

Annex 1. Estonian National Resource Adequacy Assessment 2023 Economic Viability Analysis

Tallinn 2025

Contents

Contents	2
NRAA Annex Document.....	3
Problem Description.....	3
Scope of the Analysis.....	4
1. Ongoing Developments and Perspective Projects Relating to the Estonian Electricity System	4
1.1. Ongoing Developments	4
Battery Storage Project by Evecon	4
Paldiski Pumped Hydro Underground Storage by Zero Terrain	4
Elering's Tender for Long-term Acquisition of Frequency Reserves	5
Nuclear Power	5
Interconnector Projects.....	5
1.2. Perspective New Entry Technologies.....	5
Gas Turbines	6
Internal Combustion Gas Engine	7
Battery Storage.....	7
1.3. Potential New Entry Technologies Which are Out of Scope.....	8
Demand Side Response	8
1.4. Ongoing and New Projects Conclusions	9
2. Timeline for Connecting New Capacity to the Grid.....	10
2.1. Connecting a New power Plant to the Estonian Electricity Network	10
2.2. Substations Near Gas Pipelines and Connection Challenges	11
2.3. Challenges with 'Green' Substations	12
2.4. Timeline for Network Connection and Key Considerations.....	13
2.5. Connecting to the Gas Network.....	13
2.6. Timeline Conclusions	13
3. Economic Viability of Perspective New Projects	14
3.1. Economic Viability of Thermal Power Plants	15
3.2. Economic Viability of Battery Storage	16
4. Conclusions.....	17

NRAA Annex Document

This document is an Annex to the Estonian National Resource Adequacy Assessment performed in 2023-2024¹ (the 'NRAA'). The European Union Agency for the Cooperation of Energy Regulators' ('ACER') opinion No 04/2024 of 17 September 2024 ('Opinion') on the NRAA concluded that the differences between the Estonian NRAA and ERAA 2023 are justified in terms of the national assumptions used, but noted the inconsistent application of some assumptions in the assessment. Thus, ACER identified in the Opinion the need for an economic viability consideration with the emphasis on how much support could be expected from the market participants to alleviate the resource adequacy problem. This Annex (the 'Annex') seeks to offer a comprehensive assessment of the realistic contributions and potential courses of action.

Due to at least 2,5 years of preparation time before any new connection can produce electricity to the grid the temporal scope of this Annex is 2025-2029. The need and extent for a capacity mechanism will be analyzed every year, but the procurement for a strategic reserve is done for three years.

Problem Description

The main problem in Estonia in the upcoming years is a lack of dispatchable capacity, which is necessary for resource adequacy during long interconnector outages, *dunkelflaute events*, ensuring energy security in the light of current geopolitical risks, and increasing need for ancillary services once synchronized with the Continental Europe Synchronous Area.

The Estonian energy market is facing a critical challenge due to the impending exit of a significant portion of dispatchable capacity. This is primarily driven by factors such as economic viability and the end of the technical lifetime of existing oil shale power plants. As a result, less than 400 MW of the current 1300+ MW dispatchable capacity will remain on the market, unable to meet future demands. At present, much of the oil shale capacity is already consistently generating at a loss and the primary reason why oil shale-based capacity continues to operate on the market is due to the owners' expectation document (the oil shale units are state-owned), which requires them to remain operational until the end of 2026².

Once these plants are phased out of the market it will leave a substantial capacity gap in the Estonian security of supply. At the same time, the estimated timeline for new investments into dispatchable capacity leaves several years where resource adequacy issues are identified. This situation underscores the urgency of addressing the capacity shortfall to ensure energy security and reliability already in the beginning of 2027.

In NRAA2023 it was determined that in "the scenario 639 MW" reached close to the reliability standard with LOLE of 8,3 h. Currently, the best estimate is that in 2027 and 2028 there will be 352 MW of dispatchable capacity available, this estimate gets updated in the beginning of every year. To some extent battery storage and small CHP powerplants are also dispatchable, but these are either already considered in the simulations or are unable to contribute enough to the security of supply to fill the generation gap necessary.

¹ [Estonian National Resource Adequacy Assessment 2023-2024](#)

² [Eesti Energia's owners expectation](#)

Scope of the Analysis

The following Annex provides an analysis of potential technologies and their feasibility to solve the issue market based within a suitable timeframe to mitigate the upcoming capacity shortfall. The analysis focuses on addressing the anticipated resource adequacy risks as they begin to intensify.

This evaluation is divided into three key components:

- 1) Ongoing developments and perspective projects on new production capacities to the Estonian electricity system
- 2) Timeline for connecting capacity to the grid
- 3) Economic Viability – Evaluating the financial prospects of potential new investments in terms of long-term sustainability and market competitiveness.

Collectively, these analyses aim to identify viable solutions for addressing Estonia's forthcoming resource adequacy challenges, and to assess whether, and to what extent, the adequacy issue can be resolved through market forces alone.

1. Ongoing Developments and Perspective Projects Relating to the Estonian Electricity System

1.1. Ongoing Developments

There are several in-development projects which will affect the security of supply of Estonia and the region in the future. However, the most important variable is time- many of these projects are complex and require more time than is available to solve the adequacy issue. That is why a categorization was performed as to which projects are relevant for this Annex.

Battery Storage Project by Evecon³

While performing the NRAA, the battery storage project by Evecon was in early-stage development and was thus not considered sufficiently mature for its inclusion in the NRAA base and sensitivity scenarios. As of writing the Annex the project has been developed further and will most likely be participating on the market in 2027 – the time when resource adequacy issues were identified.

This battery storage project consists of two battery parks which will have combined dimensions of 200 MW and 400 MWh. It would participate in the reserve markets as well as different energy markets, such as day ahead and intraday markets. This will have an overall positive effect on the resource adequacy levels. These parks are expected to be commissioned and synchronized with the grid in Q2 and Q3 of 2025.

Elering's experience with connecting grid scale battery storage based on this project is that from the date of receiving a connection request from the client, it takes around 40 months.

Paldiski Pumped Hydro Underground Storage by Zero Terrain⁴

Paldiski pumped hydro storage has passed assessments in several Ten Year Network Development Plans and is in the process of being qualified as an EU Project of Common Interest ('PCI'). The project

³ <https://en.evecon.ee/europes-most-powerful-battery-park-to-be-built-in-estonia/>

⁴ <https://zeroterrain.com/key-facts/>

is known by the name Energiasalv and it is looking to add 520 MW/ 6 GWh of storage capacity by 2032 (and in 2038 an additional 15 GWh).

While this is acknowledged in Estonia's national energy and climate plans, this is still an extensive and complex development, which takes time and significant capital to be realized. Further, according to the developer, project development without state support is considered under current market circumstances infeasible. Due to their expected commissioning date being in 2032 this project is seen as out-of-the scope for this analysis.

Elering's Tender for Long-term Acquisition of Frequency Reserves⁵

Elering has announced a tender for a manual frequency restoration reserve (mFRR) up-regulation service acquiring up to 500 MW of new dispatchable capacity (probably including batteries, gas turbine, gas engine and demand side response) in order to satisfy the growing need for ancillary services. The successful offers under this mechanism must be participating in the market within five years after signing of the contract meaning most capacity is expected to be available by the end of 2030. This tender will incentivize new capacity to come online, but these projects will still have at lengthy development process and thus will not affect the need for a strategic reserve in 2027.

Nuclear Power

While Estonia has made significant legislative progress towards nuclear power, the interim report of the national nuclear energy working group indicated that the earliest possible timeline for an operational nuclear power plant would be 2035⁶. The said timeline is contingent upon parliamentary approval in 2024, which however did not take place. Even given the optimistic scenario of a 2035 commissioning date, this project is considered outside the scope of the current analysis.

Interconnector Projects

There are two ongoing interconnector projects, one with Finland and one with Latvia. Combined these would increase Estonian net transfer capacity by 1200 MW. Estlink 3 is planned to be an HVDC cable with a capacity of 700 MW and Estonia-Latvia 4th interconnector is planned to be an HVAC cable which will increase the NTC by 500 MW.

Both projects are already in the NRAA and due to their long commissioning times will not affect the necessity for a strategic reserve in 2027.

1.2. Perspective New Entry Technologies

This chapter aims to identify the technologies that could be considered to address the forthcoming resource adequacy challenges in Estonia. This chapter is based on the Estonian CONE study which was used to determine the reliability standard for Estonia⁷. For each reference technology, it is crucial to assess the potential for new capacity, taking into account spatial, technical, economic, and other critical constraints.

This analysis examines the practical feasibility of technologies in addressing the issue of system adequacy, considering:

⁵ <https://riigihanked.riik.ee/rhr-web/#/procurement/7540084/documents?group=B>

⁶ <https://news.err.ee/1608754744/estonia-could-get-nuclear-power-plant-by-2035>

⁷ [Reliability standard](#)

- Has a construction time of under two years which could theoretically enable it to be synchronized with the grid before the adequacy issue is identified in 2027.
- Whether the technology has recently been under development in Estonia, is currently being developed by a market participant, or is planned to be developed between 2025-2029, during the scope of this analysis.
- Whether the development of the technology is feasible within the existing legal framework in Estonia and the European Union.

For the purposes of this analysis, the near future is defined as a period extending five years from the completion of this study, but with an emphasis on whether it could realistically be implemented by the time when the set reliability standard is expected to be exceeded in 2027.

Gas Turbines

- Gas turbines are a widely used technology globally, with no significant barriers to their deployment.
- The level of local expertise required is relatively low compared to more complex technologies like nuclear power.
- The construction capacity for gas turbine power plants is not physically limited.
- The versatility of the technology, the availability of natural gas infrastructure, and relatively short construction times make them a viable option. Gas turbines can be further categorized into three subtypes, each optimized for cost-effective performance in specific applications:
 - Combined Cycle Gas Turbine ('CCGT')
 - Simple Cycle Gas Turbine ('SCGT')
 - Open Cycle Gas Turbine ('OCGT')
- In this analysis OCGT and SCGT are technically the same technology as the only difference between them is that SCGT has a flue gas heat exchanger. This increases the capital costs and construction time, but also enables an extra revenue stream in the form of heat sales (out of scope for this analysis) for district heating or industrial processes.
- The primary practical limitation is the transmission network capacity, which can be expanded with appropriate capital investments.

In the recent past, natural gas turbines have not been developed for combined heat and power production in Estonia, as biomass cogeneration plants with steam boilers offering higher efficiency are preferred in this field. However, there are many successful examples in the nearby region and Europe where technology from certain subcategories of gas turbines has been applied.

The table below lists the most important techno-economical parameters for a 100 MW size unit.

Table 1.1 Relevant techno-economic parameters for a 100 MW unit

	Construction time, yr	Capital cost, M€	Annual fixed costs, €
Combined Cycle Gas Turbine	2,5*	100	3 600 000
Simple Cycle Gas Turbine	1,5*	73	2 400 000
Open Cycle Gas Turbine	0,2*	56	990 000

** This is an estimate used in literature, but there are many delaying factors before and after this construction time is achieved, such as necessary permitting, procurement and delivery time of specific equipment for both power plants and substations, which often have long waiting times.*

Internal Combustion Gas Engine

- Gas capacity was last deployed in Estonia in 2014.
- Internal combustion engines are highly modular and widely adopted globally, with no major challenges for deployment.
- Like natural gas turbines, they require less local expertise compared to more complex technologies.
- The construction potential for such power plants is not physically constrained.
- The primary practical limitation is the transmission network capacity, which can be expanded with appropriate capital investments.
- Same as with natural gas turbines, there are limitations for EU support and deploying state aid to lower investor risks.

In the recent past, no natural gas engine power plants have been built in Estonia. However, their construction is straightforward, and since expertise in their installation already exists in the country, building new plants could be a realistic option.

The table below lists the most important techno-economical parameters for a 100 MW size unit.

Table 1.2 Relevant techno-economic parameters for a 100 MW unit

	Construction time, yr	Capital cost, M€	Annual fixed costs, €
Gas Engine	1*	61	800 000

** This is an estimate used in literature, but there are many delaying factors before and after this construction time is achieved, such as necessary permitting, procurement and delivery time of specific equipment for both power plants and substations, which often have long waiting times.*

Battery Storage

- Electrochemical battery solutions already exist in Estonia, and market participants have demonstrated plans to establish additional facilities.
- Battery energy storage systems ('BESS') are highly modular and compact, with minimal natural constraints.
- The primary practical limitation is the transmission network capacity, which can be expanded with appropriate capital investments.

Given these characteristics, the potential for BESS is high and the business case for various storage projects increases with the addition of more renewable generation.

Battery storage projects are the fastest to build and currently the best up-to-date knowledge that Elering has is with the grid scale battery project which most likely will take around 40 months to synchronize. If conditions are favorable and another such grid scale project would submit a connection request, then it would not alleviate any resource adequacy issues before Q2 of 2028.

The table below lists the most important techno-economical parameters for a 200 MW / 400 MWh size unit.

Table 1.3 Relevant techno-economic parameters for a 200 MW/400 MWh unit

	Construction time, yr	Capital cost, M€	Annual fixed costs, €
Grid scale battery	0,2*	180	133 000

* This is an estimate used in literature, but there are many delaying factors before and after this construction time is achieved, such as necessary permitting, procurement and delivery time of specific equipment for both power plants and substations, which often have long waiting times.

1.3. Potential New Entry Technologies Which are Out of Scope

Demand Side Response

Estonian demand in 2027 is on average climate year 9,7 TWh and is broken down into sectors in Figure 1.1. The breakdown of demand is noteworthy because it sets a limitation to how large portion of a demand could be considered firstly as price sensitive and secondly could be affected by incentives to do additional investments and act as a Demand Side Response units.

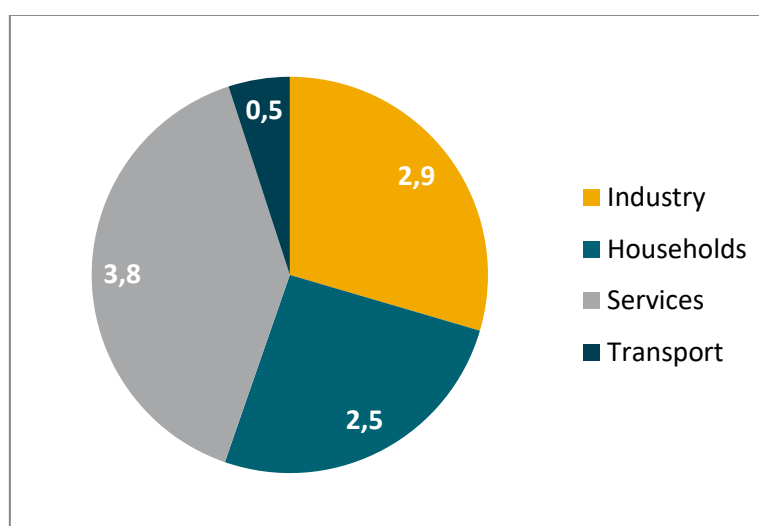


Figure 1.1 Demand breakdown by sectors

In the NRAA study there is already a DSR capability of around 10% of peak demand, which considering the breakdown of the consumption is optimistic. The growth of DSR capability is also already taken into account in the NRAA which means that it is not realistic that between 2025 and 2027 there would be large enough change in demand breakdown which would bring a significant change in the DSR capacity.

Households

Estonian households have demonstrated flexibility in establishing devices, and further installations to achieve even greater flexibility are realistic. The costs of implementing flexible DSR solutions in households vary significantly depending on the technologies used, existing household consumption systems, and their technical parameters (e.g., heat storage capacity). Due to the substantial variability in costs, DSR in households cannot be considered a standard technology.

Services Sector

There are several service providers in Estonia that aggregate the flexibility of service companies and participate in balancing markets, suggesting that further development in this direction is possible.

DSR in the services sector can involve various devices, including flexible control of ventilation systems, cooling chambers, water heaters, or building heating systems. Given the wide range of technologies and the fact that the specific investment cost for each depends not only on the equipment itself but also on the characteristics of the surrounding building, it is challenging to obtain reliable data on potential implementation costs.

Industrial Consumers

The flexibility potential of industrial consumers in Estonia has been mapped, and it has been found that with certain investments, industrial consumers could offer additional flexibility.

Industrial processes vary greatly, and the costs of implementing demand response potential can differ drastically between projects. Additionally, potential costs have not been systematically mapped, making it difficult to obtain reliable information on this topic.

1.4. Ongoing and New Projects Conclusions

As a conclusion, the market participants, have in recent years, started to show interest in investing into Estonian energy production or storage. Depending on the technology and maturity level of the project some projects can be excluded from this analysis due to their commissioning dates being out of scope.

Table 1.4 Technology consideration for the Annex

Ongoing developments	
In Scope (IS)	
Battery Storage Projects by Evecon and Eesti Energia	Will have a limited positive impact to resource adequacy
Out of scope (OoS)	
Nuclear power plant	OoS due to time restriction and maturity
Wind and solar power	OoS due to limited impact to the resource adequacy
Estlink 3 and Estonia-Latvia 4 th interconnector	OoS due to time restriction, planned commissioning in 2035
Pumped hydro power plants	OoS due to time restriction and project maturity
Perspective new technology	
In scope	
Simple cycle gas turbine	Has construction time low enough to consider its economic viability
Gas engine	Has construction time low enough to consider its economic viability
Open cycle gas turbine	Has construction time low enough to consider its economic viability
Battery storage	Has construction time low enough to consider its economic viability
Out of scope	
Combined cycle gas turbine	No existing plans and long commissioning period

Additional DSR	Has low impact; unclear realistic source for additional increase
----------------	--

2. Timeline for Connecting New Capacity to the Grid

Due to increased interest in renewable energy, the grid is congested with new applications to build out grid connections for additional capacity. This has taken up most of the free capacity in the grid and new connections entail upgrading many additional components in either substations or lines and any new connection process would take more than 2,5 years.

To connect new power plants to the grid the interested parties must submit connection applications to the electricity network. In the case of natural gas turbines applicants also need to submit an application to connect to the gas networks.

Below is a breakdown of the connection procedures for both the gas and electricity networks, and the challenges currently in the grid.

2.1. Connecting a New power Plant to the Estonian Electricity Network

When submitting a connection application for a new power plant, clients are required, under the 'Electricity System Network Code', to provide Elering AS with a decision to initiate or establish a zoning plan that allows the construction of the electrical installation to be connected to the network (unless it is a PV park). Without such a zoning plan initiation or establishment decision, Elering cannot process the connection application. So far none of the market participants have initiated such a plan, and if they decide to initiate one, the time required for the zoning procedure must be considered- depending on the municipality and the project specifics it will take at least two years.

Additionally, all clients submitting a production-side connection application must provide Elering with a financial collateral under the Electricity Market Act ('ELTS'⁸) of 38,000 €/MVA of production capacity. This collateral is non-refundable if the connection process is later terminated (e.g., due to a failed zoning procedure, significantly higher connection costs than initially expected, etc.). This helps to avoid market participants reserving grid capacity without a concrete plan to build new generation capacity. It serves as an indicator that, to date, there has been no serious intent from the client to invest in new thermal capacity. As of January 2025, a legislative proposal from ELTS has been presented to Parliament aimed at reforming the connection fee system for connecting to the transmission grid. As part of the proposed amendment, it is planned that the connection fee for accessing the Elering grid will be partially fixed, and the requirement for financial collateral is also expected to be eliminated. However, the expected timeline of the said proposal is still unclear, therefore this analysis assumes that the current system will stay in place.

Elering has a unique tool called e-grid map⁹ which gives a preliminary price and list of components which need to be upgraded in order to add an element to the grid at some specific place. This is a valuable resource for market participants to get a first estimate of how much their connection request might cost and locations in the grid where reinforcements will be made in near future.

However, even if market participants were willing to invest and provide a collateral of 38,000 €/MVA, the timeline establishing a connection point with the necessary capacity would still be a significant

⁸ [Elektrituruseadus](#)

⁹ [E-Gridmap application](#)

constraint. Assuming that a capacity larger than 10 MW could only be accommodated in the 330 kV network, an examination of the e-grid map for the year 2026 shows that while many substations are visually marked as potentially accommodating (i.e. 'green') and therefore ready to receive a connection, due to the lack of 330 kV lines, such points would allow production capacity connections of only a few tens of MW.

This presents significant challenges to connecting large-scale production facilities to the network before 2027, i.e. before the Estonian adequacy issue arises.

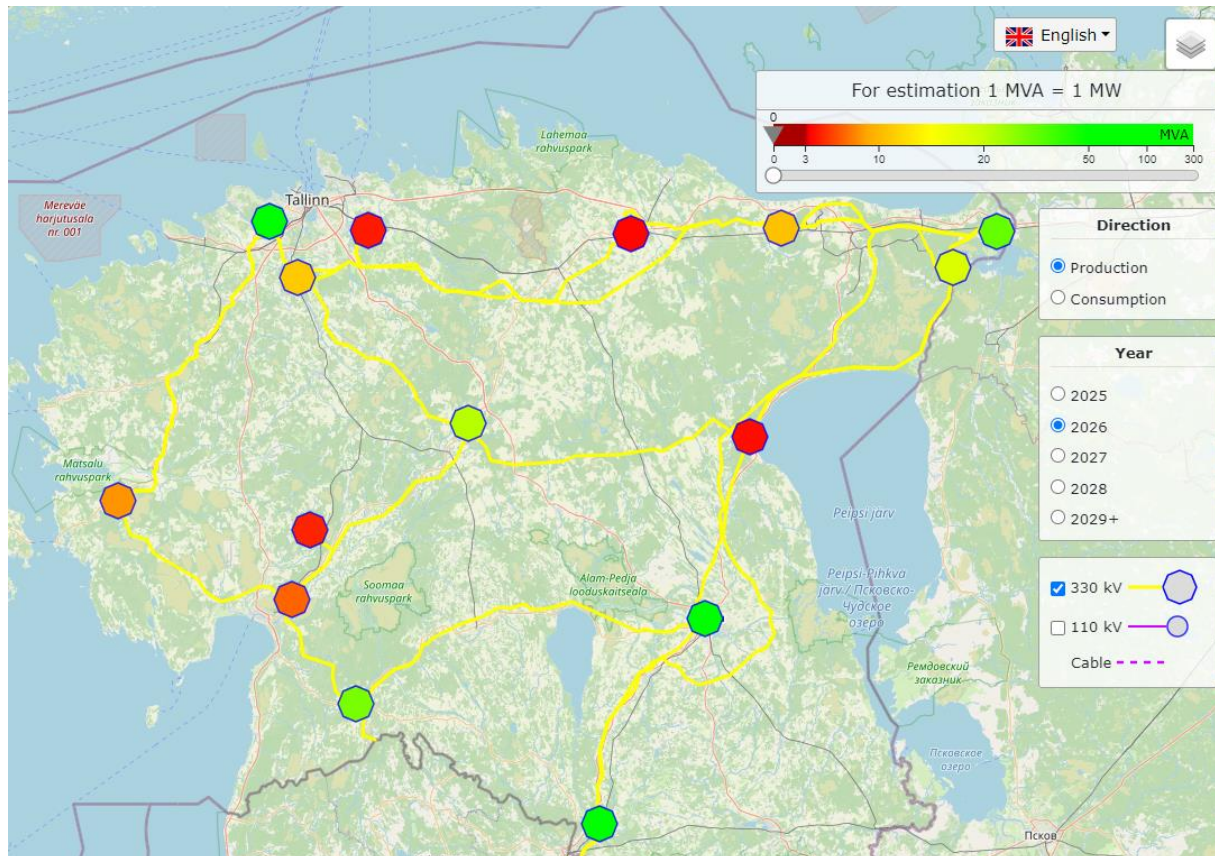


Figure 2.1 330 kV substations where colour code represents free capacity in 2026

2.2. Substations Near Gas Pipelines and Connection Challenges

The substations near gas pipelines include Harku, Kiisa, Sopi, Sindi, Tartu, Rakvere, Püssi, Viru, and Balti substations. Among these, the "red" substations, which cannot accommodate any significant MW capacity without major network reinforcements, face considerable challenges.

For example, connecting 100 MW electrical capacity (and depending on the technology approximately 200 MW of gas capacity) to the grid in such substations would require network reinforcements costing tens of millions of euros. Additionally, resolving land issues and completing the construction of these reinforcements could take more than five years.

To illustrate this, a cost breakdown is provided for connecting 100 MW of electrical capacity to the Sindi substation, highlighting the significant financial investments of 30 MEUR for the grid reinforcements, 3,8 MEUR for the financial collateral required, and a construction time depending on the availability of subcontractors and complexity of the tasks.

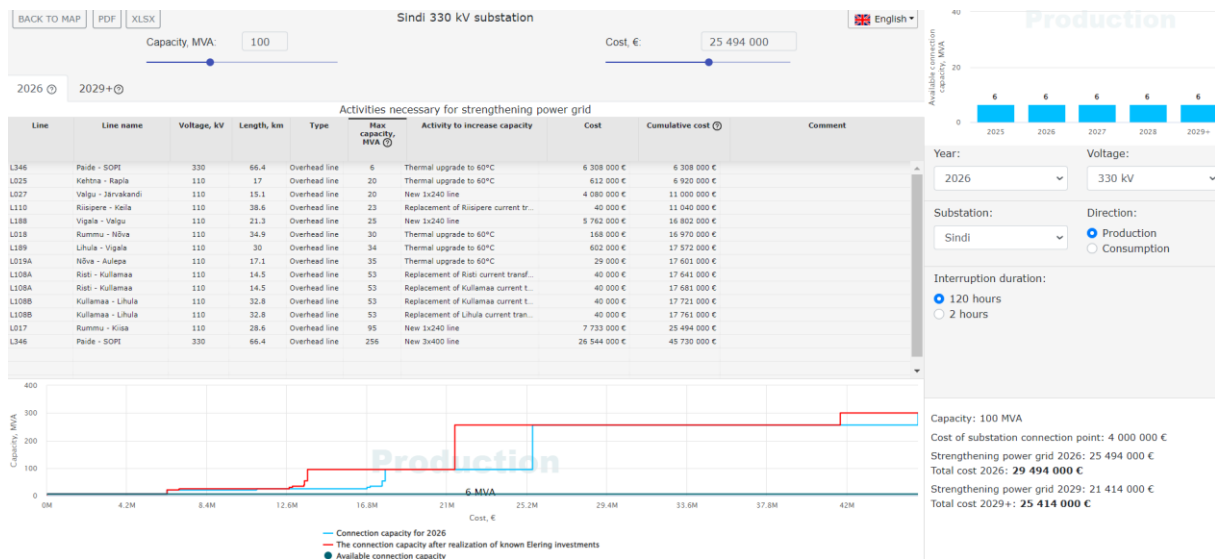
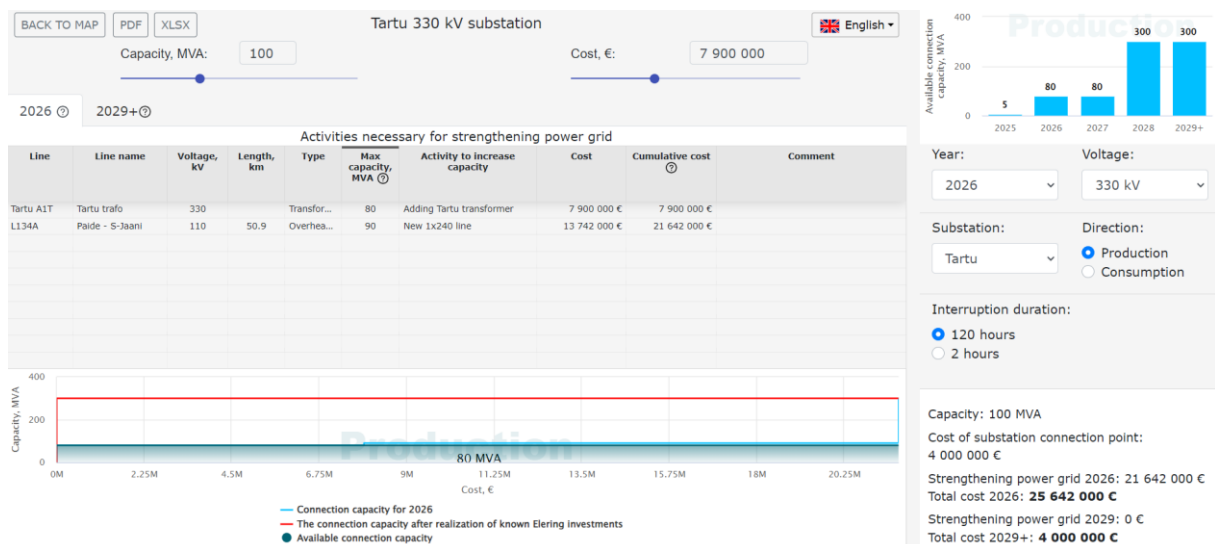


Figure 2.2 E-grid map exemplary cost breakdown for connecting 100 MW to Sindi substation

2.3. Challenges with 'Green' Substations

In the so-called 'green' substations, where it is possible to connect over 20 MW without major network reinforcements, the situation does not improve significantly when the desired capacity approaches 100 MW, which is more common for a power plant.

For example, at the Tartu substation, connecting a capacity exceeding 80 MW would require installing an additional 110/330 kV transformer at the substation and constructing a new 110 kV transmission line spanning approximately 50 kilometers. These upgrades involve substantial costs and time, making it challenging to meet the requirements for higher capacities even in substations categorized as "green."



2.4. Timeline for Network Connection and Key Considerations

Constructing network reinforcements, even without land acquisition issues, usually take 2-3 years from the signing of a procurement contract. From the moment of signing of the connection agreement reaching the signing of the procurement contract requires approximately a year.

Signing the connection agreement itself takes about 6 months after submitting a complete application. Therefore, in the most favorable scenario without land issues, connection to the electricity network is achievable in about 3.5 years after submitting the application.

If an application were submitted in the beginning of 2025, the earliest feasible connection date would be July 1, 2028. However, this assumes no need for extensive investments or land acquisition issues. If such complications arise, timelines will extend significantly.

2.5. Connecting to the Gas Network

Unlike the electricity network the consumption of gas has decreased over recent years and submitting a gas network connection application does not require the same extensive prerequisites as for the electricity network, hence, it is relatively "risk-free" for clients. Regardless of location, a new gas distribution station is always required for the level of gas consumption described, ensuring that technical complexity remains consistent across cases.

The connection fee includes the costs of constructing a new gas distribution station, which takes 33 months from the payment of the first instalment. Preparing the connection offer takes up to 3 months and is valid for 6 months. Thereafter, the client has 2 months to pay the first instalment. This adds a maximum of 11 months to the 33-month construction timeline, resulting in a total of up to 36 months for establishing the connection. Currently, gas consumption connection applications have been submitted for six locations. Only one of these has received Elering's conditions for connecting, which will start the 33-month deadline once agreed. Other applications will receive their conditions in either end of Q1 2025 or Q2 2025.

Based on the above-described calculations, should the works start today, the earliest possible gas network connection would be by the end of 2027, however, as currently there has been no such request made even the end of 2027 is unrealistic.

Additional constraints and unknowns might include legal disputes over land usage, which could cause unforeseen delays in the plans.

2.6. Timeline Conclusions

Due to the rapid increase of interest over the last year to connect renewable energy units to the grid, the electricity transmission network has little generation side capacity left without the need to upgrade some relevant elements. Depending on the substation, the estimated extent of these construction works might be expensive as well as time consuming. In the case of connecting a power plant which would also need a connection to the gas network the number of viable substations decreases relatively, and suitable substations will likely demand longer preparation time.

Both electricity and gas network connections require significant time, with electricity connections taking at least 3,5 years and gas connections approximately 3 years under optimal conditions. Land acquisition or the need for large-scale network investments could further extend these timelines.

Therefore, as the financial commitment in building a new dispatchable capacity power plant is significant, it can be considered impossible that Elering as the TSO of both electricity and gas transmission networks would not know about any new perspective dispatchable capacity which could be commissioned and synchronized before 2027, when the first resource adequacy problems arise.

The only impact identified between the NRAA 2023 and what is known in early 2025 is that there will be battery storage of around 227 MW/ 453 MWh available by 2027. A rule of thumb is that it will mostly affect the reserve market and would decrease resource adequacy risk slightly, but not enough to offset around exiting thermal capacity. If conditions are favorable and such another grid scale project would submit a connection request, then it would not reach the market before Q2 of 2028.

3. Economic Viability of Perspective New Projects

While highlighting that there are no new projects which could start the connection process and still make it to the market in time to alleviate resource adequacy problems in 2027 it is worth analyzing what could be the level of electricity prices and would this be enough to incentivize new investments.

Similarly to the NRAA, the following analysis is based on simulations performed for the target year ('TY') 2028, but is also valid for TY2027 as no significant changes in the Baltics energy market are happening between these years.

The calculations are based on NRAA input prices and simulation results from the NRAA "sensitivity with 639 MW" scenario. This scenario is the closest one to having enough generating capacity which achieves 8 hours of LOLE, meaning that if new perspective projects (approximately 200 MW) would come to the market to fulfil the reliability standard, then the electricity prices would be that of this scenario. Same climate years were chosen for this analysis as was used in ERAA 2023 EVA- climate years 2003, 1988, and 1985. For Estonia these years represent respectively an average climate year, a high RES production climate year, and cold with low RES production climate year (the one with the lowest resource adequacy levels out of 35).

In reality each country has a different Value of Lost Load ('VOLL'), but in such a Pan-European modelling like ERAA, a central assumption must be made to avoid channeling all of the scarcity to the country with the lowest set VOLL. In these simulations when there is not enough supply to cover the demand the electricity price is equal to VOLL and all of the powerplant would receive revenues based on this price. In the ERAA and NRAA model the VOLL was agreed by ENTSO-E and TSO-s to be 6000 €/MWh in 2028.

By calculating the short run marginal cost ('SRMC') of different technologies, it is estimated what would be the average full load hours ('FLH') of the technology in the upcoming years and their revenue.

The table below illustrates the input data

Tabel 3.1 Used fuel prices for 2028

	€/GJ	€/MWh	€/ton
Gas	8,797	32	-
CO₂ price	-	-	103

Tabel 3.2 Calculated marginal costs

Perspective new technology	Short run marginal cost, €/MWh
Simple cycle gas turbine	146

Gas engine	127
Open cycle gas turbine	146
Battery storage	2,6 ¹⁰

3.1. Economic Viability of Thermal Power Plants

By analyzing the average price duration curves (PDC-s) of chosen climate years, it can be estimated how many FLH-s perspective new projects could achieve. This analysis is only taking into account the day-ahead market prices and whether the technologies would be competitive in the market.

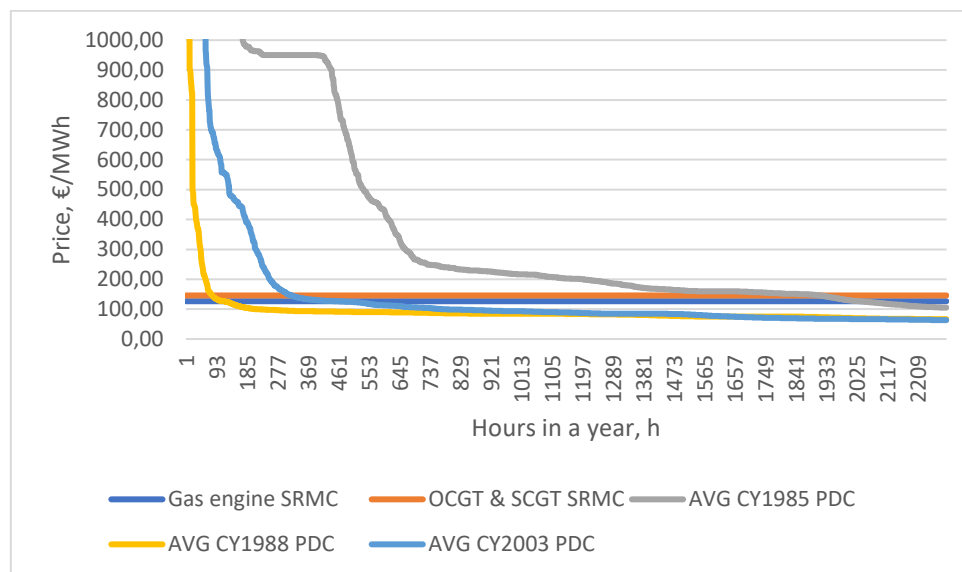


Figure 3.1 Price duration curve and SRMC intersections for target year 2028

As seen in Figure 3.1 depending on the climate years the average prices in Estonia vary significantly as well as the subsequent FLH-s for chosen technologies. The figure shows only the intersection between the PDC and SRMC curves for the technologies, as both the max price and total hours in a year would distort the graph and would not show the differences between climate years (CY).

Tabel 3.3 Average economic results for perspective technology

		CY2003	CY1988	CY1985
SCGT & OCGT	Full load hours, h/yr	319	79	1917
	Revenue, M€	24,4	3,0	98,9
SCGT	Annual fixed costs, M€	2,4		
OCGT		0,99		
Gas engine	Full load hours, h/yr	445	114	2028
	Revenue, M€	25,1	3,1	102,6
	Annual fixed costs, M€	0,8		

¹⁰ Based on the Danish energy agency [Technology Data for Energy Storage](#)

With each following year electricity consumption is estimated to increase together with renewable energy generation. This will incentivize flexibility and power plants which are able to ramp up and down according to residual load levels such as these technologies highlighted in this chapter. It is expected that the following target years would yield similar FLH-s for the technologies and thus it can be estimated that the viability of gas power plants would vary significantly depending on the weather over the year. Fortunately for the business case of gas power plants, these numbers are only representing the day-ahead market, while much of the revenue for dispatchable capacity would be coming from the reserves market.

Based on this analysis it can be concluded that all technologies would exceed their annual fixed costs with revenues from the day-ahead market, meaning that such existing gas power plants would remain in the market. Regarding new investments- there is much uncertainty around returns compared to different weather scenarios as seen in Tabel 3.3. It is more likely that an investor will focus on the economic parameters from an average climate year and will want to reduce the risk of losing their investment instead of planning their revenues and cash flows based on extreme weather years. By analyzing the spread of revenues it can be concluded (as is also seen from the behavior of the market participants/investors) that they need some sort of risk hedging mechanisms to secure an investment. It is also evident that commonly categorized as “peaking technologies” like gas engines and OCGT technology would yield better returns on investment as their capital costs are much lower than the competing technologies while the possible revenues from the market are in the same range.

3.2. Economic Viability of Battery Storage

Batteries are a versatile resource and grid scale battery parks could have several revenue streams from different markets and products like energy arbitrage, frequency regulation and other ancillary services. It is expected that battery operators in the Baltics will receive the most of their revenue from the reserves markets and it will be the most viable business case for them. However as simulating reserve markets in the NRAA is too simplified then economic calculations are done by analyzing simulated day-ahead market prices.

To estimate battery storage viability, the price fluctuations over the years have been analyzed. The Figure 3.2 shows the daily price difference in 48 gathered simulations (365 days of 3 climate years with 16 outage scenarios each - in total $3 \cdot 16 \cdot 365 = 17\,520$). For battery storage to break even the price difference should be at least 20-30 €/MWh between the cycles. In the histogram 73% of the days have the price spread of 20 €/MWh or more. It essentially comes down to what is the weather during the year, as the median daily price fluctuation:

- for CY 1985 is between 30-40 €/MWh;
- For CY 2003 it is between 23-27 €/MWh;
- For CY 1988 it is between 17-21 €/MWh.

Due to resource adequacy issues and subsequent high prices, there are a significant number of hours in the histogram where price spread exceed 200 €/MWh. Such days could yield fast returns on investment for the battery owners and would make operating a storage device very profitable.

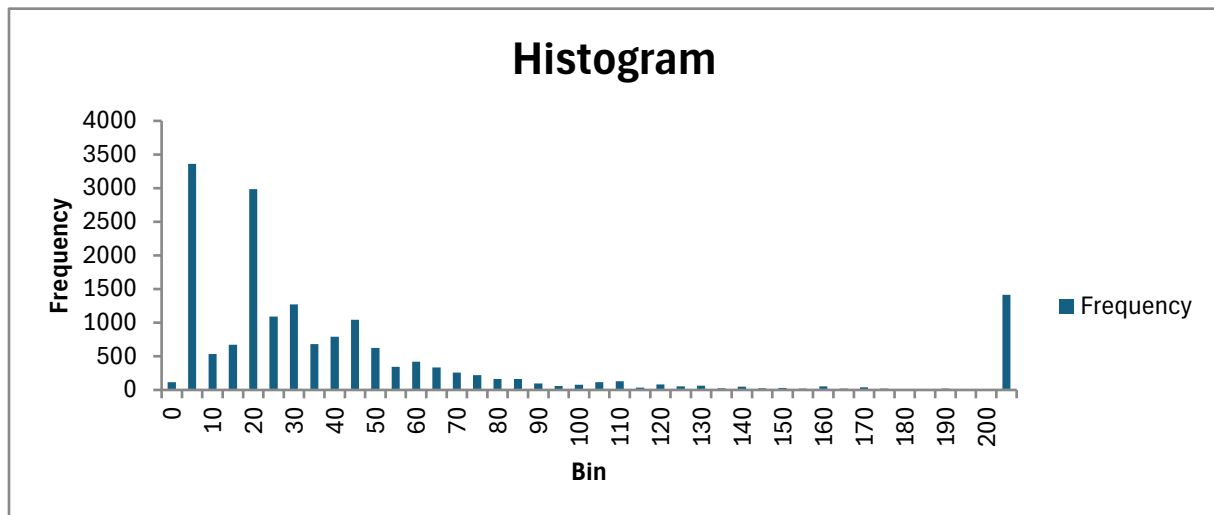


Figure 3.2 Daily price fluctuation over the simulation sample size

In conclusion, it is expected that battery projects are viable investments in Estonia as they will have several revenue streams where even operating in the day-ahead market could yield profitable returns if the weather scenario is favorable. Revenues from the reserve market are providing even more situations where a battery operator with a good strategy could find high returns on investments.

4. Conclusions

There is expected to be a resource adequacy issue upcoming in Estonia in the beginning of 2027 once much of the existing dispatchable capacity exit the market. Currently there are two mature battery projects which can be commissioned before that time, but due to their limited contribution to the resource adequacy it will not be enough to cover all of the needs and therefore, the strategic reserve is necessary.

The only impact identified between the NRAA 2023 and what is known in early 2025 is that there will be battery storage of around 227 MW/ 453 MWh available by 2027. A rule of thumb is that it will mostly affect the reserve market and would decrease resource adequacy risk slightly, but not enough to offset the amount of exiting thermal capacity. If conditions are favorable and such another grid scale project would submit a connection request, then it would not reach the market before Q2 of 2028.

All new projects will face the challenge of connecting to the grid, which, since the time when renewable energy projects became cost-efficient, has mostly run out of available capacity. Both electricity and gas network connections require significant time, with electricity connections taking at least 3,5 years and gas connections approximately 3 years under optimal conditions. Land acquisition or the need for large-scale network investments could further extend these timelines.

There is much uncertainty around returns in different weather scenarios and it can be concluded that investors require some sort of risk hedging mechanisms to secure an investment. The business case for dispatchable capacity improves if they plan to participate in electricity and balancing markets. Isolating these markets and calculating viability based solely on day-ahead markets will result in high uncertainty regarding revenues during years of high or low renewable energy sources (RES) production. New perspective projects could help alleviate resource adequacy issues as early as 2029, as there are no mature enough projects that could enter the market before that time.

In the context of the timeline, Estonia no longer has sufficient time to plan for the addition of new capacity by market participants before the adequacy issues arrive. Consequently, it is imperative to initiate a procurement process for a strategic reserve, which would ensure the availability of dispatchable capacity that can be activated when necessary. Should sufficient market-based capacity become available in the future to ensure resource adequacy, the strategic reserve will not be extended. However, at present, there are clear indications that strategic reserve is necessary in the short- to mid-term.