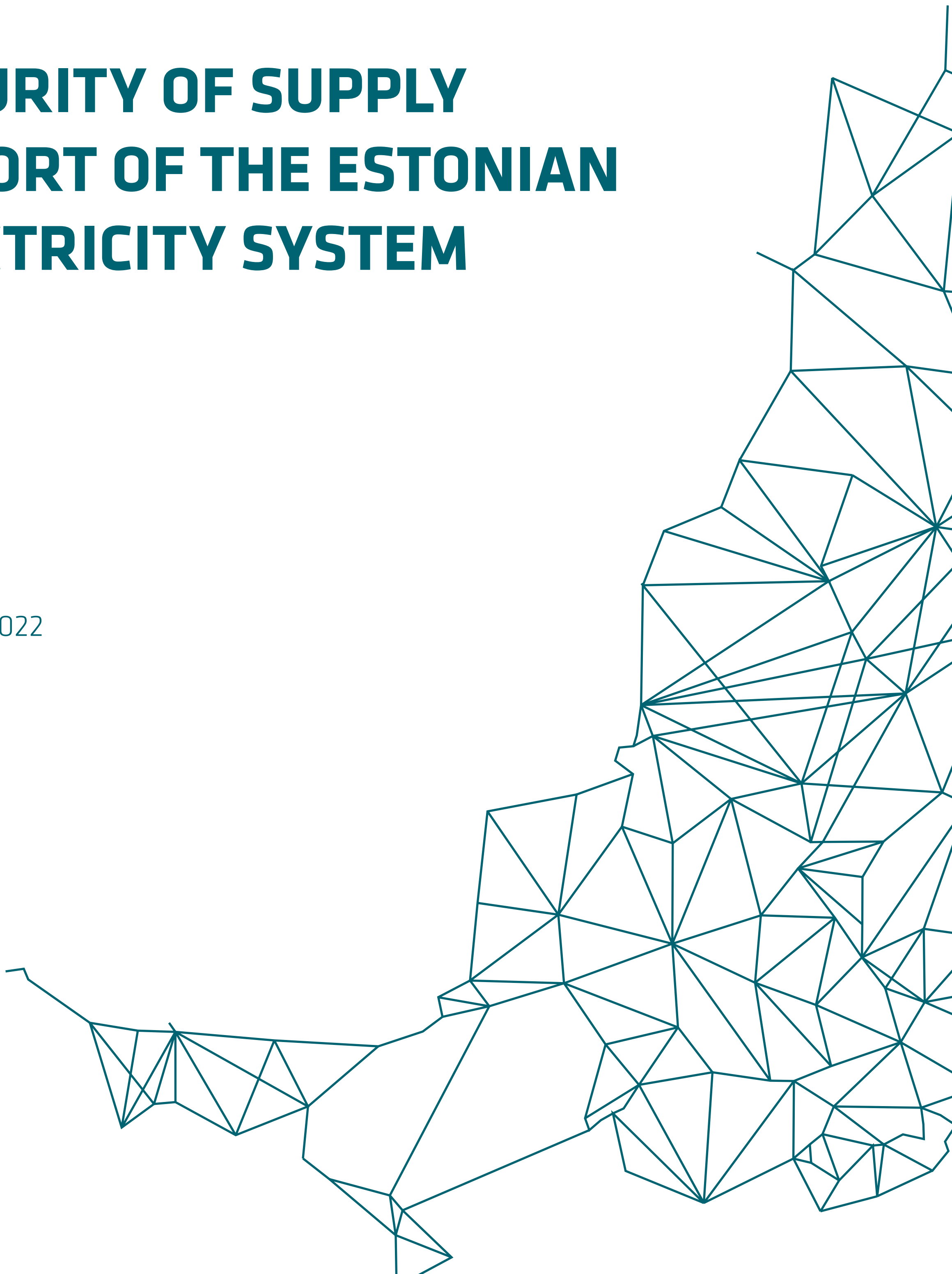
SECURITY OF SUPPLY REPORT OF THE ESTONIAN ELECTRICITY SYSTEM



TALLINN 2022

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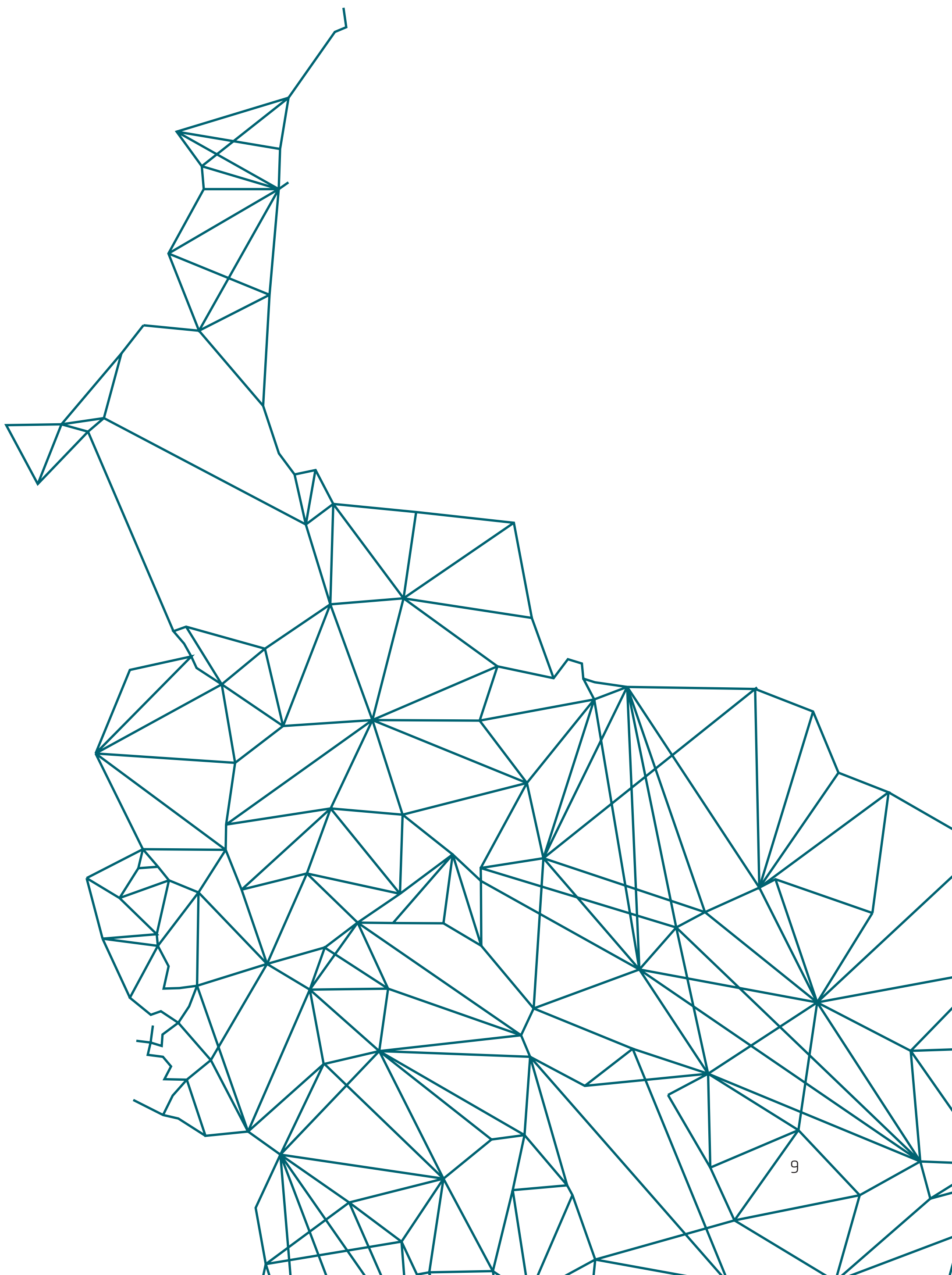
SECURITY OF SUPPLY REPORT OF THE ESTONIAN ELECTRICITY SYSTEM

Elering is an independent and autonomous operator of a combined gas and power transmission system, the main goal of which is to ensure a 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 (subsection 39 (7) and (8); subsection 66 (2), (3) and (4). The assessment of the system adequacy reserve was conducted pursuant to the sections 14 and 141 of the Grid Code on the functioning of the electricity system.

CONTENTS

Foreword



In spite of the increased risks, security of supply is ensured

Additional risk mitigation measures

Russia's full-scale invasion of Ukraine on 24 February 2022 dramatically increased the risks to security of supply of energy, both for Estonia and Europe as a whole. In the course of an extraordinary assessment of risks to the energy systems conducted in March 2022, we identified two particularly high risks for Elering – the interruption of the gas supply in winter 2022/2023 and failure of the electricity system due to an unplanned disconnection of the Baltic electricity system by Russia. To mitigate these risks, we put together a large-scale plan of additional actions that will keep the lights on and homes warm in Estonia. Although there is still fear and uncertainty in society, additional measures for hedging risks have been successfully implemented in the last nine months. The risks continue to exist but are much lower than initial projections.

To cover gas supply to the region in the winter of 2022-2023, we developed in late winter and early spring an action plan based on three pillars: first of all, temporarily reducing gas consumption and a transition to alternative fuels, secondly, maximising reserves and creating an Estonian national gas reserve and third, creating an additional gas supply chain to the Gulf of Finland region. We have been successful in realising three initiatives in a very short timeframe – gas consumption has dropped substantially, reserves are much greater than expected and the infrastructure in the Gulf of Finland region needed for the additional gas supply chain is nearing completion. Ensuring gas supply is important for ensuring a supply of electricity to the region. The Russian electricity historically imported to the region and the support of the Russian power system in desynchronisation must be replaced mainly with power generated in the Finnish and Baltic gas-fired power plants.

To mitigate the risks to the power system and increase readiness, we put together the following set of additional actions:

- Completely ending trading of electricity with Russia and Belarus. Lack of trading significantly decreases the chance of failure of the Baltic electricity system due to being forced into unexpected island mode, since it allows the Baltic imbalance in respect to Russia to be minimised.
- Technical capacity established on the Lithuanian-Polish border (at Alytus substation in Lithuania) for extraordinary synchronisation with the continental European electricity system. An agreement and procedures are in place with the heads of the continental European electricity system for carrying out extraordinary synchronisation without additional coordination, and the synchronisation would be executed in an estimated 6-12 hours.
- An agreement and procedures for implementing measures for ensuring frequency stability with the Nordics on the EstLink1, EstLink2 and NordBalt connections. In total, we can use up to 400 MW of fast reserve capacities from the Nordics..
- The decision of the Government to maintain approx. 1000 MW of power generation capacity based at Eesti Energia power plants until the end of 2026. Eesti Energia has begun to resolve the problem of cooling water availability faced by Narva plants through potentially lowering the water level in Narva reservoir.
- Pan-Baltic coordination in regard to timing of maintenance and renovations of large generating equipment. Agreement with Elektrilevi for limiting consumption by 200 MW should generating capacities prove insufficient.
- Maintaining the agreed time schedules for all investments into synchronisation with the continental European electricity system, activities for developing markets and increasing electricity system administration capacity in spite of the increased complexity, higher prices and supply problems.

A more unpredictable situation than ever before

Although everything agreed in the late winter has largely been accomplished, there are still a number of risks in the years ahead that cannot be completely neutralised. Above all risks related to attacks on physical infrastructure (such as attacks on Nord Stream), cyberattacks (à la attacks on the Ukrainian power grid), fuel availability (such as restrictions on fuel and coal supply) or operational reliability of power plants (à la Olkilouto 3). We live in an energy economy that has never before been so unpredictable. This behoves us to be ready for anything.

To ensure longer-term security of supply on the energy market in these limited-visibility conditions, Elering proposes to utilise the strategic reserve in Estonia. Future-looking analyses show that in spite of today's high energy prices, by 2027 the market may change in the direction of Estonia's oil shale plants no longer being competitive on the electricity market. To ensure Estonia's security of supply, it will be necessary to have firm capacities in the amount of about 1000 MW. For precisely maintaining these generating capacities in a situation where it may no longer be commercially profitable for Eesti Energia, Elering proposes to utilise the strategic reserve. On the basis of the strategic reserve, Estonia would maintain sufficient generating capacities for a situation where it ceases to be commercially profitable on the energy market.

Carbon footprint of energy generation

Although today security of supply and price of energy are on the forefront, there is no other long-term alternative when it comes to countering climate change but to reduce carbon emissions from the energy sector, since the sector contributes 70% of global CO2 emissions. Elering's vision is to ensure the security of supply of electricity to Estonian consumers in a climate-neutral manner, supporting the Estonian economy's competitiveness.

Estonia today has network capacity to draw on renewable energy generation in an extent that ensures supply of electricity to Estonian consumers in a climate neutral manner. Estonia has approximately 6 GW of built or pending network connections for electricity producers. As a reminder and for context, Estonia's all-time peak demand was 1.59 GW and the Estonian electricity system is largely designed for back and forth movement of 3 GW of electricity. The aforementioned 6 GW network connection capacity would allow 4 to 5 GW of renewable-energy-based generating capacities in near future, plus approximately 2 GW of offshore wind. Connecting this much generation capacity is more than enough for supplying Estonia's consumers. 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 establishing new generation capacity. Elering has proposed to establish a new measure that imposes a fee for all network connection capacities that are not used for feeding electricity to the market within two years. This measure will create economic motivation for taking idle network capacity into actual use.

Taavi Veskimägi
Chairman of the Elering management board

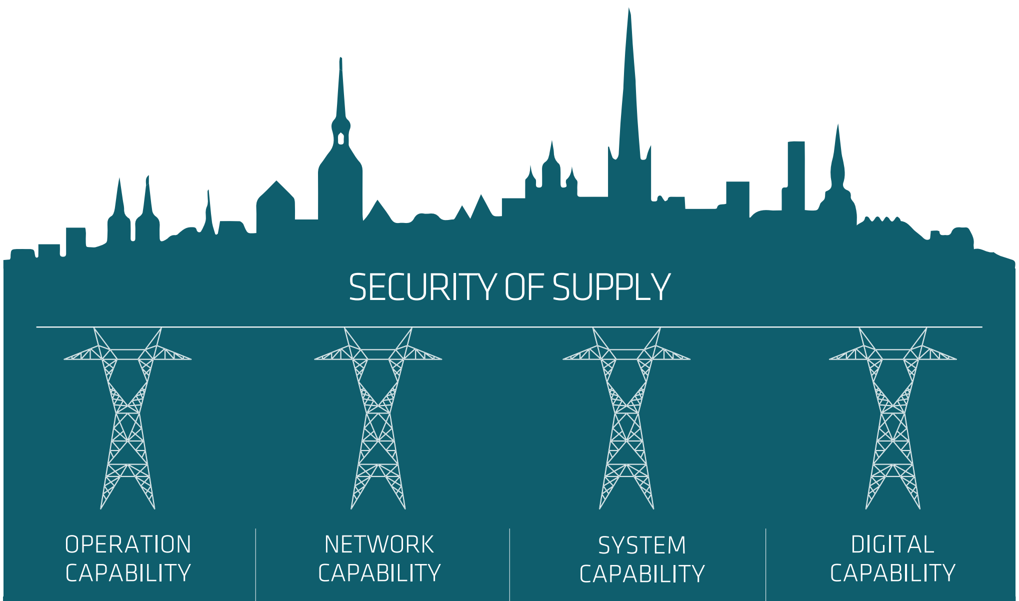
1 Summary

1 SUMMARY

Risks to security of supply have grown due to the Russian invasion of Ukraine.

This security of supply report gives an overview mainly of security of supply of electricity, but since the security of supply of electricity is partially based on security of supply of natural gas, this report will devote more attention to security of supply of energy more broadly. Elering assesses security of supply through four capabilities – system, network, operation and digital. More detailed assessments of each of these components are found in the thematic chapters.

It is important to emphasise that in giving as assessment of security of supply, our focus is above all on whether there is sufficient power generation and supply infrastructure and markets to ensure at all times the availability of energy. If the security of supply is ensured and the "lights are on", Elering does not pass judgment on whether the price on the market is right or wrong. But it is important for the offers from market participants to be justified and no one misuses their dominant position[1].



The capability to keep the electricity system as a whole operational and to cope with interruptions and malfunctions. Ensuring a sufficient amount of reserve capacity.	The capability of the transmission network to ensure that electricity reaches consumption centres; coping with the most common failures in the network and ensuring their rapid resolution. Local distribution networks are responsible for supplying electricity to the end consumer.	The capability to ensure electricity production along with sufficient foreign connections such that production and consumption are in balance in the electricity system at any moment of time.	Capability of automating and raising the efficiency of the company's business processes to ensure the everyday management and security of supply even in an environment with cyber threats increasing.

Figure 1.1 Ensuring security of supply through four components

Compared to the time of publication the last report, risks to security of supply have grown mainly due to Russia's invasion of Ukraine, which has led to fluctuations in energy prices, energy fuel supply disruptions and increased risk of damage to energy infrastructure by the Russian Federation. In addition, the dry summer has led to low hydro reserve levels in many places in Europe and technical problems at nuclear power plants have led to lower power generation capability, mainly in France and Sweden. The foregoing has in turn led to a rise in prices and general increase in insecurity in the run-up to the winter. Elering and partners from Estonia and neighbouring countries has actively addressed the risks behind the insecurity to ensure security of supply of energy in the country.

1 *Pursuant to Section 93 of the Electricity Market Act, exercise of market supervision is in the remit of the Competition Authority.*

1.1 OPERATION CAPABILITY

The probability that the Baltic electricity system may be unilaterally cut off from the Russian electricity system has grown substantially. To lower the risk, Elering and other TSOs in the region have developed the capability to join the continental European frequency area in a way least likely to affect power consumers.

Existence of operation capability means that the electricity system withstands possible disruptions, reliable operational planning and real-time management processes are in place and there is a sufficient number of reserve capacities.

The probability that the Baltic electricity system may be unilaterally cut off from the Russian electricity system has grown substantially. To lower the risk, Elering and other TSOs in the region have developed the capability to join the continental European frequency area in a way least likely to affect power consumers.

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. The probability that the Baltic electricity system may be unilaterally cut off from the Russian electricity system has grown substantially. Elering and Baltic TSOs have addressed mitigation of this risk and the first infrastructure projects for enabling accession to the continental European frequency area are now ready, e.g. the third electricity Estonia-Latvia connection and transformers in Lithuania that will enable connection with Poland. By 1 January 2026, the Baltic states' power systems will be synchronised with the continental European electricity system, by which time all of the projects necessary for standalone operation will have been completed. The transition from one frequency area to the other will be the greatest change from the standpoint of operation of the electricity system and a challenge that Elering is actively addressing.

Baltic TSOs have developed actions plans and reached agreements that will allow extraordinary synchronous operation with the continental European frequency area should the Baltics be cut off from the Russian electricity system. In addition, contracts have been signed with Nordic TSOs and Enefit Power for supplying rapid frequency reserves should the Baltics be cut off from the Russia electricity system. Since all investments in the project for synchronising with continental Europe have not yet been performed, this would involve extraordinary synchronisation, and all systems do not yet function in the required form. Electricity consumers will probably not detect any change, but due to the level of technical readiness, operating reliability of the electricity system will be lower than usual and disruptions more likely. In addition, it is necessary to actively use the Baltic states' power plants for managing the system and in certain situations there may be a need to limit electricity trading with the Nordics, which will mean additional expenses that will show up on consumers' electricity invoices. The need to use these activities will decrease as the investments planned for synchronisation near readiness.

To improve regional cooperation in the Baltics, the Baltic regional coordination centre (Baltic RCC) was established in Estonia. The main goal of regional coordination is to ensure a Baltic-wide picture for assessing operational reliability in the region 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. RCC-side coordination increases the efficiency of managing the electricity system, reduces risk of major accidents arising and reduces costs for the consumers through ensuring maximum cross-border transmission capacity.

After accession with the continental European frequency area, Elering uses 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.

Operation of the electricity system must take into account changes taking place in the electricity system, such as the increasing share of renewable energy (in the case of Estonia, the addition of solar and wind in particular), an increase of distributed generation in distribution grids, decrease in the share of dispatchable capacity, greater fluctuation of generation and consumption, addition of storage equipment and lower levels of the conventional technical parameters necessary for functioning of electricity system (such as inertia and short-circuit power). All of the above means that while to this point, the cornerstone of management of system adequacy was very predictable day-ahead operational planning process, now the capability of making informed real-time decisions based on processing of large number of various kinds of data has become more important. To increase this capability, Elering is upgrading its wide area monitoring, real-time monitoring and SCADA systems.

1.2 NETWORK CAPABILITY

- ***The reliability of the Elering network is very good.***
- ***Already today, the transmission network would support addition of at least double the current peak consumption capacities.***
- ***The Estlink DC cables are the most reliable cross-border electrical connections in Europe.***

From the standpoint of security of supply, it is important for the capacity and reliability of the high-voltage transmission network be sufficient for energy to be transmitted to the consumption centres . The Estonian transmission network 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 electricity to reach consumers without disruption.

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 proposal 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 very good. Since such a large number of requests for connection have been expressed, the expense of each successive connection is very high. 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. To this end, Elering has proposed to establish a new measure that imposes a fee for all network connection capacities that are not used for feeding electricity to the market within two years. This measure will create economic motivation for making actual use of idle network capacity.

2021 was a very good year for the transmission network in terms of uptime (99.9998%) and the trend of improved reliability is proved by the drop in the average number of outages over 10 years and average energy not served from the transmission network. The direct current cables administered by Elering are among the most reliable in Europe (Estlink 2 is ranked first in Europe and Estlink 1 is in fourth place). The good indicators of network reliability are the result of consistent efforts, well-administered investments and maintenance plans. A reliable domestic electricity system enables distribution grids to offer high-quality network service to end consumers. Reliable DC connections allow electricity prices in Estonia and Finland to be kept similar, which has a direct effect in helping to lower the Estonian end-consumers' spending on

2 *Local distribution networks are responsible for supplying electricity to the end consumer.*

electricity. Elering plans to update its asset management principles and move incrementally to a risk- and condition-based asset management, aimed at optimising the expenses on network administration without any concessions in terms of network reliability.

Elering will continue making large investments and planning for modernisation and optimisation of its network and maintaining reliability at a continued good level. 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. the pre-planning of additional connections has also started with Finland and Latvia.

In addition to the newly completed third 330 kV connection between Estonia and Latvia, the Balti-Tartu-Valmiera and Viru-Tsirguliina 330 kV high-voltage line will be renovated as part of the continental European frequency area synchronisation project. Synchronous compensators will be established at strategic points in the network, which are necessary for ensuring the stability of the electricity system and shut reactors will be installed to help maintain the electricity system's voltage in the allowed parameters.

To ensure future system adequacy and lower energy prices, it will be necessary to increase the connection capacity of additional generating capacities. Elering has an ongoing network investments programme to enable these steps. First and foremost, it will allow additional renewable energy generation capacity to be added to the grid fin western Estonia and on the islands. The investments are co-financed from the European Union RRF. As part of the investment programme, new 330 and 110 kV overhead lines will be built and existing ones renovated; a new 330/110 kV substation will be built in Lihula.

Considering the integration of the Baltic Sea region's electricity system and energy security as well as the EU's climate and renewable energy goals, it is necessary to develop and establish new and additional electricity transmission capacities in Estonia with our neighbouring countries. Elering and the Finnish TSO Fingrid have launched studies for establishing an additional Estonia-Finland connection (Estlink 3). On the basis of the study commissioned by Elering, the optimum starting point for the connection in Estonia is Paldiski. There is also an additional connection with Latvia being planned. In 2021-2022, a preliminary analysis of potential corridors for the fourth Estonia-Latvia transmission line 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 Kura peninsula in Latvia. The potential transmission capacity of both connections is 700-1000 MW.

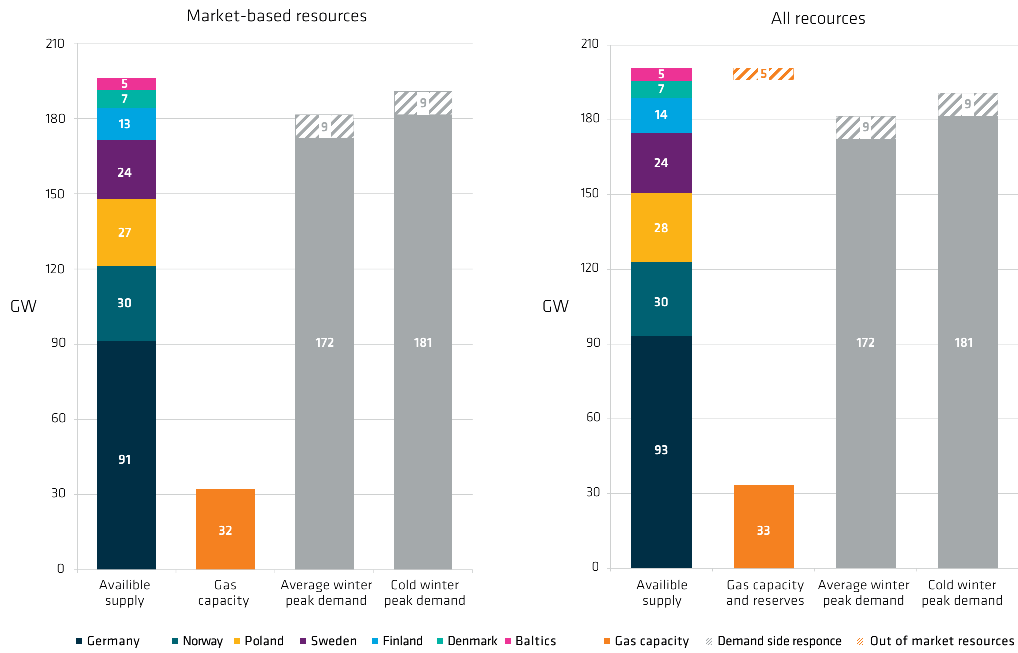
Due to the broader electrification of energy consumption, we can expect a faster growth of loads in Tallinn, Tartu and Pärnu compared to the rest of Estonia. Besides normal growth of capacities, we expect an additional increase in loads due to electrification of electrical transport, district heating and natural gas. It is planned to reinforce existing overhead lines and establish new high-voltage cable lines and substations in consumption centres. The planned investments ensure the network's capabilities to cover growing consumption in future as well, and further, also help to increase security of supply in these regions.

1.3 SYSTEM ADEQUACY

- ***There is enough electricity to cover peak demand, but compared to previous years, risks to security of supply have increased substantially, mainly due to Russia's invasion of Ukraine.***
- ***To speed up the increase in energy independence from Russia, it will be important to maintain and strengthen intra-European cooperation.***
- ***The probability of demand curtailment is low. Should risks become realised, there is a process that has been developed for restricting consumption in a way that poses the least impact for consumers.***
- ***In the case of economic unsustainability of old generation capacities and delays to new investments, state aid measures will have to be used to ensure the necessary generation capacities in the interim period.tagamiseks.***

We consider electricity system adequacy as constituting a situation where the expected electricity consumption is covered with the local generation, imports and demand response possibilities. Analyses of the capacity of the electricity system in future show that the Estonian electricity system will get by in this winter in a normal situation and consumers are guaranteed to have electricity. There is enough electricity to cover peak demand, but compared to previous years, risks to security of supply have increased substantially, mainly due to Russia's invasion of Ukraine. The Baltic region TSOs' analyses shows that the usable generation capacities in the region total 196 GW. At the same time, the expected winter peak consumption is 182 GW and, in a cold winter, the peak is 191 GW. That means that the reserve capacity for an average winter in the region will be about 14 GW and, for a cold winter, about 5 GW (figure 1.2). Considering the region's consumption volume, there is a low generation reserve and this will not allow a high risk to be realised simultaneously.

Figure 1.2
Winter generation capacities and peak consumption in the Baltic Sea region



Most significant risks to Estonian security of supply, which have significantly grown in the last year:

1. Extraordinary desynchronisation from the Russian electricity system.
2. Worsening of availability of natural gas and other fuels.
3. Shutdown of Narva power plants due to actions of Russian Federation.
4. Delay in completion of Olkiluoto 3 nuclear power plant and unproved reliability of the new plant. The new nuclear plant would replace electricity previously imported from Russia.

In addition to the increased risks mentioned above, the electricity system still entails risks that the electricity system can withstand under ordinary conditions but in combination with realisation of the above risks can lead to problems with security of supply.

- An extraordinarily cold winter that increases consumption of electricity (and natural gas).
- Low hydro reserves in the Nordics and unfavourable wind conditions in countries on the Baltic Sea.
- Extraordinary malfunctions affecting generation capacities and transmission capacities.

3 *Demand response is the voluntary response of consumption to electricity market price signals that usually takes place through shifting electricity consumption to periods with a lower price*

Even if there are no security of supply problems in the current winter, prices of energy carriers will likely be very high. There are no grounds to think that energy carriers will be cheaper than the previous winter, but there is also the potential for much higher prices should risks become realised. It is necessary to support consumers with prices so high but support measures that strip consumers of the motivation to react to high prices of electricity should be avoided. Consumers' price sensitivity and controllable consumption contribute to the reliable operation of the electricity system if consumers shift their consumption to a cheaper period. In addition, moving consumption from peak hours to other hours will help the person managing consumption save money and reduce the price of electricity for society as a whole.

Due to the decrease in import of natural gas from Russia, the risk that Europe will lack sufficient natural gas to meet demand has risen significantly. As to whether and how much natural gas deficit may be, that depends on how much of the Russian supply can be replaced with other sources, how extensive the transition to alternative fuels is and how high gas consumption will be. Pan-European analyses show that in an average winter, there will be enough natural gas in Europe for all consumers. If it is a cold winter; there may be a natural gas shortfall in Europe of up to 10%, but since all EU countries have agreed in a 15% reduction in gas consumption, no gas deficit is expected even in a cold winter.

The Baltic states and Finland imported a large part of the natural gas they consume from Russia. Based on gas TSOs' analysis, it is possible to cover gas demand without importing from Russia provided that an additional LNG terminal is built. The new LNG terminal construction is under way and it was planned for completion before the onset of winter 2022-2023. When the LNG terminal is completed, the region's supply channels will be sufficient for importing enough gas to cover gas demand. The forecast for gas consumption regressed to one year for this period is 42 TWh and the capacity of the LNG terminals and the Latvian gas storage totals 67 TWh. There is still a risk related to availability of LNG from the world market and its price.

Narva thermal power plants (Auvere, Balti, Eesti) require constant cooling water drawn from the Narva River and reservoir through cooling water channels. Half of the spillways along the Narva reservoir impoundment are controlled by Russia, which could in principle lower the reservoir level to a point where Narva power plants would experience problems obtaining cooling water. This is above all a significant risk in the case of extraordinary desynchronisation from the Russian frequency area. To mitigate this risk, the operator of the Narva power plants, Eesti Energia, has drawn up an action plan for implementing additional measures to ensure the capability of the generating equipment needed for normal operation of the electricity system.

In accordance with the plans known at the time of the report, Finland will start generating electricity at the 1600 MW Olkiluoto 3 nuclear power plant starting December 2022. Nevertheless, the launch of generation at Olkiluoto 3 has been postponed repeatedly and this risk must be taken into consideration in the run-up to this winter. The Olkiluoto 3 capacity plays a key role in replacing import of electricity from Russia. During the testing period, Olkiluoto 3 supplies electricity to the grid pursuant to the test plan, which has already made a considerable contribution to power generation. In addition, it is unknown what the operational reliability of the new nuclear plant will be. If Olkiluoto 3 goes down, it is still possible to cover peak demand in the region, but TSOs' reserves may be necessary for covering successive malfunctions.

To reduce risks, the region's TSOs have stepped up cooperation to coordinate maintenance of major generation equipment and connections so that a perfect storm of circumstances would not result in many key system elements being offline at the same time.

It is important to continue cooperation with neighbouring systems in the field of electricity trading as well. Due to the increased risks, a number of countries in Europe have signalled the need to limit electricity exports. This is a very concerning message and not in line with law on a European common energy market. To speed up the transition to energy independence from Russia, it will be important to maintain and strengthen intra-European cooperation. To ensure replacement of Russian energy imports, European countries' interdependence will grow for the winter of 2022-2023, but for this to happen good teamwork and dialogue must continue. With such a significant change taking place, the tensions are understandable and the desire to prefer the home country is understandable. In these conditions, European cooperation has been very good, including in the energy sector, where among other things agreement has been reached in reducing gas and power consumption in the winter of 2022-2023 as well as using energy companies' profits to support consumers.

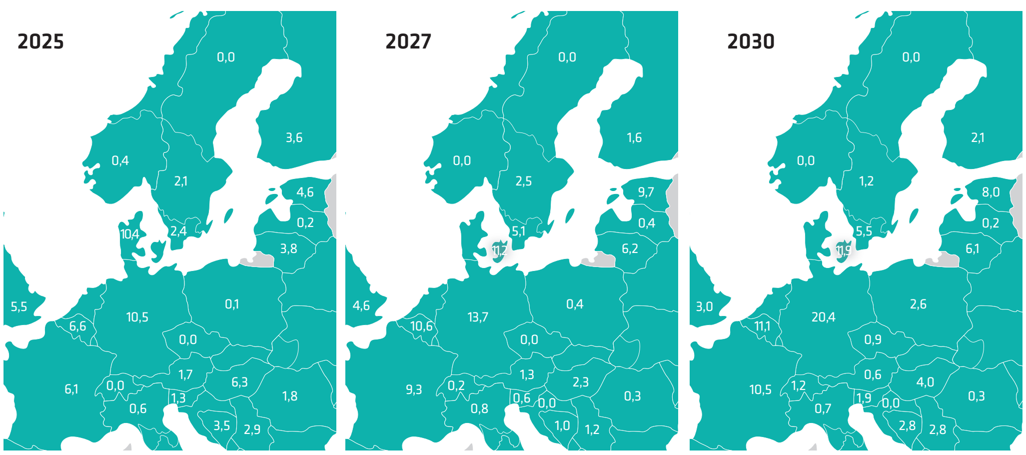
In Estonia, the government has decided to ensure 1000 MW generation capacity at Narva power plants at least until 2026. This is also consistent with the conclusions of Elering's security of supply analysis for the recent years, which found that Estonia must have at least 1000 MW controllable capacity in country.

Understandably, power consumers are most interested in the need for demand curtailment. Although there is a low probability of this occurring, if risks do become realised to such an extent that it is necessary to limit consumption to prevent the electricity system from shutting off, there is a process developed. Elering will communicate to Elektrilevi the necessary extent of curtailment and the latter will implement the limits. The rolling outages will be implemented to prevent interruption of service to critical consumers (such as vital service providers and general-interest service providers) and consumers will be rotated so that the outage for each individual consumer will be as brief as possible. People should think through how to cope in the event of a power outage lasting a few hours, similar to a situation that might occur during an autumn storm, which is common in Estonia.

Analyses with a perspective on the more distant future show that in spite of today's high energy prices, by 2027 Estonia's oil shale plants may no longer be competitive on the electricity market. This will bring the value of hours with limited service (LOLE) to 9.7 hours per year, which is higher than the reliability standard of 9 hours (figure 1.3). To ensure security of supply in Estonia, it will be necessary to have firm capacities in the extent of 1000 MW. To ensure security of supply even in this sort of future situation, Elering proposes to utilise the strategic reserve, as a result of which sufficient generating capacities for ensuring security of supply will be maintained in Estonia. New investments into generation capacities are currently being planned in Estonia. Interest in joining the electricity network is extraordinarily high and the planned capacities planned for the decade ahead outstrip Estonian peak demand severalfold. The Estonian government has set the goal of generating by 2030 enough renewable energy to cover the whole of electricity demand.

In this light, it is clear that there is potential and a plan for making investments into electricity generation. It will be important to ensure that sufficient generation capacities are added in a timely manner and if necessary, Elering will propose and apply state aid measures to make it happen.

Figure 1.3
Average numbers of loss of load expectation in Europe, based on the long-term system adequacy analysis



1.4 DIGITAL CAPABILITY

Elering will continue to reinforce the ability of IT systems to withstand cyberattacks and readiness for responding to incidents in order to ensure generation capacities.

The risk environment in the digital domain has also changed significantly. After Russia's invasion of Ukraine, uncertainty has increased along with the related potential risk to Estonian vital services. The invasion has also been accompanied by some waves of attacks against Estonian information systems, but the impact of these attacks has so far been less than expected. We continue everyday cooperation with movement institutions and partners to ensure that readiness for responding to incidents remains high. In 2021 and 2022, no energy was left unserved by the Estonian transmission system due to cyberattacks.

Management of the Estonian electricity system and updating the digital systems used for that purpose involves one of the greatest changes in history due to the process of joining the continental European frequency area. In joining the continental European frequency area, Estonia will have to start to manage the frequency of its electricity system. Both the primary and reserve management systems; system planning solutions, and stability and quality monitoring solutions will be updated as a result of the above. We will be carrying out the upgrade and renovation of management systems up to 2024.

Electrification increases the role of electricity in society and adds to the complexity of the system. We are moving toward an energy system with more participants, smart devices and data volumes. The changes taking place in the system are also faster. With increasing renewable energy capacities, the operation of the electricity system will have to take inverter-based equipment into account more than before. The inertia of such equipment is not so high and generation changes can be faster. Due to the volatile nature of renewable energy, more data move in a shorter timeframe and more operations are performed to manage it. This creates a need to have greater automatic control functions, which humans cannot optimally manage in real time on their own without digital solutions. As a result, there will be a growing need for smart and learning technologies to help electricity system operators control the electricity system in real time.

We are upgrading our data exchange platform Estfeed, through which data exchange takes place on the electricity and gas market for changing open supplier, transmission of 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 that their business processes work. Due to electrification, and the growth of renewable energy and dispersed generation, we are moving toward an energy system with more participants, smart devices and data volumes, with the changes taking place in the system are also faster. This creates a need to have greater automatic control functions, which humans cannot optimally manage in real time on their own without digital solutions. As a result, there will be a growing need for smart and learning technologies, which are based on high-quality consumption and generation data and Estfeed.

At the European level, the TSO community is developing the digital twin concept. This approach will make it possible to improve availability and usability of market participants' energy traders' generation and storage units and primary TSO network infrastructure data. It could become an important tool for increasing and raising efficiency of data-based analysis of the energy system's operation, planning, flexibility and economy:

2 Operation capability

- ***All of the activities needed for synchronising the electricity system are in the timetable, but until synchronisation with the continental European electricity system, the risks arising from being synchronised with Russia will remain in play.***

- ***In the event of extraordinary desynchronisation from the Russian electricity system, the Baltic electricity system is capable of rapidly synchronising with the continental European electricity system. Electricity consumers will probably not detect any change, but due to the level of technical readiness, operating reliability of the electricity system will be lower than usual and disruptions more likely. The situation will improve as the investments planned for synchronisation near readiness.***

- ***The Baltic RCC established in Estonia will intensify cooperation between the Baltic states in ensuring continuity and improve coordinated planning.***

2.1. SYSTEM ADMINISTRATION

2.1.1 Ensuring operational reliability of the electricity system and administration in real time

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

The electricity system operation process is carried out by dispatchers who have received the relevant training and whose knowledge is checked periodically and updated in emergency drills and at training courses. The 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 dispatchers to monitor transmission system equipment's location, status and measuring data and control their operation. Partners' and clients' data needed for managing the operation of the electricity system are also sent into 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 of the supply of electricity taking place in the transmission system. Thus, the control centre provides for redundancy of all of the most important equipment and employees. Dispatchers engaged in real-time management of the electricity system's operation must be capable of standing in for other dispatchers in the same shift, a SCADA backup server is in use, reserve communication channels and the technical functions of the operation centre are redundant. The control centre engages in close international cooperation with the European association of TSOs, ENTSO-E system operations committee (SOC) 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, cooperation in the field of control with Russian and Belarusian TSOs has been organised through the BRELL organisation, founded in 2001 (Belarus, Russia, Estonia, Latvia and Lithuania).

2.1.2 Estonian and Baltic region system stability

Besides planning stable operation, it is also important to assess the system's capability to continue normal operations after system problems – i.e. to maintain system stability. Three types of stabilities are distinguished in an electricity system:

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.
2. **Rotor angle stability** – Rotor angle stability means 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.

4 https://www.riigiteataja.ee/akt/12831412

For the purposes of assessing stability of the electricity system, static and dynamic stability are also distinguished, respectively 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[5].

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 sufficient inertia and short-circuit power in the system.

2.1.3 Estonian and Baltic regulation reserves

It is necessary to keep generation and consumption in balance at every instant in time in an electricity system, otherwise the system will generate more than is consumed or vice versa and the system frequency will start rising or falling compared to nominal 50 Hz. Should the frequency change significantly, electrical equipment may quit working. A disparity between generation and consumption is termed system imbalance and can be assessed as an energy balance for a given period and as an instantaneous value – the power balance.

2.1.3.1 Frequency management in synchronous operation with the Russia and Belarus electricity systems

The Estonian electricity system is part of a large 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 with three 330 kV transmission lines. 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, which allows 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 website.

In addition to voluntary regulation bids made on the Baltic regulation market, Baltic TSOs must ensure that there are firm reserve capacities available in any case to cover the imbalance that would be caused if a major generation unit or AC connection is switched off. The greatest unit capacity in the Baltics is the NordBalt DC connection between Lithuania and Sweden with a transmission capacity of a maximum 700 MW. That means that should NordBalt be cut off the Baltics must definitely have 700 MW of reserve capacities. Estonia's share of these capacities is 250 MW, which are maintained by Elering at Kiisa emergency reserve power plants. At the same time, if an imbalance occurs either due to a malfunction or change in consumption and generation, first the bids made on the regulation market are used up and only then the Kiisa emergency reserve power plant is used as the "power plant of last resort."

5 *M.Meldorf, J.Kiler, "Elektrisüsteemi stabiilsus", 2011*

2.1.3.2 Frequency management in the event of Baltic island mode

If the Baltic electricity system operates separately from other frequency areas, frequency needs to be regulated with Baltic electricity system power plants. 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.

During the 2009 tests of desynchronisation of the Estonian electricity system, local power plants' capacity was used to regulate frequency. In addition to power plants, both DC connections between Estonia and Finland also 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 Estonian electricity system. The NordBalt connection between Lithuania and Sweden has similar capability, as does the Lithuania-Poland connection LitPol Link. Island mode capability is a prerequisite for the Baltics to join the continental European frequency area.

The Baltic TSOs are constantly carrying out actions for better organising frequency management in Baltic island mode, 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.

2.1.4 Ensuring inertia in the Estonian and Baltic electricity system

Inertia is the ability of the electricity system to maintain a stable operating point even in major interruptions – until fast reserves are activated, thus staving off major frequency changes. To ensure frequency stability of the Baltics during accession to the continental European synchronous area, at least 17100 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. Currently, inertia in the Estonian electricity system is ensured by conventional power plant's generating equipment. At the same time, however, to be sure of the existence of the necessary quantity of inertia 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 1750 MWs of inertia, have the capability of regulating reactive energy in the range of ± 50 MVAr and support the system with 900 MVA short-circuit power. Short-circuit power is necessary in the system for the normal functioning of DC connections. The first synchronous compensator will be installed in Püssi substation and will be completed in the first half-year of 2023. The other ones will be ready by the end of 2024.

2.1.5 System re-electrification

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 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 proximity to the Estonian electricity system took place in summer 1984. As a result of this malfunction, the Latvian, Lithuanian and Belarusian electricity systems. 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 use the following to electrify and restart the Estonian electricity system:

- Estlink 1 black start;
- electrify the Estonian electricity system via lines between countries connecting neighbouring electricity systems;
- use generating equipment at Estonia's major power plants that are allocated for own use (local load) to electrify the Estonian electricity system;
- Elering's emergency reserve power plants at Kiisa.

2.1.5.1 Imposing constraints on consumption

Demand is limited only in the case of very serious emergencies. This option is used if there is a risk of permanent damage to important electrical equipment or a risk to reliability of the electricity system that cannot be eliminated by other means. In such cases, Elering command centre dispatchers organise the limiting of distribution grids and major clients pursuant to the limitation plan developed in advance. Should a need for limiting 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.

2.1.6 Elering's 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. To fulfil this obligation, Elering uses emergency reserve power plant I (110 MW) and II (140 MW). The total capacity of the two emergency reserve power plants is 250 MW, ensuring that Elering has 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 unexpected 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 on 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 for ensuring 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 for incrementally electrifying the Estonian electricity system, synchronising other power plants with the electricity system and restoring consumption

2.2 SYNCHRONISATION

2.2.1 Principles of joining the continental European synchronous area

It is planned for the Baltic states to join the continental European synchronous area in late 2025. By that time, the necessary investments will be made and the necessary processes agreed on. To join the continental European Synchronous Area, Elering and the other Baltic TSOs must fulfil the principles set forth in the Synchronous Area Framework Agreement – SAFA. The SAFA agreement can be read in detail on the ENTSO-E website. The Baltic TSOs operate in concert to implement the necessary changes in the system operation principles to ensure performance of the SAFA agreement. Below is a list of the SAFA agreement principles:

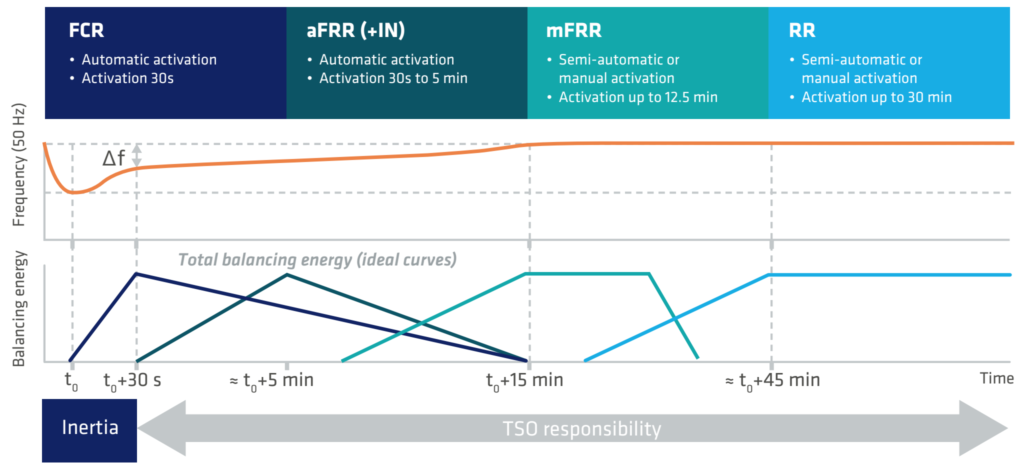
- The Load Frequency Control principles, which cover requirements and principles that TSOs operating in the continental European frequency area must adhere to. The main requirements of this policy cover:
  - TSOs' obligations in frequency control processes;
  - agreements between TSOs on operating and sharing/exchanging frequency control reserves;
  - determination of quantities of frequency control reserves;
  - 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. The policy describes the content of the supply plans to be coordinated, the frequency of transmission and data transmission standards.
- The Accounting and Settlement principles, which establish rules and principles for coordination of border measurement data and the process of maintaining frequency in the frequency control area, ramping period and the Methodology for calculating and determination of quantities and prices of energy exchange arising as a result of unplanned energy exchange.
- Coordinated Operational Planning principles, describing how cooperation between TSOs proceeds for coordinating state operational data to carry out regional reliability analyses and ensure the capability for controlling the system.
- Emergency and restoration principles, describing requirements for the TSO for ensuring operation of the system in a state of emergency, and what sorts of principles should be used to restore the system and what requirements this poses for the system.
- Data exchange principles, describing TSOs' data exchange principles nationally and between TSOs. Events and developments on reserve markets

2.2.2 Events and developments on reserve markets

2.2.2.1 Frequency control in the continental European electricity system

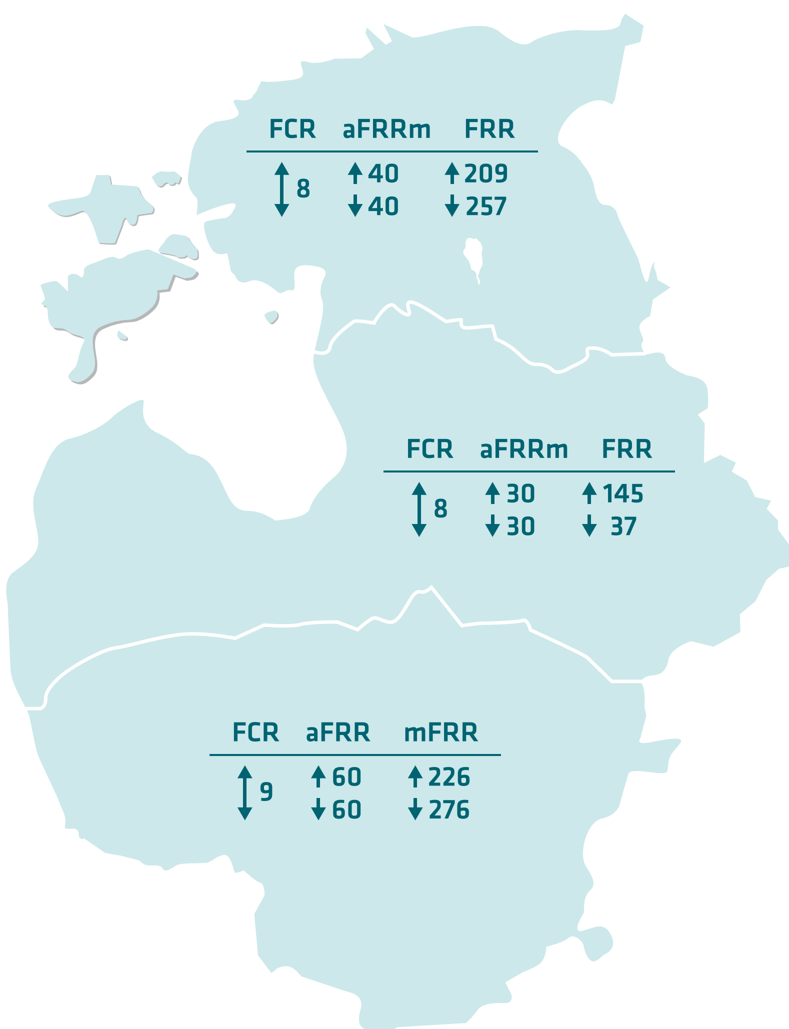
Upon joining the continental European synchronous area, the Baltic states' TSOs will have the obligation to start managing the Baltic AC balance in real time based on capacity, which would also take into account the balancing impact of different electricity systems. In addition, the Baltics will have 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 the system frequency to the nominal frequency. The technical requirements and quantities needed regionally are determined pursuant to the principle of European regulations. Figure 2.1 depicts the general sequence of activation of frequency control reserves and general technical principles.

Figure 2.1 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 an 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 what principles are 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 on Figure 2.2.

Figure 2.2 Assessed needs for frequency control capacities for 2026



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

Baltic TSOs carried out a market test of frequency reserves' capacities to evaluate whether they were available in sufficient quantity in the Baltics. All of the owners of generation equipment expected to be operated by 2025 and, based on their feedback, the reserves' volumes used in power plants took part in the test. The following conclusions can be drawn from the market test:

1. Individually, the Baltics do not cover the necessary frequency reserves, due to which it is important to create a joint reserve capacities' market. The greatest likelihood of a deficit is aFRR up and for Estonia mFRR down. Separately, states would be capable of ensuring only their own MFR up reserves.
2. In regard to existing reserve units, there may be situations with a shortfall of reserve capacities, and as a result additional investments by market participants will be necessary (there would be a deficit both in regard to FCR and FRR);
3. On the basis of the feedback obtained from market participants, the necessary reserve capacities would be covered in regard to reserve capacities' additional investments.

In addition, it should be noted that the existence of reserve capacities is strongly dependent on cross-border capability to share reserves (i.e. the transmission capacity used for reserve capacities) and usability of plants that provide greater reserve capacity. Should these factors appear, a deficit in reserves could emerge, which will increase the importance of additional investments.

2.2.2.2 The MARI and PICASSO European energy platforms

Elering and other Baltic TSOs are joining the MARI and PICASSO, which consolidates energy bids on European regulation markets, and are aimed at operating mFRR and aFRR energy bids, respectively. Market platforms collect all bids and optimise activation of reserves to achieve the greatest socioeconomic benefit. Baltic TSOs have received an exception to join the MARI platform at the same time as Nordic TSOs and no later than 24 July 2024. The Baltic accession to PICASSO will take place in Q4 2024.

2.2.2.3 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 other Estonian market participants who desire to offer reserve service to the Finnish TSO. Additional information for joining the project is available on Elering website.

As of Q2 2022, the Elering and Fingrid pilot has pre-qualified 40 MW up regulation and 65 MW down regulation aFRR capacities. The reserve equipment that took part in the aFRR pilot can be pre-qualified under simplified procedure for use of the Baltics and PICASSO aFRR markets.

2.2.2.4 Pre-qualification of frequency management 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 capability to offer the service. Technical pre-qualification is both a precondition for participating in future European energy platforms MARI and PICASSO markets and also gives the right to take part in the Baltic FCR, aFRR and mFRR capacity markets to be set up in future. The Baltic TSOs have developed common requirements for pre-qualification of frequency management reserves , based on which the TSO prepares state pre-qualification test plans.

7 *elering.ee/sites/default/files/2022-03/Harmonised%20principles%20for%20Baltic%20LFC%20reserve%20prequalification__updated_version.pdf*

The state documents on prequalification of frequency reserves at Elering can be found on the Elering website, based on which frequency management service providers can pre-qualify their assets for future frequency management 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 Development of solutions necessary for real-time management and operational planning of the electricity system

2.2.3.1 Updating the SCADA 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 electricity network and the assessment of network stability, which will require TSOs to extend existing or create new control systems. To join the continental European synchronous area, SCADA must include the following additional functionality

- Frequency Restoration Controller for controlling aFRR reserves
- Frequency Stability Assessment System
- Dynamic Stability Assessment System

To add these functions to SCADA, Elering has launched a SCADA update project. The project started in Q4 of 2021, where SCADA bidders were pre-qualified; in Q4 of 2022, one of them will be awarded the contract. The expected deadline for the new SCADA completion is Q4 2024.

2.2.3.2 Updating the wide area monitoring system

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 real-time measurement for monitoring and real-time analysis. To ensure the necessary data quality, a wide area monitoring system is used. It 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 has the following capabilities:

1. Conducting analysis of interruptions
2. Validation of data modelsSündmuste alarmeerimist;
3. Event alerts;
4. Monitoring phase angles and rotor angle stability;
5. Monitoring voltage stability;
6. Monitoring of damping of oscillations within and between regions

The wide area monitoring system's measurement data allow the SCADA network model to be made more detailed and the process of analysis more reliable. The wide area monitoring system gives the automatic control information systems more detailed measuring data on frequency and active power, which allow the requirements of synchronisation with continental Europe to be fulfilled.

Elering launched updating the capability of the wide area monitoring system in Q4 2021 and the broad monitoring system will be completed in Q3 2022.

2.3 EXTRAORDINARY SYNCHRONISATION WITH THE CONTINENTAL EUROPE ELECTRICITY SYSTEM

According to the assessment of the European Resource Adequacy Assessment (ERAA) prepared by ENTSO-E, Estonia meets the reliability standard in Europe. At the same time, ERAA assumes a functioning European electricity market and does not take in account black-swan events. As Elering's function is to ensure security of supply and balance of the electricity system at every point in time, Elering must also analyse extremely low probability events and find solutions for ensuring security of supply of the electricity system should such events occur.

Of the very-low-probability events, the most likely one is that a separate Baltic synchronous area will occur. A Baltic synchronous area can arise if the Baltic states' electricity systems go into island mode for some reason, meaning that they operate separately from the Russian and Belarusian systems. Besides possible technical reasons, Baltic island mode can also arise if Russia and Belarus unilaterally disconnect the Baltic states' electricity system from the current synchronous area. After the synchronisation of the Baltic electricity systems with continental Europe at the end of 2025, such a situation can occur if for some reason the AC connections between Lithuania and Pound are severed.

Should a Baltic synchronous area arise, Elering and the other Baltic TSOs will carry out actions for reconnecting the Baltic electricity systems to the larger synchronous area. The Baltic TSOs and the Polish TSO have prepared an agreement on extraordinary synchronisation, which ensures that the Baltic TSOs would be connected with the continental European frequency area under exceptional circumstances. As the result of extraordinary synchronisation, the Baltic TSOs should adopt the principles of operating the continental European frequency area as quickly as possible.
Starting in 2026, this would mean eliminating the cause of being disconnected from the continental European frequency area (for example, remedying a technical fault in the Lithuanian-Poland lines or substation equipment) and after that, restoring connections to the continental European frequency 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 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.

Since Baltic island mode is a low-probability event, the assumption for analysis of this situation is that DC connections between Estonia and Finland, Lithuania and Sweden, and Lithuanian and Poland are usable. For the Baltic synchronous area to function, all Baltic electricity systems must be capable of ensuring their electricity system balance i.e. 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 in 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 of too great a sudden load. Based on the current assessment, DC connections up to 400 MW can be used. This 400 MW also includes reserves that support frequency stability and which 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 in turn means that solar plant output cannot always be counted on for covering 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 capacities will be needed locally in Estonia in addition to the energy from the two EstLinks. 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.

The other very-low-probability events (such as a separate Estonian frequency area) is even less likely than a Baltic island mode and thus, it is also less likely that such an event will be of long duration compared to a Baltic island mode scenario. At the same time, the existence of 1000 MW in firm generation capacities in Estonia allow to resolve problems in ensuring supply of electricity to Estonian consumes should such events occur.

2.4 FOUNDING THE BALTIC RCC

2.4.1 What is the 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 independence of the RCCs from TSOs and state interests, ensuring a neutral view with regard to the entire region.

In cooperation with Latvian and Lithuanian TSOs, a Baltic RCCs 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 TSO, 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 and employees to ensure joint cooperation and broad-based knowledge in all fields.

2.4.2 What functions RCC fulfils

The purpose of the RCC is to organise coordination of regional activities between TSOs as needed for 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 provides certain operational planning functions that to this point had been performed by the TSOs. At the current time, the Baltic RCC provides Baltic TSOs five main services, which were taken over form 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). By using a single network model to model network states in order to find potential malfunction situations where normal operation of the network could be disrupted, and corrective actions to be used for eliminating the situations.
- 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.

The list of services to be provided by Baltic RCC in future will expand, since electricity internal market regulation 2019/943 sets forth up to 16 different services that RCCs must or may provide to TSOs. To define services' content and requirements in a unified manner, the Baltic RCC and TSOs and other RCCs take part in developing methodologies for the service.

2.4.3 What does the RCC mean from the standpoint of regional functioning of the electricity system

The main goal of regional coordination is to ensure a Baltic-wide picture for assessing operational reliability in the region 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.

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

2.5 ENSURING OPERATIONAL CONTINUITY OF THE SUPPLY OF ELECTRICITY AS A VITAL SERVICE

2.5.1 Provision of vital service

Pursuant to the Emergency Act, supply of electricity is a vital service and arrangements must be made for its continuity. The continuity of vital services is the capability of the vital service provider to function consistently and capability to restore consistent functioning after a service interruption. Elering, being the TSO, is one of the vital service providers as defined by the Electricity Market Act. The quality and security of supply of electricity is one of the most important bulwarks of a functioning modern society. Any longer-term interruption of the power supply causes noteworthy damage to individuals and the economy. The main goal of Elering's activity as a TSO carrying out the functions of electricity TSO is to provide the required network service, thereby also ensuring the functioning of the electricity system as a whole. The Estonian electricity system connects the power plants, network operators and power consumers located in Estonia to each other. The Estonian electricity system is part of the large BRELL system that works in synchronisation and which is also comprised of neighbouring countries Latvia and Russia connected to Estonia via AC lines and in turn, their neighbours Lithuania and Belarus. Synchronous operation means that all of the electricity systems that make up the united system have the same electricity frequency. In addition, Elering also relies on the Kiisa emergency reserve power plant (hereinafter referred to as EBPP) rated at a total 250 MW to ensure electricity system control capability; the power generated by the EBPP does not take part on a daily basis in the electricity market. The plant is used only in emergency situations in exceptional cases; if there are no market-based possibilities and a technical test launch taking place once a month during one hour. Via the 330-110 kV electricity network, Elering transmits electricity from domestic and neighbouring countries' electricity producers to clients who have connected to the transmission system (at voltages of 6-330 kV), export of electricity generated by electricity producers and transit, within the limits of technical possibilities.

2.5.2 Risk scenarios

Main risk scenarios

One of the main risk scenarios in the risk analysis compiled by Elering is the unplanned disconnection of the Baltic electricity system from the Russian united energy system. Such an isolation is most likely to occur as a result of a political decision by the Russian Federation. To this point, the frequency of the united electricity system has been regulated by Russian power plants, after disconnection the Baltic states would have to get by on their own after being disconnected. Generation coupled with cross-border power flows must precisely equal consumption at every point in time in the electricity system, only then does the electricity frequency remain stable. If any major piece of generation equipment (or network element) should go down unexpectedly (medium probability of occurrence, usually several dozen times a year) the electricity system must have enough rapid-reacting generation capacities combined with the possibility of shutting off consumption in order to rapidly compensate for the influence of the switched-off equipment (see 2.2.2.). The electricity system must also have enough inertia that should slow the speed of the frequency drop in the case of a malfunction and thereby give time for responding to fast reserve capacities (see 2.1.4). If capability for this is lacking, frequency drops rapidly and below a certain limit, automated equipment will disconnect a majority of consumers and if this is not sufficient, the whole electricity system may shut down. Baltic TSOs have agreed on action plans for such situations. Immediately after disconnection from the Russian electricity system, the Baltic electricity system will operate for a brief time in what is known island mode. That means that the electricity systems of the three Baltic states are not in synchronous connection with any larger electricity system. At that time, the risk of the abovementioned frequency dropping and the electricity system switching off is highest; because the Baltic electricity system is a very small system and any larger accident in the network or key power generation equipment may cause a major frequency change. Baltic TSOs have entered into an agreement with the Polish TSO under which the

Baltic electricity system is connected during 6-12 hours through Poland with the larger continental European electricity system. After that, the risk of a frequency drop and the system switching off will fall significantly as the impact of a single accident on the frequency is much less when working in synchronisation in a large system.

In addition, Russia has the possibility of affecting power flows in the Baltic electricity system and in the worst case, it can create power flows through the Baltics that overload cross-border and intra-Baltic lines. For Baltic TSOs, this could mean the need to limit electricity trading with EU countries, extraordinary activation of reserve capacities or disconnection of lines due to congestion which could lead to a widespread malfunction in the Baltic electricity system.

Elering carries out the investment plan with the goal of reducing the impact of realisation of the abovementioned risks. The action plan for hedging these risks and restoring normal functioning should they realise is set out in the recovery plans of Elering and other Baltic TSOs.

The following risks are dealt with in the risk analysis as additional risks:

- Shutdown of the electricity system or a part thereof due to a cyberattack. Action plans have been prepared for mitigation of risks. Also, preventive measures for forestalling and resolving cyberattacks.
- The switch-off of several key network elements due to natural phenomena. Natural phenomena such as strong wind, ice and forest fire may over a relatively short span render multiple important transmission lines non-operational. To hedge the risks, the most important network elements have been made redundant and backed up. Should equipment be damaged, the state of the equipment shall be assessed and an emergency maintenance or replacement of the equipment shall be performed.
- Deficit in generation capacities due to extraordinarily cold weather. The electricity system can function only if the generation of electricity is equal to consumption at every moment in time. This is a technical condition that exists independent of national borders. As long as deficits in a given country are covered with surplus generation in another and there are adequate cross-border transmission capacities, the electricity system of none of the countries is at risk. The risk to the functioning of the electricity system occurs if there is extraordinarily cold weather in winter and all the electricity systems in the region lack enough generating capacities to cover the system's total consumption. To hedge risks, the corresponding action plans and procedures have been prepared, which help to ensure critical power supply in the case of a power deficit.
- Power outages due to technical condition of equipment. Unlike general construction, defects and deficits in electrical equipment are not usually detectable with the naked eye: Defects may be in automated equipment, primary equipment housing (such as in transformers). Defects in automated equipment or their configuration may in the worst case lead to needless disconnection of equipment, while damage to transformers, switches etc, can lead to short circuits as a result of which automated equipment will switch off the damaged primary equipment and power outages may occur. To hedge the risks, the most important network elements have been made redundant and backed up. Should equipment be damaged, the state of the equipment shall be assessed and an emergency maintenance or replacement of the equipment shall be performed.

2.6 OVERVIEW OF SYSTEM OPERATION CAPABILITY

2.6.1 Winter period 2021/2022 (November - February)

Temperatures in winter months 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 2.2 degrees warmer.

Average net consumption decreased by 1% in winter 2021/2022 compared to the winter period the year before to 1082 MW and 1552 MW was measured as peak consumption. The average power output grew by about one-third compared to the year before, to 863 MW. Maximum and minimum output was measured at 1491 MW and 255 MW. Maximum generation in wind farms connected to the Elering network was measured at 308 MW.

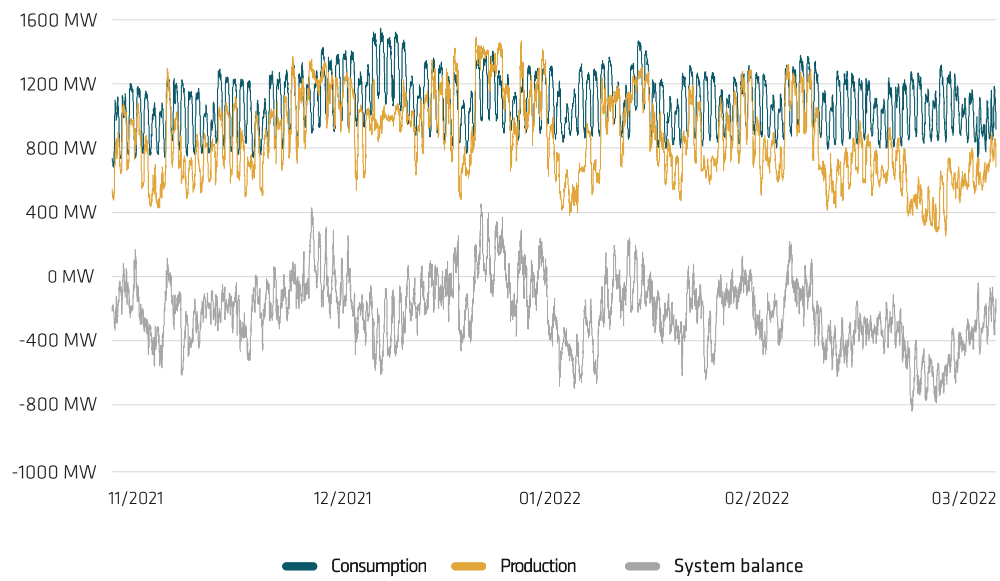
In spite of the increase in output, the electricity system still imported electricity for the bulk of the time – local generation covered domestic demand during 14 per cent of the time on average. The electricity system imported an average of 219 MW.

Summary of the Estonian electricity system operational parameters in 2021/2022 winter period (1.11.2021-1.03.2022) is set forth in the following table (Table 2.1) and the figure (Figure 2.3).

Table 2.1 Operational parameters of the Estonian electricity system in winter 2021/2022.

	Value, MW	Time interval / Time
Estonian maximum net consumption	1552	7.12.2021 10:55-11:00
Estonian minimum net consumption	677	1.11.2021 03:55-04:00
Estonian average net consumption	1082	1.11.2021 00:00 - 1.03.2022 00:00
Estonian maximum net generation	1491	20.12.2021 10:20-10:25
Estonian minimum net generation	255	22.02.2022 03:55-04:00
Estonian average net generation	863	1.11.2021 00:00 - 1.03.2022 00:00
Maximum generation of wind farms connected to the Elering network	308	27.11.2021 19:30-19:35
Estonian maximum export	452	21.12.2021 01:10-01:15
Estonian maximum import	-838	17.02.2022 14:25-14:30
Estonian average export	-219	1.11.2021 00:00 - 1.03.2022 00:00

Figure 2.3 Consumption, generation and import/export, Estonian electricity system in winter period 2021-2022.



2.6.2 Summer period 2022 (May-August)

The air temperature in the summer period 2022 proved warmer than the multi-year average – the temperature measured in June and August was two degrees warmer than the multiyear average, while the one degree cooler in May.

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 1328 MW, 10% higher than last year.

The electricity generation indicators grew significantly compared to the past period. On average, 832 MW of electricity was generated and the maximum generation was 1658 MW. Compared to the previous year's summer period, these indicators proved 46 and 60 per cent higher, respectively. The maximum solar plant output was 381 MW and the maximum output from wind farms was 202 MW.

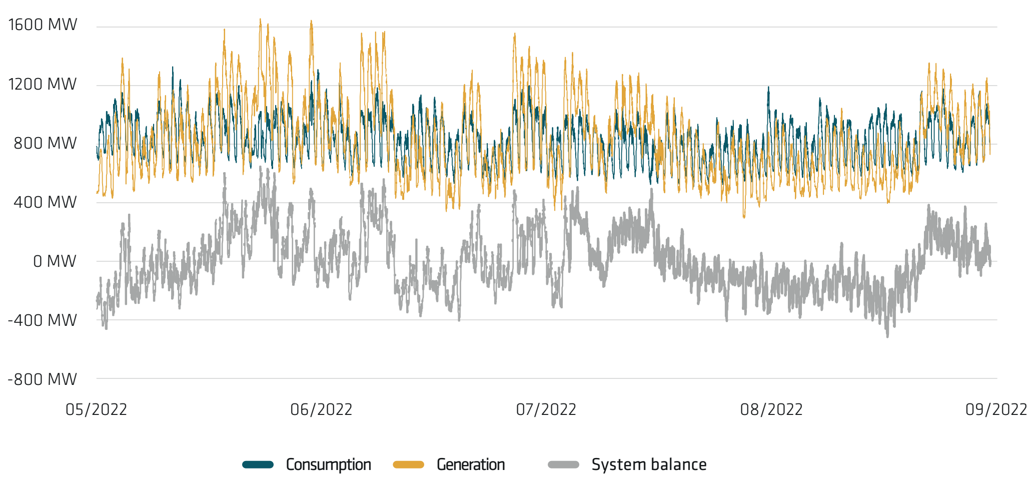
While last year's summer period saw the Estonian electricity system cover consumption with local generation only 3% of the time, in summer period 2022, local generation covered demand in 46% of hours. The maximum export in the summer period was 650 MW and maximum import was 520 MW. On average, the Estonian electricity system was a net exporter by 8 MWh.

Summary of the Estonian electricity system operational parameters in 2022 summer period (1.05.2022-1.09.2022) is set forth in the following table (Table 2.2) and the figure (Figure 2.4).

Table 2.2
Operational parameters of the Estonian electricity system in the summer period 2022.

	Value, MW	**Time interval / Time**
Estonian maximum net consumption	1328	11.05.2022 11:10 - 11:15
Estonian minimum net consumption	513	24.06.2022 04:30 - 04:35
Estonian average net consumption	824	1.05.2022 - 1.09.2022
Estonian maximum net generation	1658	23.05.2022 13:15 - 13:20
Estonian minimum net generation	295	29.07.2022 03:10 - 03:15
Estonian average net generation	832	1.05.2022 - 1.09.2022
Maximum generation of wind farms connected to the Elering network	202	3.05.2022 14:50 - 14:55
Maximum generation of solar plants	383	5.08.2022 13:00 - 14:00
Estonian maximum export	650	23.05.2022 13:15-13:20
Estonian maximum import	-520	17.08.2022 21:35-21:40
Estonian average export	8	1.05.2022 - 1.09.2022

Figure 2.4
Consumption, generation and import/export, Estonian electricity system in summer period 2022.



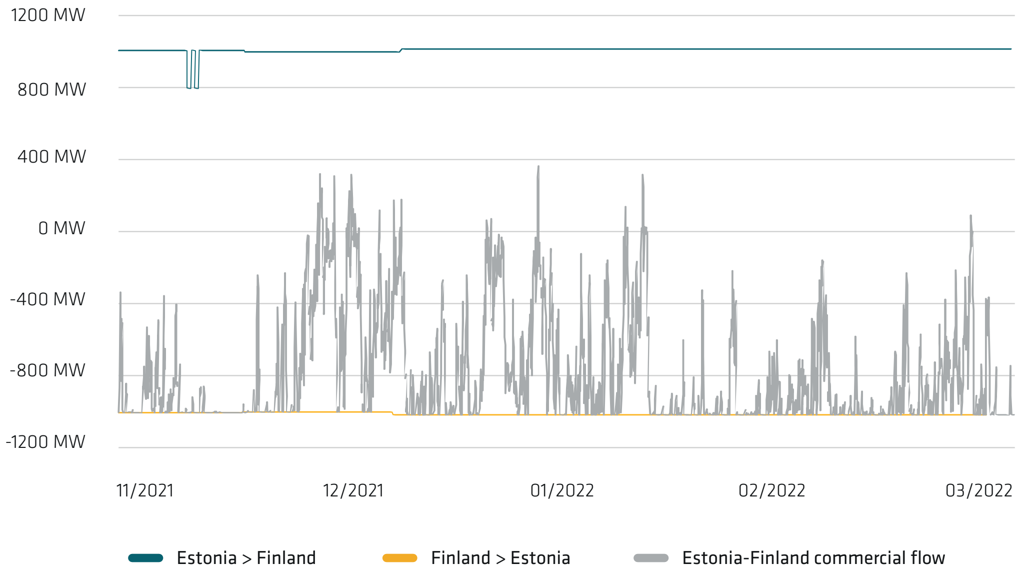
2.6.3 Maximum cross-border transmission capacities (TTC) in the winter period 2021/2022

In the 2021/2022 winter period, electricity transport flowed from Finland to the Baltics 98% of the time, achieving the maximum transmission capacity limit 37% of the time.

In the Estonia-Finland cross-section transmission capacities were limited in both directions at a maximum 15 MW, which was applied for the purpose for ensuring reliability of the Estlink 2 submarine cable . This constraint was imposed until 9 December. On 10-11 November, constraints were applied at 218 MW in connection with maintenance work at Kiisa substation . Cross-section transmission capacities and physical energy flows were listed on figure 2.5.

The average flow on the Estonia-Finland cross-section increased by 18% compared to the same period last year, being an average of 795 MW (last winter period, the average flow was 675 MW).

Figure 2.5 Power flows in the Estonia-Finland cross-section in winter period 2021/2022.

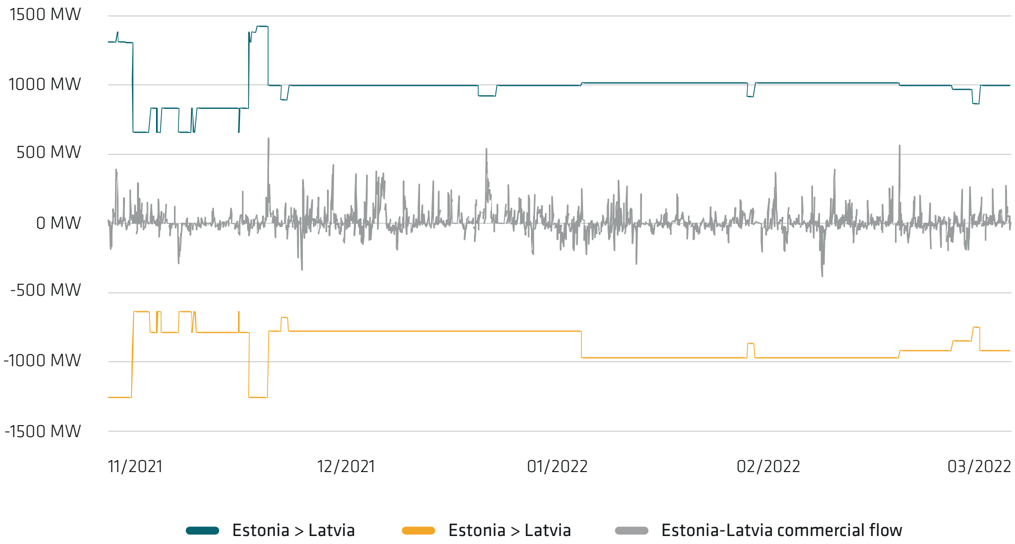


The average flow between Estonia and Latvia shrank significantly compared to sane period last year, being an average of 13 MW (last winter period, the average flow was 213 MW). The number of hours when the transmission capacity from Estonia to Latvia was in maximum use was just 1. Power flowed from Estonia to Latvia 49% of the time, 51% of the time in the other direction. The maximum transmission capacity in the winter period in the Latvian direction was 1424 MW and in the Estonian direction, 1259 MW. The minimum transmission capacity in the Latvian direction was 660 MW and in the Estonian direction, 640 MW.

The transmission capacities for 2021/2022 in the Estonia-Latvia direction and total power served during the winter period are shown on Figure 2.6.

8 *https://umm.nordpoolgroup.com/#/messages/fb5f6681-3cc6-4345-bbb2-80f690311f1a/3*
9 *https://umm.nordpoolgroup.com/#/messages/892c2f1c-8258-4d2b-823e-2a0b811c02d6/2*

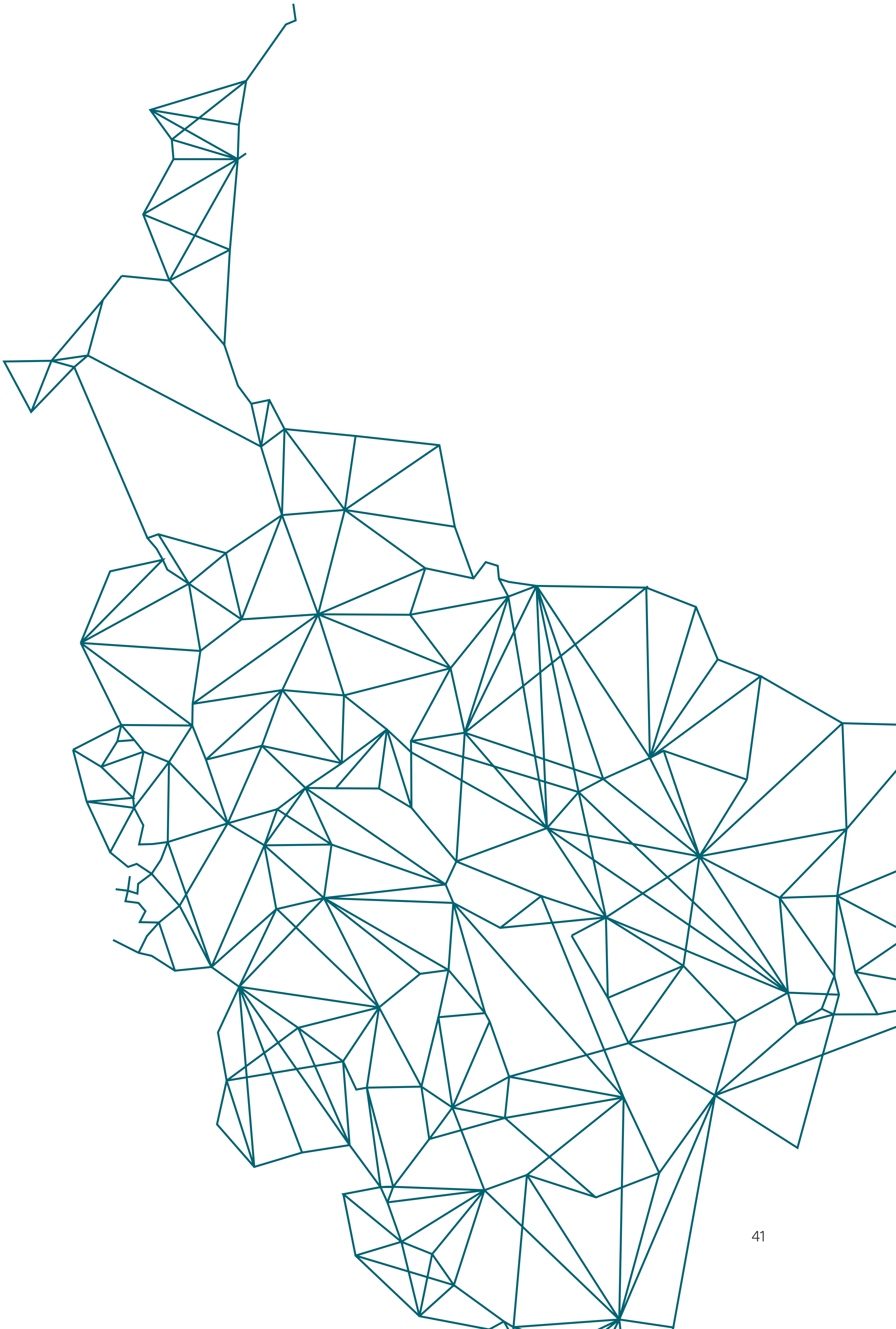
Figure 2.6
Power flows in the Estonia-Latvia cross-section in winter period 2021/2022.



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 8 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). 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 overloaded and there is a risk of a transmission cut. To avoid it, countertrading is used in cooperation between TSOs. No countertrading was performed last winter period. 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



3 Network capability

- ***The power grid has remained stable in the past year and Estonian DC connections are among the most reliable in Europe.***
- ***By autumn 2022, there are about 5000 MW of network connections in the transmission network, which significantly exceeds Estonian peak consumption and further connection capacities will be added to the grid.***
- ***Elering's largest network investments that will be made in the years ahead are related to the central Europe synchronisation programme and the EU recovery package and we have started pre-planning of additional connections with Finland and Latvia.***
- ***Elering has developed investment plans to be ready for the growth of load centres' consumption in connection with electrification of energy consumption.***

The power grid's capability is part of security of supply and impacts electricity not served. An indicator that describes power grid's capability and can be directly transposed to security of supply is the grid's reliability, and one of its quality indictors is likewise energy not served. Today's transmission grid's reliability can be considered good and it has been on an upward trend. Extraordinary events have a very great impact on electricity not served. Unfortunately, it is not possible to predict extraordinary events and they cannot be used in forecasts. Major faults are handled separately by Elering, carrying out a thorough analysis. On the basis of analysis results, additional measures and precautionary measures are applied where necessary to prevent potential future extraordinary events. Aspects of reliability are detailed in the Network reliability section.

The efficiency of the grid and capability of joining the grid are not measurable directly with energy not served to end consumers; rather, certain standards and principles have been developed which help fulfil the objective of security of supply. The chapter on the grid development plan describes prospective investments into the grid. In planning investments into the grid, the point of departure has been the balancing point between enough resistance to failure-proofness pursuant to the standards in the Grid Code and the European system administration rules. Every future investment is weighed carefully with an attempt to find solutions to ensure adequate security of supply at lower cost to society. The lowest cost to society takes into account grid investment and operating costs. The chapter on the optimal grid development plan summarises investments related to synchronisation with continental Europe and domestic grid development plans. The optimal power grid cannot be regarded in future without flexibility. Today ways are being explored for replacing or postponing grid investments with an adequate quantity flexibility service (control of consumption and generation). Through flexibility it is theoretically possible to achieve maximum use of limited network resource, where the congestion margin is replaced in a guaranteed amount with controllable capacity regulation service. The principle of flexible control is described in the chapter below. Today, flexible capacities have already joined Elering and in the event of congestion, they can be down regulated according to principles agreed with clients.

The capability of joining the network ensures that new generating equipment is connected to the grid for generating the necessary electricity and the grid could be attractive to new generation equipment. Ultimately, electricity comes from a power plant and balance between electricity generated and consumed must be ensured in the shorter or longer timeframe. The possibilities for joining the grid and the concept of joining flexibly is described in detail in the chapter on capability for joining the grid. One problem area in the context of capability for joining the grid is so-called phantom power plants, for which connection points have been built and for which capacity has been reserved but which actually do not contribute to security of supply. Such a situation keeps actual generation equipment from being connected to the grid, ones that would be prepared to do so now but due to the network resources reserved for phantom power plants under contract, the new generation equipment joining would have to perform additional network reinforcements. This in turn makes the project non-profitable and the development of new generation equipment comes to a halt. The situation of new generation capacities joining can in fact be considered good, considering the fact that the options for joining the Estonian power grid outstrip Estonian peak demand severalfold. It is important for power plant projects to actually be realised.

The map below gives an overview of investments made into the Estonian transmission network in 2022-2031. The map shows only large-scale investments such as the construction of new lines/substations and the renovation or replacement of existing lines with cable lines. A more detailed investment plan can be found on the Elering AS website. The investment plan is expected to be updated in January 2023. In addition to investments approved by Elering, the map shows potential development prospects. The investments shown on the map fall into the following categories.

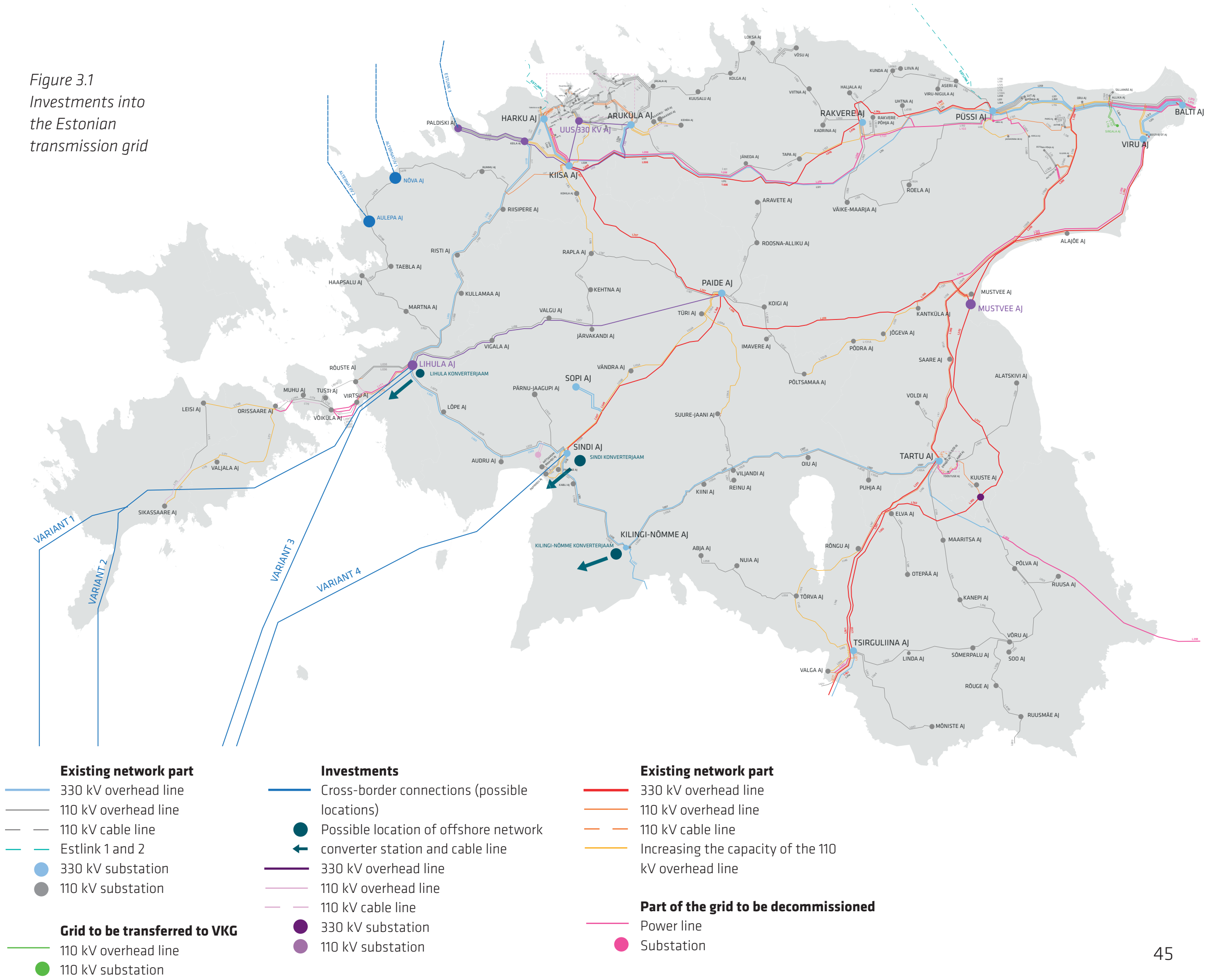
- **Investments for synchronisation with the continental Europe frequency area**
  The construction of the third Estonian-Latvian 330 kV interconnection has been completed and the renovation of the north-south 330 kV overhead lines is now in progress. The investments are discussed in more detail in chapter 3.1.1.

- **Cross-border network investments**
  The third Estonia-Finland and fourth Estonia-Latvia interconnection are in the planning stage, and so is the Baltic Sea offshore grid development project. The investments are described in chapter 3.1.2.

- **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 3.1.3.

- **Internal Estonian grid developments**
  These are investments made to ensure reliability, efficiency and sufficient transmission capacity of the power grid and are described in chapter 3.1.4.

Figure 3.1
Investments into the Estonian transmission grid



3.1.1 Synchronisation with continental Europe frequency area

The precondition for synchronisation is the reinforcement of the Estonian north-south 330 kV grid and existing Estonia-Latvia 330 kV overhead lines and the third Estonia-Latvia 330 kV overhead line between Tallinn and Riga. The third Estonia-Latvia connection is ready and in operation. The completion of the third connection meant a significant increase in security of supply of the Estonian and Latvian electricity system and capacity between Estonia and Latvia.

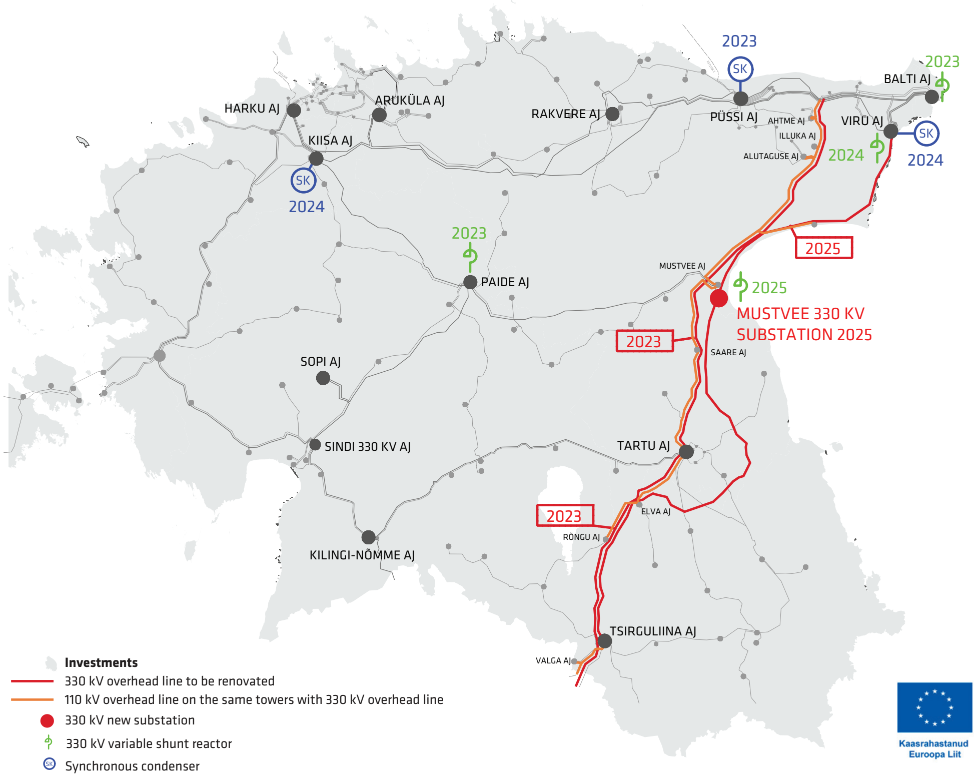
The reconstruction of the existing Balti-Tartu-Valmiera and Viru-Tsirguliina 330 kV overhead lines has begun. During renovation of the Balti-Tartu and Tartu-Valmiera overhead lines, the Ahtme-Illuka, Illuka-Alutaguse, Alutaguse-Mustvee, Mustvee-Saare, Tartu-Saare, Tartu-Elva, Elva-Rõngu and Tsirguliina-Valka 110 kV overhead lines that run in parallel line corridors with them will be installed in part on the same towers. The tower sharing allows environmental impact to be reduced and savings on maintenance costs on corridors and lines. The Mustvee 330 kV new substation is also being constructed, and the Viru-Tsirguliina and Viru-Paide 330 kV overhead line will be connected to the new substation, resulting in Viru-Mustvee, Tsirguliina-Mustvee and Paide-Mustvee 330 kV lines. There is an agreement for 75% funding from the EU structural funds in order to carry out these investments.

Another significant precondition for synchronisation is ensuring the minimum necessary inertia and short-circuit power, which guarantees the frequency, voltage and rotor angle stability of the electricity system in both normal situations and during disruptions. 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 for the system with short-circuit power and where necessary, reactive power reserve. The synchronous condensers will be installed at Viru, Püssi 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 of generation capacities in north-eastern Estonia and the decommissioning of lines connecting Estonia 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 condensers and voltage control equipment are shown on the figure below:

Figure 3.2
Power lines which will be renovated in the synchronisation project, synchronous compensators and voltage control equipment



3.1.2 Cross-border network investments

Baltic Offshore Grid Initiative

In 2020, Elering and other TSOs on the Baltic littoral (Finland's Fingrid Oyj, Sweden's Affärsverket Svenska Kraftnät, Denmark's Energinet SOV, 50 Hertz Transmission GmbH in northern Germany, Latvia's AS Augstprieguma tīkls and Lithuania's Litgrid AB) signed a joint declaration of intent to launch cooperation to develop a joint offshore energy grid . The Baltic Offshore Grid will be an energy transmission network that joins the Baltic Sea countries and wind farms to help achieve climate and energy policy goals throughout the region. One of the outputs of the Baltic Offshore Grid is to ensure energy security of supply and security in the region through better grid connections. As part of cooperation between TSOs involving other relevant organisations and companies (such as ENTSO-E, the European Commission) various research and analysis will be conducted for development of the Baltic Sea energy network.

Estonian offshore grid

Considering the integration of the Baltic Sea region's electricity system and energy security as well as the EU's climate and renewable energy goals, it is necessary to develop and establish additional cross-border connections with our neighbouring countries. This need is clearly signalled by the price difference that has grown in the last year (2022) between the Estonian and Finnish bidding areas, where the price difference has at times increased by a factor of several hundred . The reason for the increased price difference is wind energy investments made into Finland and transmission capacity bottlenecks for exporting that energy.

EstLink 3

In June 2022, the Estonian and Finish TSOs Elering and FinGrid signed a memorandum of mutual understanding in which they agreed on launching a joint work process for establishing a third electricity connection between the two countries (Estlink 3) (also known as Estonia's north-oriented offshore grid). Under the agreement, joint activities will cover technical questions, the necessary investments and relevant time schedule. The planned capacity of the third connection is 700-1000 MW. The new connection is expected to be in operation by 2035. To find the best possibilities for a line corridor on land and at sea, Elering conducted a preliminary study for the Estlink 3 corridor. As a result of the work, it was found that the optimal solution was to build the third interconnection from Paldiski. The analysis also included Lääne County substations at Nõva and Aulepa , but the corridors were longer compared to the Paldiski one- shorter corridor from Paldiski means a lower cost of construction. The additional advantage of the Paldiski-Keila corridor was the aspect that the corridor would precisely follow the detailed plan for the Keila-Paldiski 330/110 kV high-voltage line . In the course of the detailed plan, the locations of the lines were reviewed in detail and agreement was reached with land owners and offices in the most critical locations.

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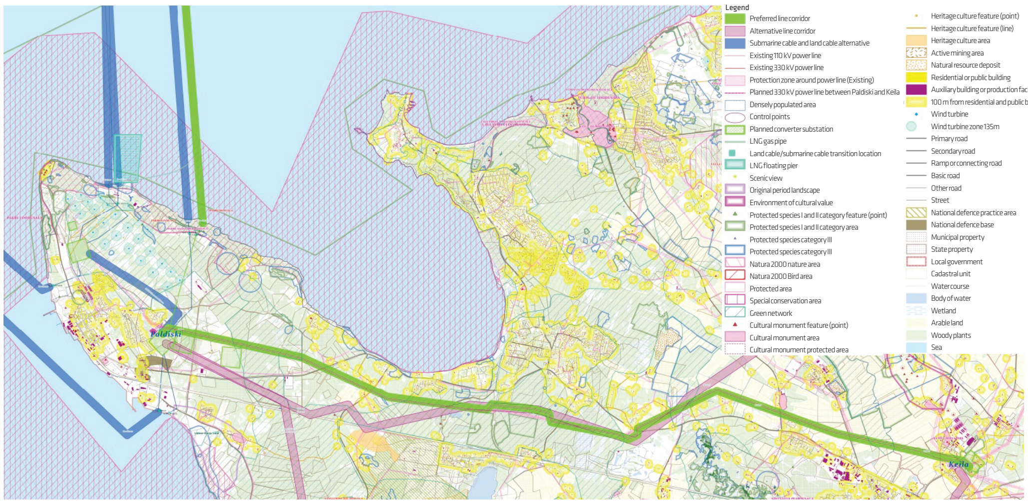
10 *https://elering.ee/en/tsos-agreed-strengthen-cooperation-future-offshore-grid-baltic-sea*

11 *NordPool: where e.g. on 16 August 2022 at 23:00, the price of electricity in Estonia is 500.96€/MWh and in Finland it is 13.75€/MWh. https://www.nordpoolgroup.com/en/Market-data1/Dayahead/Area-Prices/ALL1/Hourly/?view=table,*

12 *Harku Municipality Council and Lääne-Harju Municipality Council have, respectively with decision 94 of 26 November on 2020 and decision no. 60 of 31 August 2020 initiated the detailed plans for the Keila-Paldiski 330/110 kV power line's corridor and an strategic environmental impact assessment. The plan is expected to come up for approval in summer 2022.*

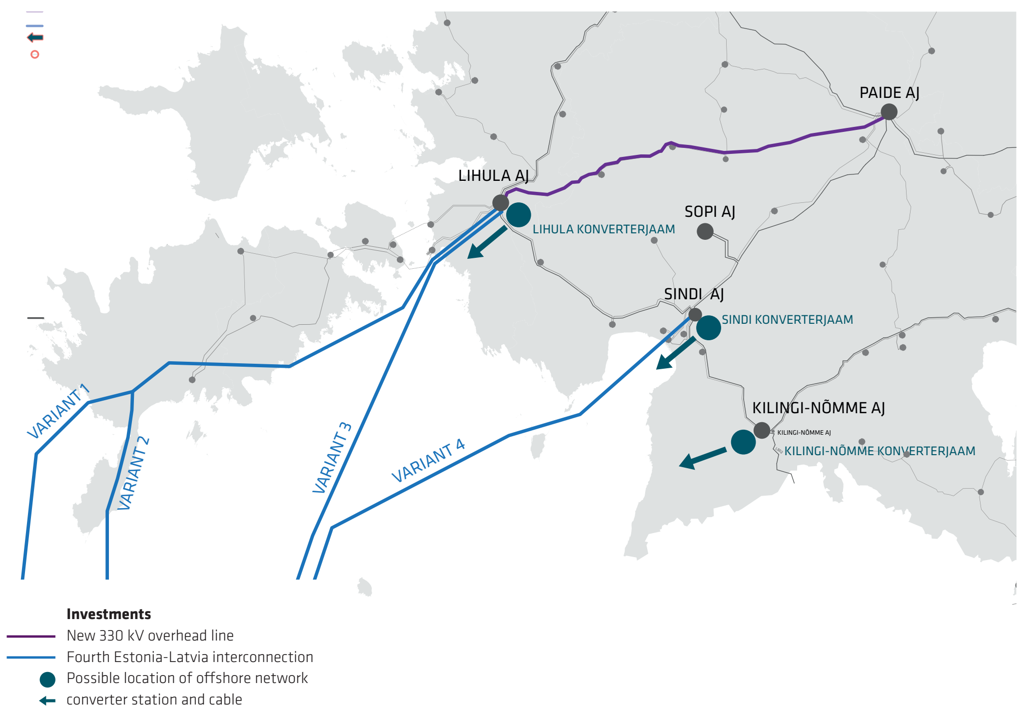
Figure 3.3
Possible Estlink 3 corridor



4th Estonia-Latvia interconnection

Elering is developing additional cross-border connections with Latvia as well (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 , 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 Estonia-Latvia 4th transmission line corridor and the exact technical solution are not yet in place as of now, as it depends on the assessment of environmental impacts and the design development. In 2021-2022, a preliminary analysis of potential corridors for the fourth Estonia-Latvia transmission line 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 Kura peninsula in Latvia. The figure below depicts the options for the fourth connection and possible locations of substations in the existing transmission system and the new Lihula-Paide 330 kV overhead line (which is necessary for reinforcing the existing transmission system).

Figure 3.4.
Possible corridors for the 4th Estonia-Latvia connection



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

3.1.3 Reinforcements of the western Estonian and islands‘ power grid – investments made through European Commission’s Recovery and Resilience Facility funding

The package of investments described in the chapter is co-financed from the European Union recovery package (RRF).

Historically, generation of electricity has been centred in one region of Estonia – Ida-Viru County. The suitable locations for renewable energy generation (wind farms, solar plants) are located Estonia-wide, above all in western Estonia, which has the weakest grid in terms of connecting 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 transmission 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 carry out the investments from 2022 to July 2026.

The entire length of the 330 kV Kiisa-Paide line will be reconstructed to increase the transmission capacity. The Viru-Paide 330 kV overhead line will be dismantled from Viru substation up to the future Mustvee substation and from Mustvee substation to Paide substation, a new line will be built (the corridor will decrease by ca 85 km) in other words Viru-Paide line will be replaced by a Mustvee-Paide line.

A new 330/110 kV substation will be built in Lihula. With the new substation, the lengths of the 110 kV lines will decrease in the western region, and as a result negative impacts caused by voltage drop will ease, security of supply will increase and the integration between 330 - 110 kV grid 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 transmission flows, especially on weaker lines.

Lines that supply power to the islands from the mainland will be renovated in order to increase security of supply, from Lihula substation to Rõuste and Virtsu substations. A new 110 kV overhead line must be built to connect Rõuste and Virtsu substations. On the island of Muhu, part of Võiküla-Orissaare and Rõuste-Muhu-Leisi overhead lines are on the same towers- to avoid power cut off from the mainland in case of a tower failure, Võiküla-Orissaare line will be built on separate towers from Rõuste-Muhu-Leisi overhead line. In order to increase the security of supply in the Sikassaare area, the lines connecting the Sikassaare substation will also be built on separate towers. To decrease environmental impacts and increase weatherproofing, the segment of overhead line across the Väike vain strait causeway has to be converted to cable line. The existing overhead line across the Väinatamm causeway passes through a bird migration corridor and since the line passes over the sea, there is greater than usual icing risk and more exposure to winds. To increase the capacity; the existing 110 kV lines in the western Estonia and islands region will be improved – the distance between ground and phase wires will be increased.

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

Figure 3.5
Investments that allow increasing the capacity of the western Estonian and islands' dispersed and renewable power grid

14 *https://www.consilium.europa.eu/et/policies/the-eu-budget/long-term-eu-budget-2021-2027/*

3.1.4 Estonian domestic network development plan

3.1.4.1 Tallinn and Tallinn vicinity

Tallinn is the area with highest electricity consumption in Estonia 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 land cable and overhead line (cable part is ready)
- L012 Harku-Kadaka land cable and overhead line (cable part is ready)
- L001 Harku-Veskimetsa partial land cable and overhead line
- L002 Harku-Veskimetsa partial land cable and overhead line
- L009 Partial replacement of Kopli-Paljassaare overhead line with land cable
- L010 Partial replacement of Paljassaare-Volta overhead line with landcable
- L8108 Construction of Iru-Viimsi 110 kV land cable
- L087 Replacement of Harku-Tabasalu overhead line with land cable

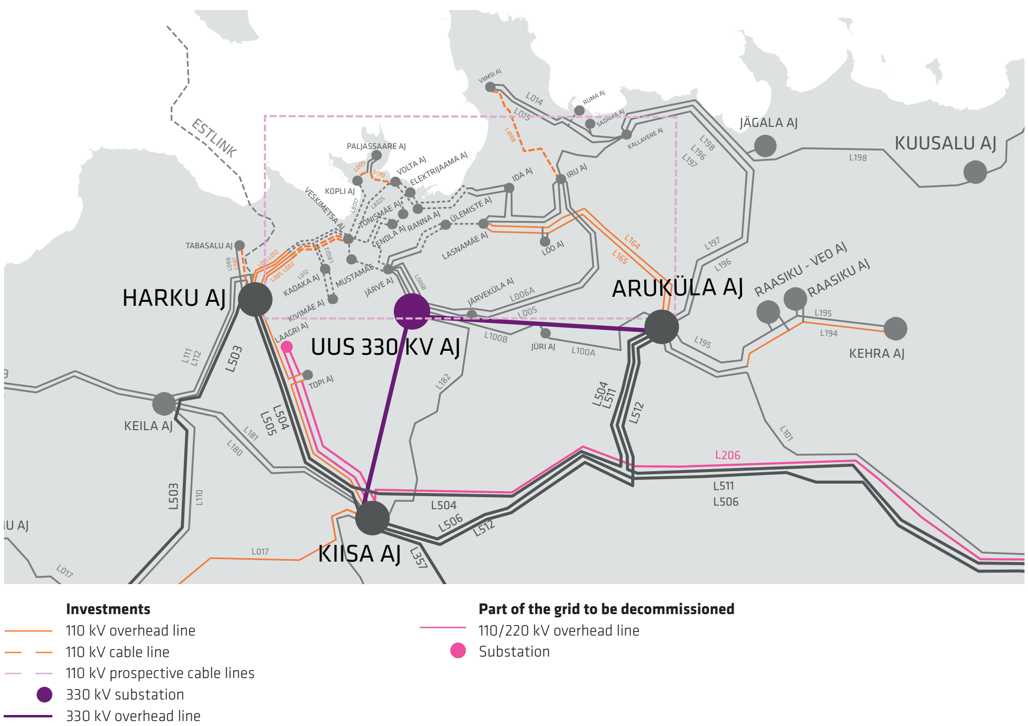
The Veskimetsa-Kadaka L8023, Veskimetsa-Kopli L8017 and Veskimetsa-Volta L8025 land cables are completed.

Of the 110 kV overhead lines, the Aruküla-Lasnamäe 110 kV overhead lines and Kehra-Aruküla lines will be established on separate towers so that the Kehra substation supply would be ensured on two single-circuit lines. 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. Keila-Rummu and Kiisa-Ellamaa 110 kV overhead lines will be joined to form the Kiisa-Rummu overhead line. The only 220 kV line in the Estonian electricity system, L206 Püssi-Kiisa, is being dismantled.

The grid in Tallinn is currently not sufficient to transmit increasing capacities and therefore an additional 330/110 kV substation must be established in Tallinn (exact location is not yet known). Two 200 MVA 330 kV power transformers are planned in the substation and the substation will be connected to new 330 kV lines to the Kiisa and Aruküla 330 kV substations. The 110 kV lines connecting 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 land cables. New land cables will also be clarified in the course of further analysis.

The new substation yields 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 a majority of the load and will reduce power flows from the directions that are likely to be congested.

Figure 3.6 Development projects in the Tallinn region of the grid

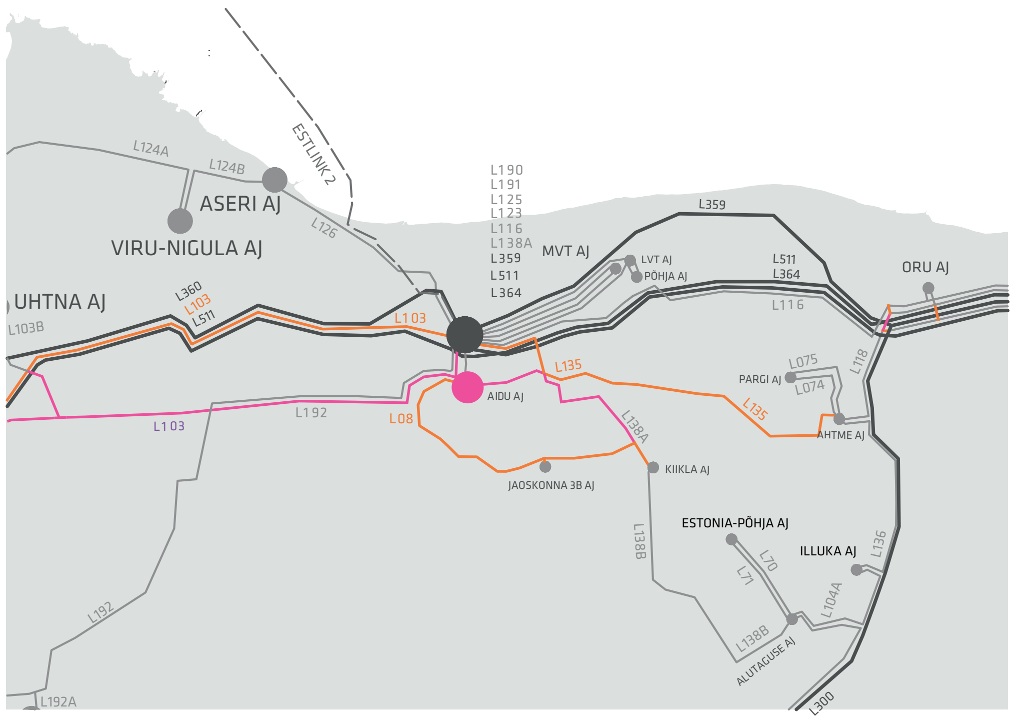


3.1.4.2 North-eastern Estonia

Power flows will change in the north-eastern Estonian region, since after Estonia's synchronisation to 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 reconfiguration will take place in the Püssi-Ahtme-Alutaguse 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 is built from the Jaoskonna 3B substation to Kiikla substation. Transmission capacity will be increased on the Aidu-Jaoskonna 3B and Ahtme-Püssi 110 kV lines. In future, the Aidu 110 kV substation will be decommissioned. It is planned to renovate the 110 kV Rakvere-Püssi line in the dismantled 220 kV Püssi-Kiisa overhead line corridor.

Figure 3.7 Development projects in the Tallinn grid region



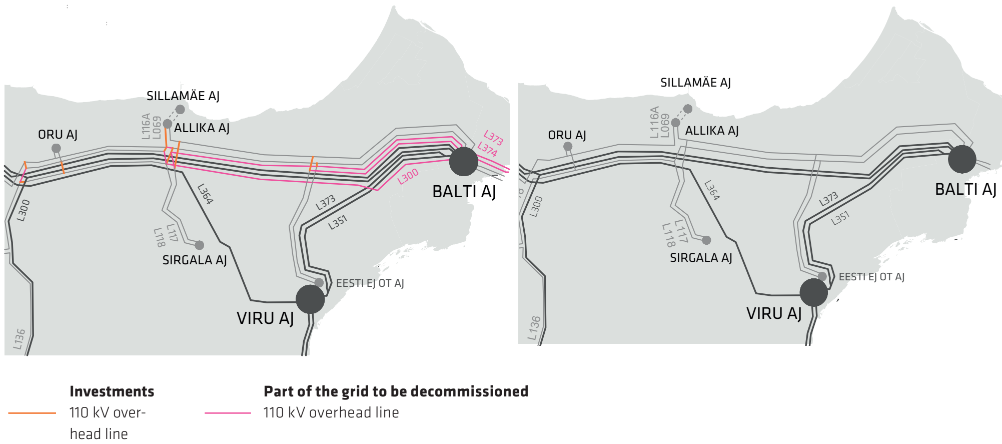
Investments
110 kV overhead line

Part of the grid to be decommissioned
110 kV overhead line
Substation

The configuration of 110 kV lines from the Balti substation is also planned to be optimised (figure below). In the course of optimisation, 110 kV lines will partially be dismantled from Balti-Sirgala and Balti-Eesti OT to Balti substation. The 110 kV line Balti-Püssi will be disconnected from tower M98 (near Allika substation) and connected to the 330 kV line segment freed up in the course of renovation of the Tartu-Balti 330 kV overhead line and the Ahtme-Balti line to be created will pass in the Tartu-Balti 330 kV overhead line corridor until the remaining part of Tartu-Balti. The Ahtme-Balti 110 kV line will run on the same towers with the Tartu-Balti 330 kV line up to Ahtme substation. When renovating Tartu-Balti 330 kV overhead line, the option of shared towers will also be used for the Ahtme-Illuka, Illuka-Alutaguse and Alutaguse-Mustvee 110 kV lines.

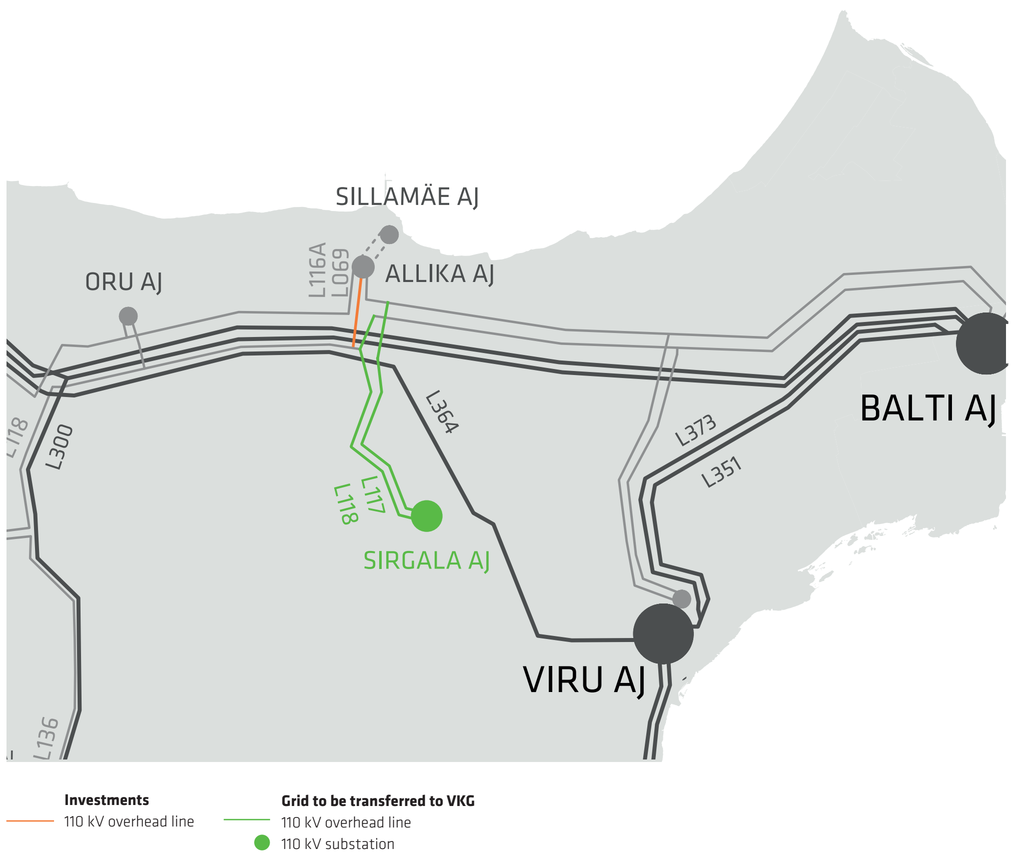
The existing lines Balti-Püssi and Sirgala-Ahtme will be joined in parallel in the part where they are on the same towers, resulting in the creation of the Püssi-Allika line. The first feed of the substation Eesti OT is connected as a branch to the Allika-Balt line, and the second feed is connected as a branch to the Ahtme-Balti line. Oru substation's first feed will be connected as a branch to the Allika-Balti line and the second feed as a branch on the Ahtme-Balti line.

Figure 3.8
Reconfiguration of Balti-Allika-Ahtme grid region



In addition to the reconfiguration of the power grid planned for the region, it is possible to additionally reduce the 110 kV grid if VKG abandons its connection pointin Sirgala substation and the Sirgala 110 kV switchgear is decommissioned. The lines connecting Sirgala substation will be transferred to VKG. VKG will switch to 110 kV connection point at Allika substation and build at Allika substation new medium-voltage switchgear and 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 land cable to Oru substation.

Figure 3.9
Optimised scenario of the Balti-Allika-Sirgala grid region

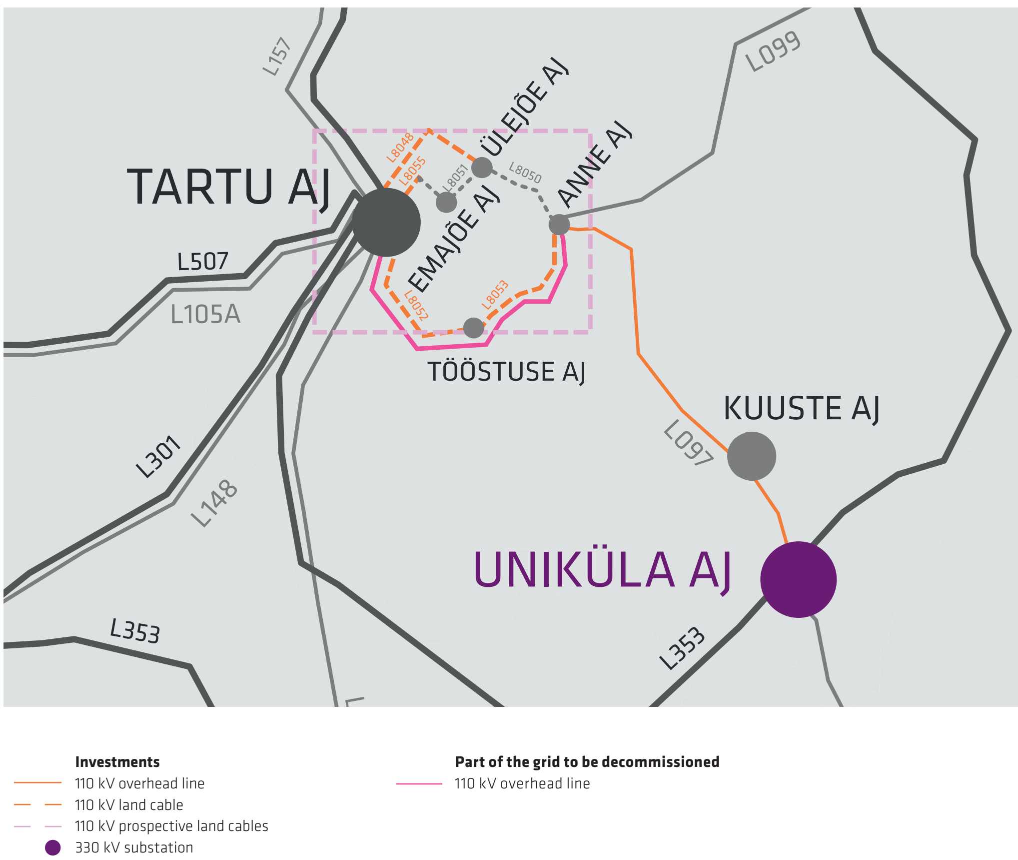


3.1.4.3 Tartu region

Estonia's second largest city 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 buried lines. In addition, it is planned to establish a new 110 kV Tartu-Ülejõe land cable and replace the Emajõe-Tartu overhead line part with a cable line.

Tartu's security of supply is currently provided by just one 330 kV substation and to eliminate the risk of security of supply, it is planned to build an addition al 330 kV substation which will ensure Tartu city's power if Tartu substation is disconnected. The new substation is planned at the Uniküla area. The substation will have one 200 MVA 330 kV power transformer and 353 Viru-Tsirguliina 330 kV overhead line and L141 Kuuste-Põlva 110 kV overhead line will be connected to the substation (in other words, a Viru-Uniküla-Tsirguliina 330 kV line and Kuuste-Uniküla-Põlva 110 kV line will be formed). As part of the project, the Anne-Kuuste-Uniküla 110 kV overhead line will be renovated with 2x240 mm2 phase wires, which will allow the entirety of the load in the Tartu city area to be transferred in case of Tartu 330/110 kV substation malfunction. The Viru-Tsirguliina 330 kV overhead line will be renovated as part of the continental European frequency area synchronisation project.

Figure 3.10
Development projects in the Tartu grid region

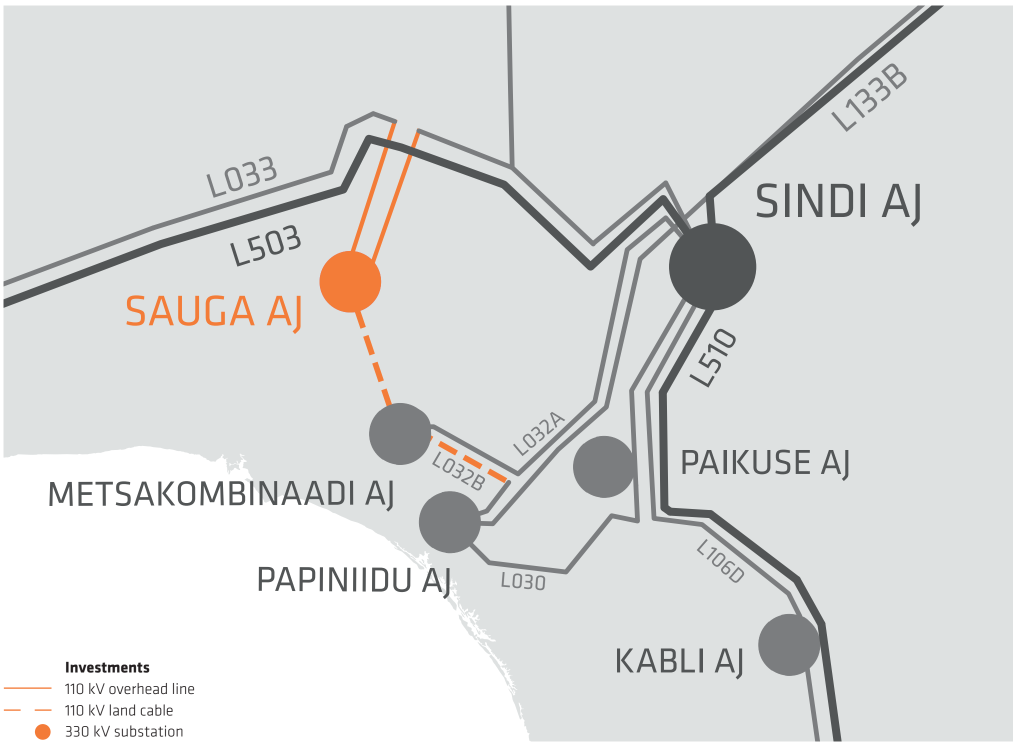


3.1.4.4 Pärnu region

After Tallinn and Tartu, Pärnu is also one of the highest electricity consumption regions in Estonia. Besides normal growth of consumption, 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. Also a problem is security of supply – the Pärnu power supply is ensured from Sindi 330 kV substation. 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 Metsakombinaadi substation via the new 110 kV land cable.

In addition it is planned to renovate the Metsakombinaadi-Papiniidu 110 kV overhead line to land cable in the section where Metsakombinaadi-Papiniidu L032B is located on the same towers with the Sindi-Metsakombinaadi L032A overhead line.

Figure 3.11 Development projects in the Pärnu region



3.2 NETWORK CONNECTION CAPABILITY

3.2.1 Available connection capacities

Available connection capacities are the capacities in the case of which it's 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 best overview on changes in available connection capacities can be found in the available connection capacity app.

The grid connection capacity is increased by the investments made in the ensuing ten years, described in the previous chapter, into synchronisation, the offshore grid and the western Estonia and islands network investments programme. The following figures compare the available connection capacity now and in five years and after the realisation of investments provided for in the Elering investment budget.

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 offer 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 very 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. To this end, Elering has proposed to establish a new measure that imposes a fee for all network connection capacities that are not used for feeding electricity to the market within two years. This financing measure will provide incentive for freeing up or making use of the capacity of old power plants removed from use or new generation equipment not built for some reason.

Figure 3.12
Distribution of available production-oriented connection capacities of 110 kV substations

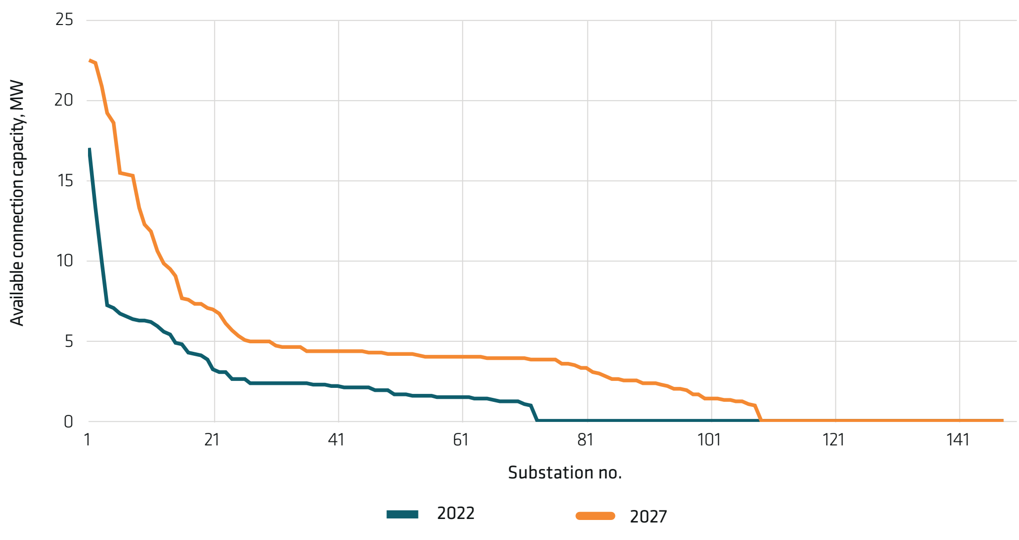


Figure 3.13
Distribution of available demand-side connection capacities of 110 kV substations

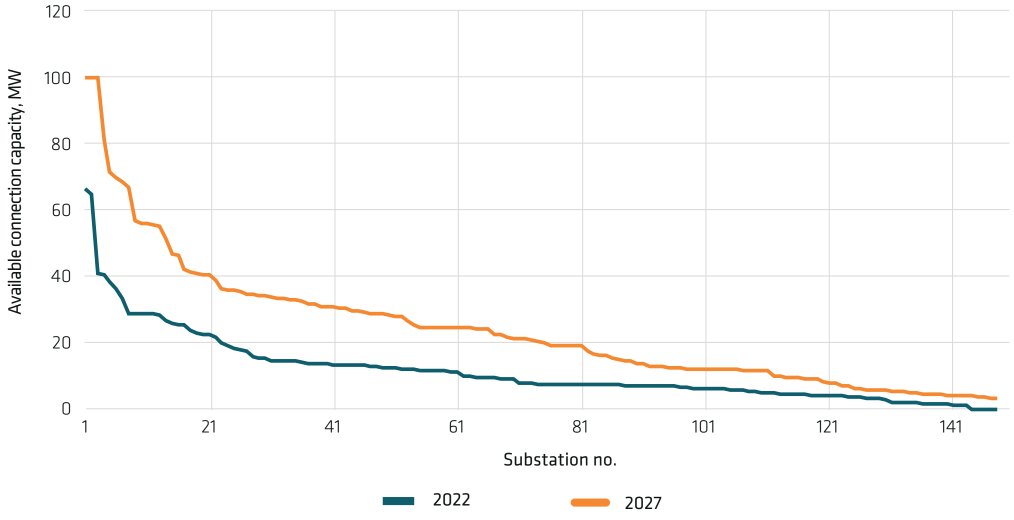


Figure 3.14
Distribution of available generation-side connection capacities of 330 kV substations

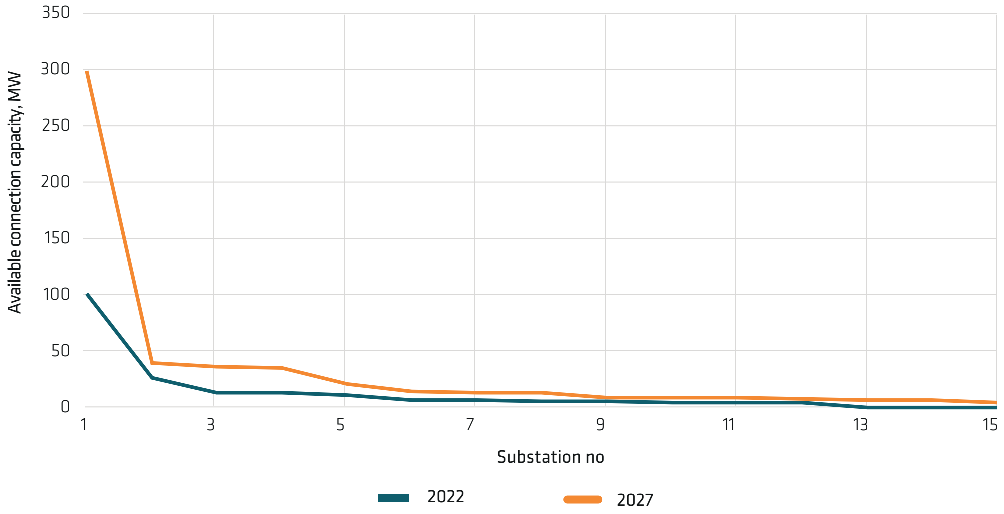
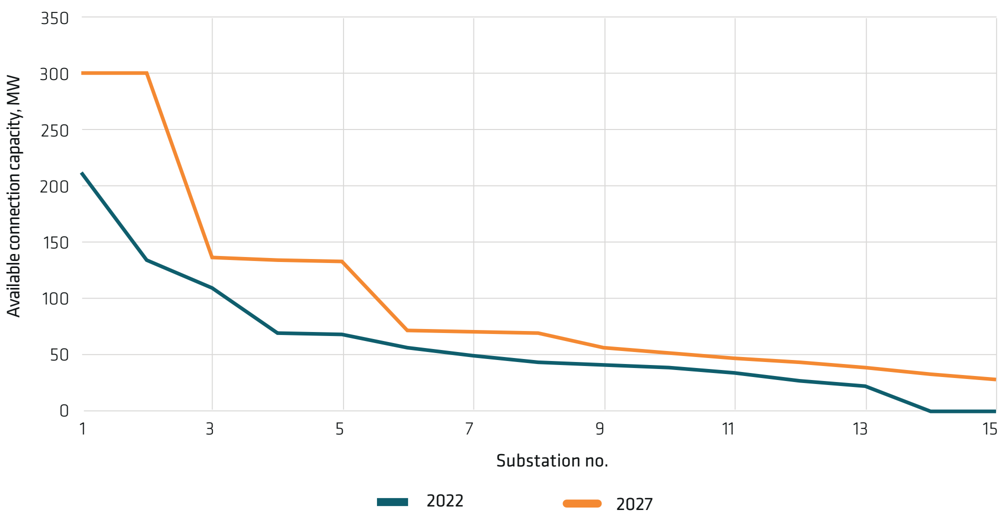


Figure 3.15
Distribution of available demand-side connection capacities of 330 kV substations



Elering's five-year investment budget projects have the most impact on demand-side available connection capacities at 110 kV and 330 kV substations. 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.

3.2.2 Use of separation points in the 110 kV power grid

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 separation 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 also enable the amount of electricity generated from renewable sources to be increased, which in turn will help Estonia to fulfill its climate goals.

A study conducted by Elering AS showed that the separation 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 separation 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 connection 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.

3.2.3 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 overloaded 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 is inserted in the grid model and it´s impact on the electricity system in the case of various generation and/or consumption limit scenarios is 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. Besides traditional connection agreement offers, which include expenses on upgrading the grid, Elering can make alternative offers to customers allowing them to use the desired connection subject to restrictions. No investments into increasing grid capacity need to be made in such cases. Such alternative connection agreements also specify the capacity starting from which one or more grid elements are considered overloaded, and which grid elements, when overloaded, entitle Elering to limit or turn off the customer's demand and/or generation 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 grid elements that could potentially cause an overload have been switched off. With this knowledge about the cost of upgrading the capacity of the potentially overloaded 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 overloaded grid elements, and 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 noon 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 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.

3.2.4 Option of connecting storage equipment

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 hydro pump power 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.

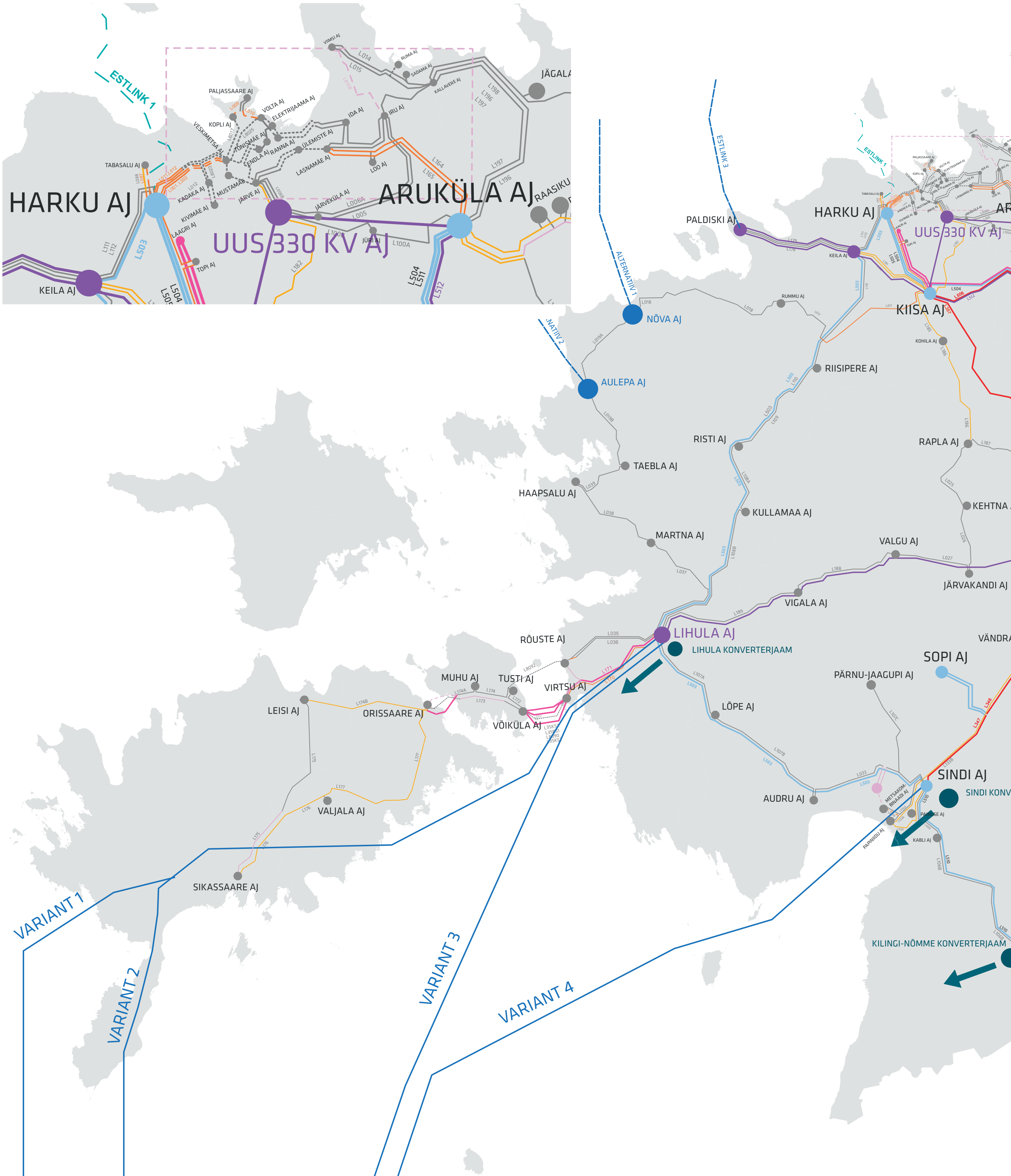
When connecting to the grid, storage equipment is subject to similar requirements as generation modules and/or HVDC converter systems. Storage equipment also require sufficient network capacity just as when new ordinary generation and consumption connections are added. If storage equipment is designed 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 Estonian electricity system. However, in the more distant future, a number of large-scale pump hydro power 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. As of today, about 25 connection applications for storage equipment amounting to a total 3334 MVA have been submitted, of which Paldiski pump hydro plant is 500 MW and the rest are comprised of fuel cell-based storage equipment.

To sum up, the network for connecting storage equipment is ready; it will only be necessary to develop system services and other regulation markets for the storage equipment.

Furthermore, Elering plans to develop a more suitable transmission fee structure for storage equipment, establishing a separate tariff of rates 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.



Existing network part

- 330 kV overhead line
- 110 kV overhead line
- 110 kV cable line
- Estlink 1 and 2
- 330 kV substation
- 110 kV substation

Grid to be transferred to VKG

- 110 kV overhead line
- 110 kV substation

Investments

- Cross-border connections (possible locations)
- Possible location of offshore grid converter station and cable
- 330 kV overhead line
- overhead line
- 110 kV cable line
- 330 kV substation
- 110 kV substation

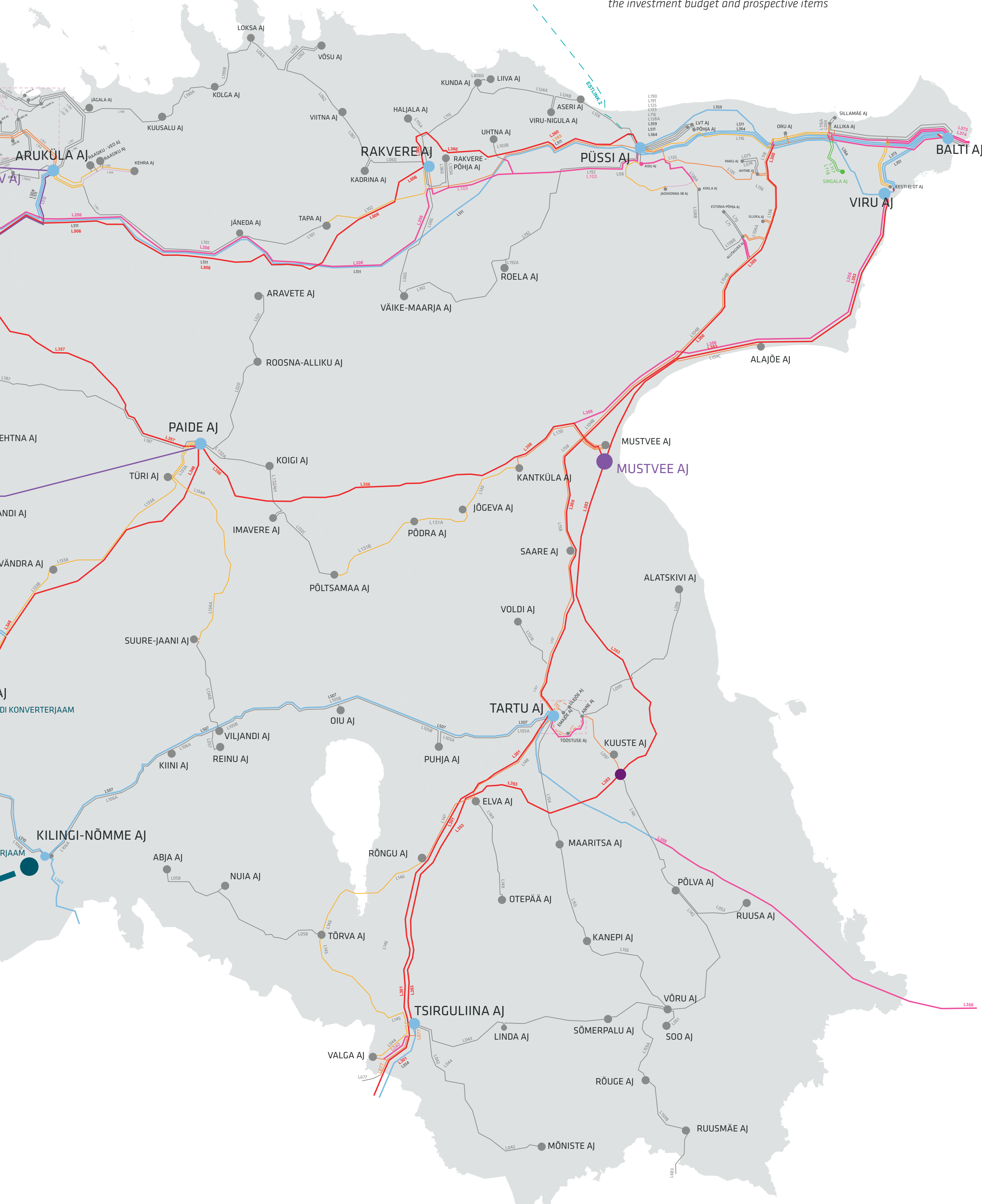
Existing network part

- 330 kV overhead line
- 110 kV overhead line
- 110 kV cable line
- Increasing the capacity of the 110 kV overhead line

Part of the grid to be decommissioned

- Overhead line or cable line
- Substation

Figure 3.16
Diagram of the Estonian power grid along with items currently in the investment budget and prospective items



3.3 OPERATIONAL RELIABILITY OF THE POWER GRID

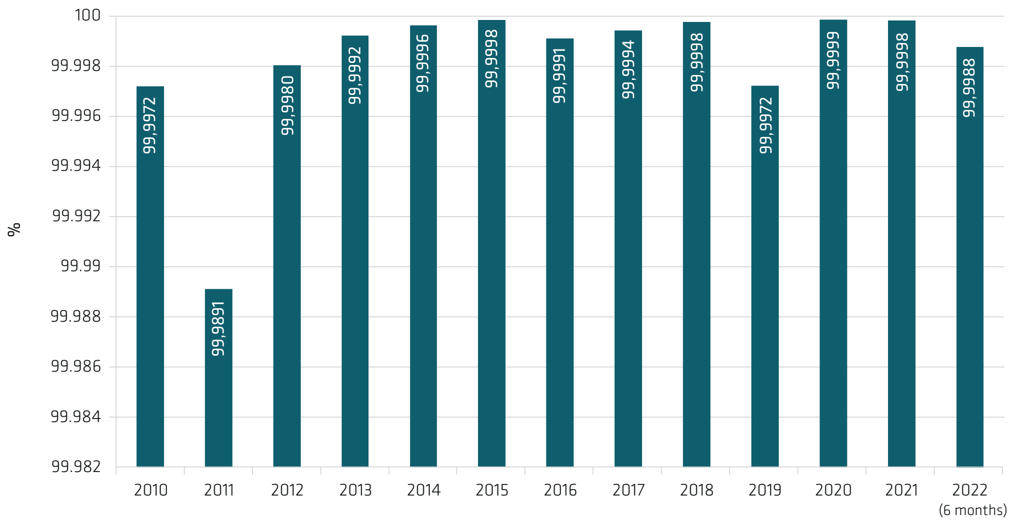
2021 was a very good year in terms of grid operational and availability. The third best result of all time, with the differences being very marginal. Taking into account both indicators simultaneously, both the electricity not served and number of outages, 2021 has been outstripped by 2020 and 2018. The indicators can be seen on the graphs below, which provide a cross-section of years.

The first half of 2022 did not continue this performance, as Kunda substation experienced an incident where an unknown person intentionally caused outages for consumers. Security institutions are investigating the incident and Elering is introducing changes at its substations and procedures to keep such incidents from happening again. The situation as regards availability may improve in 2022.

Moreover, the Elering-administered DC connections (the Estlink cables) are among the best in Europe in terms of reliability.

In general, reliability of the grid has been very good in recent years, and the ten-year trend is positive. In past years, tall trees in the corridors and near lines – which caused outages – are no longer a considerable problem, but consistent efforts are still required in this area.

Figure 3.17 Transmission reliability by year in the period 2010-2022



2022 saw fewer outages due to freezing rain, which is something that cannot be avoided in our weather conditions. In addition, lifts and excavators caused outages in both years by colliding with overhead line wires. Such situations do not depend directly on Elering's actions as they were not coordinated in advance. The only way to prevent such incidents caused by actions uncoordinated and not announced to Elering in the immediate vicinity of lines is good PR and communication outreach.

In addition to the above, it is important to consistently invest in improving the technical condition of lines and substations and thereby improve reliability and constant periodic maintenance of overhead line corridors.

With regard to investments occasioned by depreciation of equipment (age), the major hub substations have all undergone the renovation cycle. A new one is approaching. First to be renovated will be mainly the high-voltage equipment, which are directly necessary for transmission of electricity. Systems that assist and support transmission of electricity, such as relay protection, automation, communication telemechanics, control, signalling and other equipment have a significantly shorter life cycle and will occasion new investment needs, while high-voltage equipment will be able to continue operating for some time. The share of low-voltage equipment in the total substation investment volume is not as Noteworthy As that of high-voltage systems, but is nevertheless considerable. Smaller substations not working at full capacity will be reviewed as needed.

The principle behind maintenance of Elering's power grid, including both substations and lines, is to prevent faults.

Maintenance of substation equipment is mainly schedule-based, 98% according to the manufacturer requirements and based on readings. 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 based mainly on defects discovered by annual inspections. That is in addition to maintenance of line corridors, and clearing them of tall brush and hazardous trees, which is one component of maintenance.

Elering devotes much attention to issues of reliability of the Estlink connections. To this end, long-term maintenance and repair agreements have been concluded, covering both scheduled preventive maintenance and emergency response. Set criteria for assessing the technical and commercial availability of Estlink 1 and Estlink 2 are followed.

2021 was an extraordinarily successful year for the high-voltage DC connections between Estonia and Finland in spite of the fact that the usage of Estlink 1 and Estlink 2 was the highest of the past years. The technical reliability of the HVDC connections was very good. There were few unplanned outages of the HVDC connections in 2021 and their total duration was brief. For the first time in 15 years when Estlink 1 was in use, no malfunctions or events occurred in 2021 that restricted the transmission capacity of Estlink 1. Two incidents took place on Estlink 2 in 2021, causing an outage on the DC connection or preventing it from being operated in a timely manner. Also, four incidents took place on Estlink 2 which caused temporary curtailment of transmission capacity. All six outages on Estlink 2 connections had a total duration of less than 17 hours. Including planned maintenance, the technical reliability of the Estonia-Finland DC connections in 2021 was excellent: The figure for Estlink 1 was 98.12% and for Estlink 2 99.79%.

The first half of 2022 was successful for the Estonia-Finland DC connections. In regard to both Estlink 1 and Estlink 2, both connections experienced 3 unplanned outages with a total duration on each Estlink of about 7 hours. The causes of the outages have been identified and eliminated.

3.3.1 Outages and electricity not served

Disconnections of network devices/elements take place by way of automated equipment for protection of humans, equipment or other equipment if the device is in a hazardous or non-operational state. Disconnections of equipment do not generally mean an outage for consumes since all systems are redundant or can be reserved. Statistics on disconnections are kept on high-voltage equipment through which electricity transmission takes place, disconnection via automated equipment when power transmission is interrupted, such as a high-voltage line pylon, high-voltage transformer etc. Statistics on disconnections are not kept on low-voltage, i.e. auxiliary equipment whose downtime does not lead to an outage, such as relay protection or automation equipment, lighting, heat; etc. If a problem in any of these does result in a power cut, the event Is included in statistics.

The number of outages in 2021, 108, was lower than the year before – 113, being 96% of the 2020 figure but higher than in 2018 (86, the record-low). The number of outages in 2021 was the six-year average but is much lower than the 10-year average, which is 142. The company has a limit of 180 disconnections per year.

2021 saw 59 disconnections due to line equipment, 47 due to substation equipment, 2 due to DC equipment and none due to emergency reserve plants, which amounts to 54.63%, 43.52% and 1.9% of the 2021 total, respectively.

The number of outages in the first half of 2022 is 40. It would be premature to compare it to past full years but compared to the half-year figures for the last 10 years, we see it is slightly higher than the ten-year average – 51 – and the five-year average – 47. Compared to the recent years, the first half of 2021 had 55 disconnections and 2018 with the fewest had 36 in the first half-year.

In the first half of 2022, there were 16 disconnections due to line equipment, 19 due to substation equipment, 5 due to DC equipment and none due to emergency reserve plants, thus respectively 40%, 47% and 12.5% of the 2021 total.

Besides the malfunctions that reach disconnection stage, there were also faulted that were prevented in the course of inspections. These are potential disconnections – i.e. preventive interruptions where the device must be immediately disconnected to prevent the device from spontaneously switching off. There were 46 of them in 2021, of which 34 were in substations, 9 on limes and 3 in DC equipment. The average for the last five full years was 30.

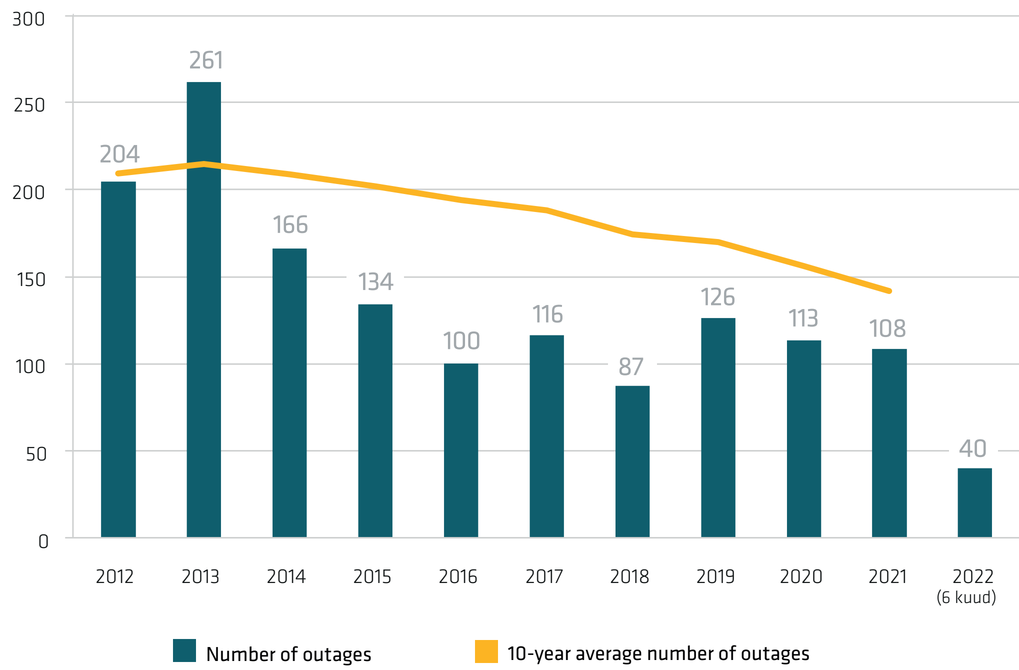
There were 39 forced interruptions in the first half of 2022, of which 26 were at substations, 12 on lines and 1 on DC equipment. The five-year average has been 21.

As regards reliability of the grid, we keep separate track of disconnections of Elering equipment which were not caused by a fault in Elering equipment but on the client or neighbouring grid side, but where an Elering equipment protection device that depending on the scheme that belongs to Elering or client operated to protect the device and ensure safety and disconnected the Elering device. There were 50 such disconnections in 2021. Of these, 46 were caused by clients and four were caused by neighbouring grids – 92% and 8% of the total, respectively.

Such disconnections occurred on 15 occasions during the first half of 2022. Thirteen of them were caused by clients and 2 by neighbouring grids – 87% and 13% respectively.

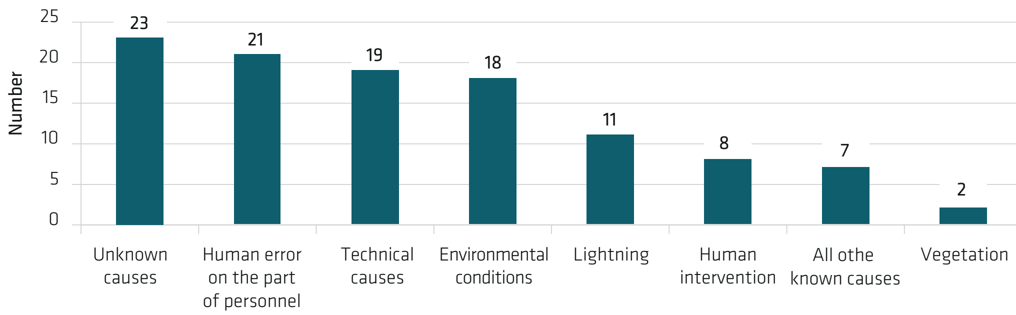
The disconnections caused by clients and neighbouring grids amounted to 32% of all disconnections in 2021. The respective figure for the first half of 2022 was 27%.

Figure 3.18
Number of outages by year, where the figure for 2022 is for the first half of the year



Categorising outages by cause, the greatest number of outages in both 2021 and the first half of 2022 were undetermined, since inspection revealed no visible sign of anything that might have caused the outage and the device functioned after being manually or automatically switched on again without any further problems. 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 etc., or a protection device activated in a substation and switched off the device but an inspection of the device did not turn up anything amiss. And after the device was switched on again, it functioned without further problems. In other cases, the device was so damaged, in some cases irreparably, so 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. This was the case in 23 instances – 21% of instances – in 2021. The second most frequent category was human error – 21 or 19% and third most common was environmental reasons – 19 disconnections, which amounted to 18% of all disconnections owing to Elering.

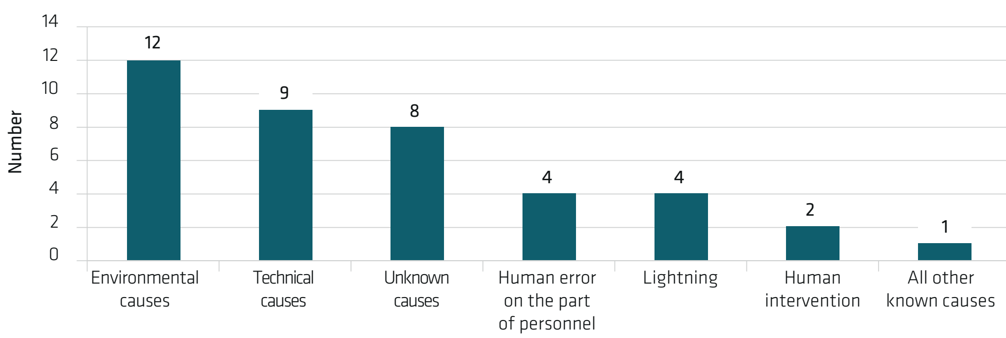
Figure 3.19 Disconnections by case, 2021



The greatest number of outages by subcategory in 2021 was "undetermined". These included both first-time and recurring events. There was a total of 23 of these. They were followed by disconnections caused by birds and other wildlife on 16 occasions, and lightning on 11 occasions. Next came disconnections caused by ageing lines – 7 instances. On six occasions, the cause of improperly calculated settings, and infrequent technical causes. On five occasions, the cause of error on the part of Elering employee. The numbers of the rest of the causes were distributed with each cause making up a marginal number.

The most frequent category of cause in the first half of 2022 was environmental conditions, which occurred in 12 of 40 cases – 30% of the total number of outages caused by Elering. The second most common category was technical causes, with 9 instances (23% of the total) and in 8 cases, the cause was "undetermined". These made up 20% of the total number of Elering-side disconnections.

Figure 3.20 Outages by cause, first half of 2022



The most common subcategory of outages by cause in the first half of 2022 was snow and freezing rain (part of the environmental conditions category) on 8 occasions; the cause remained unknown in another 8 instances with both first-time and recurring ones equal in number. On five occasions, the causes of an equipment defect. These causes were followed by lightning and birds/other wildlife, four instances in both cases. On two occasions, the age of the equipment was to blame, and the rest of the causes each occurred in one instance.

Most extensive faults in 2021:

- On 15.01.2021 at 7:01, immediately after the disconnection of reactor R2, the 330 kV autotransformer A2T tripped at Sindi substation. The transformer had been installed in 2019. The transformer underwent expert analysis at the manufacturer plant, and during removing the active part, damage to the coil was found. The expert report stated that the malfunction occurred since the Contracting Entity/Elering failed to adopt all measures for protecting the transformer against overvoltage and the Contractor/BEST plant did not take into consideration the operating modes and frequency of switching of shunt reactors connected undervoltage coils and did not provide recommendations on its part for raising the insulation class of the undervoltage coils and about the operating modes of the shunt reactors. The parties split evenly the costs of the works to restore the transformer.

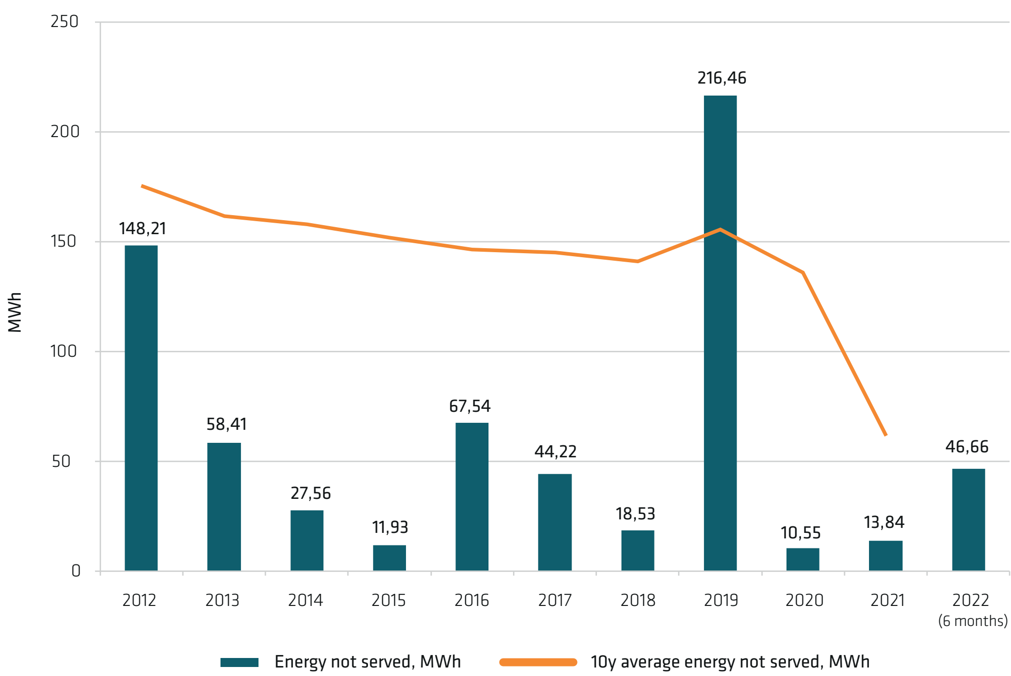
- On 13.04.2021 at 00:34, the L507 Tartu - Kilingi-Nõmme tripped. The outage was caused by the bursting of A-phase of power voltage transformer 3OPT4 of the Kilingi-Nõmme substation.. On 11.08.2021 at 11:58, the L507 Tartu - Kilingi-Nõmme tripped. The outage was caused by the bursting of B-phase power voltage transformer 3OPT4 of the Kilingi-Nõmme substation. The cause of the damage to the power voltage transformer OPT was internal damage caused by dynamic forces, the exact cause of which could not be found out. The cost of the power voltage transformer OPT restoration works is being clarified.

- On 12.05.2021 at 15:44, the L159A Võru-Rõuge tripped with an unsuccessful AR. Consumers served by the Rõuge and Ruusmäe substations experienced an outage. At 15:53, a reenergizing failed. Power to the Rõuge substation was restored at 16:18 by Aluksne. The second reenergizing of L159A at 23:27 was successful. At 23:42, Rõuge and Ruusmäe were transferred to being supplied by Võru substation. The fault was caused by a breach of the external dimensions in span M54-M55 between the 110 kV and ELV 10 kV overhead lines. A month before, a maintenance contractor had replaced insulators in that span and it is suspected that the span was extended by a few centimetres during the replacement. Due to the criticality of the external dimension, this was enough to create a flashover between two phase wires. On 17.05.2021 the gauge of the wires was adjusted, 110 kV phase wires were tightened in the anchor span 54-55 and EC lowered the 10 kV overhead line.

  The amount of energy not served in 2021 was third-best of all time, but the variations between the years are marginal.

The amount of energy not served in 2021 was 13.84 MWh, which is third-best of all time. The three causes of the largest incidents resulting in energy not served were ageing of equipment 6.32 MWh, error on the part of maintenance worker 6.32 MWh and error on the part of Elering 2.68 MWh. The quantities of energy not served due to other causes were less than 1 MWh.

Figure 3.21
Electricity not served by year, where the figure for 2022 is for the first half of the year



- The largest quantity of electricity not served occurred on 5 April 2021, when at 12:09 the overhead line L176/L177 Sikassaare-Valjala-Orissaare tripped. At the same time, L173 Võiküla-Orissaare was undergoing repairs and was out of service. Consumers served by the Valjala and Orissaare substations experienced an outage. It was caused by the broken wire of one phase of bus disconnector SVL LL 11001, in Sikassaare substation. This was a fault caused by ageing equipment. The durations of the outages at places of consumption were 45 and 98 minutes. The energy not served amounted to 5.13 MWh.

- On 17.08.2021 at 18:04, Jõgeva transformer C2T tripped. ELV consumers experienced an outage. Transformer C2T was energised at 19:35. IDuring the dismantling of cables damaged in a fire at Jõgeva substation, an employee of maintenance company dismantled a 35 kV current circuit cable of operational differential protection equipment. Upon immediately realising the error, the employee reconnected the circuit, but not as it was originally configured. The differential protection tripped the transformer C2T caused by the Elektrilevi Grid short cirquit. That means that the differential protection of the transformer C2T switched the transformer off from work because of short cirquit in Elektrilevi Grid. The duration of the outage at places of consumption was 172 minutes. The energy not served amounted to 4.39 MWh.

- On the Elektrilevi side, Jüri kauplus substation's load disconnector KOL 19 had a short circuit. The Elektrilevi dispatcher had accidentally switched a 10 kV earthing switch to a 3-phase short-circuit at approx. 9 kA current, which was also envisioned by Elering's differential protection. The 10 kV overcurrent protection of Elering's differential protection tripped the transformer's 10 kV cirquit breaker. At the time, the 10 kV switch could not be seen on Elering's SCADA due to problems with the existing RTU (renovation works on the relay system were ongoing at Jüri substation). The transformer's 10 kV switch tripped. Consumers experienced an outage due to Elering's fault. The duration of the outages at places of consumption was 32 minutes. The energy not served amounted to 2.68 MWh.

- 27.04.2021. The transformers C1T and C2T tripped at Jõgeva substation on the 10 kV and 35 kV side, and Jõgeva substation consumers experienced an outage. The 10 kV and 35 kV cables were burning. At 16:37, the transformer C2T at Jõgeva substation was turned on to supply auxiliary equipment, C1T transformer was down. At 02:40, transformer C2T and the 35 kV line L57 Jõgeva-Puurmani were energized. The fault was caused by the client equipment, but 170 MWh of electricity was not served by Elering as a result.

In the first half of 2022, the amount of energy not served due to faults in the Elering Grid was 46.66 MWH, which exceeds the figure for the last there years (including 2022) by fourfold.

- On 10.04.2022 at 20.41 at Kunda substation, the 110 kV cirquit breakers L124A VL 110245, C2T VL 110025, L115 VL 110155, MVL 110065, C1T VL 110015, L8060 VL 110605 were switched off, by a human operator, as it turned out later. L8060 Estonian Cell and all 6 kV consumers of Kunda substation's experienced an outage. According to SCADA data, the incident was preceded by signals from Kunda substation "Aku laadimine puudub", "L115 väljal. ahela rike", "110 MVL või RK op.ah.rike", "110 kV Is SA ja 110 kV IIs SA töö", indicating that a battery was not charging and that faults in circuits had been detected. All the doors of the cabinets of the drives of the switched-off cirquit breakers were open and the keys of control mode of the cirquit breakers had been skilfully turned to "local" position, due to which the dispatcher's remote control attempts were blocked. At 22:05, normal mode was restored at the substation and energy supply was restored to consumers. The outages at 20:41 at Kunda substation were caused by an intentional action by an unknown person. The energy not supplied amounted to 45.18 MWh.väljalülitumised olid põhjustatud tahtlikult tundmatu isiku poolt. Andmata energia 45,18 MWh.

The rest of the faults in 2022 resulted in unsupplied energy which was less than 1 MWh.

The most energy not supplied in 2021 was caused by ageing equipment – 6.32 MWh, maintenance worker error – 4.48 MWh, and Elering employee error – 2.68 MWh. The quantities of energy not supplied due to other causes were less than 1 MWh.

The greatest amount of energy not supplied in the first half year of 2022 was caused by vandalism – 45.18 MWh, and the rest of the causes amounted to less than 1 MW.

Figure 3.22 describes the outages caused by Elering by reason in the period 2012-2022 where the data for 2022 is for the first half of the year

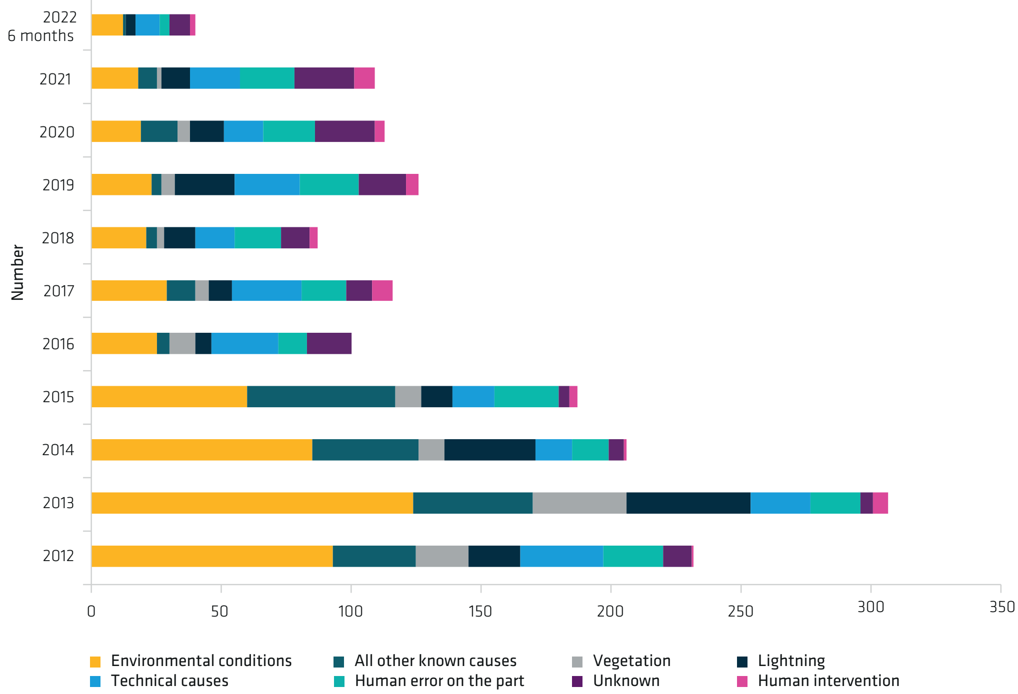


Figure 3.23 Reliability of international connections, 2014-2022 where the figure for 2022 is for the first half of the yea

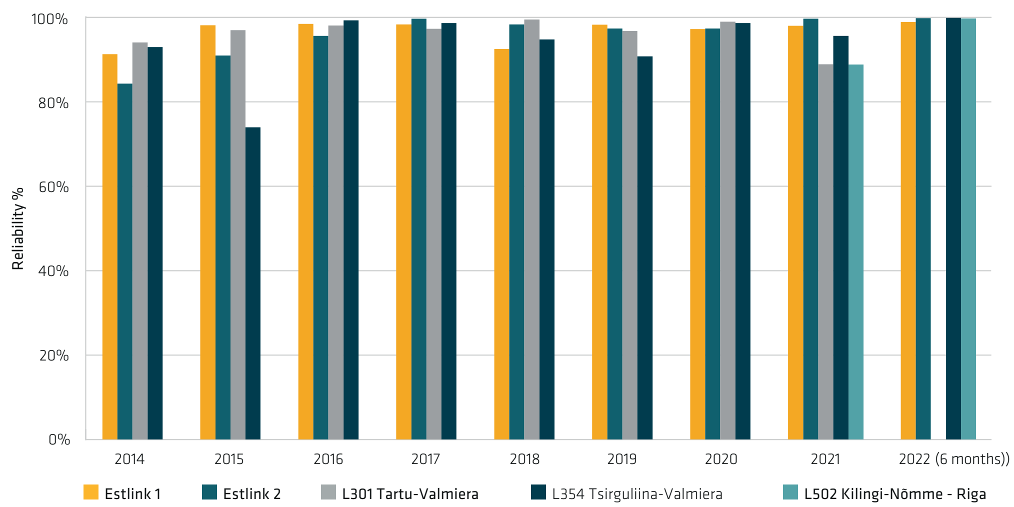


Table 3.1 Statistics on Estonia-Finland 2022

Description	**Estlink 1**	**Estlink 2**
Use of electricity	57.96 % (ca 1777 GWh) EE->FI: 14 GWh FI->EE: 1763 GWh	87.74% (4996 GWh) EE->FI: 53 GWh FI->EE: 4943 GWh
Technical availability	98.12% (0.75% higher than 2021)	99.79% (2.3% higher than 2021)
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 constraint: 4, transmission interruption: 2

On the Estonia-Finland cross-section in 2021, there were a total 3613 bottleneck hours – 41.24% of the hours in the year, of which:

- the total Installed transmission capacity was used (i.e. the Estlink cables were used at full capacity without constraints): 2205 hours, which is 25.17% of the year;
- transmission capacity was limited owing to Elering or Fingrid network (including due to constraints on GVDC connections) during 1387 hours, which is about 15.83% of the year. NOTE: There were a total 125 hours – i.e. 1.43% of the hours of the year – in which less than 1000 MW of the Estonia-Finland transmission capacity was at the disposal of the electricity market.
- Constraints caused by the speed of change in Nordic capacity occurred in 21 hours – i.e. 0.24% of the year.

Figure 3.24
The transmission reliability, or availability, of the DC cables in the Nordic and Baltic countries in % of the full capacity in 2021. Constraints, disruptions, planned and unplanned outages are taken into account.

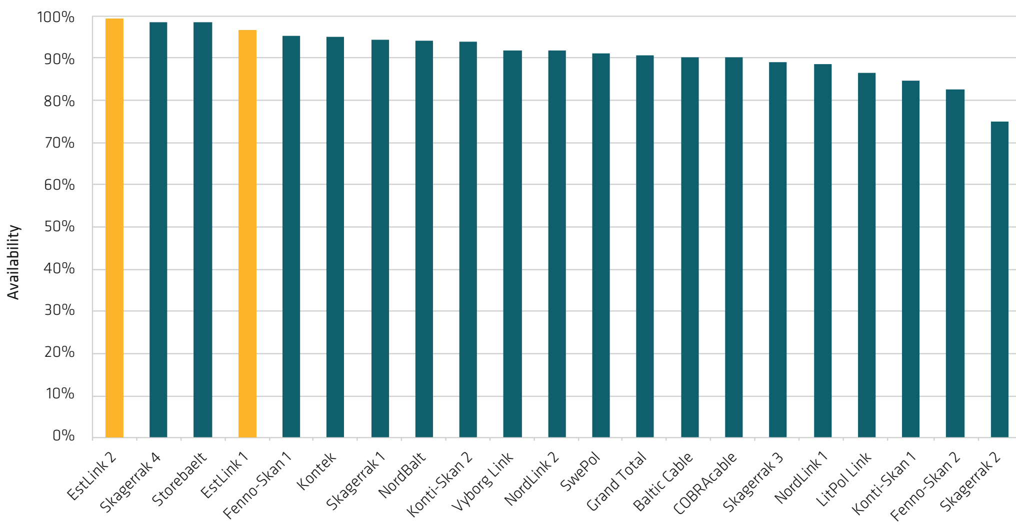


Figure 3.25 shows the geographic locations of the 20 HVDC connection in 2021.

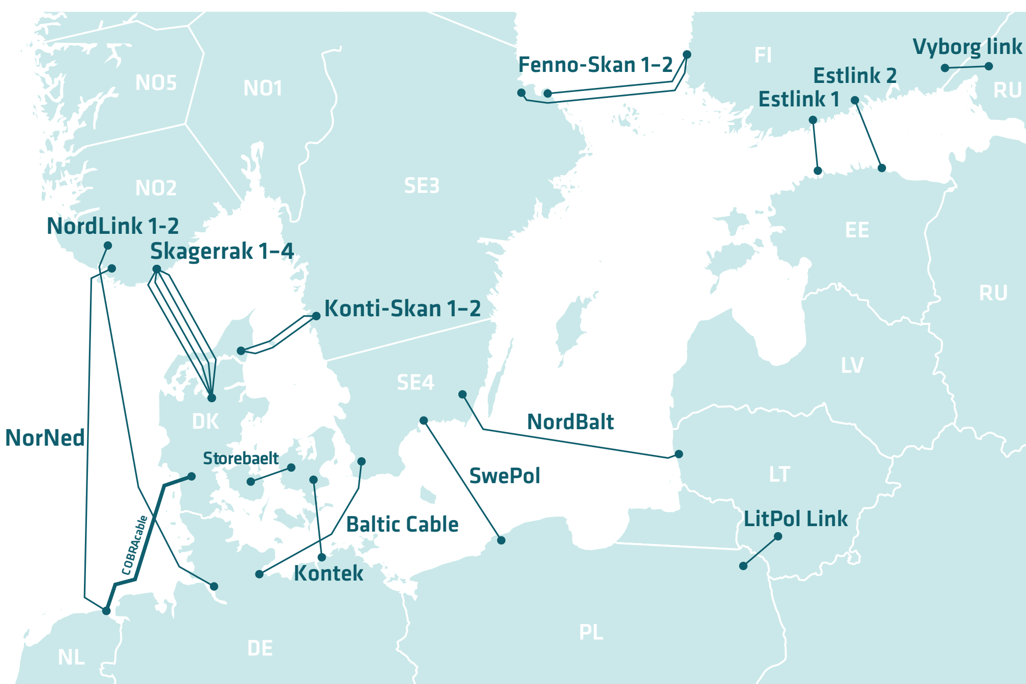


Figure 3.26 Reliability of EstLink1, 2007-2022, where the figure for 2022 is for the first half of the yea

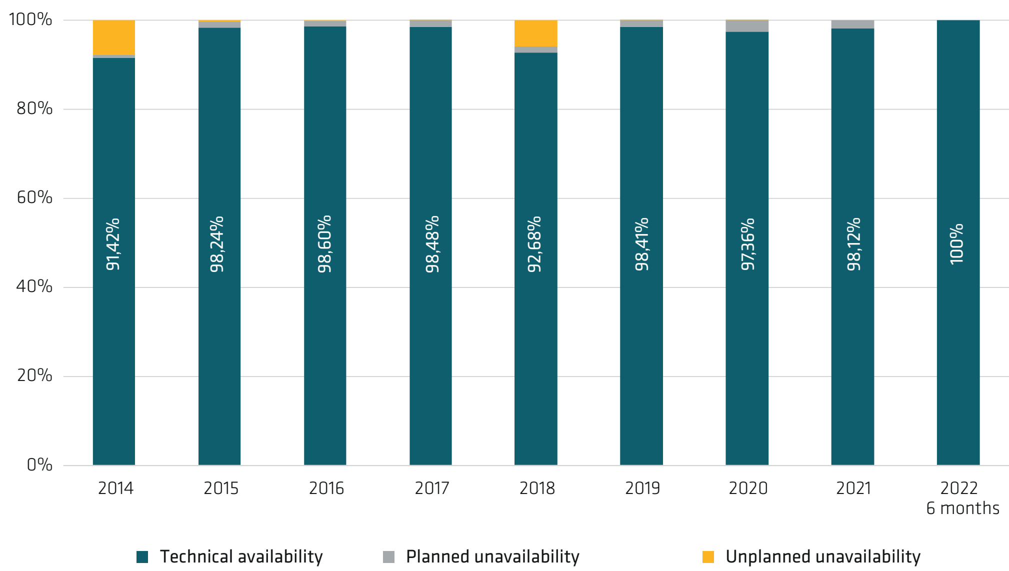
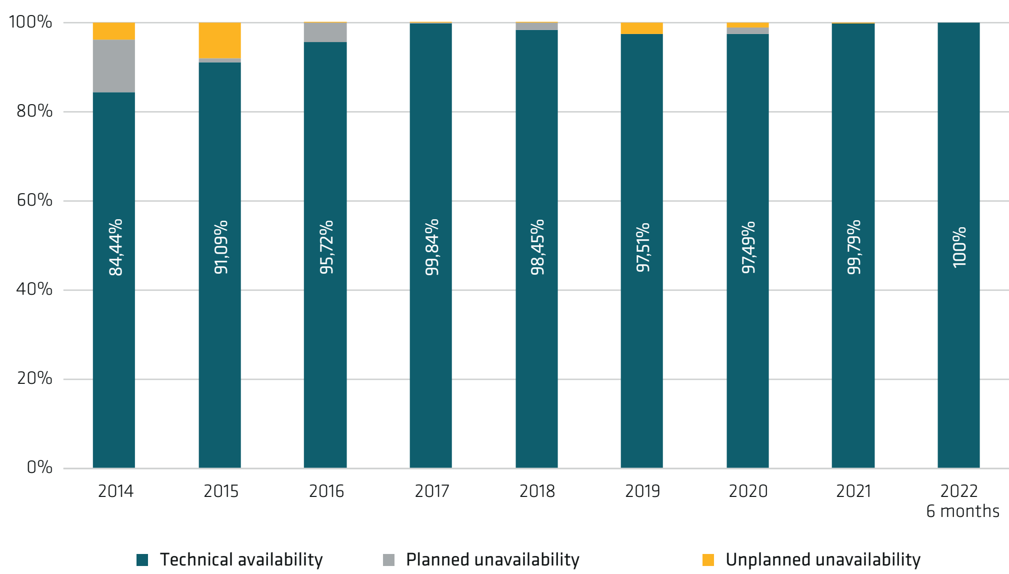


Figure 3.27 Reliability of EstLink2, 2014-2022, where the figure for 2022 is for the first half of the year



3.3.2 Fulfilment of the tree trimming and grid reliability programmes

To fulfil the goals, 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 and corresponding actions and goals have been updated in this plan.

The goal of the "Reliable grid" plan is to improve quality of maintenance, including 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 the 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 for 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 served due to outages is related to human activity in electrical installations.

This plan encompasses actions whose goal is:

1. to reduce the number of outages and faults and in that connection, energy not served;
2. maximise the lifespan of equipment in that connection, to reduce the need for investments in future;
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 potential amount of energy not served, impact on NTC (Network Transmission Capacity) and safety aspects.

The total area of protection zones around overhead and cable lines as of early 2021 was 33,003 hectares, of which about 52% was in forested areas. About 200 hectares of the forested areas is unfelled forest and the rest is brushy.

3.3.3 Updating the Elering asset management principles

The strategic goals of administering Elering's power grid assets are related to grid equipment reliability in order to reduce power outages or the risk thereof and doing so cost-effectively.

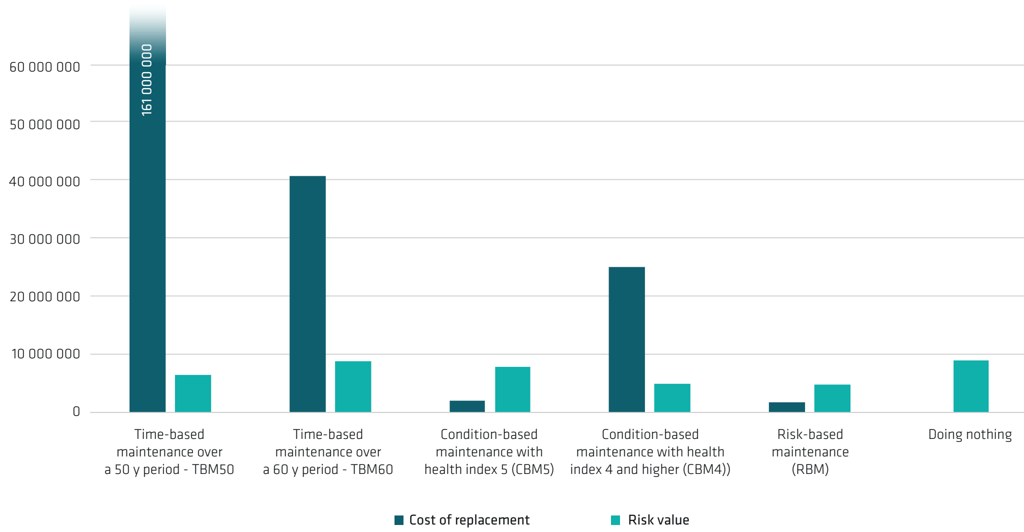
Maintenance of power transmission grids traditionally relies on a time-based approach – time-based maintenances take place based on pre-agreed intervals, e.g. every three years for a given piece of equipment or after a certain number of switching iterations. Time-based maintenance is easy to use but it intrinsically leads to overinvestment. The time-based maintenance and investment approach may be justified in certain cases, but does not take into account the actual situation of these assets, i.e. some of these assets may not necessarily required maintenance or on the other hand, maintenance should have taken sooner and risks related to assets located in different locations and having different functions necessitate a different approach to principles of maintenance and investment. All this results in overused of funds or a decline in security of supply as a whole. Nor may investments into the equipment that is in worst condition necessarily be the most cost-effective decisions since demand and supply patterns have changed so much since the grid construction time.

To obtain a better overview of the state of our assets and related risks and manage them more reasonably, Elering is updating its asset management principles. The goal is to progress from conventional time-based approach of power grid component maintenance to planning of risk-based maintenance and investments and thereby raise network reliability and optimise expenses. Elering also has an interest in developing Estonia's technical competence in this field. Additional factors that support this approach today are related to measurement options for various parameters of the equipment and increase of computing capability, including the rapid-developing IoT devices for monitoring the operation of equipment. Various kinds of sensors and options for processing measurement data are available. The cost of measurement and analytics hardware has also come down in price.

In updating its asset management principles, Elering has thus fat focused on updating investment and maintenance strategies for overhead lines. In the past, overhead lines have also been the primary cause of faults and energy not delivered. The unknown technical state of components in overhead lines has also been a significant source of risk, where unfavourable weather conditions (storms, ice) can cause extensive damage to overhead lines. Ageing of electricity system equipment will result in a significant wave of replacement of equipment in the next decade – the overwhelming majority of investments to be made must be directed at improving the technical condition of high-voltage lines, which makes it important that Investment decisions be based on the actual state of equipment and are directed at replacement of components that would minimise risks to security of supply.

Starting from 2016, Elering has studied and implemented ways of evaluating the state of lines and risks related to lines. As a result, Elering employee Henri Manninen wrote a doctorate this year focusing on data-based asset management and methods for evaluating the state of overhead lines in the transmission system. His findings show that the proposed methods allow lifecycle maintenance costs of overhead lines to be reduced significantly. The results of implementing the new status evaluation methods give hope that they can significantly reduce the time and costs spent on inspections and evaluations of overhead lines and also increase the reliability of the results. The proposed methodology allowed risks in the power grid to be minimised more cost-effectively than the standard methods and also allowed the most critical elements in the grid to be identified.

Figure 3.28
Comparison of different asset management strategies based on residual risk and replacement investment



The research presents a risk-based and data-based asset management approach where the quality of input data has a significant impact on the effectiveness of the decisions. The health indexes for overhead lines are used to calculate the probabilities of risks becoming realised. The health indexes are assigned to each individual element based on their actual condition. To determine consequences of risk; a method based on energy not served has been proposed, which includes forecasting of the duration of risks and calculation of indirect costs. Traditionally, the condition assessment of overhead lines in transmission systems is based on manual visual inspections, but it is costly to conduct these and they may yield subjective results. To achieve better results, the doctoral dissertation divides the overhead lines into smaller parts where evaluation criteria describing the stage in the life cycle were developed for each component. This approach allows the quality of the visual inspections conducted by Elering on overhead lines to be improves and makes it less subjective. Additionally, a machine learning based health index forecasting model was developed, allowing the technical condition of pylons to be forecasted in a case study compiled based on Estonian transmission system data at an accuracy rate of close to 80% without additional activities.

Aerial vehicles are increasingly relied upon for inspections of overhead lines, this being an easy way of gathering a large quantity of high-res images. To automatically and efficiently identify images, it is planned in future to also harness the neural network-based image identification methods proposed in the dissertation. The approaches proposed would be able to automatically identify defects in overhead lines without assistance from electricity installation workers and thereby assess the actual condition of components.käidupersonali abita ja nende alusel hinnata komponentide tegelikku seisukorda.

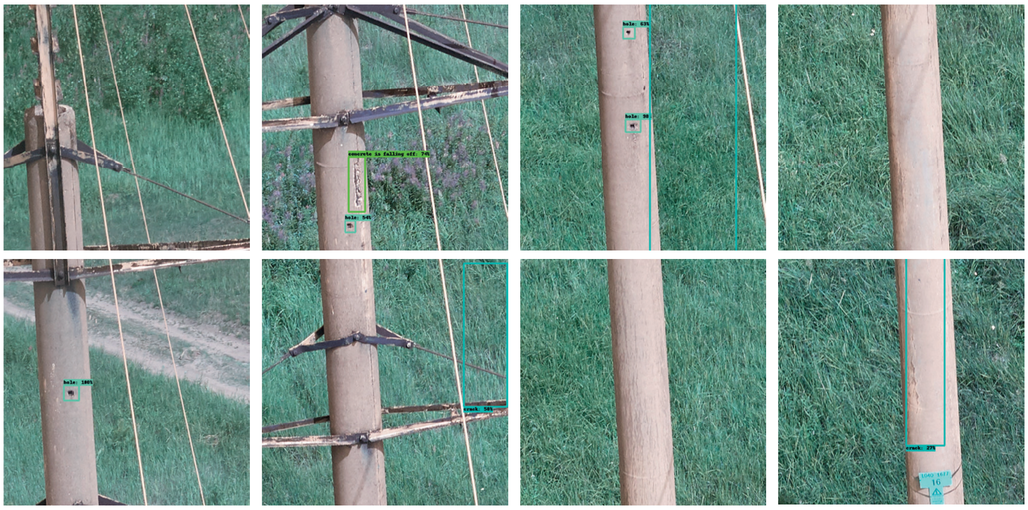


Figure 3.29
Defects in reinforced concrete overhead line pylons found by way of image recognition

This year, Elering launched an R&D project in cooperation with TalTech where the main focus is on monitoring equipment condition data and developing risk- and condition-based maintenance and investment principles. A key part of the project involves real-world trials and analysis of the measurement data thus obtained, all of usually requires time resources in order to achieve reasonable results. Additionally, it should also be remembered that the field is developing one and readymade solutions for carrying out online monitoring, using IoT equipment and mega data analysis are only in an emerging stage.

The trigger for the project was the main hypotheses:

- New technologies and measurement equipment will make it possible to gather much more data based on the condition of equipment
- The more detailed information about equipment condition will allow use of an asset management strategy that increases network reliability and reduces costs in both the short and long term
- New technologies will allow installation safety to be increased

As the end result of the project for updating the substation maintenance and investment principles, it is planned to update the principles and develop a prototype solution for monitoring of evaluation of substation equipment by 2026.

4 System adequacy

- ***The region has enough generation capacity to cover peak demand, but compared to previous years, risks to security of supply have increased substantially, mainly due to Russia's invasion of Ukraine.***
- ***To speed up the increase in energy independence of Russia, it will be important to maintain and strengthen intra-European cooperation.***
- ***The probability of reining in demand is low. Should risks become realised, there is a process that has been developed for restricting consumption in a way that poses the least impact for consumers.***
- ***The risk to security of supply will decrease with the completion of a new LNG terminal in the Gulf of Finland and the full launch of the Olkiluoto 3 nuclear power plant.***
- ***An analysis of the capability of the Europe-wide system showed that Estonia will have overrun its reliability standard by 2027, since the existing capacities are not economically sustainable. A follow-up Elering analysis found that if the oil shale fired units are kept on the market, the reliability standard would be ensured. We will table a proposal to the Competition Authority and the Ministry of Economic Affairs and Communications to develop and implement the strategic reserve.***

4.1 SUMMARY

We consider electricity system adequacy as constituting a situation where the expected electricity consumption is covered with the local generation, imports and demand side management possibilities.

In the chapter on system adequacy, we are analysing the possibility to cover electricity demand short term- the winter of 2022-2023 and thereafter in a longer timeframe of 15 ahead. The status of generation capacities and consumption in the next winter have been viewed in the context of both Estonia and the Baltic Sea as a whole. The longer-term system adequacy has been analysed from Estonia, regional and European perspective using both deterministic and probabilistic methods.

The available generation capacities in the region and in Europe are sufficient in an ordinary situation and in the case of major outages to cover peak electricity consumption both in the winter of 2022-2023 and in years to come. Nevertheless, compared to previous years, risks to security of supply have increased substantially, mainly due to Russia's invasion of Ukraine and the risks that it poses to energy markets.

Main risks to Estonian security of supply, which have significantly grown in the last year:

Extraordinary desynchronisation from the Russian electricity system.

1. The availability of cooling water for Narva power plants due to the level of water in the Narva reservoir.
2. Worsening of availability of natural gas and other fuels.
3. Delay in completion of Olkiluoto 3 nuclear power plant and unproved reliability of the new plant.

In addition to the increased risks mentioned above, the electricity system still entails risks that the electricity system can withstand under ordinary conditions but in combination with realisation of the above risks can lead to problems with security of supply.

- An extraordinarily cold winter that increases consumption of electricity (and natural gas).
- Low hydro reserves in the Nordics.
- Extraordinary malfunctions affecting generation capacities and transmission capacities.

Due to the decrease in import of natural gas from Russia, the risk that Europe will lack sufficient natural gas to meet demand has risen significantly. As to whether and how much natural gas deficit may be, that depends on how much of the Russian supply will continue to Europe, how much of it can be replaced with other sources, and how high gas consumption will be. Pan-European analyses show that in an average winter, there will be enough natural gas in Europe for all consumers. If it is a cold winter; there may be a natural gas shortfall in Europe of up to 10%, but since all EU countries have agreed in a 15% reduction in gas consumption, no gas deficit is expected even in a cold winter.

Regulatory intervention in the pricing of natural gas and electricity for the purpose of supporting end consumers may strip consumers of the motivation to plan consumption and conserve energy. In principle, it is the right move to support consumers in coping with high prices, but in certain cases it may work at cross-purposes to ensuring security of supply.

The Baltics and Scandinavia have imported significant quantities of electricity from Russia in previous years – about 7 TWh last winter, which has now ceased and must be replaced with local capacities. Since there is a limited quantity of capacities, unplanned outages during peak hours may result in reserves being activated. To reduce risks, the region's TSOs have stepped up cooperation to coordinate maintenance of major generation equipment and connections so that a perfect storm of circumstances would not result in many key system elements being offline at the same time.

The European energy markets are experiencing unprecedented challenges – rising energy prices and low availability of generation capacities, which may cause problems for system adequacy. Besides the war, the influence of climate change is increasingly keenly felt in Europe. The summer of 2022 was the driest in the last 500 years, which lowered flow rates in rivers and decreased availability of hydro energy.

Water levels in Norwegian reservoirs, one of the most important energy resources in the Baltic Sea region, were long very low[15].

In Estonia, the cabinet has decided to ensure 1000 MW generation capacity at Narva power pants until at least 2026. This is also consistent with the conclusions of Elering's security of supply analysis for the recent years, which found that Estonia must have at least 1000 MW controllable capacity in country.

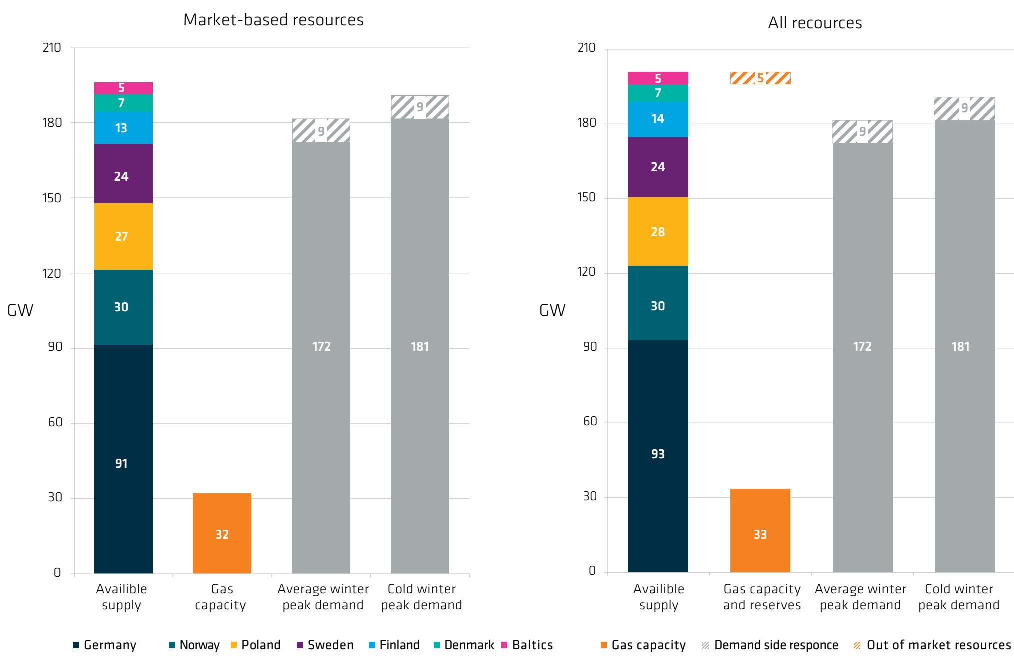
Looking farther into the future, the Europe-wide security of supply analysis shows a risk that from 2027 on, Estonian oil shale burning power plants will not be competitive on the market. This year was the first time that the economic sustainability analysis looked past 2025. To ensure Estonia's security of supply, it will be necessary to have firm capacities in the form of 3-4 oil shale units. To ensure security of supply even in this sort of future situation, Elering proposes to utilise the strategic reserve, as a result of which sufficient generating capacities for ensuring security of supply will be maintained in Estonia. In addition to strategic reserves, it is planned to implement additional frequency reserves markets in Estonia and the Baltics, which coupled with long-term agreements bring additional flexible generation capacity.

4.2 VIEW OF THE NORDIC-BALTIC WINTER POWER BALANCE

The Baltic Sea TSOs led by Elering (In addition to the annual ENTSO-E Winter Outlook) evaluate peak consumption in the region in the winter of 2022-2023 and situation with available capacities (Winter Power Balance 2022-2023). Figure 4.1 shows the market-based resources in the Baltic Sea region and in addition to other resources outside the market, TSOs' reserves and demand side managementcapability.

The expected power balance in the Baltic Sea region in the case of both an average and cold winter peak consumption is positive but the differences are very minor. Taking into account the various risks related to extraordinary malfunctions, fuel availability, extraordinarily low wind or hydro energy productivity, the balance values for the available capacities may fall.

Figure 4.1
Winter resources and peak consumption, 2022-2023



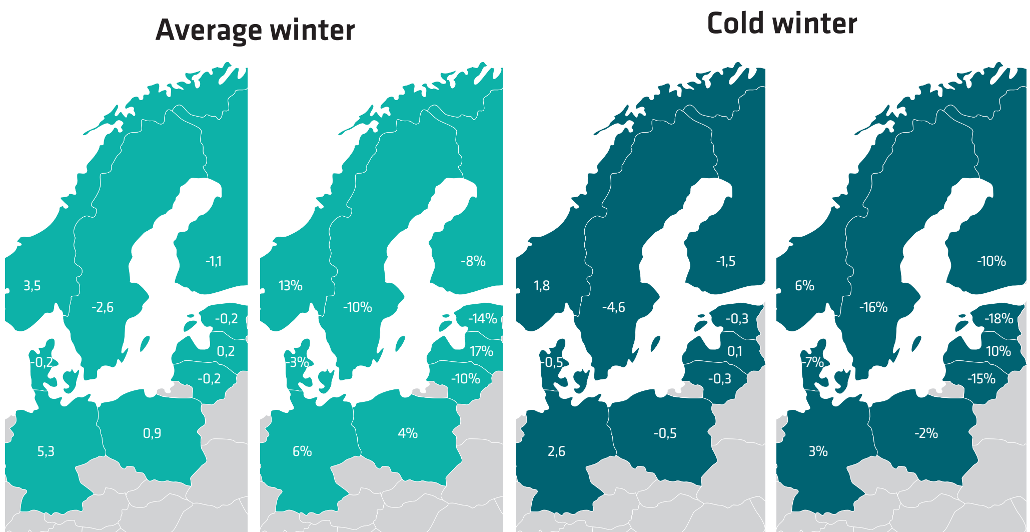
15 https://www.statnett.no/en/for-stakeholders-in-the-power-industry/data-from-the-power-system/#hydrological-data
16 https://www.entsoe.eu/outlooks/seasonal/

During wintertime peak consumption, the region has about 193 GW of market-based generation capacities, i.e. about 11 GW more than average winter peak consumption and about 2 GW more than a peak consumption in a cold winter, for a 6% and 1% surplus, respectively. Of this capacity, 32 GW (16%) is use natural gas as a fuel, whose availability is in doubt this winter.

About 9 GW (5%) of the expected peak consumption is price-sensitive consumption or controlled consumption, which reduces consumption need if prices are very high. In addition, the region has another approx. 5 GW of non-market capacity that TSOs can activate to avoid having to institute consumption constraints or to balance the system.

Even though the region has adequate capacities, figure 4.2 shows that the surplus is not distributed equally between countries. Only Germany and Norway have larger surpluses and the balances are negative in most countries. To ensure that surplus electricity makes it where it is needed the most, high transmission network reliability and good coordination by TSOs is required. The Baltic Sea region is generally well connected, which means that countries may import electricity significantly depending on the surrounding situation.

Figure 4.2
Power balance for market-based resources in winter 2022-23



As mentioned in the section on the region's balance, TSOs also deal with various resources Outside the market that are activated when the day-ahead market ceiling has been reached (at the time of the report, the day-ahead market's ceiling was 4000 €/MWh). Making use of such additional resources depends on the specific situation, since they are also needed for controlling the electricity system. As can be seen on figure 4.1, about 5% of the consumption in the region is price-sensitive and in a real-world situation some of the consumers will have decided before the day-ahead market price ceiling hour that they do not want to consume power at such a high price.

During peak consumption in a cold winter there is the risk that should malfunctions occur simultaneously at power plants, there may still be a need to limit consumption even if reserves are utilised. The presumption in the drawings above is that Olkiluoto 3 is participating in the market at peak hour, but one major risk is a delay in the nuclear plant going online – at the time that this report was written, the new nuclear plant unit was undergoing start-up trials and had already achieved its peak capacity, although the actual reliability is not known.

In addition to covering peak demand, a cold winter also runs the risk of fuel adequacy. About 16% of the region's available capacities uses natural gas as a fuel. Due to the decrease in import of natural gas from Russia, the risk that Europe will lack sufficient natural gas to meet demand has risen significantly. As to whether and how much natural gas deficit may be, that depends on how much of the Russian supply will continue to Europe, how much of it can be replaced with other sources, and how high gas consumption will be. The first impact is the rapid increase in the price of natural gas, which will result in decreased consumption due to replacement of natural gas with other fuels or a halting of generation by industrial consumers. The rapid rise in the price of natural gas will immediately show up in the price of electricity, as a considerable share of European power plants uses natural gas as their fuel.

Pursuant to analysis by the European TSO association ENTSO-G, gas depositories contribute significantly to security of supply of gas. On 1 October 2022, the level of EU storage facilities (89%) was at one of the highest levels in years (985 TWh) . During an ordinary winter, the gas system manages to ensure a balance between demand and supply. In the case of a cold winter (one out of 20), a deficit of about 10% is likely, which the agreement between European Union member states to cut consumption by 15% will help avoid.

In the event of high demand and a cold winter period, assuming that LNG is available on the world market, LNG import during the winter may increase up to 1150 TWh, which is Much greater than the maximum volumes (approximately 700 TWh). In a cold winter, that additional supply may significantly decrease the risk of decreased demand in Europe.

The Baltic and Finnish region have historically used Russia as the source of most of their natural gas. The gas adequacy risk is lessened by the new LNGH terminal on the shores of the Gulf of Finland to be utilised in winter.

In addition to the availability of natural gas, the supply of production capacities may be affected by a cold winter throughout Europe.

Cold weather increases electricity consumption and thereby reduces the reserve production capacity. Besides temperature, the generation reserve is also impacted by availability of solar and wind energy. More favourable solar and wind circumstances help covering consumption directly, but also reduce the consumption of hydropower and natural gas, which ensure a higher availability of these production capacities throughout the winter.

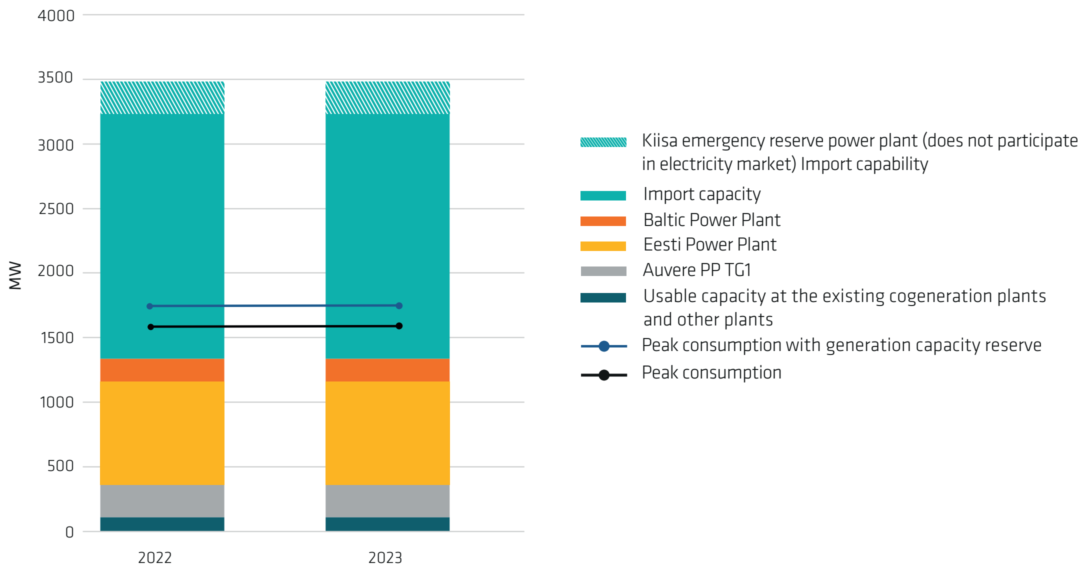
From the Estonian perspective, the availability of cooling water needed by Narva power plants can be stated as a risk due to potential issues with the level of the Narva reservoir. Narva's thermal power plants (Auvere, Balti, Eesti) require constant cooling water drawn from the Narva River and reservoir through cooling water channels. The amount of water flowing through the channels depends on the level of Narva reservoir, which in turn depends on the influx of water from the Narva River and how much water is allowed to spill through the reservoir dam. In a normal situation, the spillways are opened only during spring high water. Half of the spillways along the Narva reservoir impoundment are controlled by Russia, which could in principle lower the reservoir level to a point where Narva power plants would experience problems obtaining cooling water. Since Estonia is still synchronised with the Russian electricity system, it is not expected that Russia will excessively lower the level of the reservoir since Russia's own generation equipment would have to compensate the shutdown of the power plants. But the lowering of the reservoir level is a significant risk when coupled with an extraordinary desynchronisation from the Russian frequency area. To mitigate this risk, the operator of the Narva power plants, Eesti Energia, has drawn up an action plan for implementing additional measures to ensure the capability the generating equipment needed for normal operation of the electricity system.

17 *https://agsi.gie.eu/#/*

4.3 VIEW OF THE UPCOMING WINTER IN ESTONIA

Figure 4.3 shows the generation capacities and transmission capacities available for Estonia in the winter 2022-2023, During an average winter, the Estonian peak consumption can be covered with the guaranteed production capacities located in Estonia. During a cold winter, there may be a need for additional imports if peak consumption coincides with windless and sunless weather.

Figure 4.3
Available generation capacity, import capacity and forecast of peak demand in winter



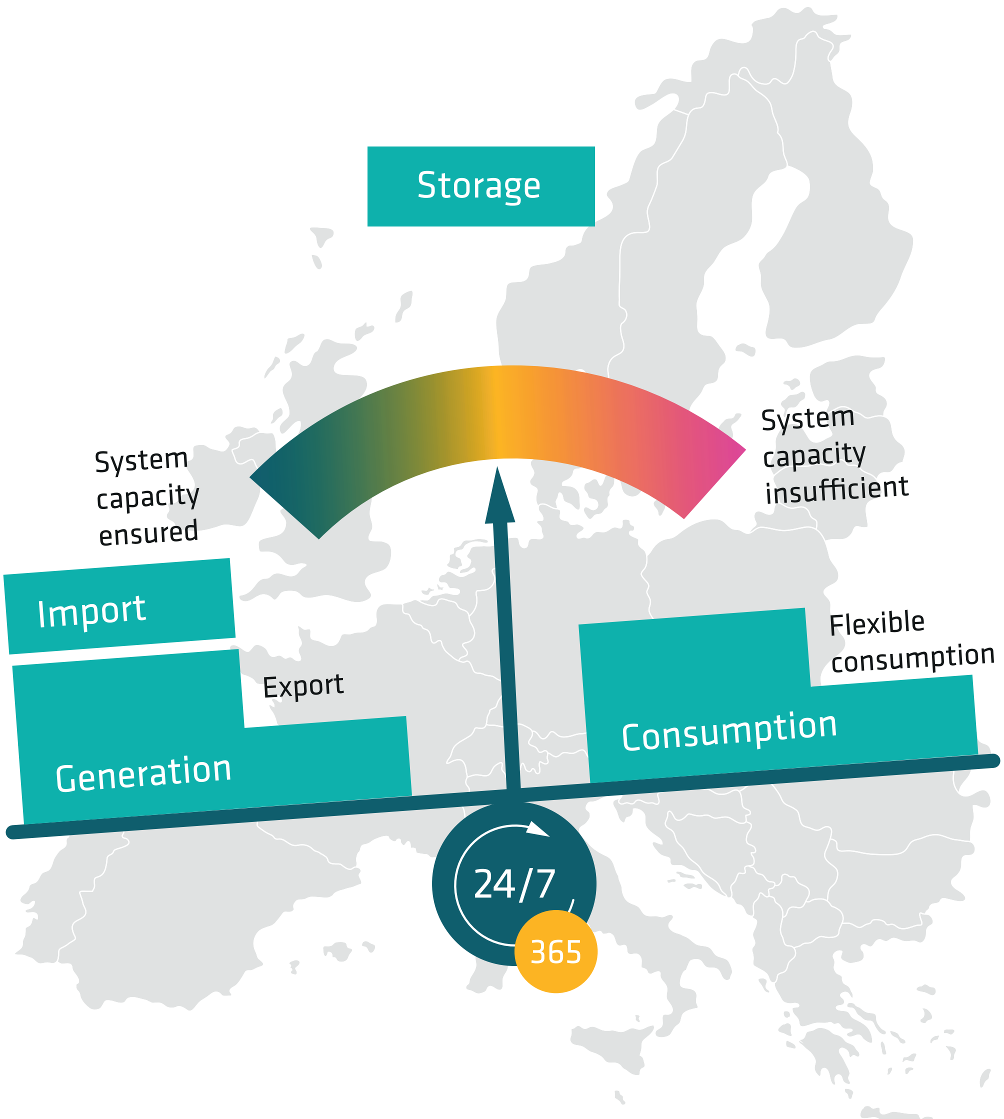
The Winter Outlook 2022/2023 compiled by ENTSO-E will analyse in more detail whether the system adequacy is ensured for the whole winter.

To sum up, the winter of 2022-2023 will be very challenging dependent on whether risks become realised. The most likely result of the tense situation is a high price on the electricity market. Elering will closely monitor the situation shaping throughout the winter and implement the necessary remedies in order to ensure the security of supply for Estonian electricity consumers.

4.4 DEFINITION OF SYSTEM ADEQUACY AND ITS ASSESSMENTE

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 4.4. 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 4.4
Components and balance of long-term system adequacy



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

- establishing a reliability standard (see 4.4.1) pursuant to the balance between energy not served and investment costs on new capacities;
- evaluation of the long-term electricity system adequacy (see 4.5.1. for exact description of the methodology) and see 4.5.2 for detailed results can be found for countries in the Baltic Sea region;
- if the long-term assessment of the electricity system shows better system adequacy values than the reliability standard envisions, 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 4.4.2 for more details).

Figure 4.5
Stages of ensuring system adequacy

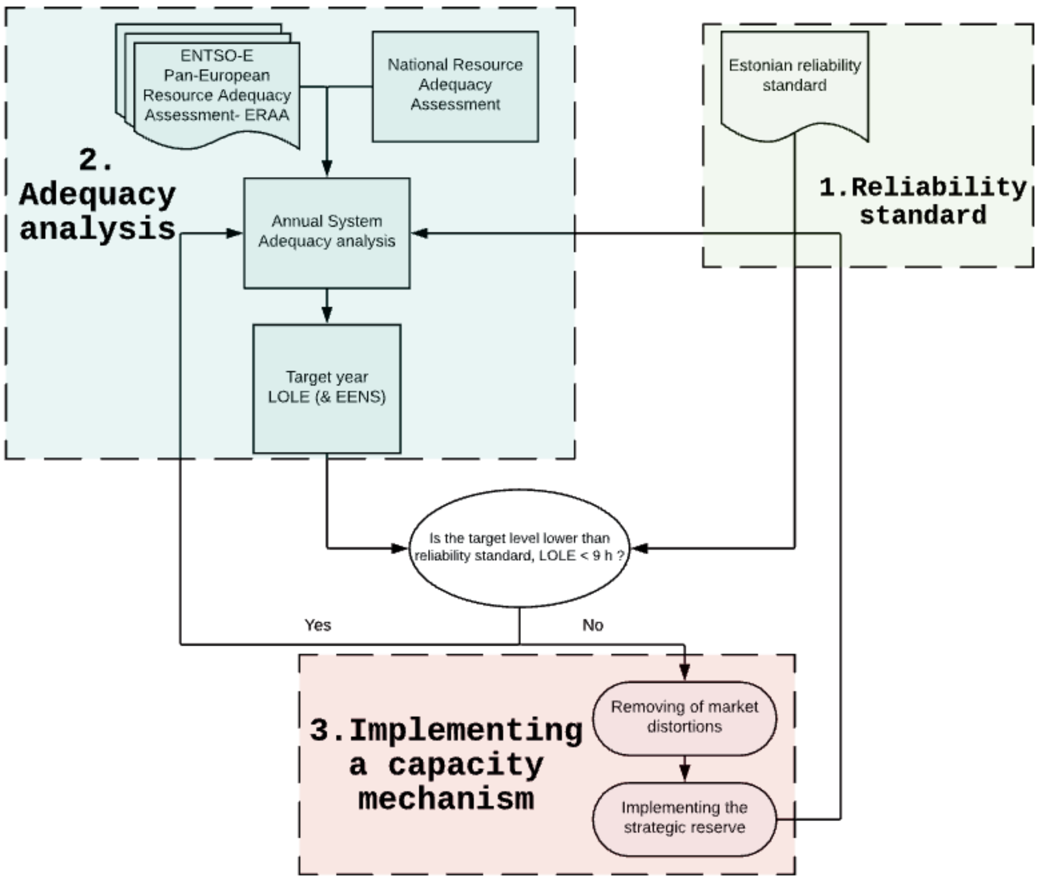


Figure 4.5 shows various stages in which the system adequacy analysis is conducted each year. The reliability standard was established in spring 2021 and the implementation of the capacity mechanism takes place when the capacity no longer meets the standard.

4.4.1 Estonian reliability standard

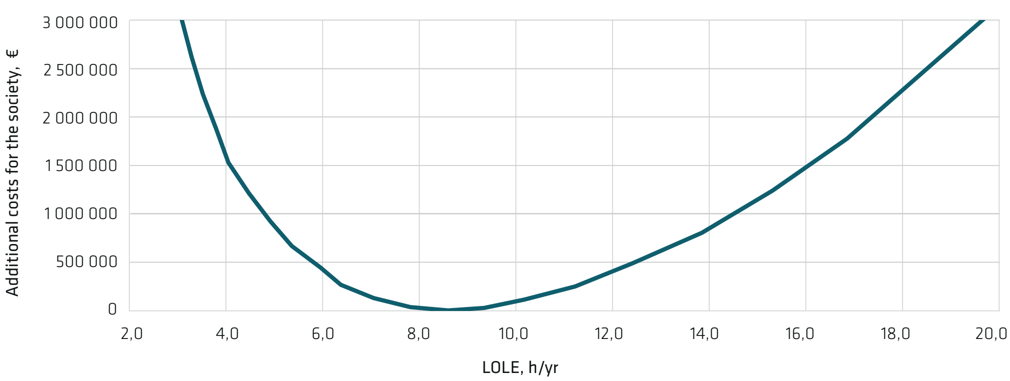
According to the European electricity internal market regulation, all countries must establish a national reliability standard in line with the Europe-wide common methodology approved by ACER. Under the standard, each member state determines the acceptable level of the capacity of their electricity system, 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 managed consumption 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 Served – EENS. The parameters used for determining the reliability standard are the Value of Lost Load - VOLL), measured in [EUR/MWh] and the Cost of New Entry – CONE, measured in [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[18].

In Estonia, the optimum security of supply level for LOLE was established at 9 hours per year on average[19]. 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 capacity of the system are assessed according to the aforementioned standard.

If there are deviations in the optimal nine hours, society will bear higher costs. Figure 4.6 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 3 MEUR more per year in Estonian conditions.

Figure 4.6 Socioeconomic cost curve pursuant to LOLE level[20]



18 *https://elering.ee/varustuskindluse-standardi-uuring*

19 *https://www.riigiteataja.ee/akt/112052021001*

20 *https://elering.ee/sites/default/files/2021-10/Varustuskindluse%20standard_2.pdf*

4.4.2 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 interruption 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[21]– 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 which is separate from the remainder of the electricity market. Due to the fact that the capacity is not participating on 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 on other electricity markets and the receipt of capacity mechanism payments distorts the normal market price and competition on 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 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 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 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 strategy has been submitted to the Ministry of Economic Affairs and Communications and the Competition Authority.

21 https://elering.ee/sites/default/files/public/T%26A/Study%20on%20a%20Capacity%20Remuneration%20Mechanism%20for%20Estonia.pdf
22 https://elering.ee/loppenud-konsultatsioonid-alates-oktoober-2019#tab3

4.5 ANALYSIS OF SYSTEM ADEQUACY

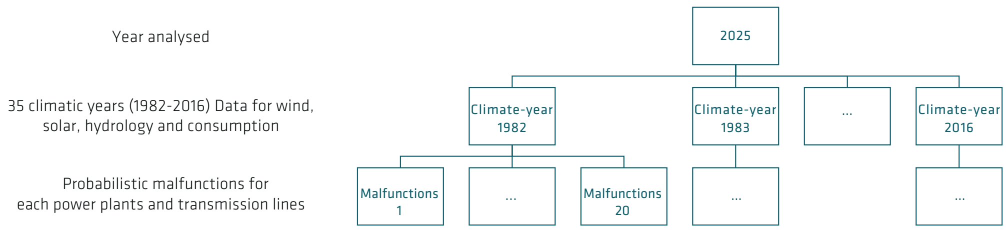
European regulation 943/2019 on the internal market for electricity describes the best practices for analysis of the system adequacy in European member states. Additionally, ACER developed a detailed approach for pan-European assessment of the capacity of the system[23], which is conducted annually by ENTSO-E. Elering cooperates with ENTSO-E and other European TSOs to implement the methodology for the pan-European ERAA and assessments of national system adequacy. Both now and in years to come, the electricity system is experiencing rapid change and to ensure security of supply, countries must work together and contribute to developing analytical methodologies.

4.5.1 Methodology for the probabilistic analysis

The analysis methodology used by Elering and ENTSO-E is the most thorough and accurate method in the world on this scale for assessing the long-term capacity of the electricity system. Hundreds of experts from European TSOs contribute in this regard every year. The used data and expectations are inspected and verified by European system operators, which renders the results reliable.

The capacity of the electricity system is assessed using a probabilistic method. The methodology is based on the Monte Carlo method, which optimises every hour of 35 climate years in which there are different hour-based values for demand, wind conditions, solar radiation, and hydrological situation. During the simulations, randomly occurring malfunctions in system elements are generated (see Figure 4.7). That means that each scenario in this analysis consists of 700 years optimised by way of simulation – 35 climate years – and 20 random malfunction profiles for each one. When performing a large number of simulations, the expected result is that in addition to regular situations, there are also unlikely and extreme situations where, for example, emergencies in several major power plants also coincide with peak consumption and with low renewable energy production, which is an essential situation concerning the system adequacy.

Figure 4.7
Scheme of the Monte Carlo simulations



Such an analysis makes it possible to assess the probability of deficits in the capacity of the electricity system. As the result of the simulations, the annual average EENS and the average number of hours of limited service (LOLE) are calculated. The ENTSO-E methodology can be seen in more detail on the ERAA[24] website with materials on the input data. As a result of the analysis, EENS and LOLE indicators in European countries are given for 2025, 2027 and 2030 in the case of different scenarios, which factor in development of generation capacities in European countries based on the best of current knowledge and economic analysis of generation units.

Figure 4.8 and Figure 4.9 show the most important examples of various duration curves which characterise the variable nature of climate-years from the standpoint of resources. The blue, orange and green lines on Figure 4.8 denote the average annual duration curve and the area shaded in the same colour around it denotes the minimum and maximum wind productivity year's duration curve – i.e. most of the profiles fall within that area. By simulating such situations based on historical data that also take into account climate change, it is possible to also review the most extreme situations such as extraordinarily dry years and/or years with extremely low wind power.

23 *https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual%20decisions%20Annexes/ACER%20Decision%20No%20 24-2020_Annexes/ACER%20Decision%2024-2020%20on%20ERAA%20-%20Annex%20I.pdf*

24 *https://www.entsoe.eu/outlooks/eraa/2022/*

Figure 4.8
Variation in wind resource by climate year and geographic area

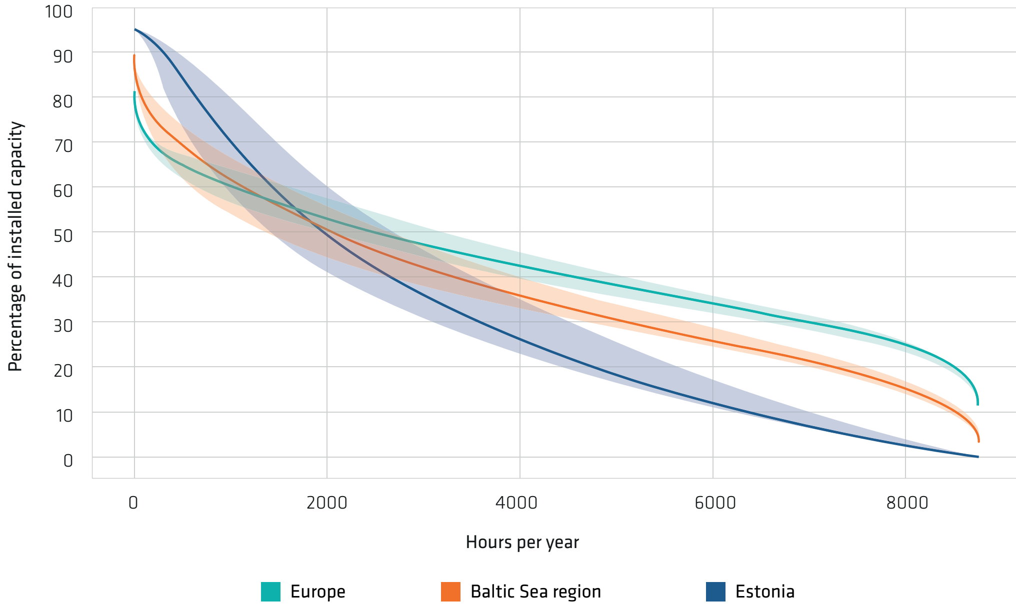
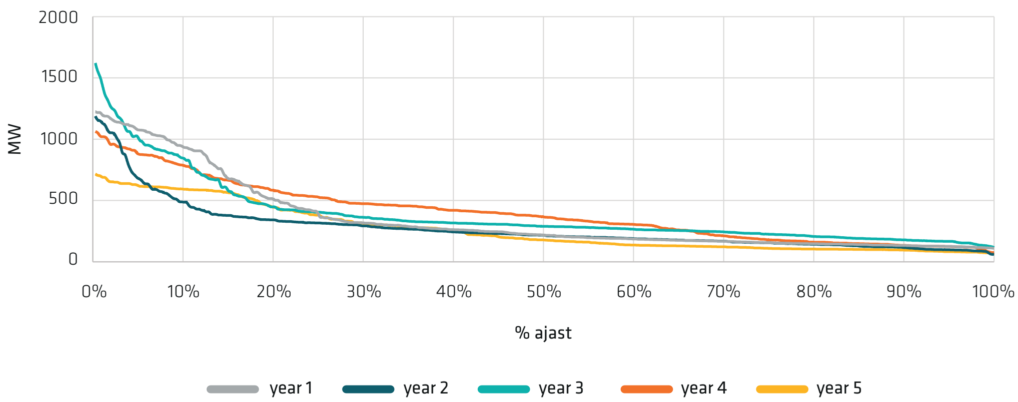


Figure 4.8 shows that if a larger geographic area than Estonia is viewed, the lowest value available simultaneously from wind generation exceeds 0%. That means that there are no hours where wind energy generation for the region as a whole is 0 MW. Looking at the Estonian curve, there may be hours where it is completely calm and no power is generated from the wind, but in The Baltic Sea region, the firm generation capacity can be up to 10%, depending on the climate year and for Europe as a whole, it is at least 10%. These curves shift upwards if only the winter months are taken into account; the weather is usually windier then. In the winter period, the minimum wind power production for Europe is approximately 16% of the installed capacity.

Looking at the seasonal energy availability from hydro plants (Figure 4.9), the differences between different climate years are even greater than for wind. The difference in hydropower may even double between years with more and less precipitation in the Baltic countries. Here, only the volumes of influx from Latvian and Lithuanian rivers is considered, since Estonia has so little installed capacity that modelling it does not exert a noteworthy influence on analysing system adequacy.

Figure 4.9
Baltic hydropower inflow curves



As indicated in the figures, the impact of the climatic years on the production of hydropower has been significant. Therefore, when analysing the system adequacy, it is important to use a large number of different climatic years that would provide a statistical overview of future conditions. This ensures a realistic overview of the potential situations and the likelihood of the occurrence thereof. The objective of this chapter is to illustrate some main resources graphically in order to give an example of the variability of the inputs with which the probable modelling operates. All of the climate data used are publicly available on the ENTSO-E system adequacy website[25] as a pan-European Climate Database file.

25 *https://www.entsoe.eu/outlooks/midterm/*

4.5.2 Results of the analysis of system adequacy

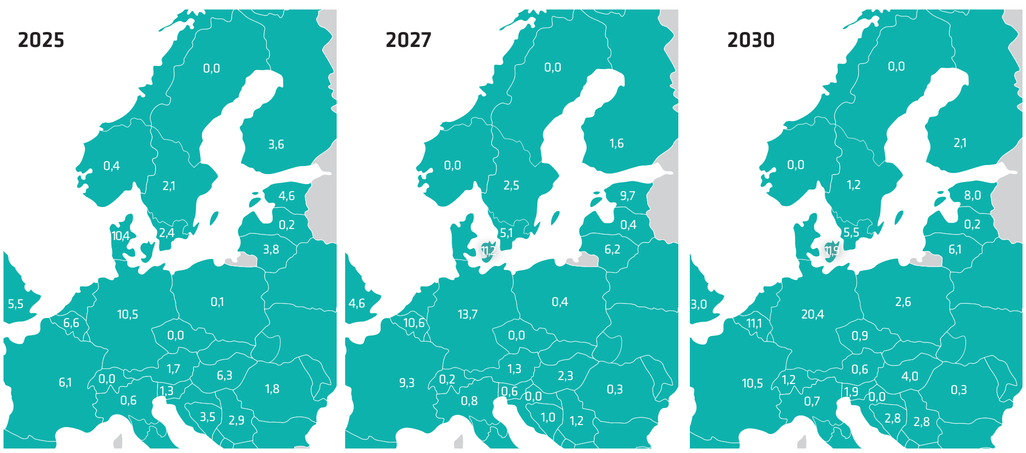
It is an extremely challenging task to assess system adequacy several years ahead, considering how fast the energy landscape is changing. There are many variables and trends in one country alone. In the case of Europe's single energy market, electricity or deficit thereof moves from one country to another and therefore system adequacy is a regional challenge and Elering evaluates system adequacy through several levels.

ENTSO-E in cooperation with Elering and many other TSOs each year compiles a European Resource Adequacy Assessment. This year, the probabilistic system adequacy analysis goes up to 2030 and the results include the indicators for electricity system adequacy for all European countries in the years 2025, 2027 and 2030. Analysing these years, the basis for the data are the national energy and climate plans submitted by all EU countries, the best available knowledge of the TSOs and according to ERAA methodology, the simulation model calculates which power plants are economically sustainable. Europe has many inefficient capacities that in conditions of growing fuel prices and ambitious climate goals no longer are able to cover their fixed costs with revenue from the energy-only market. There are also countries whose electricity system is underinvested and the model adds capacities with the necessary properties (storage, flexible consumption or a generation unit for some definite fuel). Elering uses the ENTSO-E analysis results as a starting point for gaining an even better overview of the situation ahead.

ERAA's results are based on the system adequacy parameters LOLE and EENS. Figure 4.10 shows the result of number of hours of limited service where:

- the Economic Viability Assessment has closed loss-making plants and added investments into new resources.
- If there is a deficit, countries proceed from the principle of curtailment sharing, which also applies in the current market system.

Figure 4.10
Average numbers of loss of load expectation in Europe, based on the long-term system adequacy analysis



As a result of the ERAA EVA, the following changes occur in the input data for the 3B+FI compared to the TSOs' best knowledge:

- from 2027, all of the oil shale fired units in the model will be closed, 660 MW. Additional investment will be made in 2030 into 80 MW demand side response capability and 50 MW gas-fired power plants.
- In Latvia, 180 MW gas capacities will be closed in 2024 and 80 MW of demand side response capability will be added in 2030.
- In Lithuania, nothing will be closed and in 2030, 120 MW of demand side response capability will be added
- In Finland, 240 MW coal capacity and 80 MW gas capacity will be closed. Finland will invest into 120 MW demand side response capability.

According to the analysis, the oil shale fueled units in Estonia will not be sustainable past 2027 and these should be closed given market-based behaviour. A decline in the sustainability of thermal power plants is a result of higher renewable energy goals in European countries for the purpose of reducing dependence on Russian energy sources, which in turn will drive conventional power plants out of the market in an increasing number of hours. This would result in hours of limited service in Estonia where the average exceeds the reliability standard established by the cabinet in 2021 – 9 hours of limited service per year.

Elering repeated the simulations performed by ENTSO-E to find whether system adequacy in Estonia would be ensured and the system adequacy parameters within the range defined in the reliability standard if oil shale units were brought back on the market. Other region-specific details were introduced in the repetition of the simulations:

- Unlike ERAA methodology, the computational model is not allowed to close any power plant or add any investments.
- To keep the system adequacy from being overestimated, more conservative presumptions have been made regarding adding renewable energy capacities planned for the region. The 2030 100% renewable energy generation volume goal has not yet been factored in for Estonia, not the generation capacities to be added through renewable energy auctions.
- Up to 2026, there will be 7 oil shale units (with total capacity of 1330 MW) and after that it is assumed that there will be 4 units left (total capacity of 831 MW).
- Modelling of reserve sharing between the three Baltics has been added; this corresponds to the structure of the LFC unit to be created.

Figure 4.11 shows the result of Elering follow-up analysis of the main parameter of system adequacy of the region - hours of limited service/LOLE. Leaving the existing controllable capacity In Estonia, with the ERAA, the number of hours of limited service in Estonia will drop from 4-6 hours to zero in 2025 and from 9.7 hours to 0 in 2027.

Based on ERAA and Elering system adequacy analyses, Elering acts in accordance with the Electricity Markets Act and the previously prepared action plan (see Figure 4.5 and chapter 4.4.2), notifying the Competition Authority and the Ministry of Economic Affairs and Communications of security of supply problems and making a proposal to establish a strategic reserve.

By 2030, consumption in the region will have caught up sufficiently to the currently known generation units' level and a considerable number of LOLE hours may arise even with this structure. One limiting factor for Estonia is the fact that there is a need to maintain reserves, but there are not many rapidly reacting capacities that are capable of offering reserves. The model prefers reliability of the electricity system to covering consumption, due to which energy not served will arise before a reserves deficit.

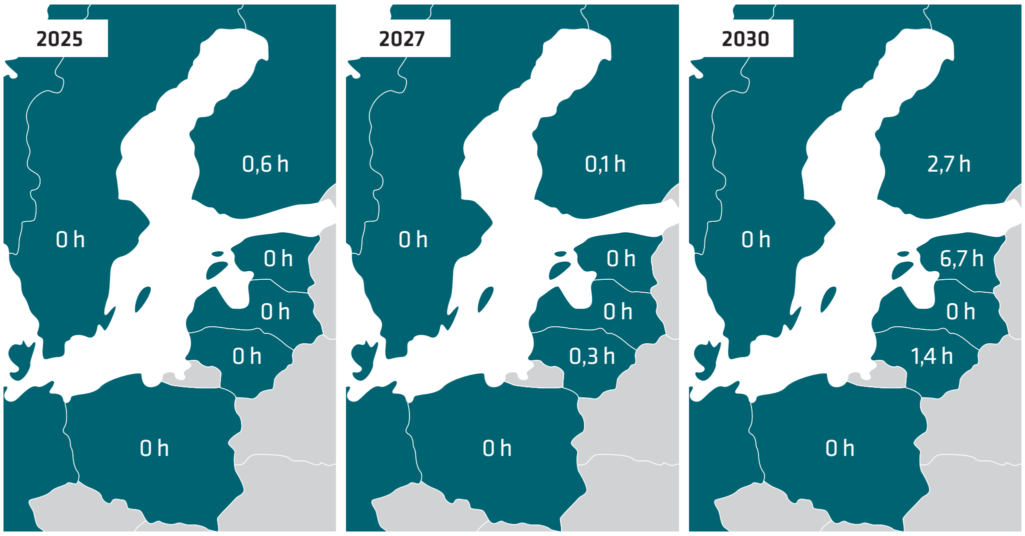


Figure 4.11
Average number of loss of load expectations service in the region, 2025, 2027 and 2030

4.5.3 Regional deterministic analyses

The deterministic method visually compares the expected generation and transmission capacities that are available during the peak demand hours and also including the reserve requirements. 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 end 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 assumptions:

- 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%. 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.[26]

- Olkiluoto 3 is operating at full capacity during peak loads. Plans for Fennovoima's Hanhikivi nuclear power plant (1200 MW) to be added by 2032 have been scrapped.

- According 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 coping 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 gone according to plan, but Harmony link will be delayed and is expected to come online in 2027. No trade takes place on the Lithuanian and Poland AC connection in 2026; the line is intended to be used for reserves.

- "Other" capacities comprise the quantities used by smaller electricity producers. "Other" includes, e.g. biomass, waste incineration and fuel oil plants.

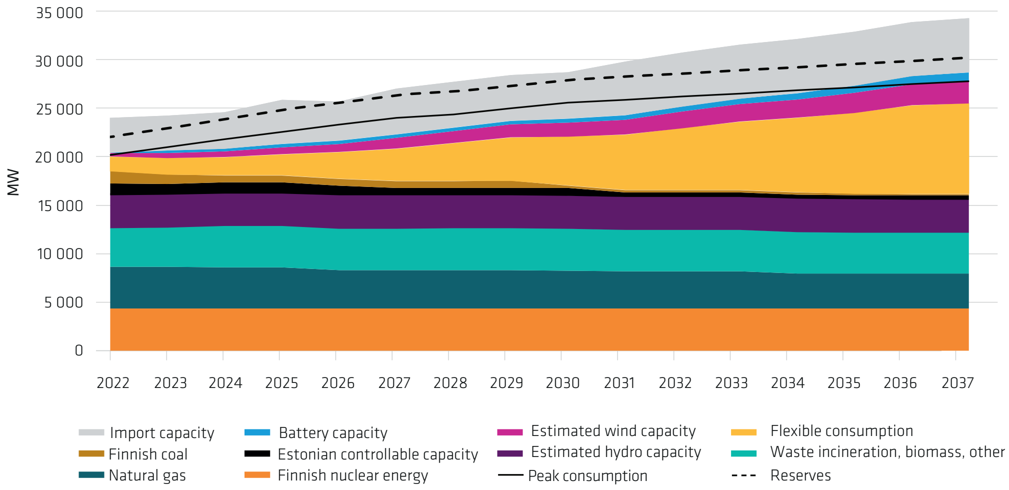
- Hydro plants generally not operate during peak hours at their maximum installed capacity and therefore 50%, 24% and 77% were used as the percentages of installed capacity for Lithuanian, Latvian and Finnish hydro.

- 100% is used as the amount of battery capacity used, as these usually participate on the reserves market where they are activated too rarely to manage to be recharged in the same day.

Figure 4.12 shows that in ordinary situations the Baltic and Finland region rely heavily on import capacity in order to cover peak demand. Without international connections to Sweden, Poland and Norway, Finland and Baltic frequency reserves could not cover consumption: On the figure, hydro capacities are indicated as shaded areas. Since depending on the situation, they may make a significantly greater mark in an actual peak hour, the more conservative presumption mentioned previously has been used as the basis. Finnish potential consumption potential is also shaded 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 conditions and the length of the high demand period, but the entirety of the resources will have likely been implemented before the TSOs impose demand curtailment.

26 *Although solar energy is not generally available during winter peak hours, it does have a positive impact on wintertime security of supply in the sense of reduction of total consumption. It is possible to use storage capacities and hydro capacities more and solar power less during peak demand times.*

Figure 4.12
Available generation and transmission capacities in the Baltics and Finland in 2022-2037

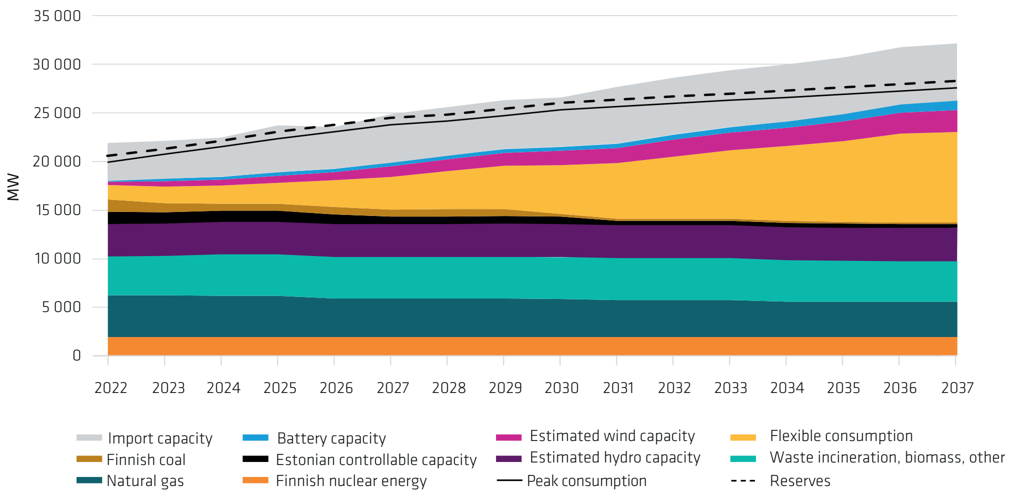


TSOs take into account various malfunctions in the system. Figure 4.13 includes a deterministic analysis about a situation where the first and second element in the Baltic and Finland region go down – an N-2 situation, as it is known.

Compared to the presumptions used for figure 4.12, the differences for N-2 are the following

- The largest elements whose loss is factored in is Olkiluoto-3, which is 1600 MW, and Olkiluoto 2 nuclear reactor, which is 890 MW.
- Should OL3 go out of service, the constraint on the Sweden-Finland border will disappear and import capacity will increase by 300 MW. 300 MW of consumption previously agreed with Finnish consumers will also be lost[27].
- To balance its system, Finland initially uses all of its previously maintained reserves and therefore the 3B+FI region will have decreased demand for reserves only for the reserves maintained by the Baltics.

Figure 4.13
Generation and transmission capacities in an N-2 scenario in the Baltics and Finland in the 2022-2037 period



To sum up the region's deterministic scenario, the region will, in order to reduce import dependency, need investments into either generation units or technologies that shift consumption such as flexible consumers and batteries. Investments into wind and solar capacities will make an important contribution for covering peak consumption but in terms of their unplannable generation cycle, this is lower than the contribution made by controllable consumption. From the standpoint of planning the capacity of the electricity system, more weather-independent solutions like thermal power plants, storage capacity or demand side response would be required. In Finland, Fingrid sees a lack of capacities that would be capable of replacing the capacity of large nuclear power plants during outages (several days to a week) and Estonia has a lack of solutions that supply frequency reserves to the electricity system.

27 *https://www.fingrid.fi/en/news/news/2022/impact-of-olkiluoto-3-on-transmission-capacity-given-to-electricity-market-between-finland-and-sweden-on-northern-interconnections/*

4.5.4 Extraordinary scenarios

One of the presumptions for the foregoing system adequacy assessment is a functioning European electricity market and potential black-swan events are not taken into account. Nevertheless, Europe's energy-based electricity market is bedevilled by a number of market failures, and thus the market-based inception of investments needed to ensure system adequacy are in doubt in a number of European countries. For those reasons, Elering has also analysed additional continuity scenarios. When analysing these scenarios, we use the deterministic method.

This analysis does not yet take into account the added import capacity in Finland due to the completion of Estlink 3. According to the initial assessment, Estlink 3 should be ready by 2035 and have a capacity of 700-1000 MW. Since the technical details are not yet in place, it is not certain how Estlink 3's capacity will change in the case of extraordinary scenarios.

4.5.4.1 Baltic island operation 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 extraordinary synchronisation plan, when the Baltic states desynchronise from the Russian frequency areas, the synchronisation of the Baltic states with continental Europe will happen in a matter of hours. Thus, it is not likely that the Baltic states will have to operate in island mode for a long time.

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

Presumptions:

- The Baltic states must be prepared for the 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 frequency area until 2027, 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 largest generation capacities are likewise limited to 400 MW.
- 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 4.14
Baltic island mode scenario

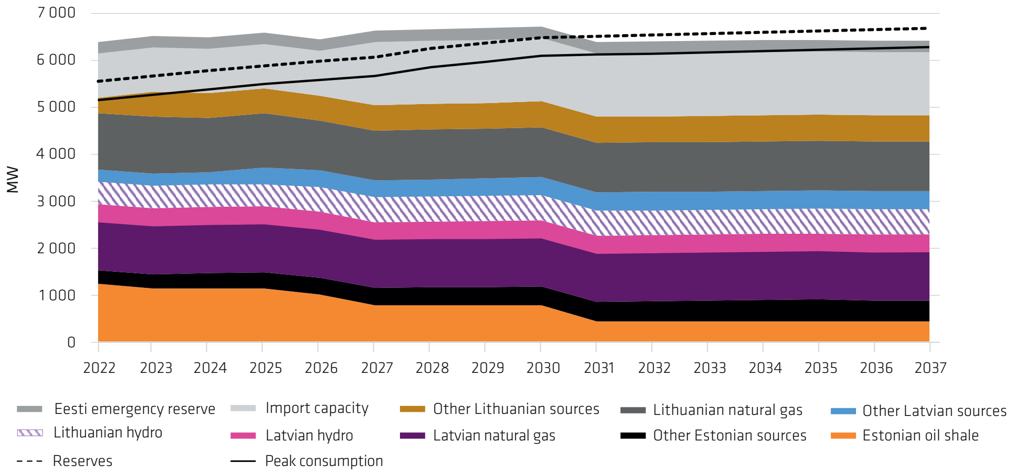
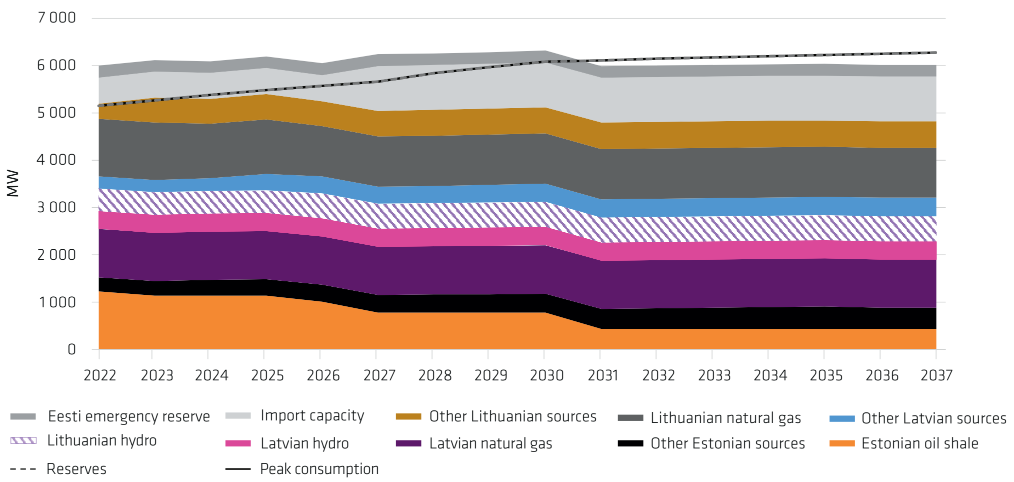


Figure 4.15
Baltic island mode N-1 scenario



Analysis of the Baltic synchronous area scenario given on figures 4.14 and 4.15 shows that the Baltic system adequacy level would be covered using controllable generation capacities and transmission capacities until 2030. From 2030 on, there may be situations where it is not possible to keep enough reserves during peak consumption in island mode and in an N-1 situation there may be shortages in generation capacities.

Together with the other Baltic TSOs, Elering is increasing readiness to operate in island mode. Readiness is being established by way of investments made as part of a synchronisation project. The impact of remaining in island operation scenario on the stability of our electricity system is gradually reducing as more investments are made.

According to the current assessment, upon the realisation of the Baltic synchronisation area, the Estonian electricity system must have approximately 1000 MW of guaranteed production capacity. In combination with the other generation capacities in the region and DC connections that are available in reduced capacity, it is possible to ensure Estonian power generation during peak loads and fulfil the reliability standard.

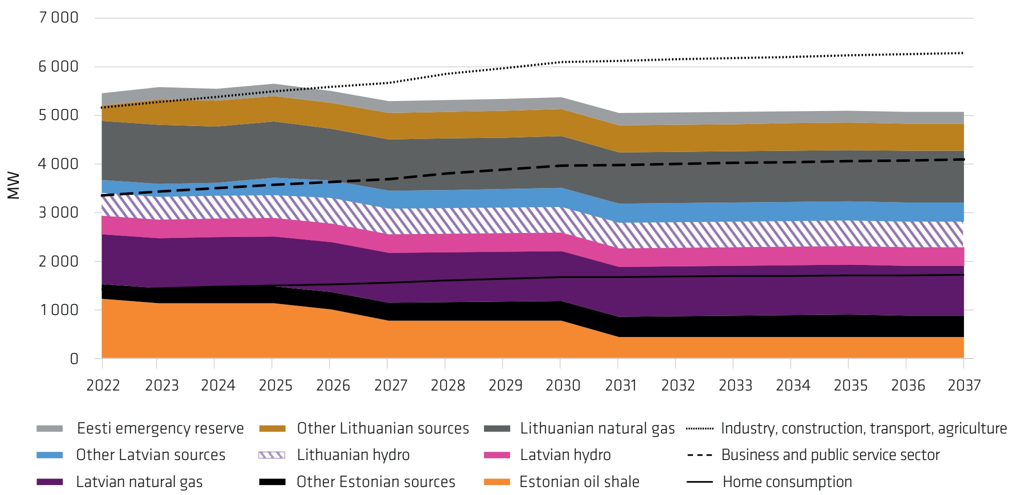
4.5.4.2 Baltic emergency continuity scenario

A more severe situation than 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.

Presumptions:

- The Baltics are in island mode in respect to the European energy system and make up a separate Baltic synchronous area.
- There are no direct current connections with other regions.
- The estimated duration of the scenario is two months during which 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 4.16
Baltic emergency continuity scenario



In this scenario, where none of the DC connections in any of the Baltics are available, controllable 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. 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 not possible today for the Baltic countries to simultaneously ensure sufficiently fast reserves for frequency and covering consumption, due to which malfunctions may result in additional automatic phase-out of consumption. More information about the capacity of frequency reserves in the Baltics is available in Chapter 2.2.1.2. The respective capacity will be acquired within the framework of the synchronisation project.

It should be emphasised that this scenario has a low chance of occurring. It would be 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 and sufficiently high consumption in the winter period.

4.5.4.3 Estonian vital service scenario

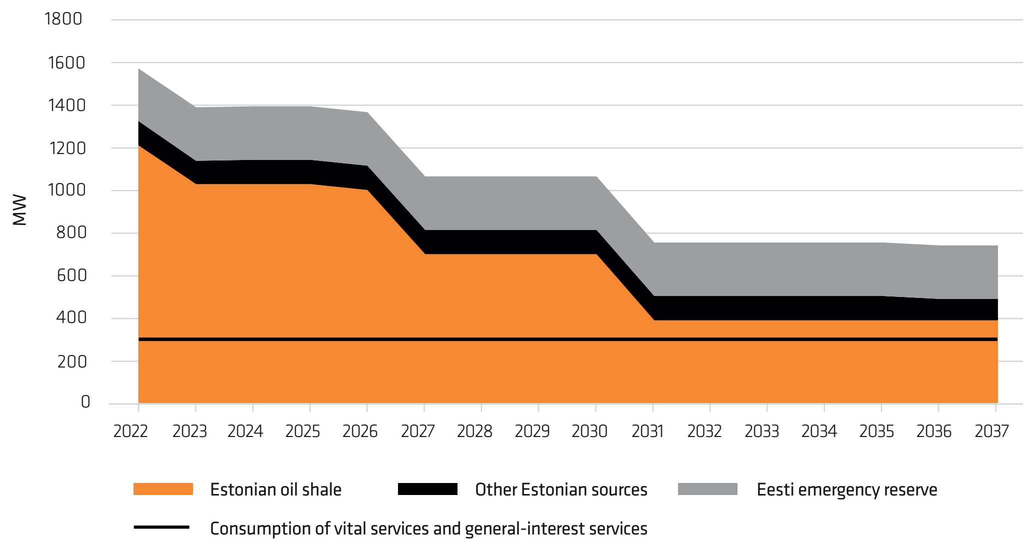
The Estonian vital service scenario describes a situation where Estonia has lost all connections with neighbouring countries. In such a situation, the priority is to firstly cover the consumption of vital services, followed by the consumption of services of general interest. A vital service is a service with overwhelming influence over the functioning of society whose interruption poses an immediate hazard to the life or health of people or the functioning of other vital services or services of general interest.

Presumptions:

- 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 4.17 shows that Estonian vital service and general-interest service consumption is about 300 MW, which is covered many times over during the entire period under observation. This value was found in cooperation with the distribution grids, which the majority of vital service and general-interest service providers have joined. The actual peak consumption of vital service and general-interest service is lower but since there are a number of other consumers at points of connection besides vital service providers, distinguishing them and disconnecting them is a complicated manual task and thus a buffer of 300 MW is factored in. 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 4.17 Estonian vital service scenario



Elering estimates that Estonia should have about 1000 MW controllable capacity, and that would ensure safe operation of the electricity system. After 2030, Estonia will have significantly less than 1000 MW and ensuring the same level of security of supply will require additional investments into generation capacities.

4.6 DEMAND FORECAST

The following sub-chapter gives an overview of the forecast for Estonian end-consumer demand and potential factors that affect the demand. The forecast will be kept up-to-date based on updated statistics and the results of the completed studies.

Electricity consumption in future will be influenced by several factors, of which many are based on the European Green Deal, the Fit for 55 package proposed by the European Commission and fossil energy competitiveness compared to renewable energy (see chapter 4.91).

The three main factors that influence electricity demand:

- Increase in building renovation and distributed generation –In July 2020 the Government approved a long-term strategy for the renovation of buildings, the main goal is to renovate all buildings built before 2000 by 2050. Together with the strategy, minimum energy efficiency requirements for new and renovated buildings were established. The minimum requirement for energy performance of new buildings is class A – nearly zero-energy buildings, one way of complying with it is to install local renewable energy generation systems (solar panels). These energy efficiency measures will ensure an increase in energy performance through reducing heat loss but will also result in increased energy consumption due to the installation of ventilation systems as part of the renovation. The installation of solar panels will reduce the growth rate of energy demand in the system but will result in greater volatility in grid demand, unless local energy storage (batteries or heating system accumulation tanks) or demand side response is used. The influence of building renovation and distributed generation to the Estonian electricity demand was assessed in a Study to determine Estonian electricity demand scenarios[29].

- The partial transition from natural gas consumption to electricity consumption – due to building energy performance requirements, the number of small and less efficient district heating networks that to this point used natural gas will decrease and a changeover will take place to local electric heat pumps. New local gas heating-based buildings will not be built since according to the building energy performance 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 co-generation plants, and these will be able to harness heat from local bodies of water or city wastewater. Fit for 55 includes a proposal to use a separate emissions trading system for the fuels and motor vehicles used for buildings. Introduction of this system would likely make the use of renewable-energy-based electric heat pumps more competitive than fossil natural gas. The extent of the transition from natural gas to electricity was assessed last year's Estonian gas consumption study and the study to determine Estonian electricity demand scenarios[29]. The size 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.

- Electrification of the transport sector – in the first half of 2022, more than 10% of sold vehicles 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 in Estonia as well, the share of electric vehicles in the overall fleet is expected to increase. The developments in charging infrastructure, rise in people's awareness and the relatively high price level of liquid fuels will be contributing factors. Besides the Fit for 55 proposals are to impose motor vehicle fuel sellers the obligation to buy emissions allowances and auto makers will be obliged to sell only zero-emissions vehicles and minivans from 2035. The study of Estonian electricity demand scenarios[29] found that the electrification of the transport sector would amount to about half of the increase in electricity demand. But it also found that according to studies conducted thus far and usage statistics, it is extremely unlikely that all electric vehicles charge at the same time, thus the growth in the number of electric vehicles will not be a very acute problem for the electricity system. Moreover, as smart charging technologies become widespread, the more evenly electricity consumption will be spread out over the days of the week and the hours of the day. Furthermore, introduction of EVs will help

28 https://elering.ee/sites/default/files/2021-10/Eesti%20gaasitarbimise%20uuring_0.pdf
29 https://elering.ee/sites/default/files/2022-10/Study%20-%20Electricity%20demand%20scenarios.pdf

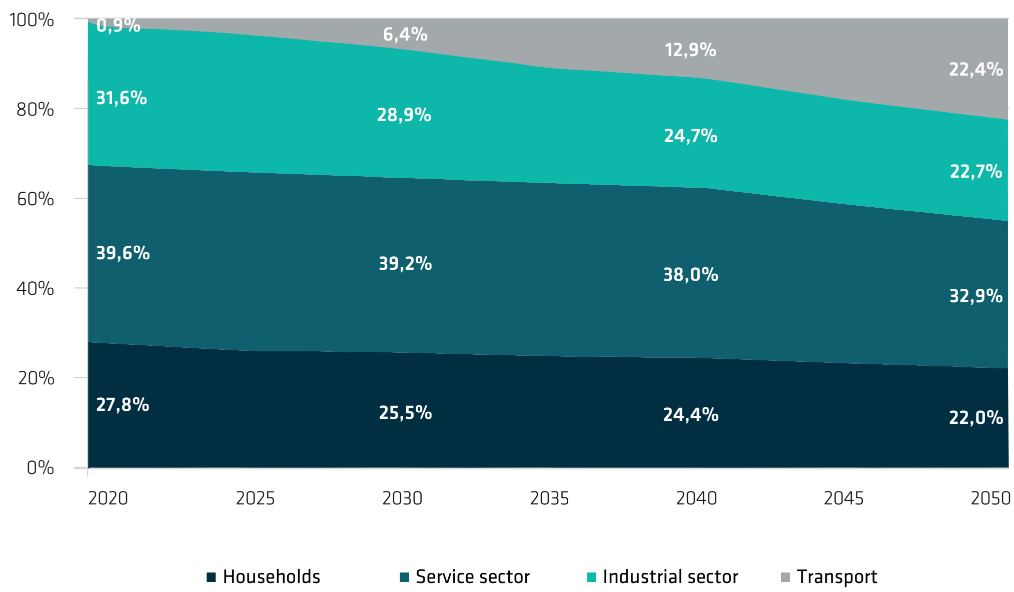
Table 4.1 shows the forecasted annual growth in electricity consumption and growth in peak demand stemming from the electrification of each 10,000 passenger cars, 1000 trucks and 100 buses.

Table 4.1
Road transport sensitivity analysis[29]

	Cars and vans	Trucks	Buses
Number of vehicles	10,000	1000	100
Average annual distance travelled, km	15,383	23,306	64,958
Annual consumption, GWh	36.5	31.8	8.9
Peak demand, MW	10.1	9.6	2.2
Lowest demand, MW	1.1	0.4	0.3

Consumers can be categorised by sector: services, industry, households and transport. 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 foresee 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 4.18 shows how the forecasted consumption share will be distributed by sector up to the year 2050.

Figure 4.18
Forecasted share of consumption by sector



In various sectors there are a certain number of electricity consumers who are responsible for providing vital services[30] 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 4.2 are a statistical aggregation of the last 15 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.

29 https://elering.ee/sites/default/files/2022-10/Study%20-%20Electricity%20demand%20scenarios.pdf
30 https://www.riigiteataja.ee/akt/103032017001

Table 4.2 Consumption statistics and forecast up to 2030

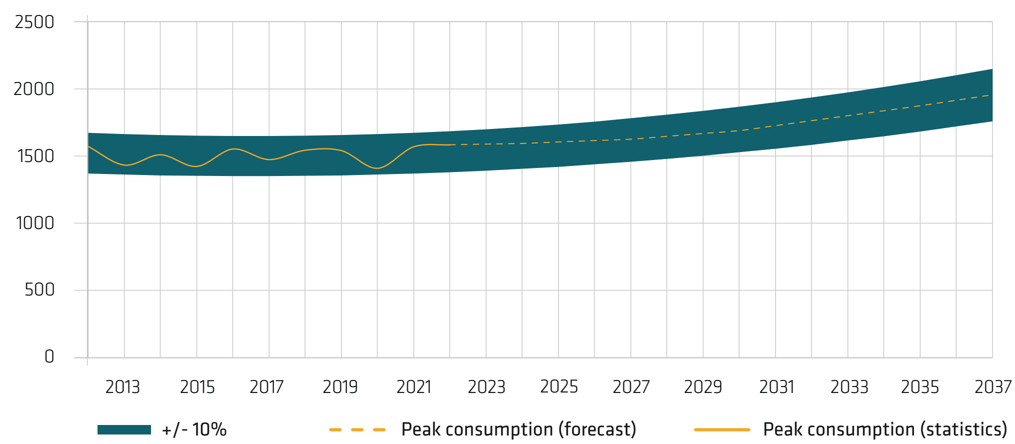
Consumption statistics		
year	**Annual consumption, TWh**	**Peak load, MW**
2012	8,1	1433
2013	7,9	1510
2014	8,1	1423
2015	8,1	1553
2016	8,4	1472
2017	8,5	1474
2018	8,7	1544
2019	8,6	1541
2020	8,4	1409
2021	9,0	1570

Consumption forecast		
year	**Annual consumption, TWh**	**Peak load, MW**
2022	9,0	1585
2023	9,0	1590
2024	9,1	1595
2025	9,1	1605
2026	9,2	1616
2027	9,3	1626
2028	9,3	1635
2029	9,4	1644
2030	9,4	1653
2031	9,7	1697
2032	9,9	1742
2033	10,2	1786
2034	10,4	1830
2035	10,7	1875
2036	10,9	1916
2037	11,2	1957

The forecasts in the table were made for the ENTSO-E system adequacy assessment based on modelling results and the Elering-commissioned study on Estonian electricity consumption scenarios[30]. Each year, ENTSO-E prepares several dozen hour-based consumption profiles, which consider various direct variables such as number of electric cars, number of heat Pumps, historical consumption and other factors such as weather patterns and climate warming based on climate years (climate-year is defined in 4.2.2). All these variables were compiled in the Trapunta tool, and unique consumption profiles are generated for all climate-years for each target year. Starting in 2030, the findings of the study commissioned by Elering have been used, which takes 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 gradual electrification of the energy sector.

Figure 4.19 illustrates the consumption trend and the volume of the generation reserve necessary for meeting consumer demand based on section 14 of the Grid Code on the functioning of the electricity system. 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 of 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 4.19 Peak consumption statistics and forecast up to 2037



30 *Study of Estonian electricity consumption scenarios.*

Since statistics on overall general electricity consumption began to be gathered, general electricity consumption has shown a slight growth trend, but the peak loads on the electricity system have remained essentially unchanged in the last decade – between 1400 and 1600 MW. The peak load of 1587 MW was recorded 11 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 electricity demand growth, it should be noted that general electrification will foremost increase the annual end consumer's demand. The volume of grid demand will grow at a slower pace due to the increase in distributed generation. The energy consumptions electrification together with the introduction of electric vehicles, the flexibility of electricity demand will increase (i.e. the capability to control, time and store electricity) which will support the transition to renewable energy sources, general reduction in GHG emissions and of 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 capture 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 demand. 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 storage technology such as batteries and pump hydro accumulation plants) and active participation on the electricity market – this in turn will levelize the grid demand 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. We see that the average forecasted peak consumption will grow about 10 MW each year and starting in 2030, we can expect peak consumption to grow about 40 MW each year. Peak consumption will cross the 1600 MW level for the first time in 2025, but security of supply simulations illustrate that in extreme winters, that threshold will be crossed already this winter.

4.7 KEY CHANGES IN CONNECTION WITH GENERATING CAPACITIES IN ESTONIA

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 possibility to remain conservative with the data taken into consideration for analysing the system adequacy.

Table 4.3
Estonian generation capacities in 2022

<table>
<tr><td colspan="3">Controllable market-based capacities</td></tr>
<tr><th>Power plant</th><th>Installed net capacity, MW</th><th>Firm generation capacity, MW</th></tr>
<tr><td>Eesti Power Plant</td><td>866</td><td>799</td></tr>
<tr><td>Balti Power Plant</td><td>192</td><td>177</td></tr>
<tr><td>Auvere Power Plant</td><td>272</td><td>250</td></tr>
<tr><td>Iru Power Plant- gas unit</td><td>94</td><td>0</td></tr>
<tr><td>Iru Power Plant- WTE unit</td><td>17</td><td rowspan="8">111</td></tr>
<tr><td>Põhja Thermal Power Plant</td><td>77</td></tr>
<tr><td>Sillamäe Thermal Power Plant</td><td>23</td></tr>
<tr><td>Tallinn Power Plant</td><td>39</td></tr>
<tr><td>Tartu Power Plant</td><td>22</td></tr>
<tr><td>Pärnu Power Plant</td><td>21</td></tr>
<tr><td>Enefit</td><td>10</td></tr>
<tr><td>Other industrial and CHP plants</td><td>75</td></tr>
<tr><td>Total</td><td>1708</td><td>1337</td></tr>
<tr><td colspan="3">Capacities outside the market</td></tr>
<tr><td>Kiisa Emergency Reserve Power Plant</td><td>250</td><td>250</td></tr>
<tr><td colspan="3">Renewable energy capacities</td></tr>
<tr><td>Hydro power plants</td><td>8</td><td>0</td></tr>
<tr><td>Wind farms</td><td>317</td><td>0</td></tr>
<tr><td>Solar power plants</td><td>510</td><td>0</td></tr>
</table>

Biggest changes compared to 2021

- In early August, the cabinet approved the results of the fourth renewable energy tender, which will bring 540 GWh of electricity generated from renewable sources to the electricity market. 29 tenders were submitted for the reverse auction now ended with a total volume of approximately 1,200 gigawatt-hours per year. The contract was awarded to 12 tenders, representing a total 25 solar and wind energy generators and they are guaranteed sales revenue between 18.99-34.9 €/MWh[32]. Subsidies are not paid if the day-ahead market price is higher than the approved assistance level. While the green electricity tender round was originally announced for 450 GWh of green power, due to the keen interest and urgent need for growing renewable output, the volume of the tender was increased to the maximum allowed, 540 GWh. The subsidies to be paid depend on the conjunction of the price of the participant in the auction and the exchange price of electricity, which means that if the average monthly exchange price is lower than the price offered by the producer, the difference between these will be compensated for the producer. Successful tenderers must begin producing renewable energy by the beginning of 2026 at the latest. Renewable energy subsidies will be paid to producers for 12 years.

- The Ministry of Finance approved new owner's expectations for the state energy company Eesti Energia[33] in which it highlighted that until the end of 2026, at least 1000 MW of power generation capability must be guaranteed. Among this total, there must be capability to activate at least 900 MW from cold reserve in winter, 1 Nov to 28 February, and at least 600 MW from 1 March to 31 October.

32 *https://elering.ee/sites/default/files/2022-06/V%C3%A4hempakkumiste%20avamise%20protokoll_02_06_2022.pdf*
33 *https://fin.ee/riigihanked-riigiabi-osalused-kinnisvara/riigi-osalused/rahandusministeeriumi-valitsetavad-uhingud#eesti-energia-as*

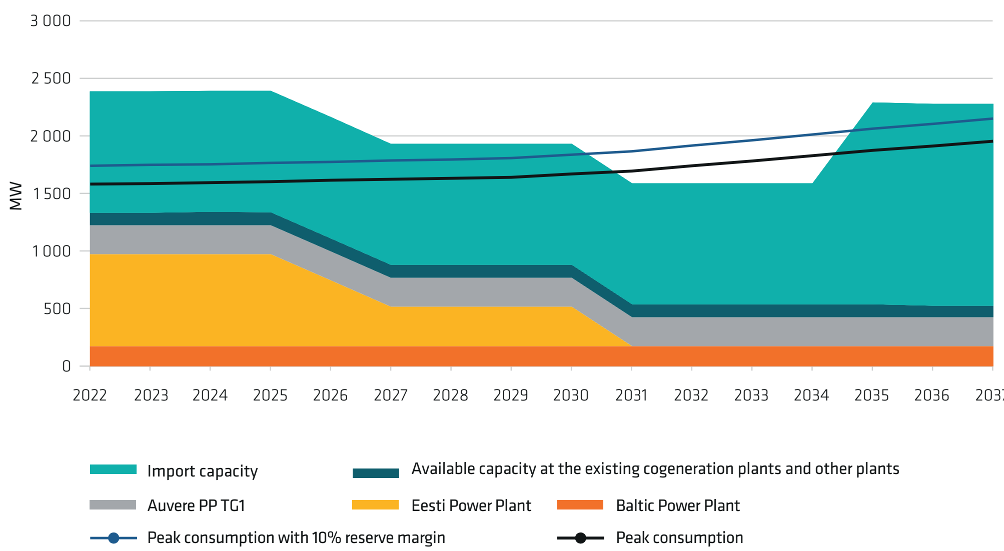
4.8 ASSESSMENT OF THE GENERATION RESERVE REQUIRED FOR MEETING CONSUMER DEMAND

Pursuant to Section 13 of the Grid Code on the functioning of the electricity system, the TSO annually carried out the generation reserve assessment necessary for meeting consumer demand. For this analysis, Elering uses the data on the production capacities submitted by electricity producers, its own assessment of peak consumption, the availability of cross-border transmission capacity, and possible disturbances in the electricity system. Pursuant to the Grid Code, the deterministic analysis does not take into account generation capacities with a non-controllable generation cycle such as wind and solar. The assessment of the generation reserve required for meeting the consumption demand is conducted for fifteen years for both the winter and the summer periods. The winter assessment is provided according to the peak consumption forecast plus a reserve of 10%. The summer assessment is provided before the expected summer peak consumption.

4.8.1 Assessment of adequacy of generation capacities in winter

According to consumption forecasts in chapter 4.5, the winter peak consumption 15 years from now will increase to 1957 MW, which is about 20% higher than the peak forecasted for 2022, 1585 MW. Together with the additional 10% generation adequacy reserve, peak consumption in 2037 will be 2153 MW. According to information from electricity producers and Elering forecasts, the installed controllable generation capacity will be about 1089 MW in 2030 and about 679 MW in 2037, to which Kiisa emergency reserve power plant will be added. The available generation capacity corresponding to Section 14 of the Grid Code will amount to about 850 MW in winter 2030 and about 530 MW in 2035. With regard to the import capacity, the N-2 situation has been considered, which means that two major transmission lines with neighbouring countries are out of service, i.e. this is a conservative estimate. According to the winter generation capacity adequacy assessment shown on Figure 4.20, Estonia will have enough local generation capacities and import capability in an N-2 situation to cover winter peak consumption. Winter peak consumption coupled with reserves will be covered until 2030 and again after Estlink 3 is added.

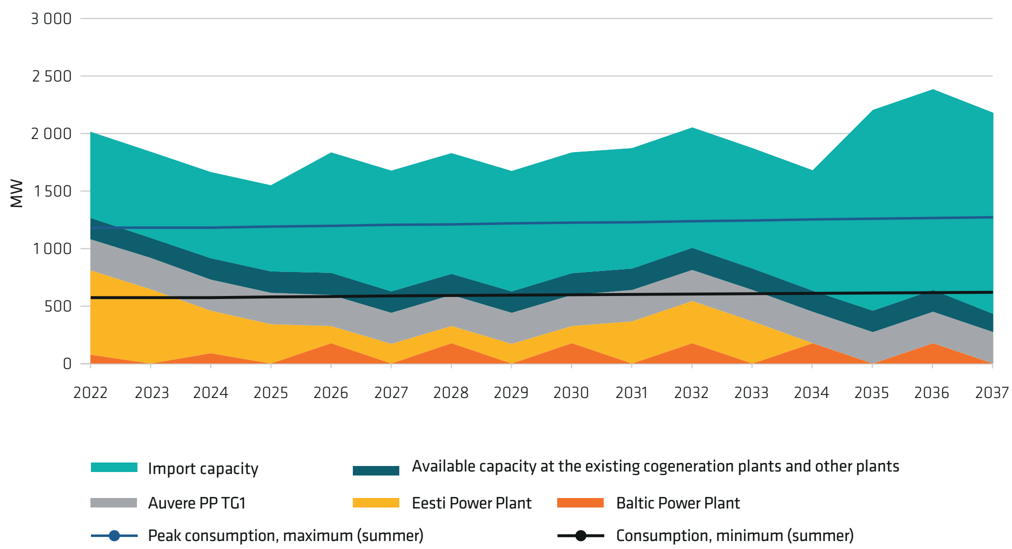
Figure 4.20 Available generation capacity, import capacity and forecast of peak demand in winter



4.8.2 Assessment of adequacy of generation capacity in summer

According to current forecasts, summer peak consumption by 2037 will be up to 1274 MW. The available generation capacity corresponding to Section 14 of the Grid Code on the functioning of the electricity system will amount to about 788 MW in winter 2030 and about 433 MW in 2037. 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. The differences in the loss of usability of power plants visible in Figure 4.21 in certain years are caused due to the maintenance of these power plants in the respective years. With regard to the import capacity, the N-2 situation has been considered, which means that two major transmission lines with neighbouring countries are out of service, i.e. this is a conservative estimate. According to the summer generation capacity adequacy assessment shown on Figure 4.21, Estonia will have enough local generation capacities and import capability in an N-2 situation to cover summer peak consumption.

Figure 4.21 Available generation capacity, import capacity and forecast of peak demand in summer



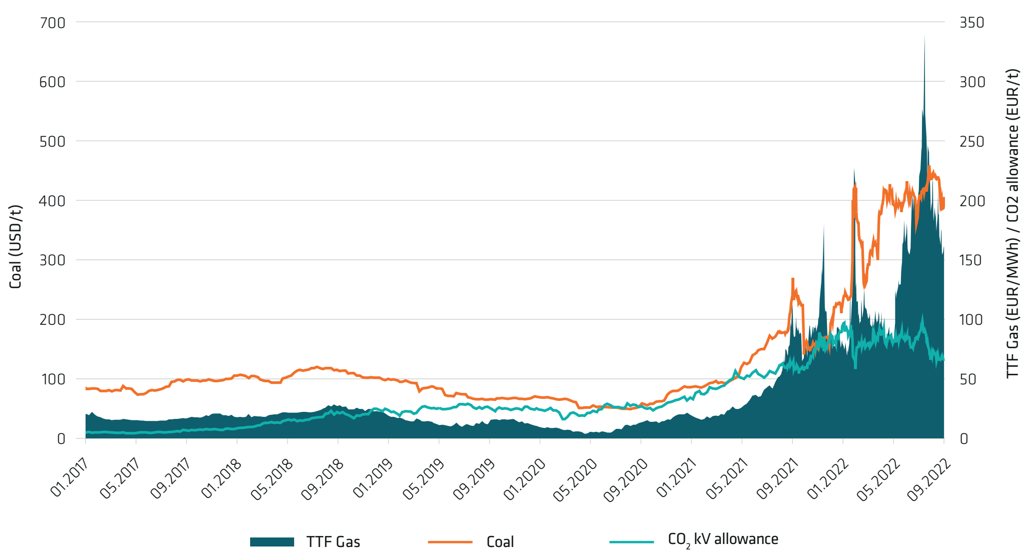
4.9 GENERAL TRENDS FOR ENSURING SECURITY OF SUPPLY

4.9.1 Changes in European energy policy and power generation input prices

As an EU member state, Estonia participates in achieving joint environmental goals and implementing the energy policy. Estonia's domestic goal is to increase renewable energy to 42% of total end consumption by 2030 and the amendment to the Energy Sector Organization Act, which raised the share of renewable energy to 65% of total energy consumption by 2030[34] and the goal of renewable electricity to 100% by 2030. In its Fit 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 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 in finding innovative solutions will be stimulated. All this will bring new energy generation to the market, improve system adequacy, reduce GHG emissions and reduce Estonian and European dependence on third countries.

Figure 4.22 Price of natural gas, coal and CO2 allowances, from 01.2017 to 09.2022[35]



34 REKK 2030. https://www.mkm.ee/et/eesmargid-tegevused/energeetika/eesti-riiklik-energia-ja-kliimakava-aastani-2030
35 https://tradingeconomics.com/commodity

In the second half of 2021, the input prices of power generation such as natural gas, CO2 allowances and coal grew significantly due to the increased energy consumption that followed the pandemic and the low gas supplies from Russia, which led to the low volumes in the gas storage going into the winter. The invasion of Ukraine in February in 2022 and the decreased energy imports resulting from it resulted in increases in gas, oil, wood chip and coal prices even further, which led to unprecedented prices on the wholesale electricity market: The high electricity prices are largely the consequence of the invasion and fossil fuel prices. To lower the prices and improve the adequacy of the European energy system, it is necessary to increase low-variable-cost renewable energy generation capacities.

The transition period to emission-free generation capacities is however a challenge for all TSOs, because large-scale development of these capacities takes time, but the security of supply must be guaranteed at all times in any case. In addition to renewable energy generation capacities (wind and solar parks), investments must also be made into building storage technologies (pump hydro and battery storage), increasing flexibility of the electricity system and demand side response and establishing additional transmission capacities.

Likewise, a Pan-European functioning market, good cooperation between neighbours and well-functioning connections with neighbouring countries are important for ensuring the security of supply in order to make sure that at peak load moments, electricity is supplied to where it is needed the most.

4.9.2 Power market and price formation on the pan-European market

On the electricity market, the price is formed at the balancing point of supply and demand. The market participants submit their sale and purchase offers to the exchange. Each offer indicates the volume of the respective offer and the price at which the market participant is willing to purchase or sell electricity. Sale and purchase offers are sequenced based on price, and they result in sale and purchase offer graphs. The point of intersection of the graphs determines the electricity produced and consumed at the respective moment in time and the respective market price.

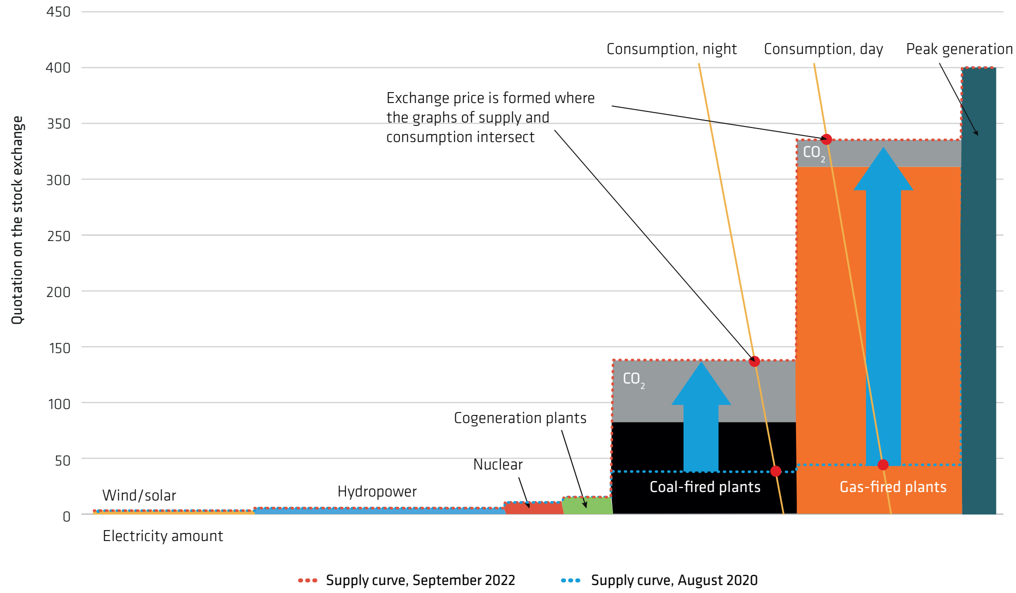
Electricity can be consumed by all consumers who are willing to pay the market price or higher than the market price for their consumed electricity according to their offer. Likewise, producers who are willing to produce electricity at the price equal to the market price or a price lower than that are able to access the market. All of the producers and consumers who have entered the market receive and pay the market price for their electricity, regardless of what the price described in their tender was.

This brings out an important nuance of the electricity market: the market price of electricity is formed according to the most expensive production unit that is currently able to access the market. Even if the majority of the consumed electricity is covered by renewable energy sources with low variable costs, but in a low volume, there is a need, for example, to launch an expensive power plant operating on natural gas, it results in a high market price of electricity.

Figure 4.23 illustrates how the market of electricity is formed on an open market. On the figure, the different production units are indicatively sequenced based on price. At the point where the curve of the production tenders intersects the consumption curve, the y-value is the market price of electricity at that moment. In the short period when the number of power plants making offers to the market or, for example, the price of fuels does not change, the price can change thanks to changes in consumption. The electricity system has a regular daily rhythm with lower consumption at night and higher during daytime, which generally also causes a similar fluctuation in market prices.

The figure also shows how in comparison to 2020, the second half of 2022 has seen a significant increase in production costs at coal and natural gas plants, mainly due to more expensive fuels but also because of the rise in the price of EU ETS. Because of this; the market price appears at a much higher level than in the previous period. This is in spite of the fact that the quantity of generation capacities in the system has remained at the same level.

Figure 4.23
Formation of market price on the day-ahead market price according to consumption and production costs of plants

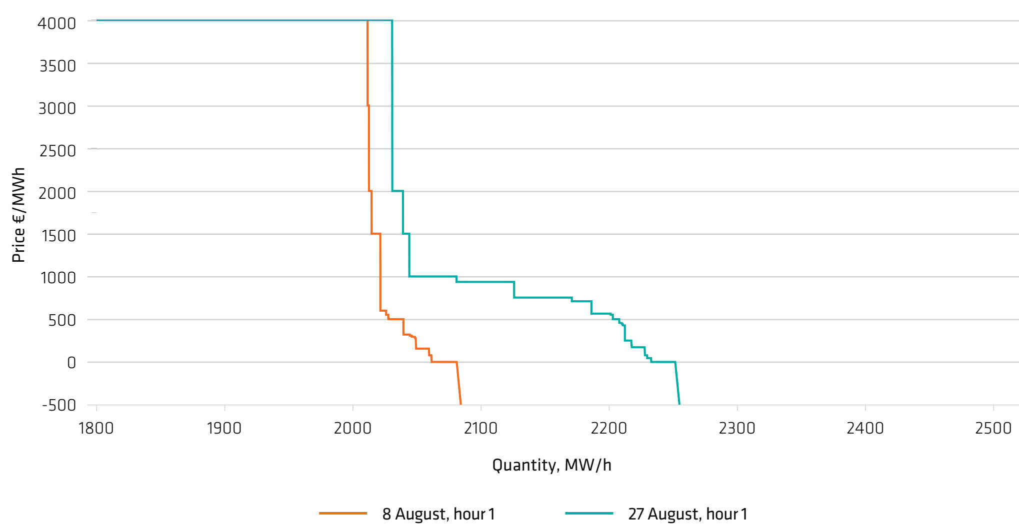


The situation shown in the figure illustrates the fact that the market price of electricity can change significantly when power plants' expenses change, without there being noteworthy changes in the generation portfolio in use on the market. Therefore, a higher price may not always mean an inferior system adequacy situation.

4.9.3 Power consumption price elasticity

Besides the scale of consumption, consumer groups may have a different price sensitivity. In economic theory, price-elastic goods are distinguished from non-elastic goods. If the price of goods or services change and demand moves in the opposite direction, this is called elastic demand, and if demand stays the same or sees only a minor change, that signals inelastic demand. On energy markets, price is determined as a function of demand and supply and looking at the market's aggregated bidding graphs, it is possible to distinguish what part of it is "price-sensitive" or price-elastic consumption and what part is not. Figure 4.24 shows the historical electricity exchange demand and supply graph in the Baltics. We see that consumption of over 2000 MW in this hour is completely inelastic, as there is readiness to consume this amount for even the maximum back then – 4000 EUR/MWh.

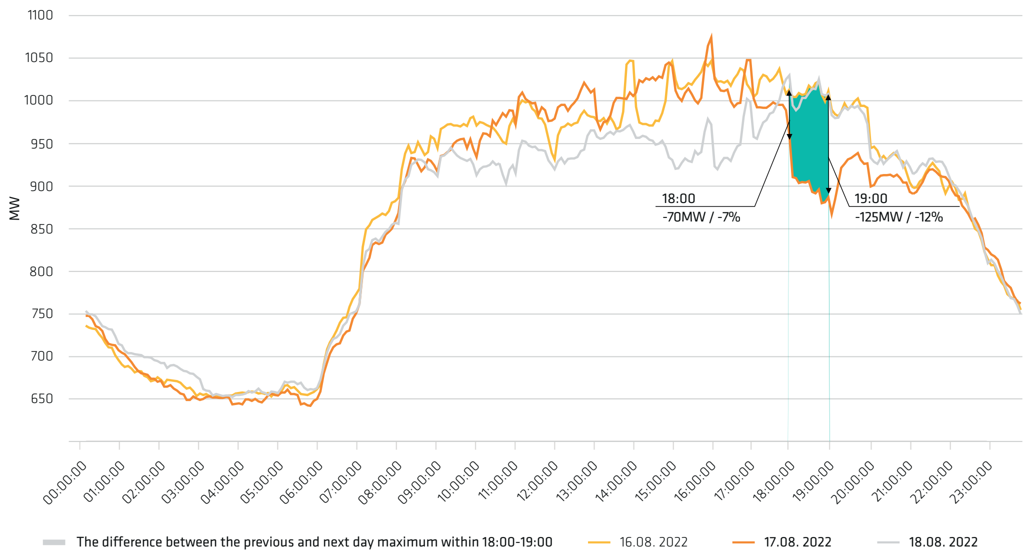
Figure 4.24
Demand and supply price curves in the Baltics 8 August 2022



After the price reached its peak on 17 August, the situation of bids placed on the market improved as it turned out consumption was more price-elastic than balance administrators had thought to that point in making their bids. The price elasticity of consumption has a positive impact on system adequacy and price of electricity.

The response to the power exchange hourly price was particularly noteworthy in the Estonian bidding area, where all consumers had hour-based meters and least noteworthy in Lithuania where hour-based meters are not common. In Estonia, during the 4000-euro price hour, according to measurements by Elering's SCADA system, electricity consumption fell a bit more than 10% compared to the same hour the previous and next day.

Figure 4.25 Estonian electricity consumption profile before and after the 4000 €/MWh electricity price hour



It should be considered that consumption changes according to the time, day of the week, weather and other external factors and days are not always directly comparable, but price is certainly a factor that influences consumption.

Bearing in mind growth of consumption in future and digitalisation of society, we can expect flexibility and price elasticity of electricity consumption to grow without it significantly affecting consumer comfort and convenience and quality of life. Digital solutions, some of which are already available or being developed today, allow power consumption to be shifted to a less congested hour, saving money for the users and keeping the energy system's costs low.

5 Digital capability

- ***Elering will continue to bolster the ability of IT systems to withstand cyberattacks and readiness for responding to incidents.***
- ***In the context of increasing digital capability, we are upgrading a number of control systems and digital solutions as regards energy data to be prepare for growing data volumes related to the creation of reserve markets and large-scale dispersed generation.***

5.1 DIGITAL INITIATIVES AND NEW TECHNOLOGIES

Digital capability refers to different resources at a company (people, knowhow, technology) that allow for automating and raising the efficiency of the company's business processes to ensure the everyday management and security of supply.

Increasing digital capability and growth of new technologies

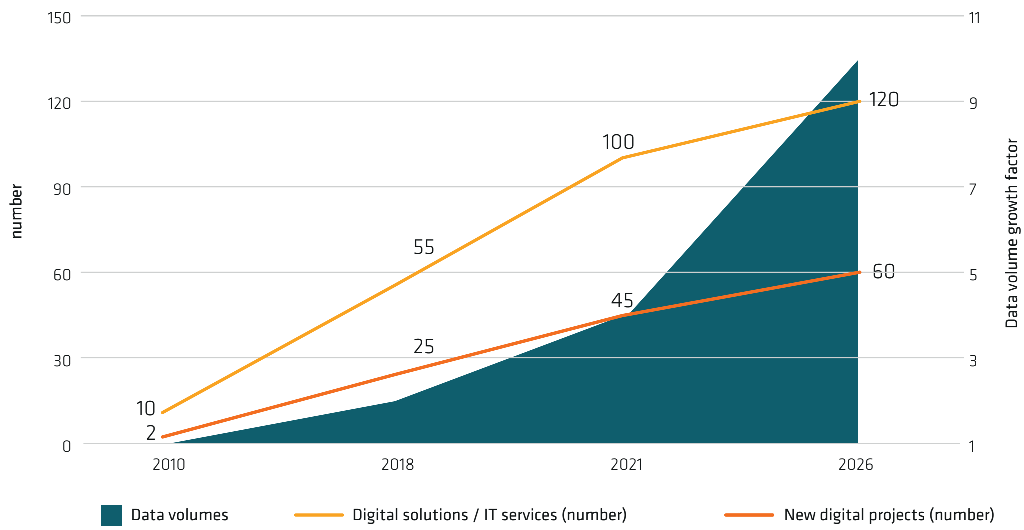
After joining the Continental European frequency area, the Baltic States will be subject to the technical requirements for the operation of the electricity network and the assessment of network stability, which will require TSOs to extend existing or create new control systems. In order to ensure a stable network service, it's 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. Existing control systems are upgraded and new ones will be procured between 2021 and 2024. Elering will take over frequency control after synchronisation with Continental Europe.

Electrification increases the role of electricity in society and adds to the complexity of the system. We are moving toward an energy system with more participants, smart devices and data volumes. The changes taking place in the system are also faster. With increasing renewable energy capacities, the operation of the electricity system will have to take inverter-based equipment into account more than before. The inertia of such equipment is not so high and generation changes can be faster. Due to the volatile nature of renewable energy, more data move in a shorter timeframe and more operations are performed to manage it. This creates a need to have greater automatic control functions, which humans cannot optimally manage in real time on their own without digital solutions. As a result, there will be a growing need for smart and learning technologies to help electricity system operators control the electricity system in real time.

We are upgrading our data exchange platform Estfeed, through which data exchange takes place on the electricity and gas market for changing open supplier, transmission of 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 that their business processes work. At Elering, the Estfeed brand is the umbrella for the whole topic of energy data. That avoids doubling efforts and ensures conformity to data protection and data security requirements.

Elering's digital solutions volume in 2010-2022 has grown significantly. Data volumes have also increased considerably. Data volumes will grow even further in future, because more and more smart devices have been introduced, all transmitting great data volumes. Since we are moving increasingly to real-time decision-making, smart devices that gather real-time data will help make the necessary management decisions in real time.

Figure 5.1
Digital solutions
and data volumes



Most important digital initiatives 2022-2025:

1. To ensure the reliability of the system at all times, the existing digital solutions must be improved and new ones implemented to ensure that energy not served as a result of digital solutions would remain 0 MWh in future as well.
   - We ensure high availability of critical IT services (99.98%) through redundancy of services at the backup control centre.
   - We update and raise the efficiency of incident resolution process and digital solutions to ensure rapid response to critical event resolution.
   - We reduce dependence on individual technology suppliers and increase the security of solutions. To do this, we standardise the digital solutions of gas and power grid features (configuration manager, accesses, consolidation of digital solutions).

2. To fulfil the requirements necessary for synchronisation with continental Europe, we need the following solutions for frequency control and management:
   - To control the system and frequency and for potential extraordinary synchronous operation with continental Europe, including for managing reserves, we will implement by the necessary solutions by the 2023 and for regular synchronous operation by the end of 2025.
   - We will develop and implement substations' data communication concept pursuant to the need for synchronisation with continental Europe to be prepared for extraordinary synchronous operation by 2023.

3. 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 faults 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. To this end, we improve our work processes and create a central solution where information has been consolidated and the administration of configurations is systematic and controlled.

5.2 ASSESSMENT OF THE IMPACT OF CYBER SECURITY FROM THE PERSPECTIVE OF SECURITY OF SUPPLY

None of the energy not served in 2021 was caused by cyber incidents and Elering's activity has been aimed at preventing energy from not being served in future as well.

Digitalisation increasingly encompasses traditional industrial sectors, including energy. For that reason, cyberattacks and information system malfunctions may be a significant cause of power outages alongside storm damage and fallen trees. Elering's cyber security mission is to anticipate, prevent or mitigate such risks, and should they become realised, ensure an efficient response.

In its 2021 overview of risks[36], the European cyber security agency ENISA enumerates the main cyber threat trends:

- The number of elaborate and high-impact attacks on the supply chain has increased and service providers are prized targets for cyber criminals.
- The COVID-19 pandemic encouraged cyber espionage and opened up new avenues for criminals.
- Criminals are increasingly motivated by such methods as ransomware. Crypto assets are the most common method of payment.
- Cybercrime is increasingly targeting critical infrastructure.
- The two most common means of ransomware infection are phishing and RDP protocol.
- The number of business models that involve ransomware is growing. Ransomware users do not only encrypt your data but leak it and threaten partners and clients as well.
- The spread of malware has been dropping for several years in a row. Malware that targets container environments has become more frequent.
- E-mail incorporation has grown and become more sophisticated and targeted.
- To an increasing degree, DDoS attacks utilise wireless networks and IoT devices.
- More and more, Cyber criminals use misinformation as a component in their activity.
- In 2020 and 2021, the number of non-malicious incidents soared. The pandemic made human errors and misconfiguration of systems several times more likely to occur. Most of the successful attacks in 2020 took place due to errors or vulnerabilities in the targeted object. A major leap took place in the security of misconfigured cloud services.

Besides the general trends, Russia's invasion of Ukraine has created uncertainty has increased and has posed a potential risk to Estonian vital services. The invasion has also been accompanied by some waves of attacks against Estonian information systems, but the impact of these attacks has so far been less than expected. Still, we continue everyday cooperation with movement institutions and partners to ensure that readiness for responding to incidents remains high.

In the last year, Elering has carried out a number of development projects to improve cyber security, and these have increased situational awareness and reduced the impact of data leaks and attacks. In addition, we have updated our internal procedures and requirements to better meet the challenges of the changing world. in the years ahead, it is planned to supplement the security of critical ˇinformation system, computer network monitoring and processes related to construction and management of critical infrastructure.

36 https://www.enisa.europa.eu/publications/enisa-threat-landscape-2021

6 Abbreviations

AREJ	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, 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]*
DSR	Demand Side Response
EENS	Expected Energy Not Served
EL1	Estlink 1
EL2	Estlink2
ELV	Elektrilevi
ENTSO-E	pan-European organisation of TSOs
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 served 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	the 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 operations committee
TK	place of consumption
TLA	automatic system for reswitching
TSO	Transmission System Operator
VOLL	Value Of Lost Load) [€/MWh], estimated maximum electricity price the consumer is willing to pay to avoid outages

7 Annexes

ANNEX 1. 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 2022. 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 the installed capacity that is firm is separately listed in table 4.3 found in chapter 4.7.

Name of power plant	Type of generation equipment	Fuel	Generation capacity, MW
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			**367.6 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
Aravete Biogaas OÜ	gas engine	biogas	2
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	2.0
Linnamäe hydroelectric plant	hydro turbine	water	1.1
Other small producers	hydro turbine	water	4.9

Name of power plant	Type of generation equipment	Fuel	Generation capacity, MW
WIND FARMS			**317.3 MW**
Aulepa wind farm	wind turbine	Wind	48
Paldiski wind farm	wind turbine	wind	45
Tuhavälja wind farm	wind turbine	wind	39.1
Wind	wind turbine	wind	24
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 510 MW and it was distributed across counties as shown in the table.

Name of power plant	Generation capacity (MW) as of 2021
SOLAR PLANTS in aggregate	**510 MW**
County	Generation capacity as of November 2022 MW
Harju	84
Viljandi	63
Tartu	62
Lääne-Viru	56
Pärnu	47
Jõgeva	34
Ida-Viru	29
Valga	29
Võru	28
Rapla	20
Järva	19
Saare	17
Põlva	14
Lääne	5
Hiiu	4
Saare	17
Hiiu	4

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