THE FUTURE OF EUROPEAN ENERGY AND TRANSFORMATION CHALLENGES FOR LATVIA

LATVIAN ECONOMISTS ASSOCIATION

European Parliament

ECR PARTY

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The Latvian Economists Association consistently defends the foundations of Latvian economic growth and competitiveness – an open economy, free business initiative, and inclusion in the European Union's market.

The Latvian Economists Association was founded in 1994 to promote economic thought and the long-term development of the national economy in Latvia. It is one of the oldest non-governmental organizations in the restored Republic of Latvia. The main activities of the association are to conduct economic research, organizing conferences and discussions as well as evaluate the economic programs of political parties.

THE COMMISSIONER

The European Conservatives and Reformists (ECR) Party is the Europe's leading Conservative movement. Since the founding of ECR in 2009, with more than 40 political parties, including those outside the EU, and active representation in the European Parliament, the Council of Europe, the Committee of the Regions and the NATO Parliamentary Assembly, it has strongly advocated for the common market, the importance of the EU national democracies in the EU decision-making, as well as the role of the transatlantic partnership.

THE SUPPORTER

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Energy is the basic component of the national economy, and its health directly affects the competitiveness and sustainability of the economy both at the level of the Member States and the European Union (EU). Energy has not been a priority in the EU for a long time, so a unified policy in this area has also been lacking. In the so-called "old member states", strong, well-equipped institutions are responsible for the energy field, and their capacity several times exceeds the capacity of the EU. In the new member states, including Latvia, energy policy is still at a rudimentary level. As a result, for example, consumers in Germany have enjoyed much lower energy prices for years than in Latvia, Lithuania, and Estonia (Germany has also rejected the EU-wide joint energy procurement). On the other hand, we now see how Germany has become enormously dependent on energy resources due to the policy implemented by Russia. Various think tanks and institutions have been suspiciously favorable to such decisions, which have ultimately benefited Russia.

Climate change, the pandemic, and, especially, Russia's invasion of Ukraine have created a new situation in energy in particular and the economy in general. Finally, to reorient to the types of renewable energy, to stop the dependence on Russian energy resources, to diversify electriciy generation methods and supply routes – here are some of the challenges that are relevant for Latvia, the Baltic States, and the whole of Europe. Therefore, the present research is particularly important at the moment. It comes at a time when energy policy has become a priority and decision-makers need a comprehensive and, at the same time, detailed view of possible development scenarios.

We thank the sponsors of the study – Balticovo, Naftimpeks, and the ECR Party – for their support, as well as the authors themselves for their work, which will make a significant contribution to the further development of the Latvian energy sector.

Ojārs Kehris, The President of the Latvian Economists Association

This study is published at a time when energy in all its manifestations has become the most discussed topic in the European and world media, as well as on political discussion platforms. From the prices of firewood and pellets to the construction of liquefied gas terminals, home heating, and solar panels on rooftops – we are talking about electriciy generation, supply and price, because these three components affect every business, every family, and every person.

In the spring of 2022, the European Commission (EC) published a plan called *RePowerEU*, which outlines the EU's path to divert from Russian energy sources by 2027. Europe understands that it is necessary to revise the Green Deal guidelines and adapt them to the current geopolitical situation. During the war, the Green Deal cannot be implemented in the same timeframe as planned – before the Russian invasion of Ukraine, which means that in short term, the funds can be used for less "green" purposes to get rid of Russia's energy resources faster. However, in the long term, re-orientation from Russian gas and oil products will have to be balanced with sustainability and the Green Deal goals. For all of Europe, including Latvia, this creates great challenges in the energy policy – from decision-making to practical implementation. That is why I'm glad that this balanced and thorough study will allow policymakers to see both the common European direction in energy and the special potential of Latvia in it.

Roberts Zīle, The Vice President of the European Parliament

SUMMARY

Transitioning to a low-emission economy, the European Union (EU) energy sector is committed to sustainable, safe, and more affordable electriciy generation. As a part of the Green Deal, the EU has set a binding goal of achieving climate neutrality by 2050. However, recent upheavals related to energy supply disruptions to Europe, as well as rising prices of key energy resources, have led to more urgent energy policy action in the winter season of 2022/2023. The high dependence on the import of energy resources and the sensitivity to geopolitical upheavals indicate that the EU needs to reassess the distribution of its energy portfolio and accelerate the progress toward sustainable energy solutions.

Despite the rapid development of renewable energy sources (RES), more than half of the EU's total energy supply still comes from oil, oil products, and natural gas. In addition, the EU's dominant energy sources, namely oil and natural gas, are the most import-dependent. The main supplier of both natural gas (41.3 %), crude oil and liquefied natural gas (26.9 %) is Russia. Natural gas prices have fluctuated significantly over the past three years. After falling to 3 euros (EUR) per megawatt hour (EUR/MWh) in the summer of 2020, the natural gas prices reached a record high of 346 EUR/MWh on the Dutch TTF exchange in August 2022. Due to the correlation with the natural gas prices, the influence of geopolitics and the additional increase in carbon dioxide (CO_2) costs, the electricity market could not escape the price avalanche either. The price of electricity in Latvia increased from an average of 31 EUR/MWh in July 2020 to the absolute peak of 4,000 EUR/MWh on August 17, 2022.

The transition to more sustainable and safe energy can be achieved in the long term with various policy instruments, and by creating a relevant energy portfolio. Analyzing several energy policy transition scenarios until 2050 (*Bloomberg*, IPCC, IEA, IRENA, BP, *McKinsey*, DNV, Shell, OECD, *Equinor,* etc.), it can be seen that despite the economic development and the use of more energy-intensive equipment and processes, a significant reduction in greenhouse gas (GHG) emissions is predicted. Energy efficiency measures compensate for the increasing energy demand. In principle, all scenarios have a common conclusion that the energy transition process is significantly based on: (1) reduction of energy demand by increasing efficiency; (2) electrification of end-use, and (3) decarbonization of electricity generation. The options for the gradual replacement of fossil-fuel power plants by 2050 (in addition to growing RES presence) evaluated in the scenarios are mostly based on a combination of natural gas, nuclear energy, and hydrogen technologies. None of the scenarios envisages that natural gas would be completely replaced by other energy sources.

Scenarios with a relatively lower proportion of natural gas in 2050 predict faster development of nuclear energy. Overall, almost all scenarios reviewed an increase in nuclear power. In 2022, the world is experiencing major global upheavals caused by the convergence of several crises: climate change, the Covid-19 pandemic, and the war in Ukraine started by Russia on February 24, 2022. Although the impact of these crises is uneven in the world, their consequences could be felt at all levels of society. Energy experts believe that the situation in the world could stabilize in up to five years.

Evaluating scenarios for the security of energy supply in **the heating season of 2022/2023 in the EU**, it should be taken into account that the European energy market is well integrated. The electricity price difference is formed based on interconnection capacity, energy supply (which depends on the electricity generation portfolio), and demand in the respective price zone. Electricity generation requires the installed capacity of power plants and an energy source. Natural gas, coal, and nuclear power can provide base load power generation on a large scale with existing technologies. At the same time, crises situations have significantly affected normal market operation.

Historically, the price of natural gas in Europe has been lower than in Asia. However, the natural gas prices in Europe have closely followed liquefied natural gas (LNG) prices in Asia in recent months. At high natural gas prices, the EU has the opportunity to attract part of the natural gas supplies from Asian markets. Several countries, such as Germany, the Netherlands, Austria, and France, restarted their coal-fired power plants as an energy crisis management measure. It should be noted that a complete ban on the import of "all types" of Russian coal has entered into force in the EU, anticipating the replacement of coal produced in Russia with alternative supplies (for example, from the USA, South America and South Africa). The price of coal in the summer of 2022 was 2.5 times higher than that of the previous year. The availability and price of coal in the 2022/2023 heating season are determined mainly by China and India, which are the largest consumers of coal.[1]

France, the EU's main nuclear power country, has relatively old nuclear power plants (NPPs) that require careful and regular maintenance, while several repairs were postponed due to the Covid-19 pandemic, affecting the next 5-year renovation plans. These facts indicate that during the winter season, French NPPs will be available with less capacity than it was usual before. This increases the challenge of ensuring the sufficiency of energy resources.

Between 2015 and 2020, **the EU installed capacity of RES** increased by an average of 193.2 gigawatts (GW) per year. In 2021, despite supply chain disruptions, construction delays, and rapidly rising material costs, new RES capacity reached nearly 295 GW. However, experts believe that the pace of the transition from fossil fuels to RES is insufficient to meet the 1.5 °C targets.

In the past ten years, solar photovoltaic (PV) modules in particular have become much cheaper and more widely used. The weighted average levelized cost of electricity (LCOE) for large-scale solar PV plants in 2021 was $0.048 per kilowatt-hour (USD/kWh). This is 88 % less than in 2010. In 2021, the total capacity of solar PV installations reached 843 GW. At the same time, in 2021, the cost of materials, which until now tended to decrease, experienced a significant increase – the price of polysilicon, widely used in the production of solar PV modules, increased more than four times. Copper, steel, and aluminium prices also increased, as did freight costs. Wind energy generation is also developing rapidly in the EU. In terms of the LCOE, onshore wind is currently the cheapest RES for electricity generation. In

[1] Nikkey Asia, 2022. https://asia.nikkei.com/Spotlight/Market-Spotlight/Russian-sanctions-threaten-to-make-coal-dirtier-more-costly

2021, the LCOE of onshore wind was $0.033 per kWh, down by 68 % compared to 2010. During the relevant period, the LCOE of offshore wind decreased by 60 % and was 0.075 USD/kWh in 2021. Both segments have benefited from technological advances that have resulted in increasing wind turbine sizes and improvements related to safe operation, as well as larger turbine heights and rotor diameters.

Hydropower is a relatively simple technology that has been used for a long time around the world. In 2021, the LCOE of hydropower projects was 0.048 USD/kWh. The possibilities of implementing new economically profitable hydropower projects, especially in mature markets like Europe, are limited. Consequently, developing hydroelectric power plants (HPPs) in locations with more challenging conditions will increase LCOE of these projects. Other RES sources (mainly primary solid biofuel and biogas) account for 16 % of the electricity produced by RES and biofuels in the EU. Bioenergy is also used in heating and other areas. Along with the wider application of circular economy principles, biomass is finding more and more new applications as a production material. The total demand for biomass is significantly higher than it is possible to produce without jeopardizing the set GHG emission reduction targets. Therefore, policymakers will have to evaluate how to use biomass.

Hydrogen is an important source of energy that can be used as an alternative fuel, and modern technologies offer ways to decarbonize a range of sectors, including long-distance transport, chemical production, and the iron and steel industries, which are energy-intensive and difficult-to-reduce emissions. In 2030, the estimated production capacity of green hydrogen could reach 50 GW, which is 25 % more than the targets set by the EU. Trends show that green hydrogen will form a stable part of the future energy portfolio. At the same time, hydrogen technologies have not reached maturity yet.

There are currently 173 nuclear reactors operating in Europe, of which 109 are located in the EU. The EU is building new NPPs in France, Finland, and Slovakia. Construction is also underway in Ukraine and the UK. Estonia has announced its goal to build a nuclear power plant. In 2021 the Netherlands announced plans to build two new reactors (previously there was a decision made to completely ban nuclear power). Poland has serious plans to develop NPP as well. At the same time, several countries plan to close the existing NPPs: Germany by December of this year (currently the closure is postponed) and Belgium by 2025.

In Latvia, the energy consumption portfolio mainly consists of RES (42 %), oil products (32 %), and natural gas (21 %). No significant changes in the final consumption of energy resources have been observed in ten years. Last year, the biggest consumers of energy resources were households (28.9 %), the transport sector (28.2 %), and industry (23.6 %). In Latvia, the electricity production portfolio in 2021 mainly consisted of Daugava HPP (46.7 %) and CHPs (34.3 %), as well as smaller amounts of biomass (6.5 %), biogas (4.7 %), small-scale CHPs (4 %), wind energy (2.5 %), small HPP (1.2 %) and solar energy (0.04 %). The Baltic States have historically worked and are currently working synchronously with the electricity systems of Russia and Belarus. Work is currently underway on the desynchronization project from the Russian-managed power network, with the goal of synchronization with the continental European grids in 2025. The synchronization project increases the need for local generation, as the Baltic States will have to be able to provide both balancing and stable grid operation.

The Finnish, Latvian and Estonian regional gas market, established in 2020, improves market liquidity and increases its attractivity to participants, as the natural gas consumption of individual Baltic country does not ensure a sufficient interest on the market of Latvia for alternative suppliers. The consumption of natural gas in the region shows a slightly downward trend, which has been influenced mainly by metrological conditions, the price of electricity in *NordPool,* and the general trend in the reduction of CO_2 emissions. Energy industry analysts are very cautious about forecasting the natural gas price trends due to the volatility of the global energy market. *The Ice* analytics platform predicts Dutch TTF Gas Futures with the higher natural gas price for the 2022/2023 winter season, with a further gradual price decline afterward. Physical flows to the Latvian natural gas transmission system are coming from Russia (entry point Korneti), Lithuania (entry point Kiemenai), and from the Inčukalns underground gas storage (IUGS) during the natural gas withdrawal (winter) season (entry point IUGS). In 2021, the total amount of natural gas transported in Latvia reached 39.3 terawatt-hours (TWh), which increased by 5 % compared to the previous year, while in the summer of 2022 it significantly decreased. As of August 1, 2022, the filling of IUGS was 53.3 % (11.62 TWh), which corresponded to 94.2 % of Latvia's annual natural gas consumption. At the same time, it should be mentioned that the services of IUGS are actively used by natural gas traders from other countries, and information about how much of this gas volume is intended for Latvian users is confidential and, therefore, is not publicly available.

Joseph Gatdula, the Head of the oil and gas function at *Fitch Solutions*, believes that current global natural gas supply is unlikely to replace all of Russia's gas imports to Europe – almost 150 billion cubic meters (BCM) – in a short period. The current LNG capacity in the USA is adequate, but not enough to meet all of Europe's demand. "However, exports will increase significantly by mid-decade as liquefaction capacity increases in the USA and Qatar. These new volumes could force Europe to permanently move away from Russian gas imports if the increase in RES and the decline in the natural gas consumption take effect, based on the EU's plans to diversify Russian energy imports", states Joseph Gatdula.

As of the end of summer 2022, the only entry point where it was possible to receive natural gas in Latvia was through the LNG terminal in Klaipėda, Lithuania. However, in practice, there is a fierce competition for the availability of Klaipėda LNG terminal capacity, and Lithuania is interested in providing access to the terminal primarily to the Lithuanian traders. LNG terminals in Latvia will be developed by AS Skulte LNG Terminal. Estonia and Finland have agreed to the joint commissioning of one floating storage and regasification unit (FSRU) and are building piers on both sides of the Gulf of Finland – Paldiski and Hamina LNG terminals. The construction and availability of new LNG terminals in the region are critically important for the security of the energy supply in Latvia for the 2022/2023 heating season.

At the EU level, the EC has proposed in its *REPowerEU* plan to accelerate and expand the implementation of RES projects to increase their use in electricity generation, industry, the construction sector, and transport. A high share of RES in Latvia is mostly related to historical achievements, rather than recent developments. Currently, RES projects with a total capacity of 3,500 megawatts (MW; excluding the project of "Latvijas vēja parki Ltd." and offshore wind farm projects) have applied for connection permits to the transmission network on land, as well as 1000 MW of connection capacity to the distribution network. When evaluating investments in the network, the probability of implementation of all applied projects should be realistically assessed, because unused network capacities increase the electricity tariff for all Latvian electricity consumers, consequently reducing the country's competitiveness.

Regarding the development of nuclear energy, the building of two 300 MW NPP reactors with a total capacity of 600 MW is reviewed. Ensuring their capacity factor at a level of about 80 %, more than 4 TWh of electricity could be produced annually. Assuming that in 10 years electricity consumption were in the range of 7.6 to 8.3 TWh, such reactors would be able to supply half of the electricity consumed in Latvia. At the same time, the NPP construction process is time- and resource-intensive.

As a part of the research, scenarios **of the electricity generation portfolio for 2022/2023 and a 10-year perspective have been developed**. The scenarios have been developed based on public data without an in-depth evaluation and include many assumptions that increase the possibility of bias.

To reduce the natural gas deficit, it is necessary to make maximum use of the opportunities for replacing natural gas with other alternative energy sources and technologies that do not use natural gas for energy generation. At the same time, the actual possibilities of implementing such changes should be evaluated, taking into account the limited timeframe. Replacing natural gas with other energy sources, electricity and thermal energy can be obtained by increasing the use of biomethane and biomass, as well as by installing heat pumps, solar panels, and wind generators. It is also possible to use fuel oil and diesel more. The use of coal-fired power plants is also increasing in Europe. At the same time, even if the current solar generation capacity doubles, the impact on Latvia's overall energy portfolio is supposed to be minimal. It is not expected that large-capacity biomethane, biomass, or heat pump energy generation projects will be implemented by the winter of 2022/2023. In September 2022, the 58.8 MW wind energy park in Tārgale, near Ventspils, started operating, slightly increasing a share of wind energy in the Latvian energy portfolio. This shows the critical role of alternative supplies of natural gas.

The consumption of natural gas is significantly affected by the outdoor temperature and the price of natural gas as during the period of high gas prices the electricity produced from it is less competitive in the *NordPool* exchange. Accordingly, such electricity is demanded and sold less. Similarly, industrial users of natural gas are forced to reduce the intensity of its usage, as products, in production of which the costs of natural gas play a significant role, lose their competitiveness. It is possible to reduce the deficit of natural gas by reducing the total consumption of energy resources by implementing different saving measures. Changes in the potential electricity generation portfolio for the next heating season are mainly carried out by adjustment of consumption, rather than the implementation of a new generation.

Taking into account the geopolitical situation, and its significant impact on natural gas prices, and actual availability, it is predicted that in the coming years the natural gas demand in Latvia will decrease, but in the medium term it will recover to the previous level. On the other hand, **in the longer term**, natural gas consumption will decrease according the goals of Latvia's energy sector decarbonization agenda. When creating future energy scenarios, it is important to remember that, as RES generation increases, the necessity to provide balancing capacities for stable system operation and satisfaction of less flexible demand in absence of variables RES becomes crucial. As the proportion of RES to traditional baseload capacities increases, balancing becomes more expensive. Thus, it is essential to achieve a sustainable ratio between variable and baseload energy sources.

According to the long-term scenario of Latvia's electricity portfolio (without NPP), a larger share of electricity in Latvia will continue to be provided by HPP. The next largest source of electricity could be wind power (mainly onshore wind farms due to their lower costs compared to offshore wind farms and relatively freely available land areas in Latvia, if an initiative is being approved by the municipality). Thermal power plants would mostly act as a backup generation source at times when variable generation would not be able to meet the electricity demand surplus. The amount of natural gas burned by the thermal power plant could decrease both along with the increase in the amount of biogas in the natural gas grids (up to 15 %) and due to the appearance of hydrogen (up to 5 %).

In the long-term scenario of Latvia's electricity portfolio (with NPP), a larger share of electricity in Latvia will be provided by NPP, taking into account that two small power reactors with a total installed capacity of 600 MW (2x300 MW) can produce more than 4 TWh of electricity annually. In such a scenario, surplus of electricity will be generated. The scenario envisages that hydrogen will be produced from part of the electricity produced by the NPP, which can, in turn, be more actively used for the operation of thermal power plants. The surplus of electricity will be exported to other countries (at the same time, the research does not assess the competitiveness of the electricity, taking into account the planned generation of other countries). Along with higher hydrogen production, more active use of CHPs is foreseen compared to the first scenario. Therefore, it is expected that the hydropower plants will fall to the 3rd place in the electricity generation portfolio if the current electricity generation volumes remain. The scenario also assumes that wind energy will form a relatively insignificant part.

When evaluating possible solutions in the energy sector, it is necessary to follow trends in the region, because the energy sector in Latvia cannot be viewed separately from the countries that are participants of the same energy market. It is important to be aware of the increasing risks of electricity traders when offering fixed electricity price services, as the fees of customer contracts may not be sufficient to cover the actual costs. It is also important to recognize the effect of the energy crisis on other areas. When evaluating possible project solutions, the risk of overinvestment in infrastructure should also be evaluated in contrast to the intensity (efficiency) of their use. Also, the risks of long-term liabilities should be cautiously assessed when concluding agreements in times of turmoil.

BCM – Billion Cubic Meters
Bcf/d – Million Cubic Feet per Day
BP – British Petroleum
Btu – British Thermal Unit
CCUS – Carbon Capture, Utilization, and Storage
CO_2 – Carbon Dioxide
CSP – Concentrated Solar Power
CANDU – Canada Deuterium Uranium, the Canadian pressurized heavy-water reactor design
DEA – Danish Energy Agency
DNV – Det Norske Veritas
CHP – Combined Heat and Power Plant
EC – European Commission
EJ – Exajoule
EU – European Union
EUR – Euro
GIPL - Gas Interconnection Poland–Lithuania
GW – Gigawatt
GWEC – Global Wind Energy Council
H_2 – Hydrogen
HPP – Hydroelectric Power Plant
IEA - International Energy Agency
GDP – Gross Domestic Product
IUGS – Inčukalns Underground Gas Storage
IRENA – International Renewable Energy Agency
IVN – Environmental Impact Assessment
kWh – Kilowatt-Hour
LCOE - Levelized Cost of Electricity
Mcf/d – Million Cubic Feet per Day
MCM – Million Cubic Meters
MJ/m^3 – Megajoule per Cubic Meter
Mt – Megaton
MW – Megawatt
MWh – Megawatt-Hour
NEKP - The National Energy and Climate Plan
NO_x – Nitrogen Oxides
NPP – Nuclear Power Plant
OECD - Organization for Economic Co-operation and Development
UGS – Underground Gas Storage
PJ – Petajoule
PV – Photovoltaic
RES – Renewable Energy Sources, Renewables
RUB – Russian Ruble
LNG – Liquified Natural Gas
GHG – Greenhouse Gas
SMR – Small Modular Reactor
Tcf – Trillion Cubic Feet
TEN-T – Trans-European Transport Network
TSO – Transmission System Operator
TWh – Terawatt-Hour
US – the United States of America
USD, $ – US Dollars
WPP – Wind Power Plant
£ – British Pound

THE EUROPEAN ENERGY FUTURE

THE EUROPEAN ENERGY SECTOR

Moving towards a low-emission economy, the EU energy sector is fully committed to more sustainable, secure, and affordable electriciy generation. As part of the European Green Deal, the EU has set a binding goal of achieving climate neutrality by 2050. However, recent upheavals related to energy supply disruptions to Europe, as well as rising prices of key energy resources, have led to a more urgent risk factor for energy policy planning – the winter season of 2022/2023. The high dependence on the import of energy resources and sensitivity to geopolitical upheavals indicate that the EU needs to reassess the distribution of its energy portfolio and accelerate the progress of its energy transition.

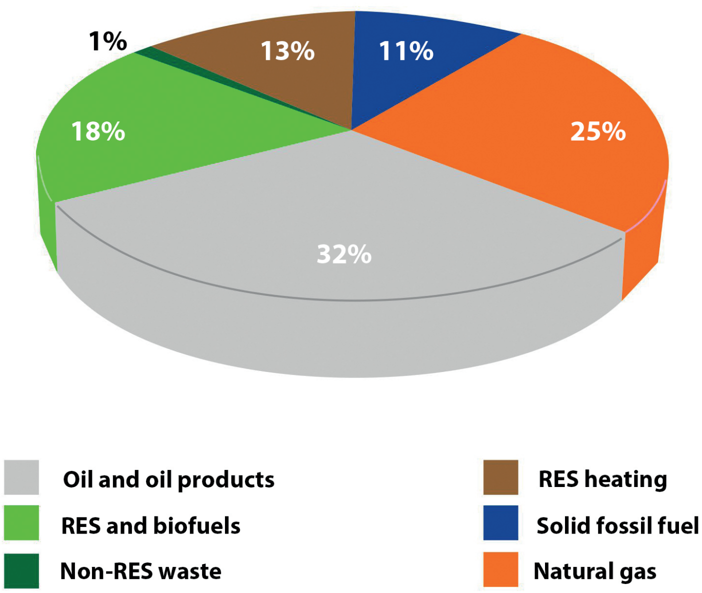
Despite the rapid development in the RES sector, more than half of the EU's total energy supply still comes from oil, oil products, and natural gas.

In addition, the EU's dominant energy sources, namely oil and natural gas, are the most import-dependent. The situation becomes even more critical because the main supplier of natural gas (41.3 %), crude oil, and liquefied natural gas (26.9 %) is Russia. The second largest natural gas supplier – Norway – provides only 16 %, and the second largest oil supplier – Iraq – only 9 % of the EU's annual natural gas and oil imports.

Natural gas prices may vary in the EU Member states. They directly depend on supply and demand. Typically, prices are determined by traders at specific exchanges or location-specified hubs. Natural gas prices have fluctuated significantly over the past three years. After falling to 3 euros per megawatt-hour (EUR/MWh) in the summer of 2020, natural gas prices faced an unprecedented rise in the second half of 2021. Later, in March 2022, the Dutch TTF experienced a record-high natural gas price of 229.06 EUR/MWh, but on August 26, 2022, the price reached a maximum of 340.81 EUR/MWh.

Due to the correlation with the natural gas prices, the influence of geopolitics, and the increase in carbon dioxide (CO_2) costs, the electricity market could not avoid the avalanche of prices either. Monthly day-ahead electricity prices in the Latvian price zone increased from 31 EUR/MWh in July 2020 to 210.29 EUR/MWh in June 2022. In December 2021, the price reached the historical maximum of 1000 EUR/MWh. On July 21, 2022, Latvia and Lithuania were shocked by a new historical electricity price record of 2100 EUR/MWh. On the other hand, on August 17, 2022, the absolute electricity price maximum was reached on *Nordpool* – 4000 EUR/MWh.

Fig. 1 Electriciy generation in the EU (types of energy resources, 2020 (%))

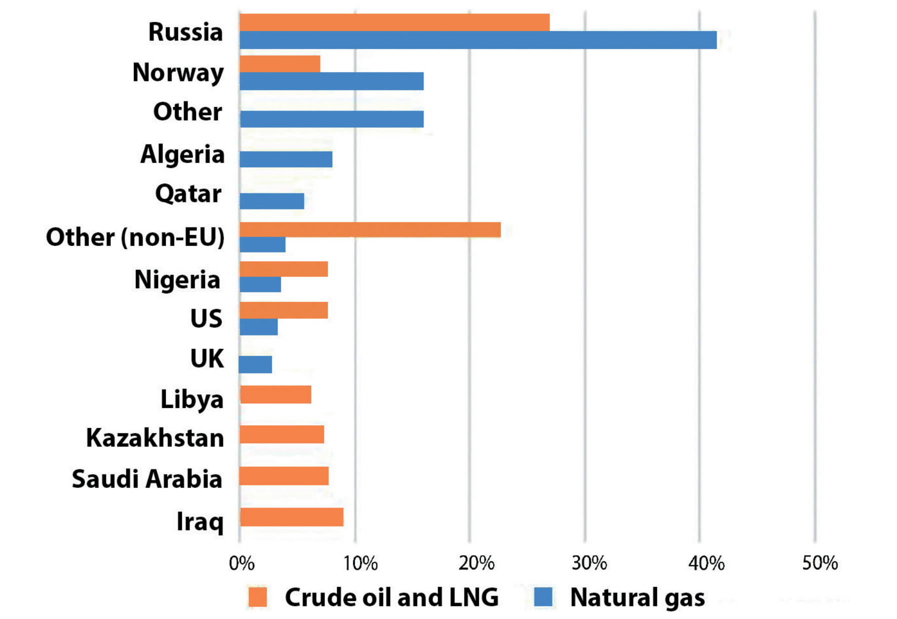


Source: Eurostat, 2022. https://ec.europa.eu/eurostat/databrowser/view/ten00122/default/table?lang=en

Fig. 2 Dutch TTF natural gas prices (EUR/MWh)

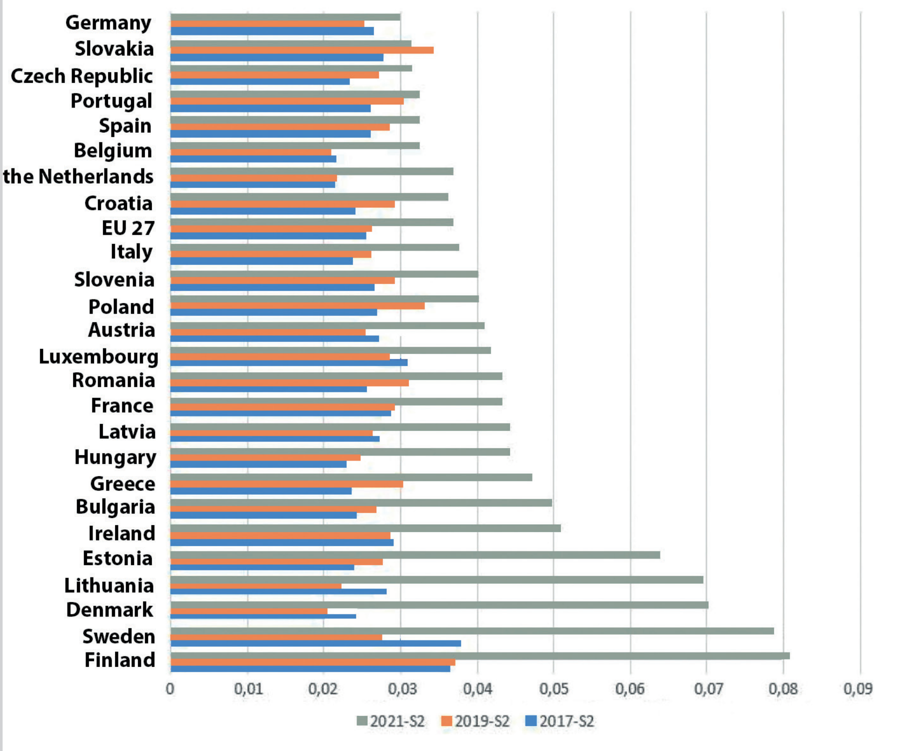
Source: Trading Economics, 12.09.2022. https://tradingeconomics.com/commodity/eu-natural-gas

Fig. 3 Crude oil and natural gas supplier countries in the EU



Source: Eurostat, 2022. https://ec.europa.eu/eurostat/databrowser/view/ten00122/default/table?lang=en

Fig. 4 Natural gas prices, non-household consumers, EUR/kWh



Source: Eurostat, 2022. https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_203/settings_1/table?lang=en

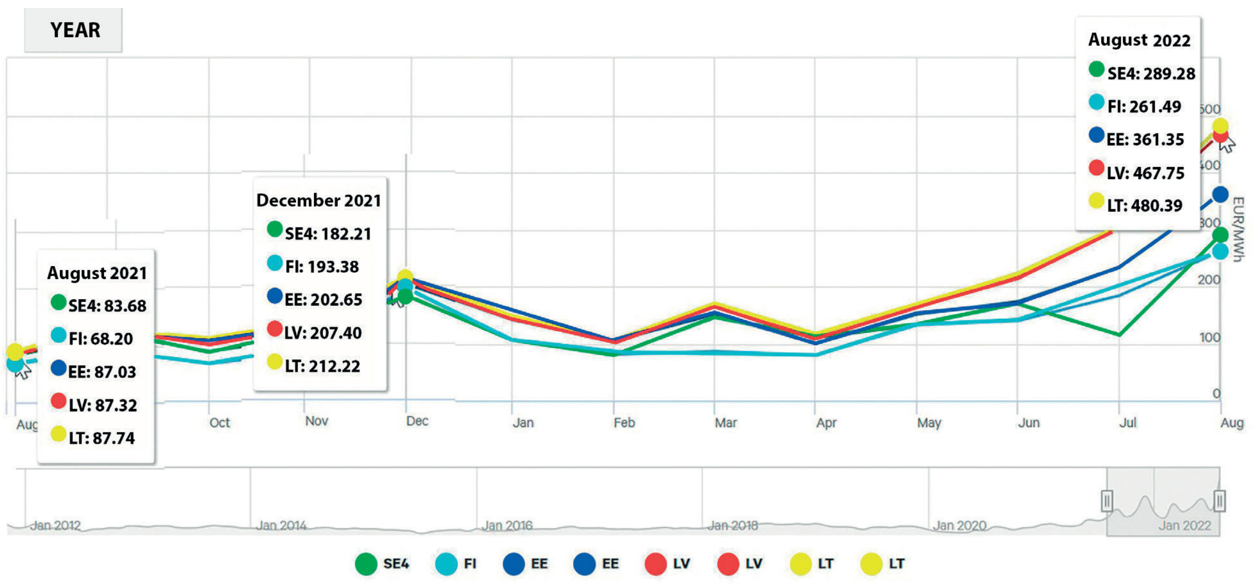
MOVING AWAY FROM RUSSIAN GAS (long-term perspective)

The transition to a more sustainable and safe energy supply can be achieved using different policy instruments, resulting in a different structure of energy systems. Analyzing several energy policy transition scenarios until 2050 within the framework of the World Energy Council expert working group, as well as those developed by Bloomberg, IPCC, IEA, IRENA, BP, *McKinsey*, DNV, Shell, OECD, Equinor, and others, it can be seen that all of them, despite the positive trend of economic development and, therefore, more extensive use of more energy-intensive equipment and processes, predict a significant reduction in GHG emissions. The increasing energy demand is compensated by significant energy efficiency measures. All scenarios share the conclusion that the energy transition process relies heavily on three main pillars: (1) reduction of energy demand through increased efficiency; (2) end-use electrification, and (3) decarbonization of electricity generation.

All scenarios predict a rapid increase in RES electricity production – some scenarios have more ambitious targets, others less ambitious. There is less consensus regarding the choice of technologies that will provide a baseload when RES generation is not available in sufficient quantities due to its volatility. The future of coal in the global context is questionable – the reason why coal still does not disappear from the scenarios is the relatively recent commission time of many power plants in Asia. However, the total share of oil and natural gas consumption worldwide do not generally lose its position compared to the current levels. Most of the scenarios published before 2018 predicted a sharp increase in the use of natural gas, offsetting the decline in oil and coal. Natural gas was considered the most convenient transition energy source. However, a number of scenarios published after 2020, such as IRENA's *World Energy Transition Outlook*, *Bloomberg* NEF, and NGFS, predicted a decline in the natural gas supplies by 2050. Most global scenarios also assumed that the intensity of nuclear energy use would increase.

In a conclusion, it should be mentioned that the gradual liquidation of fossil fuel-based power plants and their replacement with, preferably, RES technologies, evaluated in the

Fig. 5 Monthly day-ahead electricity prices, *Nord Pool*, EUR/MWh



Source: *NordPool,* 10.07.2022. https://www.nordpoolgroup.com/en/Market-data1/Dayahead/Area-Prices/ALL1/Monthly/?view=chart

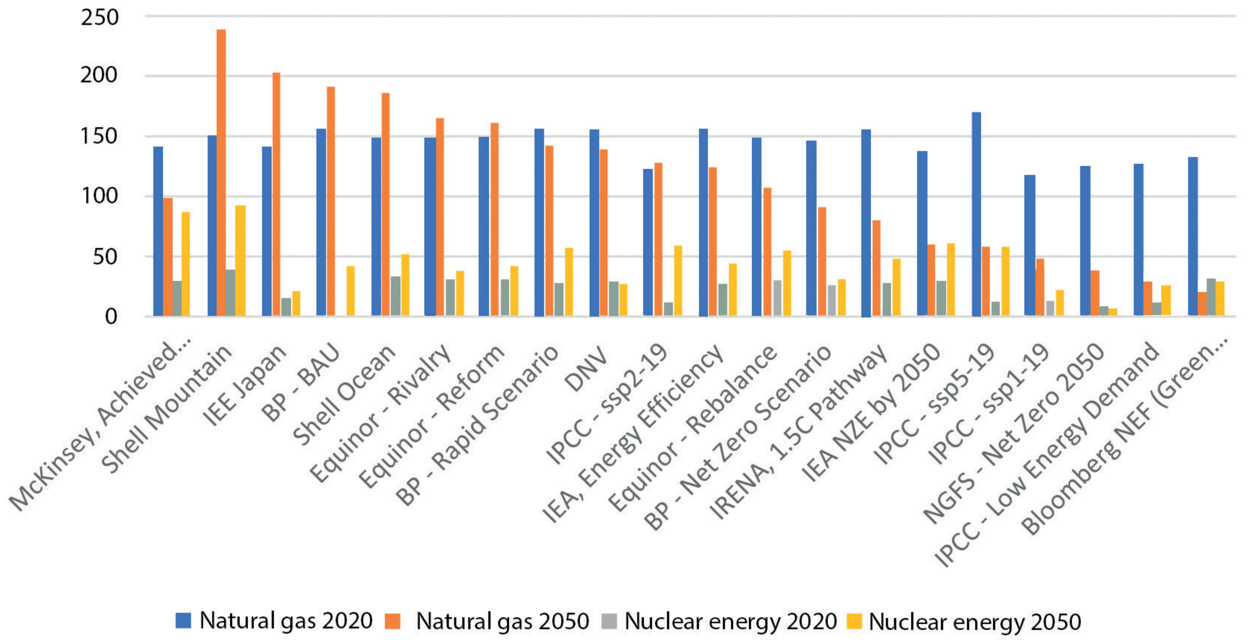
scenarios are mostly based on the combination of natural gas, nuclear energy, and hydrogen technologies.

None of the reviewed scenarios envisages a situation where natural gas will be completely replaced by other energy sources. However, scenarios with the lowest share of natural gas in the energy portfolio in 2050 show an increase in nuclear power generation. In general, almost all of the scenarios considered predict an increase in nuclear power generation. However, none of the scenarios mentions that nuclear power will soon overtake natural gas in total installed power generation capacity.

At the same time, scenarios predict that the demand for natural gas in the electricity generation sector will increase until 2030–2035. Later, its share will begin to decrease, and only then is it predicted that natural gas will increasingly fulfill the function of RES reserve.

Even though hydrogen technologies are actively mentioned in almost all scenarios, a few provide concrete predictions. At the same time, some scenarios (for example, *Bloomberg*) regard hydrogen as the backbone of the future economy. Likewise, IRENA's scenario especially emphasizes the role of batteries for future progress toward climate neutrality. On the

Fig. 6 Trends in use of the natural gas and nuclear energy in global scenarios in 2020 and 2050



Source: table created by the authors, based on international scenarios data other hand, *Bloomberg* scenario indicates that nuclear energy will play a leading role in the future of clean energy.

In general, in all the scenarios, a decrease in the natural gas demand after 2030 is determined by wider electrification, increased use of RES, and introduction of green hydrogen in the energy, building, and industrial sectors.

At the same time, the scenarios note that natural gas could play a new role in the production of blue hydrogen and ammonia, and the natural gas infrastructure could be used for low-carbon fuels such as hydrogen and biogas, or to transport CO_2 to carbon capture, utilization, and storages (CCUSs).

THE WARTIME IMPACT ON THE ENERGY SECTOR AND TRANSITIONING FROM RUSSIAN GAS (short-term perspective)

The world is suffering from global upheavals caused by the convergence of several factors: climate change, the Covid-19 pandemic, and the Russian invasion of Ukraine on February 24, 2022. Although the impact of these factors is uneven, it is felt at all levels of society. The survey conducted by the World Energy Council in April 2022, in which 696 energy experts from 87 countries have participated, reflects the assessment and expectations of global and regional trends by world energy leaders.

The European energy security crisis and the global climate crisis occupy the first place on the list of energy problems. At the same time, 46 % of energy managers admit that it is important to maintain a balance between all three dimensions of the Energy Trilemma – energy security, sustainability, (as of April 2022) the governments'

and availability. The significance of the impact of the Covid-19 pandemic has decreased proportionately throughout the world, except for Africa and Asia. More than 80 % of global respondents have reported a direct and/or indirect impact of the European energy security crisis on their energy supply chains. The same number of respondents predict long-term or even permanent disruptions in energy markets, and 25 % doubt that markets will ever return to pre-crisis conditions.

86 % of global respondents believe that governments should intervene in the functioning of the market, ensuring access to energy for users. At the same time, respondents indicate that (as of April 2022) the government's actions have been very limited in terms of energy supply security and price.

More than 50 % of global respondents expect the current turmoil to accelerate moving towards climate neutrality. This opinion is especially strong in Asia, Europe, and North America.

Investments in the diversification of energy sources are considered a priority in addressing the challenges of energy supply security and availability; almost all regions agree that a new electricity market design is needed. Likewise, the restoration of coal and nuclear power generation is being considered in Europe and Asia, while the introduction of wholesale market price ceilings has been discussed in Latin America and the Caribbean region.

Diversification of energy supplies is focused mostly on RES, while investments in oil and gas have increased despite the decreasing tendencies of recent years. Energy efficiency is undoubtedly the first choice on the demand side of energy management. Balanced and diversified investments in energy storage and infrastructure are considered a global priority.

Repeating a similar survey in July of this year, energy experts admitted that the world is suffering from global upheavals caused by the convergence of several factors: climate change, the Covid-19 pandemic, and the war launched by Russia in Ukraine on February 24, 2022. When answering the question of how long it would take for the world to stabilize, taking into account the existing crises, most experts note a period of up to 5 years.

Evaluating scenarios for the security of energy supply in the EU during the 2022/2023 heating season, several aspects must be taken into account:

- The European energy market is fairly well integrated. The electricity price difference is formed based on interconnection capacity, energy supply (which depends on the electricity generation portfolio), and demand in the respective price zone. A single price zone can combine several countries or one country can be divided into several price zones;
- normal market operation principles are significantly affected in crises;
- electricity generation requires the installed capacity of power plants and the energy source;
- natural gas, coal, and nuclear energy can provide base-load generation on a large scale with current technologies.

The largest EU energy producers, which use natural gas, coal, or nuclear energy as an energy source, and their installed capacities are shown in Table 1. On the day and time chosen for a sample, demand and supply correspond to the normal trend (except for the correction to high prices of natural gas, which affects the choice of the generation energy source in the market) and can be used for the evaluation of the sample. The table shows that there is currently a large potential of unused nuclear energy in France.

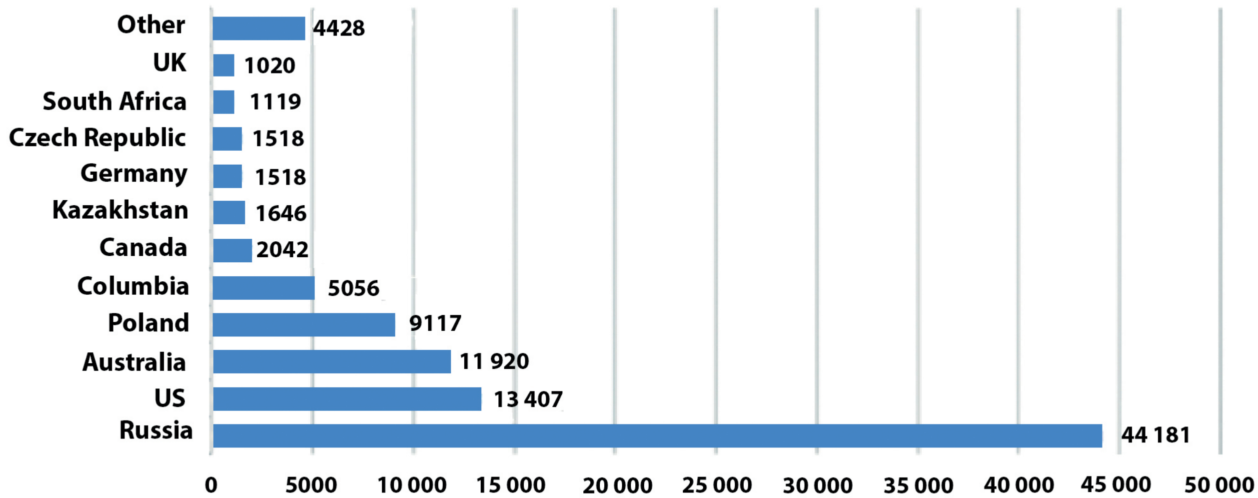
The baseload power plants

Evaluating possibilities to redirect electricity generation from Russian natural gas, three options would be possible in the short term: alternative suppliers of natural gas, greater energy generation in coal plants, and greater energy generation in nuclear power plants.

As can be seen in Figure 7, the EU countries predominantly (46 %) import fossil fuels, for example, coal, from Russia. The only EU country that exports coal to other countries is Poland. At the same time, Poland's export to third countries (to India – 941 thousand tons) is not sufficient to significantly improve the security of energy supply, diverting this amount to the internal demand of the EU. Assuming that the natural gas supplies from Russia to the EU are disrupted for political reasons, reducing the risk of energy dependence by putting more emphasis on operating coal-fired power plants would be possible by diversifying coal supplies.

Several countries, such as Germany, the Netherlands, Austria, and France, are preparing their coal-fired power plants in case if emergency energy crisis occurs. At the same time, in April 2022, the EU agreed on a complete

Fig. 7 Solid fossil fuel imports in the EU in 2020, thousand tons



Source: Eurostat, 2022. https://ec.europa.eu/eurostat/databrowser/view/NRG_TI_SFF__custom_3120348/default/table?lang=en

Fig. 8 Supply energy portfolio and diversification (global scale)

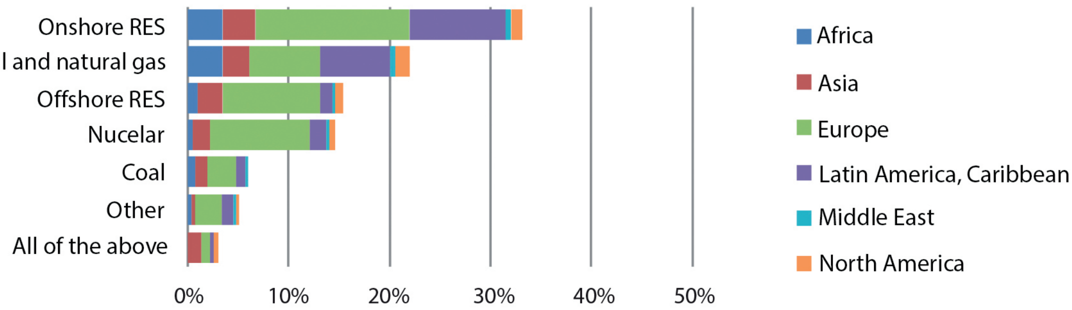


Fig. 9 Demand-side energy portfolio and diversification (global scale)

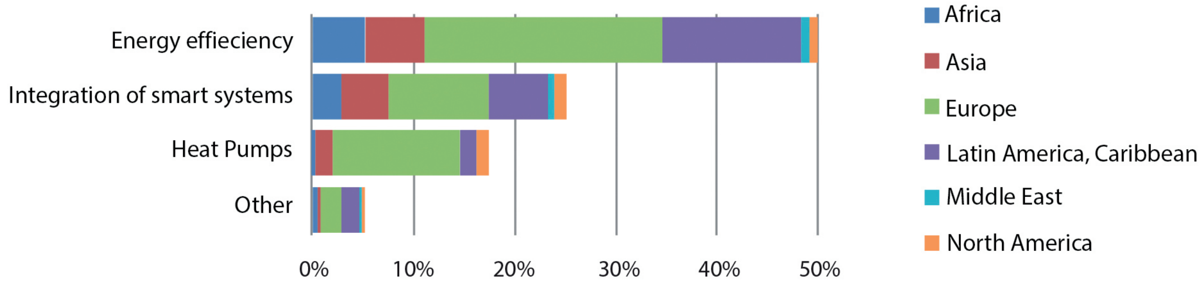


Fig. 10 Storage and energy infrastructure (global scale)

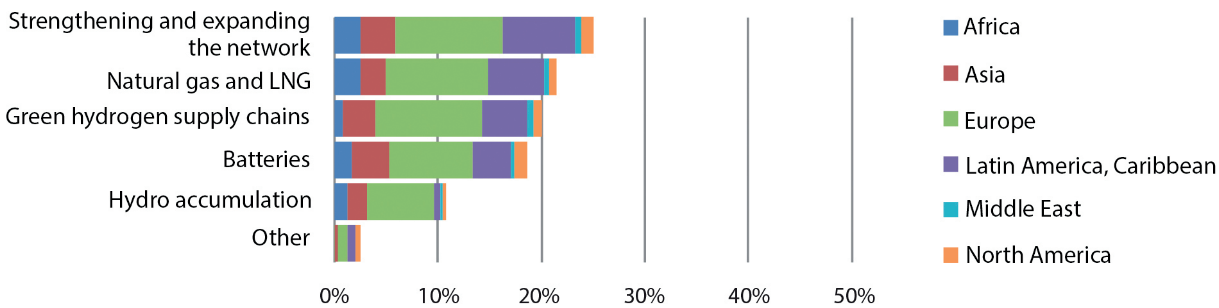


Fig. 11 Installed and used baseload capacities of power plants (MW)

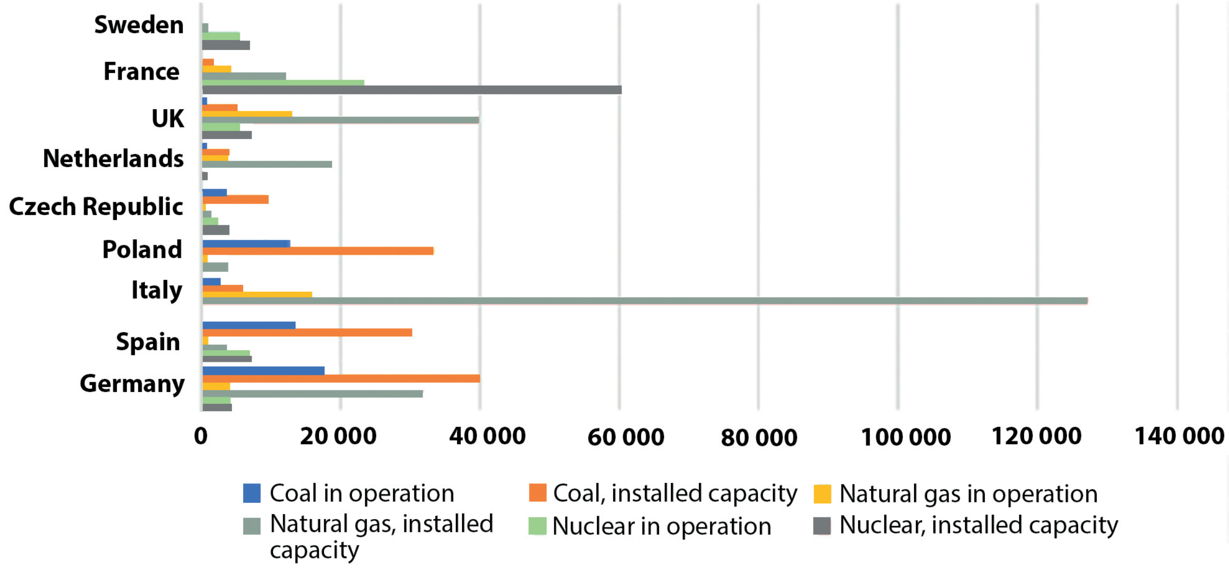
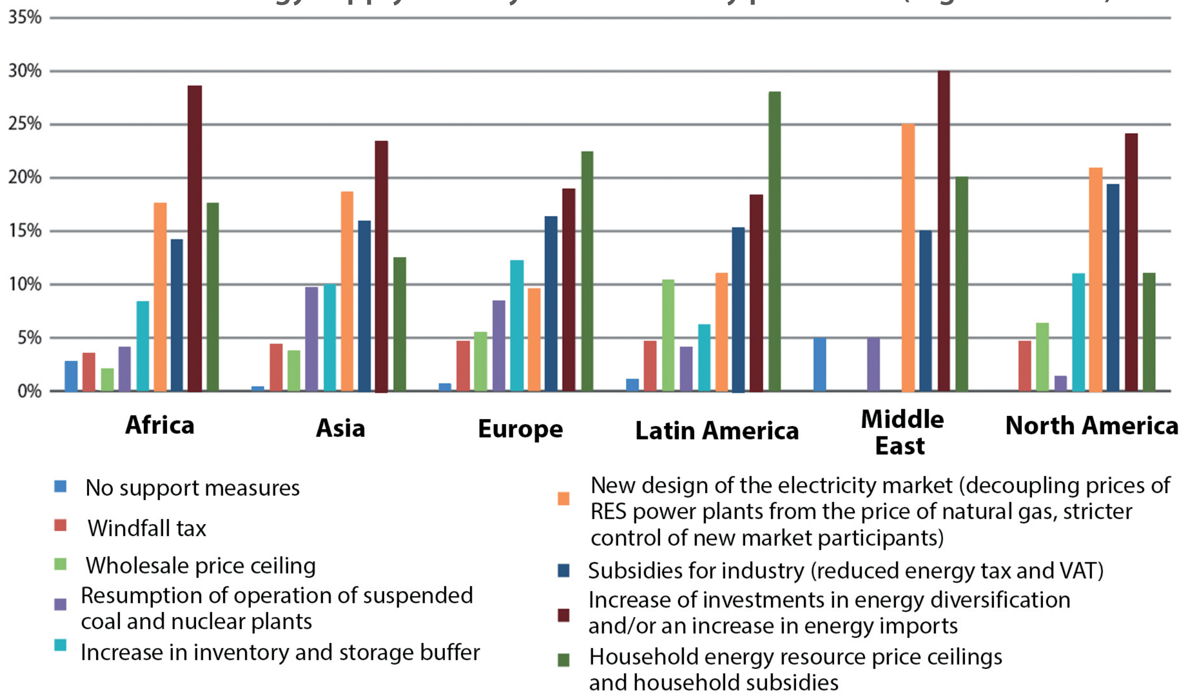


Fig. 12 Which of the following support measures are used in your country to address the new energy supply security and availability problems? (regional-scale)



Source: World Energy Council, 2022. https://www.worldenergy.org/assets/downloads/World_Energy_Pulse_2022.pdf?v=1651662106

ban on the import of "all types" of Russian coal, which entered into force on August 10, providing for the replacement of coal produced in Russia with alternative supplies. Analysts predict that coal could come to Europe from the USA, South America, and South Africa. At the same time, the price of coal in the summer of 2022 was already 2.5 times higher than in the previous year, and the availability and price of coal in the 2022/2023 heating season would be determined mainly by China and India – the largest consumers of coal.

Increasing the intensity of NPP operation in the short term should be evaluated from a technical point of view. The largest installed capacity of NPP in the EU is located in France. By end of July 2022, the capacity is used for ~40 %. This is explained, on the one hand, by safety considerations in hot weather and planned maintenance and repair. On the other hand, there is a very unusual and problematic situation at the *Blayais 1* nuclear power plant, whose employees have gone on strike, preventing the planned maintenance measures from being carried out. As a result, the NPP operated in the summer at the market price in the French price zone of 500 EUR/MWh. However, with a high degree of probability it will not be able to operate in January 2023 (very likely also in February) with forward prices of 1000 EUR/MWh, creating not only additional tension in the markets but also increasing the

Table 1 Installed capacities of baseload generation and their loading sample on 26.07.2022 at 15:00

	Installed capacity, nuclear	In exploitation, nuclear	Delta, nuclear	Installed capacity, natural gas	In exploitation, natural gas	Delta, natural gas	Installed capacity, coal	In exploitation, coal	Delta, coal
Germany	4 060	3 970	98%	31 700	4 100	13%	39 900	17 800	45%
Spain	7 120	6 950	98%	3 760	1 020	27%	30 200	13 400	44%
Italy	0	0	0%	127 190	15 999	13%	6 020	2 329	39%
Poland	0	0	0%	3 770	716	19%	33 300	12 600	38%
Czech Republic	4 040	2 370	59%	1 230	571	46%	9 280	3 420	37%
Netherlands	485	219	45%	18 500	3 900	21%	4 010	590	15%
UK	6 850	5 510	80%	39 800	13 100	33%	5 240	690	13%
France	61 400	23 500	38%	12 200	4 280	35%	1 820	41	2%
Sweden	6 870	5 540	81%	698	0	0%	0	0	0%

Source: table created by the authors, using NordPool and ENTSO-E data

risk of blackout in winter. France has relatively old NPPs that require careful maintenance, at the same time several repairs were postponed due to the Covid-19 pandemic, affecting the repair plans for the next 5 years. These facts indicate that during the winter season French NPPs will be available at a lower capacity than usual.

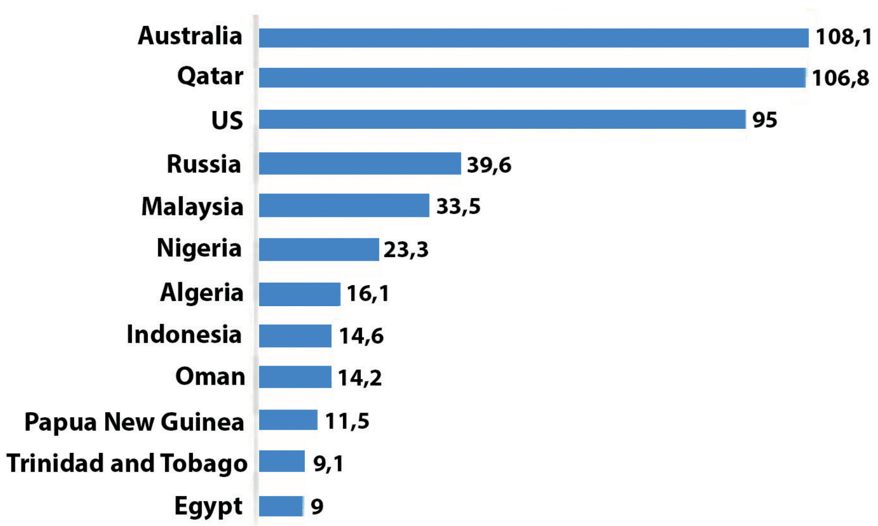
Alternative LNG supplies are reflected in Figure 13. In 2021, the largest share of LNG supplies to the EU was obtained from the USA, Qatar, and Russia. According to the data of CEDIGAZ, these three countries together accounted for almost 70 % of total European LNG imports. The US became Europe's largest source of LNG in 2021, accounting for 26 % of all LNG imported by the EU member states and the UK, followed by Qatar with 24 % and Russia with 20 %. In January 2022, the US supplied more than half of all LNG imported to Europe during the month.

In recent years, the natural gas supply disruptions in Europe and low storage volumes in the underground natural gas storage (UGS) facilities have contributed to the increase in the US LNG exports to Europe. Natural gas production in Europe has been steadily declining both due to the curtailment of production in the Groningen field, the Netherlands, and the reduction of the natural gas production volumes in the North Sea fields. To meet the demand, the import of natural gas in Europe, especially from Russia, has increased in recent years.

According to *Refinitiv Eikon*, the natural gas pipeline flows from Russia decreased in 2021. Pipeline flows from Russia at the three main entry points (Kondratki in Poland, Greifswald in Germany and *Velke Kapusany* in Slovakia, which together account for 14.3 billion cubic feet per day (Bcf/d) of import pipeline capacity from Russia) averaged 10.7 Bcf/d in 2021, compared to 11.8 Bcf/d in 2020 and 14.1 Bcf/d in 2019. A larger amount of natural gas delivered via pipeline from Norway, which increased from 10.4 Bcf/d in 2019 and 2020 to 11.1 Bcf/d in 2021, was not enough to offset reduced pipeline gas deliveries from Russia.

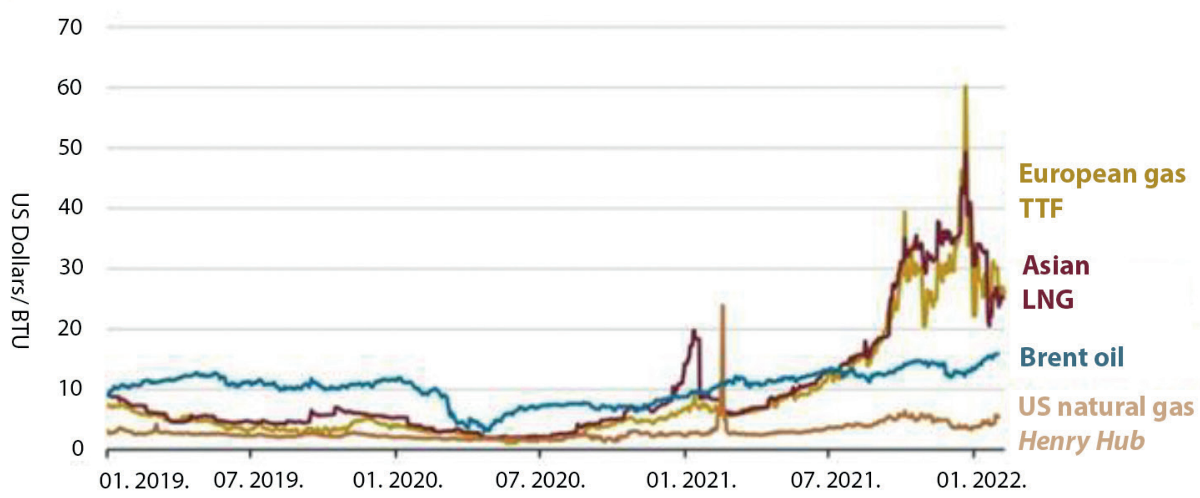
Supply problems in the European market have led to an increase in regional natural gas prices. The spot price of natural gas on the TTF exchange in the Netherlands – the most liquid virtual natural gas hub in Europe – has been high at all times. From September 2021 to the first week of February 2022, TTF averaged $28.52 per million British thermal units (MMBtu). The TTF price peaked on December 21, 2021, at USD 60.20 per MMBtu. Before this sharp increase, TTF averaged $9.28/MMBtu from January to August 2021, $3.28/MMBtu in 2020, $4.45/MMBtu

Fig. 13 The leading LNG exporting countries in the world, 2021, BCM



Source: Statista, 2022. https://www.statista.com/statistics/274528/major-exporting-countries-of-lng/

Fig. 14 The natural gas prices in Europe, Asia and the USA



Source: US Energy Information Administration, 2022. https://www.eia.gov/todayinenergy/detail.php?id=51358"https://www.eia.gov/todayinenergy/detail.php?id=5135

in 2019, and $6.45/MMBtu from 2014 to 2018. Historically, the price of natural gas in Europe has been lower than in Asia. However, natural gas prices in Europe have closely followed LNG prices in Asia in recent months. On some days, the price of natural gas in Europe has even exceeded the price of LNG in Asia, attracting a larger volume of flexible LNG supplies to Europe (see Figure 14). LNG imports to Europe increased in December 2021 and January 2022, averaging 10.8 Bcf/d and 14.9 Bcf/d, respectively, partly in response to an increase in the TTF price above LNG spot prices in Asia.

These data indicate that at times of high natural gas prices, the EU has the opportunity to divert part of its natural gas supplies from Asian markets.

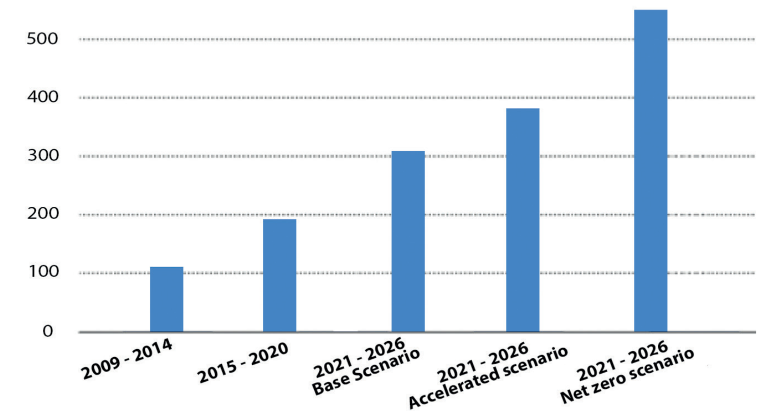
THE RENEWABLE ENERGY POTENTIAL

Discussions about the future of RES are closely related to climate change and the reduction of GHG emissions. Consequently, future development visions and scenarios are often depicted as conditions to be fulfilled and goals to be achieved. On a global scale, the Paris Agreement adopted in 2015 outlines the policy guidelines for the energy transition to non-fossil fuels. Countries have agreed to keep the increase in global average temperature below 2 °C (preferably 1.5 °C) compared to the pre-industrial era and to ensure an increase in the share of RES in the energy portfolio as an integral part of achieving this goal. However, the GHG emission reduction targets set by the countries so far have not been sufficient to achieve the goals set by the Paris Agreement.[1]

Consequently, there is an opportunity to set more ambitious goals, as evidenced by, for example, Finland's recent commitment to become carbon neutral, that is, to achieve the goal of net zero emissions, by 2035.[2] The government used an analysis commissioned by the Finnish Climate Change Panel to calculate Finland's share of the global carbon budget to meet the 1.5 °C mark set by the Paris Agreement. Considerations took into account Finland's share of the global population, the country's comparative ability to pay for emissions reductions, as well as its historical responsibility for past emissions. The calculations also recognized the importance of the national forests: both as a source of bioenergy, which plays a crucial role in Finland's energy portfolio, and as a carbon sink, since forests absorb part of the CO_2 emissions entering the atmosphere.[3] In terms of RES, Finland has one of the highest percentages of RES in the EU (44 % in 2020) and plans to reach at least 51 % by 2030. To achieve this target, among other things, in Finland, it is planned to increase the amount of electricity production from bioenergy sources (mostly from wooden biomass), as well as to increase the installed capacity of wind and solar energy.[4]

In recent years, the capacity of RES has increased not only in planning documents, but also in reality – especially the amount of electricity that can potentially be produced using RES has increased. Estimates by the International Energy Agency (IEA) show that between 2015 and 2020 the installed RES capacity increased by an average of 193.2 gigawatts (GW) per year.[5] Last year, despite supply chain disruptions, construction delays and skyrocketing material costs, new RES capacity exceeded previous forecasts to nearly 295 GW.[6] However, most experts agree that the increase in RES generation and transition from fossil fuels to greener energy options are insufficient to meet the 1.5 °C target. For example, the IEA has developed its scenario of net zero emissions until 2050, indicating the necessary increase in RES capacity and other necessary changes in the coming years, which significantly exceed the number of changes that countries have made so far, as well as the expected changes.[7]

Fig. 15 Average annual global renewable electricity capacity additions, historical and forecasts, 2009-2026 (GW)



Source: IEA

A similar analysis has been carried out by other organizations. In its latest report, the International Renewable Energy Agency (IRENA) identifies six technological applications that could help meet the Paris climate goal. All these applications are related to RES to some extent, either directly or indirectly, when direct use of RES is not possible: (1) wider use of RES in electricity generation and in other applications such as heating; (2) increasing energy efficiency; (3) electrification of end-use sectors; (4) increased use of green hydrogen in hard-to-electrify sectors; (5) increased use of bioenergy combined with carbon capture and storage (CCS); (6) wider use of CCS to decarbonize fossil fuel emission processes (mainly in the industry).[8]

Europe is one of the leaders in the energy transition. In response to the Covid-19 pandemic, an analysis of fiscal recovery spending by G20 economies in 2020 and 2021 shows that globally only 6 % (about $860 billion) of eco-

[1] United Nations / Framework Convention on Climate Change. 2021. Nationally determined contributions under the Paris Agreement. Revised synthesis report by the secretariat. https://unfccc.int/sites/default/files/resource/cma2021_08r01_E.pdf

[2] Suomen Säädöskokoelma. 2022. Ilmastolaki (423/20222). https://www.finlex.fi/fi/laki/kokoelma/2022/sk20220423.pdf

[3] The Finnish Climate Change Panel. 2019. An Approach to Nationally Determined Contributions Consistent with the Paris Climate Agreement and Climate Science: Application to Finland and the EU. https://www.ilmastopaneeli.fi/wp-content/uploads/2019/10/Finlands-globally-responsible-contribution_final.pdf

[4] Ministry of Economic Affairs and Employment of Finland. 2019. Finland's Integrated Energy and Climate Plan. https://energy.ec.europa.eu/system/files/2020-01/fi_final_necp_main_en_0.pdf

[5] IEA. 2021. Net Zero by 2050. https://www.iea.org/reports/net-zero-by-2050

[6] IEA. 2022. Renewable Energy Market Update: Outlook for 2022 and 2023. https://www.iea.org/reports/renewable-energy-market-update-may-2022

[7] IEA. 2021. Op. cit.

[8] IRENA. 2022a. World Energy Transitions Outlook 2022: 1.5°C Pathway. https://irena.org/publications/2022/mar/world-energy-transitions-outlook-2022

nomic recovery stimulus funds have gone to support areas that will help reduce GHG emissions. The EU performed much better, with almost half of its total financial stimulus (just under $500 billion) going to climate-friendly measures, with additional investments also made at the level of member states.[9] These are steps in the right direction, but more needs to be done, as IRENA estimates that Europe will need to invest $3.6 trillion to increase RES capacity to meet the 1.5°C thresholds. The global RES installed capacity, which was 610 GW in 2020, should increase three times by 2030 and six times by 2050.[10] In any case, the energy transition will not be an easy and quick process. This has been the case with the energy transition process in the past[11], and it is also currently indicated by at least the short-term complications caused by the Russian invasion of Ukraine.[12]

SOLAR ENERGY

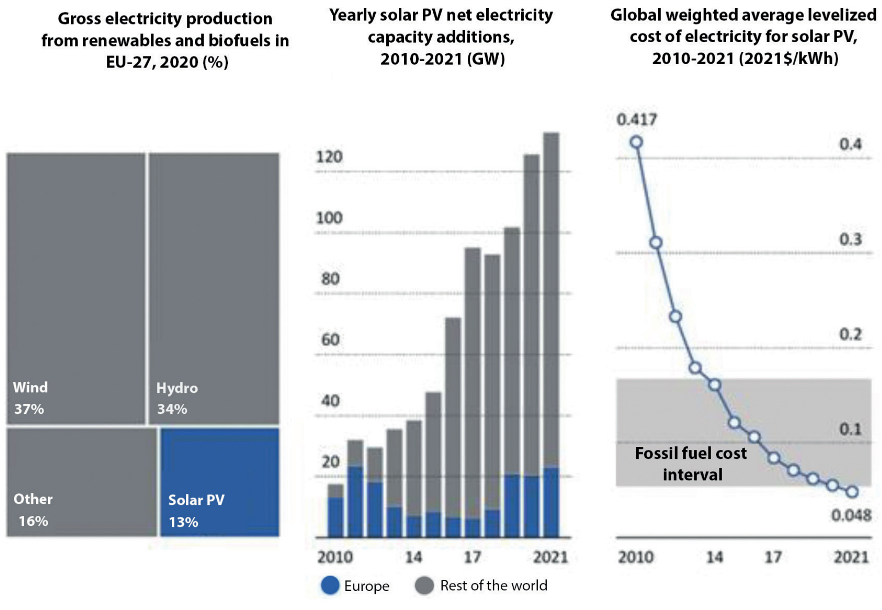
Currently, RES can be used most efficiently in the production of electricity. In the past ten years, solar photovoltaic (PV) modules have become much cheaper and more widely used. The weighted average Levelized cost of electricity (LCOE)[13] for large-scale solar PV plants in 2021 was $0.048/kWh. This is 88 % less than in 2010. In 2021, a total capacity of solar PV plants reached 843 GW. The annual increase was even higher with the 2020 record – 133 GW, of which 23 GW were installed in Europe. In turn, the growing amount of installed capacity has allowed equipment manufacturers to make technological improvements, as a result of which a significant increase in competencies and knowledge in the field of solar PV technologies has been achieved in the past decade. Most of these improvements have enabled the production of cheaper solar PV modules, which account for 45 % of the LCOE reduction of solar PV. Only 17 % of the reduction in solar PV LCOE is related to improvements in other aspects. Engineering, procurement, installation, and other costs have also decreased, while market maturity has improved financing conditions. The implementation of projects in areas better suited for the use of solar energy has allowed for increasing the predictable amounts of electricity produced throughout the projects' life cycle.[14]

In 2021, the cost of materials, which previously tended to decrease, experienced a significant increase – until March 2022, the price of polysilicon, widely used in the production of solar PV modules, increased more than fourfold. Copper, steel, and aluminum prices also increased, as did freight costs. These developments have already put pressure on module prices in at least some markets. Analysts predict that material costs will remain high for at least the next two years. However, from the point of view of competitiveness, the development of solar energy, as well as other RES, has not been hindered, since the prices of fossil fuels and electricity have grown even faster recently.[15]

In the EU, solar PV accounts for 13 % of gross electricity generation from RES and continues to grow.[16]

At the national level, the Netherlands has the highest per capita solar installation in the EU (825 watts per capita).[17]

Fig. 16 Electricity production, capacity additions and costs for solar PV



Source: Eurostat, IRENA

Legally, the recently published report comparing administrative, spatial planning, grid access and other barriers to the development of solar and wind projects at the EU member state level ranks the Netherlands second only to Luxem-

9 Nahm, J. M., S. M. Miller and J. Urpelainen. 2022. G20's US$14-trillion economic stimulus reneges on emissions pledges. Nature, Vol. 603. https://doi.org/10.1038/d41586-022-00540-6

10 IRENA. 2022a. Op. cit.

11 Smil, V. 2017. Energy Transitions: Global and National Perspectives, 2nd Ed. Santa Barbara, California: Praeger.

12 McKinsey & Company. 2022. The net-zero transition in the wake of the war in Ukraine: A detour, a derailment, or a different path? https://www.mckinsey.com/business-functions/sustainability/our-insights/the-net-zero-transition-in-the-wake-of-the-war-in-ukraine-a-detour-a-derailment-or-a-different-path

13 LCOE is calculated as a ratio of lifetime costs (investment, fuel, operations, and maintenance, etc.) to lifetime electricity generation. Government incentives or subsidies are not included. All components are discounted back to a common year using a discount rate that reflects the average cost of capital. All costs are denominated in real terms with overall price changes taken into account. For precise formulas and calculations see IRENA. 2022b.

14 IRENA. 2022b. Renewable power generation costs in 2021. https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021

15 IEA. 2022. Op. cit.

16 Eurostat. 2022. Production of electricity and derived heat by type of fuel [nrg_bal_peh]. https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_bal_peh&lang=en

17 SolarPower Europe. 2022. Global Market Outlook for Solar Power 2022-2026. https://www.solarpowereurope.org/insights/market-outlooks/global-market-outlook-for-solar-power-2022

bourg.[18] One of the problems that can negatively affect the development of RES, including solar energy, is the surplus of installed capacities of power plants. This is demonstrated by the situation in Spain, where the construction of RES plants was financially supported based on overly optimistic electricity demand forecasts and inadequate planning for the restructuring of the power grid. As a result, significant surpluses of installed capacities were created in the system in some places, and further increase of RES capacities elsewhere was slowed down.[19] In 2021, the share of RES in the total installed electricity capacity in Spain was 59 %. On the other hand, the amount of electricity produced with RES in 2020 reached 42 % of all electricity produced.

Electricity can be produced not only in solar PV, but also by concentrated solar power plants (CSP), whose LCOE also decreased significantly in the last ten years – in 2021 it was equal to $0.107 /kWh. However, it is necessary to mention, that the current calculation is based on one project, the implementation of which was completed last year.[20] There are also some developments of solar energy applications in heating, but installations remain low.

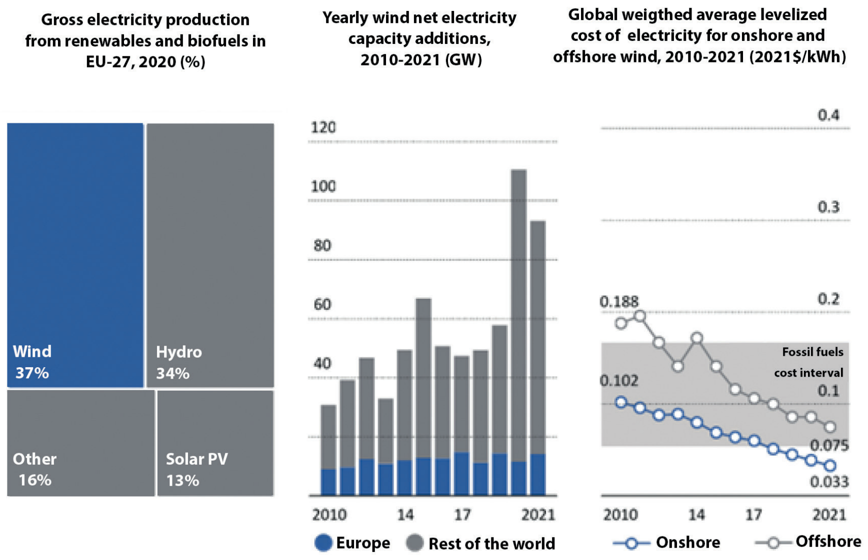
WIND ENERGY

There are two interrelated, but, at the same time, different segments of the wind energy market in terms of technology, regulatory framework, and other aspects: onshore and offshore wind energy. In terms of LCOE, onshore wind is currently the cheapest RES for electricity generation, outperforming all currently available fossil fuel electricity generation technologies. In 2021, the LCOE of onshore wind was $0.033/kWh, which was 68 % lower than in 2010. In the same period, the LCOE of offshore wind decreased by 60 % and was $0.075 /kWh in 2021. Both segments have benefited from technological advances that have resulted in increasing wind turbine sizes and improvements related to safe operation, as well as larger turbine heights and rotor diameters. In onshore projects, wind turbines are the most important cost item, accounting for 64–84 % of the total cost. An additional risk factor for offshore wind farms is the harsh marine environment. As a result, the planning, realization, connection to the grid, as well as subsequent operation and maintenance of these projects are more complex and expensive. However, the utilization ratio of offshore wind farm projects is higher on average, and the ever-growing number of implemented projects helps further reduce the specific costs, which could lead to a decrease in LCOE of offshore wind power below the cost benchmark of onshore wind farm projects in the future.[21] In addition, the limited availability of suitable sites for the implementation of onshore wind farm projects and the costs caused by negative public attitudes can tip the scales in favor of offshore wind projects.[22]

According to IRENA, the total installed capacity of wind farms reached 825 GW in 2021 (of which 769 GW or 93 % onshore). The overall rate of wind capacity installation in 2021 decreased. This was predicted in advance and mainly related to the project delays in China, which occurred a year earlier, which made 2020 a record year – in total, wind capacity increased by 110 GW in 2020. In Europe, in 2021 a total of 14 GW of wind capacity was installed (11 GW of which was onshore), with Germany, the Netherlands, France, Sweden, and Denmark contributing the most.[23]

If we compare the amounts of electricity produced, it is wind energy that accounts for the majority (37 %) of the amount of electricity produced from RES and biofuels in the EU.[24] Among the member states, the leader in the use of wind energy is Denmark. In 2020, wind energy in Denmark not only accounted for 70 % of the RES used for electricity

Fig. 17 Electricity production, capacity additions and costs for onshore and offshore wind



Source: Eurostat, IRENA

[18] Eclareon. 2022. Barriers and best practices for wind and solar electricity in the EU27 and UK. https://www.eclareon.com/sites/default/files/res_policy_monitoring_database_final_report_01_0.pdf

[19] Del Rio, P. and L. Janeiro. 2016. Overcapacity as a Barrier to Renewable Energy Deployment: The Spanish Case. Journal of Energy, Vol. 2016. https://doi.org/10.1155/2016/8510527

[20] IRENA. 2022b. Op. cit.

[21] IRENA. 2022b. Op. cit.

[22] Hevia-Koch, P. and H. K. Jacobsen. 2019. Comparing offshore and onshore wind development considering acceptance costs. Energy Policy, Vol. 125. https://doi.org/10.1016/j.enpol.2018.10.019

[23] IRENA. 2022c. Renewable Capacity Statistics 2022. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Apr/IRENA_RE_Capacity_Statistics_2022.pdf

Eurostat. 2022. Op. cit.

[24] Eurostat. 2022. Op. cit.

production but also allowed for the production of 57 % of all electricity produced in the country.

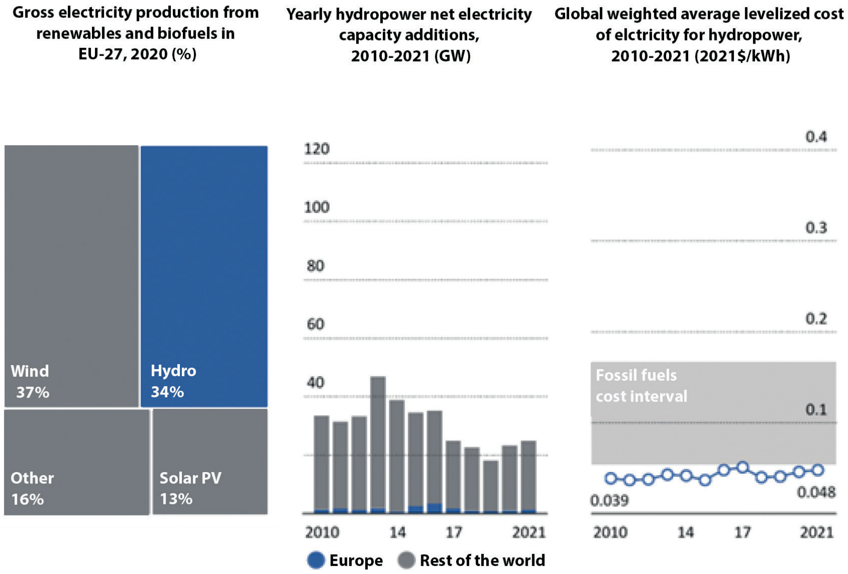
This is the result of a deliberate policy conducted by Denmark for almost 30 years. Looking back, in 1993, the share of RES in electricity production in Denmark was small and amounted to only 3 %.[25] At the same time, Denmark has also developed production and research related to the implementation of wind energy projects. The Danish company *Vestas* is one of the largest wind turbine manufacturers in the world with a 17.7 % market share in 2021.[26] Denmark is also often praised for developing or implementing good practice standards in administrative and market regulation. For example, the Danish Energy Agency (DEA) acts as a one-stop agency for offshore wind project developers, serving as a link between developers and the various authorities involved in licensing offshore wind projects. The DEA was also one of the first to organize technologically neutral RES production tenders, where solar and wind project developers were forced to compete with each other, offering the cheapest solutions.[27]

HYDRO ENERGY

Hydropower is a relatively simple technology that has been used worldwide for a long time. In 2021, the LCOE of hydropower projects was $0.048/kWh. Between 2010 and 2021, the LCOE for hydropower increased by 23 %. Historically, however, LCOE for hydropower has consistently been below or within the cost range of fossil fuel power generation. Also in 2021, 97 % of commissioned hydropower projects had LCOEs in or below the above-mentioned cost range. However, LCOEs for hydropower projects vary more than for solar and wind projects. Hydropower is a capital-intensive technology characterized by a long period of project development and implementation. The possibilities of standardization are limited because the parameters of hydropower projects differ, as well as their role in the national energy systems. The possibilities to develop new economically profitable hydropower projects are also limited, especially in mature markets like Europe. Consequently, developing hydropower projects in areas with more challenging conditions will increase LCOE of these projects. Globally, the total installed capacity of hydropower far exceeds the amounts of solar and wind power. In 2021, the total amount of hydropower capacity reached 1360 GW. On the other hand, the increase in installed capacity in the last five years was smaller – the total capacity of hydropower projects implemented in 2021 was 25 GW, of which only 1.5 GW was in Europe.[28]

The share of hydropower in the gross electricity production from RES and biofuels in the EU is 34 %, but it has decreased over the past ten years.[29] However, hydropower can be very important for energy systems that rely mainly or exclusively on RES. When hydropower plants have a reservoir or pumped storage capability, they can play a critical role in providing grid flexibility services such as frequency regulation, peak load handling, and rotating reserve.[30] For example, last year Norway – the European leader in installed hydropower capacity with 35 GW, – not only increased its hydropower capacity by 1 GW, but also completed the North Sea Link, an underwater electricity interconnection between Norway and the United Kingdom (UK). The new interconnection improves the security of the system across the North Sea region and also allows Norway to export electricity stored in hydropower reservoirs. On the other hand, the UK has the opportunity to export the remaining electricity from its wind parks.[31]

Fig. 18 Electricity production, capacity additions and costs for hydropower



Source: Eurostat, IRENA

OTHER TYPES OF RENEWABLE ENERGY SOURCES

Other RES is currently used less for electricity generation. In addition to solar, wind, and hydropower, IRENA monitors LCOE dynamics for geothermal and biofuel projects. Relatively few such projects are commissioned each

[25] DEA. 2021. Energy Statistics 2019. https://ens.dk/sites/ens.dk/files/Statistik/energystatistics2019_webtilg.pdf

[26] GWEC. 2022. Wind Turbine suppliers see a record year for deliveries despite supply chain and market pressures. https://gwec.net/wind-turbine-suppliers-see-record-year-for-deliveries-despite-supply-chain-and-market-pressures/

[27] Eclareon. 2022. Op. cit.

[28] IRENA. 2022b. Op. cit.

[29] Eurostat. 2022. Op. cit.

[30] IEA. 2021. Hydropower Special Market Report: Analysis and Forecast to 2030. https://www.iea.org/reports/hydropower-special-market-report

[31] BBC. 2021. Full power ahead for the UK to Norway under-sea power cable. https://www.bbc.com/news/uk-england-tyne-58772572

year and their cost structures as well as capacity factors are very specific to each particular project and location. Global weighted averages, therefore, vary considerably from year to year and should be interpreted with caution. The LCOE for geothermal projects commissioned in 2021 was $0.068/kWh, while for bioenergy projects it was $0.067/kWh. These numbers are slightly above the cost of electricity offered by the cheapest new fossil fuel-fired power generation projects.[32] The total installed electricity capacity from other RES (geothermal, bioenergy, wave and tidal energy) was 160 GW in 2021 (44 GW of them in Europe).[33] The increase in net installed capacity corresponded to 12 GW, of which the European contribution was only 0.4 GW.

Other RES sources (mainly solid biofuel and biogas) account for 16 % of the electricity produced by RES and biofuels in the EU. Bioenergy is also used in heating and other areas. Part of it is still used in traditional inefficient ways of heating and cooking, which harm both human health and contribute to forest degradation. In the future, we can expect further replacement of traditional biomass – especially solid fuels – with modern alternatives derived from woodworking, forestry and agricultural waste and solid waste, as well as with the wider use of other technological solutions (e.g., heat pumps).[34]

Looking at biomass as a whole, more than two-thirds of it used for energy in Europe comes from forestry, and one-third – from the agriculture and waste processing sectors.[35] Calculations show that current trends of ever-increasing biomass use in Europe are not sustainable, and the limited biomass resources will have to be used in areas where their added value is the highest. Currently, in Europe, approximately 6 exajoules (EJ) of biomass per year are diverted to electriciy generation, while approximately 4 EJ of biomass are used as materials in other industries (e.g., wood industry, pulp, paper, and other production).[36]

Associations and think tanks of various energy industries offer significant increases in the amount of biomass use for electriciy generation: 4–5 EJ for road transport, 5–6 EJ for biogas production, 7 EJ for electricity production, more than 4 EJ for chemical industry. However, with the wider application of the principles of the circular economy, new possibilities of use for biomass are being found as production materials, and it is expected that the consumption of biomass materials could increase by an amount equivalent to 2–5 EJ. Therefore, the total demand for biomass is significantly higher than 11–13 EJ that can be produced in Europe without jeopardizing the climate change and GHG emission reduction goals. Policy makers will have to evaluate how to use limited biomass resources. The highest added value of biomass is currently associated with its use as a production material. On the other hand, traditional applications in bioenergy, together with the electrification and the improvement of green hydrogen extraction technologies, are likely to become relatively less profitable.

Instead, in the energy sector, biomass could be most optimally used in niche applications, where electrification options are limited and hydrogen utilization is difficult, but where nearly continuous high-temperature thermal energy is required to ensure the production process. Likewise, biomass as an energy source will retain its potential for use in aviation and electricity generation to ensure the flexibility of the system.[37]

32 IRENA. 2022b. Op. cit.

33 IRENA. 2022b. Op. cit.

34 IRENA. 2022b. Op. cit.

35 Bioenergy Europe. 2021. Policy Brief: Biomass Supply. https://bioenergyeurope.org/article/330-biomass-supply-2021.html

36 For comparison, 1 EJ is equivalent to 55 million t of wood, or the output of 5-7 million ha of cropland.

37 Material Economics. 2021. EU Biomass Use in a Net-Zero Economy – A Course Correction for EU Biomass. https://materialeconomics.com/latest-updates/eu-biomass-use

THE POTENTIAL OF HYDROGEN

THE HYDROGEN SYSTEM

Hydrogen is one of the most abundant elements in the universe, but its potential for electriciy generation is only now being explored. It is predicted that hydrogen technologies will be able to solve critical problems in the energy sector, especially in the energy storage and transformation. Hydrogen can be used as fuel or as an energy carrier. Modern technologies offer ways to decarbonize a range of industries, including long-distance transport, the chemical industry, and the iron and steel industries, which are energy-intensive and where a decrease in GHG emissions is challenging.[38] In addition, hydrogen can also help improve air quality and strengthen energy security.

Several technologies and resources are used for the production of hydrogen; thus, the palette of hydrogen is multi-colored, which also significantly changes the impact of the technology on nature. Green hydrogen is one of the tools that will help to achieve the decarbonization goals set by the EU. This is also reflected in the proposals of the EC on the use of green hydrogen in the package "Fit for 55".[39] It is planned that green hydrogen will comprise 50 % of the total hydrogen consumption in the industry and 2.6 % of all consumed fuel by 2030.

In May 2022, the EC, with the publication of the *REPowerEU* plan[40], implemented the European Hydrogen Strategy, which simultaneously showed Europe's ambitions for renewable hydrogen as an important energy carrier to prevent fossil fuel imports from Russia.

Green hydrogen provides an opportunity for the decarbonization of several sectors, as well as increases the flexibility of the energy system. It gives support for systems with a high share of variable generation. Green hydrogen is produced through an electrolysis process by consuming surplus electricity from, for example, wind, solar, and hydropower plants, thus providing variable generation integration into the electriciy generation process and balancing service.

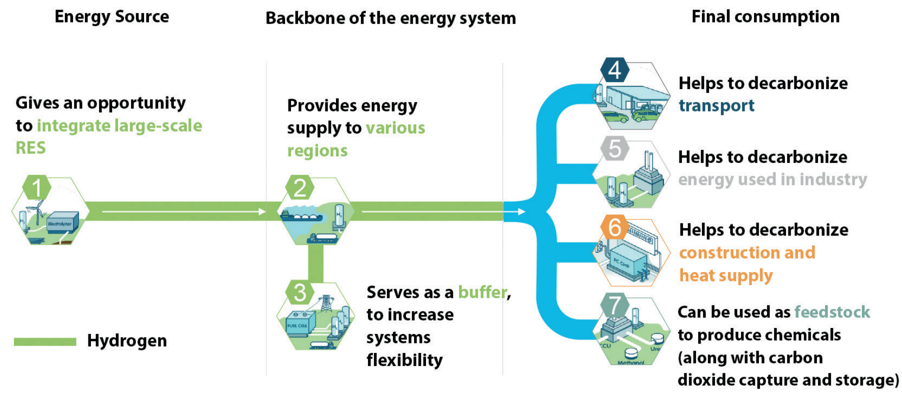
Green hydrogen storage is a buffer between electricity demand and supply. Hydrogen has a high energy density, so it can be easily stored and transported. Transporting green hydrogen facilitates the spread of RES within regions and countries. Green hydrogen production will also help integrate RES not only in energy, but also in other inflexible sectors where gaseous fuel is needed to ensure processes in industry and transport. Green hydrogen technologies can provide sustainable synergy between sectors and reduce their impact on the climate.[41]

In the energy sector, green hydrogen is developing rapidly and in 2021 it was reported that the estimated production capacity would reach 50 GW[42] in 2030, which would be 25% more than the goals set by the EU. Even before the Russian invasion of Ukraine, in many European countries, such as the Netherlands, Spain, Denmark, Greece, and Germany, the energy sectors were planning the capacity of electrolysis plants that exceeded 5 GW by 2030. Trends show that green hydro will form a stable part of the future energy portfolio, helping reduce the climate impact of inflexible sectors.

Table 2 The main types of hydrogen production

Type		Technology	Resources used and CO2 impact
(green)	Green	Electrolysis	Energy from RES, no CO_2 impact
(blue)	Blue	CCSU	Energy from fossil fuel, CO_2 is captured and stored
(gray)	Gray	SMR	Energy from fossil fuel, CO_2 released into atmosphere

Fig. 19 Role of the green hydrogen



Source: Hydrogen Council, Hydrogen scaling up, A sustainable pathway for the global energy transition, 2017, https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-Scaling-up_Hydrogen-Council_2017.compressed.pdf

[38] IEA, The Future of Hydrogen, 2019, https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf

[39] Eiropas Komisija, Eiropas zaļais kurss un paketē "Gatavi mērķrādītājam 55 %", 2021, https://www.consilium.europa.eu/lv/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

[40] Eiropas Komisija, 2, REPower EU, 022, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483

[41] A Gas for Climate report, Market state and trends in renewable and low-carbon gases in Europe,2021,https://www.europeanbiogas.eu/wp-content/uploads/2021/12/Gas-for-Climate-Market-State-and-Trends-report-2021.pdf

[42] A Gas for Climate report, Market state and trends in renewable and low-carbon gases in Europe,2021,https://www.europeanbiogas.eu/wp-content/uploads/2021/12/Gas-for-Climate-Market-State-and-Trends-report-2021.pdf

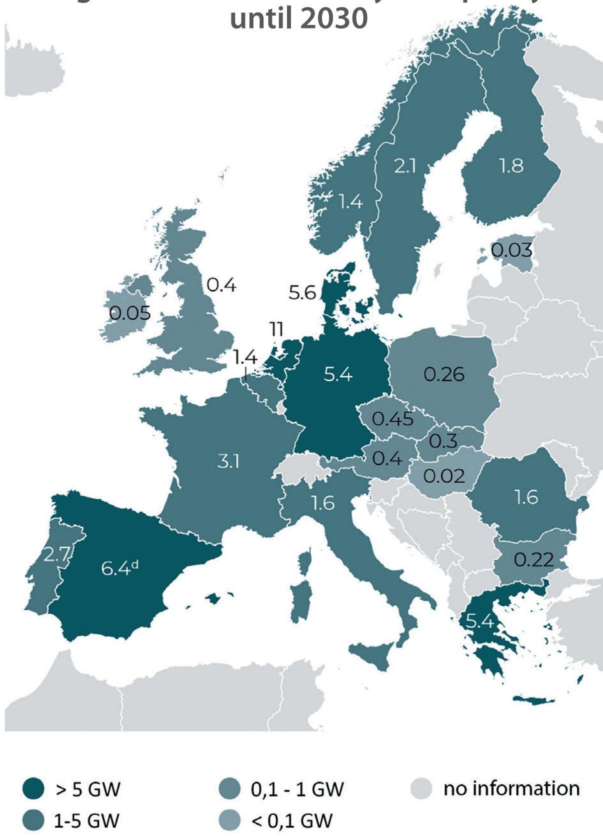
HYDROGEN GAS

Green hydrogen production provides the economy with sustainable energy resources, production of which does not come from fossil fuels. Replacing natural gas with green hydrogen ensures the reduction of CO_2 emissions, promotion of diversification, and saving of natural gas. It is possible to blend hydrogen gas into the natural gas grids, but before it is done, a technical assessment is required, as the two gases have different physical and chemical properties. Hydrogen is characterized by high chemical activity; thus, it harms materials, subjecting them to brittleness. Hydrogen in liquefied form can also be moved with specialized transport. In case when mixing is provided on-site, an additional hydrogen storage or production facility is required.

The permissible proportion of hydrogen in the gas blend injected into the transmission network in the EU can vary from country to country. For example, only 0.5 % is allowed in Sweden, 4 % in Austria and Switzerland, 5 % to 10 % in Germany (depending on the availability of the gas infrastructure). A gas blend with a hydrogen content of up to 12 % is permitted in the Dutch gas network.

A complete transition to hydrogen is possible, but it requires a completely new infrastructure. The *H21 Leeds City Gate* project plans to convert the city of Leeds in the UK completely to a 100 % H_2 gas network for heating, power and household use – from cooking to operation of the boilers. This should be done by 2028. The first phase of the project focuses on providing hydrogen heating in the city. The first techno-economic results of the project for the transformation of the natural gas networks into a hydrogen network were successful.[43]

Fig. 20 Planned electrolysis capacity until 2030



Source: A Gas for Climate report, Market state and trends in renewable and low-carbon gases in Europe,2021

Fig. 21 H21 Leed City gas infrastructure

Source: Leeds City Gate, H21 report, 2016

Under the Green Deal, green hydrogen plays a critical role in the decarbonization of industry and other inflexible sectors. This is especially important for production of iron and steel, ammonia and fuels (including high-value chemicals (HVC)), where hydrogen is mainly used as a feedstock.[44] For example, the picture shows "green" and "traditional" steel production. In "traditional" steel production, natural gas is used to obtain syngas. In the "green" production process, instead of syngas, green hydrogen is immediately used. As a result, natural gas is not used in steel production anymore.

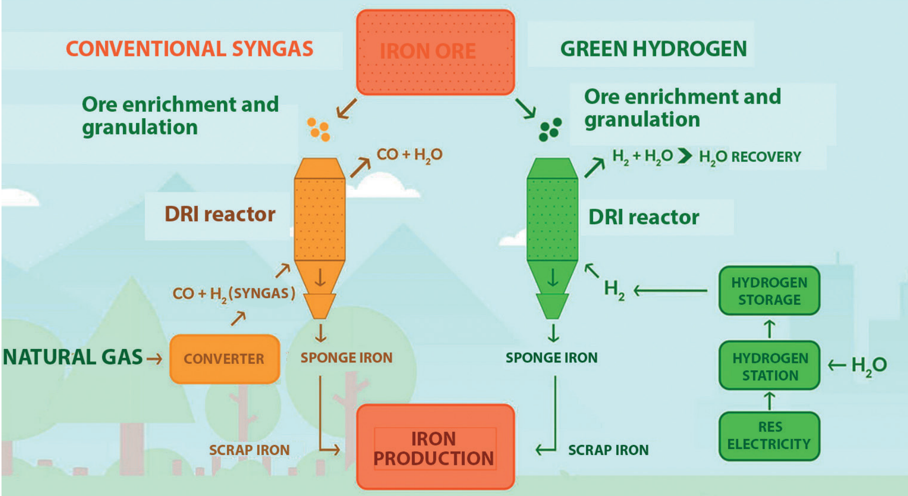
The transition of the European steel industry to the use of green hydrogen will accelerate rapidly: by 2030, the production capacity of hydrogen-based steel will operate at approximately 41 Mt/year, which is approximately 35 % of the current industry capacity.

[43] H21 Leeds City Gate, 2022, https://h21.green/projects/h21-leeds-city-gate/

[44] Anthony Wang and others, 'Analysing Future Demand, Supply, and Transport of Hydrogen', European Hydrogen Backbone, 2021, https://transparency.entsog.eu/

For hydrogen, this could mean about 80 TWh/year of demand. In the Baltic region, the leading large-volume hydrogen-consuming industries (ammonia and methanol production plants, metallurgical companies) are not present. However, there are diverse industries and active companies that are very likely to become consumers of the produced hydrogen. Active use of hydrogen in Europe provides an opportunity for regions with abundant RES, but low consumption of industries to promote their export capacity and reduce the impact on nature.

Fig. 22 Iron production from conventional syngas and green hydrogen



Source: Green Hydrogen as a Clean Process Alternative in the Iron and Steel Industry

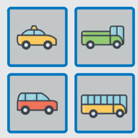
HYDROGEN FUEL

In the EU, transport accounts for about a third of CO_2 emissions, which explains the high priority of the sector's decarbonization efforts. Hydrogen's high energy capacity per weight unit makes it one of the most promising future fuels for transportation. Hydrogen contains 33.33 kWh of energy per kilogram, compared to 12 kWh for gasoline or diesel.

Hydrogen fuel cells require fewer raw materials than batteries and internal combustion engines. Likewise, the construction of hydrogen filling stations requires about a tenth of the area compared to electric car charging; hydrogen logistics processes do not require the reconstruction of electricity distribution networks, which is necessary especially for the needs of fast charging of electric cars. The EC's "Fit for 55"[45] proposals for the use of green hydrogen in transport include the following targets:

- at least 2.6 % share of renewable fuel of non-biological origin (green hydrogen and fuel produced from green hydrogen) in 2030. 0.7 % share of synthetic fuels in aviation in 2030, 5 % in 2035; 8 % in 2040; 11 % in 2045 and 28 % in 2050;
- placement of one hydrogen filling station (with a capacity >2tH2/day and 700 bar) every 150 km in the TEN-T (*Trans-European Transport Network*) main network and in every city on the main routes; placement of one filling station with liquefied hydrogen in every 450 km.

A public bus that uses diesel in its life cycle leaves behind 848 tons of CO_2, and this is in the same public place where we breathe and live, not in the area of a specific power plant. Transport that runs on green hydrogen will not produce CO_2 during its lifetime, unlike electric cars, which in most cases are not produced from RES.[46] The future energy portfolio will include cars with electric engines as well as hydrogen engines, as each of them has its strengths and weaknesses when comparing one technology against the other. The use of green hydrogen in the transport sector will significantly help reduce the overall industry's dependence on fissile resources, as well as significantly reduce its impact on nature and climate change.

	Internal combustion engine, diesel fuel, diesel train generator replacement with for hydrogen electric engines (FCEV) in various vehicles
	Substitution of diesel fuel in shipping with synthetic fuels, hydrogen is used in the production
	Substitution of aviation fuel with synthetic fuels, hydrogen is used in the production

[45] Eiropas Komisija, Eiropas zaļais kurss un pakete "Gatavi mērķrādītājam 55 %", 2021, https://www.consilium.europa.eu/lv/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

[46] Hydrogen Europe, Run on water report gab,2021, https://hydrogeneurope.eu/reports/

THE EUROPEAN NUCLEAR ENERGY POTENTIAL

THE EUROPEAN NUCLEAR ENERGY SYSTEM

Thirteen EU member states produce nuclear energy and, according to *Eurostat*, in 2020 they generated a total of 683,512 gigawatt hours (GWh) of electricity, which accounted for 25 % of total European electricity production and provided baseload capacity in many member states. Nuclear energy, like hydro, wind and solar energy technologies, does not directly produce CO_2. In Europe, nuclear energy produced half of the low-carbon electricity in 2019, so it must be taken into account in the framework of the Green Deal and sustainable development.

Today, nuclear energy is one of the most mature conventional technologies, and it generally corresponds to the highest technology readiness level (system operation is successful, and technological solutions are competitive). At the end of 2021, 437 nuclear reactors in 32 countries were used for electricity production worldwide.[47] Their total installed capacity was 389.5 GW. In 2021, they supplied more than 2,600 TWh of electricity or about 10 % of the global total electricity consumption.

The first nuclear power plants (NPP) were built in the 1950s. Initially, the power of the reactors was only a few tens of megawatts (MW), then gradually, with the development of science and technological capacity, their power reached several hundred MW. Since 2019, the largest nuclear reactor is in operation in China (Taishan-2 with a gross electrical capacity of 1750 MW, and thermal capacity of 4590 MW). The largest reactor in Europe is located in Finland (Olkiluoto-3 with a gross electrical capacity of 1720 MW). The tendency to increase the capacity was to improve the scale effect of the plants and to reduce the variable costs of electricity production.

The largest NPP capacity fleet globally is in the USA – almost 100 GW. France is the second in line (with about 60 GW); however, NPPs are much more important for France than the USA, because nuclear energy produces about 70 % of the country's electricity (68.98 % or 360.7 TWh). The third largest NPP energy producer is China (about 52 MW); however, the construction of NPP in this country is very fast and in a few years it most likely will overtake France. In 2021, China announced a €425 trillion[48] plan to build around 150 new nuclear power plants over the next 15 years to meet growing energy demand and reduce the climate impact of its energy sector.

The EU uranium supplies are geographically diversified. The biggest suppliers are Niger, Russia, Kazakhstan, Canada and Australia. In 2020, the share of no country exceeded 20 % of the total EU uranium deliveries.

Source: fortum.com

The Loviisa nuclear power plant, Finland

Source: depositphotos.com

Temelin nuclear power plant, the Czech Republic

Consequently, the EU would have a rather small risk that uranium supplies could be disrupted or used as a means of geopolitical manipulation, as practiced by Russia with the natural gas supplies.[49]

There are currently 173 nuclear reactors operating in Europe[50], of which 109 are in the EU. According to *Eurostat*, in 2020, the largest nuclear power producers in the EU were

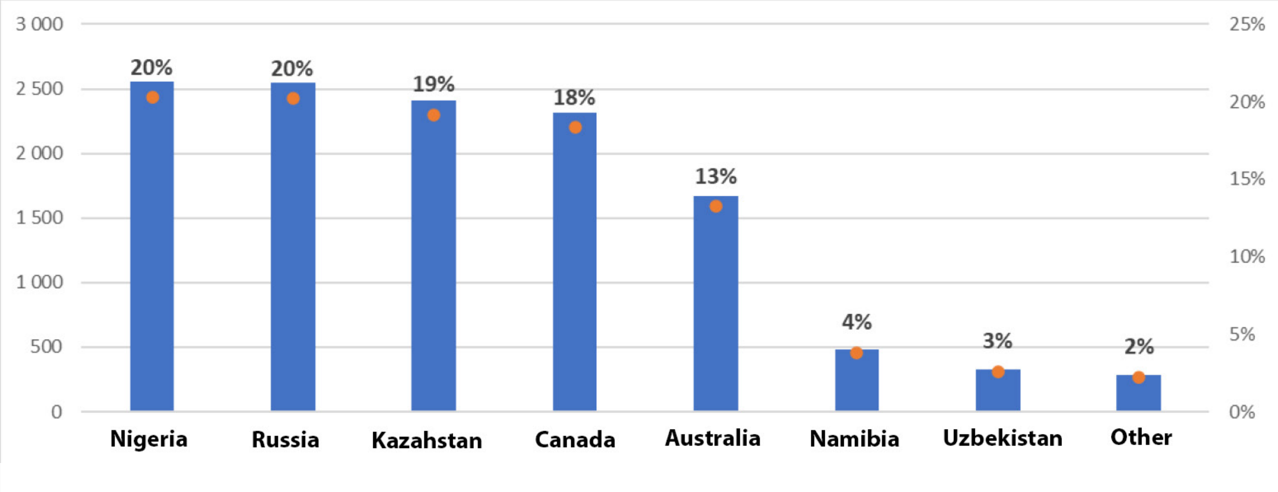
[47] The International Atomic Energy Agency, Amid Global Crises, Nuclear Power Provides Energy Security with Increased Electricity Generation in 2021, https://www.iaea.org/newscenter/news/amid-global-crises-nuclear-power-provides-energy-security-with-increased-electricity-generation-in-2021

[48] Bloomberg GreenEnergy & Science, China's Climate Goals Hinge on a $440 Billion Nuclear Buildout, 2021 https://www.bloomberg.com/news/features/2021-11-02/china-climate-goals-hinge-on-440-billion-nuclear-power-plan-to-rival-u-s

[49] Eurostat dati 2020, https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220111-1
and World Nuclear Association, informācija, 2022
https://world-nuclear.org/information-library/country-profiles/others/european-union.aspx#:~:-text=In%202019%20in%20the%20EU,more%20than%20half%20of%20that.

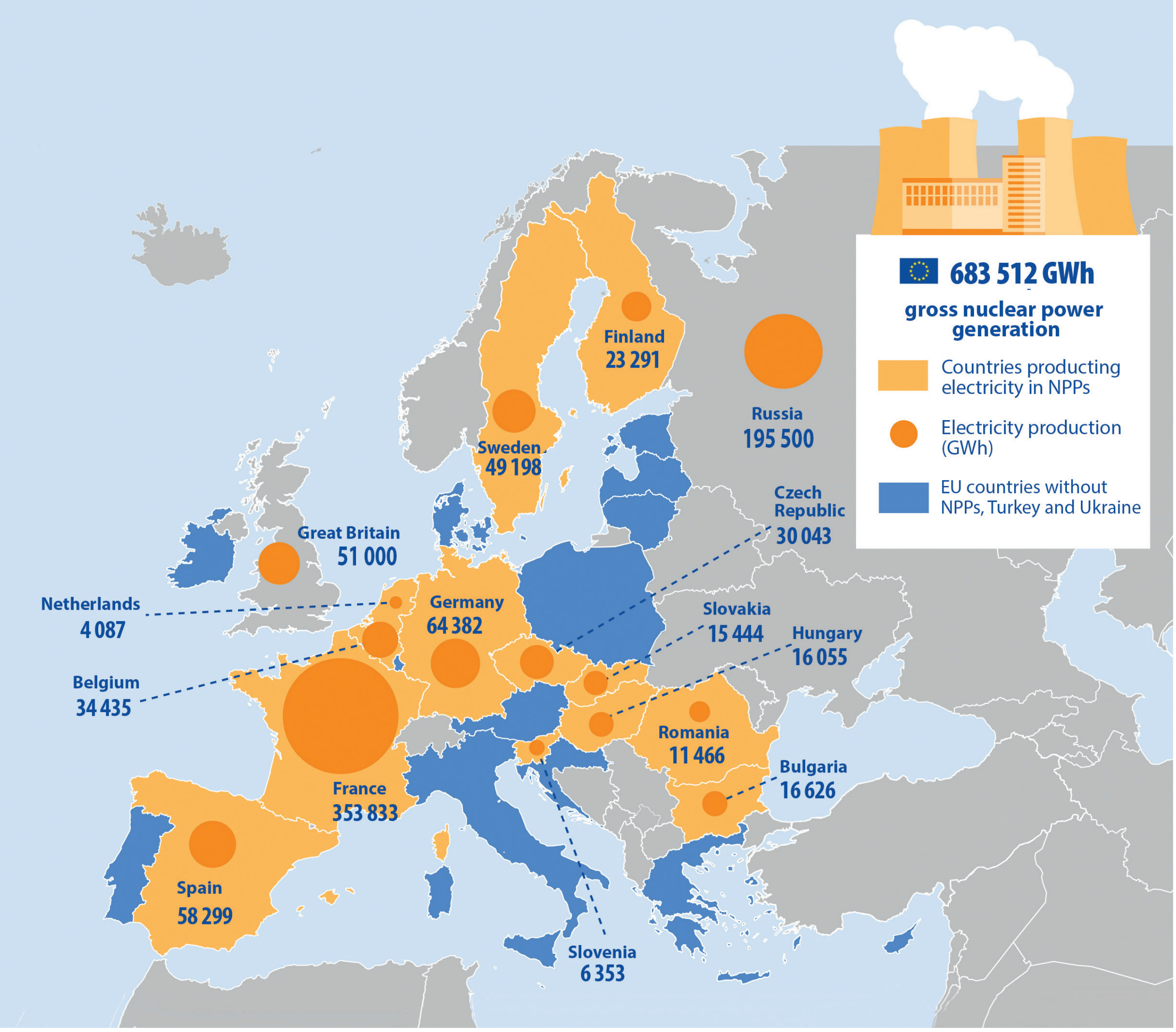
[50] The European Nuclear Society, 2022,
https://www.euronuclear.org/glossary/nuclear-power-plants-in-europe/
and World Nuclear Association, 2022,
https://world-nuclear.org/information-library/country-profiles/others/european-union.aspx#:~:-text=In%202019%20in%20the%20EU,more%20than%20half%20of%20that.

Fig. 23 Countries supplying EU uranium 5 year average



Source: Supply Agency of the European Atomic Energy Community, Annual Report 2020, 2021,
https://euratom-supply.ec.europa.eu/publications/esa-annual-reports_en

Fig. 24 Nuclear energy in Europe



Source: Eurostat dati 2020, https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220111-1 un World Nuclear Association, informācija, 2022
https://world-nuclear.org/information-library/country-profiles/others/european-union.aspx#:~:text=In%202019%20in%20the%20EU,more%20than%20half%20of%20that.

France, Germany, Spain and Sweden. Together, these four countries accounted for more than three-quarters of the total amount of electricity produced in the EU nuclear facilities. Slovakia produced more than half of the electricity in nuclear power plants (54 %). In Hungary, this indicator was 46 %, in Bulgaria – 41 %, in Belgium – 39 %, in Slovenia – 38 %, in the Czech Republic – 37 %, in Finland – 34 %, in Sweden – 30 %, in Spain – 22 %, in Romania – 21 %, in Germany – 11 % and in the Netherlands – 3 %.

The EU is building new NPPs in France (Flamanville-3), Finland (Olkiluoto-3) and Slovakia (Mochovce-4). Construction is also underway in Ukraine (Khmelnitski-3 and Khmelnitski-4) and the UK *(Hinkley Point* C-1 and *Hinkley Point* C-2). The Estonian company Fermi Energia has announced its goal to build a nuclear power plant. In 2021, the Dutch government announced plans to build two new reactors (previously there was a decision to completely abandon nuclear power).[51] Poland has serious plans to develop NPPs. At the same time, several countries are planning to close all existing nuclear power plants, for example, Germany and Belgium. It is possible though that the exploitation period of the Belgian NPP will be extended.[52] The development of NPPs is influenced, formed or hindered by various factors. The most important of them is the availability of alternative sources of electricity, the existence of the national uranium deposits, the desire to strengthen energy independence, public attitudes (expressed in a referendum or otherwise), pressure to reduce CO_2 emissions, shortage of dispatchable power capacities, economic and financial issues, etc.

In recent years, for the EU countries a process of NPP construction has been complicated, with multiple delays and funding exceeding. For example, in Finland it was initially planned that Olkiluoto-3, the construction of which began in 2005, would start operation in 2009. The project cost was estimated to be 3 billion euros (EUR). However, due to various reasons, the power plant was commissioned only in 2021, with a plan to begin commercial operation in December 2022. At the same time, NPP construction costs reached 11 billion EUR. Part of the costs was covered by the customers, and the other part – by the builder. Income from unproduced electricity (annually about 12 TWh) could be added to the generated costs. The construction of large NPPs is a large-scale and complex process, so many countries consider small modular NPP projects, which are easier to implement and integrate into the local energy sector.

THE POTENTIAL OF NUCLEAR ENERGY TECHNOLOGIES

Historically, different countries and periods have developed different technologies. This was determined by the presence of domestic uranium, the desire to use reactors also for the production of military plutonium, the level of technological development of the country and other factors.

As a result, reactors of the RBMK type became common in the Soviet Union, which made it possible to obtain plutonium; Canada developed heavy water CANDU technology to use local uranium without enrichment; the USA and the Soviet Union transferred nuclear submarine PWR/VVR technology from nuclear submarines to commercial NPPs, etc. Each of the technologies created and developed has some positive and negative characteristics. In general, their development was aimed at reducing capital costs; therefore, due to the economies of scale, reactors of increasingly large capacity were built.

NPPs are characterized by long investment and innovation cycles, as well as the duration of the operation. It takes about six years to build a nuclear power plant that can operate for more than 60 years. Small modular reakctors (SMRs)are expected to have several additional applications beyond low-carbon electriciy generation, such as seawater desalination, hydrogen and synthetic fuel production, and heating for residential and industrial applications. In addition to these improvements in reactor technologies, there are fourth-generation systems that promise faster installation times, greater safety, and a closed fuel cycle. Some existing NPP countries, such as Canada, South Korea, the USA and the UK, are actively working on advanced reactor technologies and in particular on the development and implementation of SMR projects.

Estimates of cost of the electricity produced by NPPs are available in a wide range. The calculation is complicated by the fact that NPP has significant capital costs and relatively smaller fuel costs. Therefore, when calculating the normalized cost of electricity (levelized cost of electricity), the result largely depends on various assumptions throughout the power plant working period (which can reach 60 years).

Specific investments in reality are highly dependent on the successful implementation of the project. For example, in case of Olkiluloto-3, they were initially estimated at 1,875 EUR/MW, but after 17 years of construction (instead of the planned five years), they have reached 6,900 EUR/MW. The construction of small modular reactors allows for reducing investment risk. Fermi Energia estimates that the construction of the first 300 MW reactor would cost one billion EUR (3300 EUR/MW), and the construction of subsequent reactors would be even cheaper. In this case, the economies of scale would be achieved not by increasing the nameplate capacity, but by increasing the number of reactors.

According to publicly available data, the cost of electricity generated by Olkiluoto-3 could be 42 EUR/MWh.[53]

The electricity price for the *Hinkley Point* C NPP under construction in the UK is estimated £75/MWh for 35 years. Small NPP's LCOA costs estimated by Fermi Energia Ltd range from 45 to 100 EUR/MWh, depending on installed capacity factor and other factors. The OECD intergovernmental agency NEA (Nuclear Energy Agency) shows even lower possible LCOE – starting at about 30 USD/MWh.[54]

The European Green Deal has significantly stimulated the use of RES. However, RES technologies have the disadvanta-

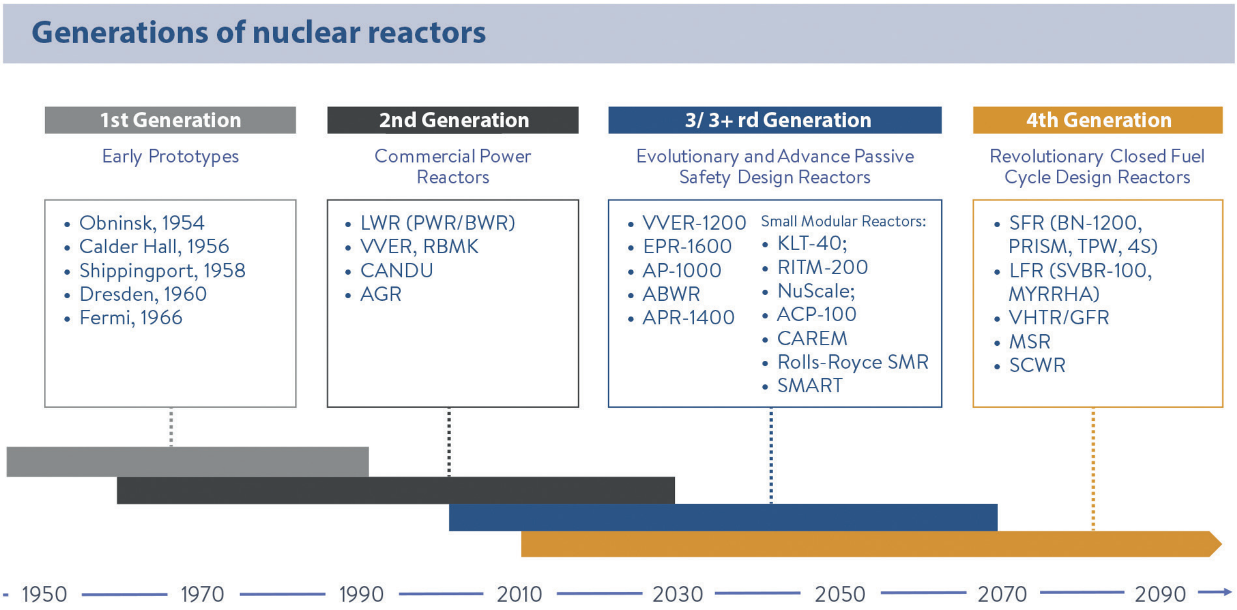
[51] EIA submitted for Poland's first nuclear power plant, World Nuclear News, 2022, https://www.world-nuclear-news.org/Articles/EIA-submitted-for-Polands-first-nuclear-power-plan#:~:text=Polskie%20Elektrownie%20Jadrowe%20(PEJ)%2C,report%20for%20the%20first%20plant.

[52] World Nuclear News, Extended operation of two Belgian reactors approved, 2022, https://www.world-nuclear-news.org/Articles/Extended-operation-of-two-Belgian-reactors-approve

[53] Olkiluoto-3 ģenerētās elektrības pašizmaksa, Informācija, 2022, https://klimatupplysningen.se/nej-vindkraft-ar-inte-losningen/

[54] OECD, Levelised Cost of Electricity Calculator, 2020 https://www.oecd-nea.org/lcoe/

Fig. 25 The periods of nuclear technology development

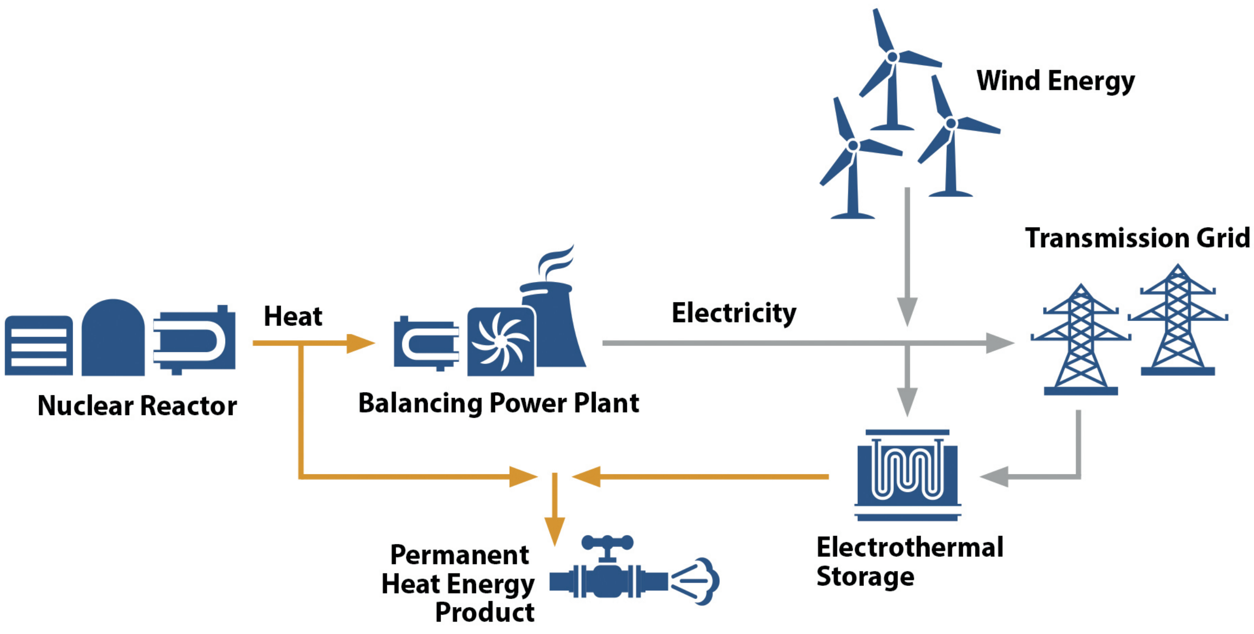


Source: World Energy Council, World Energy Scenarios 2019, 2020

ge in that they are currently unable to provide electricity generation in the baseload mode. NPP technologies provide an additional opportunity to develop a unified low-carbon hybrid system. Also, NPP produces stable baseload electricity, as well as with the residual heat of the reactor cooling, a very large amount of thermal energy can be provided, which is especially valuable for heating the cities in Northern Europe. A hybrid system consisting of wind, solar and other RES, coupled with NPP, would be able to provide the basis of the new low-carbon mixed energy system, as well as strengthen Europe's energy independence. NPPs are competitive in the long term with other production technologies.

In 2022, the world is suffering from global upheavals caused by the convergence of several factors: climate change, the Covid-19 pandemic and the war started by Russia in Ukraine on February 24, 2022. The EU's energy sector is undergoing significant changes, which are promoted both by moving towards wider use of climate-neutral technologies, reducing energy dependence, and replacing historical energy-generating technologies at the end of their service life.

Fig. 26 Potential hybrid grid model for nuclear and RES



Source: World Energy Council, World Energy Scenarios 2019, 2020

Wider use of RES is one of the main priorities of the EU's energy policy. A rapid increase in wind and solar power plants in the EU is expected in the coming years, continuing the current trend. At the same time, in 2021/2022, the cost of materials, which until now tended to decrease, experienced a significant increase – by March 2022, the price of polysilicon, which is widely used in the production of solar PV modules, increased more than four times. Copper, steel and aluminum prices also increased, as did freight costs. On the other hand, the potential of HPP technology has currently reached its maturity and its rapid further development is not foreseen. In the future, the EU could expect further replacement of traditional biomass – especially solid fuels – with modern alternatives derived from woodworking, forestry and agricultural waste and solid waste, as well as with the wider use of other technological solutions (e.g., heat pumps). The total demand for biomass is significantly higher than it is possible to produce in Europe without jeopardizing its GHG emission reduction targets. The highest added value of biomass is currently associated with its use as a production material, rather than an energy resource.

The biggest difference of opinion can be observed regarding the so-called baseload capacity provisioning technologies. Until now, the main technologies that provided baseload capacity in electriciy generation were coal, natural gas and NPPs. The number of coal-fired power plants is rapidly decreasing, which is facilitated by the rapidly rising prices of CO_2 emission allowances, the age of the respective plants, and the general political climate of the countries. With a few exceptions (for example, Poland has a very strong coal industry; thus, there is greater interest in continuing to use coal for energy generation, while making this process more climate-friendly by minimizing the amount of emissions), the EU countries plan to completely abandon the use of coal in electricity production. At the same time, the energy crisis of 2022 and the significant shortage of energy resources have forced the EU to postpone the closure of several coal-fired power plants and even to return to operation the already stopped ones. Several countries (Germany, the Netherlands, Austria and France) are preparing their coal-fired power plants in case of emergency. This trend is observed as a short-term crisis management measure. The possibilities of the gradual liquidation of fossil energy power plants and the replacement of these capacities (in addition to RES technologies) are evaluated in scenarios of world analytical institutes. They are mostly based on the combination of natural gas, NPPs and hydrogen technologies.

Natural gas CHPs and NPPs are considered transitional technologies with minimal impact on the climate. According to the EU "Fit for 55" initiative, power plants of these technologies are allowed to be put into operation until 2035. Power plants using natural gas and nuclear energy play an important role in providing baseload capacity. According to the forecasts of analytical institutes, the demand for natural gas will grow in the next decade (replacing the demand for coal), and later the amount of consumption will begin to slowly decrease, but even by 2050, a complete abandonment of the natural gas is not foreseen. Experiencing dramatic interruptions in the natural gas supplies from Russia in the summer of 2022, the EU countries make urgent decisions regarding diversification of the natural gas supply routes and sources, including, paying more attention to the infrastructure of LNG terminals, thus reducing the possibility of using natural gas as a tool of political pressure. In 2021, 70 % of LNG supplies to the EU were obtained from the USA, Qatar and Russia. The USA became Europe's largest supplier of LNG in 2021, accounting for 26 % of all LNG imported by the EU member states and the UK, followed by Qatar with 24 % and Russia with 20 %. In the situation of high natural gas prices, the EU has the opportunity to divert part of the natural gas supplies from Asian markets.

The EU member states have different attitudes towards nuclear energy, but the EU's total NPP capacity was set to decrease. Experiencing the crisis of natural gas availability and generating capacity deficit in 2022, new perspectives appeared for the future of nuclear energy. France, which is the EU country with the largest NPP installed capacity, has historically exported around 100TWh of electricity per year to neighboring countries, but now due to the age of its NPP, it has turned into an electricity importing country. This creates significant changes both in the Central European electricity market and determines the need for future generation development decisions. SMRs are considered promising due to their faster and easier construction process (in comparison with large NPPs) and greater flexibility.

Green hydrogen is considered one of the most promising technologies in the EU. For hydrogen, it is possible to use already existing natural gas infrastructure, mixing it with natural gas or completely replacing it (complete replacement of natural gas requires significant adaptations of infrastructure and equipment). Hydrogen is easy to store and transport, and it has high energy intensity, which is especially important for energy-intensive industries. Hydrogen production is attractive in times of energy surpluses, when RES or NPPs generate more energy than the market demands at a particular moment. Furthermore, its use is commercially viable when RES is not available, or in less flexible sectors that require stable power generation.

THE FUTURE OF THE LATVIAN ENERGY SECTOR

CHARACTERISTICS OF THE LATVIAN ENERGY SECTOR

The country's energy consumption portfolio mainly consists of RES (42 %), oil products (32 %) and natural gas (21 %). No significant changes in the final consumption of energy resources have been observed in ten years. Last year, the largest energy consumers were households, which consumed 48.2 petajoules (PJ) (28.9 % of final consumption), the transport sector (47.1 PJ or 28.2 %) and industry (39.4 PJ or 23.6 %). In comparison with 2019, an increase in the final consumption of energy resources was observed in production of wood, and wood products (by 2.8 %), while a decrease in consumption of energy resources by 2.5% was observed for other consumers in 2020. Due to restrictions imposed by the Covid-19 pandemic, a more significant decrease in the final consumption of energy resources in passenger and cargo transport was observed – it fell by 6.9 PJ or 12.8 %.

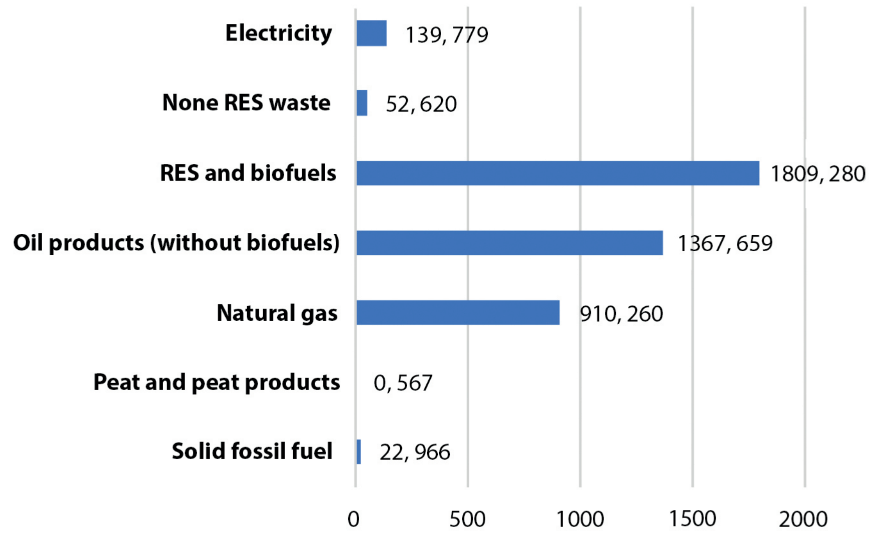
In Latvia, the electricity production portfolio (the year 2021) mainly consists of Daugava HPPs (46.7 %) and CHPs (34.3 %), as well as smaller amounts of biomass (6.5 %), biogas (4.7 %), small CHPs (4 %), wind energy (2.5 %), small HPP (1.2 %) and solar energy (0.04 %).

On an annual basis, generation capacity is not uniform. During peak periods, Latvia exports electricity, while in the dry months of the year local generation can provide less than 30 % of the electricity consumed in the country.

In 2021, 5,609,592 MWh of electricity was produced in Latvia, while Latvia's electricity consumption was 7,382,226 MWh. Accordingly, consumption was covered by local generation to the extent of 75.9 %, creating a shortfall of 1,772,634 MWh imported from neighboring countries. Only once – in 2017, thanks to favorable meteorological conditions for electricity generation, a positive net balance of electricity produced in Latvia was historically observed.

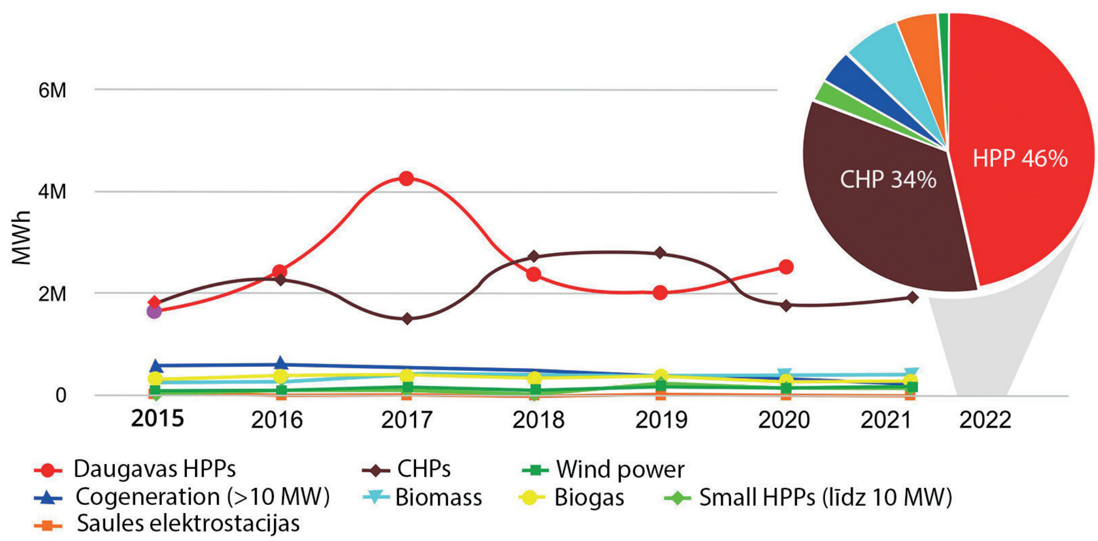
Analyzing the trends of 2021, there is a slight increase in production by 4.2 % in Daugava HPPs, by 10.7 % in large CHPs (compared to 2020), while there is a decrease in other essential types of production: wind power was produced 20 % less. Concerning small CHPs, the steady decline observed for the past five years continues with a 26.9 % drop

Fig. 27 Total energy supplies by energy product, 2020, thousand tons of oil equivalent



Source: Eurostat, 2022 https://ec.europa.eu/eurostat/databrowser/view/ten00122/default/table?lang=en

Fig. 28 The portfolio of electricity produced in Latvia and its changes



Source: AS "Augstsprieguma tīkls", 2022. https://ast.lv/lv/electricity-market-review?year=2021&month=13

in 2021. 6.6 % less electricity was produced from biomass, and 15.3 % less from biogas, while the amount produced in small HPP decreased by 1.6 % in 2021.

In 2021, the import of electricity from the third countries to the Baltics increased by 18.3 % –4,671,229 MW of electricity was imported. Last year import from third countries was possible only through the Latvian – Russian interconnection. Since May 22, 2022, due to the sanctions imposed in connection with the Russian invasion of Ukraine, it is no longer possible to import electricity from Russia; thus, the import from the countries of the EU has increased by 21 %, reaching 1,064,511 MWh. Poland exported 97,655 MWh to the Baltic States, or 27 % more than in May, while the import from Sweden and Finland increased by 21 %, reaching 419,491 and 547,365 MWh of electricity, respectively.

Regarding electricity consumption trends, over five years, the consumption of energy resources in the industry has increased by 5.6 PJ or 16.3 %, and, compared to 2019, it increased by 1.3 PJ or 3.3 %, reaching 39.6 PJ in 2020. The largest consumption of energy resources in 2020 was in the wood, timber and cork production sector – 21.2 PJ or 53.7 % of the final consumption of energy resources in the whole industry. During the last five years, the consumption of petroleum products in the industry increased by 9.3 %. The final consumption of energy resources in mining and quarrying was 0.7 PJ in 2020, which was 75 % more than in 2019 (0.4 PJ).[55]

ELECTRICITY INFRASTRUCTURE

Latvia is connected by four alternating current transmission interconnections with Lithuania, two with Estonia and one with Russia. Estonia and Lithuania also have several AC

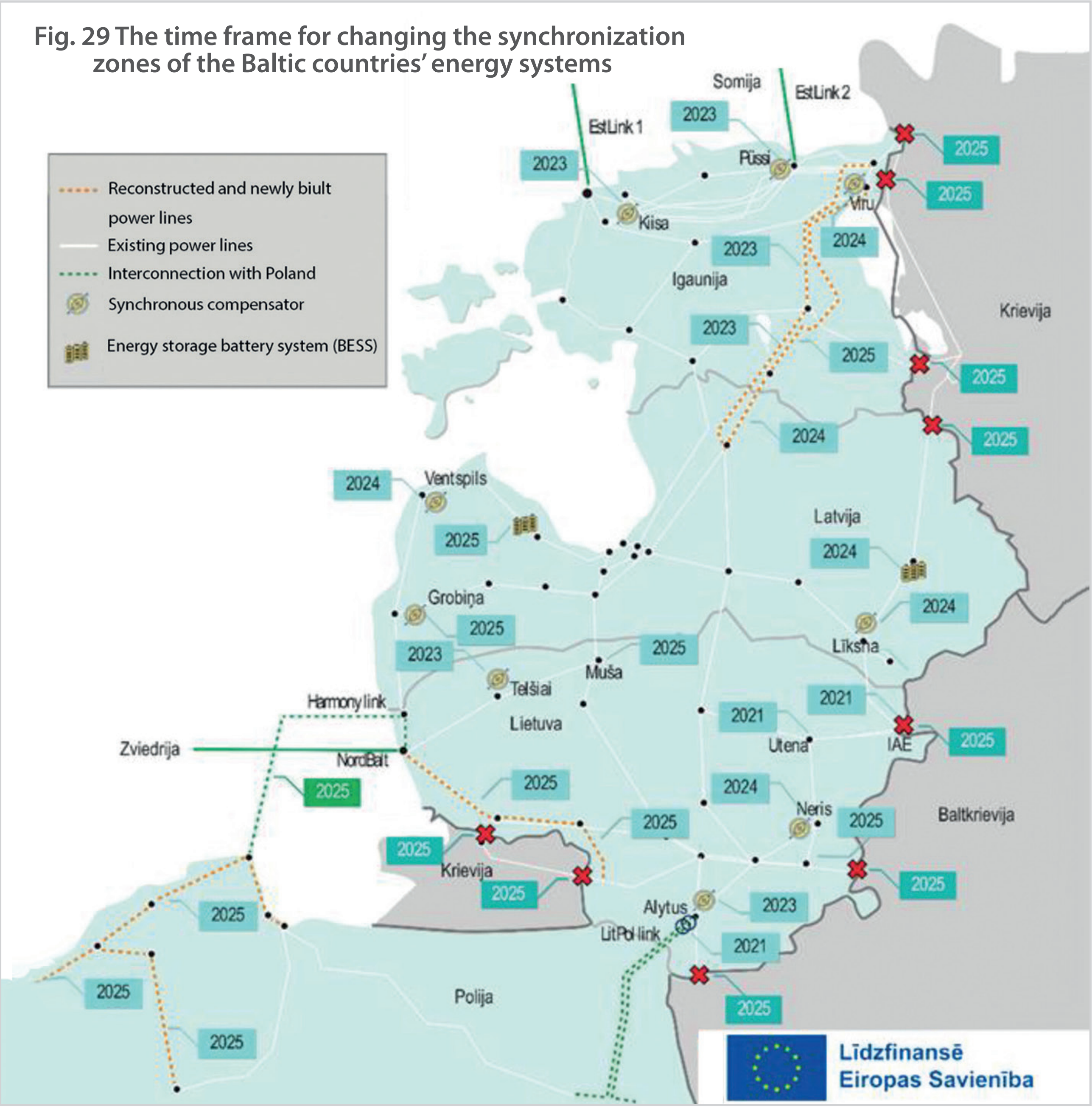


Fig. 29 The time frame for changing the synchronization zones of the Baltic countries' energy systems

[55] Official Statistics Portal, 2022. https://stat.gov.lv/lv/statistikas-temas/noz/energetika/preses-relizes/7129-energoresursu-paterins-latvija-2020-gada

interconnections with Russia and Belarus. The Baltic States (Estonia) are connected by two DC interconnections with Finland, one (Lithuania) with Southern Sweden and one (Lithuania) with Poland, allowing electricity trade to take place. All electricity produced in the region is traded in *NordPool* power exchange. The cross-border capacity of the respective interconnections affects the regional price differences.

The Baltic States have historically worked and are currently working synchronously with the electricity systems of Russia and Belarus. Currently, work is underway on the desynchronization project from the IPS/UPS network managed by Russia, with the intention of synchronous work with the continental European power system in 2025. The goal of the synchronization project is to initiate the synchronous operation of the Baltic electricity system with Europe and to reduce dependence on decisions made outside the EU. This will increase the Baltic's ability to constantly manage its electricity system, ensuring a balance between production and consumption, managing the necessary safety reserves, as well as regulating electricity flows and frequency without the involvement of the third countries. The most important benefit is security, because as a result of synchronization, the Baltic electricity transmission system will become part of the European system, which means significant independence from Russia. The projects that need to be implemented until the Baltic power grids are synchronized with Europe are shown in Figure 29.[56]

At the same time, the synchronization project increases the need for local generation, as the Baltic States will have to be able to provide both imbalance compensation and stable network operation. The year 2025 is a very ambitious deadline, until then Latvia must complete the following preparations: reconstruction projects of the Valmiera-Taru and Valmiera-Tsirguliina power transmission lines, installation of three synchronous compensators and installation of two large-scale energy storage batteries.

One of the important tasks in the synchronization preparation process is the primary frequency regulation of the Latvian electricity system and the arrangement of the frequency regulation system according to the requirements of the continental European energy system, because currently the frequency regulation is provided by the IPS/UPS. The Latvian electricity transmission system operator (TSO) Augstsprieguma tīkls plans to provide this function with the installation of new storage batteries (BESS – *Battery Energy Storage System*) with a capacity of 80MW/160MWh, because it cannot be provided with existing power plants (HPPs and CHPs belonging to "Latvenergo") due to the seasonal nature of their operation and other factors.

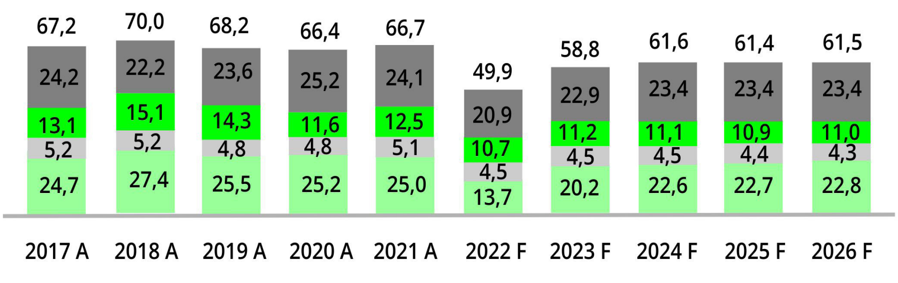
In addition, it is necessary to create and modernize the management and control of the electricity system and telecontrol system of the power transmission network by installing power control equipment in all important facilities, implementing remote operation equipment in important substations and power stations, and also modernizing and improving transmission system according to the Continental European operator SCADA system (*Supervisory control and data acquisition*) with system frequency control tools.

As for the inertia service, it is necessary to ensure stable operation of the electricity system in synchronization mode, and TSOs of the Baltic States must provide a total of 17,100 MWs of inertia on a permanent basis. Latvia must proportionally provide 5,700 MWs of inertia. To provide these services, it is planned to install three stationary synchronous compensators in Latvia. On the other hand, for frequency regulation, it is necessary to install 80MW/160MWh BESS, dividing it into two parts of 60MW/120MWh and 20MW/40MWh to ensure safety criteria.

A REVIEW OF THE NATURAL GAS SECTOR

The opening of the natural gas market in Latvia took place in 2017, separating the natural gas transmission and storage infrastructure from trading and distribution. On January 1, 2020, the single regional natural gas market started its operation, which currently unites gas TSOs from Finland, Latvia and Estonia. Such a regional model improves the liquidity of the market and increases its attractivity for traders, since separate Baltic countries cannot ensure the sufficient interest of suppliers in the market. The consumption of natural gas in the region shows a slight downward trend, which has been influenced mainly by metrological

Fig. 30 Natural gas demand in the Baltic States and Finland



Source: AS "Conexus Baltic Grid", 2022. http://www.conexus.lv

Table 3 Dutch TTF Gas Futures price forecast

Period	Winter 2022	Summer 2023	Winter 2023	Summer 2024	Winter 2024	Summer 2025
Price (EUR/MWh)	190,500	142,540	127,800	83,550	79,805	50,500

Source: the ICE, 2022. https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data?marketId=5460494&span=3

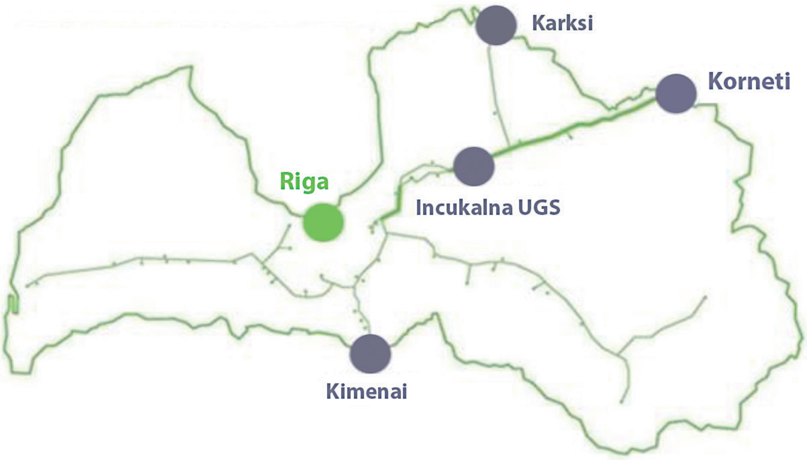
56 AS Augstsprieguma tīkls, 2022. https://ast.lv/lv/projects/sinhronizacija-ar-eiropu

conditions, the price of electricity in *NordPool* and, the overall trend toward the reduction of CO_2 emissions.[57]

Energy industry analysts are very cautious about forecasting natural gas price trends due to the volatility of the global energy market. Forecasts of *The Ice* predict that Dutch TTF Gas Futures will remain high for the 2022/2023 winter season, with a gradual price decline afterward.[58]

Fitch Solutions predicts that *Henry Hub* prices will strengthen at $4.5/mcf in 2030 and 2031. Analysts also predict that starting from 2025 and in the longer term, the *Henry Hub* price could be $2.50/mcf, and the Dutch TTF price – $5/mcf, reflecting both changes in demand and marginal production costs.

Fig. 31 The Latvian natural gas transmission system



Source: AS "Conexus Baltic Grid", 2022. https://www.conexus.lv/latvijas-gazes-parvades-sistema

The US Energy Information Administration foresees that the USA natural gas prices could be $5.72/MMBtu in 2040, rising to $6.91 per million British thermal units

Fig. 32 The Baltic regional natural gas market infrastructure

Source: ENTSO-G, 2022, https://www.entsog.eu/sites/default/files/2021-11/ENTSOG_CAP_2021_A0_1189x841_FULL_066_FLAT.pdf

57 AS Conexus Baltic Grid, 2022. www.conexus.lv

58 The ICE, 2022. https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data?marketId=5460494&span=3

Table 4 Technically possible transit flows

Finland	From Russia to Estonia (*Balticconnector*)
Estonia	From Russia via Estonia to Finland (*Balticconnector*) or Latvia
Latvia	From Russia through Latvia to Estonia or Lithuania; from Lithuania to Estonia and from Estonia to Lithuania
Lithuania	From Belarus through Lithuania to Latvia and from Belarus to Russia (Kaliningrad), from Poland through Lithuania to Latvia

Source: ENTSO-G, 2022, https://www.entsog.eu/sites/default/files/2021-11/ENTSOG_CAP_2021_A0_1189x841_FULL_066_FLAT.pdf

(USD/MMBtu) in 2050. Forecasting website *Wallet Investor's* announced an expected natural gas price target of $9.320/MMBtu for the next 12 months, seeing this figure rise to $13.026/MMBtu during the next five years.

Power grid interconnections with the Nordic region have increased competition in the power generation market, which requires greater flexibility from power producers. It is can be provided by natural gas-fired CHPs. The Nordic electricity market will indirectly, but significantly, affect the natural gas market in the Baltics, as a result of which the demand for and from IUGS during the natura the natural gas flexibility and storage options will increase.

Input physical flows to the Latvian natural gas transmission system are provided from Russia (entry point Korneti), Lithuania (entry point Kiemenai) and IUGS during the natural gas withdrawal (winter) season (entry point IUGS).

The unified transmission tariffs of the regional market and the abolition of internal commercial borders significantly ease the administrative burden for traders, as well as provide a transparent and simple tariff system, which will have a positive impact on the use of the natural gas infrastructure in the long term. The revenue generated on the external borders of the single market area is shared between the three countries, which confirms the common goal of all the members of the market to strengthen energy security in the region.

The following routes are available for the natural gas supply to the Baltic region: gas pipelines from Russia, Klaipeda LNG terminal, GIPL interconnection and IPGK, which serves as an entry point for previously delivered natural gas.

Through three entry and exit points – Korneti, Kiemenai and Karksi –, the natural gas TSO Conexus Baltic Grid allows the natural gas traders to cross the territory of Latvia in transit in order to trade natural gas in markets throughout the Baltic region or to store it in IUGS.[59]

In 2021, the total volume of natural gas transported in Latvia reached 39.3TWh, which increased by 5 % in comparison with the year before. The Estonian-Finnish interconnection *Balticconnector*, inaugurated at the beginning of 2020, has had a positive impact on the total volumes of transmitted flows, giving the opportunity to supply the natural gas to Finnish users in 2021, also using the services provided by IUGS. The amount of the natural gas transported through *Balticconnector* in direction of Finland is 6.3TWh and it accounts for approximately one third of Finland's total annual natural gas consumption.

However, in comparison with 2020, this amount has decreased, which is related to the decrease in Finnish domestic consumption due to high natural gas prices. In 2021,78 % decrease in the amount of natural gas received from Lithuania was observed, reaching only 1.7 TWh. On the other hand, the amount of transmitted gas in direction of Lithuania increased by 1.8 times during the reporting period and reached 3 TWh. This increase was observed in the first quarter of the year, when, according to the schedule of ship deliveries published by the Klaipėda LNG terminal, one gas supply was canceled at the end of January and the required natural gas volume was provided using IUGS.

IUGS can be considered the main point of convergence among Northern Europe, Russia, Poland and Western Europe, connecting natural gas traders with customers in the Baltic Sea region.

After the launch of the natural gas market, IUGS's filling began to respond to market demand fairly fast. Figure 34 shows that the maximum storage capacity decreased in comparison with historical volumes. This is due to the availability of an alternative natural gas route (Klaipeda LNG terminal) and a smaller price difference between the summer and winter seasons in several years, which reduces the motivation of traders to use natural gas storage services, thus saving funds.

As of August 1, 2022, the filling of IUGS is 53.3 % or 11.62 TWh, which corresponds to 94.2 % of Latvia's annual natural gas consumption.[60] According to natural gas TSO's 2022/2023 report, the forecast fulfillment of the storage is expected to be 59 %.[61] At the same time, it should be added that the services of IUGS are actively used by natural gas traders from other countries, and information about how big volume exactly is intended for Latvian consumers is confidential, and, therefore, cannot be disclosed. Also, part of the natural gas purchased for Latvia is necessary to reduce security risks and is not available for trading. At the beginning of the summer of 2022, "Latvenergo" purchased 2 TWh of natural gas on behalf of the state, so that in the event of an emergency desynchronization from IPS/UPS, Latvia would be able to ensure the stability of the electricity system by operating CHPs.

As for UGSs in Europe as a whole, on August 1, 2022, they were 69 % full, which corresponded to approximately 18.4 % of natural gas consumption. A similar volume of natural gas was in the storage last year as well.

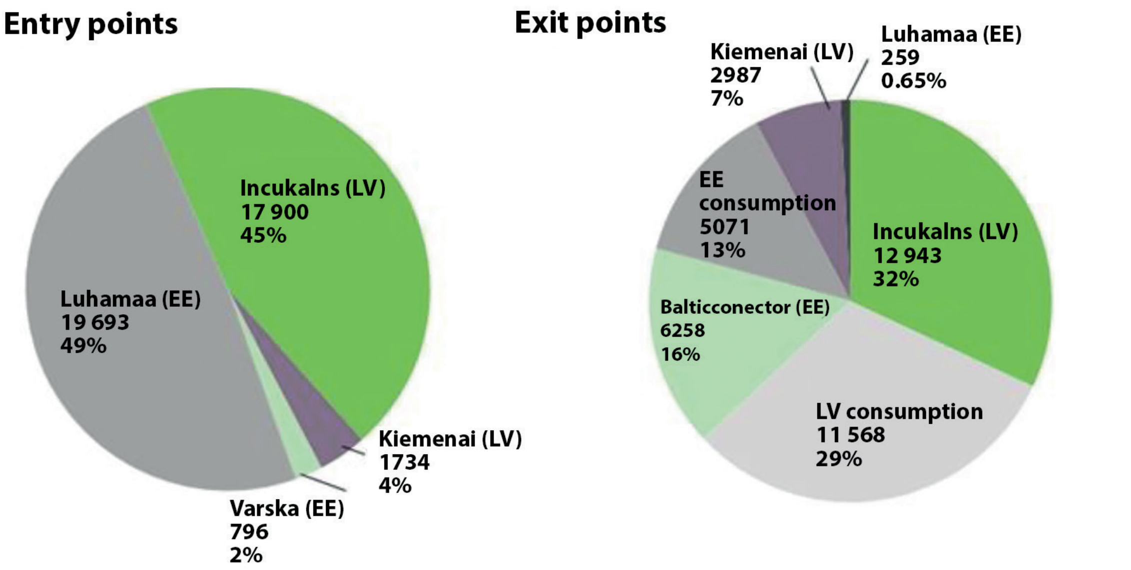
At the same time, it should be mentioned that the heating season of 2022/2023 is special with high risks of impossibility of the natural gas supply though pipelines from Russia; therefore, the amount of natural gas stored in IUGS is of even greater importance.

[59] AS Conexus Baltic Grid, 2022. https://www.conexus.lv/uploads/filedir/Zinojumi/PSO_zinojums_2022_LV.pdf

[60] AGSI, 2022. https://agsi.gie.eu/graphs/LV

[61] AS "Conexus Baltic Grid", 2022. https://www.conexus.lv/uploads/filedir/Zinojumi/PSO_zinojums_2022_LV.pdf

Fig. 33 Entry and exit points of the Baltic natural gas system

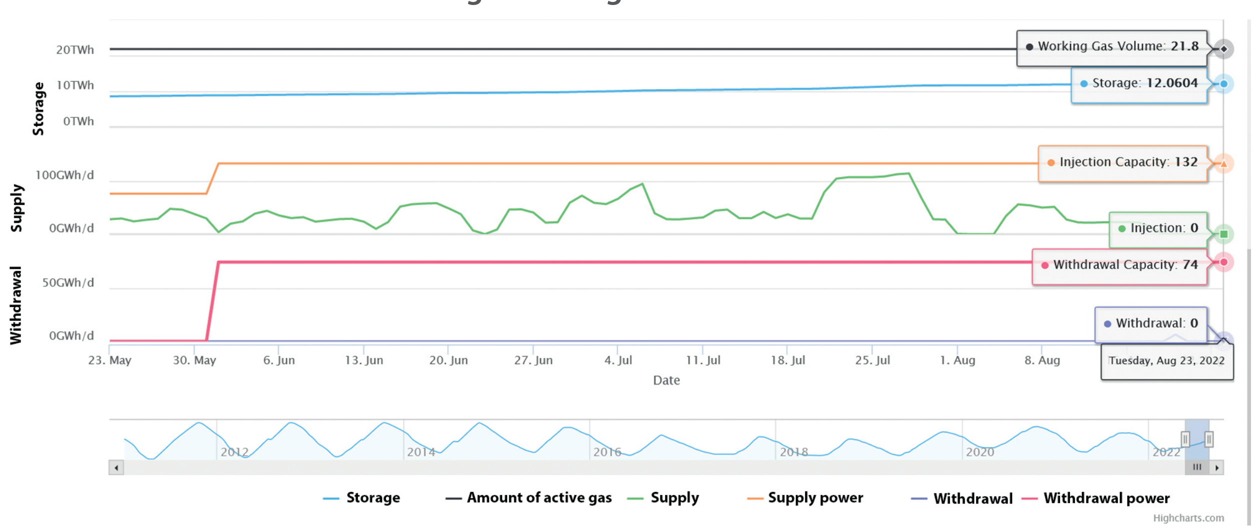


Source: AS "Conexus Baltic Grid", 2022. https://www.conexus.lv/uploads/filedir/Zinojumi/PSO_zinojums_2022_LV.pdf

The following events will affect the operation and development of the regional market in the near future:

- the improvement of the interconnection between Estonia and Latvia allows for increasing the volume of natural gas, as well as organizing the supply of natural gas from Estonia to Latvia, which is important to ensure the natural gas flows in the common market and to allow Estonian and Finnish market participants to store natural gas in IUGS. The planned technical input and output capacity of the interconnection – 105 GWh/day – will be significantly affected by the implementation of the Latvian-Lithuanian interconnection enhancement project, which is planned to be completed by December 2023. Interconnection improvements on the Estonian side were completed in 2021, but on the Latvian side, taking into account the end date of the Latvian and Lithuanian interconnection improvement project, it was planned to be completed in 2024;
- the natural gas interconnection between Poland and Lithuania (GIPL). At the end of 2021, the construction of the GIPL gas pipeline was completed and the interconnection began operation on May 1, 2022. GIPL connects the natural gas transmission systems of Lithuania and Poland, thus ensuring the connection of the Eastern Baltic natural gas transmission systems with the Central European natural gas transmission network. GIPL functions as an alternative natural gas supply route for the Eastern Baltic region, which increases the reliability of the natural gas supply in the region and allows the region to be integrated into the EU's natural gas transmission networks. The infrastructure built within the project was put into operation in full in October 2022. The planned capacity in the direction of Lithuania – 74 GWh/day, while in the direction of Poland – 58 GWh/day;
- improvement of IUGS. IUGS is the only UGS facility in the Baltic States region, which provides the region with stable natural gas supplies during the winter period. The

Fig. 34 Filling level of IUGS



Source: AGSI, 2022. https://agsi.gie.eu/graphs/LV project envisages the implementation of three main activities: improvement of surface equipment, renovation of the gas wells and improvement of operation of the gas pumping equipment. As a result of the project, the dependence between the capacity available for withdrawal and the natural gas stocks in the storage will be significantly reduced, which will help improve the reliability of the natural gas supply, as well as the efficiency of the storage operation. It is especially important for ensuring the optimal and maximally efficient operation of the Baltic-Finnish natural gas market. In addition, the implementation of the project will provide additional environmental protection measures, reducing the amount of CO_2, NO_x and other emissions. The project implementation deadline is December 2025;

- improvement of the interconnection between Latvia and Lithuania. Increasing the capacity of the interconnection will allow for a more intensive exchange of natural gas not only between Latvia and Lithuania, but will also ensure sufficient capacity in the Latvian transmission system for additional natural gas flows along with the creation of a regional natural gas market. The aim of the project is to carry out the reconstruction of the individual gas transmission facilities, pipeline diagnostic works and repair works to prepare the system for increased pressure, which will simultaneously increase the capacity of interconnection in the direction from Latvia to Lithuania to 119.5 GWh/day, and in the direction from Lithuania to Latvia to 130 .47 GWh/day. The project is planned to be completed in December 2023;
- the Estonian/Finnish LNG terminal construction;
- the construction of the Latvian LNG terminal;
- the Lithuanian LNG terminal operator Klaipedos Nafta will purchase FSRU *Independence* from Hoegh LNG and will become its owner by the end of December 2024, at the latest. On May 11, 2022, the Lithuanian government decided that the ship would be under the Lithuanian flag from 2025;
- the *Baltic Pipe* gas pipeline from Norway to Poland started operation in October 2022. At the same time, the Polish state-owned company *Polish Oil and Gas Company* (PGNiG) was not able to conclude contracts for a sufficient amount of natural gas from Norwegian or Danish partners for June 2022. On the other hand, the gas fields owned by PGNiG cannot yet provide sufficient gas output;[62]
- desynchronization of the Baltic energy system from IPS/UPS and synchronous operation with the electricity system of Continental Europe is planned until the end of 2025;
- ban on the import of the Russian natural gas starting from January 1, 2023.[63]

THE WARTIME IMPACT ON THE ENERGY SECTOR AND TRANSITION FROM THE RUSSIAN GAS

After the war started by Russia in Ukraine, the prices of natural gas in Europe increased significantly, reaching a historical record of 349.9 EUR/MWh on August 26, 2022.

Europe is willing to turn away from Russia as a supplier of natural gas and is looking for other ways to obtain natural gas.

Over the past two years, the USA has seen a significant increase in the natural gas demand from Europe, with a corresponding increase in exports.[64]

In addition, in June 2022, there was an explosion at an LNG export facility in Texas, which provided around 20 % of the American natural gas exports. *Freeport LNG*, the company that owns the Texas Gulf Coast LNG facility, announced that repairs could last until the end of the year. In the USA, the increased demand from Europe and a situation where the American supply is lower than usual also contributed to the price increase. *The Freeport LNG* explosion also had an impact on domestic natural gas markets, but in the opposite direction. Traders expected that the reduction in export opportunities would increase domestic supply in the North American market for the period of the terminal repairs.

The Asian customers are poised to face tougher competition from Europe for LNG cargoes if disruptions of the Russian gas supplies remain. For example, in the competitive battle at the end of 2021, there were several cases (LNG carriers *Hellas Diana, Maran Gas Sparta*), when LNG ships halfway to the originally planned destination changed their route because the European traders bid a higher price than China.

The price increase was facilitated by Russia's request for foreign customers to pay for natural gas in Russian rubles (RUB). According to the order signed by the President of Russia on March 31, 2022, customers buying Russian gas were obligated to open an account with the Russian Gazprombank and pay in EUR and USA dollars. Gazprombank itself would convert these currencies into RUB to make an actual payment. This announcement was followed by another jump in prices of the natural gas in global markets. This Russian request had less impact on customers using existing long-term contracts, who opened in Gazprombank accounts in both RUB and EUR. However, if new contracts are signed or outright purchases are made in the future, the new rules may require direct payment in RUB from European customers who will have to purchase RUB from the sanctioned Russian central bank.

Soon after the *gas-for-ruble* announcement, Russia suspended the natural gas supplies to Poland and Bulgaria, where customers refused to make payments in RUB.

Also, successive price jumps were caused by Russia's announcement about reducing the capacity of the *Nord Stream 1* pipeline to Germany by almost 40 % – from 167 million cubic meters (MCM) to 100 MCM due to delayed delivery of *Siemens Energy* equipment. Further, Gazprom announced that it would continue to reduce the natural gas delivery capacity through the same pipeline to 67 MCM (2,366 mcf) per day, due to "technical problems".

On June 3, 2022, the EU came up with the sixth package of sanctions and a complete ban on the import of crude oil and all oil products obtained in the sea of Russia, subject to a 6–8 month long "transition period". The ban is expected to affect 90 % of current oil imports from Russia. Deroga-

[62] DW, Baltic Pipe: How Poland is speeding up its exit from Russian gas, 2022, https://www.dw.com/en/baltic-pipe-how-poland-is-speeding-up-its-exit-from-russian-gas/a-62194327

[63] LR, Enerģētikas likums, https://likumi.lv/ta/id/334350-grozijumi-energetikas-likuma

[64] Capital, Natural gas price forecast 2030-2050: Supply disruptions to elevate market?, 2022, https://capital.com/natural-gas-prices-forecast-2030-2050

tions are possible for countries with a "particular pipeline dependence on Russia", provided they do not resell their imports to other countries. During 2022, the future price has more than doubled, reaching the amount of 4$.

Capital.com analyst Piero Cingari believes that the risk premium on Dutch TTF prices will persist in the coming years if the Ukraine crisis is not resolved. The pressure on the European natural gas market also will remain. It is difficult to predict that the market price will fall below the 75 EUR/MMBtu level in so tight market.[65]

It should be emphasized, however, that situation in the natural gas market significantly affects provision of heating energy to residents. Currently, the Latvian heat supply companies also recognize that it is a big challenge for them to buy the natural gas. There are also problems in ensuring the supply chain for many products important to society and industry, incl. those important in moving towards a climate-neutral energy sector. For example, there is certain fragility of supply chains for isotopes used in various medical and industrial applications produced in Russia, or from rare metals mined in Russia.[66]

In the medium and long term, Europe has developed a *REPowerEU* plan to reduce dependence on the Russian natural gas imports, to accelerate transition to RES and to expand the range of energy suppliers. It is an essential tool that can structurally reduce import dependence of natural gas in the long term and, thus, decrease energy prices, although the energy transition still faces significant challenges due to a lack of supply of critical materials.

ALTERNATIVE NATURAL GAS DELIVERIES TO LATVIA

Joseph Gatdula, the Head of *Fitch Solutions*, believes that the current global supply of natural gas is unlikely to replace all of Russia's natural gas imports to the EU, which stands on almost 150 BCM. The current LNG capacity in the USA is adequate, but not enough to meet all of Europe's demand.

"However, exports will increase significantly by mid-decade as liquefaction capacity increases in the USA and Qatar. These new volumes could force Europe to permanently move away from Russian gas imports if the increase in RES and the decline in the natural gas consumption take effect, based on the EU's plans to diversify Russian energy imports," said Joseph Gatdula.

In its annual Energy Outlook, published on March 3, 2022, the US EIA predicted that American LNG exports would increase to 5.86 trillion cubic feet (tcf) by 2033 from 3.58 tcf in 2021 due to strong foreign demand and the expansion of LNG export infrastructure.

On March 31, 2022, ING predicted that Europe would be able to replace only about 55 % of Russia's pipeline natural gas deliveries at best. The remaining approximately 68 BCM should be provided by increased LNG imports and Dutch/Norwegian supplies.

Amendments to the Energy Law have been adopted in Latvia, which provides for the abandonment of the import of the Russian natural gas from January 1, 2023. At the same time, on July 30, 2022 Gazprom announced the termination of the natural gas supply to Latvia due to non-observance of new payment procedures.

As of the end of the summer of 2022, the only entry point where it was possible to receive gas in Latvia was through the LNG terminal in Klaipėda, Lithuania. However, in practice, there is fierce competition for the availability of Klaipėda LNG terminal capacity, and Lithuania tries to provide access to the terminal as a priority for its traders.[67]

LNG terminals in Latvia will be developed by Skulte LNG Terminal near Saulkrasti. Skulte is a relatively attractive place for the construction of LNG terminal due to its geographical proximity to IUGS. Accordingly, delivered natural gas can be pumped into storage, providing cost savings and possibility of storing larger volumes of natural gas in comparison with surface storage at traditional LNG import facilities. Skulte LNG Terminal plans to build a terminal with a capacity of up to 6 BCM and a regasification capacity of 17 mill/m^3 a day. One of the conditions for the implementation of this project would be the conclusion of a long-term contract with the natural gas traders and consumers for use of the infrastructure for approximately 10 years. At the same time, taking into account that Latvia's largest consumer of natural gas is "Latvenergo", the conclusion of such an agreement would temporarily mean obligations to the state.

The Kundziņsala LNG terminal in the port of Riga plans to build an LNG terminal[68], which will have a regasification system that will allow natural gas to be transported through pipelines, as well as from which it can be further transported by tanker trucks. Initially, the project was planned in a small volume – 300 thousand tons of LNG per year, and provided for deliveries only by tankers in Latvia and other Baltic States. Currently, the project is intended to supply Riga and its surroundings with natural gas, as well as to supply natural gas to IUGS. Its planned capacity is from 0.75 to 2.2 mill/m^3 of gas a year with the possibility to increase it.

The project plans to use the existing natural gas distribution system, with the additional construction of ~12 km of a new low-pressure gas pipeline to connect to the high-pressure gas system and be able to deliver natural gas directly from the port of Riga to the IUGS. The construction of such a high-risk pipeline in the capital could be associated with major challenges. Also, increasing the pressure of natural gas and delivering it to the transmission system will create additional costs, which will affect the competitiveness of this project compared to projects, where the natural gas is directly injected into the transmission system.

[65] The American Institute of PhysicsIsotope Supply Chain at Risk from War in Ukraine, 2022 https://www.aip.org/fyi/2022/isotope-supply-chain-risk-war-ukraine

[66] Capital, Natural gas price forecast 2030-2050: Supply disruptions to elevate market?, 2022 https://capital.com/natural-gas-prices-forecast-2030-2050

[67] AB „Klaipėdos nafta" informācija, https://www.kn.lt/en/news/news/five-customers-to-use-klaipeda-lng-terminal-in-the-last-quarter-/5491

[68] LSM, Ekonomikas ministre: Latvijā varētu attīstīt arī divus sašķidrinātās dabasgāzes termināļus, 2022 https://www.lsm.lv/raksts/zinas/ekonomika/ekonomikas-ministre-latvija-varetu-attis-tit-ari-divus-saskidrinatas-dabasgazes-terminalus.a466705/?utm_source=lsm&utm_medium=theme&utm_campaign=theme

According to the information provided by the developers, it takes 2–2.5 years to carry out the project for building LNG storage tanks. However, if much faster supplies are provided, a gas pipeline can be built within a year. The project is being proposed by Kundziņsalas Dienvidu projekts Ltd owned by the American company Millennium Energy Partners LLC.[69]

Estonia and Finland have agreed to jointly develop one FSRU and build piers on both sides of the Gulf of Finland. The Paldiski terminal can be built faster – by November 2022 – than other terminal projects in the region, as it requires minimal infrastructure adjustments for the operation of its first stage. After the implementation of the second stage within 2–3 years, the capacity of the terminal is planned to reach 2.5 BCM/year.[70] According to the statement of the project developer "Alexela", in addition to the Estonian gas demand, the Paldiski LNG terminal would cover at least 80 % of Finland's natural gas needs. The infrastructure costs of the first phase of the terminal would reach 40 million EUR, while the entire project would total ~400 million EUR.[71] In addition to the Paldiski terminal, "Alexela" is developing the Hamina LNG import terminal in Finland, the operation of which is also planned to start in the fall of 2022. The import capacity of the project is 4,800 MWh/day, the storage volume is 30,000 m^3. Within the project scope, it is also planned to provide 3,600 m^3/day vehicle charging capacity. The Hamina LNG terminal will be connected to the Finnish national gas network as well as to the Hamina local natural gas network. These connections will provide a new physical entry point to the interconnected Finnish and Baltic gas systems.[72] The construction and availability of new LNG terminals in the region are critically important for the security of the energy supply in Latvia for the 2022/2023 heating season.

THE EUROPEAN GREEN DEAL AND THE POTENTIAL OF OTHER ENERGY SOURCES

The conditions for the use and development of RES in the EU are mainly defined in the Renewable Energy Directive 2018/2001/EU. Initially, it determined that by 2020, the member states should jointly increase the share of energy produced from RES in the EU's gross final energy consumption to at least 20 %. This task was accomplished, and in 2018 the directive was amended. The share of RES target was increased to 32 %, which was expected to be achieved by 2030.[73] Already in the summer of 2021, the EC proposed several new amendments to the directive, which included raising this target to 40 %.[74] Following Russia's invasion of Ukraine and the EC looking for ways to reduce the EU's dependence on fossil fuel imports from Russia, the desired share of RES was further increased to 45 %.[75] The member states have now agreed on a position on the proposed amendments, which include a 40 % target value as well as several more ambitious sub-targets for sectors (e.g., transport, heating and cooling, industry and buildings) where uptake of RES has been slower.

Once the overall goals are set, the EU member states must set out actions to achieve the goals in their energy and climate plans. The current plans were mainly approved in 2019 and 2020, but would need to be updated in 2023 and 2024. Currently, Latvia has committed to obtain at least 50 % of its gross final energy consumption from RES by 2030. The EC has assessed such a commitment as adequate, but as the overall EU RES target increases, one could expect their revision at the member state level as well. Compared to the neighboring countries, Latvia's current achievements in energy transition and level of ambitions for further actions are slightly lower than in Sweden and Denmark, but higher than in other Baltic States and, especially, they are higher than in Poland. However, it should be taken into account that the national energy systems have a certain inertia and Latvia still benefits from previously installed hydropower capacities that have been modernized, but have limited expansion possibilities.

Comparing the installed electricity capacity of Latvia and its neighboring countries and electricity production from RES, certain correlations can be highlighted. Firstly, although the share of solar energy in installed capacity portfolio of some countries has increased, the level of electricity generation, at least until 2020, from these sources has been relatively low. Secondly, for some countries, such as Denmark, wind energy is an important source of electricity, both in terms of installed capacity and actual production. Compared to neighboring countries, solar and wind energy is not well developed in Latvia – in 2020, only 0.1 % of all produced electricity came from solar and 2 % – from wind energy sources.

The use of RES in other sectors (heating, cooling and transport) is currently dominated by biofuels, especially solid biofuels in the heating and cooling sector and liquid

69 NRA, Zināms, kad aptuveni darbību varētu sākt Kundziņsalas sašķidrinātās dabasgāzes terminālis, 2022 https://nra.lv/latvija/riga/379482-zinams-kad-aptuveni-darbibu-varetu-sakt-kundzinsalas-saskidrinatas-dabasgazes-terminalis.htm

70 LNGprime. Infortar joins Alexela's Paldiski LNG import project in Estonia, 2022 https://lngprime.com/europe/infortar-joins-alexelas-paldiski-lng-import-project-in-estonia/48815/

71 3rd Three Seas Initiative Summit, Commissioning of the regional LNG terminal in Paldiski, Estonia, 2022 https://projects.3seas.eu/projects/commissioning-of-the-regional-lng-terminal-in-paldiski-estonia

72 Hamina LNG Oy, https://www.haminalng.fi/

73 European Union. 2018. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast). http://data.europa.eu/eli/dir/2018/2001/oj

74 European Commission. 2021a. Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0557

75 European Commission. 2021b. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions REPowerEU Plan. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2022:230:FIN

and gaseous fuels produced from biomass in transport. This could change with the increasing application of circular economy principles where, for example, woody biomass is used according to its highest economic and environmental added value. Also, in the transport sector, it will be possible to observe an increase in electrification and hydrogen use, which will have a positive effect on overall RES targets.

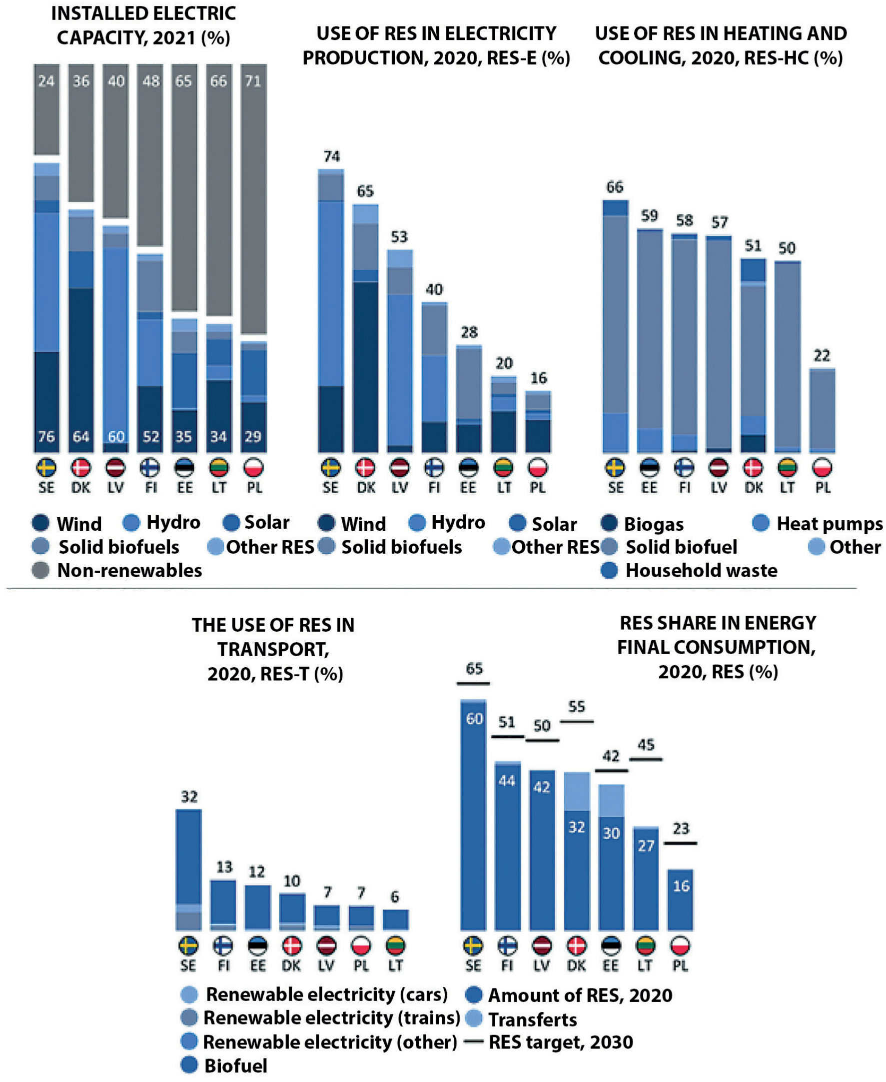
THE RENEWABLE ENERGY POTENTIAL

At the EU level, the EC has proposed in its *REPowerEU* plan to accelerate and expand the implementation of RES projects to increase its use in electricity generation, industry, the construction sector and transport. The EC has recommended to speed up the issuance of permits for RES projects and to identify “go-to areas for renewables” .[76] This mainly concerns wind and solar energy projects, which are relatively underdeveloped in Latvia. However, they can play an important role in the country’s energy portfolio, as other countries with similar conditions of solar radiation intensity and wind speed have successfully used these technologies.[77]

Progress towards the transition to RES has been delayed in part due to the historically unsuccessfully created support mechanisms that were too generous and non-transparent, and also promoted the use of natural gas.[78] The conflicting support schemes have probably also not increased the overall public support for RES projects, which is necessary to implement the projects in a reasonable period of time. For example, wind farm developers, when carrying out an environmental impact assessment (EIA) process, are faced with various objective and emotional objections from representatives of local communities related to the distances from the areas designated for wind parks to nearby settlements (wind farms must not be located closer than 800 m), the level of noise generated, the impact on the bird and bat population, as well as the impact on habitats and the surrounding landscape.[79] In order to reduce the negative attitude of local residents, RES projects should benefit not only their developers, but also local communities, which have been minimal until now. As a result, the development of wind projects is delayed and some of them will definitely not be implemented.

Assessments carried out at the beginning of 2022 show

Fig. 35 Share of renewable energy resources (RES): electricity capacity*, Renewable Energy Directive indicators of economic sectors (electricity, heating and cooling, transport) and gross final energy consumption**



Source: IRENA, Eurostat, National Energy and Climate Plans

*The parts of the installed electricity capacity are calculated based on the capacity data published by IRENA. ** RES utilization rates and the share of RES in the gross final energy consumption is from Eurostat calculations and is based on the formulas specified in the Renewable Energy Directive. The target values are obtained from the national energy and climate plans of Denmark, Estonia, Finland, Latvia, Lithuania, Poland and Sweden

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76 European Commission. 2021b. Op. Cit.

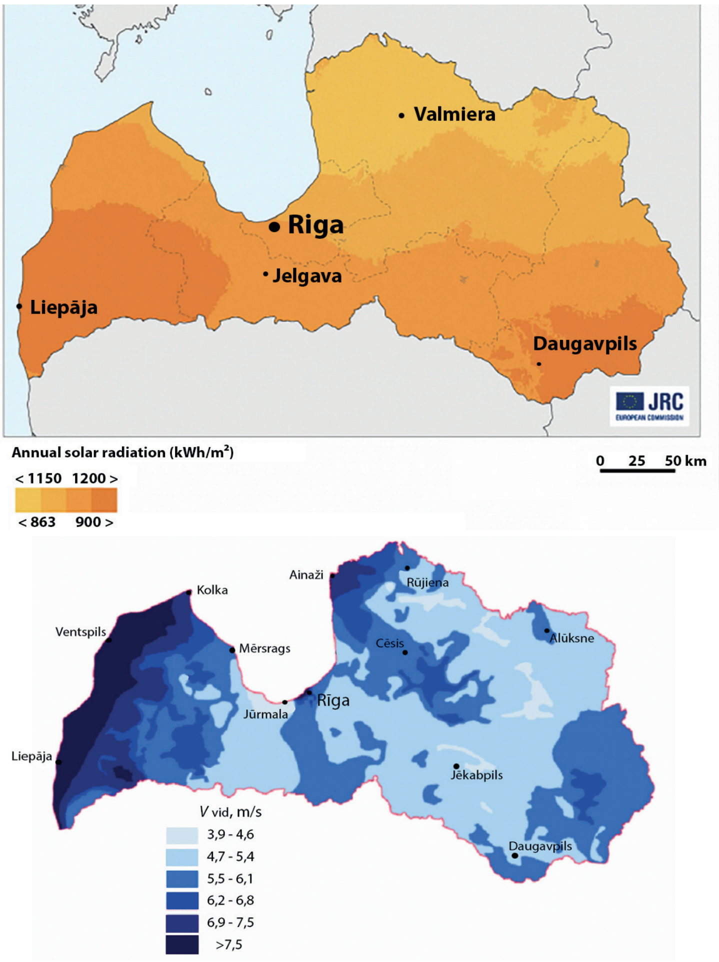
77 Lindross, T. et al. 2018. Baltic Energy Technology Scenarios 2018. https://doi.org/10.6027/TN2018-515

78 OECD. 2019. OECD Environmental Performance Reviews: Latvia 2019. https://doi.org/10.1787/2cb03cdd-en

79 Šveicars, R. 2021. “Patīk” vai “nepatīk” nav argumenti. Kāpēc kritiķi ir pret vēja parku izbūvi Zemgalē un Ziemeļkurzemē? la.lv, 2021. gada 6. decemrī. https://www.la.lv/pretvejs-iii-ietekmes-uz-vidi-novertejums-ierasts-veja-parku-stopkrans

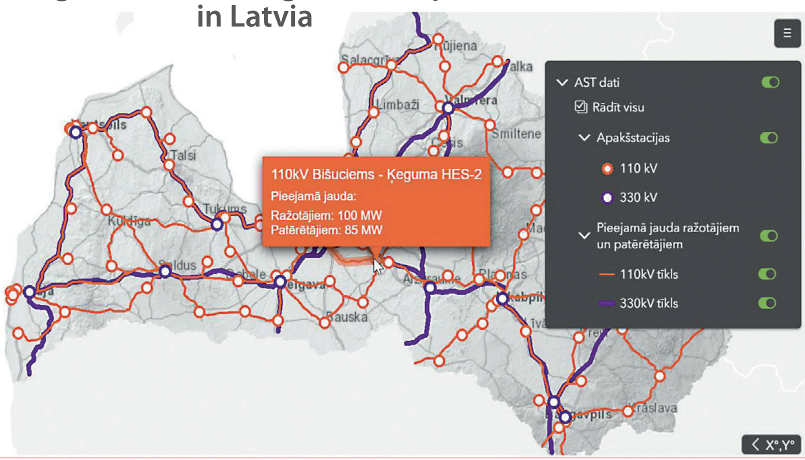
ECR. 2022. Green deal implementation - wind energy development, what are the challenges?, 2022, https://ecrparty.eu/wp-content/uploads/2022/05/Wind_Energy_Study_Final_2022_02_23-1.pdf

Fig. 36 Solar and wind energy potential in Latvia



Source: World Bank Group

Fig. 37 Free and registered capacities of connections in Latvia



that there are 15 wind energy projects in various stages of development, the expected total capacity of which would reach 2300 MW. They are mostly planned to be built in the most economically advantageous areas with the highest average wind speed in Kurzeme. It would not be possible to connect such territorially concentrated amounts of power to the existing power grid at the moment. Tto solve the problem, it would be necessary to plan the capacities more carefully, as well as to invest in strengthening of power grids, where it is necessary, and to adjust the location of the projects to the currently available power grid capacities, thus increasing efficiency of the use of the overall system.[80]

RES projects with a total capacity of approximately 3,500 MW have applied for land-based transmission network connection permits (excluding "Latvijas Vēja Parki" project and offshore wind projects), as well as 1,000 MW of connection capacity applied for the distribution network.[81] Latvia's peak load in the winter is around 1.2–1.3 GW, this amount of implemented projects is very unlikely. When evaluating investments in the network, the probability of implementation of the applied projects should be realistically evaluated, since in the future unused network capacities will significantly increase electricity tariffs for all Latvian electricity consumers. The free capacities and applied capacities of the connections are illustrated in Figure 37.

Latvia has stated in its National Energy and Climate Plan (NECP) that it plans to increase the share of electricity produced from RES, mainly by installing new wind and solar energy capacities.[82] Latvia intends to cooperate with other Baltic States to study the development possibilities of offshore wind parks in the Baltic Sea. In 2020, Latvia and Estonia signed a memorandum of understanding, which envisages the implementation of a joint wind park project with a total installed capacity of 700–1000 MW. The implementation of the project is still at an early stage, and the new wind park could start operating not earlier than 2030.[83] NECP also notes that there are administrative obstacles and territory planning conditions that limit the development of onshore wind parks. The plan envisages solving them, as well as evaluating the Latvian state forest territories as potential sites for construction of RES generation

[80] ECR. 2022. Green deal implementation - wind energy development, what are the challenges?, 2022, https://ecrparty.eu/wp-content/uploads/2022/05/Wind_Energy_Study_Final_2022_02_23-1.pdf

[81] LA.LV. 2022. Sadales tīkls: vēlme ar elektrostacijām ražot elektrību pārsniedz valsts faktisko patēriņu. https://www.la.lv/sadales-tikls-nespes-sobrid-uznemt-sistema-visu-saules-panelu-sarazoto-elektribu

[82] MK. 2020. MK rīkojums Nr. 46 "Par Latvijas Nacionālo enerģētikas un klimata plānu 2021.–2030. gadam". https://likumi.lv/ta/id/312423

[83] LSM. 2020. Estonian and Latvian wind farm project moves forward one step. https://eng.lsm.lv/article/society/environment/estonian-latvian-wind-farm-project-moves-forward-one-step.a421053/

capacities. Progress can be observed in these directions, especially after the Russian invasion of Ukraine.

In February 2022, the Cabinet of Ministers gave permission to "Latvenergo" and "Latvijas valsts meži" to establish a joint venture for the development of wind parks. On July 22, 2022, "Latvijas vēja parki" was registered with a share capital of 2 million EUR, in which 80 % of shares belong to "Latvenergo", and 20 % – to "Latvijas valsts meži". The company plans to develop new wind parks (with more than ten wind turbines each) in different parts of Latvia. Their total capacity will be at least 800 MW. It is expected that the first wind parks could be built in 3–5 years.[84]

At the household level, the plan offered financial support for households considering installation of PV panels. This proposal became a reality in 2022, and households planning to improve their energy efficiency could qualify for financial support for installation of PV panels and low-power wind turbines.[85]

Recently, there has also been growing activity in the private sector regarding the implementation of larger RES projects. The Danish RES developer European Energy has announced plans to build a 110 MW solar park in the Ventspils region[86], while the wind park developer Eolus is getting closer to obtaining a permit for implementation of a wind park project with a capacity of at least 100 MW in the Tukums region.[87] Some of RES solutions can be successfully implemented in a decentralized manner, especially, if it is possible to adjust consumption and production volumes locally.

[84] LSM. 2022. Reģistrēts "Latvenergo" un "Latvijas valsts mežu" kopuzņēmums vēja parku attīstībai. https://www.lsm.lv/raksts/zinas/ekonomika/registrets-latvenergo-un-latvijas-valsts-mezu-kopuznemums-veja-parku-attistibai.a466581/

[85] Helmane, I. 2022. Atbalsts arī saules paneļu un nelielu vēja ģeneratoru uzstādīšanai privātmājās. LV portāls, 16.03.2022. https://lvportals.lv/skaidrojumi/338866-atbalsts-ari-saules-panelu-un-nelielu-veja-generatoru-uzstadisanai-privatmajas-2022

[86] LSM. 2022. Plans announced for Latvia's largest solar park yet. https://eng.lsm.lv/article/society/environment/plans-announced-for-latvias-largest-solar-park-yet.a461735/

[87] LSM. 2022. Tukuma novada dome atbalsta vēja parka "Pienava wind" būvniecību. https://www.lsm.lv/raksts/zinas/ekonomika/tukuma-novada-dome-atbalsta-veja-parka-pienava-wind-buvniecibu.a458448/?utm_source=lsm&utm_medium=theme&utm_campaign=theme

A GOOD EXAMPLE OF A CIRCULAR ECONOMY

Balticovo™

Manufacturing companies have great potential to adapt their operations by using energy obtained from RES in their technological processes.

The energy and sustainability strategy of "Balticovo" shows an excellent example of circular economy, the way how manufacturing companies are able to get involved in solving energy issues at the local level and decentralize their dependence on the market with RES. "Egg Energy" is located in the existing infrastructure of "Balticovo", which uses bird droppings supplied by "Balticovo" to transform them into biogas and produce electricity, thermal energy and organic fertilizer. The electrical capacity of the plant is 2 MW and the amount of electricity produced reaches 16,000 MWh per year, as well as 2.1 MW of thermal energy, which allows drying and pasteurization of 7,000 tons of organic fertilizers, which can be used again in agriculture in a sustainable way.

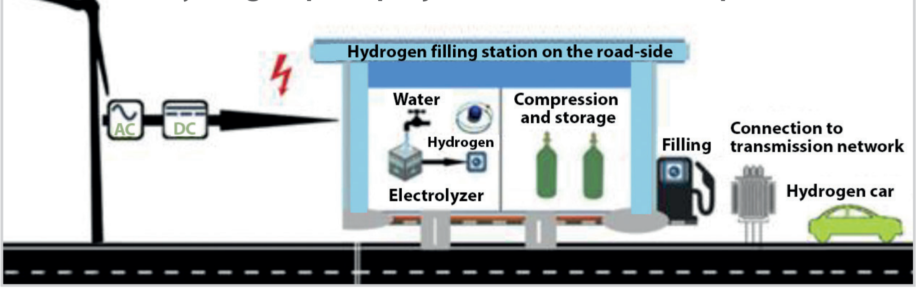
In addition, the company plans to build a solar energy park on its territory with a total capacity of 2.2 MW in order to be able to produce electricity in the hot summer months, which is necessary for cooling the flock of birds. It is during the hot summer months that the company has the highest electricity consumption and the solar park will be able to ensure sustainable energy resources for its processes, as well as supply the local region with green energy if necessary. "Balticovo" shows how manufacturing companies are able to adjust their consumption of energy resources with modern green technologies and decentralize in a smart way from dependence on the common market. Also, reducing the company's impact on nature and creating an opportunity for local residents to obtain green and nature-friendly energy.

Photo is for illustrative purpose only

Photo is for illustrative purpose only

THE HYDROGEN POTENTIAL OF LATVIA

Fig. 38 Conceptual representation of hydrogen pilot project near Ainaži wind park

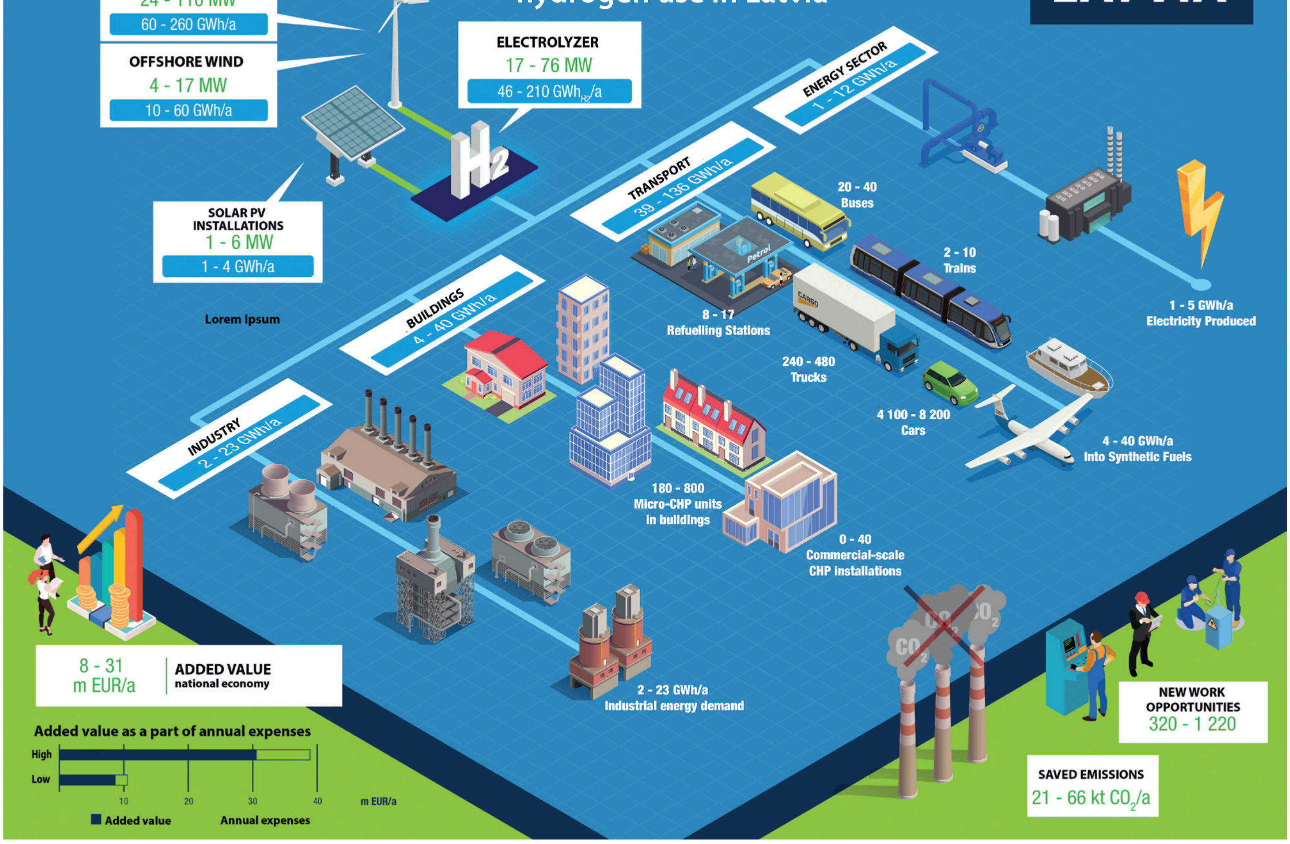


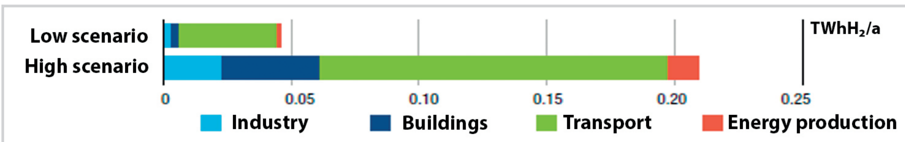
According to the FCH 2 JU (*Fuel Cells and Hydrogen 2 Joint Undertaking*) study "Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans" (2020)[88], the use of green hydrogen in the industry, transport, electriciy generation and farms is planned for 2030. The most extensive use is intended for the transport sector. The FCH 2 JU study offered two scenarios for hydrogen demand: low and high demand scenarios. In a low hydrogen demand scenario, green hydrogen will account for 0.1 % of total final energy demand (0.05 TWh/year out of 44 TWh/year). In a high hydrogen demand scenario, green hydrogen will account for 0.5 % of the total final energy demand (0.2 TWh/year out of 44 TWh/year) (see Figure 39).

Several projects can be mentioned as the ones, implementation of which is very likely in the near future.

The plan for a hydrogen filling station at Ainaži HPP envisages that a green hydrogen production point and a filling station for transport will be built at the complex of Ainažu HPP (installed capacity – 1 MW). It is planned that the capacity of the electrolysis plant will be 100 kW. An image from the study "Technical Potential of On-site Wind Powered Hydrogen Producing Refueling Station in the Netherlands" (2020) by N. Chrysochoidis-Antsos, M. Rodríguez Escudé, J.M. van Wijk is used to conceptually represent the idea.

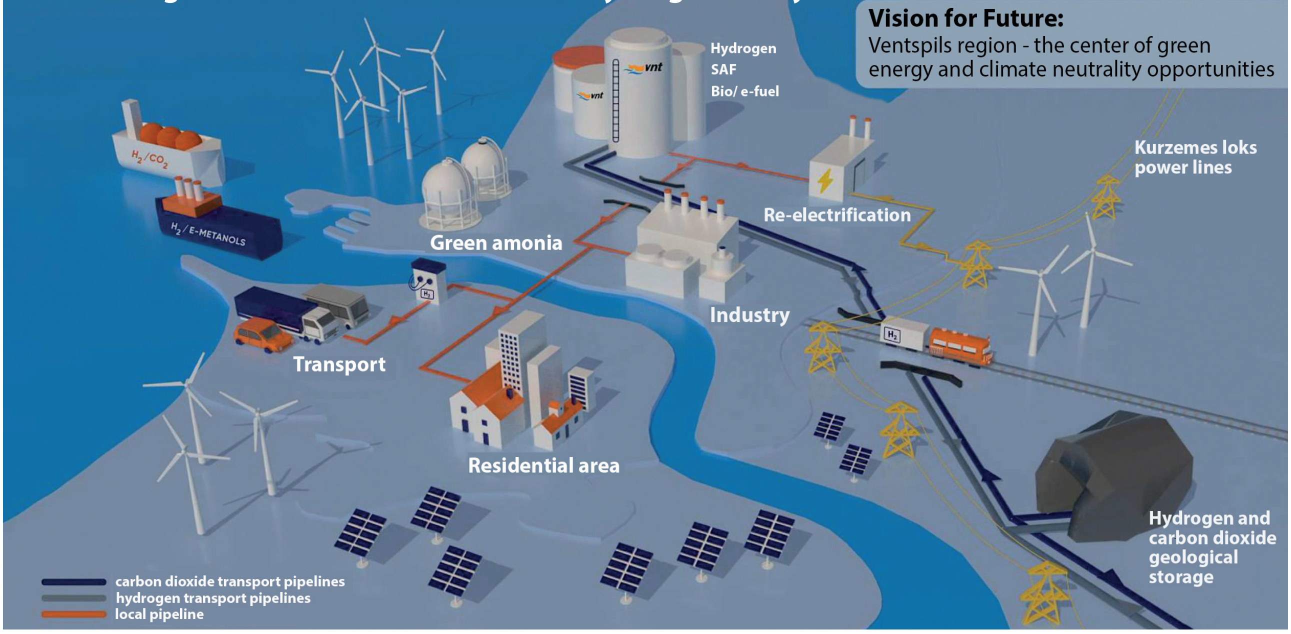
Fig. 39 FCH 2 JU study on green hydrogen use in Latvia





[88] The Fuel Cells and Hydrogen Joint Undertaking, Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans, 2020, https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Latvia%20%28ID%209473352%29.pdf

Fig. 40 VNT's future vision of the hydrogen valley



Source: BASREHRT event materials, 2022

In the future, VNT intends to create a green hydrogen valley, which would also specialize in other types of alternative fuel. The goal of the project is to provide a locally integrated green hydrogen production ecosystem for climate change mitigation and regional economic development. Hydrogen valley covers an important part of the hydrogen value chain: production, storage, transportation, end use in various sectors (industry, mobility, energy).

The hydrogen project by "Latvenergo" envisages (see Figure 41) that the green hydrogen will be produced using polymer electrolyte membrane electrolysis equipment, and electricity will come from variable generation, Daugava HPPs, CHP-2 solar batteries or from the planned wind parks. The produced hydrogen will be stored or used immediately for combustion in gas turbines at CHP-2. Before burning, the produced hydrogen will be mixed with natural gas in a mixing unit. Its proportion in the gas mixture should not exceed 5 % (by volume) in order not to affect the operation of CHP-2 equipment. Hydrogen storage is intended for its later use in cooling the CHP-2 electric generators and/or for sale to external users such as transport companies (e.g., public transport, railways) or the industry.

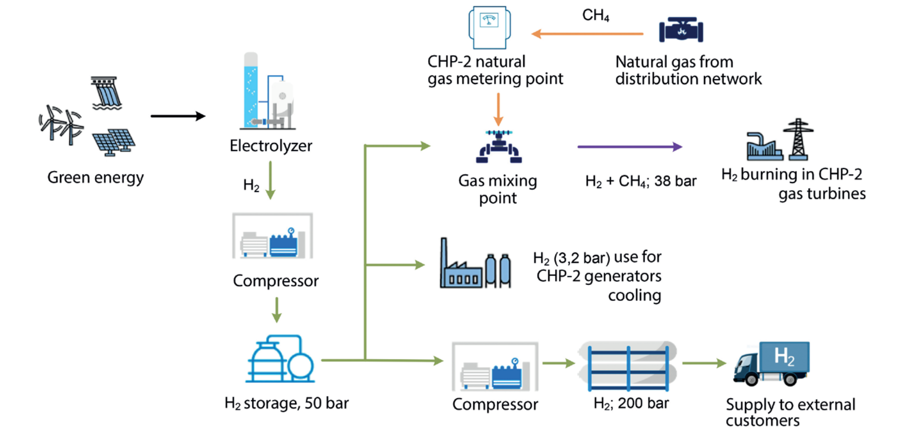
Based on the initial research results, the electrolysis capacity of 6.5 MW was determined. Refinement of the initial assessment (in-depth study) is currently underway with the involvement of external experts. It outlined that electrolysis capacity could reach up to 20 MW and storage capacity up to 40,668 kg. Transport (cars, buses, heavy-duty vehicles) is predicted to be the largest consumer of thr produced hydrogen. Changes will be made to the schematic representation of the hydrogen project after further investigation.

Another potential solution for the utilization of produced hydrogen is to inject it into the natural gas network. "Latvenergo" is evaluating the possibilities of building a new gas pipeline to connect directly to the gas transmission infrastructure. The potential transmission natural gas pipeline together with the existing distribution gas pipeline can be used to inject a mixture of hydrogen and methane into the gas network, but without changes in consumer equipment, the hydrogen admixture can only reach 20 %.

The hydrogen pilot project is planned to be implemented until 2025, but until 2030–2035 a larger capacity electrolysis plant (over 100 MW) would come online. For the production of green hydrogen, "Latvenergo" plans to significantly increase the capacity of wind and solar plants, which can exceed 2000 MW in total. Together with existing hydropower capacities, it can provide electrolysis plants with green electricity at competitive prices.

Currently, the research is being carried out in cooperation with the Latvian Hydrogen Association, in which the concept of hydrogen projects is clarified and indicators for the use of

Fig. 41 Initial schematic representation of the hydrogen project, CHP-2



hydrogen in Latvia in 2030 and 2050 are evaluated. The indicators presented in the table are indicative and may change. Certain hydrogen consumptions are also not quantified, such as the replacement of aviation fuel with synthetic fuels due to a lack of information on production plans.

THE NUCLEAR ENERGY POTENTIAL OF LATVIA

The Salaspils scientific nuclear reactor operated in Latvia until 1998. Latvia has been a member of the International Atomic Energy Agency since 1997; however, the country does not yet have the prerequisites for building a commercial NPP. Large NPP projects, such as Finland's Olkiluoto, are complex and construction deadlines are difficult to predict, so SMR technologies, which are easier to install and easier to integrate into the local energy infrastructure, are more suitable for the Baltic States.[89]

The Estonian company Fermi Energia has spent several years performing various preparatory works: starting from improving public awareness and ending with specific steps for the implementation of the NPP project. The project received political support at both the state and local government levels. The attention of investors and various international organizations has been attracted. Local specialists are trained and foreign experts are recruited. Estonia's first modular nuclear reactor is planned to be commissioned in 2032. It will most likely be *GE Hitachi BWRX-300* boiling water nuclear reactor (see Figure 42), which has a thermal output of 870 MW and an electrical output of 300 MW. This technology is currently in the licensing process. Such a reactor is already planned to be used by the Canadian company Ontario Power Generation at its Darlington NPP.

Latvia is a few years behind Estonia in its NPP project vision. It can be estimated that the construction of the Latvian SMR would be delayed in comparison with the one of Estonia. Although the idea of constructing a nuclear power plant in Pāvilosta was not implemented in Latvia in the 1980s, some preliminary knowledge in this field was obtained. The Salaspils scientific nuclear reactor operated in the country from 1961 to 1998. In 2006, the governments of the Baltic States agreed on the construction of a joint nuclear power plant in Lithuania. Within its framework, several studies were carried out.

The Latvian company Siltumelektroprojekts works as a subcontractor in several NPP projects (Hanhikivi-1 in Finland, Paks 2 in Hungary, Akkuyu in Turkey, El Dabaa in Egypt).[90] The construction of NPP in Latvia will be significantly facilitated by the implementation of a familiar project in Estonia and Poland. Latvia has the appropriate human capital and knowledge so that we can design and develop such projects.

According to the EU Taxonomy Delegated Act, nuclear energy is considered a method that will enable the transition from fossil fuels to climate-neutral energy. Therefore, it is intended to allow for the construction of new nuclear power plants during the transition period. In the case of a new nuclear power plant, the construction license must be obtained by 2045 (this is one of the restrictions of the EU taxation). In order to implement the Latvian NPP project, construction must start in the period from 2030 to 2045. By that time, all large-scale works for the preparation of the project must be completed.

The first step to be taken, if the construction of NPP is considered, is the development of state planning documents. In 2022, the Energy Law was revised, where several recommendations related to the construction of a nuclear power plant in the territory of Latvia and its connection to the system operator's network were considered.[91] By September 30, 2022, the Cabinet of Ministers had to submit a report to Saeima on the feasibility of constructing a nuclear power plant in Latvia. When conducting the evaluation, the geopolitical situation, the development of the cost, and the availability of energy resources are taken into account. In case the report of the Cabinet of Ministers is positive, the next step could be to foresee the construction of NPP in the Energy Development Guidelines or in another bin-

Table 5 Indicative indicators of hydrogen consumption in Latvia

Hydrogen use	2030	2050
Transport (internal combustion engine and diesel fuel replacement with hydrogen el. for engines)	14,04 kt (0,46 TWh)	593,56 kt (19,60 TWh)
Stationary energy (hydrogen admixture in the natural gas network; use of hydrogen for electriciy generation)	5,3 kt (0,17 TWh)	65,5 kt (2,16 TWh)
Electriciy generation, balancing/accumulation (hydrogen as energy accumulator and transmitter; as raw material energy in production)	6,9 kt (0,23 TWh)	156 kt (5,15 TWh)
Hydrogen as a raw material For chemical production	It is difficult to define, because there are just a few hydrogen-consuming companies in Latvia. Export opportunities should be considered	
Hydrogen in synthetic fuel production (using hydrogen in CCS)	32,4 kt (1,07 TWh)	291,6 kt (9,62 TWh)

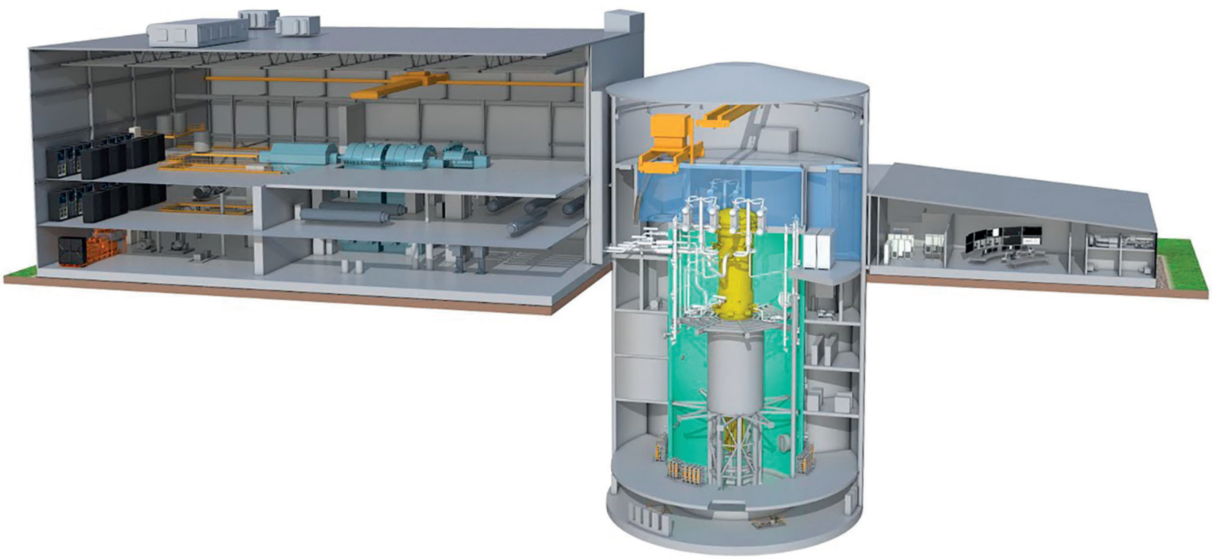
1 TWh = 0,0303 mill. t H_2

89 GE Hitachi Nuclear Energy, 2022, The BWRX-300 is SMR model, https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300

90 AS "Siltumelektroprojekts" https://sep.lv/

91 LR Saeimas ziņojums, 2022, https://titania.saeima.lv/LIVS/SaeimasNotikumi.nsf/webSNbyDate?OpenView&count=1000&restrictToCategory=20.04.2022

Fig. 42 BWRX-300 type nuclear reactor



Source: GE Hitachi Nuclear Energy, 2022, The BWRX-300 is SMR modelis, https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300

ding long-term planning document. Other steps to be taken would be the establishment of a regulator and nuclear safety inspection, adoption of a law on the construction of NPP in Latvia, lobbying for media support, selection of a site, preparation of NPP service personnel, coordination of the project with neighboring countries, construction of a used nuclear fuel storage facility, etc.

If two small nuclear reactors were built with a total electric power of 600 MW (2×300 MW) and capacity factor of about 80 %, they could produce more than 4 TWh of electricity a year. The Latvian TSO predicts[92] that in 2032 electricity consumption will be between 7.6 and 8.3 TWh, so such SMRs would be able to supply half of the electricity needed by the country. It could be used by all electricity consumers in Latvia. This amount would significantly reduce electricity imports, improve the reliability of electricity supply and improve the country's external balance of payments. In 2021, consumption in Latvia was covered by local generation in the amount of 75.9 % (1.77 TWh of electricity was imported).[93] The trade balance of goods and services had a deficit of 2.1 % of the GDP, or 940 million EUR.[94]

The construction of two SMR reactors would help Latvia to become more independent electriciy generation-wise, and the NPP would be able to work in synergy with the planned wind and solar parks, the existing Daugava HPPs, as well as with the planned green hydrogen projects. In the development of common infrastructure, Latvia would also be able to become more climate neutral, as well as a strong energy exporter within the Baltic region.

Table 6 Implementation stages of the NPP construction project

	CONSIDERATION PHASE BEFORE THE DECISION IS MADE TO START THE PROJECT	STAGE OF PREPARATION CONTRACT WORKS FINAL DECISION MAKING	CONSTRUCTION PHASE CONSTRUCTION OF NPP		EXPLOITATION PHASE
	2022 2023 2024	2025 2026 2027	2028 2029 2030	2031 2032	2033
Management	Creation of a working group And research	Territorial planning and the issuance of construction permit		NPP licensing process	
Management	Legislation preparations	Creation of a regulatory authority and development of the normative base	Supervision of construction works, commissioning and testing		Regulatory supervision
Operator	Further research and choice of technology	Preparation for construction and licensing process	Territory improvement, carrying out construction works and equipment assembly		Commercial operation

National Designated Spatial Plan

92 Pārvades sistēmas operatora ikgadējais novērtējuma ziņojums; Rīga; 2022

93 AS "Augstsprieguma tīkls" dati, 2022, https://ast.lv/lv/electricity-market-review?-year=2021&month=13

94 Latvijas bankas dati, 2021, https://datnes.latvijasbanka.lv/lmb/LMB_2021.pdf

THE FUTURE SCENARIOUS OF THE LATVIAN ENERGY SECTOR

Description of situation at the eve of the 2022/2023 heating season

As part of the research, scenarios of the electricity generation portfolio for the situation of 2022/2023 and a 10-year perspective have been developed. The scenarios have been created based on publicly available data, without an in-depth evaluation. The described scenarios are based on many assumptions that increase the possibility of bias and are not scientifically based.

According to the 2022/2023 report of the natural gas TSO Conexus Baltic Grid, the predicted fulfillment of the IUGS is 59 %. According to the assumption of the mentioned TSO scenario, in case of the the natural gas supplies to the Baltic-Finnish region from Russia do not take place starting from 2023, the natural gas reserves at IUGS could be exhausted in March 2023, creating the natural gas deficit of at least 30 TWh per year during the heating season. Only part of natural gas stored in IUGS is intended for consumption in Latvia (the information on exact amount is confidential). The TSO forecast is based on an assumption that deliveries from Russia in 2022 will not take place only in May and June, and that 33.29 TWh of the natural gas will be delivered trough the Klaipeda LNG terminal, 1.46 TWh – trough Hamina LNG terminal, but the annual consumption of natural gas in Latvia will be 11.34 TWh.[95]

At the same time, this assessment was prepared before Gazprom stopped the natural gas supplies to Latvia on July 30, 2022, before the end of the delivery season. Thus, the actual situation in the heating season of 2022/2023 is associated with even higher risks. It is critical for the availability of natural gas to provide alternative ways and sources of its supply.

Building new infrastructure takes time. An additional LNG terminal in Latvia, Estonia or Finland would be necessary to meet the predicted demand. LNG terminals in Estonia and Finland are expected to start operating in autumn 2022.

It is essential to make the capacity of the Klaipėda LNG terminal available to Latvian traders without any discriminative requirements. It should be noted that the negative balance of electricity in Lithuania (consumption significantly exceeds generation) is one of the determining factors for the high price of electricity in the price zones of Latvia as well. If natural gas is not available to operate CHPs for market needs, the price of electricity in Latvia and Lithuania (thanks to the large interconnection capacity between the two countries) can reach a significantly higher level.

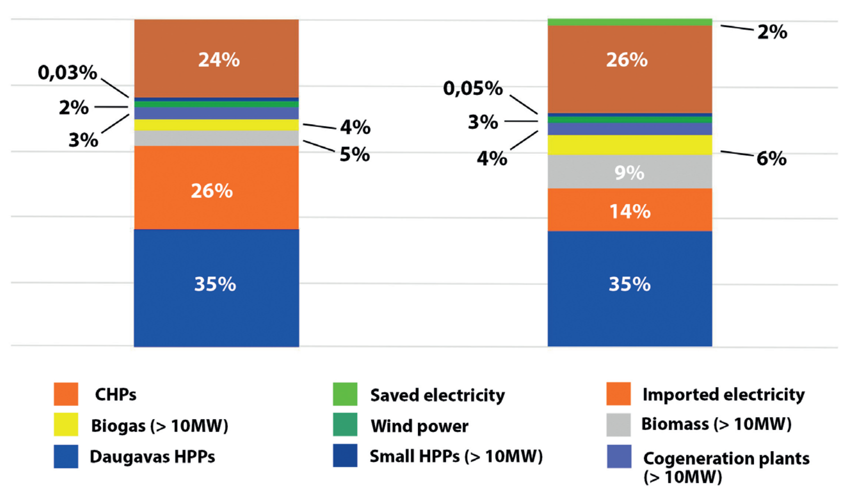
It is also critical that the natural gas traders not only have available infrastructure capacity, but also gas itself as a product. Availability of tankers to deliver natural gas to its destination port is also important for the availability of it as a product. As previously mentioned, natural gas is in short supply throughout Europe, and the European natural gas consumers face fierce competition for natural gas deliveries with Asian counterparts. This creates a significant speculative risk. In addition, there are also logistics problems – as the demand for LNG increases significantly in the EU, there is also a shortage of tankers.

In order to reduce natural gas deficit, it is necessary to make maximum use of the opportunities for replacing natural gas with other alternative energy sources and technologies that do not use natural gas for energy generation. At the same time, the actual possibilities of implementing such changes should be evaluated, taking into account the time restriction. Replacing natural gas, electricity and thermal energy can be ensured by increasing the use of biomethane, biomass, as well as by installing heat pumps, solar panels and wind generators. It is also possible to use fuel oil and diesel as fuel. The use of coal-fired power plants is also increasing in Europe.

At the same time, even if the current solar generation capacity doubles, the impact on Latvia's overall energy portfolio would be minimal. It is not expected that large-scale biomethane, biomass or heat pump energy generation projects would be implemented until the winter of 2022/2023. In September 2022, 58.8 MW wind energy park in Tārgale near Ventspils started operating, slightly increasing the share of wind energy in the energy portfolio.

The scenario is created based on an assumption that in the heating season of 2022/2023, the weather conditions will be similar to the previous year and the intensity of

Fig. 43 Electricity generation portfolio in 2021 and possible scenario



Source: table created by the authors, based on www.ast.lv data

[95] Conexus, PSO paziņojums 2022., https://www.conexus.lv/uploads/filedir/Zinojumi/PSO_zinojums_2022_LV.pdf

Table 7 The natural gas consumption during the year and the heating season

	2021	2020	2019
Final consumption, MWh	12 707 312	11 750 894	14 506 469
Heating season (October-April), MWh	8 223 633	9 828 140	8 503 685
Consumption during heating season, % of annual consumption	65%	84%	59%

Source: Oficiālā statistikas portāla dati, https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__EN__ENB/ENB020m/

HPP operation will be similar to the previous year as well. Also, the scenario assumes that:

- the use of PV panels will double. At the same time, the impact on the total electricity production portfolio would be below 1 %;
- the increase in the amount of electricity produced from wind, biomass, biomethane will not be significant (+58.8 MW wind);
- electricity imported from other EU member states will cover the amount of electricity that cannot be covered by consumption savings.

According to the data of the Central Statistics Office, the consumption of natural gas in the heating season in the last three years made up 59–84 % of the annual consumption of natural gas, which was 8.2–9.8 TWh (see Table 7). It should be noted that lowering the indoor air temperature significantly increases fuel consumption. Natural gas consumption is also significantly affected by the price of the natural gas, as at a high gas price, electricity produced from it is less competitive in *NordPool*. Accordingly, such electricity is not demanded and sold on the market. Similarly, industrial consumers of natural gas are forced to reduce the intensity of natural gas use, as products in whose production costs the natural gas play an important role, lose competitiveness.[96]

Comparing the first six months of 2022 to the same period in 2021, natural gas consumption in Latvia has decreased by 31.8 %. In addition, during the summer months of 2022, CHPs were practically not operated (even at the historically highest electricity price on the stock exchange of 2100 EUR/MWh on July 21, 2022 and 4000 EUR/MWh on August 17, 2022). This ensures relatively larger natural gas reserves at the beginning of the heating season.

IUGS is used both by private local companies and state-owned and international companies representing various business sectors – the natural gas wholesale and retail, energy producers, heating operators and manufacturing companies. According to publicly available information, the storage has 5.6 TWh of natural gas owned by companies registered in Latvia (press release dated 5 August 2022). At the same time, according to regulatory enactments, 2 TWh of natural gas is intended to form a reserve for ensuring stability of the electricity system in case of emergency desynchronization from IPS/UPS. This shows the critical role of alternative supplies of natural gas.

It is possible to reduce the deficit of natural gas by reducing the total consumption of energy resources and implementing saving measures. The EC has proposed to reduce the consumption of natural gas by 15 %.

A part of the reduction in consumption will occur naturally due to high gas prices. For example, by the summer of 2022, the consumption of natural gas in Latvia had already decreased by 30 % compared to the corresponding period of the previous year. This is mostly because CHPs, which are Latvia's largest gas users, were not operated. At the same time, less CHP operation allows for higher and more frequent electricity price maximums to appear.

In Latvia, Prime Minister Krišjānis Kariņš has instructed all ministers and the State Chancellery to prepare for the implementation of energy-saving measures in the upcoming heating season. Various austerity measures are widely implemented across the EU, including determining the air temperature in the premises, the violation of which is punishable. There are other measures introduced or considered in other countries, such as buying drinks from hypermarket refrigerators that are not cooled to 4 °C, but rather 8 °C, and even paying extra for a cooler bottle compared to the one out of the shelf. Organization of sport competitions and concerts is proposed to be only during the day, thus avoiding the use of light systems. Reduction of use of artesian fountains and lighting of public buildings is also proposed by some experts. Options like reducing of Christmas markets and *Oktoberfest* activities this year have been considered, too. These are just a few useful (and sensible) "next-level" measures for periods of geopolitical and energy turmoil. But all of them come with social and political price tags that may further fuel social unrest in the region.

Other trends

Recently, along with significantly increasing electricity prices on average and during peak hours in particular, there is a tendency for energy consumers to switch from exchange-based electricity price contracts to fixed-price contracts. Although, for example, household consumption is relatively small, this trend in general, especially in the long term, can be evaluated negatively, as it reduces motivation of consumers to respond to market signals and evaluate possibilities of shifting their consumption to the time of a smaller energy generation deficit, thus not contributing to the future price increase in the country.

Also, traders who offer fixed price contracts are taking on risks that may not be covered in the event of further escalation of the energy crisis. Thus, for example, in the UK, 31 electricity traders have encountered significant financial difficulties (where government intervention was necessary) due to a sharp rise in electricity prices.

[96] https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__EN__ENB/ENB020m/

Latvia's future energy portfolio

Taking into account the geopolitical situation, its significant impact on the natural gas prices and its actual availability, it is predicted that the demand for natural gas in Latvia will decrease in the coming years, but in the medium term – it will return to the previous level. On the other hand, in the longer term, the natural gas consumption will decrease according to the goals of Latvia's energy sector decarbonization agenda.

When creating future energy portfolio scenarios, it is important to take into account that as RES generation increases, so does the need to provide balancing capacities that will be able to ensure stable system operation and satisfy less flexible demand when variable RES sources are not available. As the proportion of RES to baseload (dispatchable) increases, balancing becomes more expensive; thus, it is essential to achieve a sustainable ratio between variable and dispatchable energy sources.

Table 8 Electriciy generation costs, by technology

Technology	Capital costs, (USD/KW), median
Biomass (cogeneration)	4 689
Coal (CCUS)	4 572
Nuclear energy	3 370
Onshore wind (< 1 MW)	2 852
Hydropower (reservoirs, > = 5 MW)	2 778
Offshore wind	2 740
Natural gas (CCGT and CCUS)	2 619
Coal (cogeneration)	2 240
Solar PV (households)	1 653
Onshore wind (> = 1 MW)	1 439
Biomass	1 095
Solar PV (commercial)	1 085
Natural gas (CCGT)	955
Solar PV (large-scale)	923
Hydro accumulation	897
Natural gas (OCGT, combined cogeneration)	684
Lithium-ion batteries	655
Nuclear energy (long-term use)	497

Source: OECD, Levelised Cost of Electricity Calculator, 2020 Nuclear Energy Agency - Projected Costs of Generating Electricity - Levelised Cost of Electricity Calculator

When creating the future energy portfolio for electricity and heat sectors, the following principles are taken into consideration:

- electricity consumption will increase despite energy efficiency measures. This will be facilitated by a wider electrification. A 7 % increase is assumed in 2035 compared to 2021 electricity consumption;
- prioritization of the local energy resources, which both reduces energy dependence and promotes the growth of the gross domestic product through the efficient use of resources;
- diversification of energy sources and generation technologies. Diversification of energy sources will provide greater flexibility to meet the demand of the given hour, adapting to weather conditions and the prices of energy resources, their actual availability and the competitiveness of technologies, ensuring a stable supply of energy to consumers at the lowest possible prices;
- possibly minimal state intervention, allowing technologies to find the most cost-effective solution for offering energy to consumers;
- maximum use of the existing infrastructure, critical evaluation of creation of new infrastructure;
- avoiding the long-term contracts in crisis situations.

Trends in the natural gas usage:

- use of the natural gas by diversifying supply routes and sources;
- a wider use of biomethane;
- production and use of hydrogen, both by injection of hydrogen into the natural gas system with a concentration of up to 20 % and by using a separate decentralized network, where it is economically justified;
- CHP operation will decrease by 20 %.

Trends in the wind and solar energy usage:

- a wider use of wind energy, effectively using both the available capacity of transmission and distribution systems and wind potential;
- peak electricity load in 2021 was 1.2–1.3 GW. In 2035, the peak load will increase in proportion to the increase in electricity consumption;
- taking into account the current huge interest in the development of wind projects, it is predicted that the number of implemented projects will slightly exceed Latvia's peak load demand (which is the limit of commercial profitability of wind and solar energy). Accordingly, the installed capacity of wind and solar power plants could be around 1.6 GW.

Biomass utilization trends:

- the growing trends of biomass use in electriciy ge-

Baseload generation:
Natural gas ↓
Biogas ↑
Hydrogen ↑
Biomass →

Variable generation:
Wind ↑
Solar ↑
Hydro →

neration in Europe are not sustainable, and limited biomass resources will be more attractive to use in areas where their added value is the highest. The total demand for biomass is significantly higher than what can be produced in Europe without jeopardizing GHG emission reduction targets;

- traditional applications in bioenergetics together with the electrification of final consumption and the improvement of green hydrogen production technologies will become relatively less profitable, continuing to use it where electrification possibilities are limited and hydrogen utilization is difficult;
- in Latvia, biomass is a traditional source of energy, so a significant drop in its use in the near future is unlikely.

Heat pumps:

- with the development of technologies, the competitiveness of heat pumps continues to improve, promoting the wider use of electricity in heating applications. Also, when creating the scenarios, it has been foreseen that under equal conditions, the technologies compete in the market, taking into account their costs (see Table 8);
- following the above-mentioned assumptions and principles, electricity generation scenarios have been created, which can be seen in Figures 44 and 45.

Fig. 44 Electricity generation (without NPP)

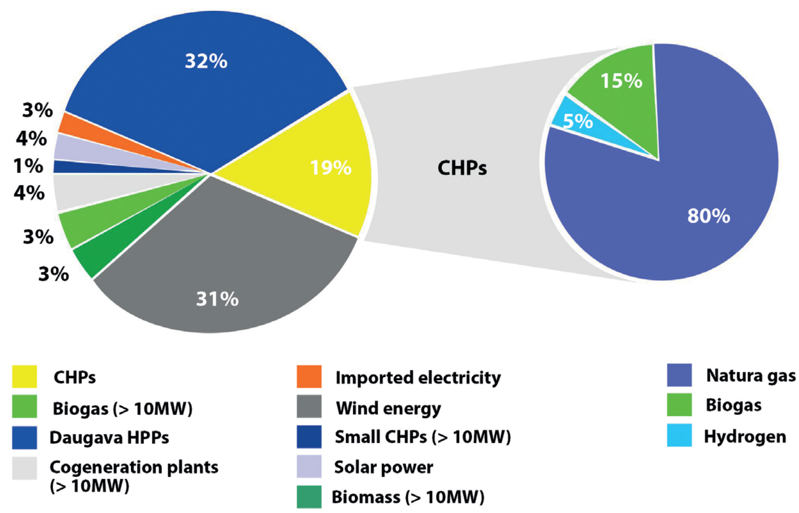
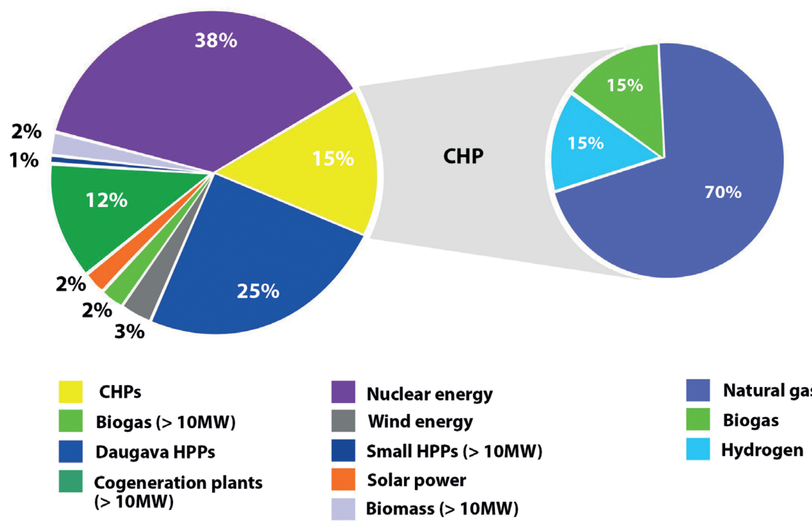


Fig. 45 Electricity generation (with NPP)



According to the long-term scenario of Latvia's electricity portfolio (without NPP), a larger share of electricity in Latvia will continue to be provided by HPPs. The next largest source of electricity could be wind power plants (mainly onshore power plants, due to their lower costs compared to offshore wind farms and relatively freely available land areas in Latvia, if no obstacles are placed by local governments). The CHP would mostly act as a backup generation source at times when variable generation would not be able to meet the demand for electricity. The amount of natural gas burned by the thermal power plant could decrease both with the increase in the amount of biomethane in the natural gas system (15 %) and with the appearance of hydrogen (5 %).

According to the long-term scenario of the Latvian electricity portfolio (with NPP), a large share of electricity in Latvia would be provided by NPP, taking into account that two reactors are needed to be able to provide backup power of one reactor in time when the other is not in operation. In such a scenario, a surplus electricity would be produced. The scenario envisages that hydrogen would be produced from part of the electricity produced by the NPP, which could, in turn, be more actively used for the operation of CHPs. The scenario envisages that the surplus electricity would be exported to other countries (at the same time, within the framework of the study the competitiveness of such electricity was not evaluated from the perspective of it competitiveness comparing with the planned generation capacities in other countries). Along with a higher hydrogen production, a more active use of CHPs is foreseen compared to the first scenario. Accordingly, the share of HPP is expected to fall to the third place in the electricity generation portfolio, if the current electricity generation volumes remain. The scenario predicts that wind energy will make up a relatively insignificant part, only around 3 %.

The Latvian energy sector: steps to be taken

When pinpointing the topicalities in the development of the Latvian energy sector, it is important to take into account events in other countries of the region, because the principle of "connected vessels" works in energy.

The following measures are critically important for the heating season of 2022/2023:

- completion of the Finnish and Estonian LNG terminals;
- immediate availability of the Klaipėda LNG terminal for the Latvian natural gas traders;
- availability of natural gas as a product (speculative risk);
- replacement of natural gas, where possible (biogas, wood chips, heat pumps, sun, wind);
- energy savings.

In addition, as the natural gas supply routes used until now are no longer available, it is necessary to immediately develop a new regional security of supply risk assessment, covering not only Latvia's needs and situation, but also the Finnish market, the Finnish-Estonian interconnection *Balticconnector* and the Lithuanian-Polish interconnection GIPL.

It is important to recognize the growing insolvency risks of electricity traders. Similar to many other EU countries, traders in Latvia who offer a fixed electricity price often experience challenges, as the customer contract fee may be insufficient to cover costs when purchasing electricity in *NordPool*, with the actual price significantly exceeds the forecast.

It is also important to recognize the effect of the energy crisis on other areas. For example, several fertilizer production plants closed in the EU due to high energy prices that would have an impact on the next agricultural season and the food sector. Natural gas accounts for about three-quarters of the cost of producing mineral fertilizer, so the European plants have simply shut down, putting more pressure on the American producers, where the price of natural gas is significantly lower. Similarly, there are high risks of production deficit in other energy-intensive areas. The impact of high energy prices on inflation and, accordingly, on the standard of living can not only negatively affect GDP growth, but also contribute to citizens' dissatisfaction with the political situation and social order.

When evaluating medium-term and long-term measures, it should be taken into account that the LNG terminal in Latvia could be built no sooner than by the end of 2023. When evaluating a possible project solution, all potential costs should be considered, minimizing the risk of overinvestment in infrastructure that is not proportional to the intensity (efficiency) of their use.

It is essential to evaluate the consequences of long-term contracts. In accordance with publicly available information, private developers of the LNG terminal are interested in concluding a long-term commitment agreement for at least 10 years. At the moment, it is not known what the gas market will be like in a few years, as well as what the demand and price of the natural gas will be. At the same time, the terminals are currently working with excess profit. It is also important to assess the risks of possible surplus of natural gas, taking into account that its consumption in Latvia should gradually decrease.

It should also be understood that the natural gas pipelines have been built between Lithuania and Poland and Norway to Poland, and LNG terminals are being built in Estonia and Finland. For example, the planned capacity of the Skulte LNG terminal is 40 TWh, which significantly exceeds the annual consumption of natural gas in Latvia. Accordingly, when deciding on the necessity of this project, the strategy of the natural gas deliveries to neighboring countries should also be foreseen.

The Ministry of Economy, which is the leading ministry in the energy policy formation in Latvia, must evaluate the mentioned above risks when advancing the proposal for making political decisions.

Particular attention should be paid to the problem of insufficient power generation capacity in Latvia and the entire Baltic region. At the same time, when evaluating possible generation stimulating measures, it is important to take into account that the projects could be mutually exclusive or their parallel implementation could require significant investments in public infrastructure, causing an impact on the tariff.

When evaluating possible solutions in the energy sector, it is necessary to follow the trends in the region, because the energy sector in Latvia cannot be viewed separately from the countries that are participants of the same energy market.

Latvian Economists Association

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Partly funded by the European Parliament