent such a situation, Elering continues to offer the option of flexible connection. In such a case, the client can choose whether to pay to increase the congested network element's capacity or agree on offloading of generation and/or consumption power in situations where congestion occurs.

A flexible connection gives a customer the option of not investing into increasing the capacity of the Elering grid, while for the TSO, it means an optimal power grid, with resulting decrease in investment and maintenance costs.

Every time a connection offer is prepared, a grid analysis is conducted, in the course of which the planned generation and/or consumption power and its impact on the electricity system in the case of various generation and/or consumption limit scenarios are determined. If as a result of the network analysis it becomes evident that one or more network elements have a likelihood of becoming congested due to the mode, the client should increase the capacity of that network element in order to ensure the desired generation and/or consumption capacity. For customers who are able to use the desired connection capacity during congestion, either fully or partially offloaded, Elering can, in addition to the traditional connection contract offer with reinforcement costs, make an alternative offer, according to which no reinforcement is necessary. At the same time, such a connection contract includes an agreement on the capacity above that one or more network elements are considered to be congested and the network elements whose congestion gives Elering the right to offload the customer's consumption and/or production capacity. No agreements are reached in regard to the duration of the restriction.

Before the client signs the connection agreement and makes the investment decision, Elering gives the client information on the types of generation and/or consumption scenarios where the model shows congestion arising and also a statistical overview of occurrence of scenarios that cause congestion. Elering also provides information on the cases in previous years where the grid elements that could potentially cause a congestion have been switched off. With this knowledge about the cost of upgrading the capacity of the potentially congested grid element and the likelihood of the temporary restrictions, the customer can make a better-informed decision on whether to opt for a flexible connection.

The constraint on capacity will be applied only if there is a risk of congested grid elements and the connection agreement with the customer specifies which elements these are. If a given grid element is included in connection agreements with more than one customer, the restriction of capacity will start with the customer who established the connection to the grid most recently, and so on, until the oldest connection is reached. The restrictions on generation and/or demand capacity must be executed by the customer pursuant to the grid operator's requirements.

The need to use flexible connection capacity by the TSO becomes evident in the course of modelling operation of the electricity system – starting from year-ahead planning to the start of the operational hour. Customers will be notified as soon as possible of the need for a partial or full restriction placed on a flexible connection. Depending on the duration of the outage, the TSO will provide corresponding information at the following times:

1. If the capacity restriction lasts over 120 consecutive hours, the customer will be notified by the 25th day of the month prior to the restriction.
2. If the capacity restriction lasts 120 consecutive hours or less, the customer will be notified by 12:00 on the previous day of the maximum allowed demand and/or generation capacity for each hour.

In the case of unscheduled restriction of a flexible connection capacity (such as a malfunction in the electricity system or extraordinary works on the grid etc.), the restriction will be implemented automatically by Elering by way of remote control.

The TSO informs the client of flexible connection capacity constraints pursuant to the data exchange format to be established by the TSO. Customers must ensure the functioning of the data connection between the TSO's SCADA and the customer's corresponding system and the adoption of the data exchange format to be established. The customer will also have to build and test a technical solution that upon receiving a command from SCADA alters the flexible demand and/or generation capacity.

At the time of writing, Elering has signed a total of five contracts with flexible terms and conditions: consumption 64 MVA (one contract) and total generation 121.5 MVA (4 contracts).

3.6.5 Connection of storage devices

Storage equipment in the electricity system are electrical installations that allow electricity to be stored at the desired time and fed back to the grid at a chosen time. The primary magnitudes that characterise the capability of storage equipment are electricity capacity, power rating, and speed of regulating output power. The most common technologies are pump hydro plants with reservoirs and fuel cell-based storage equipment. In general, technologies connected through converters are used, allowing the output power of the storage equipment to be regulated independent of the network frequency; these are also much more flexible to operate.

When connecting to the grid, storage equipment is subject to similar requirements as generation modules and/or HVDC converter systems. Storage equipment also require sufficient network capacity just as when new ordinary generation and consumption connections are added. If storage equipment is designed to decrease load on the lines, storage equipment can also be connected in places that currently lack network capacity, e.g. in combination with generation modules. The abovementioned network developments will undoubtedly enable larger-scale storage equipment to be connected, which could provide system services and earn revenue on volatility of electricity price.

At present, there are practically no storage equipment connected to the transmission network with the Estonian electricity system. However, in the more distant future, a number of storage equipment are planned, including large-scale pump hydro plants are planned in various regions in Estonia, which could definitely fill in this gap in the Estonian electricity system and give additional contribution to security of supply of the Estonian electricity system.

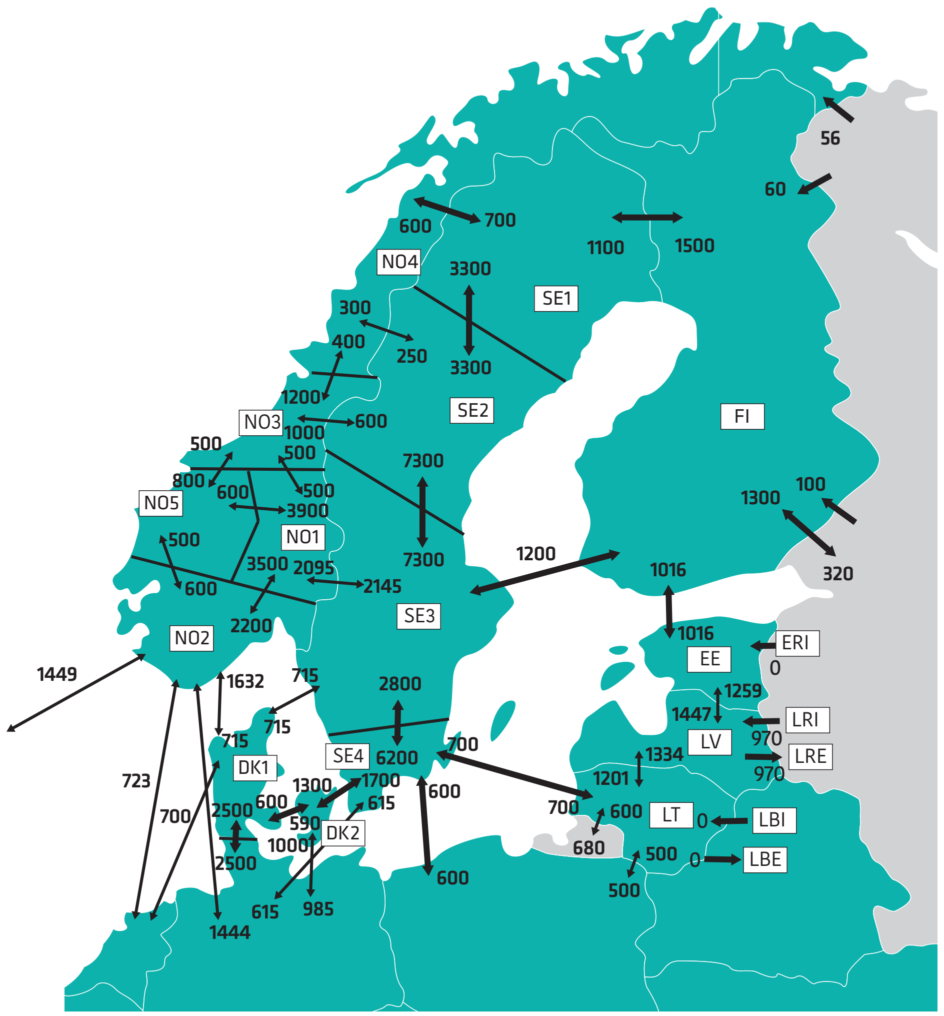
Currently, there are a total of 1087 MVA of connection contracts in progress to provide grid connections to storage equipment. The Paldiski pump hydro plant project (500 MW) is currently in the preparatory stage for a connection agreement; no connection agreement has been signed.

In summary, the grid is ready for the connection of storage equipment; only the system services and other regulation markets used for the storage equipment must still be developed. Furthermore, Elering has developed a more suitable transmission fee structure for storage equipment, establishing a separate tariff plan based solely on fixed fee components. A tariff based on a fixed fee is more suitable for storage equipment as in this case the storage does not have to pay energy-based rates, which will also allow it to participate on the electricity market at a lower variable cost.

3.7 OPPORTUNITIES TO TRADE WITH OTHER COUNTRIES

Estonia and the Baltic region electricity grids as a whole are well connected with neighbouring countries. In addition to EstLink, Lithuania's connections with Sweden (NordBalt) and Poland (LitPol) connect the Baltic states to the European electricity market. Connections with Finland total 1,016 MW, with Poland 500 MW and with Sweden 700 MW. The connection capacities with other regions are shown in the figure below.

Figure 3.33 Maximum transmission capacities of Baltic Sea region (MW) as of 25 May 2022



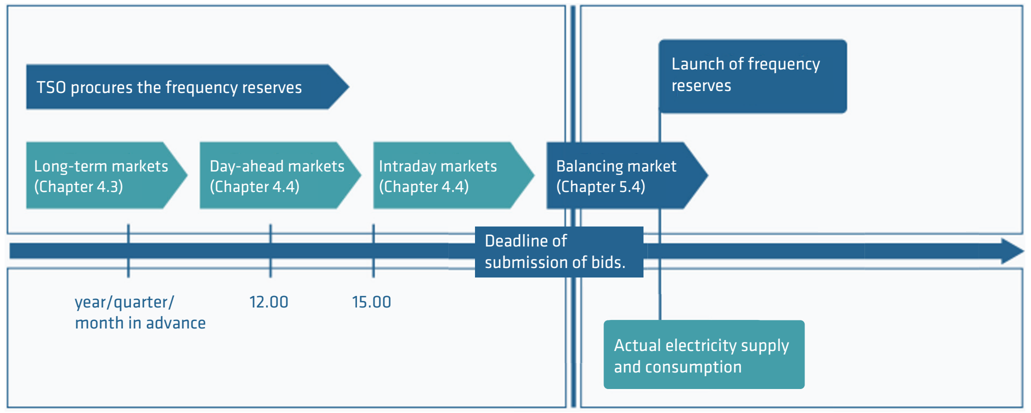
Developed historically as part of the Russian electricity system, the Baltic electricity systems also have several connections with Russia and Belarus. The electricity system of Estonia, together with the electricity systems of Latvia, Lithuania, Russia and Belarus, is part of the BRELL cooperation organisation, which will provide coordinated system operation and frequency management until synchronisation with Central Europe, which is scheduled for early 2025.

Elering as a TSO is responsible for the allocation of cross-border transmission capacities and does so in accordance with EU regulations and the Estonian Electricity Market Act.

The target set by the European Commission is to only use market-based solutions for the allocation of transmission capacity and to not give advantages to individual market participants. This approach promotes competition and increases the transparency needed for new investment decisions. The principles for the allocation of cross-border transmission capacities are regulated by EU Regulation 2019/943 and 1222/2015 (CACM NC), 2016/1719 (FCA NC), 2017/2195 (EB GL) grid codes. It is the responsibility of the TSO to ensure security of supply of the system when allocating transmission capacities. According to the Estonian Grid Code, the TSO allows the import of electricity from and its export to other electricity systems, as well as transit through the power grid of the TSO, to such extent and under such conditions so as to not damage the national electricity system, to create additional restrictions on the internal consumption of electricity and to not adversely affect the security of supply and quality of electricity for consumers of the national electricity system. It is important to note that the EU Grid Codes does not cover trade with third countries (such as Russia and Belarus). Russia's aggression against Ukraine in 2022 ended the dialogue between the TSOs, the European Commission and Russia and there is no energy trade with Russia.

On the electricity market, market participants have a variety of options at their disposal for both trading and hedging. While day-ahead, intraday and balancing (regulation) markets trade primarily in physical energy, products offered on long-term financial markets, for example, are primarily designed to hedge the price risks of market participants (see figure below).

Figure 3.34 The European Single Market Model by time period



Long-term transmission rights as forward transmission rights (FTRs) are offered by Elering at the Finnish border (in the FI-EE direction) and at the Latvian border (in the EE-LV direction) on the pan-European long-term cross-border capacity allocation platform SAP (single allocation platform) operated by the JAO[36].

The day-ahead market is the part of the electricity market where the physical electricity to be delivered on next day for each market period is traded at the power exchanges (in 2023 the market period was one hour, with plans to move to a 15-minute market period in the future). In Estonia, bilateral electricity purchase/sale contracts can only be concluded at the national level. Another way to trade electricity is to participate in the power exchange, which is part of the Single Day-ahead Coupling (SDAC) project. In Estonia, NordPool[37] and EPEX[38] have been appointed as NEMOs, but the latter did not offer trading as of 2023. On the exchange, the price is determined on the basis of bids and offers made during a fixed agreed period, on the basis of the marginal-pricing principle, for all connected bidding zones at the same time for each market time unit (hour).

The intraday market is the 'next step' for the electricity market, where market participants have the possibility to additionally trade electricity supplies on a pan-European basis (SIDC) in order to adjust the trades on the day-ahead market. The need to conclude additional purchase and sale transactions may also result from the more accurate generation/consumption forecasts (e.g. in the case of changing weather conditions). Intraday trading starts after the results of the day-ahead market have been published, and trading will also be possible on the same day up to one hour before the start of the actual supply.

The common regulation market (COBA) was launched in the Baltics on 1 January 2018. The following regulation reserve products are used on the Baltic regulation market:

- Standard product (mFRR), which is offered by regulation service providers in the Baltic states and also outside the Baltic states, the parameters of which are consistent with the criteria for a standard Baltic product. The latter are kept in the Baltic common bidding list with forecast prices.
- Specific product (ER mFRR) offered by regulation service providers operating in the Baltic States and outside the Baltic States.

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[36] https://www.jao.eu/auctions%23/
[37] https://www.nordpoolgroup.com/en/
[38] https://www.epexspot.com/en

The connection of the Baltic power grid with the Continental European synchronous area will bring about a fundamental change in the balancing arrangements of the Baltic electricity systems, as a result of which the Baltic TSOs to take responsibility to procure the capacity for load-frequency control (LFC). As part of the European system, the Baltic States must be ready to manage their electricity systems independently if necessary. The Baltic States are thereby required to join the pan-European automatic frequency restoration reserve (aFRR) platform (PICASSO) and the manual frequency restoration reserve (mFRR) platform (MARI). The necessary quantity of fast Frequency Containment Reserves (FCR) as well as the automatic and manual frequency restoration reserve (aFRR and mFRR) necessary for the three Baltic states will be procured jointly for the next day from the day-ahead reserve capacity market.

In a situation where the physical energy flows exceed the network's through-capacity and there is a risk to system control capability, countertrading must occur to remove the physical congestion. Countertrading takes place only during the hour of operation itself; it is not performed preventively (such as eight hours ahead). To perform countertrading, generation is increased in the region into which the active power flow enters and generation is reduced in the region from which the active power flow exits (exited). The increased and reduced generation has to be within the same range to ensure that the power balances of the power systems remain in balance. Primarily, countertrading has to take place between Estonia and Latvia (AC connection) in the summer period, but in addition to Latvian and Lithuanian import, the lines' transmission capacity will decrease due to an increase in ambient air temperature. Major power flows in the Latvia to Estonia direction can cause situations where the cross-border lines' cross-sections are congested and there is a risk of a transmission cut. To avoid this, countertrading is used in cooperation between TSOs. During the previous winter period, a total of one hour of countertrading was carried out on the Estonia-Latvia cross section. The maximum technical transmission capacities in winter and summer are shown in Table 3.3. The values given in the table are the transmission capacities calculated by Elering according to the current transmission capacity calculation methodology[39]. The capacity made available to the market will be coordinated with AST, the Latvian TSO, where the constraints of both TSOs will be taken into account.

Table 3.3
Maximum technical transmission capacity in Estonian cross-sections in winter and summer 2023-2033

Maximum technical transmission capacity (TTC)		**EE→LV**	**LV→EE**	**EE<->FI**	**EE→RU**	**RU→EE**
2023	winter 0 °C	1610	1600	1016	910	910
2023	summer 25 °C	820	920	1016	350	360
2024	winter 0 °C	740	890	1016	910	910
2024	summer 25 °C	475	890	1016	350	360
2025	winter 0 °C	1200	1250	1016	0	0
2025	summer 25 °C	1050	1250	1016	0	0
2026	winter 0 °C	1200	1250	1016	0	0
2026	summer 25 °C	1050	1250	1016	0	0
2027	winter 0 °C	1200	1250	1016	0	0
2027	summer 25 °C	1050	1250	1016	0	0
2028	winter 0 °C	1200	1250	1016	0	0
2028	summer 25 °C	1050	1250	1016	0	0
2029	winter 0 °C	1200	1250	1016	0	0
2029	summer 25 °C	1050	1250	1016	0	0
2030	winter 0 °C	1200	1250	1016	0	0
2030	summer 25 °C	1050	1250	1016	0	0
2031	winter 0 °C	1200	1250	1016	0	0
2031	summer 25 °C	1050	1250	1016	0	0
2032	winter 0 °C	1200	1250	1016	0	0
2032	summer 25 °C	1050	1250	1016	0	0
2033	winter 0 °C	1200	1250	1016	0	0
2033	summer 25 °C	1050	1250	1016	0	0

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[39] https://elering.ee/sites/default/files/attachments/03.10.2018_Baltic%20CCR_CCM.pdf

3.8 PHYSICAL SECURITY OF THE POWER GRID

A functioning power transmission network is essential in a crisis. National recovery plans and the necessary resources are needed to ensure that the transmission network can cope with emergencies. The existence of recovery plans and their suitability tested in exercises ensures preparedness for emergencies.

In 2024, a training facility will be built in cooperation between Elering AS and Elektrilevi OÜ for conducting crisis drills concerning the power network and improving professional skills in electricity transmission and distribution. Among other things, a typical Elering substation and a high-voltage overhead line will be built on the site. The substation on the training ground can be used for training in hazard awareness required for working in an electrical installation as well as maintenance and reconnection of equipment. In order to learn the principles of construction and maintenance of high-voltage overhead lines, masts with different structures and heights will be erected on the site.

In order to quickly restore the connections between substations, it is necessary to restore overhead lines between substations. In 2023, Elering signed a contract with the Canadian company ACIER PROFILE SBB INC for the procurement of an emergency restoration system. The system will make it possible to erect up to 10 kilometres of temporary line. The emergency restoration system also makes it possible to prepare and erect high-voltage line anchor, angle and supporting pylons in a matter of hours. The system can be used for overhead lines with different voltage classes and numbers of circuits. Temporary pylons can be erected by crane or helicopter or, depending on the conditions, by six workers, i.e. without the use of heavy machinery, for example on terrain that is difficult to access. The modular pylon system can also be used to provide temporary line sections and bypasses during repairs and reconstruction of the high-voltage network, when the power line cannot be switched off for long periods to ensure power supply.

Elering also has a reserve of standard pylons, but the erection of such pylons for the elimination of emergencies may take too long and may be hampered by transport and constraints relating to the complexity of erection. For example, erecting a regular pylon on swampy ground can be complicated and time-consuming, taking weeks and in certain cases only being possible when the ground is frozen.

Mobility is necessary to adapt to emergency situations in the electricity system, and in order to achieve this goal, Elering started a project in 2023 to procure a mobile substation. Improving the ability to adapt will enable Elering to better cope with the connection of generation capacity to the grid in situations where the equipment of the generating substation needs to be maintained or replaced. A mobile substation is indispensable in the cases where the provision of vital services in a region is severely hampered by the lack of electricity.

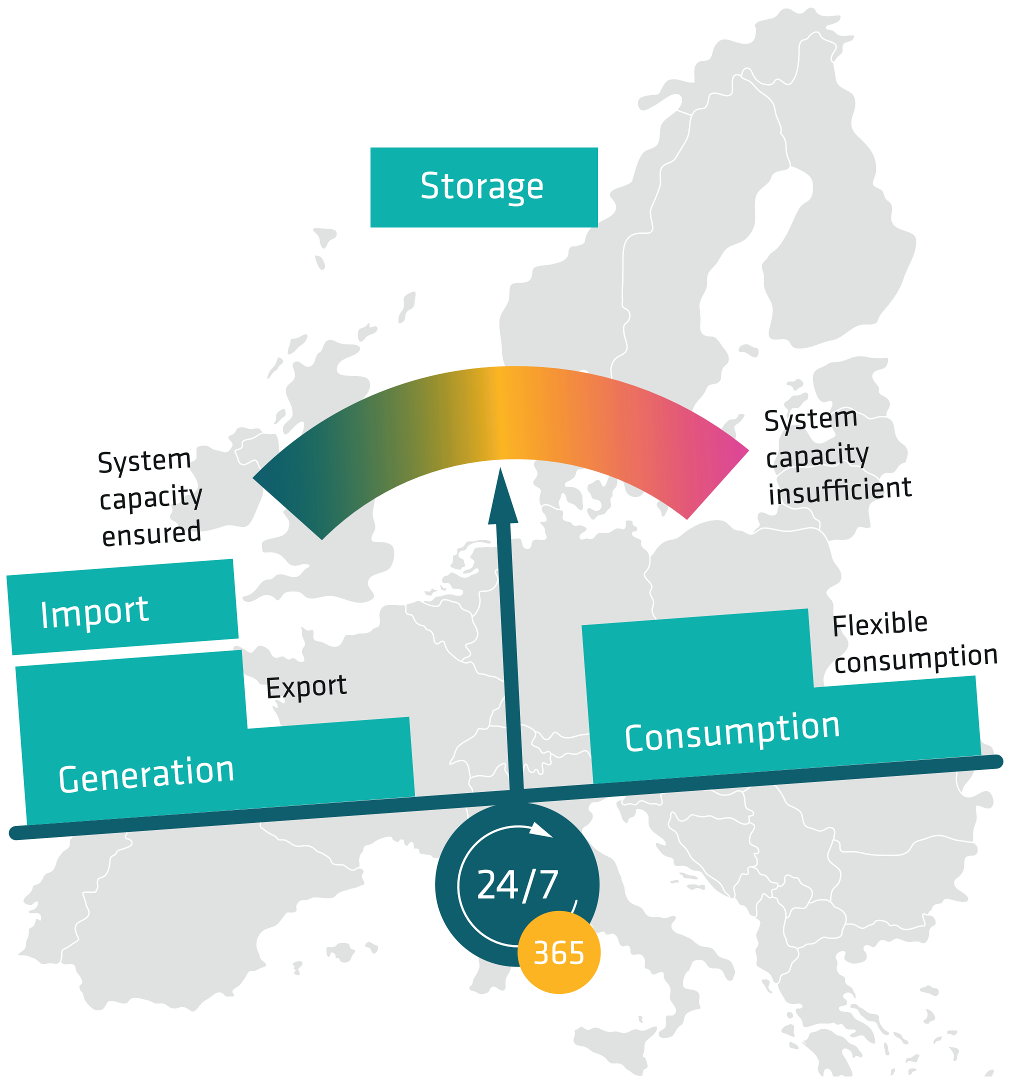
The importance and existence of stocks has become increasingly important. In 2022 and 2023, Elering has significantly increased the quantities of components needed for the restoration of the electricity and gas system and has built additional storage options for them.

4. System adequacy

4.1 DEFINITION OF SYSTEM ADEQUACY AND HOW TO ENSURE IT

In the electricity system, production and consumption must be balanced at all moments. To maintain the balance economically and ecologically, problems that come up must be anticipated long in advance and action taken so that the electricity system guarantees enough resources to cover demand. This is illustrated by Figure 4.1. The capacity of the electricity system must look several years ahead in order to make sure that the domestic electricity production, storage, import capacity and flexibility capacity are sufficient for covering consumption in different situations.

Figure 4.1
Components and balance of long-term system adequacy



There are three significant stages for ensuring the adequacy of the electricity system:

- Establishing a reliability standard (see 4.2) pursuant to the balance between energy not supplied and investment costs on new capacities
- Evaluating the long-term electricity system adequacy (see 4.4.1. for exact description of the methodology and see 4.4.4 for detailed results con countries in the Baltic Sea region);
- If the long-term assessment of the electricity system shows higher levels of resource adequacythan the reliability standard, the system adequacy is guaranteed. If the assessment shows that the situation is worse in future than the standard allows, the European Commission guidelines require that the market disruptions be eliminated, and a capacity mechanism can be announced in such a case (see 4.3 for more details).

Figure 4.2
Stages of ensuring system adequacy

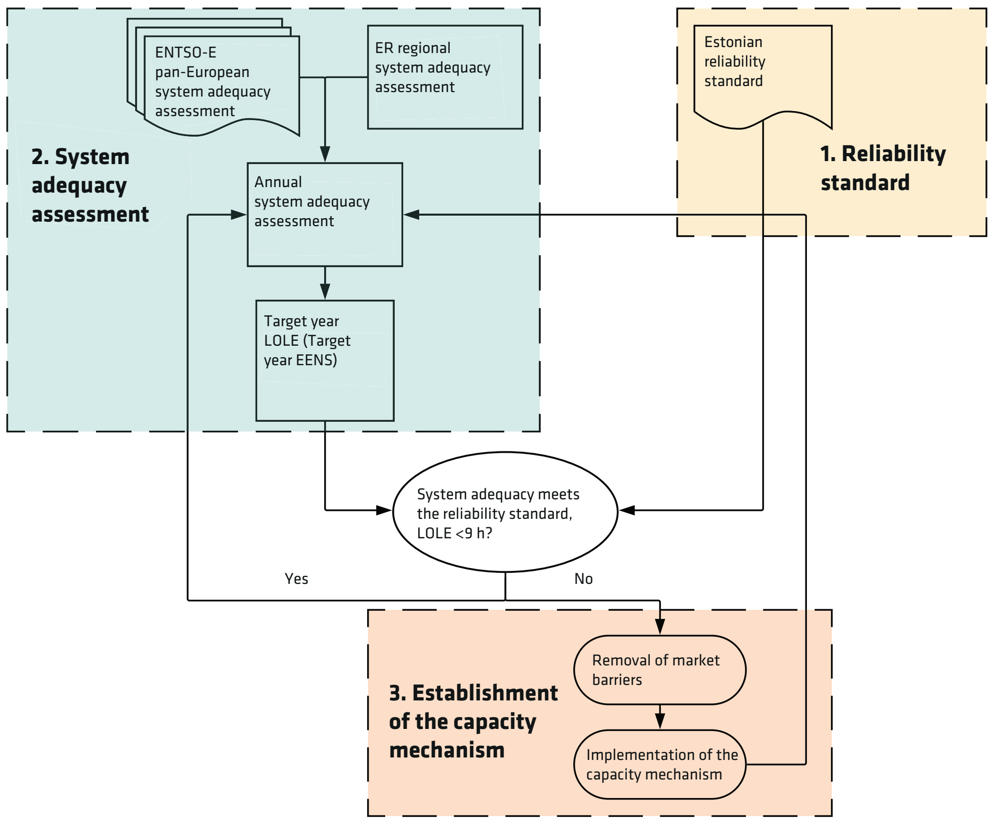
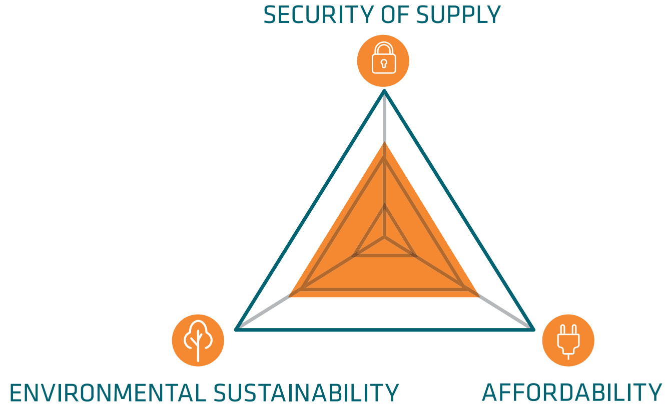


Figure 4.2 shows the different stages in which the system adequacy assessment is annually conducted. The reliability standard was established in spring 2021 and the implementation of the capacity mechanism takes place when the capacity no longer meets the standard.

The price of electricity is not analysed as part of the system adequacy. The affordability of energy is indisputably an element of energy policy. For example, the World Energy Council (WEC) describes energy policy as a trilemma (Figure 4.3). Security of supply, affordability and environmental sustainability are parts of this trilemma. The affordability of energy is not regarded as a component of security of supply but as a separate element of energy policy. The same approach is used in Estonian and European legislation, according to which Elering assesses security of supply. Methodologies for assessing security of supply and, more narrowly, system adequacy do not analyse the price of energy as a component. On the European single energy market, the price of energy is emerges in the conditions of a competitive free market. European rules prohibit countries from intervening in the electricity market (granting state aid) except in justified cases (proven security of supply problem) and where state aid is authorised. On a free market, however, it is important to make sure that there is fair competition, or in other words, that the behaviour of market participants is monitored by market operators and regulators (in Estonia, Nord Pool and the Estonian Competition Authority). In the context of a free market, the need to help the most vulnerable consumer groups in terms of the affordability of energy, for example through subsidies during periods of exceptionally high prices, is not excluded.

Figure 4.3
Energy Trilemma – World Energy Council (WEC)



4.2 ESTONIAN RELIABILITY STANDARD

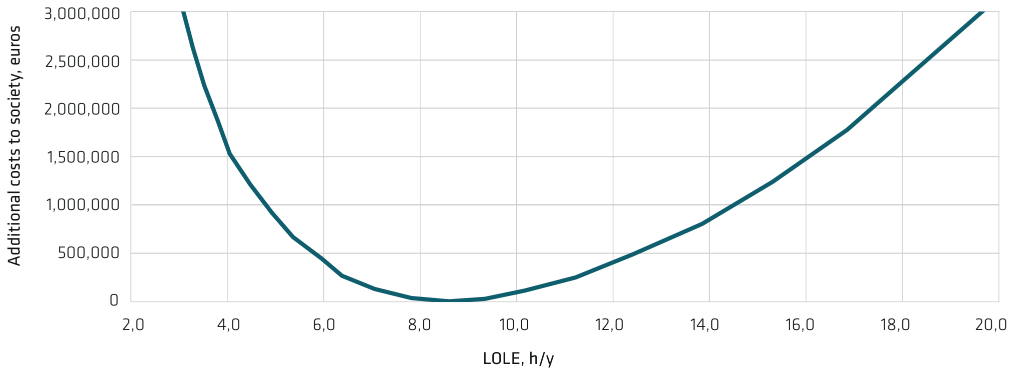
The European Internal Electricity Market Regulation requires all countries that want to apply for the implementation of a capacity mechanism in the event of a system adequacy problem to first establish a national reliability standard in line with the common European methodology approved by ACER. With the standard, each Member State determines the acceptable level of the adequacy of their electricity system, and the results of the analysis on the capacity of the electricity system are compared to it. If the conducted analysis indicates that the system adequacy situation is worse than permitted by the standard, the member state may apply for permission for state aid from the European Commission and establish, once granted permission, the capacity mechanism in the state. The capacity mechanism is essentially state aid to electricity producers or for demand side response in order to render them able to offer their capacity at the required moments.

Pursuant to the regulation, the reliability standard is expressed through two parameters: Loss of Load Expectation (LOLE) and Expected Energy not supplied (EENS). The parameters used for determining the reliability standard are the Value of Lost Load (VOLL), unit [EUR/MWh], and the balanced Cost of New Entry (CONE), unit [EUR/MW]. CONE is based on standard technologies, which are the most likely production capacities added on a market basis. Detailed explanations and values for the above parameters can be found in the study on reliability standard[40].

In Estonia, the optimum security of supply level for LOLE was established at nine hours per year on average. That means that it is less costly for society to allow there to be some hours where demand cannot be completely covered by the market than to build additional generation capacity for just those hours. Should these hours exceed more than nine, the damage to society is bigger than investments on new capacity, and therefore adding new capacity is socio-economically justified. Annual analyses and special scenarios of the system adequacy are assessed according to the aforementioned standard.

If there are deviations in the optimal nine hours, society will bear higher costs. Figure 4.4 shows to what extent annual costs will grow for society if the reliability standard were other than optimal. If more capacities were added in the desire to reduce LOLE to, say, three hours (the reliability standard in Poland, the UK and France), society would pay close to three million euros more per year in Estonian conditions.

Figure 4.4
Socioeconomic spending curve pursuant to LOLE level



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[40] https://elering.ee/sites/default/files/2021-10/Varustuskindluse standard_2.pdf

4.3 CONCEPT OF STRATEGIC RESERVE

In a situation where the reliability standard is not met, state aid measures may be implemented to ensure adequate capacities. Problems of system adequacy come up for Estonia if due to extraordinary events, a peak consumption period has coincided with low local output and multi-dimensional extraordinary events in the power grid. When analysing the Estonian system, the event with the biggest consequence is the unexpected outage of cross-border connections due to the high capacity of such elements. In this situation, it would be unable to import electricity from other electricity systems. The most suitable solution to this kind of potential problem, as shown by the study on the most suitable capacity mechanism design for Estonia,[41] is a strategic reserve.

A strategic reserve is a type of capacity mechanism where, on the pre-established conditions, the production capacity of electricity (or capacity for reducing consumption) is acquired for a limited period of time separate from the remainder of the electricity market. Due to the fact that the capacity is not participating in the electricity market, the strategic reserve does not affect the prices on the electricity market. When launching the strategic reserve, the price on the electricity market will remain the same as it would be without the strategic reserve. The strategic reserve will only be launched in extraordinary instances when there is an actual hazard in the electricity system that the market is unable to ensure the reserves required for consumption and the security of supply of the system. By its nature and by the qualification criteria, the strategic reserve is a mechanism targeted at a certain system adequacy issue that helps keep the costs required for managing the mechanism lower than a capacity mechanism that exceeds the market requirements.

The major fault in other types of capacity mechanisms is that they can also constantly participate in other electricity markets and the receipt of capacity mechanism payments distorts the normal market price and competition in the electricity market. Market disruptions created by a cross-market capacity mechanism may in turn disrupt the creation of new market-based production capacities and accelerate the closure of other capacities not receiving capacity mechanism payments, including in neighbouring countries.

A strategic reserve is seen by the European Commission as the measure that has the least impact on the unregulated electricity market and is thus most compatible with the requirements and rules, provided that a definite need exists for such a market intervention. Pursuant to the Regulation on the internal market for electricity of the European Parliament, member states must analyse whether the capacity mechanism, by means of being the strategic reserve, would resolve the issue of the system adequacy of the member state, and only if the strategic reserve is unable to do so is it possible to take into use alternative types of capacity mechanisms. In the case of Estonia, there are currently no grounds on which to consider that the creation of a strategic reserve would not be sufficient for resolving any potential problems in system adequacy.

In spring 2022, Elering conducted a public consultation[42] on the strategic reserve strategy, during which the vision of the rules governing the strategic reserve were introduced to market participants and feedback was elicited from them. By now, the concept of a strategic reserve has been submitted to the Ministry of Climate and the Competition Authority.

Table 4.1
Areas of responsibility in ensuring security of supply

Activity	Responsible party
1. Identification of the problem reliability standard	Elering
2. Notifying the European Commission of a possible capacity shortage	Ministry of Climate
3. Carrying out a national security of supply analysis, if necessary	Elering
4. Preparation of market failure analysis	Estonian Competition Authority
5. Issue of state aid clearance for capacity mechanism	European Commission

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[41] https://elering.ee/sites/default/files/public/To-A/Study on a Capacity Remuneration Mechanism for Estonia.pdf
[42] https://elering.ee/loppenud-konsultatsioonid?page=1%23tab2052

6. Proposal for concept of capacity mechanism	Ministry of Climate
7. Analysis of potential impact of capacity mechanism on neighbours and public consultation	Elering
8. Development of detailed plan of capacity mechanism and public consultation	Elering
9. Approval of detailed plan of capacity mechanism	Estonian Competition Authority
10. Possible amendments to legislation	Ministry of Climate
11. Pre-qualification of potential service providers	Elering
12. Carrying out public procurement and awarding contracts to successful tenderer(s)	Elering

4.4 SYSTEM ADEQUACY ASSESSMENT

Elering assesses the adequacy of the Estonian electricity system according to the diagram in Figure 4.2 and by applying different methodologies. The analysis can be divided into four parts:

1. In accordance with the European Internal Market Regulation, the European Resource Adequacy Assessment (ERAA) can be viewed as the first stage of the assessment of the system adequacy level, as it takes into account the trends, assumptions and economic viability required at European level.

2. The regional analysis complies with the rules of the National Resource Adequacy Assessment (NRAA) but analyses in more detail the specificities and sensitivities relevant for the Baltic states. The most important addition compared to the ERAA is the more detailed modelling of the Baltic system services market, which has a significant impact on the adequacy of the Estonian system. Due to the simplified modelling of the market for system services, the ERAA is inaccurate for the Baltics in certain circumstances. The NRAA uses the economic viability results of the ERAA as input and adds further detail. It is also used as a 'baseline scenario' in sensitivity analyses.

3. Sensitivity analysis – if ERAA and NRAA find the level of system adequacy against the assumptions made in different years, the sensitivity analysis will find the amount of capacity needed for Estonia in the more critical years to ensure the system adequacy at the nine hour limit of the LOLE.

    - If the baseline analysis shows that the situation does not meet the reliability standard, the sensitivity analysis will determine how big the shortage of dispatchable capacity is.

    - If the level of the system adequacy on the basis of an analysis of the baseline scenario is higher than the reliability standard, it is ascertained how much dispatchable capacity is the minimum quantity required to keep the system's capacity level within the scope of the standard.

4. Analysis of additional scenarios by the deterministic method because one of the presumptions for the foregoing parts was a functioning European electricity market, but potential black-swan events are not taken into account. Elering also analyses additional business continuity scenarios.

The main advantage of the probabilistic analysis (Chapters 4.4.2 and 4.4.3) is that it looks at a wide range of situations – consumption profiles are created that need to be covered by different power plant generation profiles and imports. Possible emergencies at both generation units and on transmission lines are thereby also taken into account. As major electricity systems such as Germany, Norway, Sweden, Poland have a significant impact on the Estonian electricity market, the minimum geographical view for probabilistic analyses is at least the Baltic Sea countries.

The deterministic analysis (Chapters 4.4.4 to 4.4.7) looks at a single forecast peak demand situation and assesses what capacity is available at that point and to what extent, essentially the 'most critical moment'. In such a peak demand situation, Finland, Latvia and Lithuania (3B+FI, i.e. the three Baltic States plus Finland) will have the greatest impact on the level of capacity of the Estonian system, as we are most closely linked to them.

The main parameters of this methodology are peak consumption, available production capacity and maximum import capacity. It is important to note that with the increasing share of renewable energy and the development of an electricity system based on flexibility, it is becoming increasingly difficult to get a realistic overview of the system's capacity by looking at just one peak hour per year. Notably, the hour with the highest consumption may not be the most critical for the system adequacy due to the unpredictability of renewable energy generation. The deterministic approach also requires making a lot of assumptions based on the past behaviour of market participants, but the operation of the electricity system in the future will be very different from that in the past and the decisions of market participants are difficult to predict. The growth of flexibility and storage means that planning for the 'most critical moment' becomes increasingly inaccurate.

4.4.1 Key assumptions in system adequacy assessments

This chapter outlines the key assumptions used in the system adequacy assessment for the Estonian (and Baltic) electricity system. Elering is conservative in its assumptions, which means that in the analyses we only consider the generation capacity that is most likely to be available in the year under analysis. Table 4.2 and Figure 4.5 explain the key assumptions in the assessments of Elering and ENTSO-E system adequacy.

Table 4.2
Key assumptions in security of supply analyses

Variable	Time	Description	Comment
Estlink 3	• In ERAA analysis 2033 • In NRAA and deterministic analyses 203	HVDC connection between Estonia and Finland 700 MW	At the time of collecting the input data for the ERAA analysis (spring 2023), the best knowledge was that the connection would be completed in 2033, which was later updated to 2035.
Harmony link	• In ERAA analysis 2030 • In NRAA analysis and deterministic analyses 2032	HVDC connection between Lithuania and Poland 700 MW	At the time of collect ing the input data for the ERAA analysis (spring 2023), the best knowledge was that the connection would be completed in 2030. The expected realisation was later updated to 2032.
Narva oil shale power plants		The baseline scenario was based on the manufacturer's forecast of the capacity available on the market in different years.	The profitability of the plants is checked as part of the ERAA economic viability analysis. Until the end of 2026, the capacities will be maintained according to the owner's expectation regardless of the outcome of the ERAA analysis.

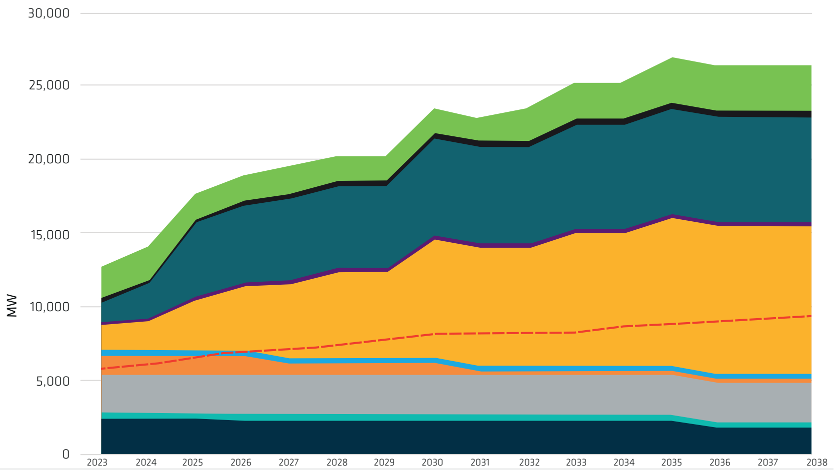
Wind energy developments		Conservative wind energy growth. The first offshore wind farm will be added in 2035.	Elering only takes into account the wind power generation capacities that, according to today's knowledge, are highly likely to materialise.
Pumo-hydro power plants	-	Not included in the analysis.	Two pump hydro plants are under development in Estonia. As there is no certainty as to when the plants will be completed, they have not been taken into account in the analysis.
Storage	-	Not included in the analysis.	Several battery plant projects are under development in Estonia. As there is no certainty as to when the batteries will be completed, they have not been taken into account in the analysis.
Estonia-Latvia 4th connection	• In ERAA analysis 2032 • In NRAA analysis and deterministic analyses 2035		At the time of collecting the input data for the ERAA analysis (spring 2023), the best knowledge was that the cable will come in 2032, which was later updated to 2035.

There are clearly emerging trends in electricity systems across Europe::

- Rapid growth in consumption (both total and peak)
- Rapid growth in renewable energy generation capacity
- Closure of fossil fuel power plants

The total generation capacities (including renewable), consumption forecast figures and trends for the Baltic states can be found in the figure below (Figure 4.5), which is the baseline scenario for the assessments. The quantity of capacities installed and resources used (including electricity from renewable sources) exceeds peak demand many times over and there should be no problem with annual electricity generation. As generation capacities based on renewable energy are not always definitely available and as will be shown in the following chapters, the Baltic system will need a large quantity of flexible generation capacities.

Figure 4.5 Capacities, flexibility resources and peak demand installed in the Baltic electricity system



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Baltic import capacity	2216	2216	1716	1716	1716	1716	1716	1716	1716	2416	2416	2416	3116	3116	3116	3116
Flexibility	260	277,5	295	350,5	332	350,5	369	387,5	400	412,5	425	437,5	450	450	450	450
Solar PV	1332	2385	4997	5220	5560	5560	5560	6570	6570	6570	7080	7080	7120	7120	7120	7120
Grid scale batteries	200	200	280	280	280	280	280	280	280	280	280	280	280	280	280	280
Wind	1726	1990	3400	4387	5037	5841	5841	8031	8031	8031	9051	9051	10051	10051	10051	10051
Waste, other	338	335	344	342	340	340	340	340	340	340	340	340	340	340	340	340
Oil shale	1330	1330	1330	1330	831	831	831	831	272	272	272	272	272	272	272	272
Water	2554	2554	2554	2664	2664	2664	2664	2664	2664	2664	2664	2664	2664	2664	2664	2664
Biomass	379	384	389	394	399	404	409	424	424	424	424	424	423	402	381	381
Gas	2498	2498	2498	2350	2350	2350	2350	2350	2350	2350	2350	2350	2350	1840	1840	1840
Peak consumption and demand for reserves in the Baltics	5917	6203	6681	7029	7222	7437	7849	8287	8331	8350	8350	8793	8972	9151	9330	9509

4.4.2. Analysis of the capacity of the Pan-European system

ENTSO-E in cooperation with Elering and the other European TSOs compiles a European Resource Adequacy Assessment every year. This time, the system adequacy assessment goes up to 2033 and the results include the indicators for system adequacy indicators for all European countries in the years 2025, 2028, 2030 and 2033.

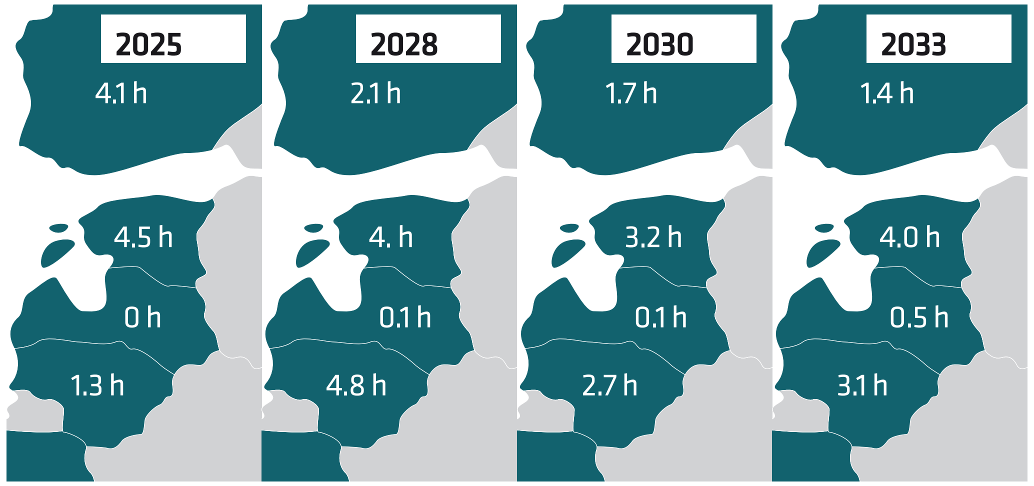
The analyses of the respective years are based on the data set out in the national energy and climate plans to be submitted by all EU countries, the best knowledge of the TSOs of the generation capacities existing in the respective year and connections between countries, consumption forecasts and historical climate data. According to ERAA methodology, the simulation model calculates which power plants are economically sustainable. You can see the methodology on the ENTSO-E website[43].

Europe has many power plants that in conditions of growing fuel prices and ambitious climate goals are no longer able to cover their fixed costs with revenue from the energy-only market. There are also countries that have underinvested in their electricity systems and the model finds capacities with the necessary properties for these regions – storage in the form of batteries, flexible consumption or gas power plants may turn out to be the optimal technologies. Elering uses the ENTSO-E ERAA results as a starting point for preparing the Estonian NRAA in order to gain an even better overview of the situation ahead.

ERAA's results are based on the system capability parameters LOLE and EENS. Figure 4.6 shows the result of number of hours of limited service where:

- Estonia's consumption figures are based on the assumptions described in Chapter 4.5;
- generation capacity development is shown in aggregated form in Figure 4.5, but in line with the ERAA methodology, in addition to the market actors and national climate targets, an Economic Viability Assessment (EVA) has been carried out and it is assumed that unprofitable plants have exited the market and investments in new resources have been added.

Figure 4.6 Average LOLE numbers in region in the ERAA 2023 analysis



The assumptions taken into account in the above figure (Figure 4.6) are that the following decisions have been made in the Baltic states and Finland in addition to the baseline scenario as a result of the economic viability assessment:

- 2025 – Estonia will reduce the capacity of oil shale units by 420 MW; Finland will convert 240 MW of coal capacity to a conserved state and invest in 120 MW of flexible consumption; Lithuania will reduce older gas-fired capacity by 90 MW.

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[43] https://www.entsoe.eu/outlooks/eraa/

- 2028 – according to the baseline scenario

- 2030 – according to the baseline scenario

- 2033 – Latvia will reduce gas-fired capacity by 270 MW, Finland will reduce gas-fired capacity by 960 MW and coal-fired capacity by 620 MW.

According to the ERAA results, Finland is the only country in the region that will not meet its reliability standard LOLE in 2025 and 2028, which is one of the lowest in Europe – the average LOLE per year is 2.1. As market-based measures will have solved the problem by 2030, a capacity mechanism would be needed in Finland to improve system adequacy, based on the current results. The security of supply levels in the other neighbouring countries in the region are within the limits of the standard and the ERAA resolution did not identify any further system adequacy issues. Similar to Estonia, TSOs in other countries can prepare an NRAA for their region to check the level of system adequacy also under region-specific, more detailed assumptions.

Last year's ERAA showed an average LOLE of 9.7 per year for Estonia in 2027, which exceeds the reliability standard. Assessments suggest that this result would occur in a situation where none of the Narva units are economically sustainable. Compared to last year's ERAA, there are some changes in both the input data and the survey methodology that specify these trends this year. As described in Table 4.2, one major variable has been the year of completion of the Poland-Lithuania interconnection Harmony Link. At the time the ERAA2022 was prepared, the best knowledge was that it would be completed by 2026 and would better connect the Baltic electricity system with Central Europe. A better connection with external markets brought down the prices in the Estonian price area in the 2022 ERAA and, in conclusion, the Narva units would not be competitive on the market. According to the assumptions in ERAA2023, Harmony Link will be added in 2030, which means that until then, the Baltic region will be less connected to its neighbours and prices in the region will be higher as a result. In such a situation, the Narva plants are more likely to remain competitive and to be able to keep system adequacy below the reliability standard. The high sensitivity of Estonia's electricity supply to both project realisation as well as small changes in the methodology for assessing system adequacy confirms that attention to detail is essential and that delays in any project can have a major impact.

4.4.3 Estonian National Resource Adequacy Assessment

The Estonian National Resource Adequacy Assessment (NRAA) uses the same methodology as the ERAA described in the previous chapter, but more detailed modelling has been carried out for the Baltic states. The NRAA simulation uses the ERAA economic viability assessment as input, but the model differs due to the following changes:

- More detailed modelling of the need for frequency reserves – according to the Baltic LFC block concept document. FCR, aFRR and mFRR (up and down) requirements added for each country (a total of 15 requirements for maintaining reserves) and the possibility to offer reserve capacities across the Baltics.

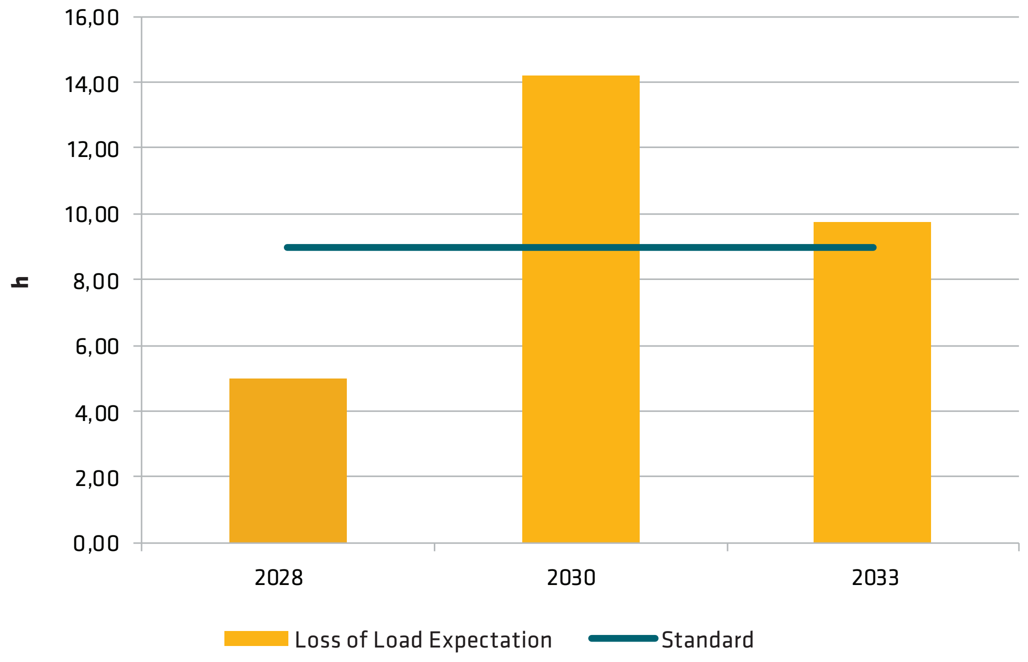
- Reduced geographical scope – ERAA takes a look at all European countries and neighbouring third countries with a more significant impact. As the calculation of such models is very time-consuming and resource-intensive, the NRAA only assesses the region that has the most significant impact on Estonia. The countries by the Baltic Sea have been modelled in the assessment, namely Estonia, Latvia, Lithuania, Poland, Germany (with offshore market zones), Denmark (with offshore market zones), Norway, Sweden and Finland.
    - ► It is important to note that in the market model, the countries connected to Germany, Denmark, Poland and Norway are modelled according to the results of the ERAA simulations. In the model, the contribution of non-modelled neighbouring countries to the system's capacity has been replaced by the calculated maximum flows generated from previous simulations that can be imported from these countries to prevent a shortfall.

- The production capacities of market participants related to the modelling of reserve markets have been specified. The Lithuanian gas power plants (Lithuanian power plant units 7 and 8 – 510 MW) have been taken into account in the assessment.

- The schedules for high-impact projects were updated, as they became available after the collection of input data for the ERAA (see Table 4.2). The most significant changes compared to assessments from previous years:
    - ► Postponement of the completion of the Lithuania-Poland Harmony Link from 2027 to 2032.
    - ► Completion of Estlink 3 and the Estonia-Latvia 4 hybrid interconnector (with a 1 GW offshore wind farm) in 2035.

When comparing the system adequacy parameters for Estonia between Figure 4.6 and Figure 4.7, it can be seen that a more detailed implementation of reserve markets according to the conditions of the Baltic LFC block and the postponement of Harmony link create significantly more LOLE in Estonia even in the baseline scenario. As a result of the regional simulations, the LOLE numbers in Estonia will almost double in 2028 from 2.6 to 5 hours, and in 2030 the LOLE numbers will increase from 1.9 to 14.2 hours, also exceeding the reliability standard. In 2033, the LOLE numbers will increase from 0.9 to 9.8 hours, exceeding the reliability standard. A significant difference between the ERAA and NRAA stems from the changing schedules of major projects, with any change having a negative impact on system adequacy. There is enough time until 2033 for market players to respond adequately and find the best solution to compete in an energy market with a high share of renewable energy.

Figure 4.7 Average LOLE numbers in the baseline scenario of the Estonian system adequacy assessment



4.4.3.1 Sensitivity analysis

Additional sensitivity analyses were carried out to find the amount of dispatchable capacity needed in Estonia to ensure the reliability standard. No sensitivity analysis was carried out until the end of 2026, as the owner's expectations for Eesti Energia are that until the end of 2026, Estonia's domestic dispatchable generation capacity of at least 1,000 MW will be ensured, regardless of the water level in the Narva River and reservoir, except during the period needed for routine maintenance and repairs or emergency repairs. At the same time, capacities of at least 900 MW will be stored in the cold reserve from 1 November to 28 February and at least 600 MW from 1 March to 31 October[44].

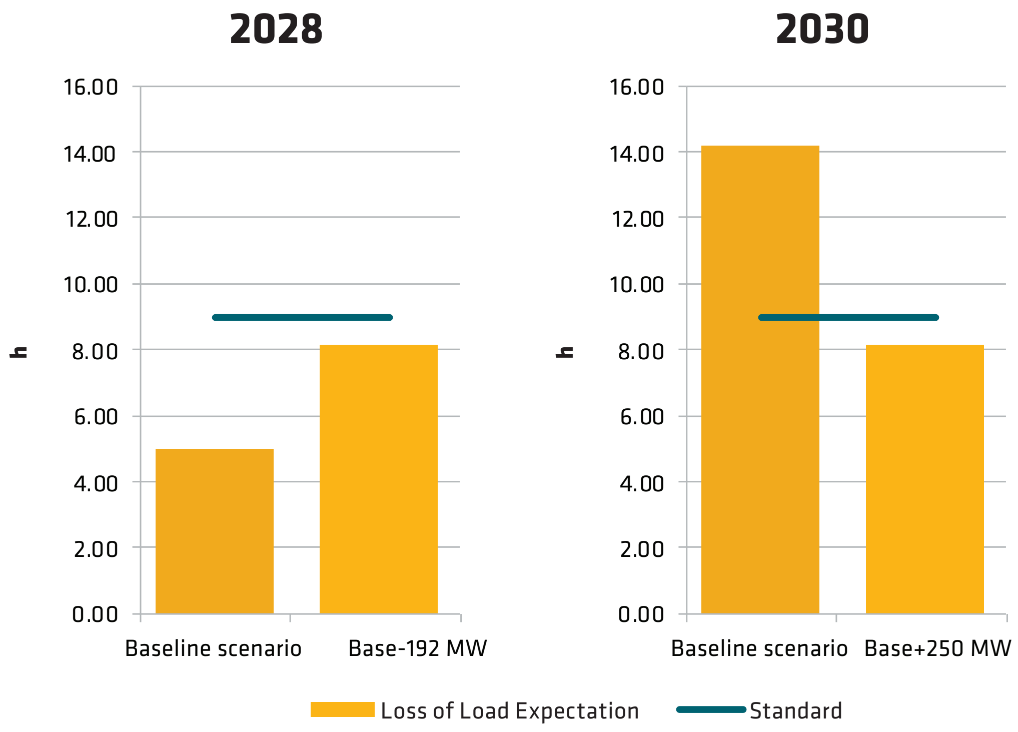
While Figure 4.7 assumed in the baseline scenario for 2028 that there would be 1,100 MW of dispatchable capacity on the market, some of which would be cogeneration plants, the sensitivity analysis in Figure 4.8 showed 930 MW of dispatchable capacity on the market and the LOLE numbers came close to the standard. Based on this, it can be concluded that some 1,000 MW of dispatchable capacity would

[44] https://www.fin.ee/uudised/rahandusministeerium-uuendas-omanikuootusi-eesti-energiale

be required in 2028 to ensure security of supply.

In particular, due to the postponement of the Lithuania-Poland interconnection (Harmony Link), the 2030 system adequacy does not meet the reliability standard. By adding 250 MW of generation capacity to Estonia (corresponds to the capacity of the Kiisa Emergency Reserve Power Plant, which is not included in the analysis in the baseline scenario), the system adequacy complies with the reliability standard. Based on this, it can be concluded that in 2030, Estonia would need about 800 MW of oil shale units and 250 MW of additional generation capacity in addition to the existing smaller power plants to ensure security of supply.

Figure 4.8
Average LOLE numbers of Estonia with sensitivity analysis



According to ERAA and NRAA, Estonia will need to maintain around 1,000 MW of dispatchable capacity to ensure security of supply in 2028. As the owner's expectation for the Narva oil shale power plants expires at the end of 2026, the risk concerning capacity adequacy arises in 2027. Therefore, it is important to be ready to implement the strategic reserve in Estonia as early as in 2027. From 2030 onwards, additional dispatchable generation capacity will be needed in the region to replace old capacities exiting the market and to provide fast reserves in the context of growing renewable energy generation. At this point, it is worth recalling that these simulations were carried out with conservative renewable energy growth; if Estonia is able to meet the goals of Estonian Renewable Energy 100%, then it would have a positive effect on system adequacy.

4.4.4 Deterministic analysis of the system adequacy of the region

The deterministic analysis methodology visually compares the expected available generation and transmission capacities in the countries under study with the projected peak electricity demand and the required amount of reserves. The advantages of this methodology are its simplicity and annual resolution.

The analysis anticipates the functioning of a single electricity market as a whole. As of the start of 2025, the analysis takes into account the synchronisation of the Baltic countries with the Central European electricity system. The expectations of production capacities are based on the data presented by the electricity producers and the assessment of the system operator, taking into consideration the

climate policy objectives and developments in the field of renewable energy.

More detailed presumptions:

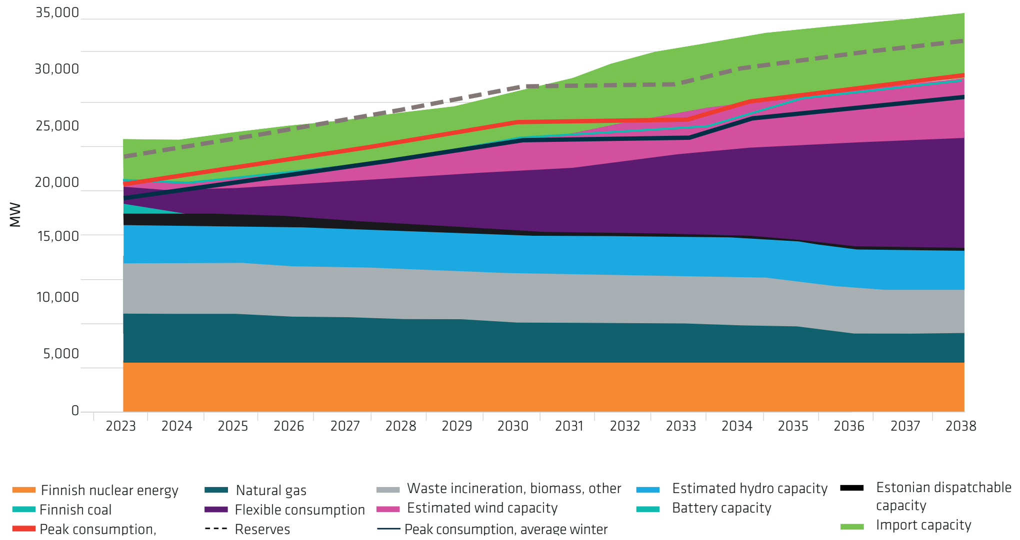
- The generation capacity for wind used during peak loads in Baltics and Finland up to 2027 is 7% of installed capacity and starting from 2027 it will be 8%. According to estimates, this is firm generation from wind farms and is available at all times. The growth stems from the fact that the wider the area in which generation capacities are deployed, the greater the probability that if the wind is blowing somewhere; in addition, new added capacities are more efficient.
- Solar energy has not been factored in for covering peak hours.
- Pursuant to the new owner's expectations, Estonian oil shale capacities will be at least 1000 MW until the end of 2026 and thereafter according to the forecast submitted by the manufacturer.
- Flexible consumers are capable of reducing their consumption during peak hours. Flexible consumption volume has been estimated based on price sensitivity of consumption during the periods with high prices in 2021 and 2022. In the following graph, it has been added as a generation unit to better convey the size visually, but in reality it would actually decrease peak consumption by increasing flexible consumption.
- Synchronisation has taken place according to the updated plan in early 2025.
- The Harmony link is delayed and is expected to be completed in 2032. No trade takes place on the Lithuanian and Poland AC connection from 2025-2032; the line is set aside for reserves.
- 'Other' capacities comprise the production capacities of smaller electricity generators. (For example, biomass, waste incineration and fuel oil plants.)
- Hydro power plants generally do not generate during peak hours at their maximum installed capacity and therefore 50%, 24% and 77% were used as the installed capacity for Lithuanian, Latvian and Finnish hydro power plants.
- Batteries are estimated to contribute 25% of their capacity. Storage will most likely participate in the reserve market, and based on Elering's analysis, this is a realistic quantity in which market participants would offer reserves.

In the figure below (Figure 4.9), it can be seen that the Baltic and Finnish regions are heavily dependent on import capacity throughout the period to cover peak consumption with their own reserves. Without international connections with Sweden, Poland and Norway, the peak consumption of Finland and the Baltics would not be covered. The most critical period for the region will be 2027-2030, when the shortfall at the peak moment will be up to 465 MW (in 2029). The most important variables within this range would be:

- at the end of 2027, the possibility to offer upregulation reserves with the Kiisa emergency power plant will end, which will reduce the available resources by 250 MW;
- the Lithuania-Poland transmission line Harmony Link, which was previously due to be completed in 2026, has been delayed. This 700 MW of import would have been sufficient to cover the deficit;
- at the end of 2026, the owner's expectation that Eesti Energia will keep the Narva oil shale units, which are important for Estonia, will end, which could lead to their closure;
- consumption and the quantity of reserves held will grow faster than the amount of new firm capacities;
- In 2031, the situation will be alleviated by the addition of the new Finland-Sweden transmission line Aurora line 2.

In the figure, the generation capacities of the hydro power plants are shown as lined areas, as in the actual peak hour the contribution may be significantly higher depending on the situation, but the more conservative assumption mentioned earlier is used here. Finnish consumption potential is also lined to draw attention to the fact that the electricity system will become much more flexible in future. The natural resource consumption decrease depends on the price of electricity formed during peak hour, the weather patterns and the length of the high demand period, but the entirety of the resources will have likely been implemented before the TSOs impose constraints on consumption.

Figure 4.9 Generation capacities used in the Baltics and Finland 2023-2038

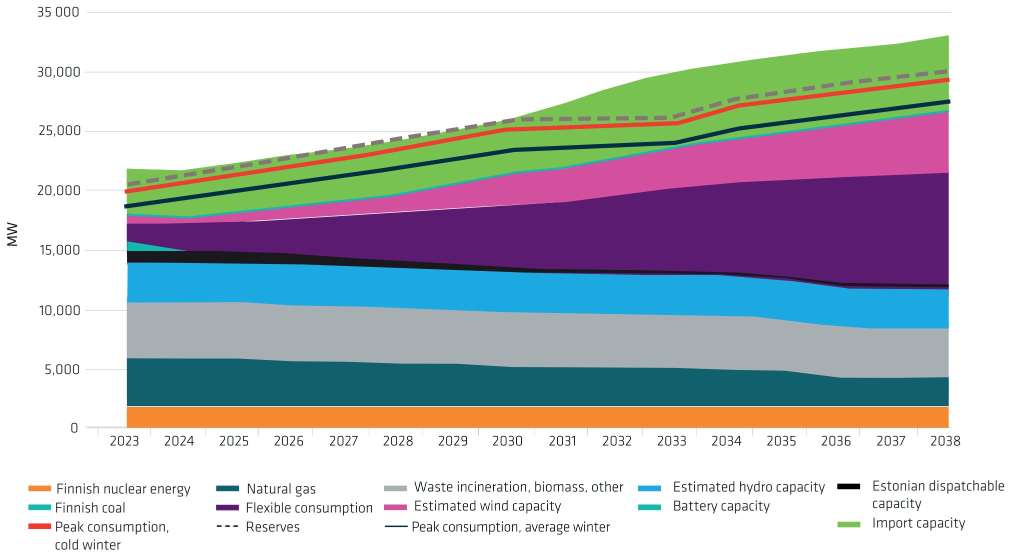


When assessing security of supply, Elering takes into account the different possible outages in the system. Figure 4.10 presents a deterministic analysis of a situation where the first and second element in the Baltic and Finland region are not available, i.e. an N-2 situation has occurred.

Compared to the situation presented in Figure 4.9, the following additional assumptions are taken into account for N-2:

- The largest elements whose loss is taken into account are the Olkiluoto-3 (1,600 MW) and Olkiluoto 2 (890 MW) nuclear power plants in Finland.
- Should the capacity of Olkiluoto 3 be unavailable, the constraint on the Sweden-Finland border will disappear and import capacity will increase by 300 MW. Consumption will also decrease by 300 MW, which was previously agreed with Finnish consumers.
- Finland uses the reserves held in gas stations to balance the system, which are triggered in an N-2 situation, and therefore the demand for reserves in the 3B+FI region has decreased. As both N-2 emergencies will occur in Finland and the Baltic states still need to keep reserves to cover the emergencies, the amount of reserves held in the Baltic States will not change

Figure 4.10 Generation capacities used in the Baltics and Finland 2023-2038 in situation N-2



In an N-2 situation, the peak shortfall is identified only in 2029 against the four previous years. The improvement of the situation is the result of an agreement with Finnish consumers that consumption will be reduced by 300 MW in the case of such an emergency and that Finland will no longer keep reserves.

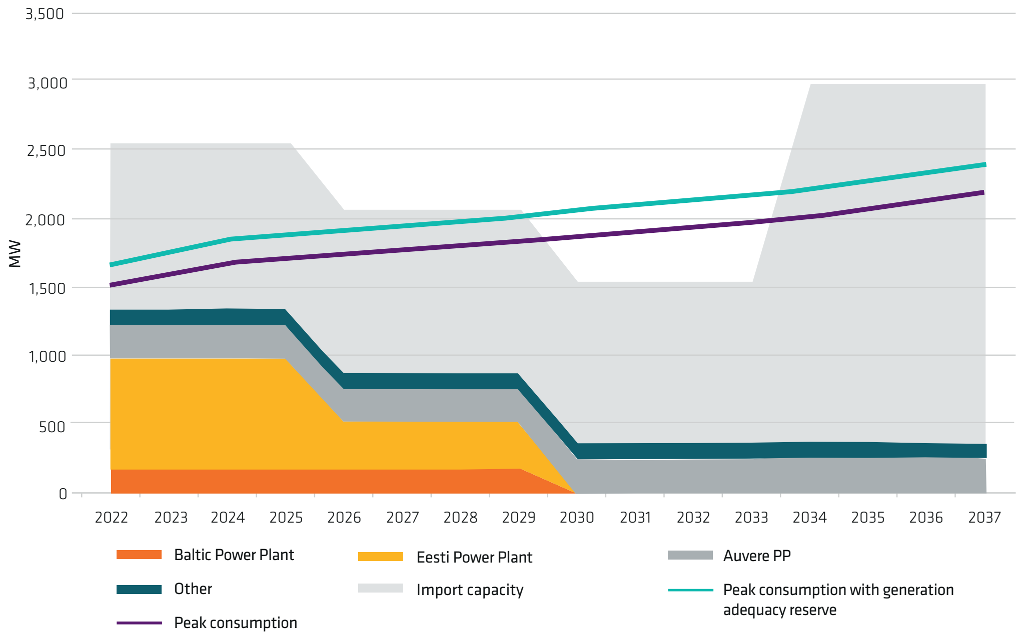
As a summary of the region's deterministic analysis, the region needs investments into either generation units or technologies that shift consumption, such as flexible consumers and batteries, in order to reduce its dependence on imports. Investments into wind and solar capacities will make an important contribution to cover peak consumption, but in terms of their variable generation cycle , this is lower than the contribution made by dispatchable generation. From the standpoint of planning the capacity of the electricity system, more weather-independent solutions like thermal power plants, storage capacity or consumption management would be required.

4.4.5 Deterministic analysis of the system adequacy of Estonia

The system adequacy situation of Estonian in winter from 2023-2038 (Figure 4.11) shows that Estonia will need electricity imports from neighbouring countries to meet peak demand each year. According to consumption forecasts, the winter peak consumption 15 years from now will increase to 2,187 MW, which is around 30% higher than the peak forecasted for 2023, 1,514 MW. Along with a reserve of 10% of generation adequacy, the peak consumption in 2038 would be 2,406 MW. According to the data provided by electricity generators and the forecasts of Elering, the installed market-based dispatchable generation capacity will amount to ca 873 MW in 2030 and ca 346 MW in 2038, plus the Kiisa emergency reserve power plant and possible strategic reserve.

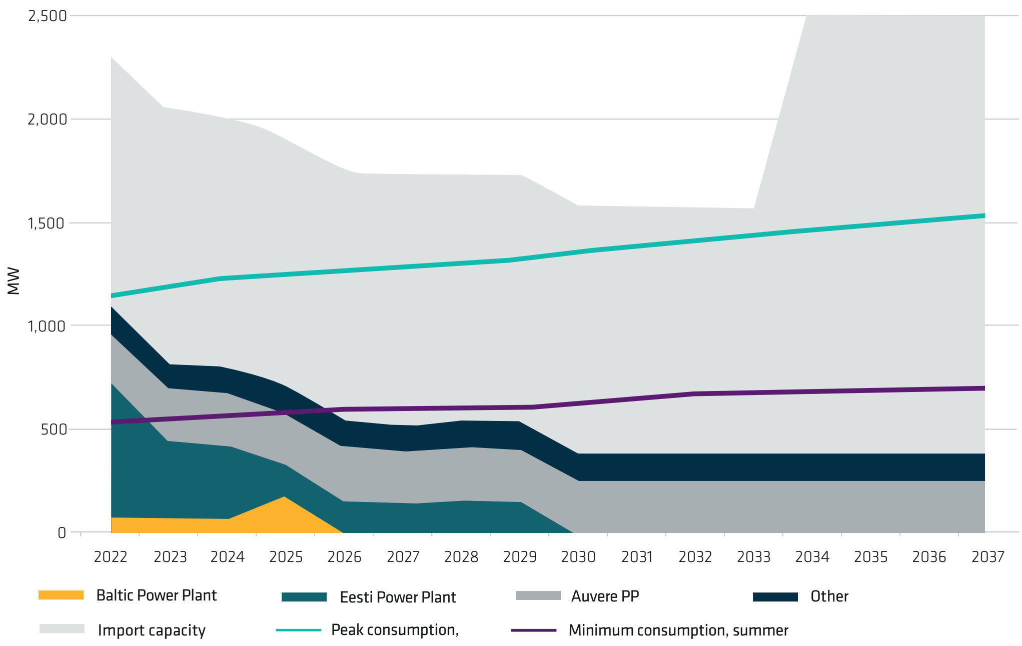
There will be an N-2 situation in Estonia until 2035, with Estlink 2 and one of the three Estonia-Latvia transmission lines down. After 2035, Estlink 2 and Estlink 3 will be in an N-2 situation. When the synchronisation with the Continental European frequency area takes place in early 2025, Estonia will have 1,200 MW of interconnections in an N-2 situation, and with the realisation of the new international connections – Estonia-Latvia 4 and Estlink 3 – Estonia's import capacity will increase to 2,616 MW.

Figure 4.11 Available generation capacity, import capacity and forecast of peak demand in winter



According to current forecasts, summer peak consumption by 2038 will be up to 1,543 MW (Figure 4.12). The available generation capacity corresponding to Section 14 of the Grid Code on the functioning of the electricity system will amount to around 589 MW in summer 2030 and around 389 MW in 2038. The usable production capacity is lower in the summer than the winter due to the maintenance of power plants and the lack of the heating load required for the operation of some cogeneration plants. According to the summer generation capacity adequacy assessment shown on figure, Estonia will have enough local generation capacities and import capability to cover summer peak consumption. In addition to the resources in the graph, solar and wind capacities have not been taken into account here.

Figure 4.12
Available generation capacity, import capacity and forecast of peak demand in summer



4.4.6 Assessment of system adequacy in the coming winter

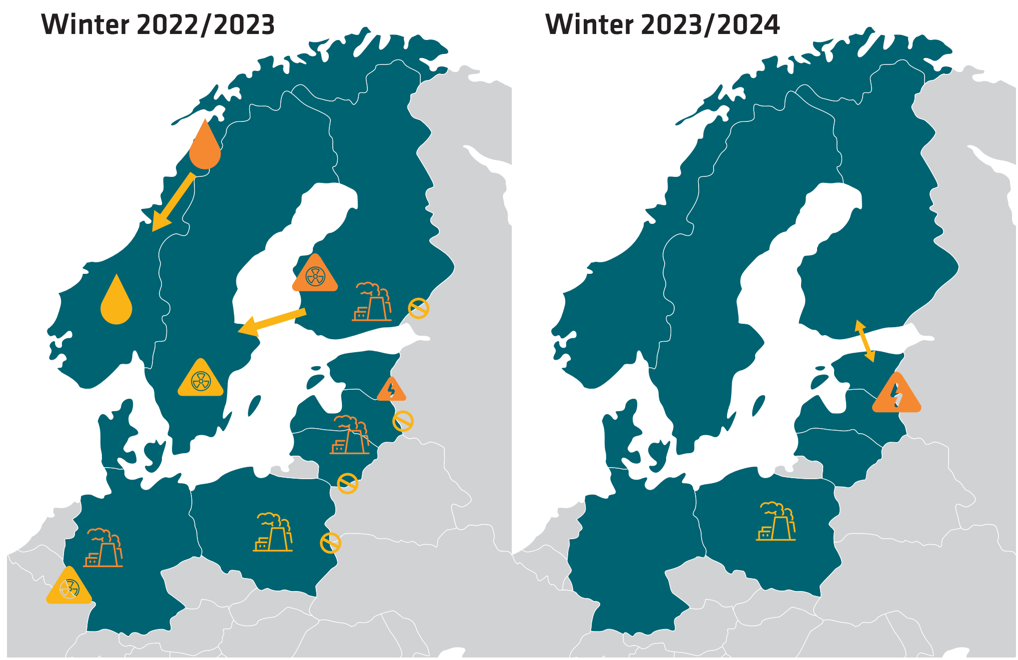
The state of systemic adequacy before last winter (2022/2023) was the tightest in recent history in the Baltic Sea region, as a number of high-impact risks were mapped in a short period of time (lighter in Figure 4.13) and a number of high-impact events had already materialised (darker). Fortunately, the winter of 2022/2023 was warmer than usual and high gas and electricity prices made consumers take a critical look at their consumption patterns (consumption control), which reduced the stress on the electricity system. This autumn, the outlook for the coming winter (2023/2024) is better.

Table 4.3
Security of supply risks last winter compared to this winter (see Figure 4.13)

	Winter 2022/2023	Winter 2023/2024
☢	Both the Swedish and the French nuclear power plants were under maintenance at the same time. Regular generation at Finland's Olkiluoto 3 nuclear power plant was repeatedly postponed.	The availability of nuclear power plants is good and long-term maintenance of French plants has been carried out.
💧	Norway's hydro reservoirs were very low throughout the summer, only starting to fill in autumn.	The level of hydro reservoirs in Nordic countries is at the median level of the last 20 years (Figure 4.14). According to the latest data, Nordic countries have 13.4 TWh more energy in their hydro reservoirs.
🏭	The uneven resource distribution created bottlenecks in the network and large price differences between neighbouring price zones.	
←	Gas, coal and lignite supply chains were hampered or available reserves were low in several countries at once.	In Poland, coal and lignite levels remain low but better than last year.
		At the time of writing, gas reservoirs across Europe are 98% full, with the Latvian reservoir at 96% full[45].
🚫		The BalticConnector accident has disrupted gas supplies between Finland and the Baltic states.
↔	Suddenly, the need to restrict energy imports from Russia emerged, and it was difficult to find alternative sources of supply in a short time.	Everyone has adapted to the new situation.
⚡	Extraordinary synchronisation from the IPS/UPS power system would have entailed high risks, as the necessary actions for safe operation had not been finished.	Great efforts have been made to ensure that the extraordinary synchronisation with the continental European frequency area does not jeopardise power supply, activities are still ongoing but preparedness is higher than last year.

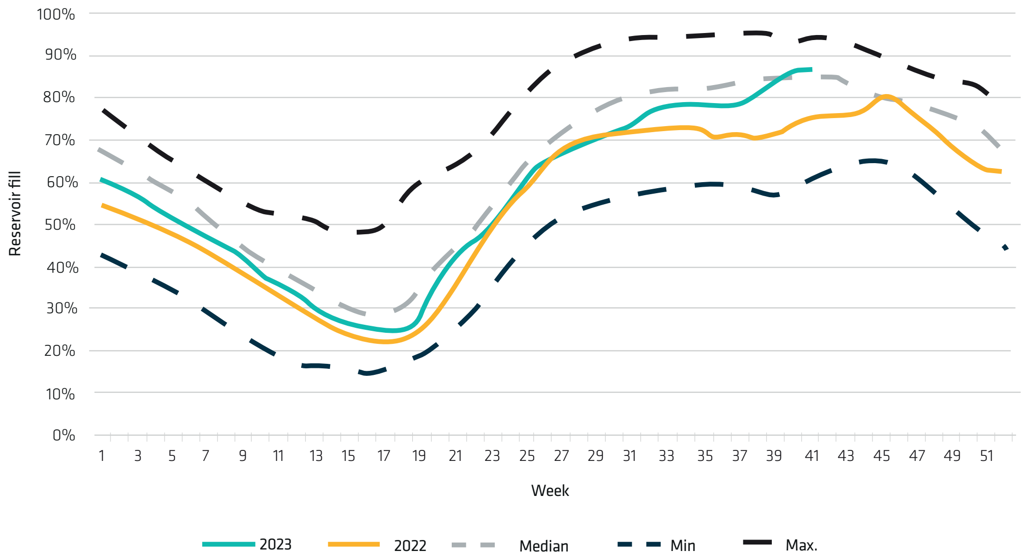
[45] https://agsi.gie.eu/%23/

Figure 4.13
Mapping of winter risks in autumn 2022 and 2023. Darker red have already materialised, lighter is a mapped risk



In the Nordic countries, hydro reservoirs have the highest electricity generation capacity in the last 23 years with 121 TWh. This level was reached in January 2012. At the time of writing, the level of reserves was 86% (Figure 4.14), or 109 TWh. In an average winter (October-April), electricity consumption in the Nordic countries (Norway, Sweden, Finland) is 218 TWh.

Figure 4.14
Reservoir fill in Norway, Sweden, Finland 2001-2023



Similar to the long-term system adequacy assessment, a probabilistic analysis for the upcoming winter – Winter Outlook 2023/2024 – will be carried out throughout Europe. At the time of writing, only preliminary results are available and they may still be specified, but there was no energy not served (EENS) in Estonia or neighbouring countries. This also confirms the qualitative assessment that risks are lower and that no problems are foreseen at the moment.

4.4.7 Extraordinary scenarios

One of the assumptions of the previous system adequacy assessment was a normal functioning European electricity market, which does not describe potential low probability events such as intentional or unintentional damage to physical infrastructure or market failures that could cause long term disturbances in the operation of the electricity system. For those reasons, Elering has also analysed additional continuity scenarios. When analysing these scenarios, we use the deterministic method.

4.4.7.1 Baltic island mode scenario

In situations where the Baltic states' electricity system will no longer have AC connections to a larger synchronised area, they will need to operate in 'island mode'. Such a situation might arise if the AC connection to the Russian electricity system is lost or after synchronisation with the continental European synchronous area.

Pursuant to the extraordinary synchronisation plan, when the Baltic states desynchronise from the Russian frequency areas, the synchronisation of the Baltic states with Continental Europe will happen within a matter of hours. Thus, it is not likely that the Baltic states will have to operate in island mode.

Island mode can last longer if there is a desynchronisation from the Continental Europe frequency area. It could be triggered above all by a outage in the Lithuania-Poland connection. In such a situation, there must be readiness to operate in island mode until the outage is eliminated.

Prerequisites:

- The Baltic states must be prepared for an islanded Baltic synchronous area scenario at every moment in time.
    - ▸ A separation of the Baltic states from the Russian frequency area during a period when the Baltic states are still part of that area. If that should happen, they will be capable of synchronising with the Continental European frequency area, the actions for this purpose having been agreed beforehand.
    - ▸ During a period when the Baltic states are part of the Continental European frequency area, the Lithuania-Poland AC connection is cut off and the Baltic states must get by on their own until the AC connection is restored. This situation may last longer until such time as the cause of the disconnection is resolved.
- Being in the Continental European synchronous area until 2032, the transmission capacity on the Lithuania-Poland border is 0 MW, with only frequency reserves being exchanged through that connection. When the Harmony link is completed, trading will start taking place there and the existing Litpol link will be reserved for products needed for synchronous operation.
- Direct current connections to the Nordic countries and Poland are available, but at a reduced volume, taking into account the maximum element limit of 400 MW. The greatest generation capacities are likewise limited to 400 MW.
- An N-1 situation means the switch-off of one more direct current cable.
- In such a situation, the Baltic countries depend on fast frequency reserves on direct currency connections with neighbouring systems.

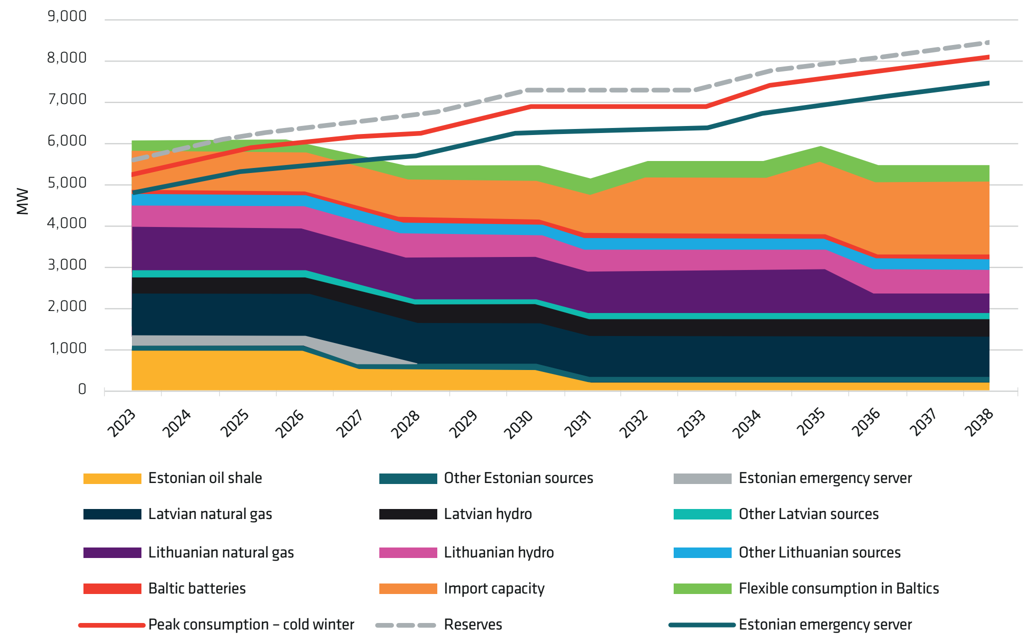


Figure 4.15
Baltic island mode scenario

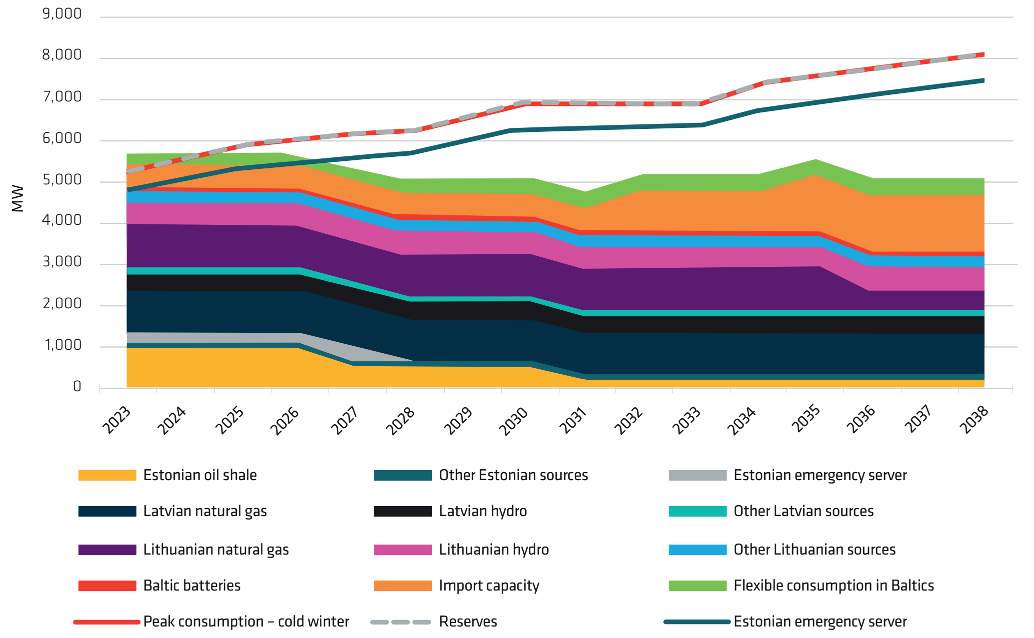


Figure 4.16
Baltic island mode N-1 scenario

The analysis of the island mode scenario of the Baltic synchronous area given on figures 4.15 and 4.16 shows that with known dispatchable generation capacities and transmission capacities, the Baltic system adequacy level would only be covered until late 2024. After that, there would be a shortfall in the reserve coverage during the peak consumption hour in 2026. After 2026, it will not be possible to fully cover either the peak consumption or the reserve needs. It is important to note that neither wind nor solar farms, which are the main new generation capacity currently being invested in, have been taken into account in this graph. It is important to keep in mind that wind and solar have a positive effect on covering peak hours in winter, but as the geographical area is quite limited, peak consumption and a period of no wind can occur at the same time. As the annual peak consumption in winter usually takes place either in the morning or evening, it is also the dark time and solar parks do not generate electricity.

Elering, together with the other Baltic TSOs, is increasing the readiness to operate in island mode that will be created by investments in the synchronisation project. The impact of the risk of ending up in island mode on the stability of our electricity system will be reduced by gradual investments, but the best mitigation of the risks of islanding would be investment in dispatchable generation capacities or storage that would allow the use of solar and wind resources.

4.4.7.2 Extraordinary synchronisation with the Continental European frequency area

The Baltic region will be connected to the IPS/UPS, or the Russian power grid until February 2025, when the last connection between Estonia and Latvia will be completed and synchronisation with the Continental European frequency area will take place. For more details on synchronisation, see Chapter 2.2. Given current events in Ukraine, as well as deliberately caused or unintentional accidents against various critical infrastructure objects, a situation could arise where the Baltic region is disconnected from the Russian power grid before all the necessary preconditions are met.

Figure 4.17
Capacity balances in case of planned and emergency synchronisation

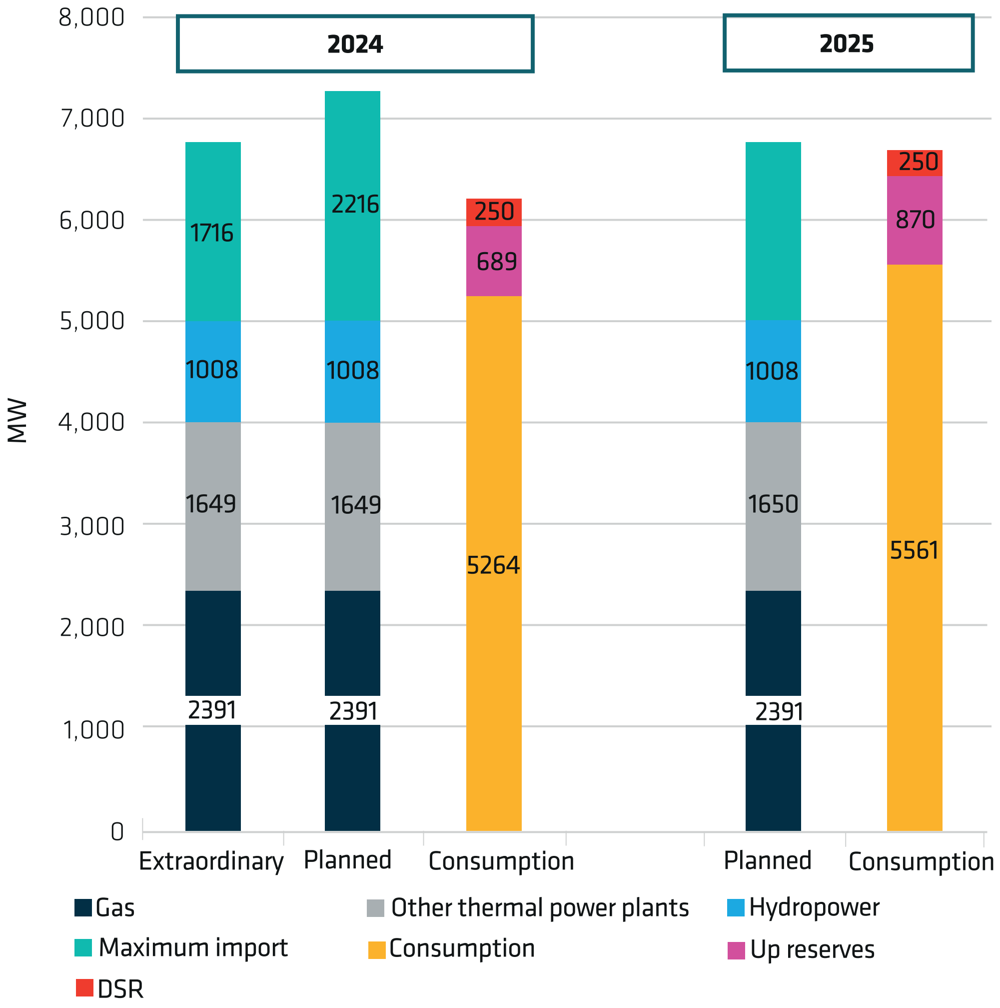


Figure 4.17 describes the situation where, in the event of emergency synchronisation, the Baltic region is switched to the Continental European frequency area for a few hours and the Lithuania-Poland transmission line is used only for system services. In 2024, the capacity of the transmission lines between Estonia and Latvia would also decrease, as the Estonia-Russia transmission line currently allows more trading volume to be delivered on the Estonia-Latvia line. If emergency synchronisation were to take place and the Estonia-Russia lines were to be disconnected, trade on the Estonia-Latvia line would have to be restricted to ensure the safe operation of the system.

After synchronisation, the demand for the reserves to be procured will increase significantly and the capacity balance between supply and demand will become more critical. The TSOs also expect overall electricity consumption to grow rapidly in the coming years, thanks to various trends described in more detail in Chapter 4.5. The growth in consumption and the need for reserves is faster than the growth in additional capacities and, similar to the analysis of the other scenarios in the preceding chapters, Figure 4.17 also shows that the level of system adequacy will deteriorate.

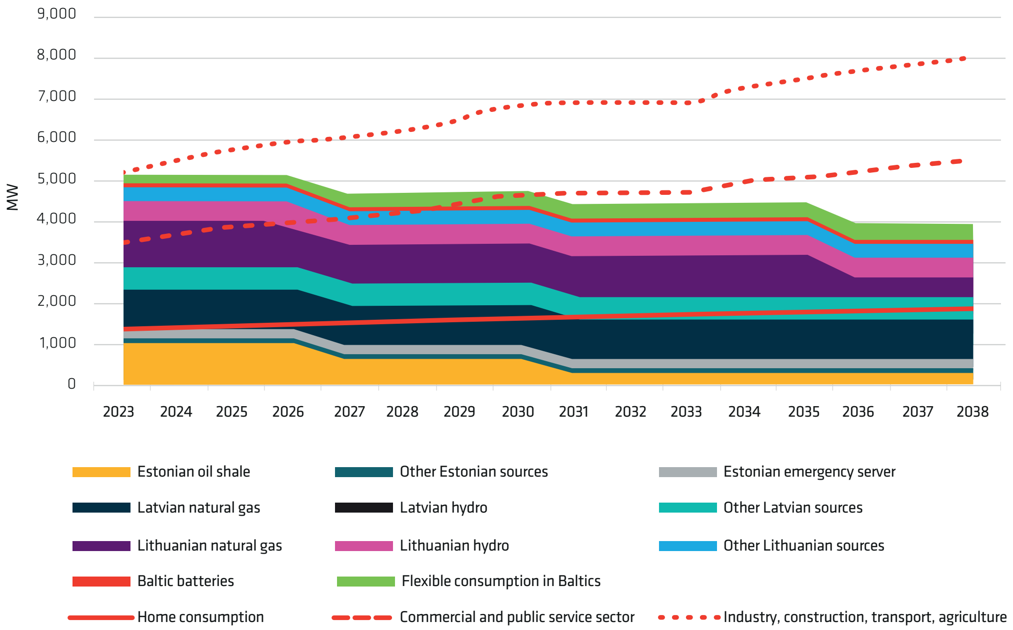
4.4.7.3 Baltic emergency continuity scenario

A more severe situation than the Baltic island mode scenario is the Baltic emergency scenario, where in addition to island mode, there are no DC connections to neighbouring systems. The probability of such a scenario being realised is low and would probably take a coordinated attack against energy infrastructure.

Prerequisites for preparing the analysis:

- The Baltic States are in island mode in respect to the European energy system and make up a separate Baltic synchronous area in island mode.
- There are no connections with other regions.
- The estimated duration of the scenario is two months, during which time it would potentially be possible to restore at least one direct current connection.
- The consumption data of the sectors have been found from the databases of statistical offices of the Baltic countries, through which the share of the sector in the total end consumption has been found and it has been estimated that the share of the sector will also remain the same during peak consumption.

Figure 4.18
Baltic emergency continuity scenario



In this scenario, where none of the DC connections of the Baltic states are available, dispatchable generation capacities are out of service, wind and solar output is zero and the forecasted consumption load is growing, it will not be possible to cover all consumption with generation capacities at every moment in time (Figure 4.18). Analysis shows that in the absence of DC connections, the Baltic electricity system would be adequate for ensuring households, business and public services with a supply of electricity, while other sectors would have to be limited during peak load times: Due to the increasing electricity consumption, the electricity supply of the industrial sector should be more and more limited if this scenario is realised. In such a scenario, it should also be taken into account that the quality of the electricity supply would be significantly disturbed. Without transmission capacities, it is currently not possible for the Baltic states to simultaneously ensure that consumption is covered and sufficiently fast frequency reserves, due to which outages may result in additional automatic cut-off of consumption. More information about the frequency reserve capacity in the Baltic states is available in Chapter 2.2. The respective capacities are obtained within the framework of the synchronisation project.

It should be emphasised that this scenario has a low chance of occurring. It would be an extreme case if many low-probability events coincided: an interruption in operating in synchronisation with the IPS/UPS or continental Europe frequency area and the interruption of at least four DC connections at the same time as well as sufficiently high consumption in the winter period.

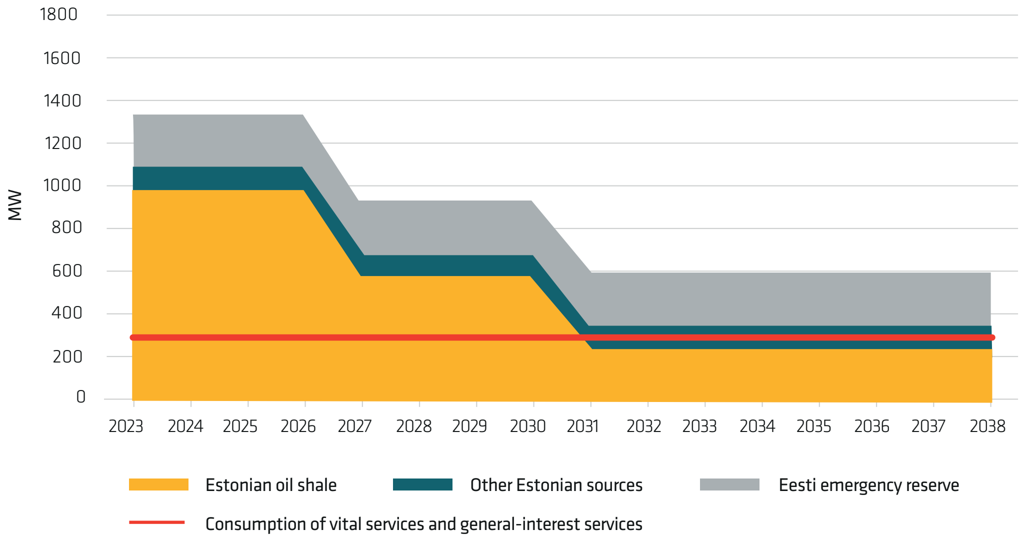
4.4.7.4 Estonia's emergency continuity scenario

Prerequisites for preparing the analysis:

- Estonia has been left in island mode due to extraordinary circumstances.
- There are no electrical connections with other countries.
- The electrical system should be ready to operate for an unlimited period of time.
- The electricity system must be able to constantly cover the consumption of vital services and the consumption of general-interest services.

Figure 4.19 shows that vital service and general-interest service consumption in Estonia is around 300 MW, which is covered many times over during the entire period under observation. This value was found in cooperation with the transmission networks, to which the majority of vital service and general-interest service providers are connected. The actual peak consumption of vital services and general-interest services is lower but since there are a number of other consumers at connection points besides vital service providers, distinguishing them and disconnecting them is a complicated manual task from the viewpoint of the network and thus 300 MW is considered here. Regardless of the fact that this scenario covers all the essential consumers, a critical situation may come about due to ensuring the stability of the electricity system and ensuring the balance of production and consumption.

Figure 4.19
Estonian vital service scenario



4.5 CONSUMPTION FORECAST

The following sub-chapter gives an overview of the forecast for Estonian end-consumer consumption and potential influences on consumption. The forecasts will be updated according to updated statistics, the results of completed studies and updated climate targets. Electricity consumption in the future will be influenced by many factors, several of which are based on the European Green Deal, the Fit for 55 package proposed by the European Commission and fossil energy competitiveness compared to energy generated from renewable sources.

The three main factors that influence electricity consumption:

- **Increase in building renovation and dispersed generation** – in July 2020, the Government approved a long-term strategy for the reconstruction of buildings, the main goal of which is to renovate all buildings built before 2000 in full by 2050. Minimum energy efficiency requirements for new and renovated buildings were established with the strategy. The minimum requirement for the energy efficiency of new buildings is class A – nearly zero-energy buildings, and a part of complying with this is to install local renewable energy generation systems (solar panels). These measures will ensure an increase in energy efficiency by reducing the heat loss of the buildings but will result in increased power consumption due to the installation of ventilation systems as part of the reconstruction. The installation of solar panels for the buildings will reduce the speed of the increase in energy consumption but will result in greater volatility in the consumption of energy from the grid unless local energy storage (batteries or heating system accumulation tanks) is installed or consumption timing is used. The impact on electricity consumption in Estonia from the reconstruction of buildings and the increase in distributed generation has been assessed in a study on electricity consumption scenarios in Estonia commissioned by Elering[46].

- **The partial replacement of natural gas consumption with electricity consumption** – due to the energy efficiency requirements for buildings, the number of small and less efficient district heating networks that to this point used natural gas will decrease and a changeover to local electric heat pumps will take place. No new buildings with local gas heating will be built, as according to the building energy efficiency methodology, it is not possible for them to attain an energy class higher than C. Larger district heating networks like Tallinn, Tartu and Pärnu will adopt large electric heat pumps in addition to cogeneration plants, and these will be able to use the heat from local bodies of water or city wastewater. In May 2023, the European Parliament approved the directives establishing a separate emissions trading scheme (ETS 2) for fuels used for heating buildings and motor vehicles from 2027. The introduction of said system is likely to make the use of renewable electric heat pumps even more competitive compared to the use of fossil natural gas. The extent of the transition from natural gas to electricity was assessed in the 2021 Estonian gas consumption study and the study of Estonian electricity consumption scenarios[47]. The volume of the final decrease in natural gas consumption and the extent and speed of the transition to electricity will largely be determined by the price of natural gas and its economic competitiveness compared to alternatives such as electricity. The consumption forecast assumes that an average of 800 new heat pumps will be added in the coming years, and an average of 4,500 heat pumps will be added to replace older heating systems. It is also worth noting here that the trends in electricity consumption associated with heat pumps are moving in both directions – the replacement of older electric radiators with newer and more efficient heat pumps will lead to a decrease in consumption due to increased energy efficiency, while the switch from wood and other heating sources to heat pumps will lead to a rapid increase in consumption.

- **Electrification of the transport** – in the first half of 2022, more than 10% of vehicles sold are fully electric in more than 10 European countries and, in 2021, 19% of vehicles sold in Europe were fully electric or plug-in hybrids. The respective percentages in Estonia were 3% and 5%, but the share of electric vehicles in the overall fleet can be expected to increase in Estonia as well. The developments in charging infrastructure, the increase in people's awareness and the relatively high price level of liquid fuels will be contributing factors. In addition to the aforementioned European Commission proposal to introduce an obligation for motor vehicle fuel sellers to buy emission quotas, it is proposed to impose an obligation on car manufacturers to sell only zero-emission passenger cars and small vans in the EU from 2035. The study of Esto-

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[46] https://agsi.gie.eu/#/
[47] Study of the transition of gas consumption to clean energy

nian electricity consumption scenarios[48] found that the electrification of the transport sector would amount to around half of the increase in power consumption. Consumers can be categorised by sector:

- Service sector
- Industrial sector
- Households
- Transport sector

According to the historical statistics and future projections of Estonia, the energy consumption is the biggest in the service sector. The growth of consumption can be foreseen in all sectors, but the greatest growth potential is seen in the transport sector. Due to climate policy and higher cost-effectiveness, we envision gradual replacement of vehicles with internal consumption engines with EVs, which will lead to a noteworthy increase in the percentage of electricity consumption in the transport sector. Figure 4.20 shows how the forecasted consumption share will be distributed by sector up to the year 2050.

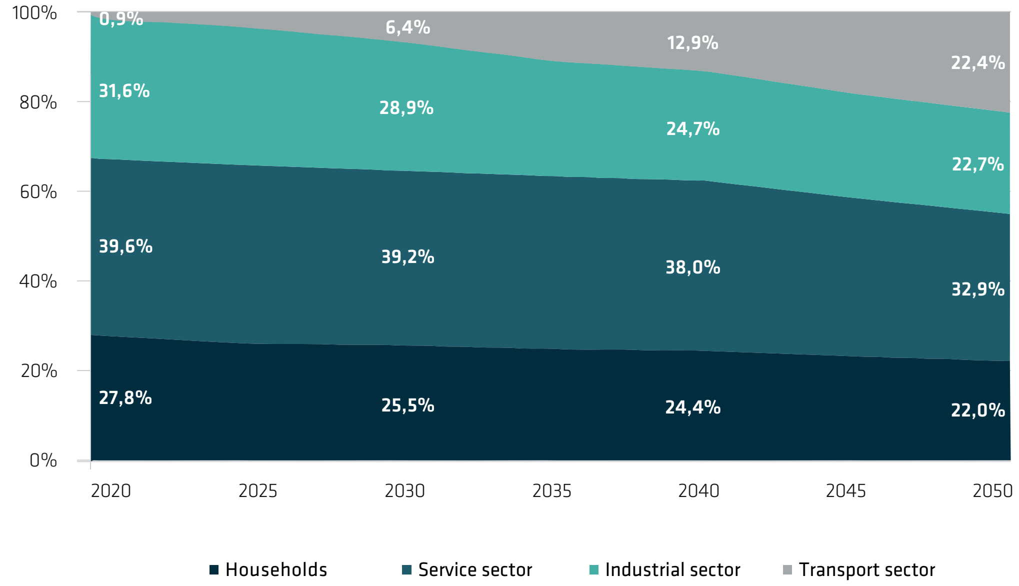

Figure 4.20
Forecasted share of consumption by sector

In various sectors there are a certain number of electricity consumers who are responsible for providing vital services[49] and they must ensure that there is a supply of electricity in all cases to ensure that society is able to function.

The values in Table 4.4 are a statistical aggregation of the last 10 years and forecast for the next 15 years. The forecast of consumption provides average peak consumption values for various years. The system adequacy analysis also takes into account climate years with extraordinarily high and low consumption.

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[48] *Study of Estonian electricity consumption scenarios*

[49] *https://www.riigiteataja.ee/akt/103032017001*

Table 4.4.
Consumption statistics and peak consumption forecast up to 2038

Consumption statistics		
year	Annual consumption, TWh	Peak load, MW
2013	7,9	1510
2014	8,1	1423
2015	8,1	1553
2016	8,4	1472
2017	8,5	1474
2018	8,7	1544
2019	8,6	1541
2020	8,4	1409
2021	9,0	1570
2022	8,5	1464

Consumption forecast		
year	Annual consumption, TWh	Peak load, MW
2023	8,6	1514
2024	9,0	1591
2025	9,2	1668
2026	9,3	1705
2027	9,5	1742
2028	9,7	1779
2029	9,9	1800
2030	9,9	1829
2031	10,3	1870
2032	10,5	1910
2033	10,8	1950
2034	11,1	1984
2035	11,3	2018
2036	11,7	2075
2037	11,9	2131
2038	12,3	2187

The consumption statistics in Table 4.4 are based on the components shown in Figure 4.21. This approach allows network losses to be taken into account without measuring them separately. Figure 4.22 shows the components of the consumption forecast. It is worth noting that the methodology for calculating the statistical consumption and the forecast consumption takes into account the electricity generation in the distribution network and behind the consumption points differently. In the case of the forecast, generation and storage are modelled separately in the security of supply analyses and the impact of these components in the modelling of electricity consumption would lead to double counting. This means that, due to the growth of distributed generation (in particular solar power generation on the roofs of buildings), there will be an increasing difference between the amount of energy that passes through the power grid and the amount of energy of end consumption, which cannot be treated as equal.

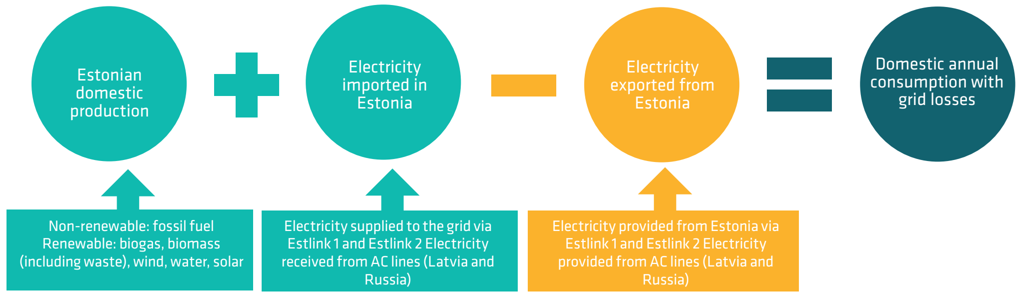
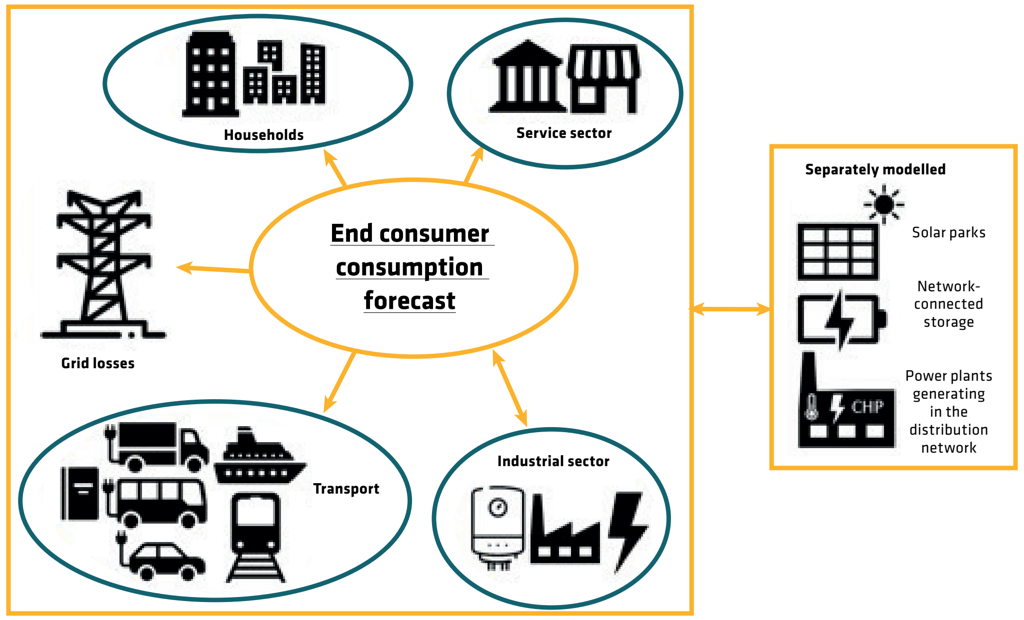


Figure 4.21
Components of formation of consumption statistics

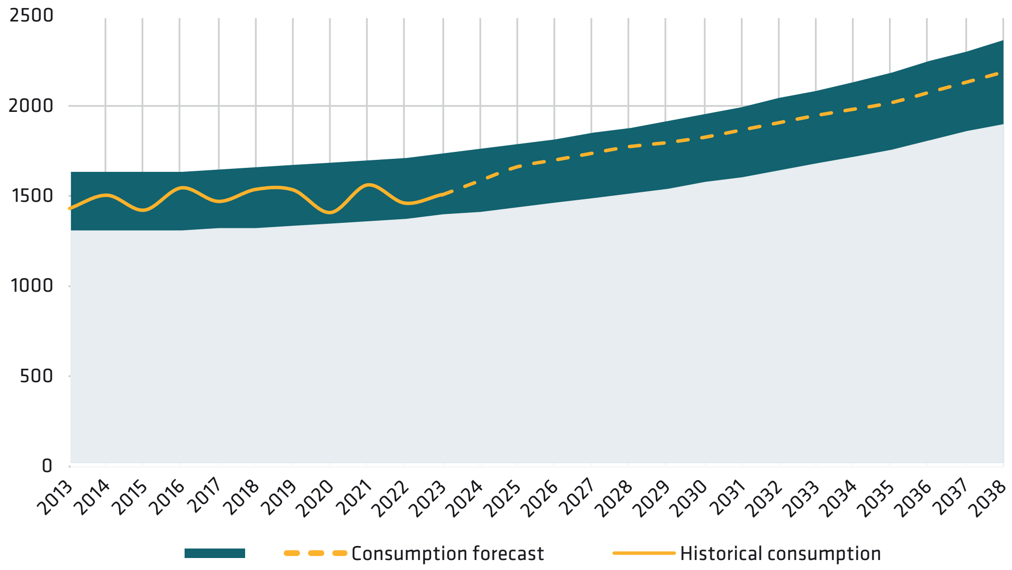
Figure 4.22
Components of consumption forecast



The forecasts in Table 4.4 are based on the results of the consumption modelling for the ENTSO-E system adequacy assessment and the study of electricity consumption scenarios in Estonia commissioned by Elering. Each year, ENTSO-E prepares several dozen hour-based consumption profiles that take into account various direct variables such as number of electric cars, number of heat pumps, historical consumption and other factors such as weather conditions and rising temperatures caused by climate change according to climate years (the nature of a climate year is explained in the ERAA methodology document[50]). Once all these variables have been compiled in the Demand Forecasting Toolbox, unique hourly consumption profiles for all climate years of each target year are obtained, using the results of a study commissioned by Elering. They take into account the different developments in Estonia and the European Union, climate and energy policies aimed at reducing the use of fossil energy and the gradual electrification of the energy economy.

Figure 4.23 illustrates the consumption trend and the volume of the generation reserve necessary for meeting consumption demand according to § 14 of the Grid Code. The historical peak consumption value has varied greatly from year to year, but the trend has clearly been upward. In future, we can expect peak consumption to accelerate due to the electrification of energy consumption. The rise in peak consumption may be boosted by the long-term high price of fossil fuels used to generate heat, which may increase the adoption of electric heat pumps and heating elements.

Figure 4.23
Peak consumption statistics and forecast up to 2038



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[50] https://www.entsoe.eu/outlooks/eraa/2023/

While overall electricity consumption statistics show a slight upward trend, peak loads on the electricity system have remained essentially unchanged over the last decade, ranging between 1,400 and 1,600 MW. The peak load of 1587 MW was recorded 13 years ago in 2010, which coincided with an extraordinarily cold winter period, and in February 2021, the peak was again approached – 1570 MW.

In the case of growth of electricity consumption, it should be remembered that general electrification will increase the annual end consumer's volume of consumption. The volume of consumption of grid power will grow at a slower pace due to the increase in distributed consumption. Together with electrification and introduction of electric transport, the flexibility of electricity consumption will grow (the capability to control, time and store electricity), which will support the transition to renewable energy sources and a general reduction in GHG emissions and price volatility and prevent peak consumption from becoming concentrated at the same time. Diverting consumption to a non-peak hour is supported by the adoption of smart technology, such as smart chargers for electric cars, use of heat pumps' accumulation tanks, heat storage devices in central heating areas, battery storage and bidirectional charging of EVs. The higher price formed at peak hours and the increase in flexibility of consumption will to a certain extent slow the speed of growth in peak consumption. The growth in the share of renewable energy in energy generation will create volatility in the grid consumption profile and electricity prices, which favours the introduction of energy capture technology such as batteries and pump hydro accumulation plants and active participation in the electricity market – this in turn will equalise the grid consumption profile and reduce volatility of electricity prices.

Nevertheless, it should be taken into account that due to electrification of energy consumption, peak loads can be expected to rise in the years ahead.

Table 4.4 shows that the projected peak consumption will grow around 45 MW in the next 15 years and, from 2030, we can expect peak consumption to grow by around 10 TWh each year. The security of supply simulations have also used more extreme years, with peak winter consumption higher than the average shown in the table and annual consumption higher than the average shown.

4.6 KEY CHANGES RELATED TO GENERATING CAPACITIES IN ESTONIA

Annex 2 to this security of supply report lists all generation units (excluding solar parks) in Estonia above 0.5 MW.

Pursuant to subsection 13 (3) of the Grid Code on the functioning of the electricity system, on generation reserves for satisfying consume demand, electricity producers must submit to TSO Elering by 1 February of each year the data specified in Annex 3 to the Grid Code on the next 15 years for assessment of the capability of the electricity system.

All electricity producing equipment, the construction intention of which has been reported to the system operator, cannot be taken into consideration as definite decisions to construct power generation equipment. Some projects are in the construction phase, and some are also in the planning phase, without a final investment decision having been made. At the same time, it can be assumed that not all of the generation equipment in the planning phase will reach an investment decision and that, in addition, it is not certain which years these projects will actually be completed in. Therefore, Elering reserves the right and the option to remain conservative with the data taken into consideration for analysing the system adequacy.

Table 4.5. Estonian generation capacities in 2022 and 2023

Dispatchable market-based capacities

Power plant	Installed net capacity 2022, MW	Installed net capacity 2023, MW	Firm generation capacity, MW
Eesti Power Plant	866	866	652
Balti Power Plant	192	192	144
Auvere Power Plant	272	272	204
Iru Power Plant – gas unit	94	94	0
Iru Power Plant – waste unit	17	17	110*
Põhja Thermal Power Plant	77	77	
Sillamäe Thermal Power Plant	23	23	
Tallinn Power Plant	39	39	
Tartu Power Plant	22	22	
Pärnu Power Plant	21	21	
Enefit	10	10	
Other industrial and CHP plants	75	73	
Total	**1708**	**1706**	**1110**
Capacities outside the market			
Kiisa Emergency Reserve Power Plant	250	250	250
Renewable energy capacities			
Hydro power plants	8	8	0
Wind farms	317	377	0
Solar power plants	510	680	0

*The contribution of these generation capacities to the firm generation capacity is aggregated, as it is made up of the output of 30 smaller power plants at peak hour, which varies widely and is difficult to forecast depending on the situation (weather, business decisions, maintenance schedules, etc.). The value shown was obtained by analysing the historical average peak-hour output of smaller power plants.

Biggest changes compared to 2022

- Bids for the generation of 1,070 GWh of renewable energy were received in the reverse auction for renewable energy generation organised by the state and carried out by Elering. A total of 10 bids from seven companies were received in the reverse auction. The producers plan to generate 893 GWh of this energy from wind and 177 GWh from the sun. The price difference of the bids is €21,89 to €44.9 per MWh. If all the received bids meet the conditions of the reverse auction, all the bids with a price of €39.8 per MWh or less would be successful. The offered price is guaranteed sales revenue per hour from which the exchange price of the respective hour is deducted upon payment of the support. The maximum support according to the conditions of the reverse auction is €20 per MWh. The objective of the reverse auction was to obtain 650 GWh of renewable electricity for the market, of which at least half must be produced in the first and fourth quarter. Successful bidders will have to start production no later than on 1 July 2027.

4.7 ASSESSMENT OF RESOURCE ADEQUACY

Compared to last year, Estonia's short-term system adequacy is significantly higher. The generation capacities and national connections in the region are in good shape, allowing the market to direct electricity to where it is most needed at any given time. Nuclear power plants across Europe are in better working order than last year. The new Olkiluoto 3 nuclear power plant, which is a very important element for our region, is now operating.

The BalticConnector accident in the autumn has disrupted gas transmission between Estonia and Finland, but both countries nevertheless have sufficient supply channels to cover their gas consumption.

The assessment of the long-term capacity of the electricity system was carried out through various analyses, which provided an increasingly accurate picture of the level of security of supply:

- the ERAA found that only Finland will not meet its reliability standard in the region in 2025 and 2028. As the problem has been solved in Finland with market-based measures by 2030, a capacity mechanism would be needed in Finland to improve system adequacy. The security of supply levels in the other countries in the region are within the limits of the standard and the ERAA resolution did not identify any further system adequacy issues. Compared to the results of last year's ERAA, it is important to note that this year's ERAA estimates that the four Narva oil shale units are economically sustainable until 2030 and that their closure would not be economically feasible.

- A more detailed NRAA, together with sensitivity analyses, identified the need to maintain around 1,000 MW of dispatchable capacity in Estonia to ensure security of supply. The importance of dispatchable capacity will increase significantly with the growth in consumption and reserve demand, so additional dispatchable capacity will be needed in the region from 2030. Ensuring upregulation reserves (aFRR and mFRR up) is the most critical, as the need for these is growing rapidly with the increase in renewable energy generation and the related error in forecasts.

- If the level of installed dispatchable capacities in Estonia falls below 1,000 MW, a capacity mechanism in the form of a strategic reserve is needed to ensure security of supply during peak hours. The capacities most needed by 2030 would be those that are able to offer fast up regulation (aFRR and mFRR up).

- Deterministic analyses identified that the future level of capacity of both the region (Baltic states and Finland) and the Estonian electricity system will be highly dependent on wind energy and imports from neighbouring countries. The most critical period will be between 2027 and 2030, when demand will grow rapidly but the decisions to invest in firm capacity have not yet been made. Significant quantities of renewable energy will be added in the coming years, which will have a significant impact on clean electricity generation, but unless complemented by storage, their contribution to security of supply at peak hours will be quite limited.

The electrification of different sectors has led to a rapid increase in electricity consumption in Estonia and across Europe. In Estonia, the growth is mainly due to electric transport and the replacement of fossil fuels with electricity in heat generation. Over the next 10 years, Estonia's annual electricity consumption will increase by nearly 2 TWh, and peak demand will grow by nearly 450 MW. The rapid growth in electricity consumption across Europe has created a situation where long-term system adequacy analyses have identified omissions in many countries that need to be addressed immediately. Elering has taken the first steps in this direction and a study has been commissioned to identify the most suitable type of capacity mechanism for Estonia. The result of the study[51] indicated that the most economically efficient and least market-distorting option for Estonia is a strategic reserve. A strategic reserve concept document[52] was prepared on the basis of the results of the study, and studying the impact of the mechanism on neighbouring markets has started.

In order to avoid a situation where, after joining the Continental European frequency area, not enough frequency reserves are offered on the market, Estonia is applying for a derogation allowing us to procure reserves for a longer period in advance. According to today's best knowledge, the total aFRR and mFRR capacities to be procured in the long term would be approximately 200 MW of upregulation capacity.

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[51] *https://elering.ee/sites/default/files/public/T&A/Study on a Capacity Remuneration Mechanism for Estonia.pdf*

[52] *https://elering.ee/sites/default/files/public/varustuskindluse konverentsid/2022/Strateegilise reservi kontseptsioon.pdf*

5 Digital capability

5.1 DIGITAL CAPABILITY

5.1.1 Increasing digital capacity and growth of new technologies

Digital capability refers to different resources at a company (people, knowhow, technology) that make it possible to automate and raise the efficiency of the company's business processes to ensure the everyday system and security of supply.

5.1.1.1 Increasing digital capacity and growth of new technologies

Electrification increases the importance of electricity in society and leads to the increasing complexity of the energy system. We are moving towards an energy system with increasingly more participants, smarter devices and larger data volumes, and the changes in the system are faster. Additional renewable energy capacities mean that inverter-based equipment has to be taken into account increasingly more than before, as the inertia of such equipment is not so high and generation changes can be faster.

Due to the volatility of renewable energy, more data need to be analysed and more frequent control actions need to be carried out over a shorter time period. This puts more emphasis on the need for automated control functions that people cannot manage in real time without digital solutions. Therefore, there is a growing demand for smart technologies that support electricity system operators in the management of the electricity system in real time as efficiently as possible.

Digitisation leads to an increase in the number of IT components and network connections, which will increase the number of the company's business vulnerabilities and attack vectors. Therefore, increasing the resilience of Elering's IT systems to cyber-attacks is important in order to keep the risk level under control. Investing in cybersecurity will also allow us to comply with legislation that is becoming stricter in the coming years, such as the European Union's Network Code on Cybersecurity or amendments to the Estonian Cybersecurity Act.

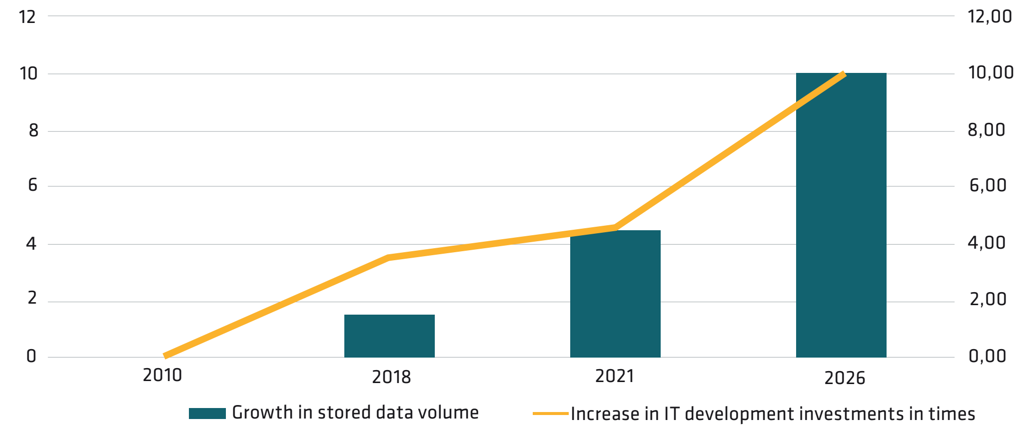
5.1.1.2 Constant increase in and management of data volumes

The digitalisation of the energy system will increase the share of new technologies and data volumes (Figure 5.1). Increased data volumes make it possible to process and analyse data close to real time in order to make the right decisions for the management of the electricity system. Decisions based on real-time data are our future.

The volume of Elering's digital solutions has grown steadily over time, reflecting the increasing complexity of the power grid and the growing number of small generators over time. This is accompanied by a continuous increase in data volumes, which is caused by the rapid spread of smart devices and the continuous flow of data they produce.

Elering has responded to this challenge by introducing changes to its key systems, technical architecture and data models. The use of cloud-based technologies is also considered to support the growing digital ecosystem. In this context, the anonymisation of data and the introduction of microservices is of key importance, as this will allow us to manage and analyse data more efficiently and provide a high level of support for real-time management decisions.

Figure 5.1
Growth in stored data and IT development investmentsv



5.1.1.3 Increasing the digital capability of people and business processes

Increasing our digital capability is not limited to introducing new solutions and technologies but covers committing to the development of our employees at Elering. We consistently invest resources into training and developing the digital skills of our team, as we understand the importance of these skills to the success of our organisation. This will make a significant contribution to our overall digital capability, enabling us to efficiently implement sophisticated digital solutions and technologies.

We also pay attention to improving business processes and systems through a number of digital transformation initiatives. Improving the efficiency of business processes and systems is central to optimising our operations and ensuring the smooth running of the organisation and high quality of services.

5.1.2 Most important digital initiatives 2024-2028:

5.1.2.1 Synchronisation with Continental Europe and introduction of new control systems

After joining the Continental European frequency area, the Baltic states will be subject to the technical requirements for the operation of the electricity network and the assessment of network stability, which create the need to extend existing or create new control systems. In order to ensure a stable network service, it is necessary to implement a frequency management procedure in line with Continental European principles, to assess the different indicators of stability of the electricity system, to ensure a high-quality data exchange between new and existing systems and to upgrade the forecasting systems for both network status and external indicators. Modern control systems are necessary for supplementing these functions. The existing control systems will be upgraded and new ones procured until 2021-2024. Elering will provide frequency control upon synchronisation with Continental Europe.

The following is planned in 2024 for synchronisation with the Continental European frequency area:

- Upgrading the SCADA technical control system of the electricity system, with various systems for real-time assessment of the status of the electricity system
- Implementing the new frequency stability assessment systems (FSAS)
- Upgrading the information wall in the control centre and building an information wall in the reserve control centre
- Implementing an automatic control system for the reserve capacities needed for frequency control

- Upgrading the balance management software
- Upgrading the forecasting systems
- Ensuring that the electricity system can be controlled from an alternative location with the same IT service capability as at the main site
- Upgrading the data communications network equipment of substations and creating a new secure data communications network

5.1.2.2 Estfeed data exchange platform

We will implement a new data exchange platform, through which data exchange takes place on the electricity and gas market for changing open suppliers, transmitting metering data and ensuring that market participants fulfil their obligations under law and safeguarding their rights. The digital platform will bring together electricity and gas companies to ensure information for input into their business processes. At Elering, the entire topic of energy data will be covered by the Estfeed brand in order to avoid duplication and ensure compliance with data protection and data security requirements.

The following is planned in 2024 during the implementation of the Estfeed data exchange platform:

- Updating the customer portfolio with new functionalities
- Building a ready-to-use interface to the new data platform and migrate the data
- Closing the old data warehouse
- Finalising preparations for data exchange on the 15-minute intraday market
- Interfacing the market participants and launching the 'datahub live' environment by the end of Q2
- Finalising preparations for the transfer of gas market data to the new datahub in the second half of the year

5.1.2.3 Risk- and condition-based asset management

To efficiently manage resources, we are creating a risk- and condition-based asset management solution. To this end, we systematically collect and aggregate data on Elering's assets, which we use to make the necessary management decisions. High-quality condition-based information helps reduce the number of outages and the time it takes to fix them. Secure and controlled management of versions, configurations and settings on devices reduces the possibility of cyberattacks and human error. For this purpose, we improve our work processes and create a central solution where information has been consolidated and the administration of configurations is systematic and controlled.

The following is planned for the implementation of risk- and condition-based asset management:

- Implementing a risk- and condition-based asset management solution (Equipment Register), which will ensure timely investments in the right equipment
- Creating data storage and processing capability. Application of analytical algorithms to data processing and visualisation of results
- Collecting and processing online data

5.1.2.4 Renewable energy

We help to bring new renewable energy technologies and generation capacity to the market in the most efficient way for society. We promote market-based energy carriers and cross-sectoral competitive solutions involving both suppliers and end-consumers. The focus is on regional and pan-European markets.

The following is planned in 2024 in the area of renewable energy:

- Refactoring and modulating of existing systems to ensure a higher quality of the current functionality and to make it possible to trade in hourly certificates of origin in the future
- There is also a need for new interfaces to reduce the manual work done by product owners and to create functionalities for new technologies (hydrogen and storage)

5.1.2.5 Modernisation of IT infrastructure

In order to ensure the continuity of a vital service, the functioning of the electricity market and the security of Elering's internal information, given the public attention related to synchronisation, the changing market organisation due to climate policy (more controlled devices, more parties exchanging data) and the general increase in digitalisation of business processes, we need to ensure that the IT infrastructure of Elering is modern and complies with requirements.

The following is planned in 2024 in relation to the modernisation and expansion of the IT infrastructure:

- Acquiring new servers, data recorder, network nodes, firewalls within the scope of the upgrade of the hardware of the Kiili and Karksi gas facilities
- Procuring four backup disk drives for both the technology network and the office network, and for both data centres, in order to upgrade the backup solution across the entire company
- Acquiring KEMP load balancers for the technical network and for the service provided by Baltic RCC
- Acquiring new servers and expanding the existing storage solution as part of the upgrades to the Kadaka database cluster
- Upgrading the IT hardware in the Kiisa Reserve Control Centre
- Upgrading the data communication equipment on all sites in the gas network in accordance with the requirements of the ECC
- Building a new Elering substation data network
- Increasing security and reducing the administrative burden in the remote management of Elering's technical facilities and in the hosting of the information systems interfaced with IT/OT systems in the facilities implementing the VmWare NSX-T solution in the technical networks in both Kadaka and Kiisa server rooms

5.2 IMPACT OF CYBERSECURITY ON SECURITY OF SUPPLY

5.2.1 General overview of risks in Estonia in 2022

The State Information System Authority (RIA) points out in its Cyber Security Yearbook 2023 that in 2022, Russia's full-scale war against Ukraine led to an unprecedented number of DDoS attacks in Estonia by pro-Kremlin hacktivists expressing their discontent in this manner. Attacks on Estonian IT infrastructure increased during politically sensitive events such as the removal of the Narva tank monument, suspension of the transmission of Russian TV channels, and the support for Ukraine expressed by Estonia. In addition to DDoS attacks, various service interruptions resulting from human error and data leaks had a greater impact.

The RIA says that the largest number of incidents are still related to scams and phishing attacks, where unsuspecting users are tricked out of passwords, bank card details and money. The number of ransomware attacks decreased and, in many cases, companies had good backups to restore the necessary data. At the same time, it is worrying that many ransomware attacks were made possible by the careless use of connections required for remote work, opening the door for attackers to use remote connections to spread ransomware.

5.2.2 Overview of the impact of cyber-attacks in the war in Ukraine

In its yearbook, the State Information System Authority points out that at the beginning of the war in Ukraine, several critical infrastructure providers came under attack. For example, there was an attack on a satellite communications company that disrupted satellite communications not only in Ukraine but also in other European countries such as France, Germany, Italy and Poland. The largest telecoms company in Ukraine was also attacked, which left nearly 80% of customers without internet for hours.

The energy sector of Ukraine was also targeted in April when an attempt was made to attack a major Ukrainian energy company. As far as we know, malware created for attacking industrial control systems was used for this and the same malware was used in the 2016 attack on the electricity system of Ukraine, which left part of Kyiv's population without electricity. The attack launched in 2022 was detected and thwarted through the cooperation of public authorities and cybersecurity companies.

The RIA estimates that Ukraine's critical services have been remarkable in terms of cybersecurity, as the country's digital services are up and running and cyber-attacks have not stopped critical services from functioning. Disruptions to critical services have been caused mainly by kinetic warfare.

One of the secrets of Ukraine's success has been the fact that cyber-attacks did not start last year, but organisations there have been targeted since 2014. Peacetime and the lack of incidents tend to make companies complacent; investments in cyber security, including making the necessary changes to systems and operational processes, can take a back seat. Therefore, it is important to invest in the detection of vulnerabilities and the correction of any identified shortcomings in a consistent and committed way.

The war in Ukraine also shows that many of the successful attacks were not aimed at the digital systems themselves, but at their physical components. Kinetic attacks highlighted the vulnerability of digital infrastructure in the real world. It also became clear how critical it is to diversify the location of data and systems by spreading them across different locations. Among other things, cloud services have proven to be a useful backup system, protecting the operation and availability of valuable services even after direct attacks against physical infrastructure.

The experience in Ukraine shows that measures to prevent attacks alone may not be enough to avoid outages. When defence is planned, it is necessary to consider how to detect and respond to attacks and how to recover information systems after a successful attack.

5.2.3 An overview of the areas to which Elering contributes

- Training and awareness raising: We organise regular training courses and seminars for our staff to keep them up to date with the latest threats and best practices, thereby raising awareness and preparedness.

- Updating technical solutions: We pay attention to remote access, protecting ordinary users and detecting attacks.

- Regular checks and assessments: We carry out regular cyber-attack simulations, security testing and security analyses to identify vulnerabilities and proactively fix them.

- Use of cloud services and distributed backup: Wherever possible, we use secure cloud services to ensure data availability and recoverability.

- Creation of different security zones: We separate less critical data and work processes that need broader access from systems that deal with critical business processes.

- National and international cooperation: We cooperate closely with international partners, public authorities and other vital service providers, sharing information on threats and best practices to strengthen cooperation within and across sectors.

- Supervision and response mechanisms: We plan to develop and upgrade real-time monitoring systems.

5.2.4 Impact of cybersecurity on security of supply

As in previous years, there was no energy not supplied due to a cyber-attack in the Elering grid in 2022. We plan our own activities with the aim of protecting Estonia's transmission network control systems and preventing disruptions to vital services.

6 Annexes

6.1 ANNEX 1 – LIST OF ACRONYMS

AERJ – emergency reserve power plant

BAU – Business As Usual, ordinary development trends and standard solutions based on technology policy and other guidelines

BRELL – bloc of TSOs, where Belarus, Russia, Estonia, Latvia and Lithuania are members

BSMMG – Baltic Sea Market Modelling Group

CEF – Connecting Europe Facility, aims to increase competitiveness at the European level through investments into infrastructure

CONE – Cost Of New Entry [€/MW], the cost of new incremental capacity

DSR – Demand Side Response

EENS – Expected Energy not supplied

EL1 – Estlink 1

EL2 - Estlink2

ELV – Elektrilevi

ENTSO-E – European Network of Transmission System Operators for Electricity

EPC – Emergency Power Control

ER – Elering

EV – power grid

FCR – Frequency Containment Reserve

FRR – Frequency Restoration Reserve

HVDC – high voltage direct current

IPS/UPS – Russian frequency area, with which the following are connected: Baltics, Ukraine, Kazakhstan, Kyrgyzstan, Belarus, Azerbaijan, Tajikistan, Georgia, Moldova and Mongolia

IPS/UPS – United Russian Energy System

KA – Competition Authority

LOLE – Loss Of Load Expectation (h/year), how many hours in the year there will be energy not supplied without there being market-based resources to cover the demand

MAF – Mid-term Adequacy Forecast compiled by ENTSO-E (this time, it spans 2021–2025)

N-1 – disconnection due to a malfunction of one element of the electricity system (line, transformer, generation equipment, etc.)

N-1-1 – disconnection of one element in the electricity system due to a malfunction where an element that has a significant impact on the operation of the electricity system is in maintenance or repair

NTC – Net Transfer Capacity

PEMMDB – Pan European Market Modelling Database

PKVA/PTLA – automatic system for reducing load/reswitching according to voltage

RLA – reserve switching automatic system

SOC – ENTSO-E System Operation Committee

TK – place of consumption

TLA – automatic system for reswitching

TSO – Transmission System Operator

TSO – Transmission System Operator

VOLL – Value Of Lost Load [€/MWh], estimated maximum electricity price the consumer is willing to pay to avoid outages

6.2 ANNEX 2 – OVER 0.5 MW INSTALLED GENERATING CAPACITIES IN THE ESTONIAN ELECTRICITY SYSTEM

The table below lists the installed generation capacities as reported by producers for the largest Estonian-based generating units in 2023. Many of these installations have noteworthy restrictions due to which Elering uses conservative, 'firm' capacities to assess security of supply, based on experiences from the years before. The percentage of firm capacity in installed capacity is separately listed in Table 4.5 in Chapter 4.6.

Name of power plant	Type of generation equipment	Fuel	Generation capacity (MW) as of 2023
POWER PLANTS			**1340 MW**
Eesti Power Plant	condensation unit	Oil shale	866
Auvere Power Plant	condensation unit	Oil shale	272
Balti Power Plant	condensation unit	Oil shale	192
Enefit power plant	steam turbine generator using residual heat	Oil shale	10
COGENERATION PLANTS			**365,6 MW**
Iru Power Plant	cogeneration unit	Natural gas	94
Iru Power Plant	cogeneration unit	mixed municipal waste	17
Põhja Thermal Power Plant	cogeneration and condemnation turbines	generator gas	77
Utilitas Tallinn Power Plant	cogeneration unit	Biomass	39
Tartu Power Plant	cogeneration unit	Biomass	22.1
Pärnu Power Plant	cogeneration unit	Biomass	20.5
Horizon tselluloosi ja paberi AS	counterpressure turbine with intermittent intake	black lye/biomass	13.9
Sillamäe Thermal Power Plant	cogeneration unit	Oil shale	10
Imavere cogeneration plant	cogeneration unit	Biomass	10
Osula cogeneration plant	cogeneration unit	Biomass	10
Mustamäe cogeneration plant	cogeneration unit	Biomass	9.3
Sillamäe I cogeneration plant	cogeneration unit	Biomass	7.1
Sillamäe II cogeneration plant	gas engine	Natural gas	5.8
Helme cogeneration plant	cogeneration unit	Biomass	6.5
Grüne Fee Eesti AS	gas engine	Natural gas	4.1
Kiviõli Keemiatööstuse OÜ thermal power plant	cogeneration unit	oil shale retort gas	1.4
Kuressaare heat and power cogeneration plant	cogeneration unit	Biomass	1.8
Paide cogeneration plant	cogeneration unit	Biomass	1.7
Jämejala cogeneration plant	gas engine	Natural gas	1.8
Repo Vabrikud AS	gas turbine	Natural gas	1.8
Ilmatsalu biogas plant	gas engine	biogas	1.5
biogas	gas engine	biogas	1.4
Oisu biogas plant	gas engine	biogas	1.2
Tallinna Prügilagaas OÜ	gas engine	landfill gas	1.9
Põlva heat and power cogeneration plant	gas engine	Natural gas	0.9
Rakvere cogeneration plant	cogeneration unit	Biomass	1
Rakvere Päikese cogeneration plant	cogeneration unit	Biomass	0.9
Kopli cogeneration plant	gas engine	Natural gas	0.9
WTC Tallinn AS	gas engine	Natural gas	0.6
Tartu Aardlapalu landfill cogeneration plant	gas engine	landfill gas	0.5
HYDRO POWER PLANTS			**8 MW**
Jägala hydroelectric plant	hydro turbine	water	2
Linnamäe hydroelectric plant	hydro turbine	water	1.1
Other small producers	hydro turbine	water	4.9
WIND FARMS			**377 MW**
Aulepa wind farm	wind turbine	Wind	48
Paldiski wind farm	wind turbine	wind	45
Tuhavälja wind farm	wind turbine	wind	39.1
Saarde Wind Farm*	wind turbine	wind	38.7
Aseri wind farm	wind turbine	wind	24

Purtse Wind Farm	wind turbine	wind	21
Viru-Nigula wind farm	wind turbine	wind	21
Pakri wind farm	wind turbine	wind	18.4
Tamba-Mäli Wind Farm	wind turbine	wind	18
Tooma I wind farm	wind turbine	wind	16
Skinest Energia Esivere TP	wind turbine	wind	12
Varja wind farm	wind turbine	wind	10
Vanaküla wind farm	wind turbine	wind	9
Esivere wind farm	wind turbine	wind	8
Tooma II wind farm	wind turbine	wind	7.1
Virtsu II wind farm	wind turbine	wind	6.9
Virtsu III wind farm	wind turbine	wind	6.9
Ojaküla wind farm	wind turbine	wind	6.9
Saaremaa wind farm	wind turbine	wind	6
Nasva wind farm	wind turbine	wind	5.9
Aburi windmill	wind turbine	wind	1.8
Nasva sadama wind farm	wind turbine	wind	1.6
Sikassaare wind farm	wind turbine	wind	1.5
Virtsu wind farm	wind turbine	wind	1.4
Virtsu I wind farm	wind turbine	wind	1.2
Türju wind turbine	wind turbine	wind	0.9
Peenra windmill	wind turbine	wind	0. 7

The installed solar plant capacities change extremely rapidly at the time of this report. Estonia had installed solar plant capacity of 680 MW, which was distributed across counties as shown in the table.

SOLAR PLANTS in aggregate	**680 MW**
County	**Generation capacity as at September 2023 MW**
Harju	120
Tartu	83
Pärnu	74
Viljandi	64
Lääne-Virumaa	61
Ida-Virumaa	53
Jõgeva	45
Valga	39
Võru	31
Järva	26
Rapla	26
Põlva	25
Saare	24
Hiiu	5
Lääne	4

6.3 ANNEX 3 – APPROVED INVESTMENTS 2023–2027

Power substations	**End of investment**
Renovation of Alutaguse 110 kV substation 2023	2023
Renovation of Audru 110 kV substation	2024
Renovation of Ellamaa (Riisipere) 110 kV substation	2023
Renovation of Elva 110 kV substation	2026
Renovation of Estonia-Põhja 110 kV substation	2026
Renovation of Haapsalu 110 kV substation	2026
ER part of Järveküla 110 kV substation	2023
Renovation of Kabli 110 kV substation	2025
Renovation of Kadrina 110 kV substation	2026
Reconstruction of Kantküla 110 kV substation	2025
Renovation of Kunda 110 kV substation	2026
Renovation of Kuuste 110 kV substation	2025
Renovation of Lihula 110 kV substation	2023
Linda 110 kV substation	2026
Reconstruction of Maaritsa 110 kV substation	2026
Renovation of Mustvee 110 kV substation	2023
Renovation of Nõva 110 kV substation	2025
Renovation of Raasiku 110 kV substation	2026
Renovation of Ruusmäe 110 kV substation	2026
Renovation of Sikassaare 110 kV substation	2023
Renovation of Sirgala 110 kV substation	2026
Renovation of Tõrva 110 kV substation	2027
Construction of Veerenni substation (abandonment of Aidu)	2026
Renovation of Alatskivi 110 kV substation into compact substation	2024
Renovation of Haljala substation into compact substation	2025
Renovation of Jaoskonna 3B substation into compact substation	2025
Renovation of Koigi 110 kV substation into compact substation	2023
Renovation of Mõniste 110 kV substation into compact substation	2025
Renovation of Oiu 110 kV substation into compact substation	2027
Renovation of Põdra substation into compact substation	2023
Renovation of Ruusa 110 kV substation into compact substation	2023
Renovation of Rõuge 110 kV substation into compact substation	2026
Renovation of Soo 110 kV substation into compact substation	2023
Renovation of Taebla 110 kV substation into compact substation	2025
Renovation of Tusti 110 kV substation into compact substation	2024
Renovation of Valgu 110 kV substation into compact substation	2025
Renovation of Vigala 110 kV substation into compact substation	2023
Power lines	
L001 Harku-Veskimetsa partial cable and overhead line	2024
L002 Harku-Veskimetsa partial cable and overhead line	2024
L005 Partial renovation of Iru-Järve	2024
L005 Partial renovation of Iru-Järve	2023
L006A Partial renovation of Iru-Järveküla	2023
L006A Installation of Järveküla-Iru fibre optics	2023
L006B Partial renovation of Järveküla-Järve	2024
L007 Installation of Iru-Ida fibre optics	2023
L008 Installation of Lasnamäe-Ida fibre optics	2023
L011 Harku-Veskimetsa cable and overhead line	2024
L012 Harku-Kadaa cable and overhead line	2024
L026 Partial renovation of Kehtna-Järvakandi	2023
L030 Partial renovation of Sindi-Papiniidu	2025
L032B Partial replacement of the Metsakombinaadi-Papiniidu overhead line with a cable line	2027
L037 Partial renovation of Lihula-Martna	2025
L042 Partial renovation of Tsirguliina-Mõniste	2023

L043 Partial renovation of Tsirguliina-Linda	2023
L043 Replacement of single Tsirguliina-Linda masts	2023
L066 Partial renovation of Rakvere-Rakvere	2024
L085 Reconstruction of Kiisa-Topi overhead line	2026
L086 Reconstruction of Topi-Harku overhead line	2026
L102 Partial renovation of Rakvere-Tapa	2026
L105C Partial renovation of Oiu branch	2025
L107C Partial renovation of Pärnu-Jaagupi branch	2023
L115 Partial renovation of Rakvere-Kunda	2023
L116 Partial renovation of Baltic-Püssi	2027
L117 Partial renovation of Baltic-Sirgala	2025
L117A Partial renovation of Estonian PP OT branch	2024
L118 Partial renovation of Sirgala-Ahtme	2027
L119 Partial renovation of Baltic-Estonian PP OT branch	2027
L133A Replacement of Paide-Vändra wire, lightning protection cable and single masts	2027
L133B Replacement of Vändra-Papiniidu wire and single masts	2027
L134A Replacement of Paide-Suure-Jaani wire, partial replacement of lightning protection cable and single masts	2024
L137 Partial renovation of Püssi-Aidu	2025
L138 Kiikla-Jaoskonna 3B overhead line	2024
L143B Replacement of single Linda-Sõmerpalu mast	2023
L156 Replacement of single Kanepi-Võru mast	2023
L164 Reconstruction of Aruküla-Lasnamäe	2025
L165 Reconstruction of Aruküla-Lasnamäe	2025
L177 Partial reconstruction of Orissaare-Valjala	2023
L180 Increasing clearances +45C	2023
L180 Partial renovation of Kiisa-Keila	2023
L181 Increasing clearances +45C	2023
L181 Partial renovation of Kiisa-Keila	2023
L182 Replacement of Kiisa-Järve wire and single masts	2026
L194 Reconstruction of Raasiku-Kehra overhead line	2026
L195 Reconstruction of Aruküla-Raasiku overhead line	2026
L347 Partial renovation of Sopi-Sindi	2023
L357 Partial renovation of Paide-Kiisa	2023
L504 Partial renovation of Harku-Aruküla	2023
L505 Partial renovation of Harku-Kiisa	2023
L506 Partial renovation of Rakvere-Kiisa	2023
Establishment of L8048 Tartu-Ülejõe 110 kV cable	2024
L8052 Tartu-Tööstuse cable line	2027
Replacement of L8055 Tartu-Emajõe overhead line with cable line	2024
L8108 Construction of Iru-Viimsi 110 kV cable line	2026
Development of grid within Estonia	
Construction of Topi substation to make it pass-through	2026
Renovation of L103 Püssi-Rakvere	2023
Increasing clearances of L135 Püssi-Ahtme overhead line	2024
Trimming clearances of L08 Aidu-Jaoskonna 3B	2023
Synchronisation (CEF co-funding)	
L300 Reconstruction of Baltic-Tartu	2024
L301 Reconstruction of Tartu-Valmiera	2023
L353 Reconstruction of Estonia-Tsirguliina overhead line	2025
Construction of Mustvee connection point	2024
Reactors and synchronous compensators	2024
Renewable Energy Interconnection Capacity Building Investments (RRF co-funding)	
Lihula 330/110 kV substation	2026
Expansion of Orissaare 110 kV substation	2025
New 110 kV line cell at Lihula substation for L171	2025
Renovation of L017 Kiisa-Rummu	2023
Construction of 110 kV overhead line of L036 Rõuste-Virtsu	2025
Construction of 110 kV overhead line of L170 Lihula-Virtsu	2025

L171 Increasing Lihula-Virtsu clearance 60C	2025
Construction of L173 Võiküla-Orissaare parallel line	2023
L174 Rõuste-Leisi 110 kB cable line section in Väike Strait	2024
Increasing clearances of L174 Rõuste-Leisi	2025
Construction of L175 Leisi-Sikassaare on separate masts from L176 Sikassaare-Valjala line	2026
Increasing clearances of L175 Sikassaare-Leisi	2024
Increasing clearances of L175A Valjala branch	2024
Increasing clearances of L176 Sikassaare-Valjala	2024
Replacement of conductor and increasing clearance of L177 Orissaare-Valjala	2026
Increasing clearances of L185 Kiisa-Kohila	2023
Increasing clearances of L186 Kohila-Rapla	2023
Reconstruction of L356 Mustvee-Paide	2026
Reconstruction of L357 Kiisa-Paide overhead line	2026

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