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TEN ACTIONS OF UKRAINE TO REJECT RUSSIAN NATURAL GAS

UABIO Position Paper № 28 of the Bioenergy Association of Ukraine is an up-to-date work of experts, which contains practical recommendations for Ukraine on how to abandon the use of the aggressor's natural gas.

The Position Paper presents the results of the technical and economic analysis of Ukraine's ways to reject russian natural gas. The urgency of the topic is due to the military aggression of the russian federation against Ukraine and the need to quickly abandon the import of russian energy resources. The successful experience of European countries in replacing fossil fuels with renewable energy sources is analyzed. The optimal measures to reject russian gas and the role of bioenergy in this process have been identified. The list of necessary organizational and legislative measures is formed. In addition, an estimate of the projected volumes of reduction and replacement of russian natural gas consumption in Ukraine as a result of the implementation of the proposed steps is provided.

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Abbreviations

CHP – combined heat and power
DH – district heating
GTS – gas transmission system
IEA – International Energy Agency
IAEA – International Atomic Energy Agency
NG – natural gas
NREAP – National Renewable Energy Action Plan
bln – billion
mln – million
Mt – million tons
Mtoe – million tons of oil equivalent
LNG – liquefied natural gas
NEC – National Energy Company
NERC – National Energy Regulation Commission
NPP – nuclear power plant
ORC – organic Rankine cycle
RES – renewable energy sources
SPP – solar power plant
TFC – total final consumption
TPES – total primary energy supply
TPP – thermal power plant
UGS – underground gas storage
PV – photovoltaic
WPP – wind power plant

Introduction

The purpose of UABIO Position Paper No 28 is to identify and describe ten most important actions for **Ukraine's complete rejection of Russian natural gas**. The analysis was performed taking into account the following basic provisions:

- Territorial integrity of Ukraine is within the state as of February 23, 2022.
- Total energy consumption is at the level of 2021 (it is believed that it will be restored within 1-2 years after the war).

During last months before the war beginning on February 24, 2022, there has been an increase and fluctuations in natural gas prices in Europe. As a result, the price "stabilized" at about **840** EUR/1000 m^3 (**80** EUR/MWh) (**Fig. 1**)[1]. After February 24, 2022, there was a significant surge in NG prices with a peak in the first half of March, but then there was a "stabilization" of the prices at around **1150** EUR/1000 m^3 (**110** EUR/MWh). Under such conditions, ***biomethane*** and all types of ***solid biomass*** are economically competitive with natural gas.

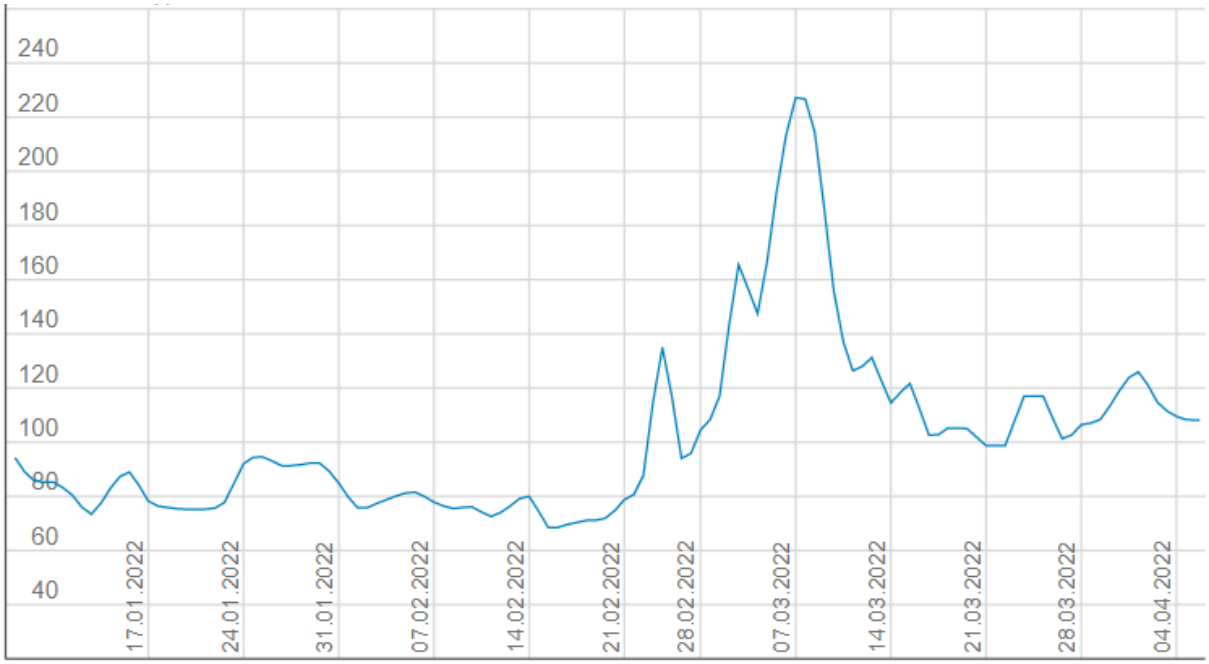

Fig. 1. Dynamics of NG price at TTF gas hub, EUR/MWH *Ошибка! Закладка не определена.*

The urgent task for the European Union and for Ukraine is to **completely reject Russian natural gas**. However, even after switching to other potential suppliers (such as LNG from Qatar or the United States), prices are unlikely to fall due to declining supply of Russian gas in the market and increased competition for this energy source. Among the priority measures to replace Russian natural gas, most experts name the large-scale development of ***renewable energy sources*** and the implementation of ***energy efficiency measures***.

[1] Ministry of Finance of Ukraine. Gas prices in the world: https://bit.ly/3L8N060.
Conversion factors: **1000 m^3 ≈ 10.49 MWh or 1 MWh ≈ 95.31 m^3.**

Measures to reduce the European Union's reliance on Russian natural gas

In early March 2022, the *International Energy Agency* presented a series of concrete steps that the EU can take to **reduce** Russian natural gas imports by more than a **third** by the end of 2022[2] [3]. These measures correlate with the basic provisions of the European Green Deal[4] adopted in late 2019. Some of the proposed steps, in particular increasing energy efficiency measures, accelerating the development of solar and wind energy, raising the share of low-carbon sources to increase the flexibility of the energy system, are based on the IEA's Roadmap to net zero emissions by 2050 (2021)[5].

IEA's version of a 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas

1. Do not sign any new gas supply contracts with Russia.
   Impact: Enables greater diversification of supply this year and beyond.
2. Replace Russian supplies with gas from alternative sources
   Impact: Increases non-Russian gas supply by around **30** billion m^3 within a year
3. Introduce minimum gas storage obligations.
   Impact: Enhances resilience of the gas system by next winter.
4. Accelerate the deployment of new wind and solar projects.
   Impact: Reduces gas use by **6** billion m^3 within a year.
5. Maximise power generation from bioenergy and nuclear.
   Impact: Reduces gas use by **13** billion m^3 within a year.
6. Enact short-term tax measures on windfall profits to shelter vulnerable electricity consumers from high prices.
   Impact: Cuts energy bills even when gas prices remain high.
7. Speed up the replacement of gas boilers with heat pumps
   Impact: Reduces gas use by an additional **2** billion m^3 within a year.
8. Accelerate energy efficiency improvements in buildings and industry
   Impact: Reduces gas use by close to **2** billion m^3 within a year.
9. Encourage a temporary thermostat reduction of 1°C by consumers
   Impact: Reduces gas use by some **10** billion m^3 within a year.
10. Step up efforts to diversify and decarbonise sources of power system flexibility.
    Impact: Loosens the strong links between gas supply and Europe's electricity security.

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[2] https://www.iea.org/news/how-europe-can-cut-natural-gas-imports-from-russia-significantly-within-a-year?fbclid=IwAR2LJyEap31DS7KGP2rywkAqCwu-YOvQIcbTdbRLw_lSLhLz1wd_pJZ4FXU.

[3] A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas, IEA, 03.03.2022: https://iea.blob.core.windows.net/assets/1af70a5f-9059-47b4-a2dd-1b479918f3cb/A10-PointPlantoReducetheEuropeanUnionsRelianceonRussianNaturalGas.pdf.

[4] A European Green Deal: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

[5] Roadmap to Net Zero by 2050. IEA, 2021: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.

The European Commission's plan to achieve EU independence from Russian fossil fuels by 2030

In early March 2022, the *European Commission* proposed the concept of **REPowerEU**[6] [7]. The goal of this plan is to make Europe completely independent from Russian fossil fuels well before 2030, starting with gas. The REPowerEU plan includes *three areas of action*: urgent actions on prices, refilling gas storages for next winter, diversifying energy sources. The implementation of these measures can **reduce** EU demand for Russian gas by **two thirds** before the end of 2022.

1. Urgent actions on prices:

- Keeping retail energy prices in check by confirming the possibility of price regulation to help protect consumers and the economy.
- Guidance on temporary tax measures on windfall profits and use of emissions trading revenues, so governments can ease the pressure on household consumers.
- State aid to companies facing high energy costs.
- Market actions assessing options for improving the electricity market design to keep electricity affordable, without disrupting supply and further investment in the green transition.

2. Refilling gas storages for next winter:

- A legislative proposal on minimum gas storage is to be prepared by April 2022. Europe will be able to better control gas supply establishing a 90% filling target by 1 October of each year, designating gas storage as critical infrastructure, and allowing incentives for refilling.
- Support to coordinated gas refilling operations, for example, through joint procurement, collecting orders and matching supplies.
- Continued investigation into behaviour by operators, notably by Gazprom.

3. Cutting dependence on Russian gas:

- More rooftop solar panels, heat pumps and energy savings.
- Decarbonising industry by accelerating the switch to electrification and renewable hydrogen and enhancing the low-carbon manufacturing capacities.
- Speeding up renewables permitting to minimize the time for roll-out of renewable projects and grid infrastructure improvements.
- Doubling the EU ambition for biomethane to produce **35** billion m^3 per year by 2030, in particular from agricultural waste and residues.
- Diversifying gas supplies, working with international partners to move away from Russian gas, and investing in the necessary infrastructure.
- A Hydrogen Accelerator to develop infrastructure, storage facilities and ports to replace demand for Russian gas with additional 10 Mt of imported renewable hydrogen from diverse sources and extra 5 Mt of domestic renewable hydrogen.

[6] Factsheet – REPowerEU: https://ec.europa.eu/commission/presscorner/detail/en/fs_22_1513.
[7] REPower EU: Joint European action for more affordable, secure and sustainable energy: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1511.

Best practices of the EU countries in replacing fossil fuels with renewable energy sources

Sweden

Sweden is a global leader in decarbonisation and has targets to cut greenhouse gas emissions 59% by 2030 compared with 2005, and to have a net-zero carbon economy by 2045. Sweden was the first country to introduce carbon pricing and has the highest carbon price in the world, which has proven effective at driving decarbonisation.

Most of Sweden's electricity supply comes from hydro and nuclear, along with a growing contribution from wind. Heating is supplied mainly through bioenergy-based district heating and heat pumps.

Most of Sweden's greenhouse gas emissions come from the transport sector, which remains reliant on oil. The government has a target to reduce transport emissions by 70% from 2010 to 2030 and is supporting transport decarbonisation through electrification and advanced biofuels. Sweden is also supporting industrial decarbonisation and is home to one of the first major projects for hydrogen-based steel production[11].

In the early 1990s, the Swedish authorities adopted two measures that have significantly changed the energy balance. The first was the creation of a tax on CO_2 emissions, with wood and some waste being exempted. The second measure provided grants to local authorities for work on heating networks powered by bioenergy, and individuals who agreed to connect their homes to these networks (up to 30% of total expenditures)[8]. Thanks to these two measures, DH is now an important component of Sweden's energy system, as it provides 90% of the heat demand in apartment buildings and almost 75% of the total heat demand[9].

By the end of 2014, Sweden ranked fifth in the EU for the consumption of bioethanol and sixth for biodiesel consumption. According to 2015 data, the country ranked first in the use of biomethane: 67% of all biogas produced in the country was converted into biomethane[10].

Over the last 20 years, the level of total energy supply in Sweden has been relatively stable at around 2,000 PJ / year (**Fig. 2**)[11]. **Natural gas is a minor fuel in Sweden:** it provides 2% of the total primary energy supply (**Fig. 3**)[12]. The natural gas network is limited to the west coast of the country where gas provides around 20% of the TPES. There, gas is a relatively important fuel both for heating and for process industries [13].

[8] Michel Cruciani. The Energy Transition in Sweden", Ifri, June 2016: https://www.ifri.org/sites/default/files/atoms/files/etude_suede_gd_ok-db2_complet.pdf.

[9] https://www.weforum.org/agenda/2020/09/sweden-energy-production-renewable-power-district-heating/.

[10] Optimal use of biogas from waste streams An assessment of the potential of biogas from digestion in the EU beyond 2020. European Commition: https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf.

[11] https://www.iea.org/countries/sweden.

[12] Implementation of bioenergy in Sweden – 2021 update. Country Reports, IEA Bioenergy: 10 2021: https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Sweden_final.pdf.

[13] Energy Policies of IEA Countries - Sweden 2019 Review: https://iea.blob.core.windows.net/assets/abf9ceee-2f8f-46a0-8e3b-78fb93f602b0/Energy_Policies_of_IEA_Countries_Sweden_2019_Review.pdf.

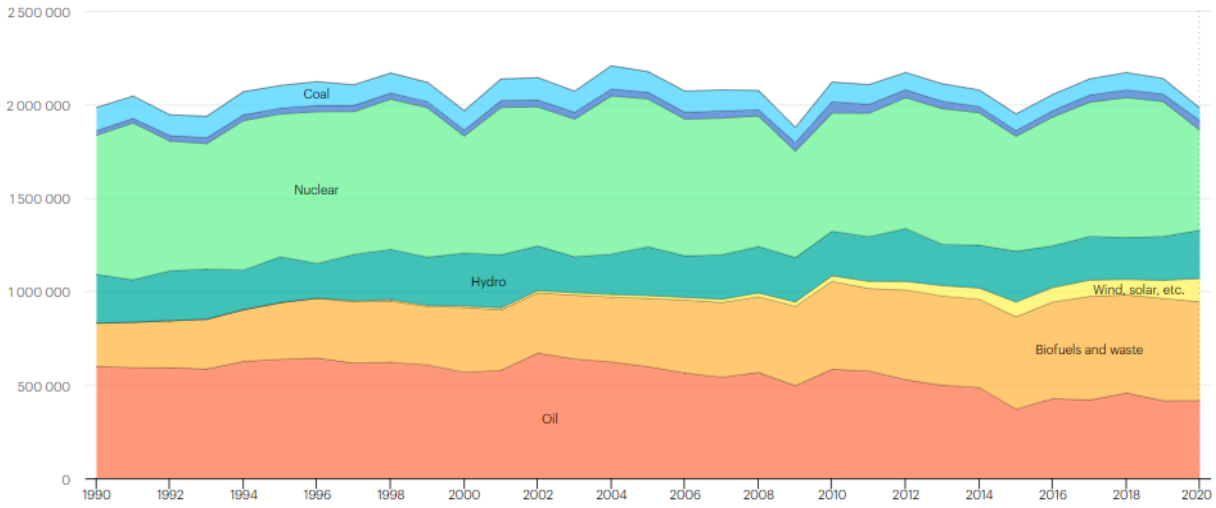


Fig. 2. Dynamics and structure of the total energy supply in Sweden, TJ[11]

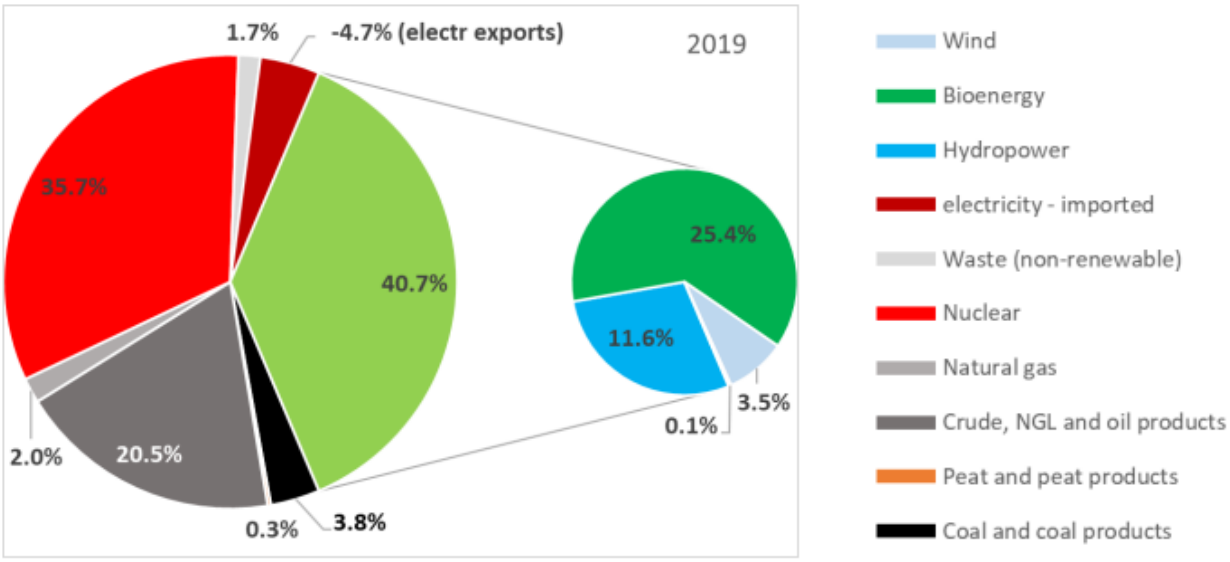


Fig. 3. The structure of TPES in Sweden (2019)[12]

All natural gas is imported into Sweden from Denmark via one pipeline, which can be considered a risk to security of supply. Biogas, on the other hand, is produced domestically, and its production sites are evenly distributed throughout the country. In line with Sweden's decarbonisation goals, the government's long-term plan is to replace natural gas with biogas. As a renewable energy source, biogas can play a major role in the future sustainable energy system.

The main support scheme for biogas use is the exemption from energy tax and the CO^2 tax when the gas is used for transport or heating. To be eligible for the exemption, the gas must meet EU sustainability criteria. In addition, biogas production by farmers is supported from the partly EU-funded *Rural Development Programme*. The budget for biogas investments up to 2020 is SEK 279 million, and it is financed between the government (59%) and the European Union (41%).

In January 2015, the government also introduced a support scheme for biogas production through the anaerobic digestion of manure. The support aims to both reduce methane emissions from manure

and substitute fossil fuels. The subsidy amounts to a maximum of 0.40 SEK per kilowatt hour (SEK/kWh) of biogas produced. Between January 2015 and September 2016, a total of SEK 69 million in aid was granted to 51 biogas plants. The subsidy programme runs until 2023 and has a budget of SEK 385 million. The subsidy programme was temporarily reinforced in 2018 with SEK 270 million as well as given a broader scope, as not only biogas from manure is eligible for aid.

The Swedish gas industry has developed a plan to increase biogas production to 7-15 TWh (the upper limit is much higher than the current gas supply). In order to achieve this goal, there may be a problem of competition from subsidized biogas production in Denmark. In Sweden, a government committee has been set up to analyse the future role of biogas in the energy system and to develop tools to its further support[11].

Denmark

Denmark's commitment to reducing greenhouse gas emissions and its achievements in the field of renewable energy makes it a European leader in the energy transition. The country aims to cut GHG emissions by 70% from 1990 levels by 2030 and for renewables to cover at least half of the country's total energy consumption by 2030. Denmark has committed to achieving net-zero emissions by 2050, in line with the Paris Agreement[14]. Moreover, the government has agreed to phase-out all coal-fired power by 2030.

The country also has a political agreement in place that targets for renewable energy to cover 100% of electricity and 55% of overall consumption by 2030. In addition, 90% of district heating is to come from non-fossil sources by 2030. The government also aims to end the sale of petrol and diesel cars by 2030.

Already, Denmark is a world leader on wind energy. It has the highest share of wind in both total primary energy consumption and electricity of any IEA country. Supported by a flexible domestic power system and a high level of interconnection, Denmark is now widely recognised as a global leader in integrating variable renewable energy while at the same time maintaining a highly reliable and secure electrical-power grid[14].

In the period after 2006, the total energy supply in Denmark has been declining and currently stands at just over 600 PJ. The share of natural gas during this period decreased from 22% to 16%, and the contribution of RES increased from 16% to 36% (Fig**. 4, 5**)[15].

Renewables make up 36% of Denmark's total energy supply in 2019. Bioenergy plays an important role, representing three quarters of renewable energy supply. The main contribution of bioenergy is in the production of thermal energy, both for individual heating and for DH, which is very developed in Denmark. Currently, biomass provides more than 60% of fuel for DH. Straw plays a significant role, as well as imported wood fuels (chips, pellets) and waste.

WPPs produce more than half of Denmark's total electricity generation; biomass contribution - 20% (electricity is mainly produced in CHPs). The role of biofuels in transport is relatively stable around 5% in the past decade, with a general application of B7 as diesel fuel (containing up to 7% biodiesel by volume) and E5 as gasoline fuel (containing up to 5% bioethanol by volume). Over the last decade, there

[14] https://www.iea.org/countries/denmark.

[15] Implementation of bioenergy in Denmark – 2021 update. Country Reports, IEA Bioenergy: 10 2021: https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Denmark_final.pdf.

has been a significant increase in biogas and biomethane production. According to BiogasGoGlobal[16], Denmark is the country with the world's largest share of renewable natural gas (biomethane) in the gas network: as of March 2022, this figure is 27.7%.

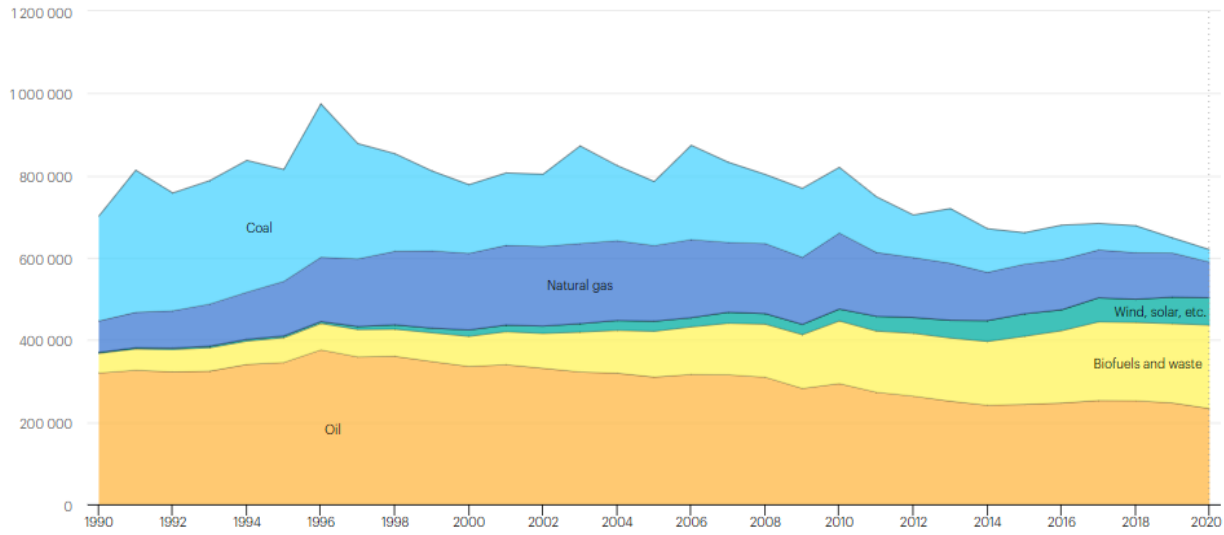


Fig. 4. Dynamics and structure of total energy supply in Denmark, TJ[14]

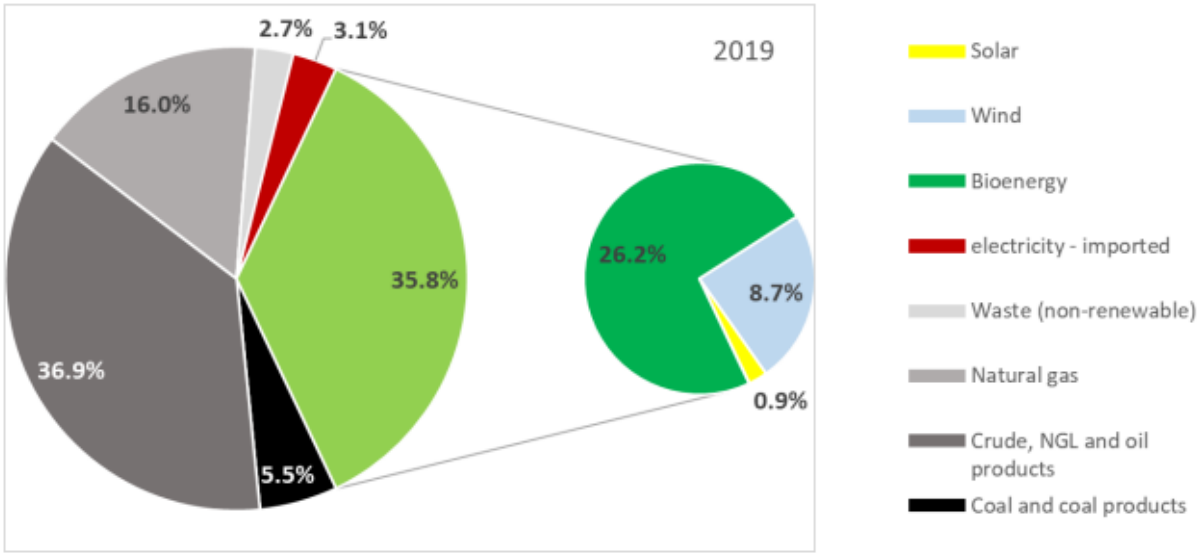


Fig. 5. The structure of TPES in Denmark (2019)[15]

The growth of green electricity production, in particular, the significant development of wind energy was facilitated by the application of subsidies defined in the *Law on Renewable Energy*. Onshore wind energy has been subsidised with fixed and variable subsidies, where offshore wind energy has been put out to tender, at which a stable settlement price is decided. The Law on Renewable Energy also provides subsidies for the production of electricity from biomass and biogas. The subsidy for the

[16] https://www.worldbiogasassociation.org/wp-content/uploads/2022/03/Cecilie-Engell-Sorensen.pdf.

production of electricity from biomass expired in 2019, but non-depreciated plants can still receive it. Another driving factor for the production of electricity from biomass is that it is exempt from CO_2 tax.

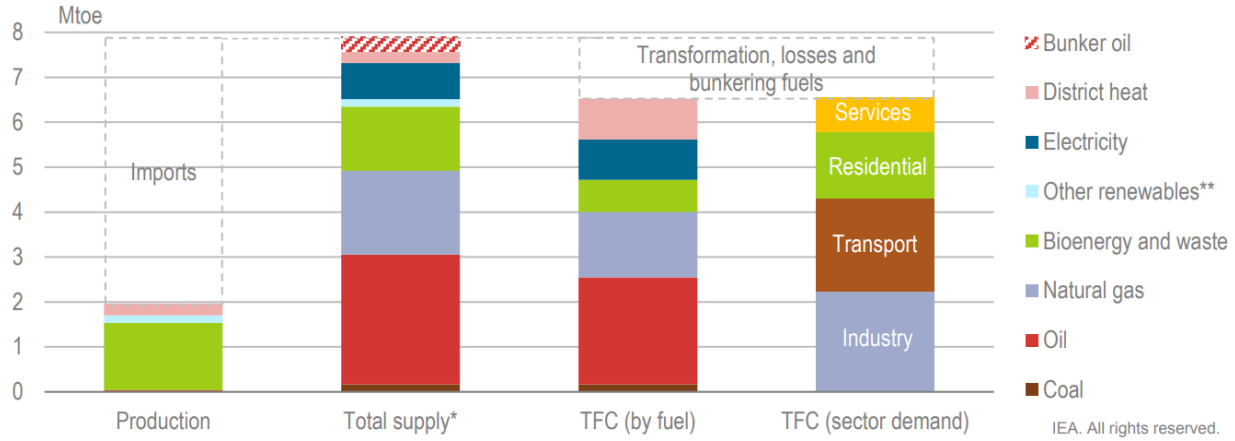
In 2018, it was agreed that by 2030 minimum 90% of Danish district heat should be based on other sources than coal, oil, and gas. This is also reflected in the development, as these fossil sources have been declining greatly and substituted with biomass. There are no subsidies for producing bioheat, however, as most of the district heating is produced in CHP plants, the subsidy for producing bioelectricity has indirectly affected the production of using biomass as heat source. Furthermore, there are no energy- and CO_2 taxation for using biomass as heat source.

In 2013, oil boilers were banned in new buildings and by 2016 it was no longer allowed to get a new oil boiler in existing buildings if it was possible to use district heating or natural gas instead.

The main incentive for renewable energy use in transport is a quota system. Selling of biogas for transport purposes is supported through a direct premium tariff[17].

Lithuania

Lithuania depends on energy imports, as in 2019 domestic production covered only a quarter of the total energy supply. Two thirds of the total energy supply comes from oil and natural gas, and a quarter - from renewable sources. (**Fig. 6**). Due to the high level of losses in the energy system, total final consumption (TFC) was 6.6 Mtoe in 2019, of which oil accounted for 37%, natural gas 23% (Fig**. 6**). Almost all coal, oil and natural gas was imported[18].



** Total supply includes bunker fuels for international aviation and shipping (not part of the total energy supply)*
*** Other renewables includes wind power, geothermal, hydro and solar energy*

Fig. 6. Structure of Lithuanian energy system by types of fuels and sectors, Mtoe (2019)[18]

Over the past decade, Lithuania has witnessed several energy transitions. With the closure of its only nuclear power plant (Ignalina's two reactors shut down in 2004 and 2009), Lithuania switched from the position of a net exporter to one of a net importer of electricity. Today, Lithuania imports over 70%

[17] http://www.res-legal.eu/en/search-by-country/denmark/.
[18] Lithuania 2021. Energy Policy Review. INTERNATIONAL ENERGY AGENCY: https://iea.blob.core.windows.net/assets/4d014034-0f94-409d-bb8f-193e17a81d77/Lithuania_2021_Energy_Policy_Review.pdf.

of its electricity needs, while bioenergy is taking the lead in domestic energy supply. Most of Lithuania's co-generation, 1 district heating and residential heat have switched from natural gas to biomass.

By 2030, Lithuania wants to reduce its electricity imports by half and produce 70% of its electricity needs from domestic renewable sources. By 2050, all electricity consumed should be generated in Lithuania. National Strategies (National Strategy of Lithuania 2030, National Strategy for Energy Independence, National Action Plan for Energy and Climate) of Lithuania envisages that by 2050 all electricity consumed should be produced domestically. The goal is to reach a share of 38% of renewable energy sources (RES) in the gross final energy consumption by 2025 and at least 45% by 2030 (broken down into at least 45% electricity, 90% district heating and cooling, 80% residential household heating and cooling, and 15% transport[19].

Natural gas has been a pillar of Lithuania's energy mix as the country decommissioned its nuclear plant. In recent years, the role of natural gas has decreased in the wake of increasing investments in renewable energies, the closure of older gas-fired combined and heating plants, and the increased use of biomass for district heating. In 2010, the share of natural gas was: 35% in total energy supply, 54% in total electricity production, 62% in thermal energy production. In 2019, these figures decreased significantly to 24%, 16% and 18%, respectively.

However, with 23% of total final consumption, natural gas is the second most prominent fuel in Lithuania, after oil. Natural gas is now mostly used by industry, including over 50% of the country's gas consumption by the region's largest fertiliser and chemicals company, Achema. Until 2014, Lithuania was fully dependent on imports of Russian gas. But, thanks to the commissioning of the Klaipeda LNG Terminal at the end of 2014, Lithuania diversified its gas supply in support of national and regional security of supply.

Lithuania has several schemes to support the development of RES, which have been adjusted over time. In 2018, the parliament approved amendments to the Law of the Republic of Lithuania on Energy from Renewable Sources, which declared the transition to a sliding feed -in premium for renewable electricity (regulated by the National Energy Regulatory Council and allocated through auctions). In 2020, a regulation was adopted for RES communities, which introduced support mechanisms for small power plants and encouraged consumers to their own production (prosumers) (2020).

Auctions are run in a technology-neutral manner and let wind, solar, biomass and hydropower installations compete for the premium based on the production cost of the cheapest technology. The government allocates a feed-in premium over 12 years on a competitive basis to reach a total of 5 TWh of electricity produced from renewables up to 2025 and to meet the target of renewable electricity in gross final consumption. The new scheme started in 2019 and annual auctions are planned until 1 July 2025 or, alternatively, until the 5 TWh target is reached.

The share of RES in DH has tripled between 2011 and 2018. This is a result of support mechanisms that have been in place since 2011 and facilitated the transition from natural gas to biomass. Support was provided to biomass heating installations and heat pumps during the transition from fossil fuels. Commitments to state-owned companies to purchase renewable heat combined with more expensive natural gas prices have led to a shift to biomass, which has also reduced the final heat price.

Lithuania's Law on the Heat Sector (Heat Law) of 2018 not only regulates the quality of supply, competition and access to heat networks, but also promotes the use of domestic sources, like biofuels and renewable energy for heat production. Heat suppliers are obliged to purchase all heat from

[19] https://www.iea.org/countries/Lithuania.

renewables generated by independent producers when such heat is cheaper than the heat produced by the heat supplier itself and satisfies environmental and quality requirements as well as standards for security of supply. Renewable energy sources for heating and cooling are exempt from pollution tax and are eligible for loans and subsidies under the Special Climate Change Program.

The *Alternative Fuels Law* was adopted by the Parliament in March 2021 in order to stimulate the use of RES in the transport sector. It offers new provisions for the support of biofuels, biomethane and hydrogen and promotes the use of electricity for the horizon up to 2030. Lithuania aims to reach a share of 15% of renewable energy in final energy consumption in transport by 2030 through a combination of measures: through reimbursement of raw materials for biofuel production; through the obligation to sell gasoline and diesel fuel in a mixture with biofuels (quota obligations); through exemption from excise tax and exemption from environmental pollution tax. It is proposed by law to increase the biofuel blending obligation for fuel suppliers (based on an energy target) up to 16.8% in 2030, with a sub -target of 3.5% of double counted advanced biofuel, and a certificate system for renewable transport fuels.

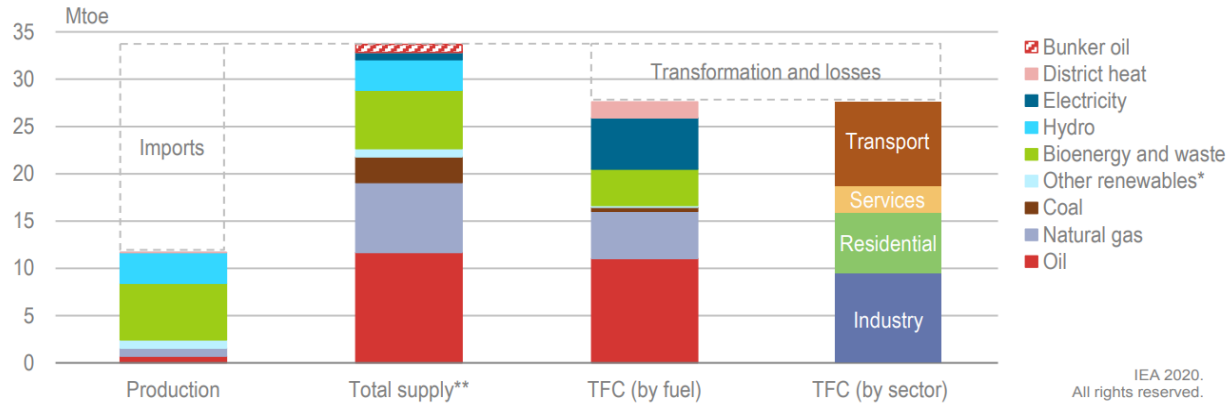
Austria

Austria's government is committed to achieving carbon neutrality no later than 2040. This will require Austria to substantially enhance de-carbonisation efforts across all energy sectors. Austria has set a target of a 100% renewable electricity supply by 2030 (national balance). In 2018, already 77% of electricity came from renewables. As in many countries, decarbonizing heat and transport is challenging and Austria's emissions growth since 2014 is largely driven by the increase in final energy consumption in buildings and transport. The government plans to phase out oil- and coal-fired heating systems by 2035, and to restrict the use of natural gas for heating in new buildings by 2025[20].

Austria is heavily dependent on energy imports, despite large hydro and bioenergy resources. Its average self-sufficiency level has been 36% over the past decade, characterised by a high and continuously increasing share of renewable energy sources. Total primary energy supply (TPES) was 32.8 million tonnes of oil equivalent (Mtoe) in 2018, of which fossil fuels accounted for around two-thirds and renewables for the remaining third. Total final consumption (TFC) by fuel was 27.6 Mtoe in 2018, of which oil accounted for 40%, electricity for 20%, natural gas 18%, and bioenergy and waste 14%. As can be seen from **Fig. 7**, natural gas is the second largest source of energy in Austria, providing 22% of TPES and 18% of total final consumption (2018).

Natural gas is also the second largest fuel in electricity production - 15% of total production. The leader in terms of natural gas consumption is industry, followed by the heat and electricity production sector, and the residential sector in third place.

[20] https://www.iea.org/countries/Austria.



** Other renewables includes wind power, geothermal and solar energy.*
*** Total primary energy supply and oil fuels used in international bunkering.*

Fig. 7. The structure of the Austrian energy system by type of fuel and sector, Mtoe (2018)[21]

Austria is a global leader in renewable energy. In 2018, renewable sources of energy covered almost 30% of total primary energy supply (TPES). The share of renewables in total final consumption (TFC) was 32% and the share in electricity generation was 77% [18]. Austria's renewable energy supply is dominated by bioenergy and hydropower. In 2018, bioenergy accounted for 17% of TPES, which includes thermal losses in heat and electricity generation. Hydro accounted for 10% of TPES and together wind and solar (PV and solar thermal) contributed 2.5%. Austria also produces biogas, which accounts for about 3% of TPES.

Domestic natural gas production in Austria has declined over the past decade and most of the gas supply relies on imports. Diversifying imports and keeping access to gas storage are important for security of supply. Austria is a major transit route for European gas supply and its role as a trading hub, based on the large gas storage facilities at Baumgarten, has increased notably since 2011. Furthermore, gas will have an important role in Austria's energy transition and the country is seeking to integrate the gas and electricity sectors and to green the gas by replacing fossil gas with biomethane and hydrogen.

Austria's long-term vision is to ensure the consumption of renewable gas of its own production. Renewable gas and hydrogen will be pumped into the gas network instead of being consumed at the place of production (current situation with the use of biogas). It is also planned to increasingly supply biomethane directly to the gas system. The use of the existing gas network for biogas, biomethane and hydrogen will help to optimally integrate RES into the electricity sector and reduce the time gap between renewable electricity production and consumption.

To support long-term coordinated planning and in the context of the development of the National Hydrogen Strategy, an Austrian Biogas Map is being developed, which will include potential production sites to facilitate their connection to the gas network. In addition, the Power to Gas Map (P2G) is being developed, which will identify the best places to build plants for the production of "green" hydrogen. In order to provide tax benefits for hydrogen and biogas producers, as well as to create legal certainty for

[21] Austria 2020. Energy Policy Review. INTERNATIONAL ENERGY AGENCY: https://iea.blob.core.windows.net/assets/ea419c67-4847-4a22-905a-d3ef66b848ba/Austria_2020_Energy_Policy_Review.pdf.

investors and unlock the necessary investments, the Austrian law "On Natural Gas Taxation" was amended (as part of the tax reform in 2020).

In Austria, electricity from renewable sources is supported mainly by a feed-in tariff. In addition, subsidies support the construction of photovoltaic installations on buildings, as well as small or medium-sized hydropower plants. Renewable electricity is provided to the grid in accordance with general legislation in the energy sector and on a non-discriminatory basis.

Heating and cooling using RES is supported by various incentive schemes both at the national level and at the level of individual federal states. The main scheme at the federal level is "national environmental promotion". A quota system is applied to RES in transport. Investment grants for the conversion of vehicles or the purchase of electric vehicles are also available under the environmentally friendly mobility promotional program[22].

Austria also supports the implementation of RES through the funding of numerous innovative pilot projects aimed at developing key areas. These projects include the construction of solar photovoltaic plants with energy storage systems, the use of RES for heating and cooling, sustainable mobility projects, the production of biogas and hydrogen from renewable sources[21].

[22] http://www.res-legal.eu/en/search-by-country/austria/.

Assessment of biomass potential in Ukraine

The assessment of Ukraine's bioenergy potential was performed based on **2020** data. Expert views on the impact of the **war effects** on the potential and directions of its use are also discussed in this section.

Ukraine has a significant potential of biomass available for energy production: in total, almost **22** Mtoe/yr (**Table 1**). The main components of the bioenergy potential are waste/by-products of agriculture (agricultural residues[23] – 9.4 Mtoe/yr or **43%** of the total potential) and energy crops (7.5 Mtoe/yr, **34%**), which are jointly defined as ***agrobiomass***. At that, the largest shares of the agricultural residues potential fall to cereals straw (36%) and by-products/waste of grain corn production (33%) (**Fig. 8**).

Table 1. Energy potential of biomass in Ukraine (2020)

Type of biomass	Theoretical potential, Mt	Potential available for energy (economic)	
		% of the theo-retical potential	Mtoe
Straw of grain crops	33.1	30	3.39
Straw of rapeseed	4.6	40	0.63
By-products of grain corn production (stalks, cobs)	39.4	40	3.01
By-products of sunflower production (stalks, heads)	24.9	40	1.43
Secondary agricultural residues (sunflower husk)	2.2	100	0.92
Wood biomass (firewood, felling residues, wood processing waste)	6.7	95	1.57
Wood biomass (dead wood, wood from shelterbelt forests, pruning, uprooting)	8.8	45	1.02
Biodiesel (rapeseed)	-	-	0.36
Bioethanol (corn and sugar beet)	-	-	0.67
Biogas from waste and by-products of agricultural sector	2.8 bln m^3 CH_4	42	0.99
Landfill gas	0.6 bln m^3 CH_4	29	0.14
Sewage gas (industrial and municipal wastewater)	0.4 bln m^3 CH_4	28	0.09
Energy crops:			
- willow, poplar, miscanthus (1 mln ha*)	11.5	100	4.88
- corn for biogas (1 mln ha*)	3.0 bln m^3 CH_4	100	2.57
TOTAL	**-**	**-**	**21.68**

** In case of growing on 1 mln ha of unused agricultural land.*

[23] To determine whether some residues are by-product or waste, one should use a decision tree from COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on the Interpretative Communication on waste and by-products: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0059&from=EN.

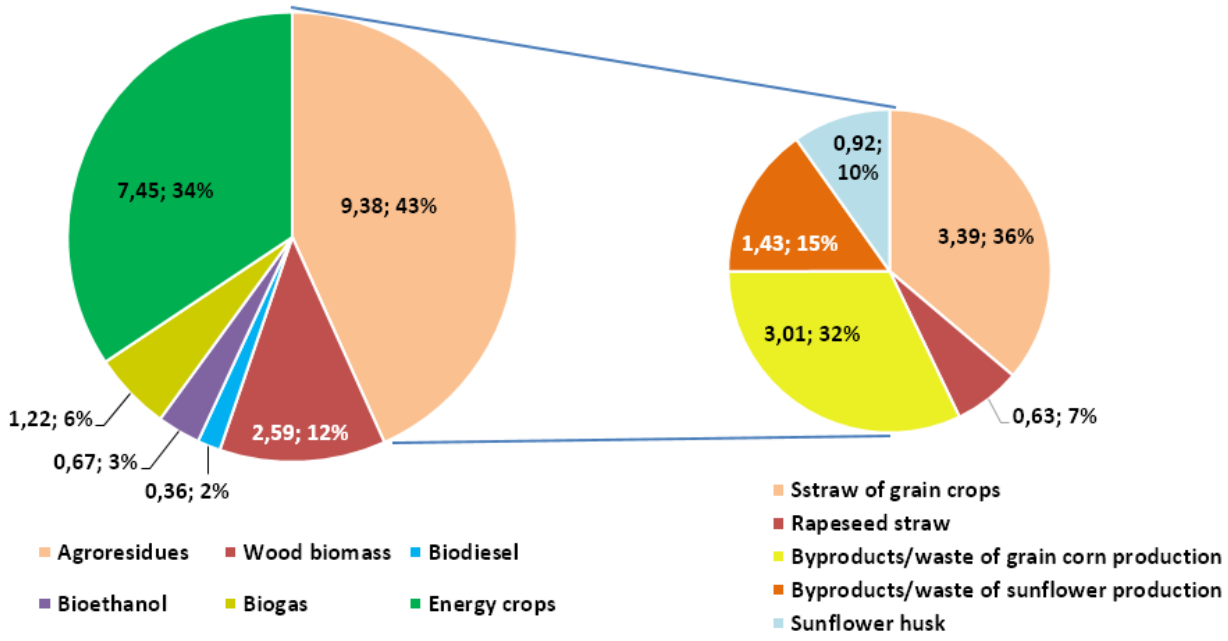


Fig. 8. Components of the energy potential of biomass in Ukraine, Mtoe (2020)

Despite some fluctuations, the volume of agricultural biomass in Ukraine increases almost every year due to the general trend of growth in the production and yield of major crops. Thus, in 2019 the country harvested a record for the last 20 years amount of sunflower, corn for grain, and some other cereals. Since 2000, the energy potential of straw of cereal eared crops, by-products and waste of grain corn and sunflower production in Ukraine has tripled, from 2.8 Mtoe in 2000 to 8.5 Mtoe in 2020.

The contribution of wood biomass to the bioenergy potential is relatively small, about 2.6 Mtoe/yr or 12% of the total. This biomass can be symbolically divided into that derived from traditional sources (firewood, logging residues, woodworking waste) and wood biomass from additional sources (deadwood, wood from the reconstruction and restoration of shelterbelt forests and other protective forest belts, waste from pruning and uprooting orchards and vineyards).

The remaining components of Ukraine's bioenergy potential (about 10%) are liquid biofuels (biodiesel, bioethanol) and biogas obtained from various raw materials such as waste and by-products of agroindustrial sector, industrial and municipal wastewater, municipal solid waste.

The situation with the consumption of biomass for energy and biofuels production in Ukraine is, in fact, the opposite to the structure of the available potential. Currently, wood biomass is most actively used (more than 90% of its economic potential), while the use of waste and by-products of agricultural origin remains low. Of the various types of agrobiomass, only sunflower husk is used quite actively for the energy needs of Ukraine, over 70% of its total potential. Production of energy/biofuels from straw utilizes around 3% of its available potential. There are individual examples of using corn stover for energy, while any examples of energy production from sunflower stalks or heads are currently unknown to the authors. On average, the energy potential of biomass is utilized by ~11% in Ukraine.

The widespread development of the usage of agricultural residues for energy is hampered by a number of barriers. Among them, the most important are lack of machinery and proven technologies for harvesting corn/sunflower stalks in the country, complexity of arranging the procurement-supply chain, general underdevelopment of the biofuel market in the country (absence of a biofuel exchange) and some others.

Analysis of the structure of biomass consumption for energy shows the need for wider use of biomass of agricultural origin and energy crops. At the same time, wood biomass from so-called additional sources should be involved in this process, in particular, waste from pruning and uprooting of perennial agricultural plantations, as well as biomass from reconstruction and restoration of shelterbelt forests and other protective forest belts.

At present, it is difficult to accurately assess the impact of war in Ukraine on the size/structure of the bioenergy potential and, in general, on the features of bioenergy development in the country in the post-war years. However, based on expert estimation, we can assume the following:

- ***Agrobiomass*** (agricultural residues and energy crops) will remain the main type of bioenergy potential in Ukraine. To expand the use of agricultural residues, it is necessary to work out technologies for baling corn and sunflower stalks.
- ***Energy crops*** for solid biofuels will continue to be grown on unused (low-yield) agricultural lands.
- The post-war period is likely to be characterized by high prices and shortages of mineral fertilizers, especially nitrogen fertilizers, which are produced using natural gas. Under such conditions, it is advisable to introduce fertilizing with ***digestate***, which is a residue of biomass anaerobic digestion. To obtain a sufficient amount of digestate, the appropriate amount of raw materials for fermentation, such as corn silage, is required.
- For the sake of the country's energy "survival" in the post-war period, some deviation from the sustainability criteria (or temporary change of these criteria) may be allowed. For example, ***corn for silage*** as a raw material for the production of ***biomethane*** (a substitute for natural gas) and ***digestate*** (fertilizer) will be grown on agricultural land.
- ***Biomethane*** production will be actively developing. For this, it is necessary to master and implement modern technologies for its production from lignocellulosic raw materials (up to 50% of the total mixture) using best foreign practices.
- Production and consumption of ***liquid biofuels of the first and second generation***, which is a promising direction for the development of bioenergy in Ukraine, will increase[24]. According to the draft *NREAP 2030*[25], the consumption of liquid biofuels in the country by 2030 will increase up to 325 ktoe/yr, including 65 ktoe/yr of second-generation biofuels.

[24] This Position Paper does not cover liquid biofuels in detail.
[25] Draft NREAP 2030:
https://saee.gov.ua/uk/events/previews/4092;
https://saee.gov.ua/uk/content/elektronni-consultatsii.

Ten actions of Ukraine to reject Russian natural gas

Action 1. Replacement of natural gas with biomass and solid biofuels for heat production

According to the Ministry of Energy[26], natural gas consumption in Ukraine in 2021 amounted to **28** billion m^3. At that, according to Ukraine's GTS Operator[27], the actual consumption of natural gas in 2021 was 26.8 billion m^3 (**Fig. 9**), including that by population – 8.6 billion m^3 (+ 5% as compared with 2020), heat producers – 6.3 billion m^3 (-24%), industry, state-financed organizations and other non-household consumers – 11.9 billion m^3 (-3%).

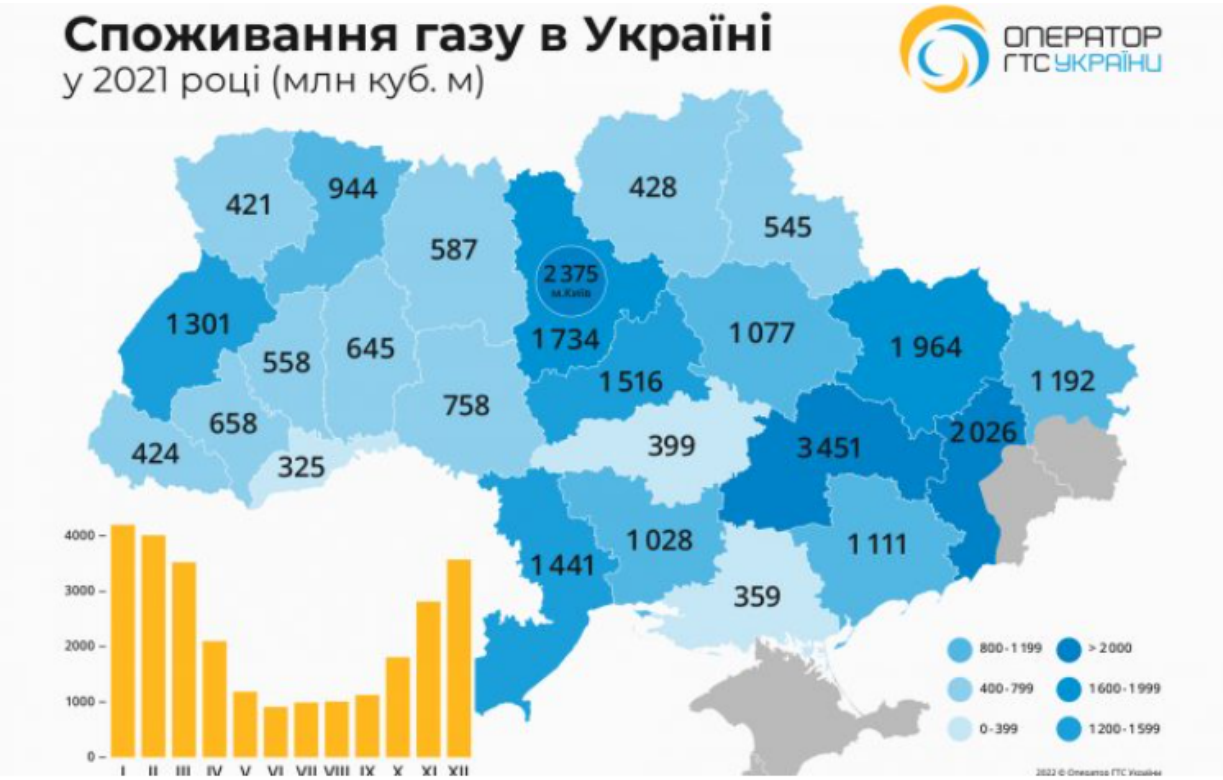


Fig. 9. Consumption of natural gas in Ukraine, million m^3 (2021)[Ошибка! Закладка не определена.]

The volume of own gas production in Ukraine is about **20** billion m^3/yr (**Fig. 10**); NG is imported from Slovakia, Hungary and Poland. Legally, the imported gas is not Russian, however, in fact it is, so Ukraine needs to get rid of these imports as soon as possible. Therefore, we consider it necessary to implement the accelerated replacement of gas boilers with biomass boilers and prevent the installation of individual gas boilers in apartments and households.

Substitution of natural gas with biomass and solid biofuels in thermal energy production is one of the most cost-effective ways to replace NG, especially given the current and projected high prices of natural gas in the EU, where Ukraine is currently buying it. The *draft NREAP 2030*[Ошибка! Закладка не определена.] envisages the production of 10,328 ktoe of thermal energy from biomass in 2030, including 9,328 ktoe from solid biomass and 1,000 ktoe from biogas.

[26] https://bit.ly/3JPE9Gt.
[27] https://ua-energy.org/uk/posts/spozhyvannia-hazu-v-ukraini-u-2021-rotsi-skorotylosia-maizhe-na-7.

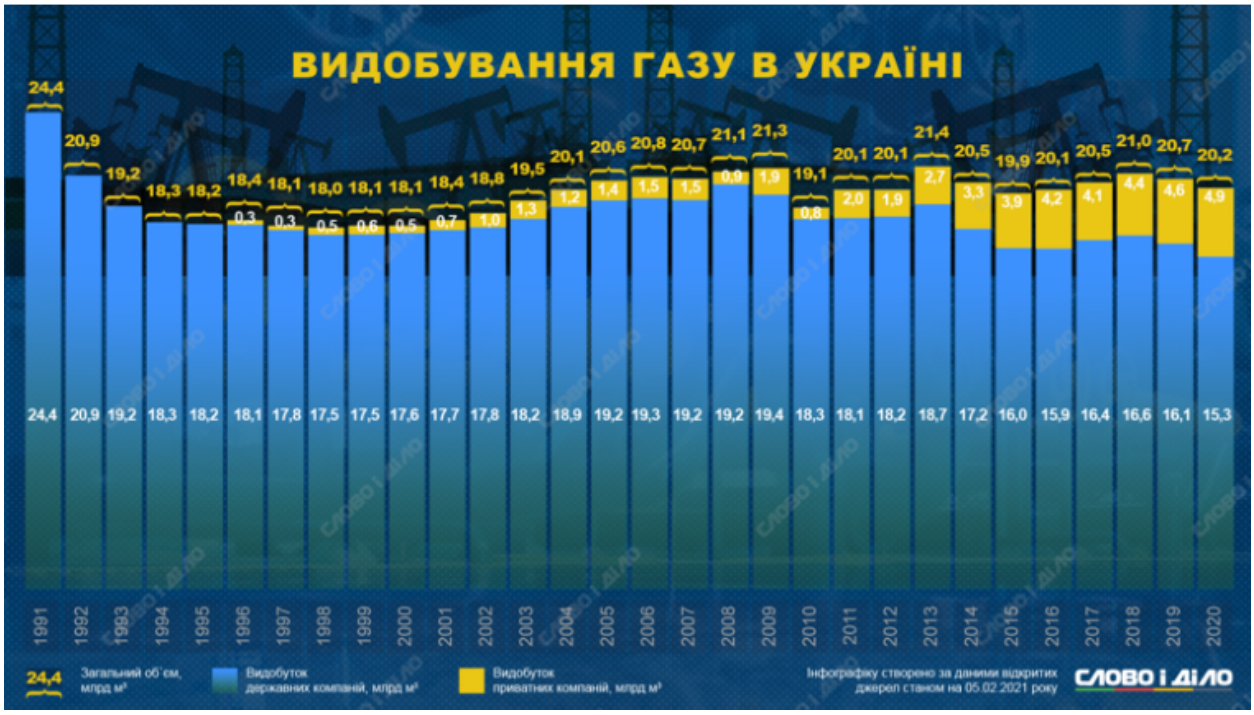


Fig. 10. Extraction of natural gas in Ukraine in 1991-2020 (billion m³)[28]

The reality of this area is demonstrated by the shares of thermal energy produced from RES, mainly from biomass, already achieved in most EU countries: Sweden – 66%, Estonia and Finland – 58%, Latvia – 57% (**Fig. 11**). In the EU as a whole, this figure is 23% of the total amount of energy used for heating and cooling, growing steadily: from 12% in 2004 to 23% in 2020.

Scenario for the introduction of bioenergy equipment elaborated in the *Roadmap for bioenergy development in Ukraine until 2050*[29], allows the total replacement of natural gas in the amount of 9.2 billion m³/yr in 2030 and 19 billion m³/yr in 2050 (**Table 2**) . The largest contribution to this substitution will be made by solid biomass: 8.9 billion m³/yr in 2030 and 17.9 billion m³/yr in 2050 due to the installation of all types of equipment such as boilers, CHP plants, TPPs (**Table 3**). Individual contribution from the introduction of ***solid biomass boilers*** (domestic and industrial boilers; DH and state-financed sectors) is *additional* replacement of **2.7** billion m³/yr of NG in 2030 and **9.3** billion m³/yr in 2050 as compared to 2020. A similar estimate for CHP plants on solid biomass is *additional* replacement of **0.8** billion m³/yr of NG in 2030 and **2.0** billion m³/yr in 2050 as compared to 2020.

It should be emphasized that the development of bioenergy makes it possible not only to replace fossil fuels, but also to create **jobs**, which is topical now and will be topical in the post-war period. Estimates made in the Roadmap for bioenergy development in Ukraine until 2050 show that the number of jobs related to the bioenergy sector could reach about **58,000** in 2030 and more than **150,000** in 2050 (see **Table 2**).

[28] https://www.slovoidilo.ua/2021/02/05/infografika/ekonomika/yak-zminyuvalysya-obyemy-vydobuvannya-hazu-ukrayini-oky-nezalezhnosti.

[29] ROADMAP FOR BIOENERGY DEVELOPMENT IN UKRAINE UNTIL 2050: https://saf.org.ua/en/news/1266/; https://uabio.org/en/materials/9115/.

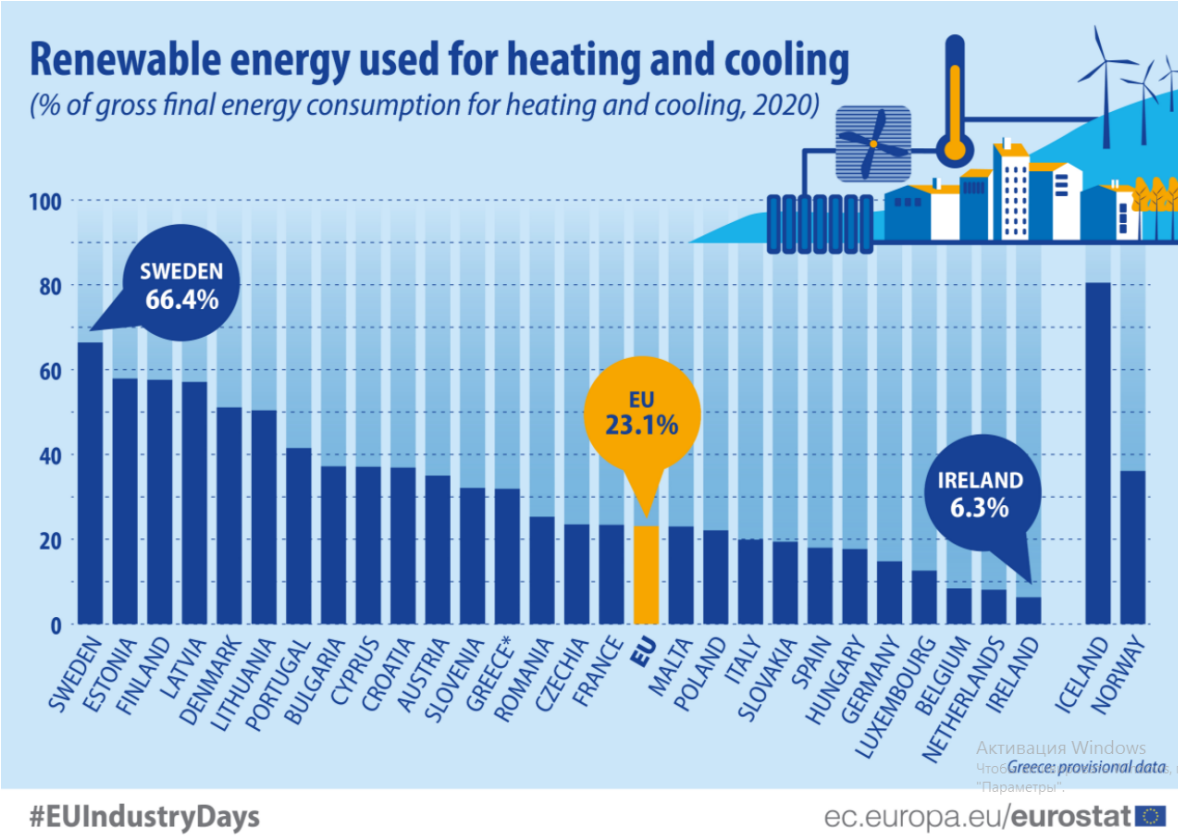


Fig. 11. RES share in the gross final energy consumption for heating and cooling in the EU, 2020[30]

Table 2. Summary indices of the Roadmap for bioenergy development in Ukraine until 2050[Ошибка! Закладка не определена.]

Year	Installed capacity of bioenergy equipment		Consumption of biofuels*, Mtoe	Replacement of NG, bln m^3	Replacement of petrol and diesel, Mt	Reduction of CO_2 emission Mt/yr	Required investments, bln EUR		Creation of new jobs, number
	MW_{th}	MW_{el}					min	max	
2020	8231	225	3.85	4.34	0.17	9.19	1.58	2.62	17342
2025	12385	918	6.09	6.39	0.26	14.35	4.32	7.0	33870
2030	19185	1886	9.13	9.19	0.43	21.20	8.08	13.1	57648
2035	29949	2618	12.74	12.66	0.60	29.37	12.04	19.5	87067
2040	38822	3265	16.10	15.72	0.82	36.91	15.87	25.6	115220
2045	44493	3740	18.73	17.71	1.11	42.62	19.02	30.7	136595
2050	48056	4091	20.70	19.00	1.24	46.71	21.35	34.5	150550

** Including liquid and gaseous biofuels for transport.*

[30] Eurostat: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/edn-20220211-1.

Table 3. Envisaged installed capacity of bioenergy equipment in Ukraine in 2050[Ошибка! Закладка не определена.]

Type of equipment	Total installed capacity in 2050	
	MW_{th}	**MW_{el}**
Household sector		
Domestic boilers and stoves on wood biomass (firewood, pellets, briquettes)	5285	
Domestic boilers on agrobiomass (pellets, briquettes, small bales)	7500	
Domestic boilers on energy crops (pellets, chips)	6000	
DH + public sector		
Boilers (wood biomass)	600	
Boilers (primary agricultural residues)	12750	
Boilers (secondary agricultural residues)	900	
Boilers (energy crops)	2750	
CHP plants (wood biomass)	225	75
CHP plants (primary agricultural residues)	1500	500
CHP plants (energy crops)	2250	750
Industry		
Boilers (wood biomass)	1400	
Boilers (primary agricultural residues)	3000	
Boilers (secondary agricultural residues)	300	
CHP plants (wood biomass)	240	80
CHP plants (primary agricultural residues)	1520	475
CHP plants (secondary agricultural residues)	300	100
CHP plants (biogas, biomethane)	1536	1151
TPPs (primary agricultural residues)		380
TPPs (secondary agricultural residues)		160
TPPs (wood)		55
TPPs (energy crops)		340
TPPs ORC (primary agricultural residues)		25
Total	**48056**	**4091**

Action 2. Further construction of wind and solar power plants

One of the key objectives of the *draft National Renewable Energy Action Plan until 2030*[Ошибка! Закладка не определена.] is to achieve **25%** of RES in the gross final **electricity** consumption. The document provides for a significant increase in the installed capacity of solar and wind power plants – up to **9,947** MW and **5,033** MW in 2030, respectively (**Table 4**). Compared to 2020 data (6,872 MW of SPPs and 1,314 MW of WPPs), this is an increase by **1.5** times for solar power plants and **3.8** times for wind power plants.

A feature of the development of wind energy in Ukraine in the period from 2028 will be the construction of offshore WPPs: by 2030, it is planned to reach the installed capacity of 300 MW.

The growth of electricity production by wind and solar power plants requires a corresponding increase in load following units' capacity. Such capacities mainly run on natural gas, which means its additional consumption compared to existing ones. NEC "Ukrenergo" has prepared a *Report on the assessment of adequacy of generating capacity to cover the projected demand for electricity and provide the necessary reserve in 2020*[31] (approved by NERC Resolution No 975 of 16.06.2021[32]). The Report considers the Target Scenario for the development of generating capacities of Ukraine's energy system. The Scenario takes into account current trends in energy saving and provides for further growth of the share of all renewables in the structure of electricity production during next 10-11 years. Implementation of such a scenario of RES development in Ukraine requires increasing flexibility of the energy system. To do this, in the near future it is necessary to construct:

- Minimum **1 GW** of load following units with quick start (full activation from the stopped state is no more than 15 minutes, the ability to start and stop at least four times a day with a control range of at least 80% of the installed capacity). At the same time, in order to maximize the production of electricity from RES and to minimize its limitations, it is advisable to build at least **2 GW** of load following units.
- **0.5 GW** of energy storage systems, provided that renewable energy sources are involved in balancing the energy system and providing reserves. Without the involvement of RES in balancing or forced limitation of NPP capacity, the need for energy storage may increase up to **2 GW**.

[31] Report on the assessment of adequacy of generating capacity by NEC "Ukrenergo": https://ua.energy/zagalni-novyny/nkrekp-zatverdyla-zvit-z-otsinky-vidpovidnosti-generatsiyi-u-2020-rotsi/.

[32] NERC Resolution No 975 of 16.06.2021: https://zakon.rada.gov.ua/rada/show/v0975874-21#Text.

Table 4. Annex 5 to the draft NREAP 2030[Ошибка! Закладка не определена.]

Estimation of the installed capacity and gross power production from different RES expected to achieve NREAP 2030 targets for 2021-2030

Power production by sources	2020		2021		2022		2023		2024		2025		2026		2027		2028		2029		2030	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydro power plants:	**4 824**	**6 002**	**4 829**	**8 149**	**4 832**	**7 270**	**4 835**	**7 167**	**4 838**	**7 173**	**5 091**	**7 680**	**5 094**	**7 686**	**5 097**	**7 692**	**5 100**	**7 699**	**5 103**	**7 705**	**5 108**	**7 715**
> 10 MW	4708	5793	4708	7879	4708	6995	4708	6900	4 708	6 900	4 958	7 400	4 958	7 400	4 958	7 400	4 958	7 400	4 958	7 400	4 958	7 400
up to 10 MW	116	209	121	270	124	275	127	267	130	273	133	280	136	286	139	292	142	299	145	305	150	315
Geothermal energy											**4**	**20**	**8**	**40**	**12**	**60**	**16**	**80**	**18**	**90**	**20**	**100**
Solar PV, including	**6 872**	**5 969**	**7 573**	**8 065**	**7 826**	**8 340**	**8 251**	**8 615**	**8 485**	**8 891**	**8 742**	**9 166**	**8 985**	**9 441**	**9 228**	**9 716**	**9 469**	**9 992**	**9 709**	**10 267**	**9 947**	**10 542**
producers	6 093	5 236	6 423	7 065	6 492	7 206	6 559	7 347	6 614	7 487	6 691	7 628	6 756	7 769	6 819	7 910	6 881	8 050	6 942	8 191	7 000	8 332
consumers, including energy cooperatives private households	779	733	1 150	1 000	1 335	1 134	1 692	1 269	1 871	1 403	2 050	1 538	2 230	1 672	2 409	1 807	2 588	1 941	2 767	2 076	2 947	2 210
WPPs, including	**1 314**	**3 271**	**1 605**	**3 992**	**2 503**	**6 750**	**2 743**	**7 681**	**3 076**	**8 613**	**3 408**	**9 544**	**3 741**	**10 475**	**3 933**	**11 406**	**4 354**	**12 688**	**4 623**	**13 970**	**5 033**	**15 251**
onshore WPPs	1 314	3 271	1 605	3 992	2 503	6 750	2 743	7 681	3 076	8 613	3 408	9 544	3 741	10 475	3 933	11 406	4 254	12 338	4 423	13 269	4 733	14 200
offshore WPPs																	100	350	200	701	300	1 051
Biomass, including	**210**	**755**	**270**	**957**	**397**	**1 532**	**540**	**2 107**	**688**	**2 682**	**835**	**3 308**	**983**	**3 932**	**1 130**	**4 607**	**1 278**	**5 283**	**1 389**	**5 958**	**1 533**	**6 633**
solid biomass	107	284	153	550	228	889	315	1 228	402	1 567	489	1 906	575	2 244	662	2 583	749	2 922	815	3 261	900	3 600
biogas	103	471	117	407	169	643	225	879	286	1 116	347	1 352	407	1 588	468	1 824	528	2 061	574	2 297	633	2 533
biomethane at generating plants that use natural gas												50		100		200		300		400		500
Load following units with quick start					**300**		**500**		**700**		**850**		**950**		**1050**		**1150**		**1250**		**1350**	
Energy storage system					**100**		**200**		**300**		**380**		**440**		**490**		**540**		**590**		**640**	
Total (RES)	**13 220**	**15 997**	**14 277**	**21 163**	**15 559**	**23 892**	**16 370**	**25 571**	**17 087**	**27 359**	**18 080**	**29 717**	**18 811**	**31 575**	**19 400**	**33 482**	**20 217**	**35 740**	**20 843**	**37 989**	**21 641**	**40 241**

Natural gas at the load following units with quick start should be replaced by ***biomethane*** produced in Ukraine. Draft NREAP 2030 envisages the increasing usage of biomethane at generating plants running on natural gas: from 50 GWh in 2025 to 500 GWh in 2030 (by electricity generated) (see **Table 4**). According to UABIO estimates, the use of biomethane at the load following units should develop even more dynamically: from 22 GWh in 2022 (in terms of electricity generated, which corresponds to 20 MW of the installed capacity) to 745 GWh (360 MW) in 2030.

Increase in the capacity of solar and wind power plants also leads to reduction in coal consumption in Ukraine as the electricity generated by such power plants replaces mostly this type of fossil fuel.

Action 3. Production of biomethane

Potentially, Ukraine can produce up to **10** billion m^3 of biomethane/yr, mainly from agricultural waste and residues: manure, cereal straw, corn stalks, sunflower stalks, sugar beet bagasse, molasses, corn silage, as well as municipal waste and others.

UABIO estimates that actual production of biomethane in Ukraine may reach **1** billion m^3 in 2030 and **4.5** billion m^3 in 2050. Of these, 0.23 billion m^3 is planned for consumption at the CHP plants in 2030 and 0.79 billion m^3 in 2050 (**Fig. 12, Table 5**).

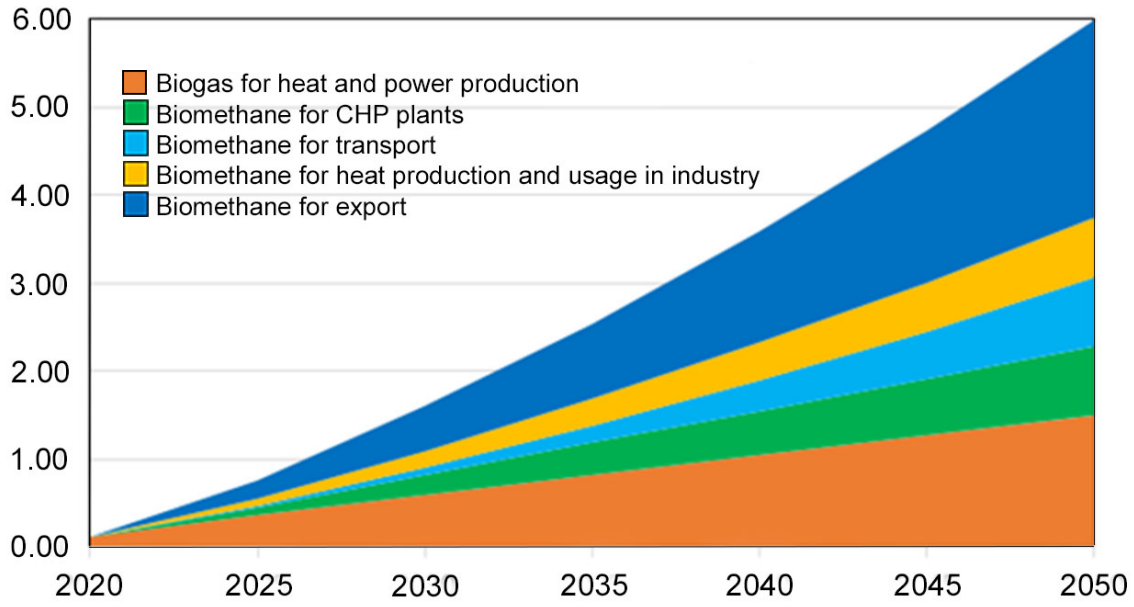


Fig. 12. Forecasted production of biogas and biomethane in Ukraine until 2050 (billion m^3) *Ошибка! Закладка не определена.*

Biomethane is absolutely ready for injection into the gas network right now. No investment is required for the modernization of gas networks and gas equipment (gas burners and fittings, gas-piston engines and gas turbines). In the field of biomethane production, Ukraine can compete with any country in the world. The country has the largest area of agricultural land in Europe and, accordingly, one of the world's best potentials of agricultural raw materials for biomethane production. Ukraine can offer the

cheapest raw materials for biomethane production. Biomethane plants, in addition to biomethane, generate digestate, which can become the main organic fertilizer needed for the revival of Ukrainian soils.

Table 5. Estimate of biogas and biomethane production in Ukraine until 2050 (billion m³) *Ошибка! Закладка не определена.*

Biogas / biomethane	2020	2025	2030	2035	2040	2045	2050
Biogas for heat and power production	0.13	0.36	0.60	0.83	1.06	1.28	1.50
Biomethane, total, including:	**0**	**0.44**	**1.00**	**1.69**	**2.50**	**3.44**	**4.50**
Biomethane for CHP plants	0	0.11	0.23	0.35	0.49	0.63	0.79
Biomethane for transport	0	0.01	0.08	0.18	0.34	0.54	0.79
Biomethane for heat production and usage in industry	0	0.10	0.20	0.31	0.43	0.55	0.68
Biomethane for export	0	0.22	0.50	0.84	1.25	1.72	2.25

Now, **biomethane is the cheapest of the possible renewable gases**. The cost of biomethane, which makes it profitable for investors to produce it, is about 1000 $/1000 m^3. At the current gas prices on EU exchanges (about 1200 $/1000 m^3), it is absolutely **cost-effective** to produce biomethane in Ukraine for both domestic consumption and export. There is a high probability that the price of natural gas will continue to rise due to a possible reduction in consumption or a complete embargo on Russian gas in EU markets.

Action 4. Increasing the flexibility and level of decarbonization of Ukraine's energy system

Unfortunately, Ukraine has one of the lowest levels of energy system flexibility in the world, which is a technical barrier to the further development of wind and solar generation. To overcome it, it is necessary to construct new energy storages and load following units on natural gas and biomethane. It is planned to use both gas-piston and gas-turbine power generating capacities.

The main barrier to the development of load following units on NG is considered to be the lack of sufficient amount of natural gas of own production. That is, the new load following units on NG will require additional gas volumes, which are not available in the country and will have to be imported at a high price.

We believe that the additional amount of natural gas required for the load following units may be reduced and replaced in the heat production sector and other sectors discussed in this Position Paper. The use of ***biomethane*** can both, increase the flexibility and level of decarbonization of the energy system.

Action 5. Improving energy efficiency in district heating systems, buildings and industry

Today, the level of energy efficiency in Ukraine is 3-5 times lower than in the EU. If Ukraine had the level of energy efficiency as in today's Poland, it could cease the import of energy at all and become an energy-independent state.

One of the consequences of the war in Ukraine is a large number of completely or largely destroyed houses and enterprises. The construction of new buildings in the post-war period should be carried out taking into account modern requirements for energy efficiency of buildings. The construction of new industrial enterprises or reconstruction of destroyed ones should be realized with the introduction of modern technologies at these enterprises (if the old ones are no longer subject to restoration).

Implementing energy efficiency measures is one of the important ways to reduce natural gas consumption in Ukraine.

The National Energy Efficiency Action Plan until 2030[33] sets the following national energy efficiency target: primary and final energy consumption in Ukraine in 2030 should not exceed 91.5 Mtoe and 50.5 Mtoe, respectively. To achieve this goal, the National Plan includes several sectoral and inter-sectoral actions to improve energy efficiency. They cover different sectors: housing and public sector, transport, industry and energy. The actions include promoting energy efficiency of industrial enterprises and residential buildings, energy labelling and ecodesign, full commercial accounting of utilities, reduction of losses in electricity transmission and distribution networks, natural gas distribution networks etc.

Examples of specific actions, envisaged for implementation in 2021-2023[34], are the following:

- Stimulating the development of the energy service market for the implementation of actions for thermal modernization of state and municipal property. *Expected result*: conclusion of at least 200 energy service contracts annually by state and municipal property.
- Encourage the introduction of new technologies that reduce energy and fossil fuel consumption and reduce greenhouse gas emissions. *Expected result:* support for the development of new technological solutions for further use in the national economy.
- Implementation of energy efficiency actions to reduce losses in electricity transmission and distribution networks and gas distribution networks. *Expected result:* implementation of investment programs to increase the level of energy efficiency of gas distribution and electricity networks.
- Development and execution of an updated action plan for the implementation of the Concept of the fulfilment of state policy in the field of heat supply for the period up to 2025. *Expected result:* the creation of conditions for assessing the potential use of **renewable energy sources** in heat supply, highly efficient combined heat and power generation (**cogeneration**) and waste energy potential.
- Dissemination of the use of technologies for high-efficiency combined heat and power generation (**cogeneration**) and the use of waste energy potential in accordance with the principles and provisions of EU legislation. *Expected result: the* creation of a legislative basis for the development of highly efficient **cogeneration**.
- Promoting the efficiency of **DH systems**, water supply and sewerage systems, including through the coordination of relevant investment programs. *Expected result*: implementation of investment programs to increase the level of energy efficiency of **DH systems**, water supply and sewerage.
- Development of a draft resolution of the Cabinet of Ministers of Ukraine on the approval of the State Target Program for ***Energy Efficiency and Development of Renewable Energy***. *Expected result*: provision of funding for priority tasks and energy efficiency measures that require budget expenditures.

[33] The government approved the National Action Plan on Energy Efficiency until 2030 (29.12.2021): https://www.kmu.gov.ua/news/uryad-shvaliv-nacionalnij-plan-dij-z-energoefektivnosti-na-period-do-2030-roku. ***The text of the National Action Plan was not found in the public access.***

[34] ACTION PLAN for the implementation in 2021-2023 of the National Action Plan on Energy Efficiency for the period up to 2030 (approved by the Order of the Cabinet of Ministers of Ukraine on December 29, 2021, № 1803-p.: https://zakon.rada.gov.ua/laws/show/1803-2021-%D1%80#Text.

A draft concept of the State Target Program for Energy Efficiency and Renewable Energy Development for 2022-2026[35] was developed recently. Among other things, the Concept provides incentives by repaying part of the loan amount to:

- population and enterprises for the implementation of energy efficiency actions;
- population for the installation of solar panels and heat pumps;
- business entities for the installation of ***biogas*** plants running on agricultural waste (anaerobic digestion) and power plants with a capacity of up to 150 kW, producing electricity from the biogas;
- encouraging business entities to implement ***energy crops*** growing projects.

Action 6. Substitution of Russian supplies with natural gas from other sources

During the period of 2016-2020, Ukraine imported a significant amount of natural gas (**10-15** billion m^3/year) (**Fig. 13**)[36]. Legally, this gas was supplied from the EU: Slovakia, Hungary and Poland, but in fact, it was of Russian origin. Gas imports to Ukraine in 2021 decreased significantly to **2.6** billion m^3, which is **6 times less** than in 2020. The main reasons for the abrupt decline in the imports in 2021 were the dramatic rise in NG cost in world markets, a certain decrease in its consumption in Ukraine, and the available gas reserves in storage facilities left from the previous heating season. We forecast that the need for natural gas imports will return to the level of 8 billion m^3/year with the stabilization of the situation in Ukraine regarding the war and the COVID pandemic. In 2021, gas was imported mainly by *virtual reverse* (backhaul), which Ukraine's Gas Transmission System Operator introduced in early 2020. Main volume of the imports came from Hungary (1.5 billion m^3, which was -64% compared to 2020), Slovakia (285.3 million m^3, -97%), and Poland (78.6 million m^3, -95%)[37, 38].

Due to the military aggression of the Russian Federation against Ukraine, the EU countries are planning to reject Russian natural gas and are already actively looking for alternative sources of gas supply. Probably, this will increase competition between consumers in the gas market and may affect the opportunities or conditions of gas exports to Ukraine.

Data on the demand and production of natural gas by regions and key countries of the world in the period from 2018 to 2022 is presented in **Table 6**. These data show that the overall demand for NG in the world tends to increase slightly. At the same time, demand for gas in Europe has been relatively stable recently, but given the current Russian-Ukrainian war and the EU's green course in recent years, it can be expected to be reduced in favour of RES and low-carbon fuels.

[35] Draft Order of the Cabinet of Ministers of Ukraine "On approval of the Concept of the State Targeted Economic Program for Energy Efficiency and Development of Renewable Energy Sources for 2022-2026": https://saee.gov.ua/uk/pressroom/3612.

[36] https://voxukraine.org/spozhyvannya-gazu-v-ukrayini-ta-jogo-tsina/.

[37] https://www.ukrinform.ua/rubric-economy/3379921-import-gazu-v-ukrainu-torik-zmensivsa-u-sist-raziv.html.

[38] https://ua.interfax.com.ua/news/economic/796658.html.

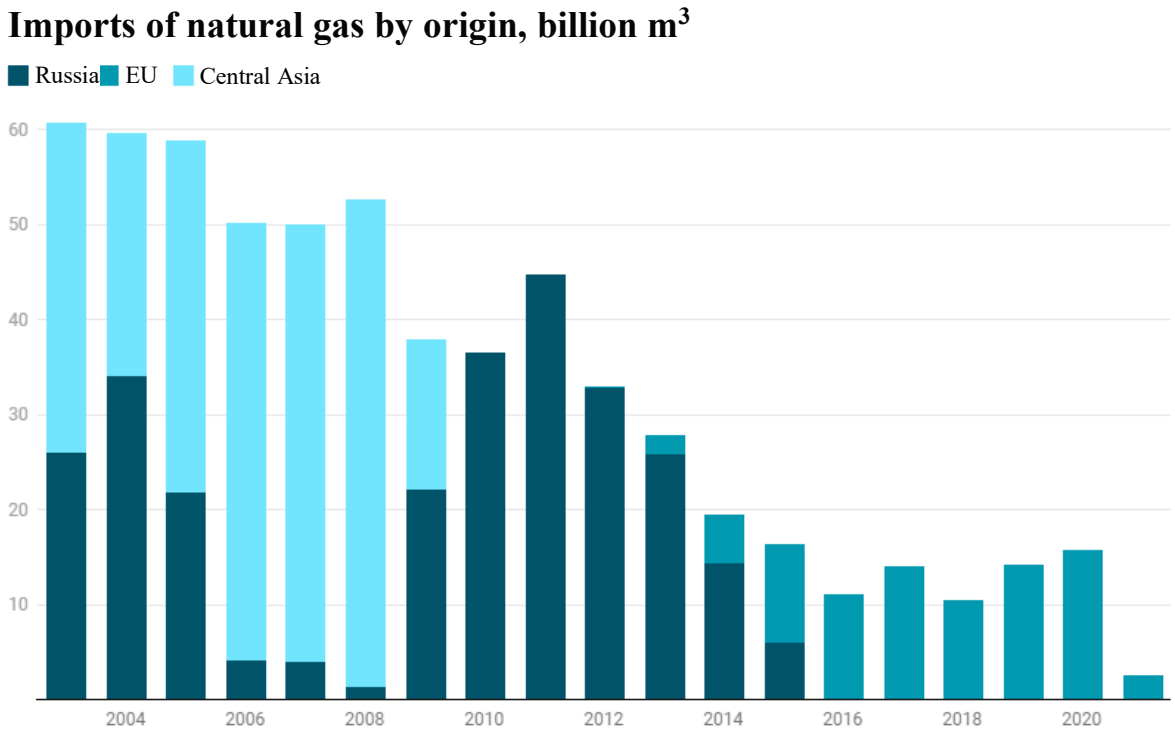


Fig. 13. Imports of natural gas to Ukraine by origin[Ошибка! Закладка не определена.]

The top 10 natural gas exporting countries (Russia, USA, Qatar, Norway, Australia, etc.) in 2020 provided 60% of total NG production in the world, 58% of NG exports by gas pipelines and 90% of liquefied natural gas exports (**Fig. 14**).

Table 6. Demand and production of NG by regions and key countries of the world (2018-2022)[39]

Regions / countries	Demand, billion m^3					Production, billion m^3				
	2018	2019	2020	2021	2022*	2018	2019	2020	2021	2022*
Africa	157	162	160	164	169	244	248	240	247	249
Asia-Pacific region	824	850	854	910	954	627	654	648	675	691
of which China	283	307	325	368	396	160	174	189	206	220
Central and South America	153	152	137	143	141	167	167	152	158	157
Eurasia	666	658	633	668	665	932	941	884	968	976
of which Russia	493	482	460	488	484	726	738	692	761	763
Europe	536	537	522	545	534	246	227	211	204	202
Middle East	544	543	547	566	583	666	677	680	694	709
North America	1 061	1 097	1 070	1 066	1 078	1 062	1 166	1 145	1 148	1 177
of which the USA	854	888	869	862	870	868	968	953	958	985
World	**3 940**	**3 998**	**3 923**	**4 063**	**4 125**	**3 944**	**4 080**	**3 960**	**4 094**	**4 161**

** Data of 2022 is the forecast made in 2021, i.e. before the Russian-Ukrainian war.*

[39] Gas Market Report Q4-2021, IEA: https://iea.blob.core.windows.net/assets/261043cc-0cb6-498b-98fa-a1f48715b91f/GasMarketReportQ42021.pdf.

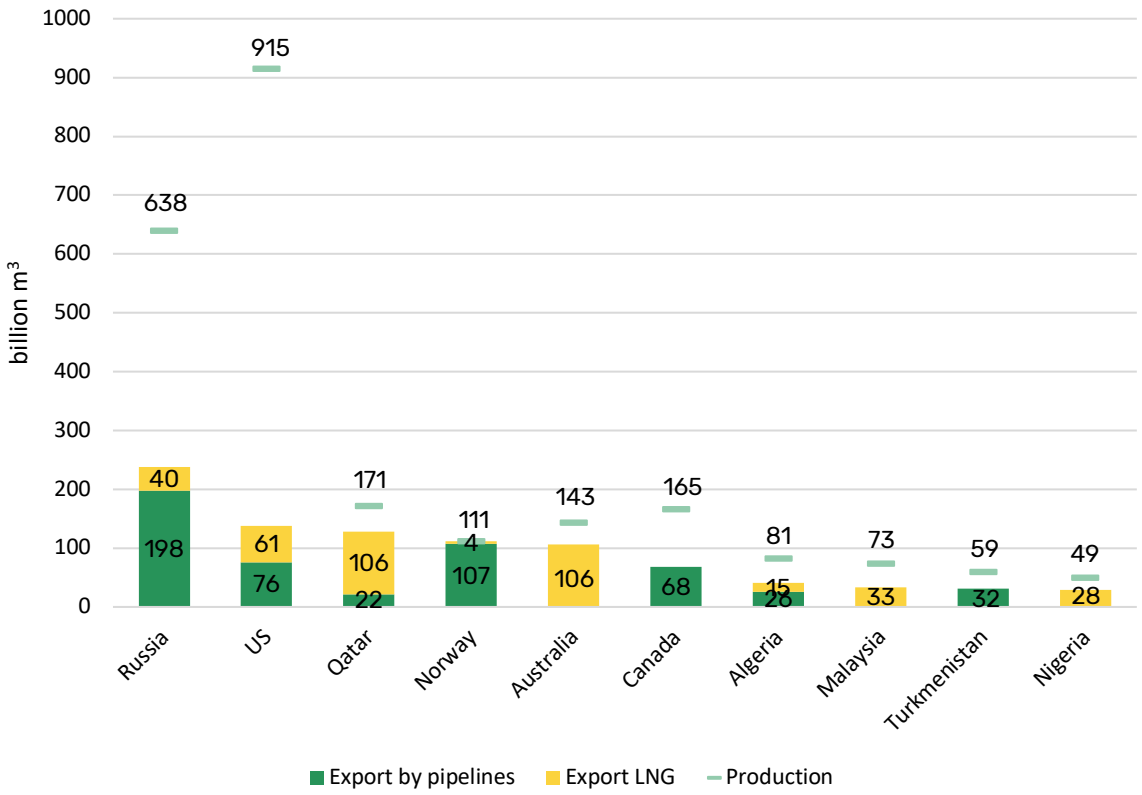


Fig. 14. The top 10 world exporters of natural gas by pipelines and LNG in 2020[40]

Exporters of natural gas to Europe in 2020[41]:

- Russia – 167.7 billion m^3 of natural gas by pipelines and 17.2 billion m^3 of LNG.
- USA – 25.6 billion m^3 of LNG.
- Qatar – 30.2 billion m^3 of LNG.
- Norway – 106.9 billion m^3 of natural gas by pipelines in the EU.
- Algeria – 21 billion m^3 of natural gas by pipelines in the EU and 13.9 billion m^3 of LNG in European countries.
- Nigeria – 14.6 billion m^3 of LNG.

As for other regions, Australia exported 106 billion m^3 of LNG to the Asia-Pacific region, including 40.6 billion m^3 to China and 39.7 billion m^3 to Japan.

The top 10 natural gas importers in 2020 accounted for 45% of total NG consumption in the world, 54% of natural gas imports by pipelines and 66% of LNG imports (**Fig. 15**). Germany is the largest importer in Europe (102 billion m^3 of natural gas by pipelines in 2020). In Europe, significant volumes of natural gas are imported to Italy (51 billion m^3 by pipelines and 12 billion m^3 of LNG in 2020), the United Kingdom (30 billion m^3 by pipelines and 19 billion m^3 of LNG) and France (26 billion m^3 by pipelines and 20 billion m^3 of LNG).

[40] UABIO representation of BP data p.l.c.: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/xlsx/energy-economics/statistical-review/bp-stats-review-2021-all-data.xlsx.

[41] UABIO representation of BP p.l.c.: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/xlsx/energy-economics/statistical-review/bp-stats-review-2021-all-data.xlsx.

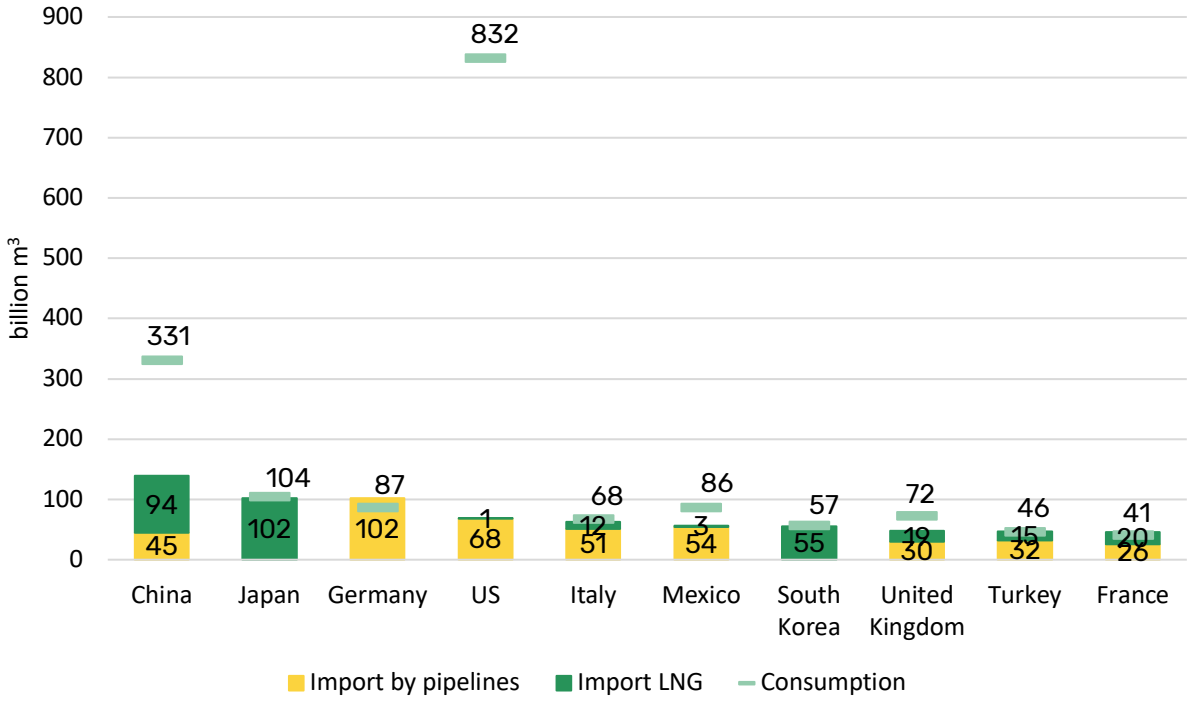


Fig. 15. The top 10 global importers of natural gas by pipelines and LNG in 2020[40]

The United States has committed to supply an additional 15 billion m^3 of LNG to the EU by the end of 2022, which should cover about 10% of the EU gas imports from Russia. In addition, the EU aims to increase LNG imports from the United States to about 50 billion m^3 per year by 2030 at the latest, which could replace about a third of this year's gas imports from Russia[42].

Italy is considered one of the EU's most dependent on Russian gas. As of the end of 2021, the share of Russian gas was 43% in the structure of its gas imports, and 19% in the country's energy sector, which was considerably more than even in Germany (12%). The situation gets complicated by the fact that at the beginning of the century Italy closed all the nuclear power plants and is now very dependent on energy import. So, now the country is trying to find a replacement for half of the volume of gas imported from Russia within two months. Negotiations are under way to increase LNG imports and supplies through existing pipelines from Algeria and Libya[43].

Germany is gradually rejecting Russian gas and has already agreed with Qatar the supply of LNG. Earlier, Germany's largest energy trader E.On announced plans to stop buying gas from Russia's Gazprom[44].

In April 2021, Ukraine and Qatar signed a memorandum of understanding in the energy sector[45], which will remain in force for three years and may be automatically extended for the same period. The Memorandum sets out the intentions of the states to develop cooperation in the field of Qatar's

[42] https://www.dw.com/uk/yes-domovyvsia-zi-ssha-pro-suttieve-zbilshennia-postavok-skraplenoho-hazu/a-61259650?maca=ukr-rss-ukrnet-ukr-all-3816-xml.

[43] https://www.eurointegration.com.ua/news/2022/03/14/7135955/.

[44] https://ua-energy.org/uk/posts/nimechchyna-domovylosia-pro-lng-z-kataru.

[45] https://www.ukrinform.ua/rubric-economy/3221633-ukraina-i-katar-pidpisali-memorandum-pro-spivpracu-u-naftogazovij-sferi.html.

investments in gas exploration and production in Ukraine, as well as LNG supplies from Qatar to Ukraine. As Qatar does not have common borders with Ukraine, as well as a gas pipeline, it is also a question of construction of an LNG terminal.

It should be noted that about ten years ago Ukraine was already considering a project on building an LNG terminal near Odesa and even signed an agreement with Spanish company Gas Natural Fenosa in 2012[46]. Unfortunately, the project was not implemented. In the absence of a domestic LNG terminal, liquefied gas supplies are possible through the terminal in Poland, as well as through the Bosporus (with the consent of Turkey).

Thus, the option of replacing Russian gas with alternative sources of supply, which is considered a priority in the EU, is unlikely to be such for Ukraine. The construction of LNG terminals in the Black Sea is currently problematic due to both, current military actions and Turkey's disapproval of liquefied gas carriers passing through the Bosporus. In addition, given deficit in the world's natural gas market, especially Russia's potential embargo, Ukraine will find it extremely difficult to compete with other countries and to find new sources of natural gas.

Action 7. Introduction of heat pumps

As a result of shutdown of a significant part of industrial enterprises on the territories of military actions in Ukraine, there is a surplus of electricity, mainly from nuclear and coal power plants. In these circumstances, the partial "electrification" of the heat supply sector with heat pumps is a logical and justified action. At that, we are talking about heat pumps for individual private homes, autonomous systems in individual multi-storey buildings and DH systems. Given that the electricity used to drive heat pumps becomes more renewable, the heat that they produce, will also become more renewable and decarbonized. ***We suppose that biomass boilers and CHP plants together with heat pumps will form the basis for future heat supply systems in Ukraine.***

The draft NREAP 2030[Ошибка! Закладка не определена.] provides for the production of **700 ktoe** of heat energy by heat pumps in 2030, including 460 ktoe by aerothermal, 160 ktoe by geothermal, and 80 ktoe by hydrothermal HPs **(Table 7).** Thus, by 2030 it is planned to increase the production of thermal energy by heat pumps by 13.5 times compared to 2020 (52 ktoe).

[46] https://fbc.ua/news/suspilstvo/sporudu-lng-terminalu-v-ukrayini-potribno-otsinyuvati-ne-z-tochki-zoru-politiki-a-z-tochki-zoru-ekonomiki-ekspert/.

Table 7. Annex 4 to the draft NREAP 2030 *Ошибка! Закладка не определена.*

Estimation of the expected heat production from different RES to achieve NREAP 2030 targets for 2021-2030 (ktoe)

Production of heat by types of sources	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Geothermal (except for low-temperature geothermal heat for the use in heat pumps)				**6**	**13**	**19**	**25**	**31**	**38**	**44**	**50**
Solar energy	**1**	**20**	**62**	**104**	**147**	**189**	**231**	**273**	**316**	**358**	**400**
Biomass, including:	**2 816**	**3 340**	**4 116**	**4 893**	**5 669**	**6 446**	**7 222**	**7 999**	**8 775**	**9 552**	**10 328**
solid biomass	2 797	3 300	3 970	4 640	5 309	5 979	6 649	7 319	7 988	8 658	9 328
biogas	19	40	147	253	360	467	573	680	787	893	1 000
Energy from heat pumps, including:	**52**	**86**	**154**	**222**	**291**	**359**	**427**	**495**	**564**	**632**	**700**
aerothermal	36	46	92	138	184	230	276	322	368	414	460
geothermal	10	24	39	54	69	84	100	115	130	145	160
hydrothermal	6	16	23	30	37	44	52	59	66	73	80
Total	**2 869**	**3 446**	**4 333**	**5 226**	**6 119**	**7 012**	**7 905**	**8 799**	**9 692**	**10 585**	**11 478**

Action 8. Extension of the service life of existing nuclear power plants

Currently, nuclear power plants (NPPs) cover more than half of Ukraine's electricity needs. According to 2020 data, **52%** (71249 GWh) of the total 137197 GWh of power was produced by NPPs[47]. The design operation life of Ukrainian NPP units is 30 years; by 2019, all but five existing units exhausted their operation life. According to the *Ministry of Energy of Ukraine*[48], expert assessments show that decommission of NPP units that have exhausted their design operation life may lead to energy crisis in the country in the absence of replacement capacity. The world experience shows that extending the service life of NPP units is one of the most effective ways to partially solve the problem of replacing generating capacity provided that nuclear and radiation safety standards are strictly met.

The Energy Strategy of Ukraine until 2035[49] states that "Ukraine considers nuclear energy as one of the most cost-effective low-carbon energy sources. Further development of the nuclear energy sector until 2035 is projected based on the fact that the share of nuclear generation in total electricity production will increase". The Energy Strategy provides for (Section "Main actions for the implementation of strategic objectives in the field of electricity generation"):

- extension of NPP service life;
- adoption of a decision and action plan to replace the capacity of NPPs that will be decommissioned after 2030;
- selection of reactor technologies for the construction of new nuclear power units to replace NPP capacity that will be decommissioned after 2030;
- development and approval of the long-term Nuclear Energy Development Program of Ukraine.

Given the shortage of gas and coal, as well as significant environmental problems created by coal generation, **the maximum possible extension of the life of existing nuclear power plants** (with the appropriate permission of the IAEA) seems logical and economically justified. This is in line with objectives of the current Energy Strategy and the Comprehensive Work Program to extend the operation life of existing NPP units[50] (approved by the Order of the Cabinet of Ministers of Ukraine on April 29, 2004, № 263-p[51]). However, the construction of ***new nuclear power plants*** in Ukraine we consider ***inexpedient*** as the existing and new solar and wind power plants, when balanced by load following units on gas and by energy storage, can produce cheaper electricity than newly-built NPPs.

Action 9. Encouraging consumers to temporarily reduce the room temperature by 1°C

In the EU, the average temperature in buildings that are heated is at present above 22°C[52], which allows to reduce it by at least 1°C not affecting comfort noticeably. In Ukraine, living spaces are often

[47] Statistical Yearbook of Ukraine 2020. Publication of the State Statistics Service of Ukraine, 2021: http://www.ukrstat.gov.ua/druk/publicat/kat_u/2021/zb/11/Yearbook_2020.pdf.
[48] Ministry of Energy of Ukraine. Nuclear energy, history of the industry: http://mpe.kmu.gov.ua/minugol/control/publish/article?art_id=244916068.
[49] Energy Strategy of Ukraine until 2035: https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80#Text.
[50] https://zakon.rada.gov.ua/rada/show/v0340558-04#Text.
[51] https://zakon.rada.gov.ua/laws/show/263-2004-%D1%80#Text.
[52] https://iea.blob.core.windows.net/assets/1af70a5f-9059-47b4-a2dd-1b479918f3cb/A10-PointPlantoReducetheEuropeanUnionsRelianceonRussianNaturalGas.pdf.

heated to the temperatures above 22°C, which is confirmed by the opened windows for cooling premises. According to standards of heating services in Ukraine, the air temperature should be 18°C in living quarters and 20°C in corner rooms[53]. Therefore, a similar action to encourage consumers to temporarily reduce the temperature in their rooms by 1°C can be introduced in Ukraine.

One of the least expensive and most effective methods of heat control in the apartment is the installation of radiator thermostats on each heater in a room[54]. In addition, the action will save households on energy bills. Similar energy-saving actions should be implemented in offices and other premises, except for premises where it is necessary to provide other temperature conditions (hospitals, schools, kindergartens etc.). Besides, the heating temperature can be further reduced on weekends and during periods when there are no people in the premises.

Reducing the indoor temperature by 1°C saves up to 6% of thermal energy[55]. Thus, taking into account the consumption of natural gas by heating plants and in the domestic sector in 2020 (without NG spent for cooking), the estimated reduction in gas consumption in Ukraine from the implementation of this action will be up to **0.7** billion m^3 per year.

Action 10. Introduction of natural gas storage obligations

It can be stated that this action has already been largely ***implemented*** in Ukraine and it is more relevant and urgent for the European Union.

The network of underground natural gas storage facilities is an important element of Ukraine's energy system. Stable and uninterrupted functioning of the gas storages is necessary for providing heating seasons, for the operation of industrial enterprises and for the fulfilment of obligations to foreign partners. The total active capacity of Ukrainian underground storage facilities is over **30** billion cubic meters[56]. They are the largest storages in Europe (21% of the total[57]) and the third-largest in the world – after the United States and Russia. Such facilities provide Ukraine with significant opportunities not only to meet its own needs but also to attract customers for gas storage, including European ones.

Subdivisions of Ukrainian Naftogaz "Natural Gas Storage Division" are part of Ukrtransgaz JSC (Gas Storage Operator). The business line manages 11 gas storage facilities located in the mainland of Ukraine (Fig. **16**). It also includes another underground storage facility located in the temporarily occupied territory in Luhansk region.

[53] https://kyivcity.gov.ua/budynok_ta_komunalni_posluhy/opalennia/nyzka_temperatura_opalennia_shcho_robyty/.
[54] https://pay.vn.ua/articles/426.
[55] https://ecotown.com.ua/news/YAk-ekonomlyat-na-opalenni-u-bahatykh-krayinakh/.
[56] Naftogaz website: https://www.naftogaz.com/business/natural-gas-storage-business-unit.
[57] Gas storage operator of Ukraine: https://utg.ua/img/menu/company/docs/2021/buklet/%D0%91%D1%83%D0%BA%D0%BB%D0%B5%D1%82_%D0%A3%D0%A2%D0%93_ua_30112021.pdf.

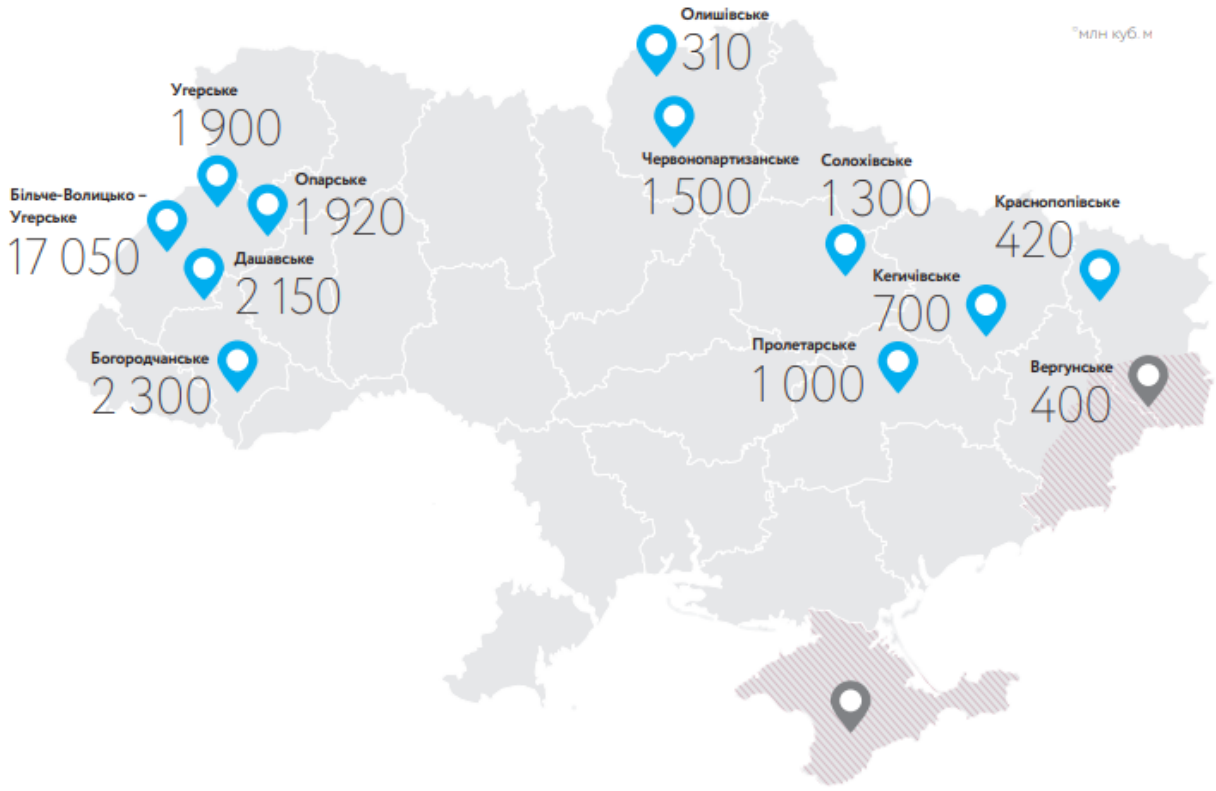


Fig. 16. Ukrainian gas storage system (capacity is indicated in million m³)[Ошибка! Закладка не определена.]

The vast majority of Ukrainian underground gas storage facilities have been established on the site of depleted deposits. Two of them – Chervonopartizanske and Olyshivske (the oldest in Ukraine, founded in 1964) – are based on aquifer structures. Bilche-Volytsko-Uherske UGS is the largest not only in Ukraine but in the whole of Europe; it can hold more than 17 billion m^3 of natural gas. 80% of the Operator's gas storage facilities are concentrated in western Ukraine, which is especially important in the current situation. The strategic goal of the Gas Storage Operator of Ukraine until 2025 is to become a customer-oriented gas storage operator in the European market.

At the beginning of the 2021/2022 heating season, **18.7** billion m^3 of natural gas was accumulated in Ukraine's underground gas storage facilities[Ошибка! Закладка не определена.], which is **sufficient to fully cover the heating season**[58]. The average filling level of UGS of Ukraine at the beginning of the extraction season in 2012-2021 is **18.8** billion cubic meters[Ошибка! Закладка не определена.].

[58] https://www.radiosvoboda.org/a/gas-psg-ukrtransgas-gasprom-opaluvalniy-sezon-taryfy/31456705.html.

Estimation of projected volumes of reduction and replacement of Russian natural gas consumption in Ukraine from the implementation of the proposed actions

Effect of the proposed actions is assessed based on the main forecasted indicators for RES, energy efficiency and energy sector development in accordance with the program documents of Ukraine and expert estimation of the authors. The results are presented in **Table 8**.

Table 8. Projected volumes of the reduction and replacement of natural gas consumption in Ukraine from the implementation of the proposed actions

Type of action	Projected volumes of NG consumption reduction/replacement, ***billion m³/year***	
	until 2030	**until 2050**
Replacement of natural gas with biomass and solid biofuels for heat production	**3.0**	**10.3**
Further construction of wind and solar power plants	**1.7**	**3.5**
Production of biomethane	**0.8**	**3.7**
Increasing the flexibility and level of decarbonization of Ukraine's energy system	**0.2**	**0.8**
Improving energy efficiency in district heating systems, buildings and industry	**2.8**	**5.6**
Introduction of heat pumps	**0.8**	**1.2**
Encouraging consumers to temporarily reduce the room temperature by 1°C	**0.7**	**0.7**
TOTAL	**10.0**	**25.8**

Under the projected development plans, by 2030, Ukraine can completely reduce/replace the imported natural gas in the amount of up to 10 billion m3/year and become completely independent of the gas import. However, we consider the deadline for achieving this target set in the program documents of Ukraine to be too long. In the current political and economic situation, which has been significantly affected by Russia's military actions, these policy documents must be revised. We suppose that **independence of the imported natural gas should be achieved much earlier, maximum within several years**.

By 2050, according to the author's estimation, Ukraine can reduce/replace more than 25 billion m^3/year of natural gas.

Organizational and legislative measures to implement the proposed actions to replace Russian natural gas in Ukraine

For the implementation of the proposed actions for Ukraine to reject Russian natural gas, some organizational and legislative measures are required.

Arrangements for Action 1. Replacement of natural gas with biomass and solid biofuels for heat production

- Introduction of an electronic trade system for solid biofuels through electronic auctions to ensure quality standards and guarantees for the supply of biofuels.
- Introduction of a state support for companies growing energy crops.
- Exemption from CO_2 emissions tax for the plants burning solid biofuels and biogas/biomethane.
- Abolition of non-market subsidies in the structure of energy costs for the final consumer, including the district heating and gas supply sectors.
- Introduction of a market price for natural gas for all categories of consumers, including the population and heat producers.

Arrangements for Action 2. Further construction of wind and solar power plants

- Ensure the financial stability of the State Enterprise “Guaranteed Buyer”.
- Raise the transmission tariff of the Transmission System Operator to a sufficient level as the main source of payment under the "green" tariff.
- Introduce a market price for electricity for all categories of consumers, including the population. Protect vulnerable groups of population through a system of monetized subsidies.
- Give the right to producers of electricity from RES to leave the balancing group of the Guaranteed Buyer and freely sell electricity on the market with the possibility of receiving compensation (contracts for difference).
- Start auctions for the state support of renewable electricity projects as soon as possible
- Develop and implement a mechanism to guarantee the origin of electricity generated by RES.
- Develop a regulatory field that will allow the implementation of direct contracts for the supply of electricity produced by RES to consumers.
- Develop a regulatory environment for the construction of RES facilities for the own consumption of electricity generated.
- Adopt the National Renewable Energy Action Plan until 2030.

Arrangements for action 3. Production of biomethane

- Introduce a system of guarantees of origin for biomethane.
- Create a Register for biomethane (envisaged by the provisions of the Law of Ukraine "On Alternative Fuels"[59]).
- Remove the requirement for mandatory state registration for digestate.
- Develop and approve a national standard for digestate for the use as an organic fertilizer or soil improver.
- Approve acceptable for biomethane requirements for oxygen content (0.2-1%) in the technical regulations for natural gas.

Arrangements for action 4. Increasing the level of flexibility and decarbonization of Ukraine's energy system

- Start auctions for the load following units and energy storage systems as soon as possible.
- Remove price-caps on the cost of balancing services.

Arrangements for action 5. Improving energy efficiency in district heating systems, buildings and industry

- Full-scale reform of the CO2 tax with the transition to an energy tax with the taxation of carbon content in fuel at the time of entry into the customs territory of Ukraine or the first sale.
- Establishment of a decarbonization fund.
- Introduction of a competitive heat market in DH systems.
- Ensuring non-discriminatory access of independent producers to DH networks.
- Introduction of auction bidding for the purchase of thermal energy in competitive DH systems.
- Introduction of the zoning principle in the development of urban heat supply schemes.
- Introduction of an administrative ban on disconnecting consumers from DH systems in DH areas.
- Giving heat supply schemes the status required for development and implementation.
- Simplify and reduce the cost of connecting new homes to DH networks.
- Establishment provisions that would require from developers of heat supply schemes:
    - agreement with national goals, including substantiation for the settlement of specific quantitative indicators of the fulfilment of the set goals that can be achieved in the current situation, as well as the implementation of certain additional measures;
    - priority consideration of cogeneration projects, the attraction of waste heat sources, low-potential energy sources, production of thermal energy from RES;
    - consideration of possibilities for expansion of DH zones by merging separate heating networks, a connection of new consumers (new buildings) or those that were previously disconnected from DH.

[59] Law of Ukraine "On Alternative Fuels" (№ 1391-VI dated 21.05.2009, as amended): https://zakon.rada.gov.ua/laws/show/1391-14#Text.

Arrangements for action 7. Introduction of heat pumps

- Introduction of a market price for natural gas for all categories of consumers, including the population and heat producers.
- Introduction of incentive tariffs for electricity consumed by heat pumps, including the "night" tariffs.

Conclusions

We believe that Ukraine needs to develop as soon as possible an effective and ambitious **program** to abandon Russian gas, coal, oil and oil products **within several years**. We consider this real and economically justified. Such a program will be needed immediately after the end of the military operations and should be the basis for Ukraine's energy recovery, including a program to support such recovery by the collective West.

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