LITHUANIAN SUSTAINABLE RENEWABLE ENERGY SCENARIO 2050
(based on Lithuanian parliament decree on national energy independence strategy[1])

Introduction
Lithuanian sustainable energy scenario 2050 (hereinafter referred to as Scenario) shows how fundamental changes in Lithuanian energy sector could help ensure that Lithuania is more energy efficient, sufficient and climate neutral by 2040. Changes implemented would enable the economy to shift from mostly fossil fuels to fully renewable energy sources, while not compromising the environment, ensuring energy democracy principles, alleviating energy poverty and contributing to more prosperous society.
The ample potential for renewable wind and solar will be started harvesting towards electrifications. This will bring many jobs and economic value as local production will replace imports. Transition from fossil fuels towards renewables will help to reduce carbon dioxide and other greenhouse gasses as well as other pollutants such as nitric oxides, particulate matter, sodium oxide etc. This transition will require massive changes in energy production, transmission and consumption. The varying and uneven nature of renewable energy production require that infrastructure will have to be flexible, able to store surplus energy and ensure uninterrupted supply to all consumers.

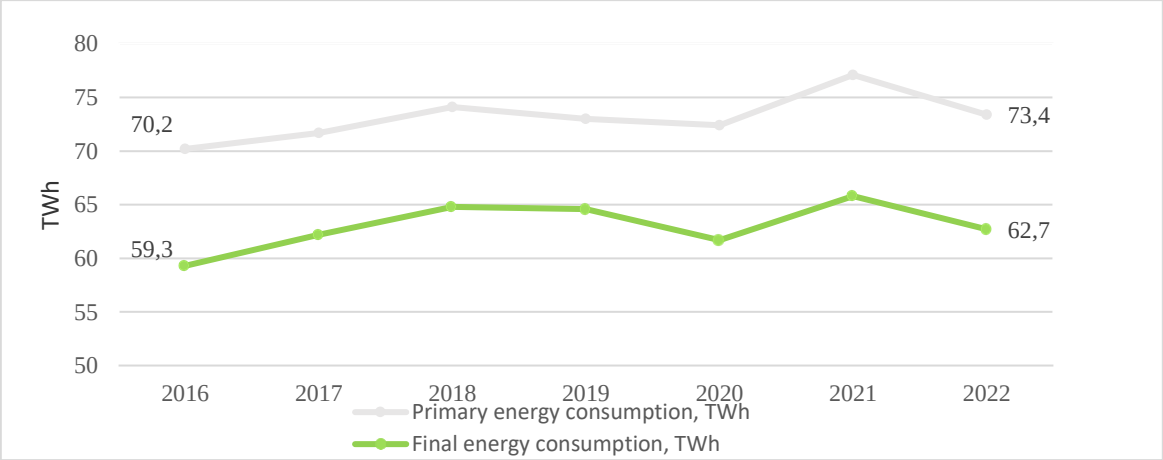
Current situation in the Lithuanian energy sector
Over the past decades, Lithuania has been freed from its previously almost absolute energy dependence on the russian Federation. Butinge oil terminal was completed in 1999. Following adoption of the first national energy independence strategy in 2007, important strategic projects were completed:

- Management of gas and electricity sectors was returned to the state.
- Unsafe Ignalina nuclear power plant's last reactor was closed in 2009.
- 450 MW combined cycle unit of the Lithuanian power plant became operational.
- Klaipeda liquefied natural gas terminal was built.
- Electricity connection lines with Poland and Sweden were built.
- Reinforced gas pipelines in Lithuania and connection with Latvia.
- New gas connection with Poland.

Significant changes have taken place in the heating sector, where natural gas and fuel oil have been replaced by biofuels in most of the district heating systems. All this enabled Lithuania to secure its energy needs from alternative sources after russia launched a large-scale military invasion of Ukraine on 24th of February 2022. Lithuania became one of the fist countries in Europe to eliminate imports of electricity, gas and oil from russia without compromising Lithuania's energy security.
However, Lithuania's main challenge remains its dependence on imported fossil energy resources - electricity, oil and natural gas. Their use in the transport and industrial sectors massively contributes to climate change and increases vulnerability to price to fluctuations and geopolitical risks.

[1] https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.429490/asr

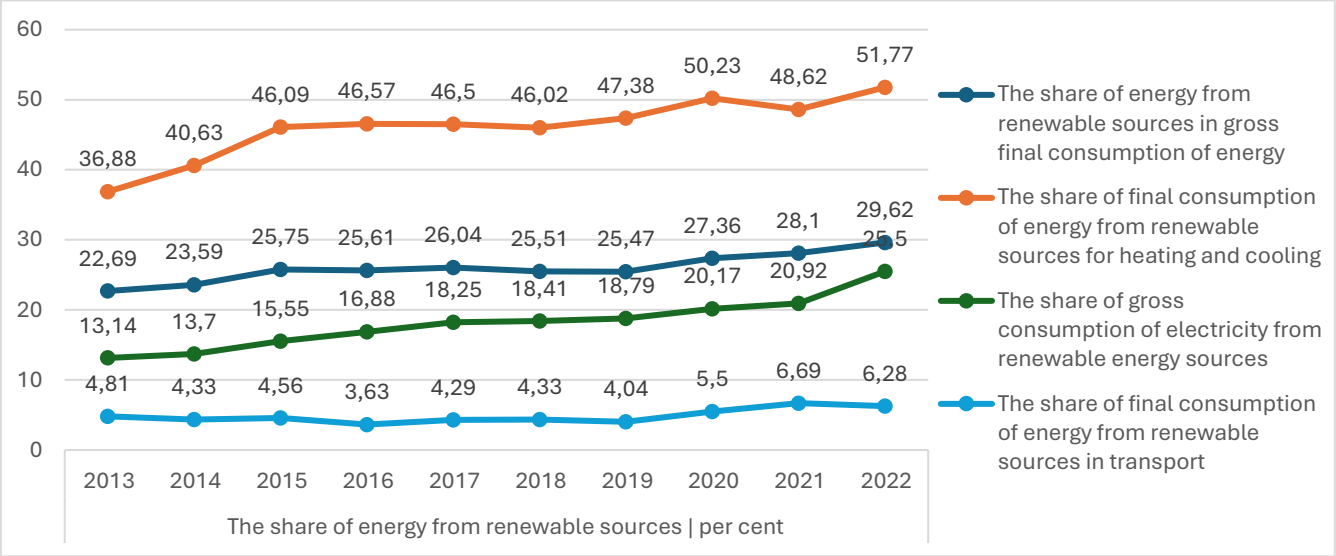
Figure 1. Primary and final energy consumption in Lithuania 2016–2022, TWh



Source: stat.gov.lt

Primary and final energy consumption[2] in 2022 has increased from 2018, but it was significantly less than in 2021. Main final energy users in 2022 in Lithuania were transport (40,4 %) followed by households (28,5 %) and industry (16,8 %). Renewable energy part in 2022 was 29,62 % of total energy consumption. This was mostly due to using RES in heating and electricity sectors, while transport sector had a very low renewable energy use – 6,28 %.

Figure 1. The share of energy from renewable sources 2013-2022, %



Source: stat.gov.lt

International commitments

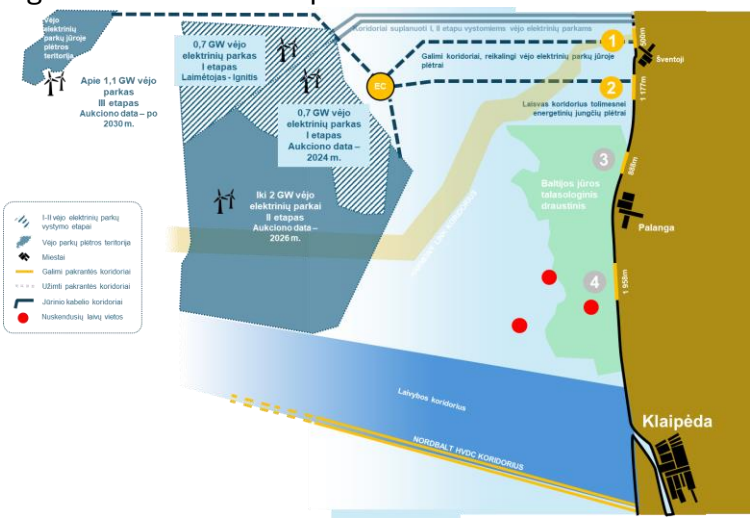
The energy sector must develop in line with Lithuania's international commitments. These commitments are aimed at managing climate change impact and reducing greenhouse gas emissions. The main commitment is in 2015 signed Paris Agreement[3], which sets out aim to keep global temperature rise below 1.5 °C pre-industrial levels.

[2] https://osp.stat.gov.lt/statistiniu-rodikliu-analize?indicator=S1R101#/
[3] https://unfccc.int/process-and-meetings/the-paris-agreement

EU countries have agreed on the need to move towards climate neutral energy technologies. This need is enshrined in the European Green Deal, which sets the objective of to transform the EU economy into a modern, competitive and climate-neutral one in 2050. This target is not enough to keep Europe (and Lithuania) on track with 1.5 °C. A much more ambitious plan[4] needs to be implemented with climate neutrality in 2040.
Some of the countries in EU already have stepped up to their fare share of GHG reduction target, such as Finland[5] and Austria[6] with targets for climate neutrality in 2035 and 2040 respectively. In the sustainable renewable energy Scenario 2050 Lithuania will also reach climate neutrality in 2040.

Sustainable renewable energy Scenario 2050
In the energy context, Lithuania is geographically well positioned, as the Baltic Sea region, with its relatively small economies and high-RES potential, will be one of the first Baltic countries in the EU to achieve a surplus of electricity in 2030-2035. The Baltic countries have a potential of 25.5 GW of offshore wind, 18 GW of onshore wind and 40 GW of solar PV.

Figure 3. Offshore wind potential in Lithuania



Source: Ministry of energy

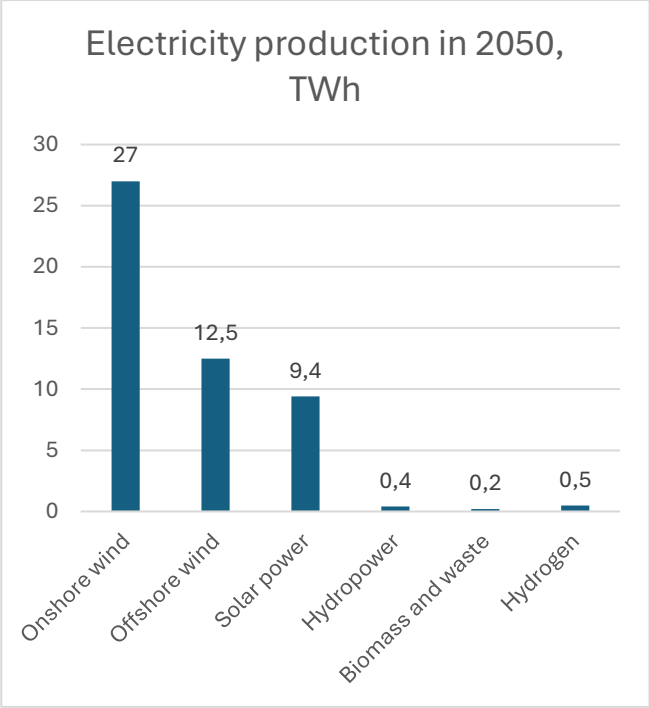
A sustainable renewable energy Scenario ensures a rapid shift towards renewable energy generation, with reduced reliance on energy imports, very significant greenhouse gas emissions reductions, and lower overall cost of the energy for consumers, including required funds for the new infrastructure.
By 2030, Lithuania will have about 10.3 GW of RES electricity generation capacity installed: 4.1 GW of solar power plants, 1.4 GW of offshore wind power plants and 4.5 GW of onshore wind power plants. These will generate as much electricity as Lithuania consumes. Annual production is expected to reach 25 TWh, while consumption is expected to reach - 24 TWh. Transport, heating and industry electrification will be the main driver. Flexibility needs in the electricity sector will be met by

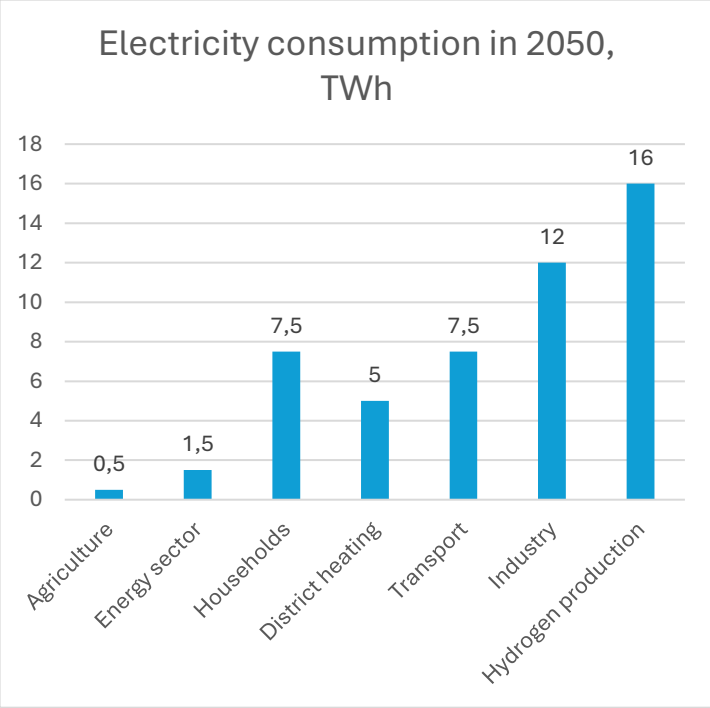
[4] https://caneurope.org/civil-society-europe-climate-neutrality-2040-scenario/
[5] https://www.sustainability.gov/pdfs/finland-nzgi-roadmap.pdf
[6] https://www.sustainability.gov/pdfs/austria-nzgi-roadmap.pdf

maintaining the existing capacity of natural gas power plants, the increased capacity of the Kruonis pumped storage plant, 1.5 GW of battery parks, international connections and more flexible electricity consumption in industry and other sectors.

In 2050, Lithuania is projected to generate 50 TWh of electricity per year. The main sources are onshore wind (9 GW installed capacity), offshore wind (3 GW) and solar power plants (9 GW). The country is expected to build 4 GW of electricity storage facilities (to balance out existing production and consumption patterns[7]), 4 GW of hydrogen electrolysis facilities, and a projected expansion of interconnection capacity of up to 10.7 GW.

Figure 4. Lithuanian electricity production and consumption in 2050, TWh





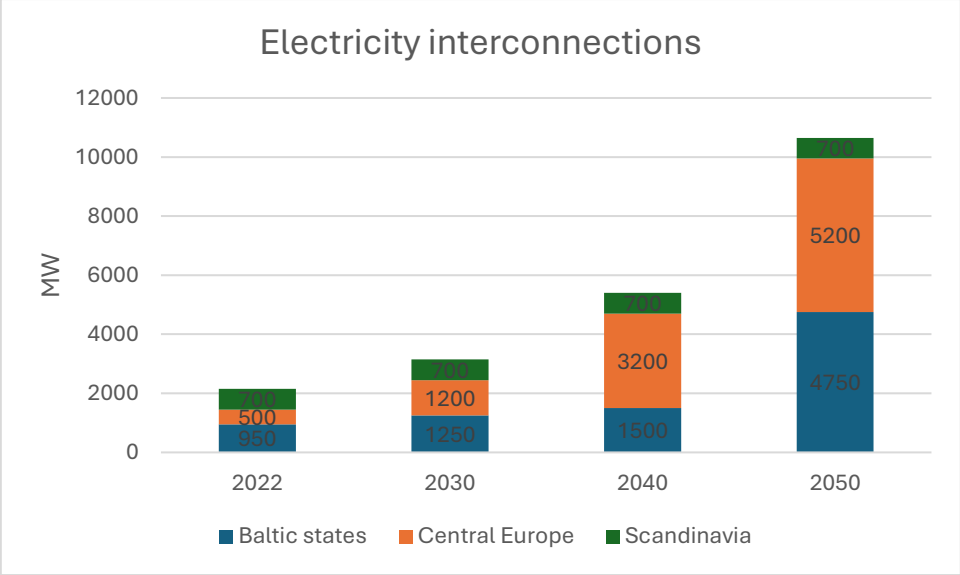
Lithuanian energy vision in 2050

Lithuania's energy vision for 2050 is a country that produces and exports energy for its own needs and has developed a climate-neutral and high value-added energy industry. This will be achieved by developing Lithuania's energy sector in a coherent manner by 2050, considering needed climate change management objectives and the national ambition of self-sufficiency in energy resources. In 2050, Lithuania will not only produce all the electricity it needs for its own needs but will also be an electricity exporter in the region. The focus is on decarbonizing whole economy primarily with electricity and then hydrogen and hydrogen derivatives such as green synthetic fuels, methanol, ammonia, synthetic methane and others. Competitive conditions will be created for the development of new production and storage capacities for electricity and other energy resources, with an aim to rapidly decarbonizing Lithuania.

[7] https://www.nrel.gov/docs/fy24osti/89564.pdf

Most of the country's energy consumption will come from wind and solar power plants. The amount of electricity they produce is highly dependent on climatic conditions, electricity production is not uniform, and the electricity system will need to have significantly more balancing and reserve capacity available than has traditionally been the case with fossil fuels. It will also require the introduction of measures and technologies to ensure flexible energy demand, which will create additional demand for electricity when the price of electricity is low in times of surplus production and reduce consumption when the price of electricity is low and the demand for electricity is high.
Lithuania will have the opportunity to participate in the European electricity trading market and not only in the regular European electricity market. The established export capacity for hydrogen derivatives and the exploited potential of the Klaipeda Seaport will allow Lithuania to participate also in the markets for hydrogen produced from raw electricity and its derivatives. The development of balancing and back-up capacity and flexible demand measures, under economically viable conditions, would exploit the country's geographic advantage to connect European countries with energy surpluses with industrial regions with energy shortages.

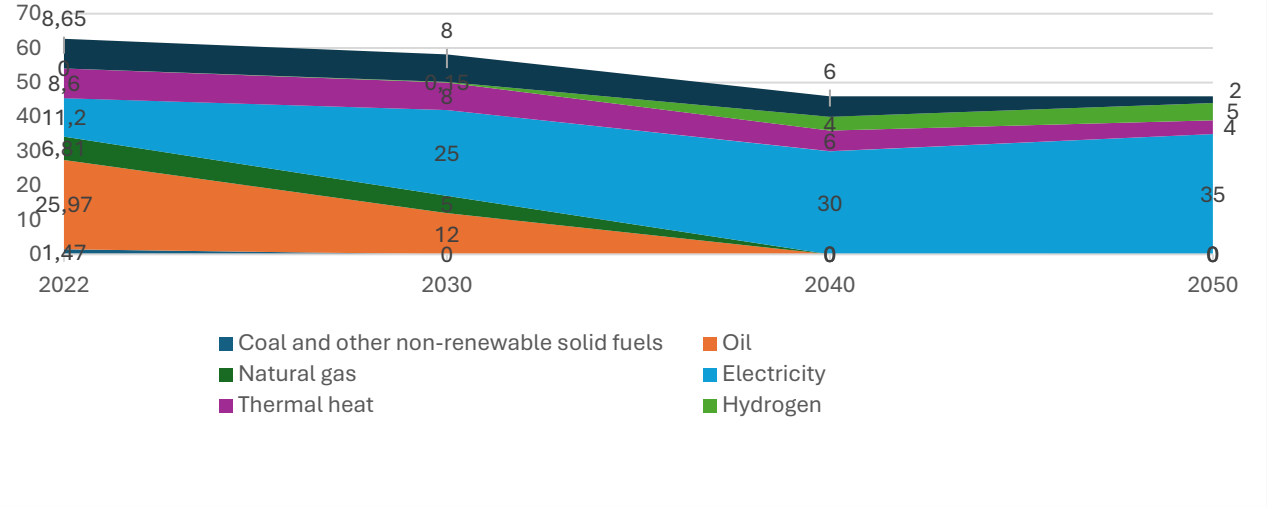
Figure 5. Electricity network interconnections in Lithuania 2022–2050 m., MW



In line with international trends, the country's economy will undergo a fundamental shift from fossil fuels to electricity. A new electricity economy will emerge. The transition to electricity consumption will be widespread: (i) in the transport sector, with the electrification of light and part of heavy transport; (ii) in the industrial sector, with a shift towards electrification and the attraction of new electricity-intensive businesses (hydrogen production, data centers, electricity storage, etc.); (iii) in the energy sector, with the creation of new hydrogen derivative production capacities, and (iiii) in the heating sector, with the extension of the use of electricity in heat generation and storage. Electricity will become the main primary energy source in the overall energy system and is therefore expected to be used largely in other sectors.
Final energy demand for energy and non-energy uses is projected at 58 TWh in 2030, 45 TWh in 2040 and 45 TWh in 2050. The share of RES will be 55% in 2030, 100% in 2040 and 2050.

By 2050, electricity consumption is projected to increase more than 4-fold from the current demand of 12 TWh to a projected 50 TWh. The largest share of the growth will come from hydrogen production (18 TWh), industrial consumption (12 TWh), transport consumption (7,5 TWh), and the heating sector (7,5 TWh).

Figure 6. Forecasted final energy consumption in 2022–2050 m. according to fuel types, TWh



Strategic objectives and their implementation

I. Safe and reliable energy supply

Lithuania will become fully energy independent. By 2050, the country will produce all the energy it needs and will be resilient to various external political and economic shocks. Imports will be possible in a favorable market situation, but the annual amount of energy produced in Lithuania must be equal to or higher than the amount consumed. A positive energy balance in the electricity sector will have to be achieved in 2030:

Lithuania's electricity system will be synchronized with the Continental European electricity system. This means that by the end of 2024, Lithuania's electricity system must be ready for interconnection with the continental European electricity grid in synchronous mode via the Polish electricity system.

The adequacy of the electricity system will be ensured, and mechanisms will be put in place to maintain and develop electricity generation reserve capacity, while also ensuring the efficient development and operation of the market for flexibility, balancing and ancillary services beyond frequency regulation, and the deployment of flexible electricity demand-side measures and technologies.

The electricity transmission and distribution infrastructure will be developed to meet the growing demand for electricity and to ensure the reliability of energy supply throughout the country. This includes investments in grid modernization and the introduction of new technologies and the development of new international connections.

Energy supplies will be diversified to reduce dependence on one or more energy sources and to ensure security of supply, even in the event of emergencies.

Crisis preparedness and emergency management will be strengthened, including stockpiling, planning and building resilience to physical and cyber threats, to respond effectively to a wide range

of crises and to ensure the continuity of energy supply. Preparedness for the adverse effects of climate change will also be enhanced.

II. 100% sustainable renewable energy for Lithuania

Lithuania will use only renewable energy sources to achieve its Green Deal goals. Further development of RES generation capacity, both offshore and onshore, will be pursued. Sufficient electricity generation facilities will be built in Lithuania to fully decarbonize energy sector. The transition to renewable energy sources and the use of alternative fuels will be promoted in the heat generation, transport, industry and other sectors. A positive energy balance in the electricity sector, ensuring that the country generates more electricity than it consumes, will have to be achieved by 2030. The goal is a sustainable renewable energy sector by 2050.

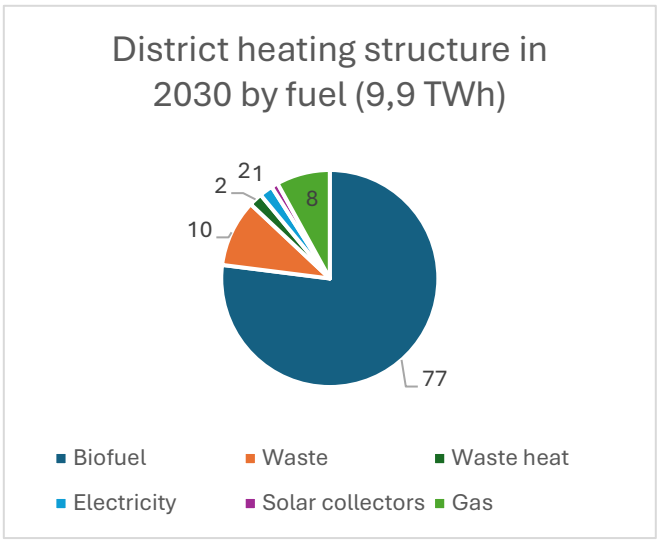
Offshore wind projects will be developed, and an offshore energy hub will be created to help achieve the 100% sustainable renewable energy target. The 2050 target is 3 GW of offshore wind farms. This will include investment in offshore wind farm infrastructure and technology to make efficient use of the Baltic Sea's wind energy potential.

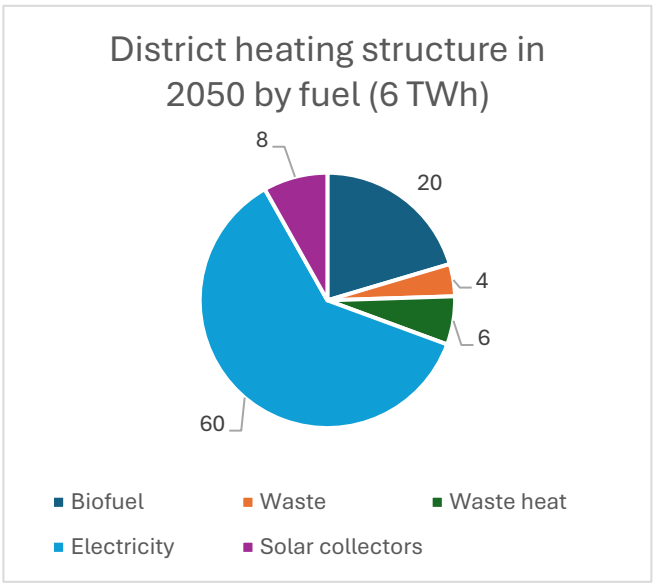
Onshore renewable energy sources such as solar and wind energy will be further developed. This will include the development of both large and small renewable energy projects to increase the share of these sources in total energy production. 2050 We need to reach 9 GW of onshore wind and 9 GW of solar.

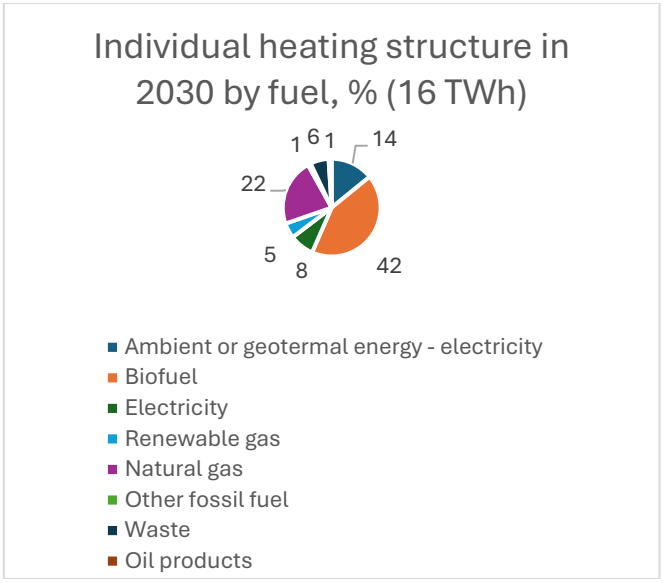
Development of green hydrogen energy and green gases as renewable energy sources will be encouraged. This will include investment in hydrogen production, storage and transport technologies, as well as the use of hydrogen in the hard to electrify industrial and transport sectors. In 2050 number of hydrogen electrolysis plants must be 4 GW and the amount of green hydrogen produced must exceed 300 000 tonnes.

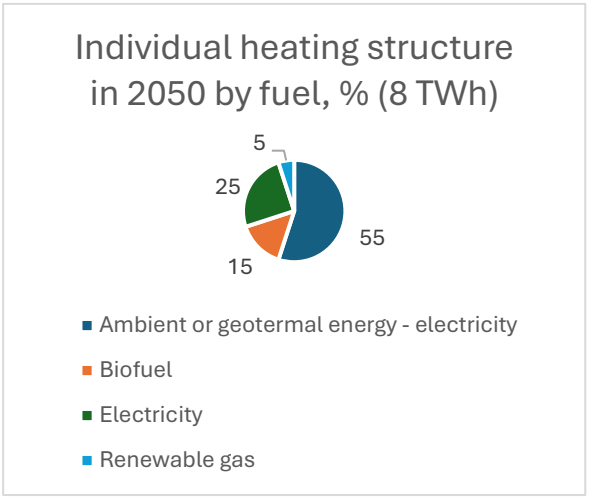
The heat sector will be modernized by switching to heat pumps, electricity and solar collectors, reducing the use of biofuels (47% of district heating in 2050) and waste, developing cooling sector to reduce emissions and increase energy efficiency. The share of RES in district and individual heat supply will reach 100% in 2040.

Figure 7. Individual and district heating structure in 2030 and 2050 by fuel









The transport sector will be decarbonized by switching to clean, climate-friendly transport modes. This will include the efficient integration of alternative fuels and the use of renewable energy generation capacity to ensure the supply of domestically produced energy to the transport sector. Vehicles powered by electricity or non-biological fuels (such as hydrogen or synthetic fuels) will account for 100% of the country's total vehicle fleet in 2040.

III. Making energy resources available to consumers

The energy transition must be accessible to everyone - from residents to businesses. The aim is also to minimize the costs of the energy transition for vulnerable populations. Developing local energy production capacity and the flexibility of the electricity system will aim to reduce energy price and supply spikes, which depend on the global energy market and its volatility.
The development of prosumers will be further encouraged, with the additional promotion of the active consumer scheme. This will include support measures for renewable energy generation installations as well as energy efficiency improvements. The country aims to have 500,000 prosumers and active consumers by 2030. Further expansion will be foreseen after assessing technical and economic feasibility.
Community energy will be promoted to reduce energy poverty and benefit vulnerable consumers. This will include financial support for the creation of energy communities, information on their establishment processes and activities and other promotional measures. The aim is to have no more than 3% of households spending a significant proportion of their income on energy in 2050.
A set of actions and support schemes will be developed and implemented to help address more effectively the negative impact of high energy prices on consumers and industry. This will include income support, tax incentives, gas saving and storage measures.
It will create the preconditions and standardized products for electricity consumers and the different energy sectors to participate more actively in the provision of flexibility services and to manage their energy consumption and bills. By 2030, regulation of flexibility services and an integrated platform will be developed where participants can access flexibility services and their economic analysis. Additional flexibility capacities will also be introduced, incorporating a range of technologies and promoting innovation and sectoral change.

Enabling the Scenario objectives

Achieving strategic objectives set out in the Scenario will be realized through the following horizontal initiatives.

I. Improving energy efficiency.

In Lithuania, around 40% of energy is consumed in the buildings and transport sectors and around 20% in the industrial sector. These sectors have the greatest potential for improving energy efficiency. By 2030, excluding green hydrogen production, Lithuania aims to reduce primary energy consumption to 63.3 TWh and final energy consumption to 51 TWh.
Efficiency gains will be achieved through the installation of heat pumps, construction of new zero-energy buildings and renovation, introduction of energy monitoring and management systems, electrification of transport, integration of hydrogen and non-biological fuels from RES, promotion of less energy-intensive industries development and other measures.

II. Preparing energy professionals for change

Demand for energy professionals in Lithuania is increasing due to the transformation of the sector: growth in prosumers, synchronization of the energy system with the electricity grids of continental Europe, development of offshore wind farms in the Baltic Sea, deployment of hydrogen technologies, and the turnover of workers due to the increasing age of the workforce. By 2030, a

shortage of at least 2 500 employees is projected in state-controlled energy companies. Offshore wind farms are also expected to create around 1 300 new jobs.
The aim is to meet at least part of the energy sector's human resource needs and to train at least 1 900 energy professionals by 2030. By 2050, the plan is to have a sufficient supply of talent and competences for the energy sector.

III. Creating centers for research, innovation and energy technology development.

Research and products developed in Lithuania must be used in Lithuania and for export, thereby supporting the country's economic growth. Focus on priority research areas and practical application of research results. Energy technology applied research centers, which will focus on cooperation between science and business (attracting energy companies), will be a key tool to achieve this goal. By 2030, at least one energy technology applied research and development center will be established in Lithuania.
Considering the specifics and needs of the Lithuanian energy sector, strategic objectives, existing and desired competences, the following priority areas of energy research and experimental development are identified: renewable energy technologies, power supply systems, control solutions, quality assurance measures, energy and cyber security, hydrogen and its derivative technologies, new methods of heat and cooling production and other technologies.

IV. Public engagement and education

Successful implementation of this scenario requires public acceptance and support, as well as consumer awareness, involvement and engagement. Therefore, to achieve the objectives, set out in this Scenario, proactive scientific communication, the provision of timely and objective information to the public, transparency of ongoing projects, and the strengthening of cooperation and information exchange between national authorities, local authorities, the public sector, business and the public will be encouraged.

Economic impact of Scenario

Decarbonization of energy sector, according to a state-owned group of energy transmission and exchange companies „EPSO-G“, could create[8] between 40 000 and 140 000 new jobs in 2050, including direct and indirect jobs. The benefits to the Lithuanian economy could be between €2 and €6.3 billion over this period, representing between 4 and 11 % of Lithuania's GDP in 2023.
Additional benefits are also expected from significantly reduced or eliminated costs for imported energy sources. Currently, around €6 billion a year is spent on energy imports, which could potentially be saved in 2050.

[8] https://www.epsog.lt/uploads/documents/files/Lietuvos%20energetikos%20vizija/DNV%20EPSOG%20Lithuania%20Energy%20System%20Transformation%20Strategy.pdf