Litgrid

DEVELOPMENT PLAN OF THE ELECTRIC POWER SYSTEM AND TRANSMISSION GRID 2022–2031

June, 2022
Vilnius

CONTENT

ABBREVIATIONS

AC – Alternating current

AIT – Average interruption time

BEMIP – Baltic Energy Market Interconnection Plan

BESS – Battery energy storage system

BtB – Back-to-Back

CBA – Cost benefit analysis

CEN – Continental European Network

END/ENS – Energy not delivered, supplied

ENTSO-E – European Network of Transmission System Operators – electricity

ESO – Energy distribution operator

ETL – Electric transmission line

EU – European Union

GDP – Gross domestic product

HPSPP – Hydro pumped storage power plant

HPP – Hydro power plant

HVDC – High-voltage direct current

IPS/UPS – Integrated power system/Unified power system of Russia

LOLE – Loss of load expectation

NEIS – National Energy Independence Strategy

PCI – Project of common interest

PP – Power plant

PS – Power system

RES – Renewable energy sources

SC – Synchronous compensator

TN/TG – Transmission network/grid

TS – Transformer substation

TSO – Transmission system operator

TYNDP – ENTSO-E Ten Year Network Development Plan

WPP – Wind power plant

INTRODUCTION

Pursuant to the Law on Electricity of the Republic of Lithuania, the electricity transmission system operator (TSO) is responsible for the stability and reliability of operation of the electric power system, the performance of the national balancing function and the provision of system services in the territory of the Republic of Lithuania, operation, maintenance, management and development of the transmission network of the power system (PS) and interconnectors with the power systems of other countries, reducing the capacity constraints in the transmission networks and taking into account the needs of the power system and electricity network users. Operator of the electricity transmission system must also forecast the long-term power balance of the electricity system and provide market participants with information on the expected shortage or limitation of the generation or transmission capacity.

The stability, reliability, power, and energy balances of the PS depend not only on the behaviour of market participants, but also on the determination of the appropriate parameters of the operation of the connected power plants, coordination of the power plants and timely development. Therefore, LITGRID, (the Company), as the Lithuanian transmission system operator (TSO), must not only properly manage the electricity transmission network (TN), but also take care of the entire electric power system: plan the long-term operation of the PS by assessing the reliability, quality, efficiency, consumption, management and environmental protection requirements. For this purpose, a ten-year 400–110 kV network development plan (the Plan) for the Lithuanian PS is being prepared, the main goal of which is to assess the current state of the PS and to anticipate the possible changes in the demand for electricity and power, in electric power facilities and generation, ensuring the adequacy of the system in the long run, PS development directions, the scope of reconstruction, to determine indicative investments for the network development and reconstruction, to prepare the necessary data for the Ten-Year Network Development Plan of the European Network of Transmission System Operators for Electricity (ENTSO-E). The Plan is prepared in accordance with the National Energy Independence Strategy (NEIS), the National Energy and Climate Action Plan for 2021-2030 (NECP), the guidelines of Directive 2019/944/EC (5 June 2019) of the European Parliament and of the Council of 5 June 2019, the strategy of the EPSO-G group of companies, the strategy of the electricity transmission system operator LITGRID the recommendations of ENTSO-E and provisions of other regulatory acts defining the activities and principles of the TSO and PS.

Constant changes in the power system and the responsibilities assumed towards consumers encourage the Company to improve, streamline its operations and take on the challenges prevailing in the rapidly and greatly changing modern environment. By implementing new systems focused on intelligent management, the most advanced management models and based on good regional and international practices, the Company aims to become a modern and advanced company. To achieve this, the Company contributes to change management, has a clear vision of the future electric power system; is interested in the latest development perspectives in all areas of its activity and is able to prioritize new technologies; is responsible for the society, ecology and the economy; manages risks and takes responsibility for creating benefits for the society; cooperates in developing cross-sectoral integration of electricity, gas and heating markets.

A long-term system development planning takes into account the operational requirements of the electric power system and interconnections, the needs of electricity network users, the implementation of the internal network development and reconstruction projects, the use of regulatory load, energy storage facilities and other resources as system development alternatives, as well as expected consumption, trade with other countries and investment plans for the European Union as a whole and for regional networks. The long-term development of the transmission network is carried out taking into account the application of new advanced technologies, research results, recommendations of scientific institutions and external organizations. To achieve this goal, the Company periodically assesses the condition of transformer substations (TS) and electric power transmission lines (ETL), develops TS and ETL reconstruction strategies and individual electric equipment's condition assessment methodologies, analyses the actual load of electrical power TN, thus determining the least loaded substations and lines. Together with the energy distribution operator, decides on the need for the construction of new electricity network facilities, the possibilities of reconstruction or dismantling of the existing facilities, performs research and analysis, and commissions external studies. To ensure the reliability of work, the Company follows the main criterion evaluating the work reliability of PS - (N-1)[1]. Cost optimization is carried out taking into account the management of electricity TN assets and operating modes and network planning, determining the level of reliability of the existing network, solving the existing network problems („network vulnerabilities"). The Company transmits high-quality electricity in accordance with the requirements of international quality standards (LST EN 50160) and the High Voltage (330 kV and higher) "Description of Permissible Frequency and Voltage Quality Parameters of the Transmission Network" prepared by the Company. These documents contain the limit parameters that must not be exceeded but maintained by all users connected to the electric power network, define the frequency and voltage limits, network voltage dips and interruptions, harmonics and asymmetry. The construction of individual network elements (new ETLs or TSs) is based on the assessment of possible technical alternatives and the economic and financial comparison of alternatives (cost-benefit analysis).

The Company is not only the initiator of projects of the electricity sector important to the state, but also the implementer who seeks to conduct the works entrusted to it efficiently and on time. **The main national priority of the state and the goal specified in the Company's strategy is the connection of the Lithuanian electric power system with the continental European networks (CEN) for synchronous operation and renewable energy sources integration.** The Company is responsible for the preparation of new and existing infrastructure, compliance of technical conditions with CEN standards, cooperation with the European and neighbouring countries' electricity TSO and solutions related to the implementation of synchronization to be adopted in expert regional working groups. The Company's projects are being implemented in accordance with the 10-year investment plan seeking preparation for the synchronous work of the Lithuanian PS with CEN and ensuring the reliability and independence of energy supply and transmission, increasing the energy security of the system. It is projected that the reconstruction and development of the TN **over the next 10 years may require about 2.03 billion EUR** (excluding electricity grid user projects, investments would amount to around 1.99 billion EUR). These indicative investments which are regulated by the legal acts in force, are planned to be used for the implementation of strategic state projects, efficient use and systematic renewal of the electricity transmission network managed by the Company, taking into account the needs of producers and consumers, ensuring the system reliability indicators (END and AIT). The Company's projects are implemented and planned in order to create the benefit and quality services are provided not only to the Company's customers (electricity transmission network users), but also to consumers throughout Lithuania.

The implementation of the projects provided in the Plan, the installation of means and other technological equipment will contribute to the implementation of the goals of NEIS; in the 10-year perspective, reliable electricity supply and transmission to consumers will be ensured; timely restored and rationally developed transmission network (minimum system reliability indicators are not higher than those determined by the State Energy Regulatory Council) during the regulatory period); consistent optimization and modernization of the electricity infrastructure will be ensured; the possibilities of integration of renewable energy sources indicated in the state goals will be ensured; the informing of the responsible institutions about the perspective of generation adequacy on a national and regional scale will be ensured; the implementation of infrastructural projects will be coordinated, the assessment of the long-term need for investment funds and project financing possibilities will be carried out.

[1] (N-1) criterion – it is the ability of the electricity system to ensure the static and dynamic stability of the electricity system in the event of the loss of one of the elements operating in the system (ETL, transformers presented in TS, electricity generating sources, etc.)

KEY INDICATORS OF THE LITHUANIAN POWER SYSTEM

		2021 m. (fact)	2031 m. (plan)
Total electricity consumption (including grid losses)	**TWh**	**12.76**	**18.7**
Maximum demand for capacity during peak load	**MW**	**2217**	**2897**
Installed capacity, total:	**MW**	**4025**	**9362**
Thermal power plants (PPs):	**MW**	**1924**	**780**
Lithuanian PP	MW	1055*	455
Vilnius PP-3	MW	360*	0
Kaunas PP	MW	170*	0
Panevėžys PP	MW	35	35
Other PPs	MW	304	290
Kruonis HPSPP	**MW**	**900**	**1010**
Power plants using RES:	**MW**	**1153**	**7306**
Kaunas HPP	MW	101	101
Small HPPs	MW	27	27
Wind PPs (onshore)	MW	671**	3600
Wind PPs (offshore)	**MW**	**0**	**1400**
Solar PPs (incl. producing consumers)	**MW**	**259**	**2000**
Biofuel PPs:	**MW**	**95**	**174**
Biomass PPs:	MW	58	142
Vilnius PP-2	MW	29	29
Vilnius co-generation PP (biomass-fuelled unit)	MW	0	79
Šiauliai PP	MW	11	11
Small biomass-fuelled PPs	MW	18	18
Biogass PPs	MW	37	37
Waste PPs:	**MW**	**48**	**70**
Vilnius co-generation PP (waste-fuelled unit)	MW	0	22
Klaipėda Fortum (Lypkiai TS)	MW	21	21
Kaunas Fortum co-generation PP (Biruliškės TS)	MW	26	26
Small waste PPs	MW	1	1
BESS	MW/MWh	0	200
High voltage transmission lines:	km	**7245.4**	**8010**
400 kV overhead lines***	km	102.7	102.7
330 kV overhead lines***	km	1894.8	2395
110 kV overhead lines***	km	4988.6	5050
300 kV DC submarine cable	km	134.3	280
300/330 kV cable lines	km	13.2	35
110 kV cable lines	km	111.8	146
HVDC converter/converter station	vnt.	**2**	**3**
High voltage transformer substations (TS):	vnt.	**238**	**257**
400 kV TS	vnt.	2	2
330 kV TS/switchyard	vnt.	17	22
110 kV TS/switchyard	vnt.	219	233
Average price for electricity at Lithuanian electricity market exchange	**EUR/MWh**	**90.5****	

* Including and units which are in reserve or preserved
** Wind PPs operating in test mode are not included
*** Overhead line length is measured by summing up the length of all the circuits
**** Day-ahead market average price

1.

OVERVIEW OF THE LITHUANIAN POWER SYSTEM AND ELECTRICITY MARKET IN 2021

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The Lithuanian transmission network consist of 400–110 kV transformer substations connected by high-voltage electric power transmission lines. Electricity generated across Lithuania's power plants or imported from other electric power systems transmits to the distribution grids via the transmission network and further to the users of electricity.

In 2021, the following TSO projects were completed: the reconstruction of 110 kV Kapsai TS switchyard. Also, were completed two synchronizations projects: Grid optimisation in North-Eastern Lithuania and expansion of LitPol Link.

In 2021, the Company signed 8 letters of intent for the RES using PP connecting to TN: 5 letters of intent for 240 MW WPPs and 3 for 145 MW SPP. Also, Vilnius cogeneration PP (biomass-fuelled unit) of 79,2 MW was connected to TN. In 2021, renewable energy developers began to be interested in the possibilities of developing hybrid (solar and wind) power parks - 2 requests were received to issue preliminary connection conditions for the connection of hybrid (wind and solar) power parks.

The maximum required capacity in 2021 was recorded on 8 December at 9 to 10 am and amounted to 2217 MWh per hour (when severe cold prevailed), while the lowest was observed on 16 May 2021 at 5-6 am and amounted to 929 MWh per hour. Compared to 2020, the maximum required capacity increased about 12.54 percent (in 2020 was 1939 MWh) and the lowest required capacity increased about 0.2 percent (in 2020 was 862 MWh).

In 2021, the final electricity consumption was 11.84 TWh, while the total electricity consumption, taking into account the technological costs of electricity networks operators, which in 2021 amounted to 0.924 TWh, was 12.760 TWh (Fig.1).

Compared to 2020, the final electricity consumption increased (7.8 %). The total electricity consumption increased 6.2 %, it was the highest total electricity consumption in a eleven years. 2021 was an exceptional year in electricity consumption between different sectors, cause in all sectors consumption growth up. The largest impact was made by the COVID-19 pandemic. The largest increase in electricity consumption in 2021 was observed in the transport sector, i.e. 12.42 %. The pandemic also had a severe impact on the electricity consumption of the population. In 2021, it increased to 3.41 TWh (amounted to 3.33 TWh in 2020), which is 11.5 % more than in 2020. In the agricultural sector, consumption increased 7.4 %. In the transport sector, consumption increased almost 6 % and reached 0.273 TWh. Electricity consumption in the industrial sector also increased – about 5.6 %. Nevertheless, this sector continues to account for the largest share of final consumption (37.8 % of total final consumption). Among all sectors, the transport sector has the lowest share of final electricity consumption (about 0.102 TWh and 0.864 % of total final consumption).

On 31 December 2021, the total installed capacity of the power plants operating in the Lithuanian electric power system was 3808 MW. Compared to the data of 31 December 2020, the total installed capacity of electric power plants increased 5.7 % (Table 1).

Fig.1. Electricity consumption in 2011–2021 according to consumer groups

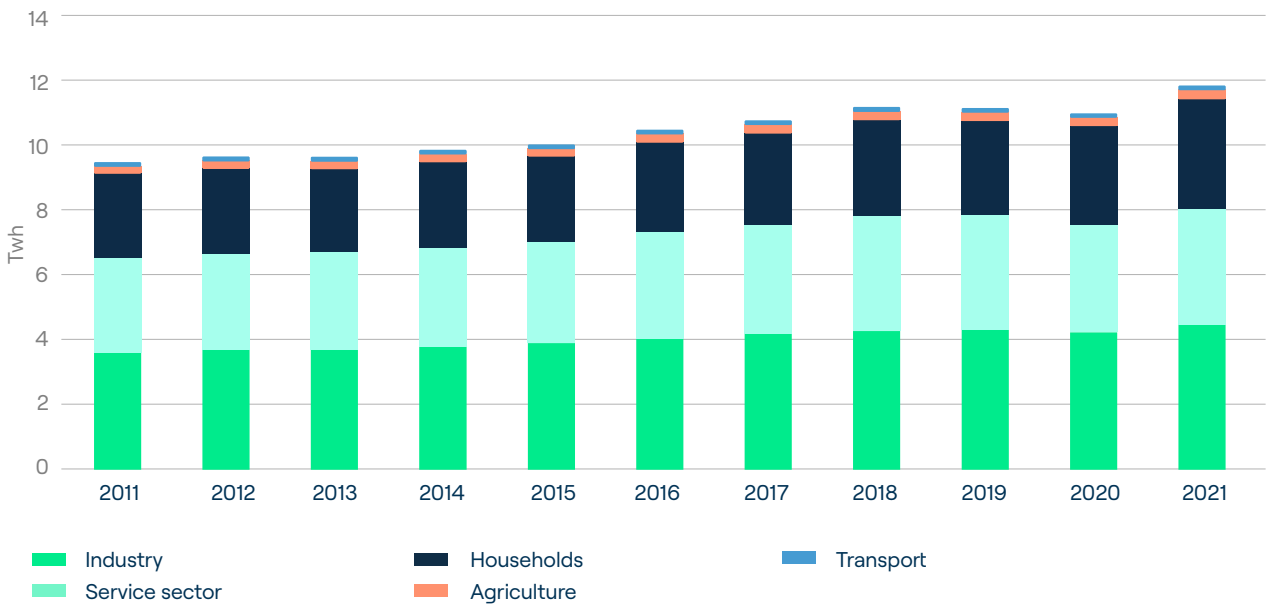


Table 1. Changes of power plants capacity, MW

Power plants and generating sources	Installed capacity in 2020	Installed capacity in 2021	Change, %
Thermal PPs:	**1924**	**1924**	
Lithuanian PP	1055	1055	
Vilnius PP-3	360*	360**	
Kaunas PP	170*	170*	
Panevėžys PP	35	35	
Other PPs	304	304	
Kruonis HPSPP	**900**	**900**	
Power plants using RES:	**936**	**1153**	**23.2**
Hydro PP:	128	128	
Kaunas HPP	101	101	
Small HPPs	27	27	
Wind PPs:	540	671	24.3
Connected to transmission grid	433	551	27.3
Connected to distribution grid	107	120	12.1
Biomass PPs	63	58	-8.6
Biogas PPs	36	37	2.8
Solar PPs	169	259	53.3
Waste PPs***	**48**	**48**	
Total:	**3808**	**4025**	**5.7**

* Estimating that reserve and preserved units that have been temporarily decommissioned but the equipment has not been dismantled
** Units of Vilnius PP-3 (2x180 MW) operation were suspended on 6/1/2022
*** Depending on the type of fuel burned, could be renewable waste or non-renewable waste

For the third year in a row, the biggest growth was in solar energy - in 2021, approximately 90 MW of solar power plants were additionally connected to the distribution network. The capacity of wind power plants increased by 131 MW, of which 118 MW was connected to electricity transmission networks and 13 MW to distribution networks. The capacity of biomass power plants decreased by 5 MW during the year, while biogas increased symbolically by 1 MW. The total power of generating sources installed in the system in 2021 compared to 2020 increased by 217 MW.

Since 2015, with the advent of bilateral electricity accounting in Lithuania, the number of consumers producing electricity[2] started to accelerate. In 2018 the number of consumers producing electricity was about 9.17 MW, in 2019 increased by 29.8 MW, in 2020 reached 89.21 MW, and in 2021 - 174 MW. Most of consumers involved in generating energy, produce in solar power plants.

Since 2015 production in Lithuanian power plants had a decreasing trend. The rise was in 2020, when production in Lithuania reached 5.14 TWh, which was 41.3 percent more than in 2019 (National balance of Lithuanian system). However, in 2021 production in Lithuania decreased again (about 9 %) and produced 4.69 TWh. Almost half of the country's total generation was created by renewable energy resources (Figure 2).

In 2021, the greater part of the electricity consumed in the country (about 71 % of the total electricity consumption or about 66 % of the total electricity demand, i.e., after considering the electricity used for loading the Kruonis HPSPP) was imported. About 19 percent the final consumed electricity was produced from renewable energy sources (without considering the costs of Kruonis HPSPP and networks).

[2] Electricity generating consumer means a natural or legal person who generates renewable electricity for its own needs and who are able to feed excess electricity generation to the grid for future consumption and recover it (who may non-used renewable electricity supply into the grid)

Despite the fact that thermal power plants generated most of the electricity (1.723 TWh), their production decreased by about 12 percent compared to production in 2020. This was influenced by significantly increased gas prices. Of the power plants using renewable resources, wind power plants generated the most. In 2021, such PP produced 1.356 TWh (which is 59.7 % of total RES production), hydro PP - 0.380 TWh (16.71 % of total RES production), and other renewable resource power plants - 0.536 TWh (23.6 % of total RES production) of electricity. Between them, the production of solar power plants grew the most, by as much as 45 percent (from 0.108 TWh in 2020 to 0.157 TWh in 2021). This was due to both sunnier days and the rapidly growing capacity of the energy distribution operator grid connected solar power plants.

In 2021, 11.92 TWh of electricity was imported into Lithuania, and 2.87 TWh was exported. Most of the electricity was imported from Latvia, Sweden and Russia. As import needs decreased, the distribution of markets also changed. 49% less of electricity was imported from Russia (2.05 TWh in total), from Belarus – 0 TWh. Instead, imports from other countries grew: from Latvia even by 66 percent (up to 5.09 TWh), from Poland - 33.6 percent (up to 0.86 TWh), from Sweden - 28 percent (up to a record of 3.72 TWh).

The reliability of the operation of the electric power system is greatly influenced by the technical condition of the main elements of the transmission system – electricity transmission lines and transformer substations.

Although 400-110 kV electricity transmission networks are quite well developed in Lithuania, a significant number of electricity network equipment has reached or even exceeded the operational time. This has a big impact on the reliability of the work of the whole PS.

Fig.2. The Lithuanian power system balance (from total electricity demand (13.74 TWh))

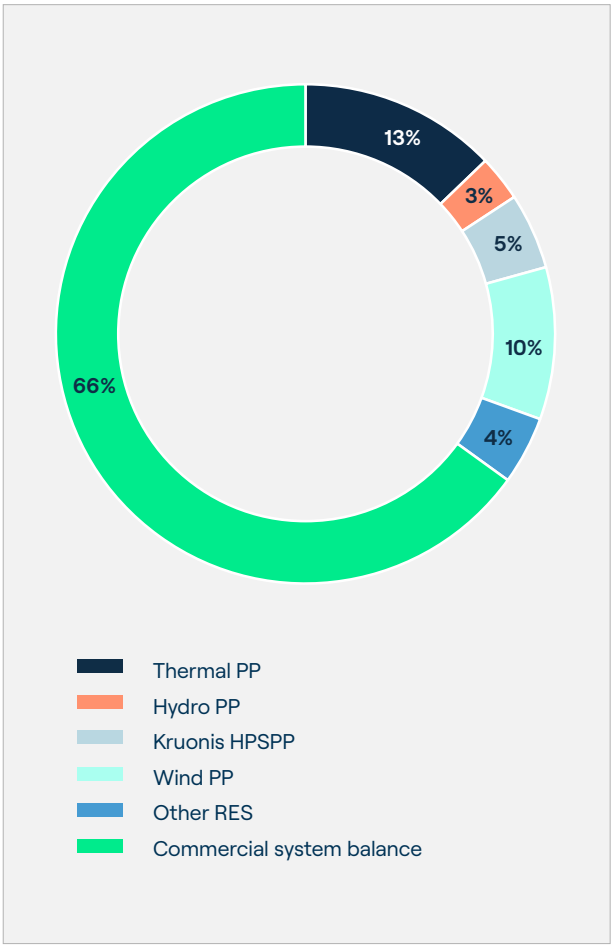


Table 2. Key reliability indicators of the electricity transmission system in 2011-2021

Indicators	Reasons for interraption	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ENS, MWh	Force Majeure	21.21	31.2	4.06	1.9	3.587	20.62	62.409	2.31	5.886	26.465	**6.819**
	External efects	43.65	11.43	10.94	31.99	24.002	6.41	13.208	30.811	14.164	0.135	**10.334**
	Responsibility of operator	7.53	7.36	6.68	5.3	4.167	1.03	1.677	0.954	32.339	5.251	**3.356**
	Not determined	0	0	0.028	0.055	0.373	0	0	0	0	0	**0**
	Total	**72.39**	**49.99**	**21.7**	**39.25**	**32.13**	**28.06**	**77.29**	**34.075**	**52.39**	**31.851**	**20.509**
AIT, min	Force Majeure	0.97	1.44	0.19	0.09	0.173	0.81	2.48	0.07	0.2	0.892	0.228
	External efects	2	0.53	0.51	1.5	1.155	0.25	0.47	1.15	0.482	0.005	0.346
	Responsibility of operator	0.35	0.34	0.34	0.25	0.2	0.04	0.061	0.036	1.102	0.177	0.112
	Not determined	0	0	0	0.003	0.018	0	0	0	0	0	**0**
	Total	**3.32**	**2.3**	**1.02**	**1.84**	**1.55**	**1.1**	**3.01**	**1.26**	**1.78**	**1.074**	**0.686**

The reliability of electricity transmission in transmission networks is assessed by two indicators:

- **ENS** or END (energy not supplied/delivered) – the amount of electricity not transmitted through the transmission grid due to power supply interruptions in the transmission system (MWh);
- **AIT** (average interruption time) - shows the average interruption time in the transmission system (min.).

For the period of 2021-2025, the following minimum reliability levels for the company were set: ENS = 6.3 MWh and AIT = 0.29 min. The amount of electricity not transmitted (sent) by the electricity transmission system and the duration of interruption are presented in Table 2.

The Company transmits high-quality electricity in accordance with the requirements of international quality standards (LST EN 50160) and in line with the description of permissible frequency and voltage quality parameters of the high-voltage (330 kV and higher) transmission network prepared by Litgrid separately. These documents define the limit parameters that must not be exceeded and maintained by all users connected to the network, specify the frequency and voltage limits, voltage dips and interruptions, harmonics and asymmetry. It should be noted that very short (up to a second) voltage interruptions in 110 kV and higher grids occur due to electrical network accidents (short circuits), which are usually caused by natural phenomena (lightning, storms, hurricanes, migratory birds, etc.). Electric power transmission networks shall be designed to eliminate such failures within <150 ms of the main protection and <250 ms of the backup protection. In reality, short circuits are removed even faster (in about 100 ms) when the basic protections are applied. In addition to the operation time of the additional disconnection logic, the operation of the switching equipment itself takes about 70-80 ms, therefore it is technically impossible to eliminate voltage interruptions in the high-voltage grid or it would cost unreasonably large money. In order to ensure the operation of consumers who are very sensitive to the quality of electricity, special reservation measures must be installed on the consumer's own farm or in low-voltage networks.

Taking into account the trends of globalization and the external environment, „Digitalisation and Technological Convergence" is expected to impact almost all aspects of TSO development, in particular the automation of transmission network management, the faster and wider deployment of smart metering systems and the enhancement of cyber security. The Company (The System Control Centre) performs remote accounting of the number of devices controlled from the dispatch control system. According to the data of December 2021, out of 1276 controlled transmission system devices, 76 % were remotely controlled (increased 3 percent compared to 2020), in all approximately 956 connections.

Lithuanian PS is directly connected with five neighbouring (Sweden, Poland, Belarus, Latvia, Russia) electric power systems:

- NordBalt direct current interconnection with the Swedish power system, with a 700 MW capacity from / to the Lithuanian system;
- LitPol Link interconnection with Poland PS – a 400 kV double-circuit power transmission line, which operates via a DC converter. The capacity of this converter is 500 MW, the cross border capacity reaches 500 MW from/ to the Lithuanian PS;
- Four 330 kV and three 110 kV lines connect with the Latvian PS. The technical cross border capacity reaches 1500 MW to the Lithuanian PS and 1200 MW from the Lithuanian PS;
- Four 330 kV and seven 110 kV lines connect with the Belarusian PS. The technical cross border capacity reaches 1300 MW to the Lithuanian PS and 1350 MW from the Lithuanian PS;
- Three 330 kV and three 110 kV lines connect with the Russian (Kaliningrad) PS. The technical cross border capacity reaches 600 MW to the Lithuanian PS and 680 MW from the Lithuanian PS.

In 2021, the highest intersystem connection load was achieved with Sweden. The loading of this section exceeded the value by 50 percent during 60.7 percent of the time of the year, but compared to the data of 2020, the load decreased by 17.4 percent. The second most loaded intersystem connection was with Poland, whose load in 2021 exceeded the value by 50 percent during 55.9 percent of the time in the year. The load on the Lithuanian-Latvian section 98.3 percent of the year was less than 50 percent. The load on the Lithuania-Belarus section 68.9 percent of the year was loaded less than 50 %. The trends of the balance of the largest physical flows remained the same as in 2020: the most flow passed through the intersystem connection with the Swedish power system (PS), the balance of intersystem flows between Lithuania and Belarus and the Russian power systems were in second and third place, and the intersystem connection with the Polish power system was operational almost all the time in the direction of flow to Poland.

The voltages of the Lithuanian PS network are controlled by employing the possibilities of controlling the reactive power generated by power plants, as well as by regulating the operation of shunt reactors and capacitor batteries. When the NordBalt and LitPol Link connections came into operation, additional reactive power and voltage control options have appeared. The biggest source of reactive power generation are Kruonis HPSPP units, the limits of reactive power generated by one unit are -120÷180 MVar when operating in synchronous compensator (SC) mode. The main reason for SC's working hours is the operation of the LitPol Link connection during the night or early morning hours, when small amounts of electricity are transferred to the Polish PS. During the night hours, when the Kruonis HPSPP does not operate in the pump mode, the voltage levels in the 330 kV nodes increase significantly and approach the maximum permissible values. In order to turn on the LitPol Link converter, it is necessary to reduce the network voltages. Currently, the only way to do that is to use Kruonis HPSPP in SC mode. In February 2021, a certificate of completion of the works was received. In addition to this shunt reactor, the Lithuanian PS operates another 10 smaller power shunt reactors, but they do not have the possibility of regulation and their influence is local. A new 10 kV 25 MVar shunt reactor will be installed in Ignalina instead of the relocated shunt

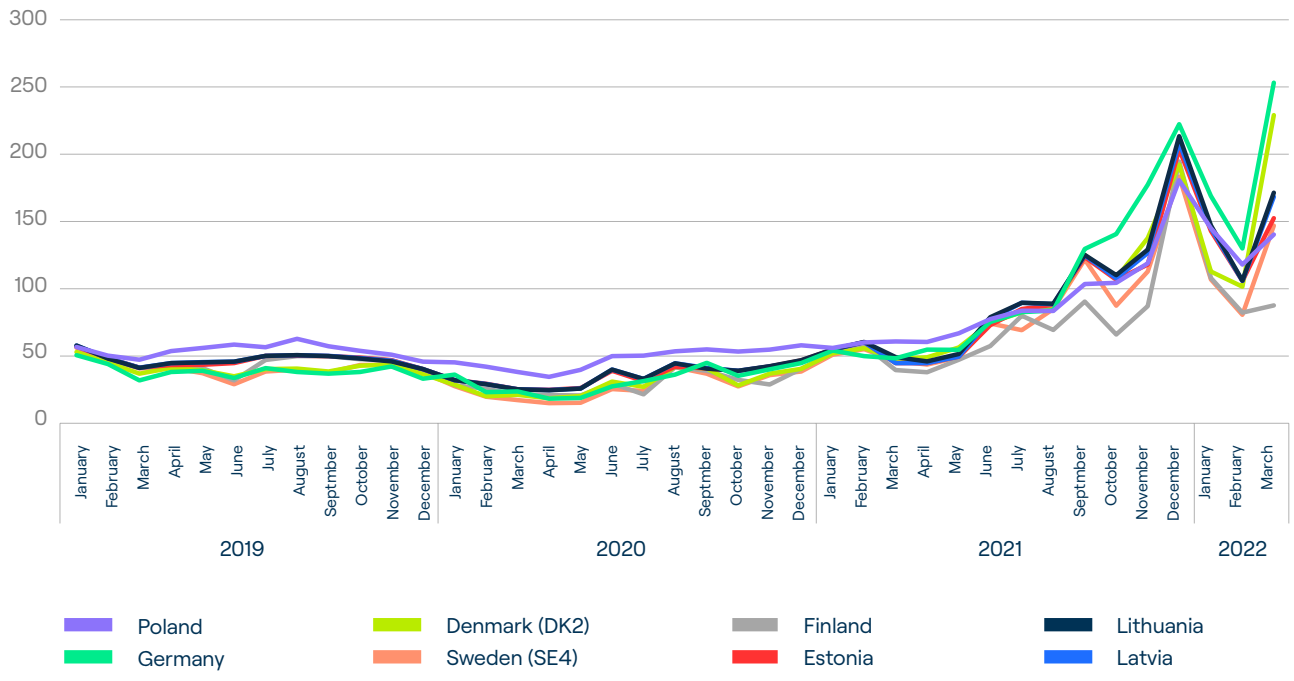
reactor. The use of synchronous compensators is also determined by the use of shunt reactors in transformer substations (TS), repairs of electrical network elements (ETL, autotransformer, disconnection of static reactive power compensation devices), and the operating modes of other power plants. It was observed that the work of Kruonis HPSPP in the synchronous compensator mode correlates with the work of the generators of the Lithuanian Power Plant — when the Lithuanian Power Plant is operating, its reactive power generation capabilities reduce the voltages in the system, so the need for Kruonis HPSPP to work in the synchronous compensator mode is also reduced.

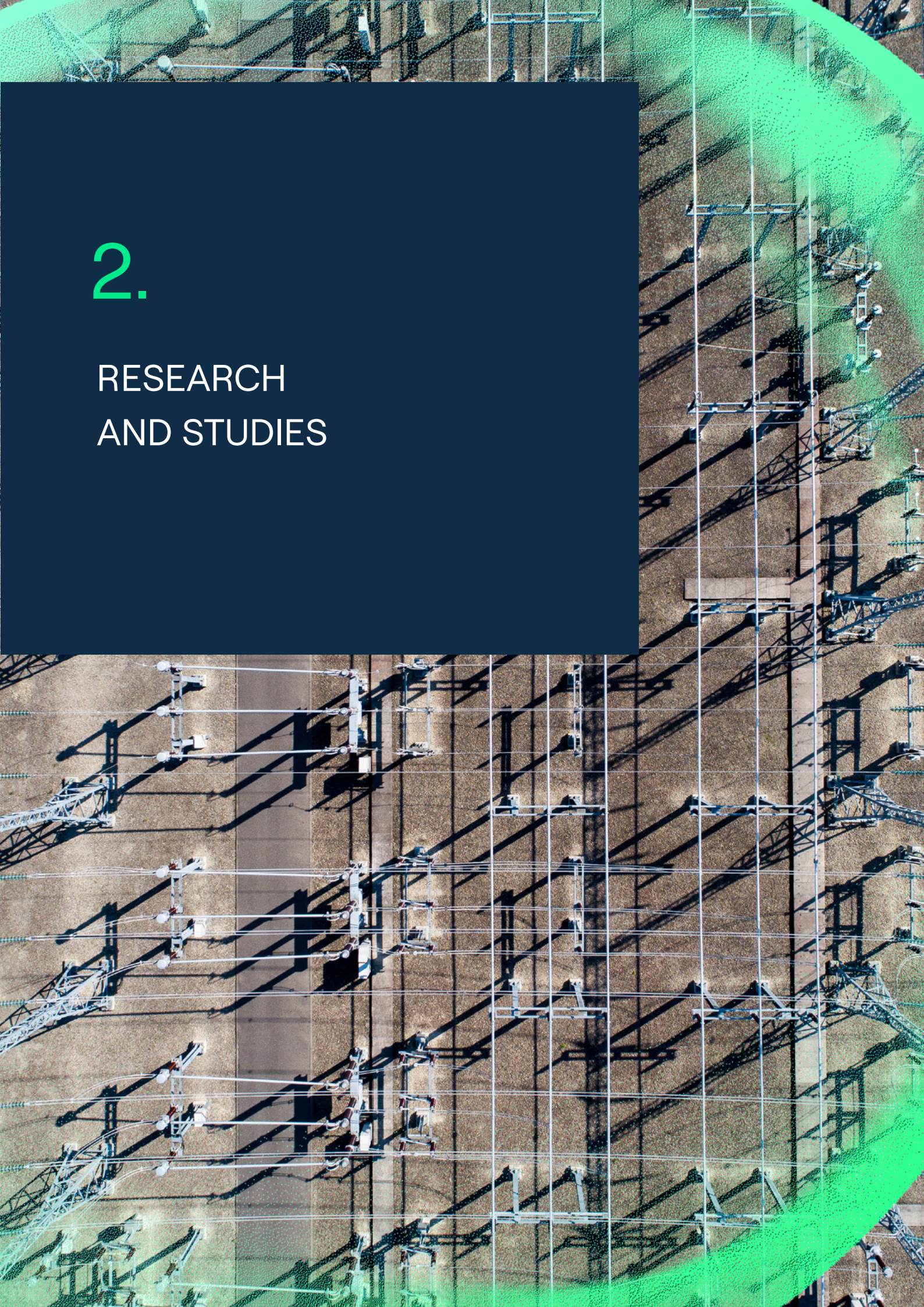
In 2021 the average price of electricity in the Lithuanian trading zone of electricity market "Nord Pool" increased more than 2.5 times and reached 90.45 EUR/MWh. It was the highest electricity price in the entire history of Lithuania. Lithuanian electricity prices were greatly influenced by the situation in neighbouring countries, where the prices also increased significantly and resulted in more expensive import to Lithuania. The price of the "Nord Pool" market system grew even more - in 2021, the price of electricity was on average 6 times higher than in 2020. Gas prices, which reached historic highs in 2021, had the greatest influence on such a jump in electricity prices. Already in June 2021, gas prices in the most liquid European gas trading site in Holland exceeded the limit of 30 EUR/MWh, which has not been exceeded in the last 10 years. As natural gas reserves are running out in Europe and there is no additional supply due to repairs and political decisions, on December 21 gas cost as much as 180 EUR/MWh. The highest average monthly electricity price in the Lithuanian trade zone was recorded in December – 212 EUR/MWh, and the lowest in April – 44.7 EUR/MWh. At the beginning of 2021, a growing demand was observed due to the established requirements dictated by the COVID-19 pandemic, but already in the summer, hydro reserves began to run out in the northern Europe, so the price of gas began to dictate the increase in the price of electricity. The price growth was also significantly influenced by the prices of emissions allowances, which rose sharply throughout the year, reaching 33 EUR/CO2t at the beginning of the year, and already exceeded 80 EUR/ CO_2t at the end of the year. Due to these reasons, an astonishing hourly electricity price has been recorded in Lithuania - on December 7 at 8 o'clock the price of electricity reached 1000.07 EUR/MWh. A comparison of price changes in Lithuania with other countries is presented in Figure 3.

Import from neighbouring EU countries grew by 31 percent. Import grew the most from Latvia - more than doubled, from Poland - by 54 %, while import from Sweden - decreased by 22 %. The total amount of import was 11.9 TWh. The export flow from Lithuania decreased by 14 percent, and the biggest decline was to Latvia - 41 percent, but the largest flow from Lithuania was directed to Poland, this amount decreased from 2.3 TWh to 1.8 TWh, and only to Sweden the export grew 83 percent. The total amount of export was 2.8 TWh.

Electricity prices increased in all the states of the Baltic Sea region and in Norway. In 2021, electricity prices were the highest in the last 20 years and prices broke hourly price records in all trade zones. The maximum hourly price in 2021 was 1000.7 Eur/MWh and was recorded in the zones of Lithuania, Latvia, Estonia and Finland. Although electricity prices grew in the entire "Nord Pool" market, compared to the electricity price of the previous year, the highest price growth occurred in the southern trading zones of Norway, where the annual price increased as much as 8 times, while the lowest price growth occurred in Poland - one and a half times. The price growth was similar in all Baltic countries, where the prices increased by about 2.5 times.

Fig. 3. Average electricity prices in 2019-2021 and January-March of 2022





2.

RESEARCH AND STUDIES

2. RESEARCH AND STUDIES

The preparation of research and studies, planning and implementation of innovation deployment activities encourages the Company to increase the efficiency of its activities by applying new methods, tools and good practices. The Company, either alone or in cooperation with research institutions and other consulting companies, carries out studies, research, analyses, diverse evaluations and pilot projects related to the activities of the transmission system operator. The studies and research carried out and/or planned to be carried out by the Company and their brief descriptions are provided below.

Planning and design of offshore electricity network seeking to integrate the potential of offshore wind power plants in Lithuania

The company continues its cooperation with the Japanese energy company "TEPCO Power Grid" and is preparing a study on the evaluation of technical and economic alternatives for an offshore power grid for the integration of wind power plants.

The study is carried out taking into account the goals of NEIS, which foresee that by 2050, 80 percent of Lithuania's energy needs will have to be produced from non-polluting resources, and 100 percent the country's total electricity consumption will consist of locally produced electricity. The development of renewable energy resources, paying great attention to the development of offshore wind, is envisaged as one of the main means to achieve these goals. Already in 2023, an offshore wind auction is planned to integrate the first 700 MW of offshore wind capacity into the Lithuanian electricity system, and the total offshore wind potential in Lithuanian territorial waters may reach up to 3.5 GW.

In order for the integration of offshore wind power plants to take place in a technologically advanced and cost-effective way, the scope of this study analyses the possible different configurations of the network required for the integration of offshore wind, including direct and alternating current technologies, their technical parameters and the investments required for installation and operation, the socioeconomic benefits of such configurations of the offshore wind. The study evaluates the development alternatives of the hybrid offshore network with the neighbouring countries, the potential of using existing and planned as well as future connections for the development of offshore wind parks.

The main conclusions of the study are planned in the summer of 2022. The results of the study will be applicable in the evaluation of the further integration of the generation potential of offshore wind power plants.

OneNet project

The "One Network for Europe" (OneNet) project aims to materialize the vision of a connected network and create the conditions for the next generation of network services that can fully exploit the response to demand, storage and distributed generation, while creating fair, transparent and open conditions for the user. Creation of one unified European system is a big challenge, but the solutions that can help different systems work together are very necessary. This is to take advantage of the opportunities provided by the smart grid. At the end of 2020, Litgrid joined this project, which together with the Energy Distribution Operator (ESO) involves more than 70 operators of transmission and distribution network, market and other partners from all over Europe. The project is divided into 4 groups and Litgrid, together with ESO, are assigned to the Nordic demonstration group (Northern cluster), which includes Ireland, Norway, Sweden, Finland, Estonia and Latvia.

Since the beginning of the year, all users in Lithuania have a practical opportunity to contribute to the flexibility of the system and its balancing. Independent aggregators, to whom the Council has issued permits for independent electricity demand aggregation, aggregate the users, and the transmission system operator, by applying the methodology for determining the amount of initial electricity demand, calculates the aggregated offers of at least 1 MW in the balancing market. This will strongly contribute to the faster integration of renewable resources into the energy system and wider opportunities to enable consumers to be active participants in the energy system.

Research on the application of innovative measures in the integration of RES power plants and the methodology for determination of optimal solutions

The company is constantly connecting new producers using renewable energy sources (RES) to 110-330 kV electricity transmission networks. New RES producers as well are coming to connect to distribution power grids of 6-35 kV voltage, and the excess electricity produced there also enters the 110 kV network, causing the so-called "reverse generation" and additionally loading the 110 kV lines. If the reverse generation enters the 110 kV network through transformer substations that are connected to 110 kV lines where there are already RES power plants connected, the flows of generated power add up, and if too many RES generating powers are connected, these flows cause overloads of the 110 kV lines. Since the expansion of the 110 kV network usually means the reconstruction of the existing 110 kV line or the construction of a new line, such investments would be disproportionately large to connect small capacities in the distribution network.

After connecting the maximum possible amount of RES to the existing 110 kV lines and substations, using the existing bandwidth of the transmission network, there is still a large amount of unconnected RES producers left, which could be connected if means were found to increase the bandwidth of 110 kV power lines without reconstructing them, but using other technical measures. In order to achieve this goal, the study "Research on the application of innovative measures in the integration of power plants using renewable energy resources and the methodology for determination of optimal solutions" is being conducted. The study will help to evaluate the possibilities of using new and innovative measures (power flow management, bandwidth monitoring, energy storage technologies) by increasing the quantities (power) of RES connection to 110 kV power grids and would determine in which cases the application of which measures would be more appropriate. In order to determine the most effective measures for the usage of the existing 110 kV network by integrating the maximum possible RES powers, it is necessary to conduct a study and a cost-benefit analysis, evaluating socioeconomic aspects as well.

The study is planned to be carried out in the summer of 2022.

Evaluation study of the frequency regulation-related service supply of the power grid and participation model in the balancing market

The purpose of the study is to prepare a calculation model that could evaluate the criteria and conditions for participation in the balancing market of participants from different segments of the electricity and system services markets. Also, to create an educational calculator that would allow to evaluate the different technical requirements and economic aspects of the provider of additional services of the electricity network. Currently, the studio purchase procedures have been initiated. It is planned to have the studio in the end of 2022.

Stability assessment studies of the Baltic system

Even before the planned synchronization of the electricity system of the Baltic countries with the grids of continental Europe, there is a risk of earlier disconnection from the IPS/UPS system. In this case, the electricity system of the Baltic countries would be synchronized with the CEN in an urgent manner and in a weakened mode, for example, when the "Harmony Link" connection between Lithuania and Poland is not yet operational. In this case, if the synchronous connection between Lithuania and Poland is disconnected, there is a risk that the electricity system of the Baltic countries would remain in island mode.

Until now, 3 stability studies of the PS of the Baltic States have already been carried out: "Study of the frequency stability of the Baltic PS", "Study of the dynamic stability of the synchronous connections of Estonia, Latvia and Lithuania with the CEN" and "Measures necessary to ensure safe operation of the PS of the Baltic States after synchronization with the CEN, and study of determination of related costs". As a result of these studies, necessary measures have been determined that should be implemented in order to ensure the stable operation of the PS of the Baltic States in the island mode after the planned synchronization with the CEN.

Currently, 3 stability studies of the PS of the Baltic States are additionally being conducted: "Study of stability of low frequency oscillations", "Study of stability of transient processes" and "Study of stability of frequency of island operation mode". The final results of all studies are expected to be received by August 2022.

3.

TRANSMISSION NETWORK DEVELOPMENT IN 2031

3. TRANSMISSION NETWORK DEVELOPMENT IN 2031

Planning of the development of the transmission network and determining the development directions of TN takes into account the following:

- provisions of the Law on Necessary Measures of Protection against the Threats Posed by Unsafe Nuclear Power Plants in Third Countries of the Republic of Lithuania of 29 April 2017;
- political memorandum signed by the Baltic States, Poland and the European Commission on the synchronization of the Baltic electricity networks with CEN via Poland of 28 June 2018. This agreement foresees synchronization of the Baltic PS with CEN using the existing 400 kV alternating current line Alytus-Elk (LitPol Link) and construction of a new submarine direct current link from Lithuania to Poland;
- the agreement adopted at the BEMIP high-level summit of 14 September 2018 on the synchronization of the Baltic PS with CEN via the existing double-circuit line Lithuania-Poland (LitPol Link), with the additional construction of a submarine HVDC link and the installation of other optimization measures, including synchronous capacitors;
- provisions of the Law on the Connection of the Electricity System of the Republic of Lithuania to the Continental European Electricity Network for Synchronous Operation adopted of Seimas of the Republic of Lithuania of 13 June 2019;
- provisions contained in the Plan of Actions and Measures of the Electricity System Synchronization Project approved by the Government of the Republic of Lithuania on 4 September 2019;
- the 18th government program and its implementation plan.

The main goal for the electricity sector is to connect the electric power systems of the Baltic States (Lithuania, Latvia, Estonia) with the CEN for synchronous operation and full integration into the Nordic electricity market. To achieve this goal:

- 330/110/10 kV Bitėnai TS was expanded - the project was implemented (2019);
- double circuit 110 kV ETL Pagėgiai-Bitėnai was built – the project was implemented (2020);
- the existing single-circuit 330 kV OHL Lithuanian PP-Vilnius reconstruction into a double-circuit (41.3 km) - the project was implemented (2020);
- the project of optimization and preparation of the north-eastern Lithuanian electricity transmission network for synchronous operation with the continental European energy system (including reconstruction of 330/110 kV Ignalina NPP and Utena substations and transportation, construction and connection of a controlled shunt reactor to 330 kV switchyard of Lithuanian power plant) - the project was implemented (2021);
- LitPol Link expansion (three autotransformers installed) - the project was implemented (2021);
- construction of a new 330 kV ETL Vilnius-Neris is carried out. The length of the line is 83 km - a new route will be built for 59.7 km, and a 22.8 km will be used for the existing 330 kV OHL Vilnius-Molodečnas;
- Harmony Link is under construction. The new DC submarine connection will connect the Lithuanian PS with the Polish PS. Within the scope of this project, a 700 MW DC converter with connection to the newly built Darbėnai 330 kV switchyard will be installed, about 330 km long cable will be laid between Darbėnai and Zarnowiec switchyards in Poland (submarine part 290 km and 20 km cable in Lithuania and Poland);
- construction of 330 kV ETL Bitėnai-Kruonis HPSPP is carried out (the length of the planned line is about 211 km, of which about 40 km will be the reconstruction of the existing 330 kV OHL Bitėnai-Jurbarkas, about 62 km new line will be built and about 109 km of 330 kV OHL Kruonis HPSPP-Sovetsk line will be used);
- construction of 330 kV EPL Darbėnai-Bitėnai is carried out (planned line length - 137 km, of which about 45.5 km of the existing 330 kV OHL Klaipėda-Grobina will be reconstructed, about 79 km of the existing 330 kV OHL Klaipėda-Bitėnai will be reconstructed and about 12 km a new line will be built for the "bypass" of Klaipėda city);
- 330 kV switchyard "Darbėnai" will be built. A new submarine cable (Harmony Link) will be connected to this switchyard;
- a new 330 kV switchyard "Mūša" will be built;
- installation of synchronous compensators is underway (synchronous compensators will be installed in Telšiai, Alytus and Neris TSs);
- 330 kV Neris TS reconstruction is underway.

One more of the most important goals of the state is the **rapid increase in electricity production from renewable energy sources**. For this purpose, the generation of green electricity is promoted and expanded. It is planned for 2030 to have a network of 1.4 GW of offshore wind power plants, 3.6 GW of onshore wind power plants and 2 GW of solar power plants. Taking this into account, the conditions for synchronizing the transmission network with continental European networks must be assessed and the requirements for the safe and reliable operation of the Lithuanian PS must be ensured.

Taking into account the NEIS approved on 2018 and the pursued goals and results presented in it, it is planned that after 2025, the development of WPP parks with a capacity of 700 MW to 1400 MW is anticipated in the offshore part of the territory. The connection of offshore WPP (700 MW) parks developed in phase I (planned until 2028) to the 330 kV network does not require additional 330 kV TS development on land. Since the ownership boundary is planned at the Darbėnai switchyard on the rear coupling, the entire marine (including part of the land cable) infrastructure (marine cable and platform) will be owned and developed at the producers' expense as stipulated by the currently valid legal acts. The company will not own or operate this

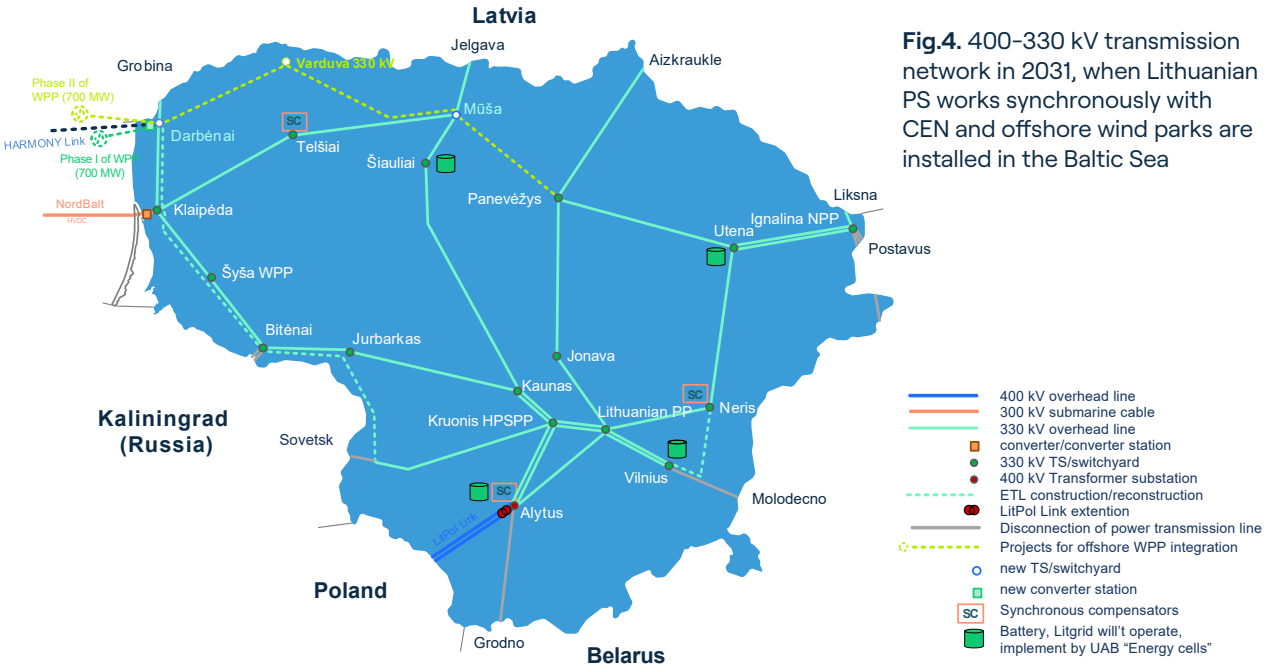


Fig.4. 400-330 kV transmission network in 2031, when Lithuanian PS works synchronously with CEN and offshore wind parks are installed in the Baltic Sea

infrastructure. The connection of offshore WPP (+700 MW) parks developed in stage II (2030) to the 330 kV network, as in alternative I, will also require marine (including part of the land cable) infrastructure (second marine cable and platform).

Accordingly, after assessing the security aspects of the Lithuanian PS in the scenarios of emergency synchronous work with Poland or isolated work, especially after desynchronization and disconnection of all lines with Russia and Belarus, the need to connect the eastern and western parts of the Lithuanian PS increasing national energy security, creating conditions for the integration of offshore wind and onshore RES, whose potential is particularly high in the western part of the system, the purposes for maintaining and increasing the level of electricity market integration with Latvia, it is planned that in the long term, **new 330 kV ETL Darbėnai-Varduva-Mūša and Mūša-Panevėžys must be built**.

The investments of the 3 countries in offshore WPP production and the projects both on land and at sea will be carried out at the initiative and expense of the producers and, as provided for by the currently valid legal acts. The infrastructure required for offshore WPP production will not be owned or operated by the Company.

Also, great attention will be paid to hydrogen energy. Taking into account the provisions of the hydrogen energy strategy approved by the EU, the aim is for hydrogen production projects to appear in Lithuania, which would contribute to the balancing of excess electricity from the renewable energy sources.

400-330 kV transmission network is shown in Figure 4.

It should be noted that the battery energy storage systems (abbreviated to accumulators or BESS) shown in Figure 4 will not belong to the Company and this project is carried out by UAB Energy Cells, a company specially dedicated for this purpose. During the project, four 50 MW BESS systems will be installed. The total power of BESS will be 200 MW. The BESS systems will be connected to the transmission network at Alytus, Utena, Vilnius and Šiauliai substations 110 kV switchyards.

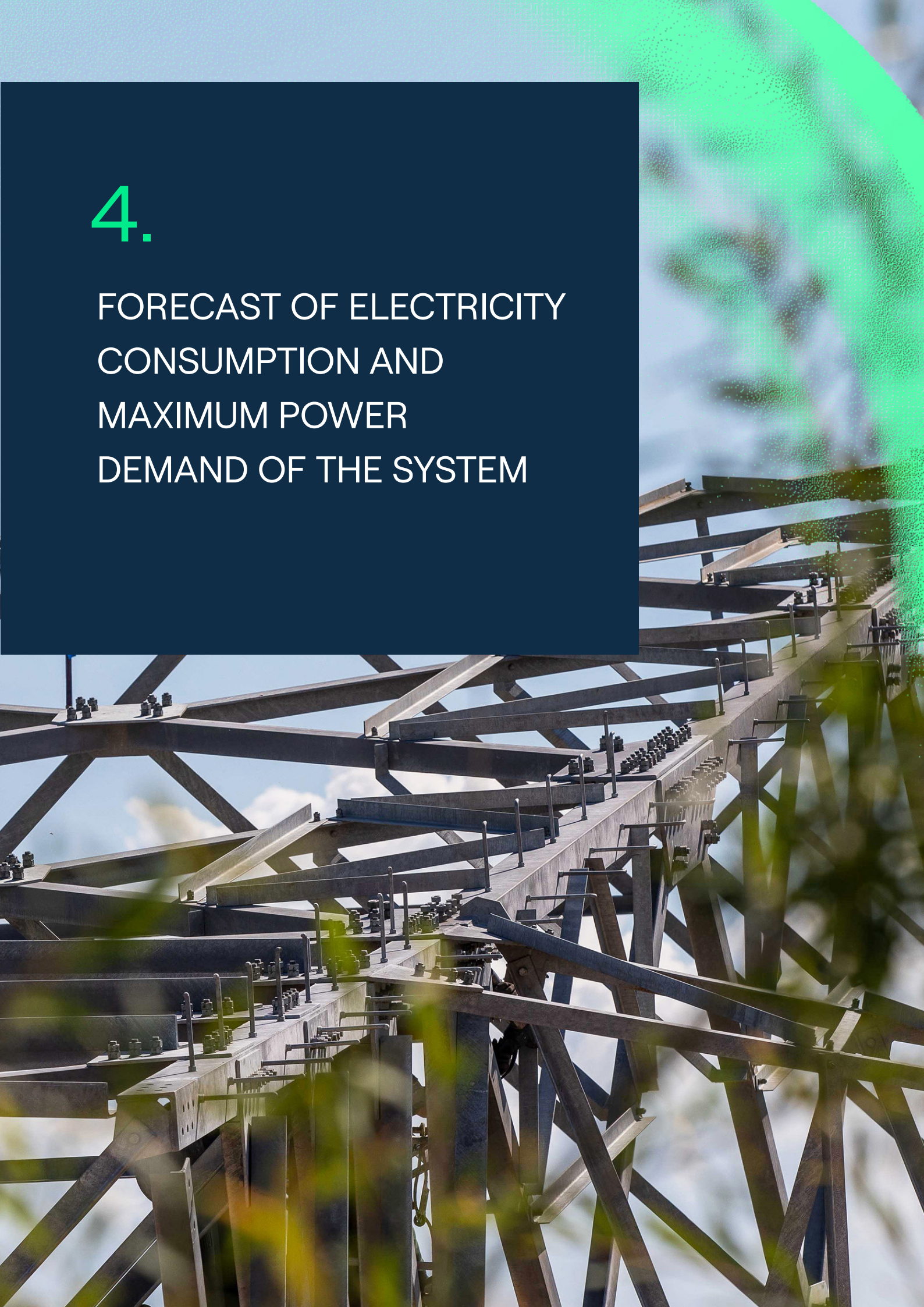
In addition to these projects, other projects related to synchronization will be implemented: modernization of control systems (installation of the control system of frequency stability assessment of the electric power system (FSAS), installation of an automatic generation control (AGC) system, implementation of the strategy of Statera information system, updating of the NordBalt high-voltage direct current link control system to ensure frequency control).

Taking into account the provisions of Article 4 of the Law of the Republic of Lithuania on Necessary Measures to Protect Against Unsafe Threats of Nuclear Power Plants from Third Countries (electricity from third countries with unsafe nuclear power plants may not enter the Lithuanian electricity market, except for energy necessary to ensure the reliability of the Lithuanian EPS and after the connection of the Lithuanian EPS to the KET for synchronous operation, it must not be possible to have direct access to the Lithuanian EPS from third countries or it can have access to the Lithuanian EPS only to the extent that may be necessary for technical reasons after desynchronization from the CIS EPS (IPS/UPS), including the Kaliningrad region), as well as to the results obtained from studies on the dynamic stability and frequency stability and the The Political Memorandum signed by the Baltic States, PL and the EC (on the synchronization of the Baltic electricity networks with the KET via Poland) and in accordance with the Resolutions of the Baltic WHO Leaders' Meeting of 4 February 2019, two additional HVDC back-to-back (BtB) converters (for transit to the Kaliningrad region) may be installed in addition to the currently available network infrastructure for the assurance of the security of the Kaliningrad EPS and the necessary system services for the Kaliningrad area (region), in addition to the currently available network infrastructure, two additional HVDC back-to-back (BtB) converters (for transit to the Kaliningrad region) may be installed if that is technically proven.

In order to desynchronize the Lithuanian PS from the IPS/UPS system, it will be necessary to dismantle about 176 km of existing 330 kV and 110 kV overhead lines. That will lead to changes in the conditions for the connection of intersystem lines in the TS (on the Lithuanian side): Kalveliai, Didžiasalis, Pabradė, Šalčininkai, Leipalingis and Kybartai, which, if the reconstruction of the mentioned TS is not planned until 2025, will require additional costs/investments.

4.

FORECAST OF ELECTRICITY CONSUMPTION AND MAXIMUM POWER DEMAND OF THE SYSTEM



4. FORECAST OF ELECTRICITY CONSUMPTION AND MAXIMUM POWER DEMAND OF THE SYSTEM

The most important factor determining electricity consumption is changes in the country's economic level which are **best defined by the gross domestic product (GDP)**. In Lithuania, electricity consumption per capita is one of the lowest in the EU, therefore the GDP growth has a significant impact on consumption, and the introduction of energy efficiency measures assists in promotion of electrification.

GDP growth. The medium-term GDP growth projection is based on the latest forecast of the Ministry of Finance of the Republic of Lithuania prepared in 31, March 2022. Taking into account that Lithuania's economy is still catching up with the developed countries, the country's GDP growth is expected to be higher than the EU average during the given period. The economic growth is likely to slow down when it approaches the EU average. The long-term GDP growth forecast is based on long-term forecast projections until 2060 provided by the Organization for Economic Cooperation and Development. It is assumed that economic growth is likely to slow down as the EU average approaches. Therefore, GDP growth following 2025 is projected to be slightly slower than over the period of 2022-2025 (Table 3).

The forecast of electricity consumption and the maximum power required by the system also involves the assessment of additional factors influencing future electricity demand:

a. electricity efficiency;
b. the number of electric cars and their electricity consumption;
c. the number of heat pumps and their electricity consumption;
d. railway electrification;
e. network losses;
f. distributed generation;
g. the impact of the development of load control measures and energy storage technologies;
h. industry development;
i. development of hydrogen production.

Taking into account a long-term energy and power forecast, the distributed generation estimated at maximum power consumption time (T_{max}), along with the introduction of various storage and demand control measures, should increase T_{max}, but accelerating electrification will

Table 3. Projection of GDP growth in the long term

Period	GDP growth in OECD countries (EURO17)		GDP growth in Litgrid consumption forecast		
	2025	2031	2022-2025	2026-2030	2031
GDP growth, %	1.23	1.1	2.5	1.0	0.6

Fig. 5. Electricity savings due to increased energy efficiency

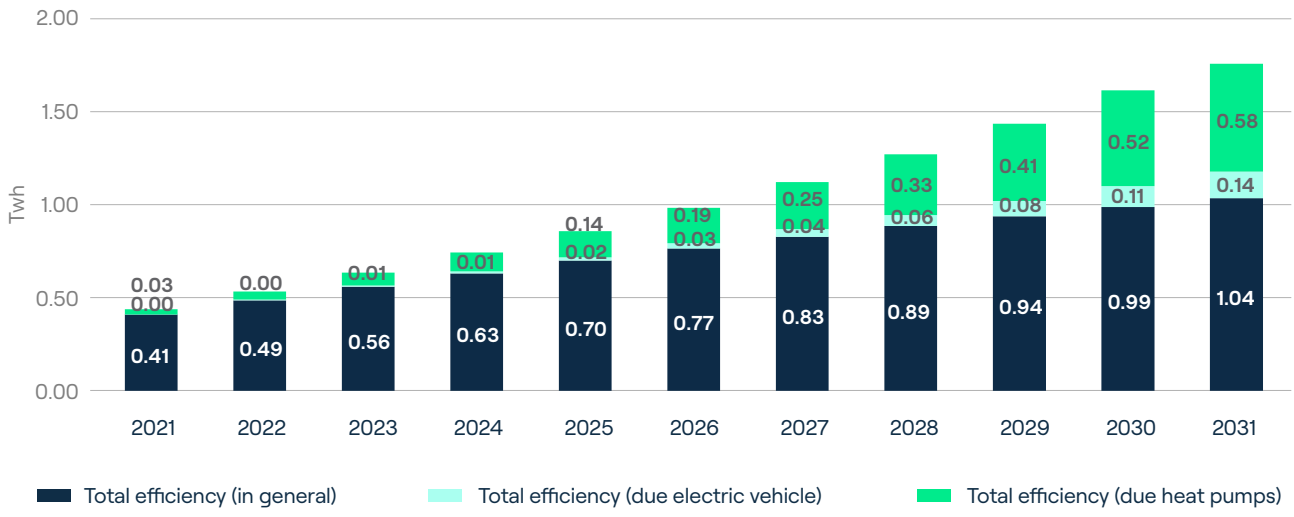


Table 4. Lithuania's total and final electricity consumption

Year	2021 (fact)	2025	2031
Total consumption, TWh	12.8	15.4	18.7
Final consumption, TWh	11.8	14.2	17.5

reduce this indicator and should remain at a similar 5900 hours level as in the period of 2012-2022 (average T_{max} – 5917 hours).

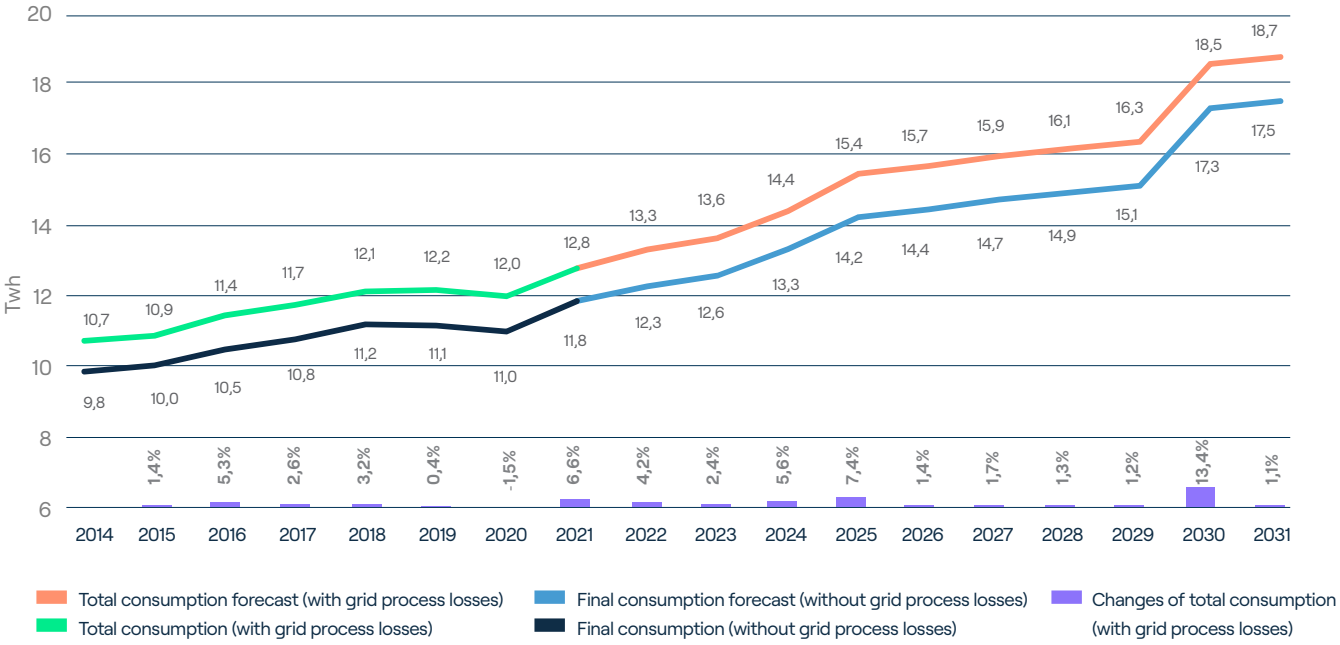
Electricity efficiency. The NEIS, approved in 2018, provides for both, the promotion of industries with low-energy and those increasing the energy consumption efficiency, and the introduction of new environmentally friendly technologies and equipment which will allow to save 1 TWh of electric power by 2030. The amount of electric power saved due to the increase in energy consumption efficiency is shown in Figure 5.

It is planned that in 2031, due to the implementation of efficiency measures, approximately 1.04 TWh and another 0.58 TWh due to the development of heat pumps and 0.14 electric vehicles can be saved. Therefore, in the future, due to improving technologies and more efficient electric cars and heat pumps, more than 1 TWh of additional electric power can be saved (total about 1.76 TWh).

Number of electric cars (electric vehicles, EV) and their electricity consumption. At the beginning of 2022, the number of electric cars in Lithuania was about 4,841[3], and an even higher growth rate is expected in the future. When assessing the NECP action plan, it can be assumed that the number of electric vehicle registrations will only increase and in 2031 the increase will reach 53,829 thousand units, and the total number of electric cars will exceed 283 thousand. Accordingly, **electric cars should consume about 596 million kWh/year in 2031**. However, taking into account the currently slow growth of the number of electric cars and based on the goals provided in the Alternative Fuels Act, that by 2030 electric cars will make up 100 percent of N1 class registered vehicles and 50 percent of M1 class vehicles, a slower growth scenario is also predicted. Based on the statistics of newly registered cars in the country, this scenario shows that in 2031 the number of electric cars in Lithuania will be about 158 thousand, and their consumption in 2031 would amount to about 284 million kWh/year.

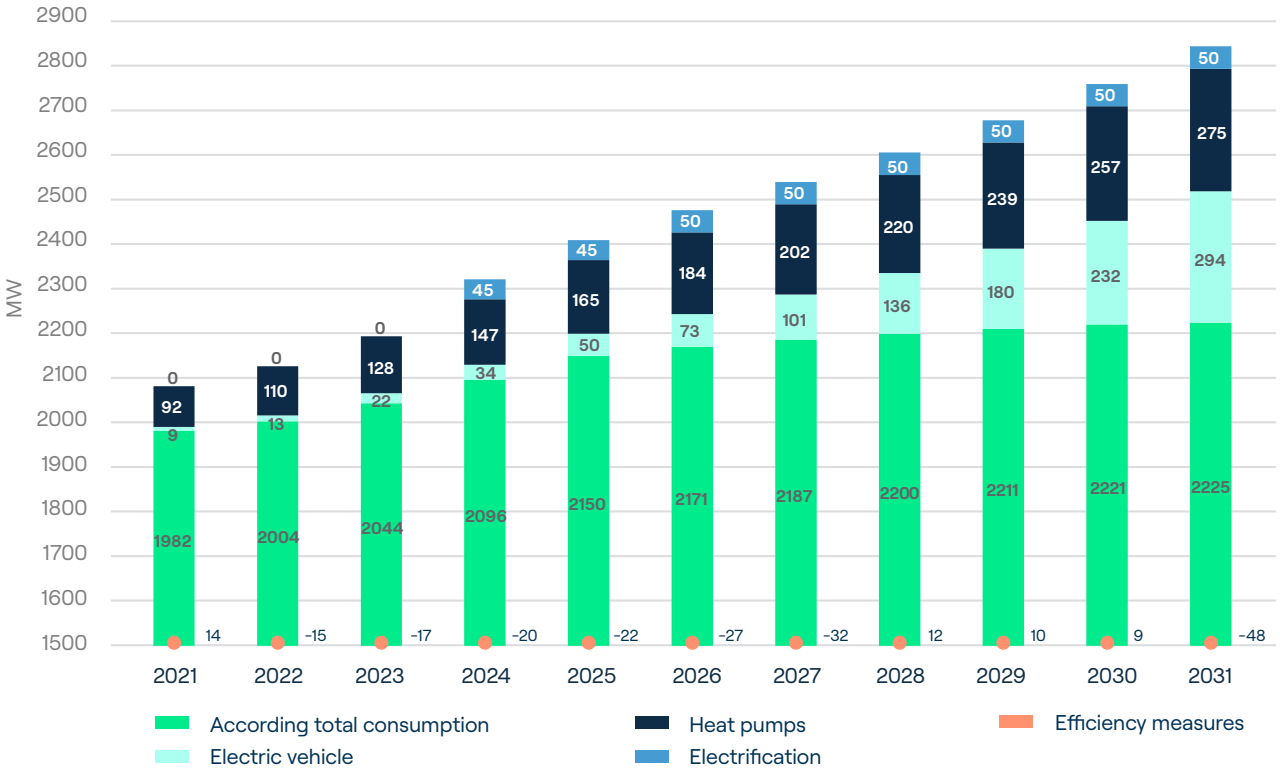
Number of heat pumps and their electricity consumption. In 2020, the number of heat pumps in Lithuania reached about 68 thousand units, and in 2031 this number should increase to 170 thousand units when evaluating both centralized and decentralized heat supply. When forecasting the increase of heat pumps, the goals set out in the NEIS action plan are taken into account - the number of heat pumps will increase by 50 thousand by 2030, and the thermal power will increase by 200 MWt in centralized heat supply. According to the 2020 statistical data, the total power of heat pumps installed in Lithuania reached 110 MWt, and the number of 50 thousand heat pumps has already been reached. Therefore, considering the development of centralized and decentralized heat supply, in 2031 the installed thermal power of the heat pumps will reach about 413 MWt. When converting thermal power into electrical, the seasonal efficiency factor is taken into account, which in Lithuania is about 4. **Annual consumption of heat pumps in 2031 should reach about 0.88 TWh**.

Fig. 6. Forecast of Lithuania's total and final electricity consumption



[3] https://www.regitra.lt/lt/atviri-duomenys/

Fig. 7. Forecast of the maximum demand for capacity in the system



Electricity consumption forecast. Based on the mentioned assumptions and the assessment of additional factors, forecasts of Lithuania's total (with technological network costs, but without energy consumed for loading/pumping Kruonis HPSPP) and final (without technological costs and energy consumed for loading Kruonis HPSPP) electricity consumption have been made (Figure 6 and Table 4).

When making the consumption forecast, the long-term development plans submitted by industrial facilities and the development of hydrogen electrolysis at the national level are taken into account, as a result of these factors, the consumption forecast from 2030 will additionally increase by approx. 2.23 TWh.

It is forecasted that Lithuania's total electricity consumption in 2031 will increase to 18.7 TWh and final electricity consumption to 17.5 TWh.

Maximum capacity demand forecast. Based on the assumptions described above and taking into account the electrification trends and the consumption forecast, a forecast of the maximum required power was made (Figure 7).

After making forecasts of electricity consumption and the maximum power required by the system, it can be said that with the development of the country's economy, the demand for energy from electricity will continue to increase. Efficient energy consumption will contribute to rational electricity consumption. And in the future, electricity consumption and the power required by the largest system will be additionally increased by electrification in the industry, household sectors and especially in the transport sector, where rapid development of electric cars and electrification of railway lines is expected. Consumption forecasts are used as input data for the demand forecast produced by ENTSO-E.

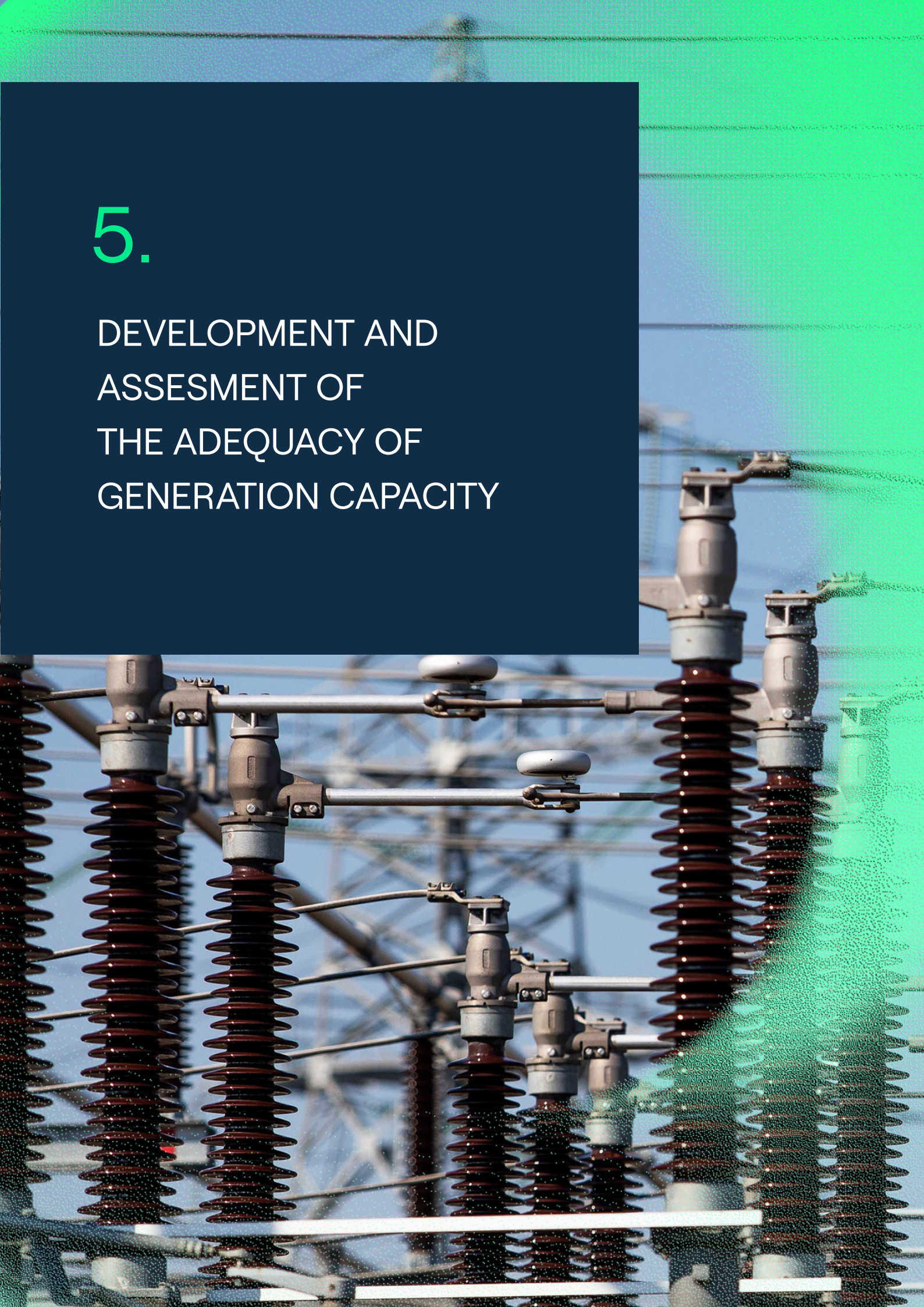
In view of the NEIS approved in 2018 and the targets and results specified there for the achievement of RES energy (by 2025, at least 5 TWh of electric power will be produced from RES, by 2030 - 7 TWh, by 2050 - 18 TWh), at the end of 2020, a Study of the development scenarios of the Lithuanian electric power system for 2020-2050 was carried out. The scope of this study estimates that even with the growth of generation from RES, the measures envisaged to increase the flexibility of the system by 2030 are sufficient and no additional measures are necessary. The study notes that the greatest opportunities for flexibility will arise in the future in line with the accelerating number of electric cars, expansion of the infrastructure of charging stations, and the development of software. Other key flexibility instruments will come from the consumer heating and cooling sector and electric power storage technologies. According to the results of the study, it is predicted that energy to gas technology will still be economically unprofitable and its development in the initial period is carried out to increase competence and will depend exclusively on incentives.

Table 5. System maximum capacity demand

	2021 (fact)	2025	2031
Maximum capacity demand (with electrification)**, MW**	2217	2419	**2897**

5.

DEVELOPMENT AND ASSESMENT OF THE ADEQUACY OF GENERATION CAPACITY



5. DEVELOPMENT AND ASSESMENT OF THE ADEQUACY OF GENERATION CAPACITY

5.1. Development of generation capacity

According to the information on perspective plans of the power plants obtained during the end of the year survey of producers in 2021, the Company's projects for the connection of generating sources, the technical projects being coordinated, signed letters of intent with developers of generating sources, guidelines for the development of renewable sources provided in the National Energy Independence Strategy and guidelines for renewable energy resources development specified by the 18th Program of the Government of the Republic of Lithuania, one scenario for the development of generation capacity was developed. The perspective of fossil fuel power plants has been assessed on the basis of information received during the annual survey of large electricity producers on the planned shutdown/decommissioning and the expected reduction of generating capacity, due to new pollution standards that will enter into force on 1 January 2024. Prospective development projects are assessed only if an investment decision has been made or regulated by the current legislation. The development of renewable resources is assessed according to the renewable energy development goals set by the Ministry of Energy of the Republic of Lithuania, ongoing projects and protocols of intent signed by Litgrid with the developers of generation development projects.

The changes in generating capacity to take place over the period from 2022 through 2031 are estimated as follows:

- In 2022, the operation of Vilnius PP-3 (360 MW) is decommissioned;
- In 2022, decommissioned of Petrašiūnai power plant (8 MW unit) (Litgrid assumption);
- In 2023, a 79.2 MW biomass unit of Vilnius cogeneration power plant is put into operation;
- In 2024, decommissioned of Kaunas TPP (170 MW);
- In 2025, the operation of the Kruonis HPSPP 110 MW 5 unit is started;
- In 2026, the operation of the 6 MW TG-2 unit of AB Lifosa is decommissioned;
- In 2030, decommissioned of Lithuanian PP units 7 and 8.

It is planned that in 2031 the total installed capacity of RES power plants by type of fuel will be as follows: 174 MW for biomass and biogas power plants, 2000 MW for solar power plants, 3600 MW for onshore wind power plants, 1400 MW for offshore wind power plants and 128 MW for hydropower plants.

5.2. Assessment of PS adequacy in Lithuania in 2022–2030

In preparing the annual national assessment of the adequacy of the Lithuanian PS under normal conditions, is followed the European Resource Adequacy Assessment (ERAA) methodology, approved by the European Agency for the Cooperation of Energy Regulators (ACER) on 2 October 2020, which takes into account the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019, concerning the general principles and objectives on electric power stipulated in the legal acts[4] of the internal market and in other EU legislation.

The 4 main input data sources used in carrying out the assessment of the national adequacy were as follows:

1. ENTSO-E European Climate database data split by year: onshore and offshore WPP, solar PP generation, load hour resolution time series, Kaunas HPSPP potential day resolution time series;

2. ENTSO-E MAF and ERAA data set: reliability parameters of traditional generation sources by fuel type and age, frequency of interconnection failure, DSR modelling results;

3. The ENTSO-E Transparency platform publishes data on the duration of scheduled repairs and failures;

4. Litgrid data: at least 3 years of historical Lithuanian PS data (reliability data of Kruonis HPSPP and Kaunas HPP, average duration of scheduled repair of interconnections and recovery of interconnection failures, hourly resolution time series of generation of power plants connected to DSO networks) and forecasts for demand and generating power for 2022-2031.

According to the current legal acts, it is assumed that until 2025, the Lithuanian Power System as part of the Baltic system will work continuously synchronously with the IPS/UPS system. After 2025, after the implementation of the project of synchronization of the Baltic States with the networks of continental Europe, the Lithuanian PS together with the Baltic system constantly works synchronously with the networks of continental Europe.

Adequacy of the system in 2022-2025

Previous adequacy assessments have shown that, under normal operating conditions, when the system works synchronously with IPS/UPS until 2025 the adequacy risks are not identified. Therefore, in 2022-2025 the ad-

[4] Directives of the European Parliament and of the Council: (EU) 2019/942, (EU) 2019/941, (EU) 2018/1999, (EU) No 1227/2011, (EU) 2019/944, (EU) 2015/1222, (EU) 2017/2195, (EU) 2017/1485, (EU) 2017/2196, (EU) 543/2013.

Table 6. The assessment of the adequacy of the national system of 2026-2030 (preliminary results)

LOLE (hours)	2026	2027	2028	2029	2030
Basic sc. 1	4.11	3.45	2.22	2.29	2.08
Sensitivity sc. 1	1.65	1.36	1.39	1.37	1.31
Sensitivity sc. 2	0.56	0.46	1.03	1.01	0.95
Sensitivity sc. 3	0.87	0.75	1.43	1.45	1.37
Sensitivity sc. 4 (the Baltic system works in an isolated operating mode during the hours when the LitPol Link connection is disconnected)	4.31	3.65	2.40	2.41	2.23
Sensitivity sc. 4' (Isolated operating mode all year)	158.24	130.20	75.26	72.65	63.17
Basic sc. 2	10.36	8.63	3.07	3.02	5.46

equacy of the system is assessed under extreme operating conditions of the system.

In addition, a sensitivity analysis of the connection with Latvia (by increasing the NTC from 0 MW to 798 MW) and a sensitivity analysis of the system mode without stability reserve was performed.

The results of the national adequacy assessment of the system in extreme conditions of 2022-2025 showed that:

1. In the scenarios of Baltic emergency synchronization and long-term isolated work in 2022-2025, after evaluating the currently declared availability of production resources by the producers and maintaining the FCR and FRR in the Baltic countries according to the sharing methodology in the continental European synchronous zone, it was determined that the duration of loss of load expectation (LOLE) is less than 8 hours/year during the entire analysed period:

In 2022, LOLE=2.59 hours/year, ENS=0.16 GWh/year.
In 2023, LOLE=1.23 hours/year, ENS=0.08 GWh/year.
In 2024, LOLE=2.43 hours/year, ENS=0.19 GWh/year.
In 2025, LOLE=5.78 hours/year, ENS=0.48 GWh/year.

It is important to mention that the adequacy task does not assess the price of energy, which will be higher in the electricity market than when the Baltic system is operating under normal conditions.

2. In the case of Baltic synchronization with CEN and isolated work scenario until 2025, the adequacy of the Lithuanian PS significantly depends on the energy flow from the Latvian connection. As traffic decreases, the level of adequacy decreases significantly.

Adequacy of the system in 2026-2030

The assessment of the adequacy of the system was carried out in the basic, assessing different demand growth scenarios, normal operating mode of the system and in 4 sensitivity scenarios:

- Basic sc. 1, heat and transport electrification are estimated in the demand forecast.
- Basic sc. 2, the development of hydrogen production in the industrial sector additionally assessed in the demand forecast.
- Sensitivity scenarios 1 and 2, when one about 250 MW (Sc. 1) or two 2x250 MW (Sc. 2) new generating capacities are added to the generation structure.
- Sensitivity sc. 3, which assumes that balancing reserves are maintained in the Baltic frequency control area, i. e. the Baltic countries secure the necessary reserves together.
- Sensitivity sc. 4, which assesses that the Baltic system works in an isolated operating mode during the hours when the LitPol Link connection (double-circuit line) is disconnected.

The assessment of the adequacy of the national system under normal conditions of 2026-2030 (preliminary results showing in Table 6) showed that:

- With the generation structure declared by the electricity producers, the duration of loss of load expectation LOLE, hours/year is less than 8 hours during the entire analysed period.
- In all scenarios, the critical year for ensuring adequacy is 2026. After 2026, the development of RES has a positive impact on ensuring adequacy.
- In the case of duration of loss of load expectation of 95th percentile, showing that there is a 5 % probability of getting a longer than average loss of load, which corresponds to a probability of 1 time in 20 years, LOLE varies in the range of 14-26 hours/year.
- In the Basic sc. 2, which in the demand forecast additionally assessed the development of hydrogen technologies in the industrial sector, the calculated LOLE exceeds 8 hours per year in 2026 (10.36 hours) and in 2027 (8.63 hours). It can be concluded that higher demand in Lithuania may cause adequacy problems.

Assessing the status of the implementation of the ongoing Harmony Link project and responding to the situation in the electrical equipment supply market, the risk of delay in the implementation of the Harmony Link project was identified. As previous adequacy assessments have shown, intersystem connections have a very significant influence on ensuring the adequacy of the Lithuanian electricity system, therefore Basic sc. 1 was supplemented with the assumption that the Harmony Link connection will be put into operation only in 2028 and the adequacy of the system was additionally assessed in 2026, 2027 and 2028 (Basic 1 sc. - Harmony Link from 2028).

An assessment of the economic viability of the generating capacity is currently being carried out. After the assessment, economically unviable capacities will be removed from the generation structure and system adequacy calculations will be performed for Basic sc. 1 - Harmony Link from 2028. If the obtained results identify a lack of capacity to ensure adequacy (calculated LOLE>8 hours/year), economically reasonable measures to ensure adequacy will be analysed and proposed.

The study is planned to be completed and the final results shall be known in August 2022.

5.3. Assessment of the adequacy of the Lithuanian system by ENTSO-E

In 2021, according to the new European Resource Adequacy Assessment (ERAA) methodology, an adequacy assessment of European resources of 10 years ahead, ERAA 2021, was prepared, which replaced the medium-term adequacy forecast MAF prepared so far. ERAA 2021 is based on the most advanced methodologies and probability analysis which seeks to model and analyse potential events that may have negative consequences for electricity supply and help stakeholders make informed decisions on strategic issues such as installation of capacity mechanisms.

The ERAA 2021 adequacy assessment is the first result of the implementation of the ERAA methodology, which includes not only the resource adequacy assessment at the basic sc., which assesses the changes in the generating capacities presented by the European TSO, but also the economic viability assessment for the "with capacity mechanism" and "without capacity mechanism" scenarios and is justification of the implementation concept of flow-based market coupling.

In 2025, the average duration of loss of load expectation for Lithuania is 7.5 hours/year (the national reliability standard is 8 hours/year). However, in the case of the 95th percentile of loss of load expectation, showing that there is a 5 % the probability of receiving a longer than average loss of load duration, and which corresponds to a probability of 1 time in 20 years, the LOLE increases to 44 hours/year. In 2030, the average duration of loss of load expectation LOLE for Lithuania decreases to 1.8 hours/year, and in the case of the 95th percentile it reaches 8 hours/year.

Part of the thermal generating capacity (in countries without special support schemes and capacity providing DSR service) does not receive enough income from the electricity market to cover operating costs (for existing capacity) or full costs (including CAPEX costs for new capacity). After adopting 15,000 Eur/MWh upper price limit in all trade zones and carrying out the assessment of economic viability, the total thermal capacity (mainly coal and lignite-fired power plants) decreased by about 75 GW in 2025 compared to the basic sc. And this is significantly more capacity than the 13 GW of identified economically viable new capacity.

The economic viability assessment showed that in Lithuania it would be more economically beneficial to replace the existing 75 MW old generation with a new 155 MW capacity. With a changed generation structure in 2025 the calculated LOLE for Lithuania – 4.3 hours/year, which increases to 23 hours/year in case of the 95th percentile.

After the assessment of economic viability, in some countries the established reliability standard is not ensured. The need for additional capacity is then assessed by iterations increasing generating capacity. Additional capacity is introduced into the generation structure of the "no capacity mechanism" scenario. Part of the additional capacity is the re-inclusion of capacity that was removed during the economic viability assessment.

In this scenario, the calculated LOLE for Lithuania in 2025 is 4.9 hours/year, which increases to 26 hours/year in the case of 95th percentile.

ERAA 2021 additionally performed sensitivity analysis of the basic scenario, of what would the impact of early decommissioning of thermal power plants/postponement of the start of operation (Low thermal sc.) be. In this sc. it is assumed that in 2025 the total installed thermal capacity in Europe will be 21.7 GW less than in the basic scenario.

In this scenario, it is observed that the reduction of thermal capacities in the neighbouring countries would significantly affect the adequacy of the Lithuanian electricity system. In 2025, the calculated LOLE for Lithuania is 10.3 hours/year, and in 2030 – 28 hours/year.

Summarizing the results of the system adequacy assessment, it can be stated that:

- When the PS of the Baltic countries is working in synchronous mode with the system of continental Europe and after evaluating the information provided by the manufacturers about the plans for maintaining and developing production capacities, no problems with the adequacy of the PS of Lithuania have been identified.
- It is important to note that with the current capacity structure (generating capacity and intersystem connections), Lithuania remains dependent on import from neighbouring countries. Given the fact that the main goal of the state is to integrate as much RES capacity as is necessary to cover Lithuania's needs, and investors do not yet plan to invest in traditional generation, the availability of traditional generation in neighbouring countries has a huge impact on ensuring adequacy, especially in periods of minimal RES generation.
- Ambitious RES development after 2026 will have a positive impact on ensuring system adequacy.

6.

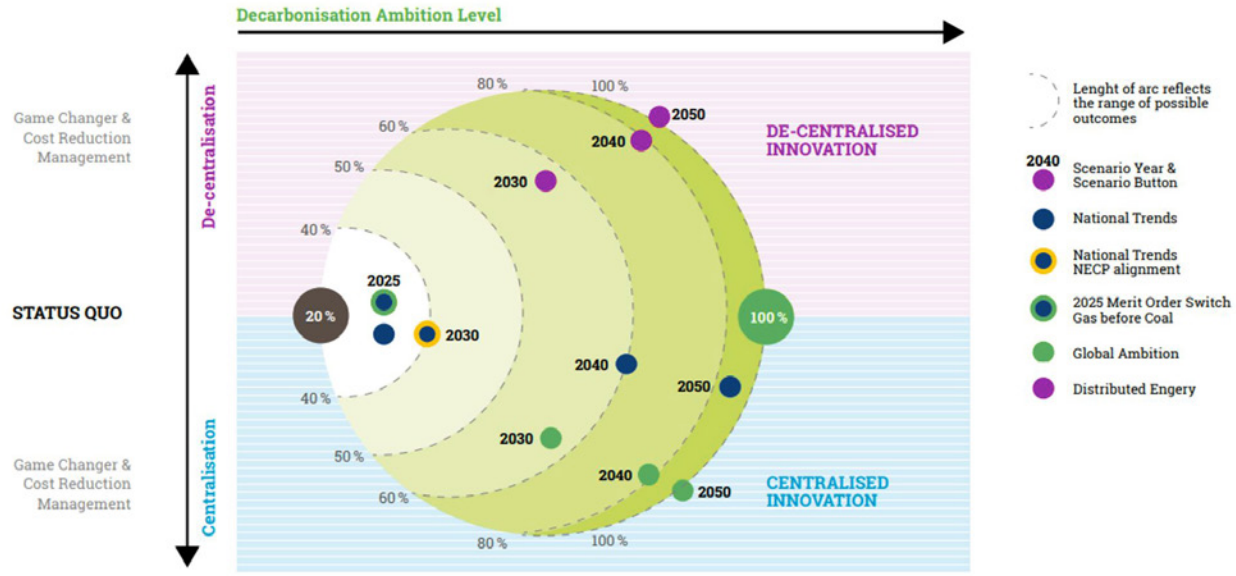
ELECTRICITY MARKET CALCULATIONS

6. ELECTRICITY MARKET CALCULATIONS

Long-term projections take into account two main perspectives for future development to achieve the set objectives: 1. reduction of carbon dioxide emissions and 2. centralization or decentralization trends. The first trend is based on the reduction of greenhouse gas emissions, while the second leads to the development of an energy system between different technologies, such as an offshore wind farm in one geographical location or small solar power plants spread over a wide geography. Different trends in the development of the electricity system determine what technologies will be distributed in the electricity system, what has a significant impact on which fuel sources will produce electricity and what impact it will have on the electricity market. For the electricity market calculations up to 2030, the scenarios have been based on best estimates, where data are collected using a bottom-up approach and reflect each country's national targets in line with current national development trends. Also, for 2030 and later, additional long-term development scenarios are developed according to the top-down approach, when the set goals form the trends of technological development. In total, 3 main development scenarios have been distinguished: national directions, global goals and distributed generation. The distribution of scenarios according to the set carbon dioxide reduction targets and technological developments is presented in Figure 8.

Electricity market calculations have been performed for ENTSO-E for 35 European countries (including 27 EU countries) according to the scenarios listed above. According to the adopted scenarios, it is assumed that the countries will be able to meet their national targets for the period 2021-2030 by reducing greenhouse gas emissions, increasing renewable energy production and efficiency measures, and expanding cross-border connections. Figure 9 shows the price difference between the different trade zones in the Baltic Sea region after the implementation of the scheduled network infrastructure projects. In Lithuania, it is planned to increase cross-border capacities on the Polish-Lithuanian section by 2025 by building a 700 MW submarine cable. The calculations for 2030 show that the price differences between Polish and Lithuanian trade prices before the development of connections amount to a critical value of more than 10 Eur/MWh, and after the implementation of connection development this difference decreases to the limit of 5–10 Eur/MWh. Also, the results of the market analysis identify that price differences between the southern and northern trade zones in the Baltic Sea region remain. The

Figure 8. Main development scenario (Source ENTSO-E)

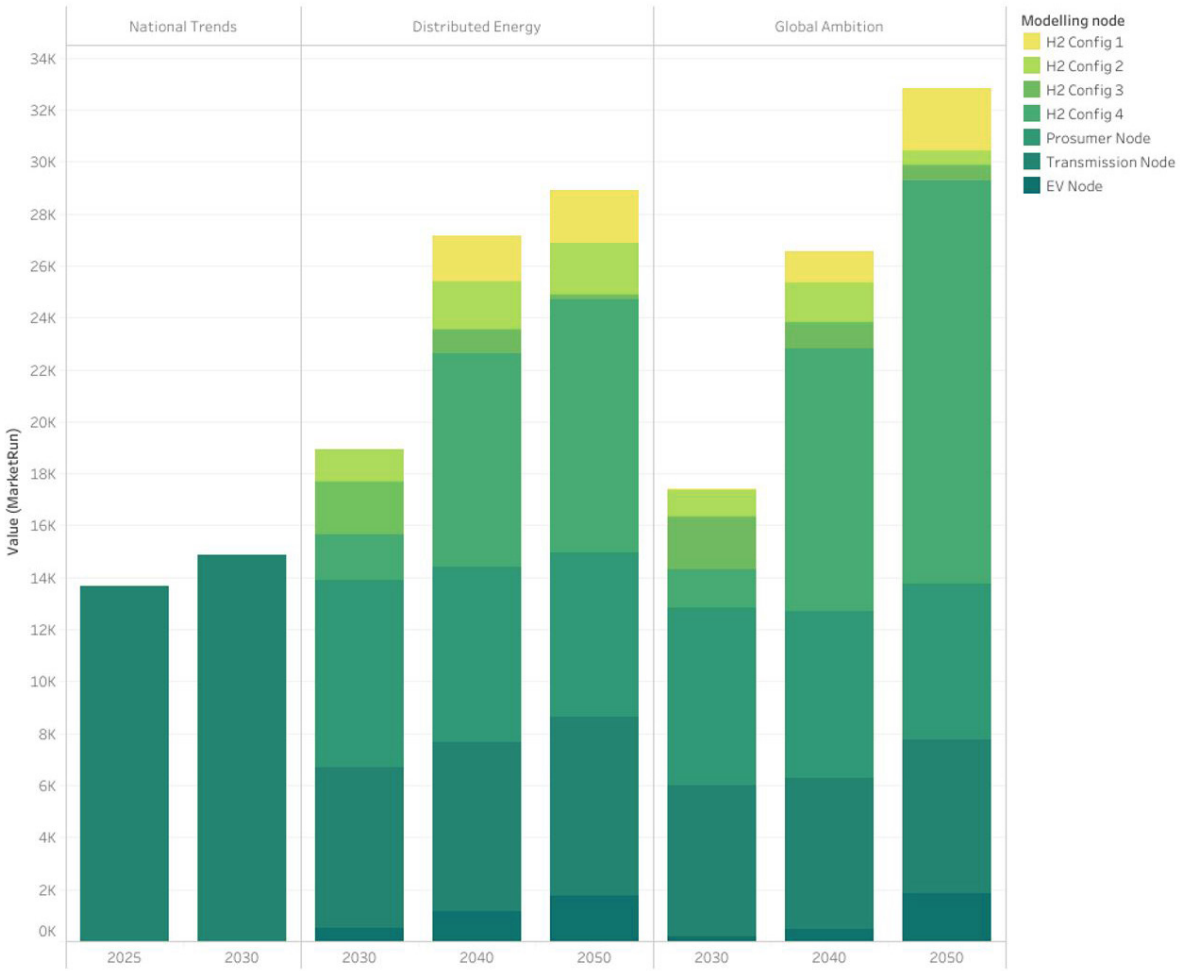


differences between the trade zones of the Baltic States with Finland and Sweden will remain in the range of 5–10 Eur/MWh, and the internal capacities of the trade zone of the Baltic States will ensure a difference of no more than 2 Eur/MWh in the Baltic States. In Lithuania, the price should not exceed 2 EUR/MWh for the prices in the Polish and SE4 trade zones. Such a small price difference between the Baltic States and the lack of infrastructure with third countries indicates that the planned internal interconnection capacity in the Baltic States is sufficient.

The capacity from RES (wind and solar power plants) envisaged in the ENTSO-E National direction is less ambitious than the plans made in the distributed generation and global goals scenarios, but these scenarios also foresee higher consumption that would grow due to hydrogen development. Adding the demand created by hydrogen would increase the demand of the Lithuanian electricity system to approximately 19 TWh in the scenario of distributed generation and to 17.5 TWh in the scenario of global goals in 2030. Lithuania's national demand forecast, which includes hydrogen and industrial development in 2030, is closer to the first scenario. After evaluating additional RES capacities and additional demand due to hydrogen development, the share of RES will still fully cover the consumption and exceed it - the share of RES is 124 percent and 134 percent from consuming in the relevant scenarios. In the TYNDP2022 plan, in 2030, the installed capacities do not differ significantly in both mentioned scenarios, but in an even longer perspective, a drastically higher wind development is predicted in the distributed generation scenario. It is important to note that both scenarios are in line with the set climate goals, although the growth of additional RES capacity would enable the achievement of ever higher aspirations for production from renewable resources. And the further distribution according to technologies and directions of development will greatly depend on the development of technologies and the created investment environment.

Based on the market analysis carried out by ENTSO-E TYNDP2022, it can be concluded that the goals set by NEIS until 2030 to reach 70 percent domestic production and 45 percent share of RES in consumption - would be implemented with the existing measures, set in the case of the national direction scenario and in other cases of the examined scenarios. In all scenarios, it is predicted that Lithuania's balance will turn from a deficit to a surplus in 2030, and the share of RES in consumption will exceed 100 percent.

Fig. 9. National directions, global goals and distributed generation scenarios for Lithuanian demand forecasting, GWh



7.

TRANSMISSION GRID PROJECTS

7. TRANSMISSION GRID PROJECTS

7.1. Connection of the Lithuanian PS to the CEN synchronous operation

Grid optimisation in North-Eastern Lithuania (reconstruction of 330/110/10 kV Ignalina NPP TS and 330/110/10 kV Utena TS, and installation of Ignalina NPP controlled shunt reactor in Lithuanian PP)

Implemented project. Within the scope of this project, **the 330/110/35 kV transformer substation of the Ignalina nuclear power plant** was reconstructed, connecting three 330 kV overhead lines and installing one autotransformer (the existing Kaunas AT-1 was brought). Already in 2019, the existing 330 kV overhead line in Ignalina NPP-Minsk TEC-5 in the territory of the Republic of Lithuania (about 8 km.) was dismantled. In the 110 kV scheme, the existing 110 kV overhead line connections are retained and the possibility of supplying electricity to the nuclear fuel storage facilities of the Ignalina NPP is foreseen; **the Utena 330/110/10 kV transformer substation** was also completely reconstructed, and the 330 kV overhead line of Ignalina NPP-"Neris" was connected to this TS. In the 110 kV scheme, the existing 110 kV overhead line connections are retained. Also, the existing operating controlled shunt reactor of 180 MVar capacity of the Ignalina NPP with 6 and 10 kV auxiliary devices, the existing relay protection automatics and control system has been transferred to the 330 kV switchyard of the Lithuanian Power Plant. In 2020 the connection works of the controlled shunt reactor were completed.

This transformation of the transmission network has prepared the transmission network of north-eastern Lithuania for operation in synchronous mode with the networks of continental Europe and will ensure the current level of reliability of the transmission network during normal network working conditions and during repairs. It will also ensure reliable electricity transmission to the storage facilities of the Ignalina nuclear power plant. The reconstruction of the substations carried out during the project will ensure the reliability of the transmission network and comprehensively solve the problem of central Lithuanian voltages in the transmission network.

LitPol Link expancion

Implemented project. During this project, three 400/330 kV autotransformers with a power of 600 MVA each were installed in the Alytus transformer station, ensuring a technical bandwidth of at least 1800 MVA. By implementing the measures of the Baltic PS synchronization plan with the CEN and managing the risks related to the stable and reliable operation of the Lithuanian electricity system during the transitional period (until full synchronization with continental European networks), the Lithuanian PS must be prepared as soon as possible for the possibility of working synchronously with the Polish PS through the LitPol Link intersystem connection. For the connection of Lithuanian and Polish PS for synchronous work, after synchronization, from 2026 it is planned to ensure 800 MW of bandwidth through this connection for the needs of the system, and in the future, after the implementation of dynamic stability measures in the Baltic system, this connection will gradually be opened to the market.

The current LitPol Link DC converter in Alytus TS until the forthcoming synchronization in 2025 will continue to be connected to the Polish power plant, as operating in normal mode, the 400/330 kV autotransformers will be switched off.

Construction of 330 kV electricity transmission line Vilnius–Neris

Project in progress. Design work is currently underway. This project is important for the synchronization of the Baltic countries with CEN. The construction of the new line will strengthen the Vilnius electricity node, ensure the reliability of electricity supply with continental European networks after synchronization, and satisfy the capital's growing **electricity demand. The Vilnius-"Neris" line, together with the already reconstructed overhead line Lithuanian** Power Plant-Vilnius and the operating overhead line Lithuanian Power Plant-Neris, will create a 330 kV ring around the capital, which will ensure reliable electricity supply in the Vilnius region by synchronizing electricity transmission networks with continental Europe. The length of the new line via the new route is about 59.7 km. In addition, about 22,745 km of the existing line will be used. The total length of the new overhead line is about 83 km.

Construction of the Lithuanian-Polish direct current connection "Harmony Link"

According to the BEMIP decisions on the synchronization scenario, in December 2018 Litgrid and PSE signed a cooperation agreement for the implementation of the preparatory phase of the **Harmony Link** project. The connection will consist of a high-voltage direct current (HVDC) cable and converter stations.

When planning the areas for infrastructure construction, the company aims to have the least impact on sensitive

areas: residential areas, protected natural and heritage objects. Part of the underground cable route will run along existing engineering infrastructure objects - roads or electricity transmission overhead lines. The "Harmony Link" underground cable on land will be built in the municipalities of Palanga and Kretinga: from the Baltic Sea at Būtingė to the territory purchased by "Litgrid" in the municipality of Kretinga district, in the village of Žyneliai, where the Darbėnai switchyard will be built.

Submarine and land high-voltage direct current link "Harmony Link" of 700 MW with a total length of approximately 330 km in 2025 will connect the Žarnovieci substation in the Pomeranian region of Poland with the Darbėnai substation in the Kretinga district of Lithuania.

The new line will strengthen the transmission network in Western Lithuania and ensure its reliable operation, after the construction of the sea connection with Poland "Harmony Link" and the disconnection from Russia's Kaliningrad and Belarus PS.

Construction of 330 kV electricity transmission line Kruonis HPSPP-Bitėnai

The objective of the implementation of the **construction project Kruonis HPSPP-Bitėnai** of the 330 kV power transmission line is to manage the overload of the 330 kV power grids after desynchronization from the electricity system of the Commonwealth of Independent States after decommissioning part of the 330 kV power transmission lines with continental European electricity networks. The total length of the line Kruonis HPSPP–Bitėnai reaches 211 km, of which a new engineering corridor will be formed of about 62 km in Vilkaviškis, Šakiai and Jurbarkas district municipalities, and the reconstruction of almost 40 km of the existing part of the line from Jurbarkas to Bitėnai has been planned using the existing infrastructure corridor. Accordingly, the scope of the project envisages the reconstruction of the existing 330 kV line Bitėnai-Jurbarkas into a double circuit (about 40 km), use of the existing 330 kV line Kruonis HPSPP-Sovietskas (about 109 km) and installation of a new 330 kV power transmission line section (about 62 km). Therefore, the project will be implemented in three stages: in the first stage, the line from Jurbarkas to Bitėnai will be reconstructed, the line will be changed from single-circuit to double-circuit; in the second stage, a new line will be built from the reconstructed section to the existing 330 kV line Kruonis HPSPP–Sovetsk in the Vilkaviškis district municipality; in the third stage, the expansion of Bitėnai TS and the connection of the newly formed line will be carried out.

In the future line will strengthen the transmission network in Western Lithuania and ensure its reliable operation by establishing a maritime connection with Poland "Harmony Link" and disconnecting from Kaliningrad and the Belarus PS.

Construction of 330 kV electricity transmission line Darbėnai–Bitėnai

The implementation of the **construction project of the 330 kV power transmission line Darbėnai–Bitėnai** will allow to manage voltages in electricity network nodes after carrying out the desynchronization from the electricity system of the Commonwealth of Independent States and decommissioning of part of the 330 kV power transmission line and electrical networks. The implementation of the project will not only solve the problem of voltage management in the nodes of the western Lithuanian transmission network but will also prevent power transmission lines from overload due to increased reactive power flows at Darbėnai and NordBalt converter stations. Within the scope of the project, it is planned to reconstruct the existing 330 kV single-circuit lines Bitėnai–Šyša, Šyša-Klaipėda, Klaipėda–Grobina into double circuits (about 125 km) and to install a new 330 kV line section (about 12 km).

The approximately 137 km long line Darbėnai–Bitėnai will connect the Darbėnai substation planned to be built in Kretinga municipality with the Bitėnai substation expanded last year in Pagėgiai municipality. Most of the line will be reconstructed by changing the supports and adding a second link within the protection zone of the existing lines, but a new section of approximately 12 km will be built bypassing the city of Gargždai, expanding the existing or forming a new protection zone.

In the future 330 kV line Darbėnai–Bitėnai will start in Darbėnai, where the Harmony Link submarine power cable will connect the Lithuanian and Polish electricity transmission networks, and will run around Klaipėda to Bitėnai, located on the border of the Kaliningrad region of Russia. It will be formed in two stages. In the first stage, the section from the future Darbėnai substation to the border of Kretinga–Klaipėda districts (about 30 km) is to be reconstructed, the line will be changed from single-circuit to double-circuit. In the second stage, the reconstruction of the Klaipėda–Grobina line in Klaipėda district will be continued (about 15.5 km), a new section of the line will be built around Klaipėda city (about 12 km) and the section of Klaipėda-Šyša-Bitėnai line from the newly built line to Bitėnai transformer substation will be reconstructed.

Construction of 330 kV switchyard „Darbėnai"

A new 330 kV Darbėnai switchyard is planned to be built in order to connect the future direct current connection with Poland Harmony Link to the transmission grid. The new switchyard will be built in Klaipėda district, near the passing 330 kV EPL Klaipėda-Grobina, with the latter to be switched on Darbėnai switchyard. A new 330 kV ETL Darbėnai-Bitėnai will be connected to the Darbėnai switchyard. The new switchyard will also provide space for other promising connections - the connection of offshore wind farms, possible prospective 330 kV lines Darbėnai-Mūša or Darbėnai-Grobina, 330/110 power autotransformers if there is a need to install a 110 kV switchyard. The Darbėnai switchyard will become an important energy node, increasing the supply of electricity both to the Klaipėda district and ensuring a reliable connection to the Polish system via the new Harmony Link connection.

Construction of 330 kV switchyard „Mūša“

Currently, two 330 kV OHL Šiauliai–Kaunas (about 134.4 km) and Šiauliai–Viskali (Jelgava) (about 60 km to the Latvian border, and the total length of the line is 88.6 km) go out from 330/110/10 kV Šiauliai TS. 330/110/10 kV Telšiai TS without 330 kV OHL Klaipėda-Telšiai (about 89 km), a 330 kV OHL line (about 93.1 km) is also connected to the Lithuanian EPS at 330 kV OHL Šiauliai–Viskali (Jelgava). The intersection of these existing 330 kV lines forms the connection of T-shaped lines. Therefore, 330 kV Viskali (Jelgava), Telšiai and Šiauliai TS are interconnected by long 330 kV OHL, the total length of which is about 182 km. Such connection of lines with a “T” connection reduces the reliability of the 330 kV PT, because in the event of a short circuit on any of these lines, all lines are disconnected together, as there are no switching devices that can disconnect only the line where the fault occurred. The greater the total length of the lines connected to the “T” connector, the more often those lines will be disconnected due to faults in one or another line location.

In order to ensure the reliability of the transmission network, to increase the controllability of the system, for the selectivity of relay protection and automation operation, to facilitate repair regimes and maintain the throughput of interconnections with Latvian and Swedish PS, a 330 kV switchyard (“Mūša”) is required. The switchyard is also necessary if a 330 kV line Panevėžys–Mūša is going to be built in the future, which would allow to integrate the installed capacity of WPP in Lithuania and the Baltic Sea. The location of the new 330 kV switchyard is planned near the territory of the existing airline intersection triangle. It is also planned to make appropriate changes to the start-up of the existing lines, which may be required by the planned construction of the Mūša switchyard at the new location.

In addition to the above-mentioned projects included in the plan of synchronization measures, other projects identified in the catalogue of measures for synchronizing the Baltic PS with the CEN will be carried out regarding synchronization: the installation of voltage control devices in the Lithuanian PS (3 synchronous compensators), modernization of control systems (installation of the control system of frequency stability assessment of the electric power system (FSAS), installation of an automatic generation control (AGC) system, implementation of the strategy of Statera information system, updating of the NordBalt high-voltage direct current link control system to ensure frequency control).

So far, the Company has already completed five of 14 projects: expansion of the Bitėnai switchyard, construction of the 110 kV line Pagėgiai–Bitėnai, reconstruction of the 330 kV line Lithuanian PP–Vilnius, the Northeast Lithuania optimization project and the LitPol Link expansion project.

7.2. 330–110 kV projects for ensuring the reliability of the transmission network and increasing the security of electricity supply (construction)

The TSO plans the operation of the PS in the long term, ensuring the rational development of electricity networks, i.e. maintaining the principle of least costs. Therefore, at the initiative of the Company, new elements of the electricity network are not being built, except for those cases when it is necessary to ensure a reliable operation of the system, full integration into the CEN and the common electricity market, an increase in the interconnection capacity. The construction of new 110 kV TSs is carried out at the initiative of electricity network users when the existing TS capacity is insufficient or when electricity network users do not have the possibility to connect to the distribution network. When connecting higher capacity electricity network users, the methodological instructions for the selection of the connection scheme approved by the Company shall be followed and a scheme shall be selected that meets the needs of both the electricity network user and the operator.

Construction of 330–110 kV TS

330 kV Vilnia TS

Taking into account not only the synchronous work of the Baltic States with the continental European system, but also the growth of electricity demand in Vilnius region, in 2027-203, it is recommended to build a new 330 kV Vilnios TS. This 330/110/10 kV transformer substation would not only reduce the loads of autotransformers in Vilnius and Neris transformer substations, but would also ensure the reliability of electricity supply and increase the security of electricity supply in Vilnius. The best place for a new substation could be next to an existing 110/10 kV Vilnios substation. In the future, the line Vilnius – Neris would be connected to this 330 kV Vilnios TS. The duration of the construction of the 330 kV Vilnius substation depends on the load growth rates of the Vilnius region.

330 kV Varduva TS

The Varduva 110 kV switchyard is an important node in the 110 kV transmission network, since the long 110 kV transit lines are connected to it, feeding an important user - the Orlen oil refinery, for which power quality and reliability of supply are very important. In the future, it may be relevant to install electrolysis devices that have a high electricity demand at the Mažeikiai Power Plant node, in which case it is necessary to build a 330 kV switchyard in Varduva, because the capacity of 110 kV lines would not be sufficient to power the electrolysis devices.

Also, around Varduva, at the 110 kV lines more wind power plants have already been connected and it’s planned to connect more (108 MW to Varduva, 150 MW around N. Akmenė), therefore, the transfer of Varduva to the 330 kV voltage level would allow for a more optimal distribution of power flows on 110 kV lines and facilitate planning of repair work regime in this region.

It is proposed to select the route of the planned construction of the new 330 kV ETL Darbėnai-Mūša so that it passes near the Varduva 110 kV switchyard, then it would be possible to build a 330 kV switchyard in Varduva and connect the Darbėnai-Mūša line to it. After the construc-

tion of the Varduva 330 kV switchyard, with the further development of transmission networks in the future, it would be possible to connect to Varduva a new 330 kV line to Latvia (if such a need was determined).

110 kV TS

The Company does not plan construction of new 110 kV TS on its own initiative.

Construction of 330–110 kV ETL

New 330 kV ETL

The construction of all 330 kV lines is related to ensuring the reliability of TN electricity supply and the synchronous connection of the Baltic PS to the CEN. Therefore, their descriptions are given above.

330 kV ETL Darbėnai-Mūša

The need for the construction of this line is caused by the development potential of RES in Western Lithuania, the need to better integrate the western part of the Lithuanian system with the eastern part and the Lithuanian electricity market with the Latvian market and the planned 700 MW direct current connection "Harmony Link". After evaluating the connected powers, the total power at the Darbėnai node is 2100 MW. Since there are also requests for the connection of RES to the 330 kV ETL Klaipėda-Telšiai-Mūša, in order to connect larger amounts of RES in the Mūša node, it is necessary to increase the bandwidth between Panevėžys, Mūša and Darbėnai and Klaipėda, so that the surplus of RES production in central and eastern Lithuania can be reliably transmitted to the Harmony and NordBalt connections during the period of excess generation of RES and from west to east Lithuania during the minimum generation of RES.

330 kV ETL Mūša-Panevėžys

In the northern part of Lithuania, the 330 kV network is not interconnected by 330 kV lines, so after disconnection of 330 kV overhead lines Lithuanian Power Plant–Kruonis HPSPP, the western and eastern parts of the Lithuanian 330 kV system remain connected through the only 330 kV Alytus TS. Such a regime would no longer ensure reliable power supply in the eastern Lithuania, including the Vilnius region, because the largest reliable power sources are in western Lithuania (direct current connections of Harmony Link and NordBalt). This problem, together with the 330 kV ETL Darbėnai-Mūša, would be solved by the new 330 kV ETL Panevėžys-Mūša.

It is also planned to build large RES power plants in North-Eastern Lithuania (according to requests received by Litgrid for connection of RES power plants for 100-400 MW and higher capacities), which are planned to be connected to the 330 kV lines Panevėžys-Utena, Utena-Ignalina NPP, Panevėžys-Jonava, Panevėžys-Aizkraukle. The power generated by RES power plants connected in all these lines would feed the Vilnius region, and the excess energy would flow to western Lithuania through the only Lithuanian Power Plant node. A new 330 kV line Panevėžys-Mūša is needed in order to equalize the power flows and evaluating the N-1 criteria.

Construction of 110 kV ETL

Under implementation projects

When the Lithuanian power plant is operating in synchronous mode with the CEN and the 110 kV OHL Vilnius–Šventininkai is disconnected and the 330 kV line Lithuanian PP–Alytus is disconnected in an emergency, the maintenance of voltage levels in Rūdiškės, Trakai and Šventininkai substations becomes complicated, and all TS from 330/110/10 kV Alytus TS up to 110 kV Šventininkai TS (110 kV transit length about 174 km) remains fed from the only source - 330 kV Alytus TS. Therefore, in order to ensure the required voltage levels and reliability, the construction of a 110 kV ETL Griškonys–Varėna (about 48 km) is underway.

Planned projects

The need for the construction of new 110 kV ETLs in Vilnius is based on the overload of the 110 kV electricity network in Vilnius due to the increased load in the Vilnius region. It is estimated that the existing 110 kV ETL Šeškinė-Šiaurinė can charge up during emergency modes. With the increase of Vilnius city load, the existing 110 kV transmission network will not ensure the reliability of electricity supply in emergency and repair system operation modes. After assessing the projects implemented by ESO in Vilnius and the generally growing demand for electricity in Vilnius, in order to ensure more reliable catering for the users of Šeškinė, Šiaurinė, Baltupis and K. Studija, it is recommended to implement the project **ensuring the reliability of Vilnius electricity transmission network** (the new 110 kV EPL Vilnia-Šiaurinė construction, about 14 km).

With the increase of Kaunas city load, the existing 110 kV TG network will not ensure the reliability of electricity supply in emergency and repair system operation modes. In emergency modes, after disconnection of the 110 kV line Kaunas–Šilainiai, the existing OHL Kaunas–Eiguliai may be reloaded. In order to increase security of supply and ensure reliability, with the growing load of Kaunas city, it is necessary to **build a second 110 kV ETL Kaunas–Eiguliai 2** (about 5-8 km).

7.3. 330–110 kV projects for ensuring the reliability of the transmission network and increasing the security of electricity supply (reconstruction)

In order to ensure the reliability of transmission network equipment in the most efficient way, it is necessary to develop new technical standards for equipment and constantly update the methodologies for updating transmission network facilities, taking into account the condition of equipment and its importance to the system. In 2022, it is planned to remotely manage about 77 % of all transmission network switching devices. This will enable to reduce the cost of operational switching and ensure the

safety of people working in substations by phasing out on-call staff at substations.

The reconstruction of a substation is a complex process that requires a lot of investment and human resources (working hours) as well as the restrictions on the operating modes of the system. Taking into account the fact that investments, human resources and ensuring reliable system operation modes have certain limitations, it is necessary to choose which substations need to be reconstructed earlier than others, taking into consideration the order (parallelism) of TS reconstructions. First of all, the most worn-out, the most important substations for the system and the ones requiring the highest operating costs must be selected for reconstruction. In order for the TP to ensure a reliable power supply, the technical equipment in it must be in good technical condition. The equipment used in the substations is aging over the years, so it is necessary to periodically check that the condition and functionality of the existing TSs are at the appropriate level to ensure the appropriate quality and reliability of electricity supply to consumers. If the TS does not meet the requirements, a decision must be made whether the substation needs to be completely reconstructed or only a partial reconstruction of it would be sufficient (i.e. to replace the single worn-out pieces of equipment with the new ones).

At the beginning of 2022, in accordance with the recommendations of the methodology for assessing the condition of transformer substations and determining the scope of reconstructions, the Company established a list of TS reconstruction for 2022-2031. This list was agreed with ESO. When compiling the list, other ongoing projects of the Company were taken into account, as well as the projects planned to be implemented. Implementation deadlines shall be set in such a way that the implementation of one project does not interfere with the implementation of others.

It is planned that by 2031 all reconstructions with GOST equipment will be started and most of the TSs will be completed. The scope of TS reconstruction and the recommendations of TS reconstruction methodology will be reviewed in 2026 and monitoring the condition of TS.

Reconstruction of 330 kV TS

During the period of 2022-2031, it is planned to continue the reconstructions of the TS of Jonava and Neris, as well as the reconstruction of the Kruonis HPSPP shall be started, after 2025 it is planned to start the reconstruction of Jurbarkas TS as well, and it is also planned to increase the power of existing autotransformers of the 330/110/10 kV substations of Utena and Ignalina NPP due to the integration of RES. In addition to full 330 kV TS reconstructions, a partial TS reconstruction (when only certain individual TS devices are replaced (relay protection and automation (RPA) devices, devices of telecommunication collection and transmission (TCT)) will be performed. Such replacement of devices is carried out considering the methodologies for assessing the condition of relay security and automation and telecommunication collection and transmission devices.

Reconstruction of 110 kV TS

In this year's Plan, restoration quantities of the 110 kV TS (TS restoration list) are compiled according to the 2020 updated and approved methodology for assessing and determining the state of TS.

From 2022 through 2031, the reconstruction of 330-110 kV substations (according to the Investment Plan for 2022-2031) will be completed, executed or started in approximately 116 units. **The terms and quantities for the reconstruction of substations are adjusted by drawing up the Company's Short-Term (for 1 year) Investment Plan and taking into account the guidelines for disconnections, and human resources.**

In addition to these projects, partial 110 kV TS reconstruction projects will be carried out, during which only part of the substation equipment (RPA, TCT, individual devices) will be replaced with new equipment.

Reconstruction of 330–110 kV ETL

In 2022 the **reconstruction of the 330 kV overhead line Alytus-Lietuva PP** is being carried out. The reconstruction of **330 kV OHL Panevėžys-Aizkraukle** was suspended in May 2022, aren't possible due to the implementation of synchronization projects and other Companies projects. In the near future, it is planned to start the reconstruction of the **330 kV OHL Lithuanian PP-Jonava**. In the first stage of the project, the section of the existing line will be dismantled (approximately 29 km from Jonava TS) and a new section of the line will be built on a new route (about 9 km). Accordingly, first of all, the preparation of territorial planning documents will be carried out. It is also planned to initiate the reconstruction of **the 330 kV OHLs Lithunian PP-Neris and Jelgava-Šiauliai (Mūša-Viskali)**. In 2024, it is planned to continue the reconstruction of the ongoing **330 kV OHL Šiauliai-Kaunas** project. From 2025, it is planned to start the implementation of reconstruction projects of such lines as **Jelgava-Šiauliai (Mūša-Šiauliai), Kaunas-Jurbarkas, Ignalinos NPP-Utena** and **Jonava-Panevėžys**. The reconstruction of the ETL is carried out taking into account the execution of the lines (Darbėnai-Bitėnai and Kruonis HPSPP-Bitėnai, Vilnius-Neris) required for synchronous connection.

In addition to the reconstruction of the 330 kV overhead line, the reconstruction of the 110 kV ETL will also be carried out. When reconstructing the 110 kV lines, if possible, it is necessary to schedule the increase of the line bandwidth in those lines where RES power plants are or will be connected, in transit lines and in those lines where overloads were actually recorded. Also, at present, a lot of 110 kV overhead line TSs are operated with different cross-section wires. Therefore, during the reconstruction of such lines, it will be recommended to unify the cross-sections of the wires by choosing wires with a larger cross-section.

7.4. Projects initiated by electricity network users

The construction of new TSs is usually determined by

the need of electricity network users. Both, the producers and consumers are connected to TN in accordance with the Order No. 1-127 of the Minister of Energy of the Republic of Lithuania of 4 July 2012 approving the Description of the Procedure for Connecting the Electrical Equipment of Electricity Producers and Consumers to the Electricity Networks. The deadlines for the implementation of all projects depend on the plans of the electricity network users.

Should the need arise and/or on a serious basis, new electricity network users' projects would be included in the Plan prepared for the forthcoming year.

Connection of new producers

The already implemented projects of the Company and newly initiated projects for which project managers have already been appointed are presented below.

A new **110 kV Degaičiai WPP TS** is being built to connect the 60 MW WPP park in the Telšiai district to the transmission networks, which will be connected to the 330/110 kV Telšiai TS 110 kV switchyard by building a new connection.

A new **110 kV Kamajai WPP TS** is being built to connect the 70 MW WPP park in Rokiškis district, which will be connected to the existing 110 kV overhead line Užpaliai-Rokiškis.

A new **110 kV Kanteikiai WPP TS** will be built to connect the 75 MW WPP park in Akmenė district, which will be connected to the 110 kV overhead line Kuršėnai-N. Akmenė.

A new **110 kV Kikoniai WPP TS** will be built to connect the 60 MW WPP park in Šilalė district, which will be connected to the 110 kV overhead line Šilalė-Rietavas.

A new **110 kV Pikeliai WPP TS** will be built to connect the 63 MW WPP park in Mažeikiai district, which will be directly connected to the 110 kV Varduva switchyard by building a new connection.

In the Jonava district, it is planned to connect two 50 and 20 MW WPP parks to the transmission networks by building a **new 110 kV Dargužiai WPP TS** and connecting it to the 110 kV overhead line Jonava-Žeimiai.

In 2021 it was planned to start operation of the Vilnius cogeneration power plant, consisting of 21.7 MW of waste-fired units and 79.2 MW of biomass-fired units. However, according to the connection conditions issued by Litgrid and the valid development permit, the manufacturer installed only a waste-burning unit. In 2021, Litgrid signed a connection service performance act with the manufacturer, which states that the Parties terminate the Agreement in the part of the 79.2 MW capacity facilities for producing electricity from biofuel, as the Manufacturer does not have the possibility to build these facilities for objective reasons. In 2021, the Producer has already applied to Litgrid in accordance with the general procedure established by legislation regarding the new conditions for connecting the **79.2 MW** biomass-fired unit to the transmission network. The operation of the second **biomass-fired unit of the Vilnius cogeneration power plant** is planned to start at the end of 2022.

Connection of new consumers

According to consumer feedback obtained in March, by 2031, about 13 110 kV TS can be connected to the transmission network.

DSO is planning the construction of a new **110/10 kV Lazdėnai TS** to supply new consumers located in the eastern part of Trakai district. It is planned to connect the new TS to the transmission network from the existing 110 kV overhead line Vilnius E3–Vievis. If the user's plans change or other unforeseen circumstances arise, the construction term of this substation would be changed.

DSO is planning the construction of a new **110/35/10 kV Sitkūnai TS** to supply new users located in the vicinity of Sitkūnai. The new TS would be connected to the existing 110 kV overhead line Kaunas–Vandžiogala. If the user's plans change or other unforeseen circumstances arise, the construction term of this substation would be changed.

For the connection of new users, ESO is planning to build a new **110/10 kV Dirvupiai TS.** The power required by consumers is 30 MW, and two 40 MVA power transformers will be installed in the substation. The new TS will be connected to the Klaipėda TS by constructing two 6 km long cable lines.

The construction of the **110/6 kV Drūkšiai TS** is planned by taking into account the development plans of the user (Public Institution Ignalina atomic power plant). If the user's plans change or other unforeseen circumstances arise, the construction term of this substation would be changed.

According to the request of AB "LTG Infra", project conditions were issued for the construction of 4 new 110 kV TSs (Linkaičių, Tarvainių, Kretingos ir Žeimių traukos TSs) and reconstruction of 2 existing 110 kV TSs (Lentvario traukos TS and Žaslių TS), due to the electrification of Lithuanian railways.

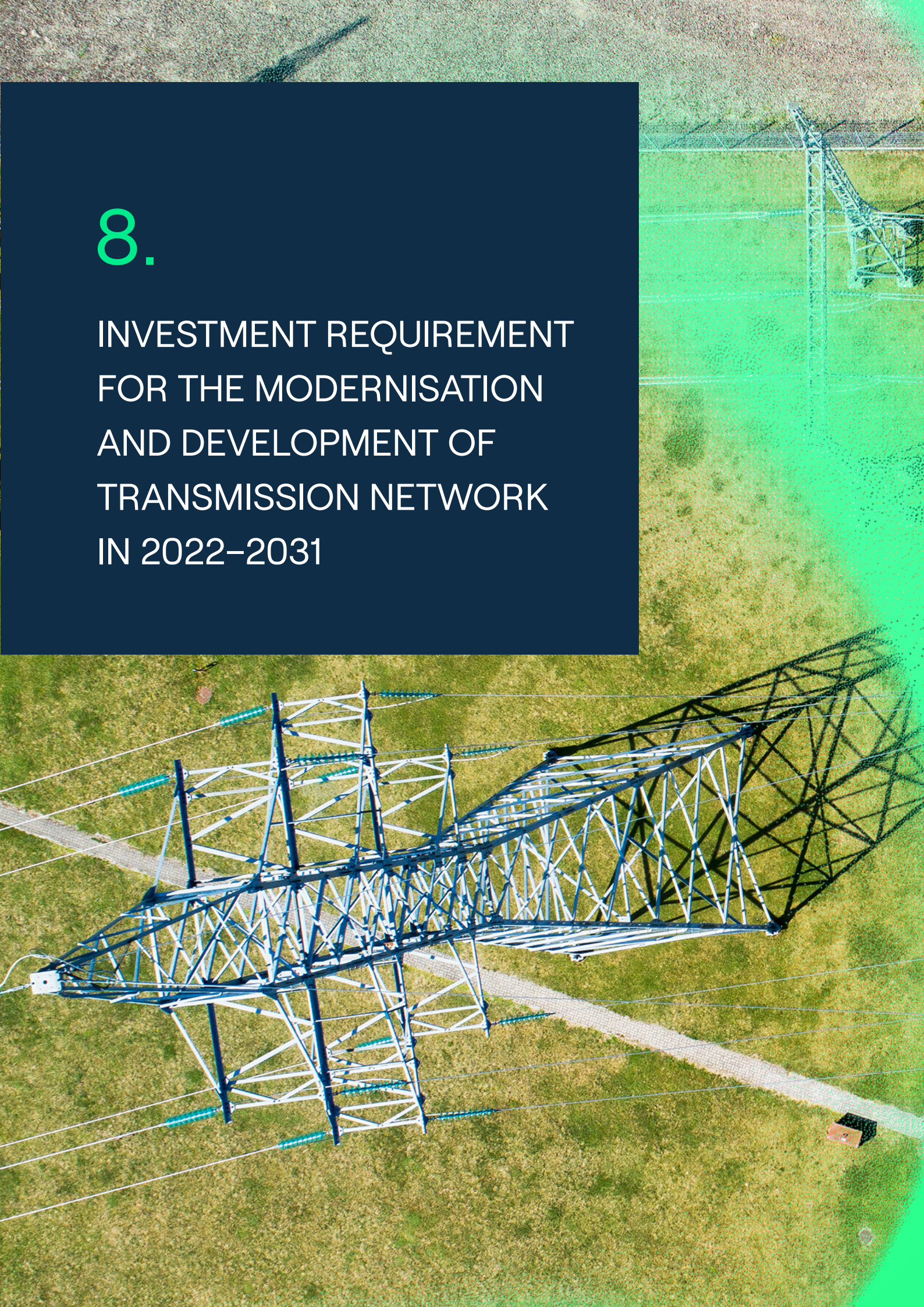
According to the information provided by SC "Lietuvos geležinkelių infrastruktura", about 5 new traction substations can be built for the electrification of Lithuanian railway lines (Panevėžys, Rykantai, Vilkyškiai, Gulbiniškiai and Marijampolė).

Replacement of 110 kV overhead lines with cable lines

The Company does not change overhead electricity lines (OHL) or underground cable lines (CL) on its own initiative, unless it is not possible to cross the territory in the OHL. **At the request of natural and legal persons**, when they are hindered by the existing OHL, **the installation of CL is carried out at the expense of the applicants**, in accordance with description of the procedure for connection of electrical equipment of electricity producers and consumers to electricity networks approved by Order No. 1-127 of the Minister of Energy of the Republic of Lithuania of 4 July 2012. In most cases, OHL are likely to be cabled in the main cities of the country.

8.

INVESTMENT REQUIREMENT FOR THE MODERNISATION AND DEVELOPMENT OF TRANSMISSION NETWORK IN 2022–2031



8. INVESTMENT REQUIREMENT FOR THE MODERNISATION AND DEVELOPMENT OF TRANSMISSION NETWORK IN 2022–2031

The total planned investments in transmission networks consist of investments in the implementation of strategic state projects, investments in ensuring the reliability of the transmission network and electricity supply, investments in information technology and other projects, and investment projects on the initiative of electricity network users.

The activities related to the investments planned, performed or executed by energy companies are regulated by legal acts, therefore they must be assessed and coordinated with the State Energy Regulatory Council in accordance with the Description of the Procedure for Assessment and Coordination of Investments of Energy Companies in the State Price and Energy Control Commission.

The total investment in the development and reconstruction of the transmission network (including projects on the electricity network users' initiative) for the period of 2022-2031 may amount to approximately 2.03 billion euros (Table 7).

Table 7. Total investment in the development and modernisation of the transmission network 2022–2031, MEuro

No.	Project groups	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total 2022-2031
	Total transmission network investments	**92.13**	**168.15**	**229.45**	**193.49**	**363.02**	**349.72**	**153.82**	**154.82**	**160.60**	**167.02**	**2032.20**
	Total Litgrid investments (excl. Network users)	**90.89**	**156.21**	**215.09**	**189.19**	**358.62**	**349.12**	**149.92**	**152.32**	**160.60**	**167.02**	**1988.98**
I.	Strategic national projects	56.57	97.97	127.89	75.46	227.72	208.14	0.00	0.00	0.00	0.00	793.74
II.	Construction	2.16	0.30	0.31	2.02	2.38	4.89	16.50	34.10	43.60	92.50	198.75
III.	Network reconstruction and modernisation	22.32	47.21	75.73	102.65	119.73	127.30	123.62	106.91	107.70	64.91	898.08
IV.	Major repair	7.65	7.21	6.97	7.11	7.57	7.60	7.60	7.80	8.06	8.27	75.83
V.	ITC projects	1.96	3.22	3.84	1.49	0.63	0.49	1.41	2.63	0.26	0.36	16.29
VI.	Research & innovation	0.25	0.30	0.37	0.47	0.59	0.70	0.78	0.89	0.98	0.99	6.31
VII.	Network users initiative (Producers& consumers)	1.24	11.94	14.35	4.30	4.40	0.60	3.90	2.50	0.00	0.00	43.23

9.

ACTIVITIES OF ENTSO-E

9. ACTIVITIES OF ENTSO-E

The Company is a member of ENTSO-E (The European Network of Transmission System Operators for Electricity) and actively participates in its activities. ENTSO-E prepares a ten-year development plan TYNDP on a two-year cycle, in which all transmission system operators belonging to ENTSO-E participate. Regional investment plans emphasize the priorities, goals and challenges of each region, and present projects in that region. During the preparation of regional plans. calculations of the electricity market and networks are performed and the locations of the networks where the capacity needs to be increased in order to ensure the efficiency of the single European electricity market and provide the greatest benefits to producers and consumers. New projects (new lines, converters) are also identified to help achieve those goals. During the preparation of the TYNDP plan, a cost-benefit analysis (CBA) is performed, which evaluates in detail all existing and newly identified projects according to different criteria.

Currently, the TYNDP 2022 plan for the perspective of 2030-2040 is being prepared. All TSOs submit network development projects that they consider to be of common interest for European countries (Projects of Common Interest - PCI), which are evaluated in the CBA analysis of market and network modelling.

There are three main stages in the execution of TYNDP: the scenario development stage, the cost-benefit assessment (CBA) stage and the identification of network needs (IoSN) stage.

The scenarios are drawn up considering the European goals until 2050 (carbon dioxide reduction goals, electricity and gas sector development goals). According to the set objectives, data is prepared for the modelling of market conditions, later used in the CBA stage. The scenarios that were also mentioned in the market section are: 2030 NT, 2040 NT, 2030 DE, 2040 DE, 2030 GA, 2040 GA (NT - "National trend", DE - "Distributed energy", GA - "Global ambitions"). It is planned to complete the scenarios in the second quarter of 2022.

At the CBA stage, market and network modelling is carried out in order to evaluate all considered projects submitted by network operators. The CBA phase is planned to be completed in the third quarter of 2022.

At the IoSN stage, calculations are made to identify the most important intersystem sections that would benefit the most from increased bandwidth. IoSN calculations are performed for two scenarios - 2030 NT and 2040 NT. An additional study on the development of offshore wind power plants will also be carried out in TYNDP 2022. The IoSN phase is planned to be completed in the second quarter of 2022.

Reports of past and new TYNDP plans are public and available at https://tyndp.entsoe.eu/documents. TYNDP 2022 study reports are planned to be completed in September 2022.

The list of TYNDP 2022 projects includes the following Lithuanian projects:

1. NordBalt Stage 2. In this project, there are investments aimed at strengthening internal networks in Sweden. there are no investments on the Lithuanian side.

2. Synchronization of the Baltic with the continental Europe. The project includes internal strengthening of networks in all the Baltic countries and Poland and the new intersystem Lithuanian-Polish line "Harmony link". This project has the status of a PCI project and has been included in the list of TYNDP projects.

3. Integration of offshore wind Stage I. Integration of the planned 700 MW offshore park of wind power plants into the Lithuanian transmission network system. Connection to the new 330 kV Darbėnai switchyard under construction is planned until 2028.

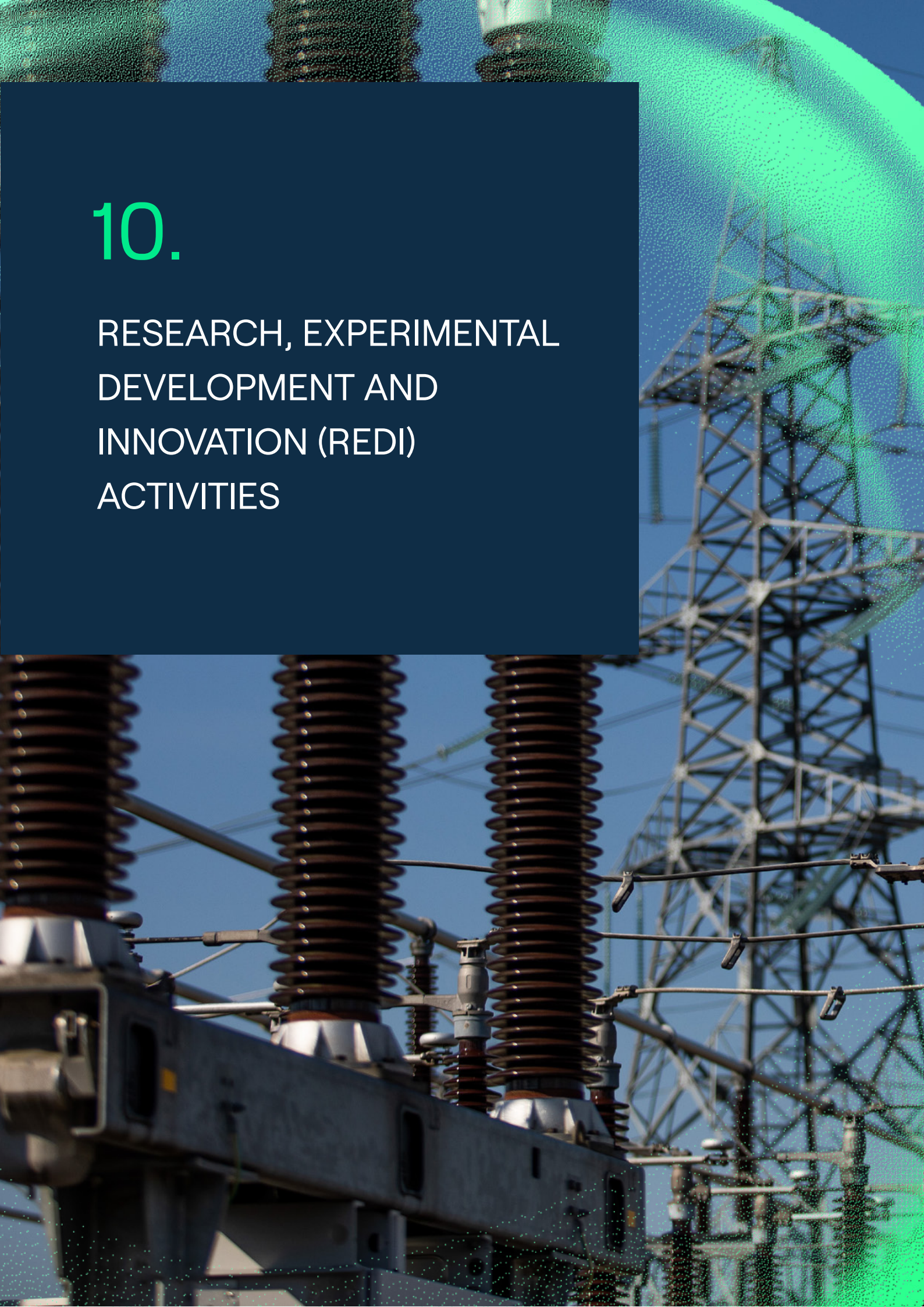
4. Integration of offshore wind farms (Project No. 1042). This is a project of wind power plants planned to be built in the Baltic Sea off the coast of Lithuania, presented for the TYNDP2020 plan for the first time. The option to build a 700 MW offshore wind farm in 2030 is presented for analysis.

The projects of European significance are approved by the European Commission (hereinafter referred to as the EC) and included in the list of PCI. PCI projects are designed to strengthen the infrastructure of interconnections in the energy sector. According to the TEN-E (Trans-European Network-Energy) regulation, the EC identifies key PCI projects for strengthening electricity, smart grid, gas, oil and CO2 interconnections in the European Union.

In the end of 2023, the PCI6 list compilation process is being carried out.

10.

RESEARCH, EXPERIMENTAL DEVELOPMENT AND INNOVATION (REDI) ACTIVITIES



10. RESEARCH, EXPERIMENTAL DEVELOPMENT AND INNOVATION (REDI) ACTIVITIES

By its active performance in the field of innovation, the Company seeks to contribute to the effective implementation of the Company's and the National Energy Independence Strategies. The Company creates an efficient innovation ecosystem, where good ideas are heard and, after the necessary time is allocated for their analysis and testing, they are implemented and introduced into daily activities.

Below are the innovations that create the biggest value.

Installation of the battery energy storage system in the Lithuanian power system

In 2021 tests of the first 1 MW battery connected to the electricity transmission network in the Baltic States were completed. The data collected during them are important in preparing the Lithuanian electricity transmission network for synchronization with continental European networks, ensuring system reliability and rapid development of renewable energy in the country.

The battery's ability to perform more than ten different functions of the transmission network has been tested under real operating conditions of the Lithuanian electricity power system. During the tests, the ability to control the battery power on site and remotely, its efficiency, emergency power function, frequency control functions, synthetic inertia response, voltage control function, isolated work operation when supplying energy to the Vilnius TS for its own needs and many others were tested. All scheduled tests succeeded. As expected, the 1 MW battery can contribute to the control of electrical system parameters. Most surprising was the battery's lightning-fast response, with a control command processing time of 0.087 seconds, and a full switch from charge to generation in an even shorter 0.07 seconds. This basically corresponds to the triggering times of the relay protection. Such parameters are optimistic that in the future the control of the electrical system will be even smoother.

Innovation platform of LITGRID AB

In addition to the 1 MW batteries energy storage functions as the system integrated network component for the safe and reliable operation of the electric energy system, the Company is considering using this infrastructure as an innovation platform for further innovative projects. Innovation projects can be developed within the Company's internal capacities and together with innovation partners. The Company's internal innovation projects could be focused on pilot projects for the improvement of electricity system variables under the responsibility of the transmission system operator (technological costs of electricity transmission network, electricity quality parameters, voltage characteristics, etc.).

Partners of the Company's innovation projects that could use the infrastructure of 1 MW battery energy storage system (BESS) could be: scientific organizations (universities, institutes, research centers, consulting companies); electricity market participants (producers, consumers, load aggregators, electricity suppliers); manufacturers of energy storage systems and developers of new energy storage systems, persons planning to build/install an energy storage facility; electricity network operators (Lithuanian and foreign transmission systems and distribution networks); other interested parties.

Currently, it is thought that innovation projects. developed together with the partners, could include: studies of the operation and stability of the electrical energy system; technological studies of battery storage systems; studies of electrical system and BESS control models; security tests of information systems and cyber electricity system and BESS; tests of the interaction of traditional and renewable energy power plants with BESS; tests for power reservation and improvement of qualitative parameters of electricity consumers; development and testing trials of flexible services using BESS; research on concepts of virtual power plants and virtual power transmission lines; projects of synthetic inertia testing. model creation and verification; tests and studies of other energy storage systems' connection and operation requirements.

Pilot Project of Dynamic Line Rating

Dynamic Line Rating (DLR) is a technology that has not yet been tested in Lithuania, which would allow to increase the effective power bandwidth of overhead lines by 10-30 percent. This is a many times cheaper alternative to the reconstruction of the line, which would provide more favourable conditions for the management of renewable energy power plants.

The operating principle of the technology is to calculate the effective bandwidth of the line based on the environment weather conditions. Sensors are installed on the lines that measure various parameters such as line temperature, vibration, current, wind speed, etc. The information collected by the sensors is supplemented by weather forecasts and all this allows to predict the bandwidth of the line up to 48 hours ahead. The information is periodically updated until it is available at the actual line bandwidth in real time. The project is planned to be completed by the third quarter of 2023.

"Power to Heat" pilot project with Vilniaus Šilumos Tinklai and EPSO-G

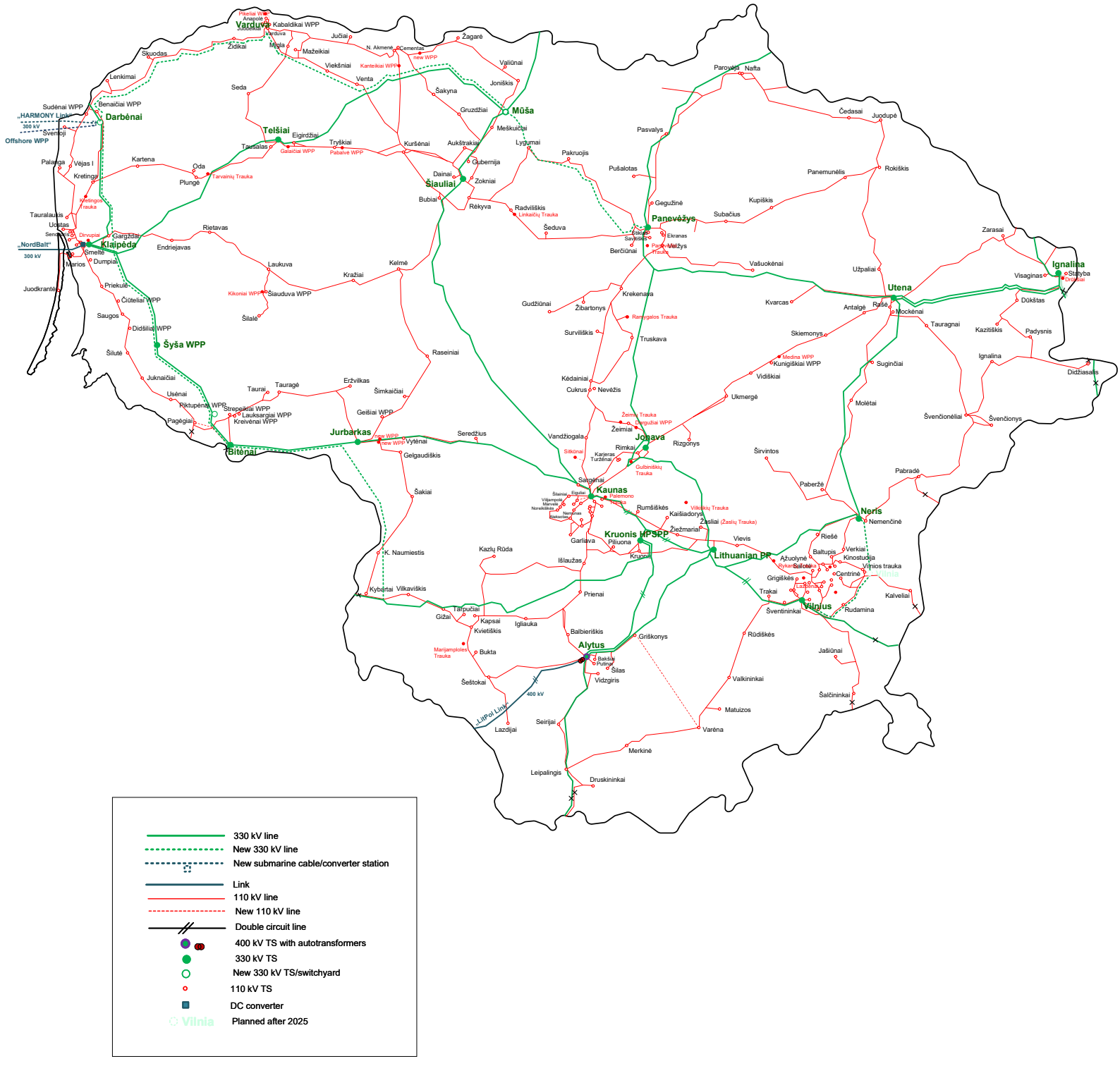
The Company and the EPSO-G group of companies together with Vilniaus Šilumos tinklai (VŠT), in December 2021 initiated the "Power to Heat Salininkai" pilot project. The project is implemented using a high-power heat pump and by VŠT participating in different segments of the electricity market. In addition to participating in the electricity market, when in the case of cheap electricity, thermal energy would be produced using a heat pump. VŠT could also participate in the balancing electricity market, since thermal energy would be used in the production of heat and hot water, and excess thermal energy would be directed to store in heat accumulator. This would allow flexible control of the heat pump power without harming the thermal process. In case of a high price of electricity in the market, the thermal energy reserve stored in the heat storage would be used for the production of heat and hot water. In this way, consumption of expensive electricity would be reduced. This would be the first project of its kind in Lithuania, which would enable the heat system to actively participate in different segments of the electricity market, providing additional services to the electricity network. The planned end of the project is the middle of 2025.

Pilot project to use satellite images for overhead lines' maintenance

The aim of the project is to identify the defects of the vegetation growing in the security area of the overhead lines and to create a simulation of the vegetation speed using the photos taken from space satellites. Also, to evaluate the activities carried out in the security area of the overhead lines, for e.g. recording of construction in the security area of the overhead lines. Finally, an attempt will be made to automatically warn of upcoming natural phenomena that could pose a threat to the infrastructure of electricity transmission networks.

The project is supervised by ENTSO-E, project partners - 6 TSOs from different countries, including the Company. New software tools are being developed, and LITGRID AB contributes to the process by giving the suppliers the opportunity to test the product they are developing on a pre-selected section of the line. Dedicated engineers periodically evaluate the functionality of the software, as well as perform a physical inspection of identified defects on a test section of the line.

Scheme of 400–110 kV transmission networks of the Lithuanian PS in 2031



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