

**ANALYSIS OF THE IMPACT OF RUSSIA'S MILITARY
INVASION OF UKRAINE ON THE ENERGY INDEPENDENCE
OF EUROPEAN COUNTRIES**

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Abstract. The article presents an analysis of the problems of energy independence and energy supply of European countries, given the impact of Russia's full-scale military invasion of Ukraine. This analysis is based on the Energy Freedom Index (*Ief*) developed by the authors, which aggregates sub-indices of energy potential, energy balance, and energy development. A rating of 142 countries of the world was formed according to the value of this index and the places of the EU countries and Ukraine in this rating were determined. Measures aimed at increasing the level of energy independence of European countries and Ukraine were analyzed. Diversification of supplies and accelerated transition to clean energy were proposed as the main measures. European countries have been clustered according to the level of economic and security losses due to the embargo on Russian energy resources. Four groups of countries have been identified in terms of their readiness to replace Russian energy resources and impose embargoes. The dynamics of the indicators of the energy freedom index and their dependence on Russian imports were analyzed, and measures to reduce this dependence were proposed.

Keywords: energy independence, energy freedom index, full-scale Russian invasion of Ukraine, reliance on Russian fossil fuels.

INTRODUCTION

The country's energy independence is a fundamental component of its sovereignty. It determines the self-sufficiency of the state in terms of energy resources, energy supply, and energy generation. In a narrower sense, energy independence determines the independence of one country from the energy resources of another and demonstrates the extent to which the economy relies on its imports to meet its energy needs. The European Union imports 90% of its gas consumption. Until recently, the share of the Russian Federation in these imports was 45% (Fig. 1). This is about 140 billion cubic meters of natural gas, of which 15 billion cubic meters were supplied in liquefied form. Russia also accounted for about 25% of oil and oil products imports and 45% of coal imports [1].

In 2021, the European Commission developed a program of gradual abandonment of Russian gas imports "Fit for 55". It presented a set of legislative proposals and initiatives to ensure that EU policies are in line with climate goals, but was rather slow, with a deadline of 2050.

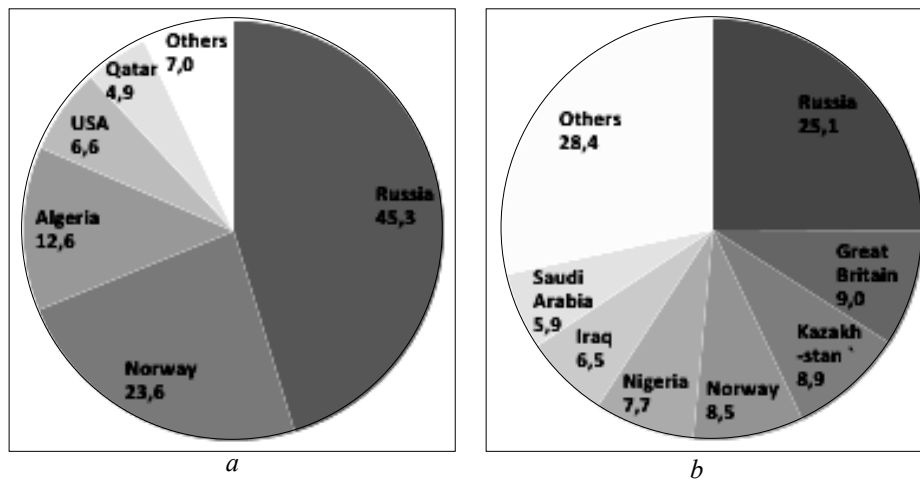


Fig. 1. Structure of imports of major energy sources in the European Union (%), 2021 [1]: a — natural gas; b — oil and oil products

The full-scale Russian invasion of Ukraine on February 24, 2024, exacerbated the problems in the energy market and necessitated an immediate review of the energy independence of the EU. This article examines the prerequisites for building such strategies and explores the possibilities of developing energy systems in Europe, given the significant reduction in dependence on Russian fossil fuels.

ENERGY INDEPENDENCE OF EUROPEAN COUNTRIES: PREREQUISITES AND PROSPECTS

Measures of the European Union to eliminate dependence on Russian fossil fuels

This situation shows that the countries of the European Union have been implementing the strategy of energy independence too slowly, probably because they saw an economic advantage in the use of imported Russian fuel resources. For each country, the ability to abandon Russian fossil fuels is determined by their energy systems' structure and state of development.

In the paper [2] we proposed a method of a quantitative assessment of the state of energy systems of countries in the form of an integrated index Energy Freedom Index (*Ief*), which summarizes the characteristics of these systems by the following groups of indicators (subindices):

1. *Subindex of energy potential (Iep)* – determines the established potential of the country in terms of access to fuel and energy resources, namely to reserves of coal, natural gas and crude oil.
2. *Subindex of energy balance (Ieb)* – reflects the annual balance between total production and consumption of electricity and heat in the country.
3. *Subindex of energy development (Ied)* – demonstrates the ability of the country's energy system to develop, increase energy efficiency and increase the capacity of electricity generation facilities, including from renewable sources.

The integrated Energy Freedom Index is defined as the product of three subindexes (Table 1):

$$Ief = Iep \times Ieb \times Ied .$$

Table 1. Characteristics of the components of the Energy Freedom Index (*Ief*)

Subindex	Characteristic	Calculation	Condition and meaning
1. Subindex of energy potential (<i>Iep</i>)	Determines the established potential of the country in terms of access to fuel and energy resources: coal, natural gas and crude oil reserves	The value of the total indicator of the overall explored reserves of coal, natural gas and crude oil, determined per capita. To determine the total indicator and reconcile the data, which differ both in units of measurement and in the range of values there was used a logistic normalization of data according to the formula: $C_{\text{norm}}(x_{ij}) = (1 + e^{-\frac{a-x_{ij}}{b}})^{-1} + 0,5,$ here parameters a and b are calculated as the mean and standard deviation of the sample of countries under analysis	Larger subindex values within the range [0,1; 1,5] – greater potential. Average value is 1,0
2. Subindex of energy balance (<i>Ieb</i>)	Reflects the annual balance between total production and consumption of electricity and heat in the country	Ratio of annual production and annual energy consumption (both indicators – in million metric tons of oil equivalent). The volume of energy production includes: production and processing of coal, crude oil and leasing condensate, natural gas; electricity generation at nuclear and hydroelectric power plants; geothermal electricity generation; production of solar thermal and photovoltaic electricity and wind electricity; production of fuel from wood and biomass waste	Subindex value $\geq 1,0$ – positive energy balance, the ability to meet the energy needs of the country's own production. Subindex value $< 1,0$ – negative energy balance
3. Subindex of energy development (<i>Ied</i>)	Demonstrates the ability of the country's energy system to develop with the possibility of energy transition	Chain growth rate of the total installed capacity of all electricity generation facilities in the country. The total installed capacity of all electricity generation facilities consists of: power of fossil fuel electricity; hydraulic accumulators; hydroelectric power plants; nuclear electricity; geothermal electricity; electricity from biomass and waste; total electricity from renewable sources without taking into account hydropower. The value of the current year's subindex is defined as a percentage of the value of the indicator for the previous year	The value of the subindex of the base year 2000 = 1,0. Subindex value $\geq 1,0$ – positive dynamics of development. Subindex value $< 1,0$ – negative dynamics of the decline

Table 2 shows the values of the Energy Freedom Index and its components for the EU and Ukraine (*Ief* values for 142 countries are given in [2]). The table also contains data on the share of energy imports from Russia in the structure of national consumption

In 2020, there have been significant changes in the EU economy and the electricity market in particular. Electricity consumption and imports decreased significantly, and fossil fuel use decreased accordingly. This was due to the slowdown in economic development due to the coronavirus pandemic and favorable weather conditions. The development of renewable generation (+80 TWh) and the increase in net imports (+13 TWh), mainly from Norwegian hydropower plants, also had a partial impact. In general, the carbon potential of the EU electricity in 2020 decreased by 14% compared to 2019 [3; 4].

Table 2. Ranking of the EU and Ukraine by the value of the Energy Freedom Index and the relationship between the index and the share of energy imports from Russia in the structure of their national consumption [2; 3]

Place in the EU ranking 2020	Country	Ief 2019	Ief 2020	Index components 2020			Share of imports from Russia in national consumption	Correlation between Ief and the share of imports of imports from Russia
				Subindex of energy potential	Subindex of energy balance	Subindex of energy development		
1	Ukraine	0,70	0,77	1,07	0,72	1,00	NA	NA
2	Bulgaria	0,59	0,76	1,00	0,69	1,11	0,40	0,20
3	Poland	0,58	0,63	1,05	0,59	1,01	0,37	-0,85
4	Denmark	0,70	0,61	0,95	0,98	0,65	0,16	-0,65
5	Czech Republic	0,55	0,59	1,00	0,63	0,94	0,24	-0,43
6	Sweden	0,68	0,59	0,94	0,63	1,00	0,08	0,57
7	Latvia	0,18	0,56	0,94	0,64	0,93	0,31	-0,29
8	Slovenia	0,47	0,55	0,97	0,55	1,03	0,10	0,10
9	France	0,48	0,54	0,94	0,58	0,99	0,09	-0,10
10	Romania	0,72	0,54	0,95	0,72	0,78	0,18	-0,58
11	Finland	0,42	0,49	0,94	0,52	1,00	0,45	0,09
12	Croatia	0,36	0,43	0,95	0,45	1,00	0,09	-0,08
13	Hungary	0,35	0,42	0,99	0,40	1,05	0,54	-0,28
14	Slovakia	0,32	0,40	0,95	0,41	1,03	0,60	-0,28
15	Germany	0,33	0,37	1,01	0,37	0,98	0,28	-0,65
16	Austria	0,35	0,32	0,94	0,42	0,82	0,03	0,10
17	Netherlands	0,39	0,32	0,95	0,35	0,95	0,55	-0,58
18	Portugal	0,23	0,31	0,94	0,35	0,94	0,05	0,49
19	Ireland	0,31	0,28	0,94	0,26	1,14	0,53	0,94
20	Greece	0,25	0,28	0,99	0,32	0,90	0,03	0,30
21	Spain	0,26	0,28	0,95	0,28	1,04	0,08	-0,39
22	Belgium	0,22	0,26	0,94	0,26	1,06	0,29	0,25
23	Italy	0,21	0,24	0,94	0,25	1,00	0,25	0,53
24	Lithuania	0,10	0,13	0,94	0,13	1,10	0,98	0,13
25	Estonia	0,18	0,10	0,94	0,11	1,01	0,16	-0,79
26	Luxembourg	0,03	0,05	0,94	0,05	1,00	0,03	0,36
27	Cyprus	0,04	0,05	0,94	0,05	1,03	0,05	-0,41
28	Malta	0,01	0,01	0,94	0,01	1,00	0,17	0,03

The Energy Freedom Index of the leaders of the European rating last year decreased – in Romania by 25%, in Denmark and Sweden – by 13%. Instead, for countries that have reduced fossil fuel consumption in 2020 – France, Germany, Belgium, Italy, and others – *Ief* has grown. The reduction in fossil fuel consumption and demand has also led to lower prices for all types of primary energy resources. Prices for coal, natural gas, and oil have been the lowest in twenty years, falling to 2000 levels.

In 2021, the EU was hit by an energy crisis. On the one hand, the post-pandemic economic recovery has increased natural gas consumption – in the EU as a whole by 4% compared to 2020. In particular, Slovakia increased gas consumption by 25%, Estonia – by 17%, Spain – by 13%, Italy – by 8%, France – by 3%, Germany – by 5% (Fig. 2, *a*). Only some countries have managed to reduce natural gas consumption. In particular, the Netherlands reduced gas consumption by 13%, Sweden – by 31%, Finland – by 23%, Lithuania – by 18% (Fig. 2, *b*).

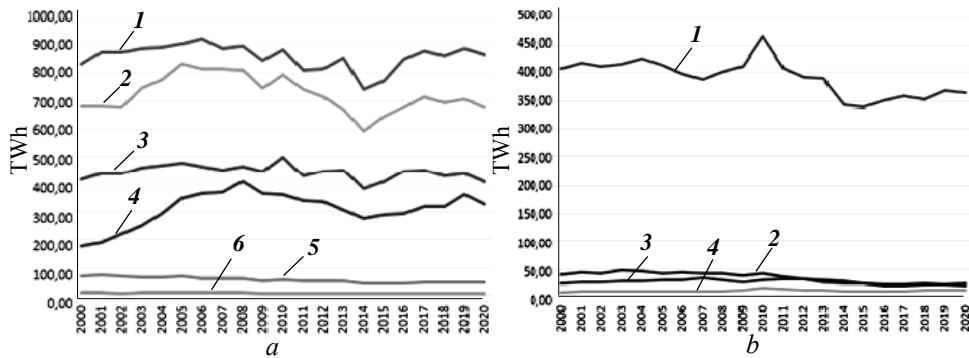


Fig. 2. EU natural gas consumption, 2000–2021 [7]; a — EU countries that have increased consumption by the beginning of 2021: 1 — Germany, 2 — Italy, 3 — France, 4 — Spain, 5 — Slovakia, 6 — Estonia; b — EU countries that have reduced consumption by the beginning of 2021: 1 — Netherlands, 2 — Finland, 3 — Lithuania, 4 — Sweden

On the other hand, the EU's own natural gas production decreased even more – by 13% compared to 2020. Quarterly production became lower than in the period 2015–2019 [6]. This showed that the reduction in domestic gas production in the EU is a long-term trend (Fig. 3).

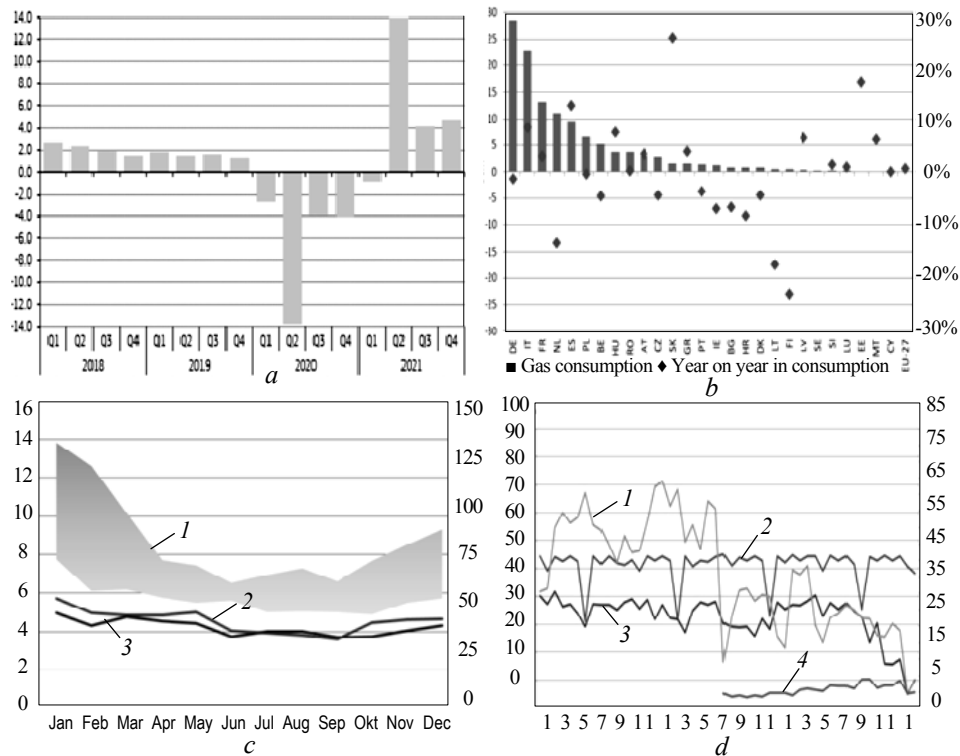


Fig. 3. EU energy market indicators, 2015–2021 [6]: a — GDP change year-on-year comparison (%); b — gas consumption in the fourth quarter of 2021, year-on-year change; c — monthly gas production EU: 1 — 2015–2019; 2 — 2020, 3 — 2021; d — monthly imports of natural gas from Russia by supply route: 1 — Ukraine transit, 2 — Nord Stream, 3 — Belarus transit, 4 — Turkish transit

The full-scale Russian invasion of Ukraine at the end of February 2022 significantly affected the situation in the European energy market. Prices have risen unprecedentedly and consumption has fallen (Fig. 4). According to forecast data,

in 2022 the demand for natural gas is expected to decrease by about 6%, which will correspond to the level of 2020 [8].

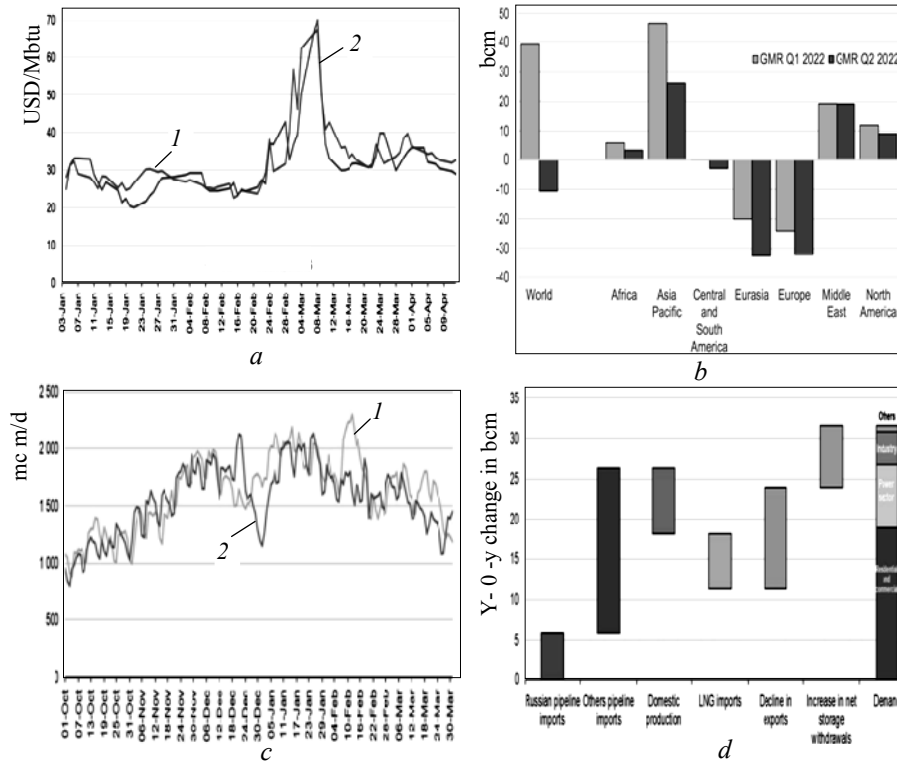


Fig. 4. EU energy market indicators, 2022 [8]: *a* — daily European month-ahead and Asian spot LNG prices: 1 — TIF, 2 — Asian spot LNG; *b* — natural gas consumption growth in the two latest issues of the Gas Market Report; *c* — daily natural gas demand: 1 — 2020/21, 2 — 2021/22; *d* — natural gas balance, year-on-year change

Energy prices, which began to rise in 2021, jumped sharply – as of March 2022 by an average of 40% compared to December 2021 (Fig. 5).

In early March 2022, the price of natural gas in Europe set a new high and exceeded USD 3 800 per thousand cubic meters. As a result, the European Commission has presented a preliminary plan to eliminate dependence on Russian fossil fuels by 2030 REPowerEU [12].

Measures of the European Union to eliminate reliance on Russian fossil fuels

The dynamics of the energy independence index of countries such as Hungary, Germany, Slovakia, Ireland, Spain, etc., indicates the presence of energy potential, but their energy balance is low and energy development is slow. Lack of activities to increase energy independence, post-pandemic economic recovery and growing dependence on imported fuels have led to an energy crisis in these countries. Countries that had a high index, on the other hand, have greater opportunities to reduce their dependence on Russian fossil fuels.

According to the plan, by the end of 2022 it is expected to reduce EU demand for Russian gas by 100 billion cubic meters or two-thirds of the total. The strategy provides the implementation of two main directions [12]:

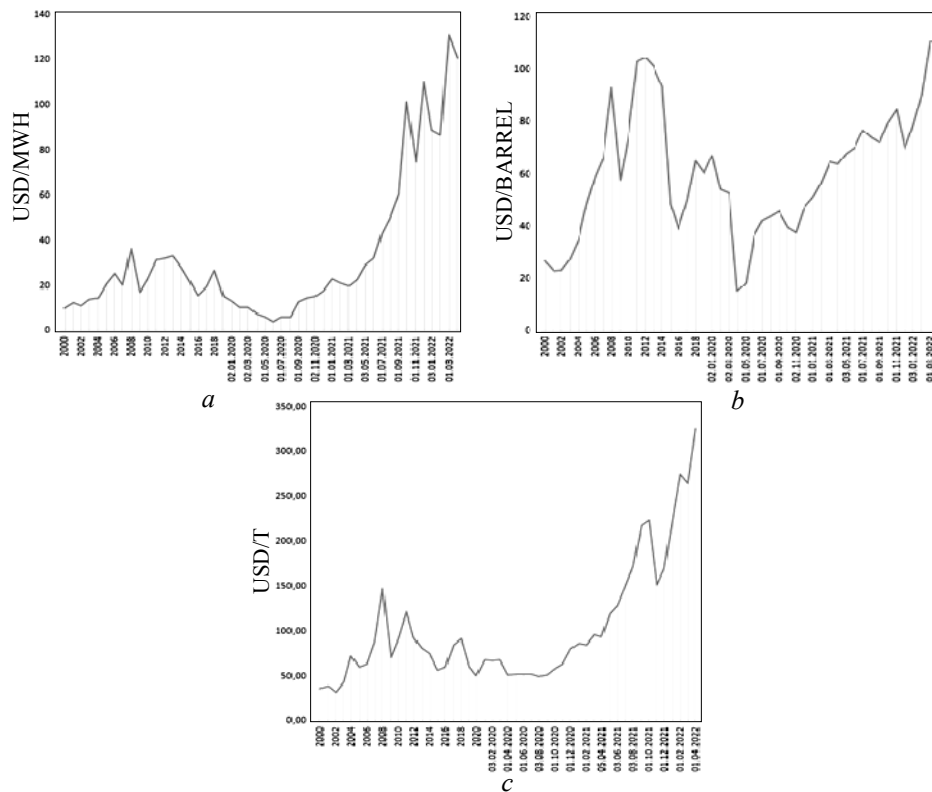


Fig. 5. Coal, natural gas, oil prices, 2000–2022 [9; 10; 11]: *a* — natural gas prices; *b* — oil prices; *c* — coal prices

The first direction is to diversify supplies and attract more renewable gas sources. In particular, it is planned to increase LNG imports (compensating for 60 billion cubic meters of gas), double sustainable biomethane production (compensating for 18 billion cubic meters of gas), increase production and imports of renewable hydrogen (20 million tons of hydrogen can compensate for 50 billion cubic meters of gas).

The second direction is to accelerate the transition to clean energy. In particular, it is planned to install photovoltaic panels on the roofs of residential buildings and enterprises, to double the speed of installing heat pumps. The commission also outlined measures to respond to rising energy prices in Europe and replenish gas supplies next winter. By the end of this year, about 25% of electricity can be generated by solar energy. In general, by the end of 2022 it is expected to reduce EU demand for Russian gas by 100 billion cubic meters or two-thirds of the total volume.

According to the REPowerEU plan, the European Commission has launched technical support for 17 EU member states to phase out Russian fossil fuels. The technical package of recommendations will allow states (Belgium, Bulgaria, Czech Republic, Estonia, Ireland, Greece, Spain, Croatia, Italy, Cyprus, Hungary, Poland, Portugal, Romania, Slovenia, Slovakia and Finland) to identify and implement political reforms and investments in such areas as diversifying energy supplies, accelerating the transition to renewable energy sources and improving energy efficiency [12].

A more detailed plan “A 10-Point Plan to Reduce the European Union’s Reliance on Russian Natural Gas” was presented in March 2022 by the International

Energy Agency [13]. In order to ensure security and protect the EU from possible changes in energy supply, the European Parliament has also adopted regulations on measures to ensure security of gas supply (№2017/1938) and on conditions for access to natural gas transmission networks (№715/2009) [14].

In support of Ukraine and opposition to Russian armed aggression, the leaders of the European Union held an informal meeting in Versailles on March 10–11, 2022. The Versailles Declaration was signed as a result of the meeting. It also agreed to stop the import of Russian gas, oil and coal as soon as possible [15].

In general, the updated energy supply strategy of the EU countries envisaged by the above-mentioned acts is based on two main directions: diversification of supplies and accelerated transition to clean energy.

In the context of the second direction, the act of “green” taxonomy of the European Union was adopted, which sets out a number of provisions for changing the structure of energy supply. In particular, the most effective way to decarbonize the economy is direct electrification of end use. 66% of European electricity has already been decarbonized, of which 50% – due to nuclear energy [16]. Increasing the use of nuclear energy by EU countries is impossible. The planned construction of 14 new nuclear reactors in Europe, in particular in France, is not enough to prevent a gradual decline in the total installed capacity of existing reactors, which are nearing the end of their technical life. The new reactors will keep the share of nuclear energy in the structure of total energy production at 50% in 2035–2050.

Taking into account the climatic characteristics of the European region it is also impossible to use renewable energy for a full maximum. However, as an additional source, it is planned to increase the use of biomass, wind or solar energy from 32% to 40% of final energy consumption by 2030.

Thus, the main direction of increasing the level of energy independence of European countries from Russia is the diversification of gas supplies. With technical support from the EU, European countries are already taking steps to reduce or stop gas and oil imports from Russia, but most of the measures are planned for five years, as their rapid implementation is problematic. There are geographical difficulties in transporting LNG. Given the different volumes of Russian gas consumption and the different capacity of LNG infrastructure, countries have different options for its replacement, as shown in (Fig. 6, 7).

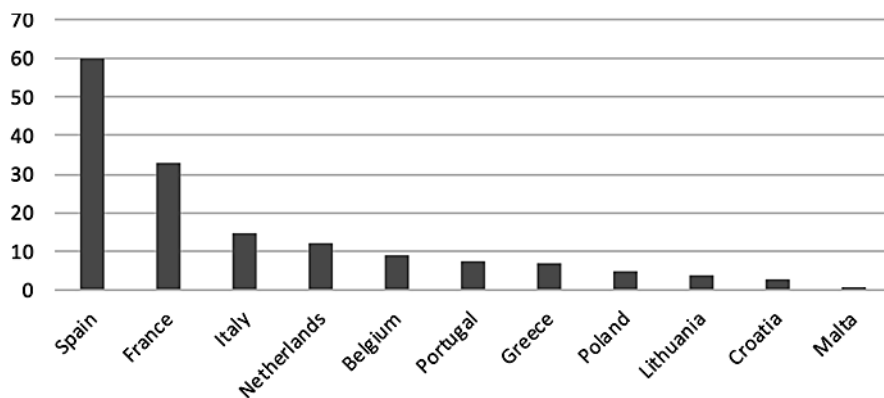


Fig. 6. Annual capacity of liquefied natural gas terminals (billion cubic meters per year), 2022 [17]

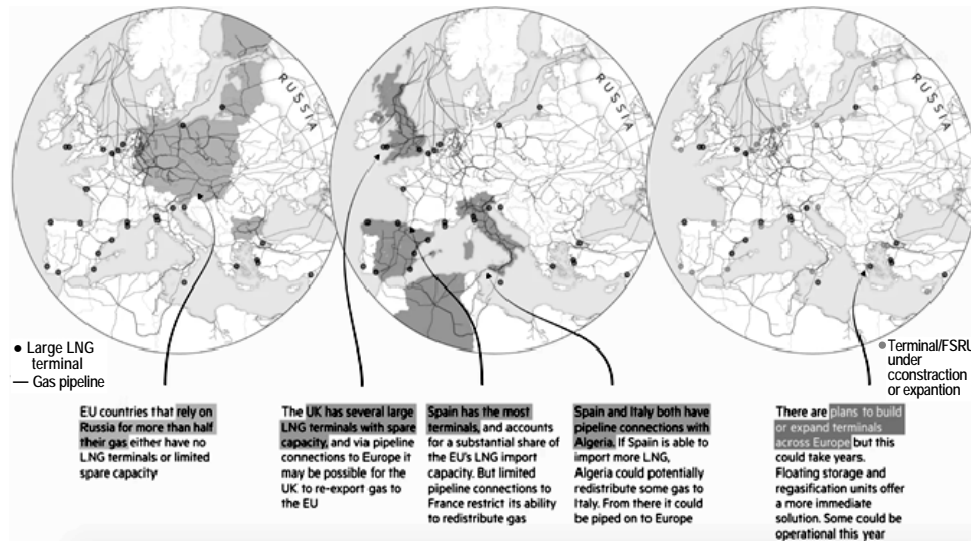


Fig. 7. Prospects for increasing LNG imports to EU countries [18]

The Baltic states were the first countries in Europe to completely stop importing Russian gas. From April 1, 2022, Russian natural gas will no longer flow to Latvia, Estonia and Lithuania. By the end of 2022, the Netherlands plans to abandon Russian oil, gas and coal.

The most difficult thing is to refuse to import Russian gas to its largest consumers – Germany, Italy and France. However, France has said it is ready to support an embargo on Russian oil and gas imports. Other countries, including Germany, are not ready to give up supplies from Russia. In case of a full embargo on imports from Russia, Germany will be able to replace only 20% of gas consumed by increasing coal combustion. At the same time, the German government has assured that it will not allow the Nord Stream 2 gas pipeline to start operating. Austria, which is 80% dependent on Russian natural gas, cannot abandon Russian natural gas in the nearest future, but the country has completely abandoned Russian oil [19].

Europe's efforts to gradually reduce gas imports from Russia are expanding the geography of supply. Already this year, the EU plans to increase liquefied gas supplies from the United States and Qatar by 50 billion cubic meters. The EU relies on Caspian producers to supply natural gas, which can supply up to 10 billion cubic meters for several months. This requires enhanced cooperation with Turkey, which is becoming a central link in alternative supply routes from Azerbaijan, Turkmenistan and Israel [20; 21]. Europe is focusing on the development of nuclear energy capacity, the generation of energy from renewable sources. New oil suppliers are being sought.

As of the end of April 2022, the EU's fifth package of sanctions has decided to impose an embargo only on Russian coal, which will take effect only in August. The European Union is currently developing the sixth package of sanctions that could affect oil and gas exports. However, some countries, such as Hungary and Slovakia, are unprepared for a total ban on Russian oil because it threatens their energy security. They will be given the time until the end of 2023 to enforce sanctions, one year more than other EU member states. In order to impose an oil embargo, the consent of the world's largest exporters is required. The UAE, Saudi Arabia, Iran, Venezuela, and others should increase oil production by a total of 10 million barrels per day. At the moment, there is the consent of some countries, but the full consent of all exporters is not yet. Therefore, the European Union admits that it will not be able to agree on the positions of all countries on the oil embargo.

Losses of European countries from the embargo on Russian energy resources and measures to reduce them

Russia's energy resources have become an important geopolitical factor. According to the Bruegel think tank, the EU pays 450 million and 400 million euros a day for oil and natural gas imports, respectively. This amount is equivalent to the estimated cost of 160 Caliber cruise missiles launched in Ukraine. In just two months of war, the EU has paid Russia more than 40 billion euros for oil and gas. This money has largely offset the impact of Western sanctions on Russia. The oil and gas sector brings in up to half of its budget revenues and more than half of its exports, and it sells 70% of its gas and 60% of its oil and petroleum products to Europe. In 2021, revenues from oil and gas exports in the federal budget of Russia amounted to 38,1% of total revenues, and profits – 119 billion dollars [22].

In response to the imposition of sanctions by European countries, on March 31, 2022, the President of Russia signed a decree defining new rules for the sale of natural gas to “unfriendly countries” from April 1. Countries-buyers should open special accounts with Gazprombank. The bank will accept payments in foreign currency and will convert it into rubles. Most EU and G7 countries have rejected this requirement, but about 10 countries, including Hungary and Italy, have already opened such accounts [23]. Due to the refusal to demand payment in rubles, Russia has already cut off gas supplies to Bulgaria and Poland. These countries have stated their readiness to stop Russian gas supplies and receive gas through alternative routes from Greece and Germany. But if a similar situation occurs with other, more vulnerable countries, it will require a partial revision of their energy strategy and structure.

All EU countries are taking active measures to replace Russian fuel with energy from other sources. However, as shown above, the level of their readiness and the time of replacement are different and are determined by the level of dependence, policies, and capabilities of countries. Different countries will have different consequences of the embargo on Russian fossil fuels, measured by losses in the country's economy and security.

For further research, a pairwise correlation analysis was conducted to determine the relationship between the Energy Freedom Index, which is a generalized measure of the country's ability to embargo, and the share of Russian energy imports in its total consumption, which is a measure of dependence on Russia (Fig. 8).

The correlation coefficient is interpreted as follows:

1. Positive coefficient:

- the growth of the Energy Freedom Index is associated with the growth of energy imports from Russia;
- the decrease in the Energy Freedom Index is associated with a decrease in energy imports from Russia.

2. Negative coefficient:

- the growth of the Energy Freedom Index is associated with a decrease in energy imports from Russia;
- the decrease in the Energy Freedom Index is associated with the growth of energy imports from Russia.

The density of the relationship between variables in the interval $[0; \pm 0,1)$ – absent, in the interval $[\pm 0,1; \pm 0,3)$ – low, in the interval $[\pm 0,3; \pm 0,5)$ – medium, and in the interval $[\pm 0,5; \pm 1]$ – high.

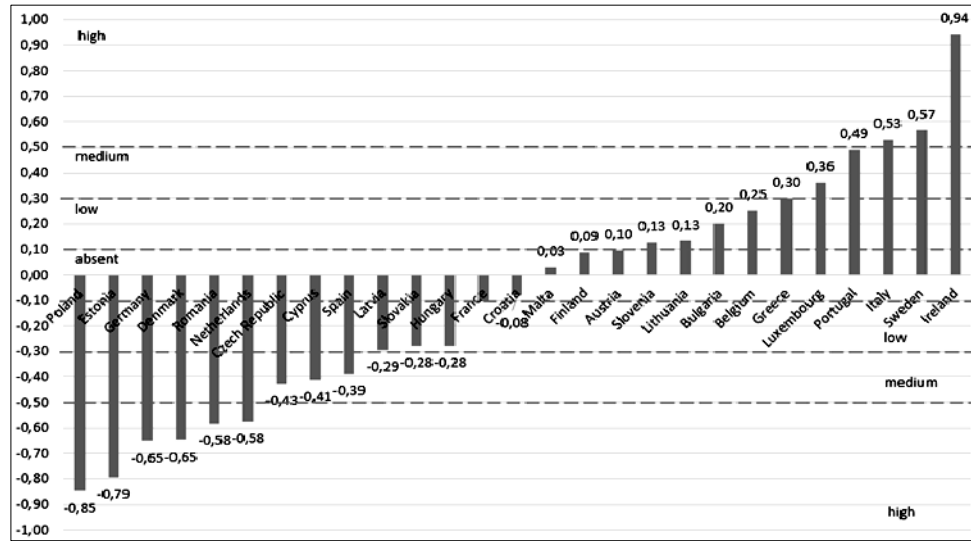


Fig. 8. Correlation coefficient and density of the relationship between the Energy Freedom Index (*Ief*) and the share of imports of Russian energy resources in the structure of their total consumption (*Imrf*) for the UE countries

Based on the results of the analysis, it is possible to group countries on the basis of the relationship between their energy freedom and the share of Russian energy imports as:

- countries with a high and medium density of the inverse relationship between their energy freedom and the share of imports of Russian energy (Poland, Estonia, Germany, Denmark, Romania, the Netherlands, the Czech Republic, Cyprus and Spain);
- countries with a low level of direct and inverse relationship between their energy freedom and the share of imports of Russian energy (Latvia, Slovakia, Hungary, Slovenia, Austria, Belgium, Lithuania);
- countries for which the relationship between their energy freedom and the share of imports of Russian energy has not been established (Croatia, France, Malta, Finland);
- countries with a high and medium density of direct relationship between their energy freedom and the share of imports of Russian energy (Greece, Luxembourg, Portugal, Italy, Sweden and Ireland).

Among the established groups of countries, only the first can show that for these countries, increasing dependence on energy imports from Russia may reduce the level of their energy independence and vice versa. The rest of the groups have either a weak and no correlation between variables, or results that contradict the hypothesis about the nature of the relationship between the energy freedom of countries and energy imports from Russia.

Thus, the correlation analysis does not allow to clearly identify patterns of dependence of countries on energy imports from Russia and to determine which of them are willing to abandon such imports and take measures to reduce this dependence.

Another approach to grouping countries takes into account the risk of refusing to import energy resources. The grouping of countries in the two-dimensional field of parameters – Energy Freedom Index (*Ief*) and the share of imports of Russian energy resources in the structure of total consumption (*Imrf*) – provided an opportunity to distribute countries according to the level of risk. According to the results of grouping for 2020 data (Fig. 9):

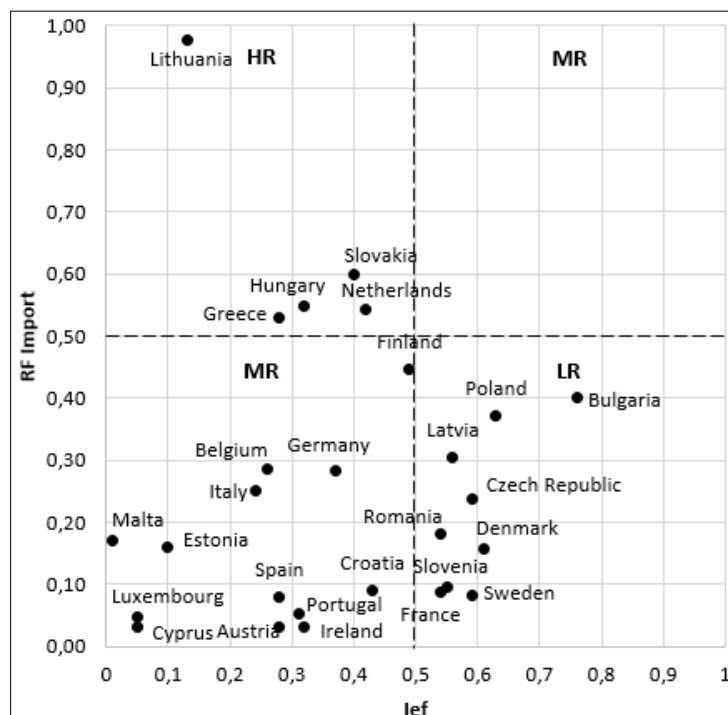


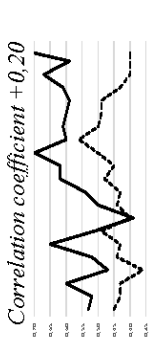
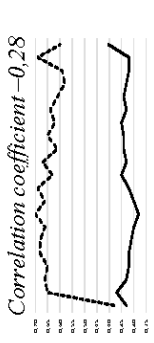
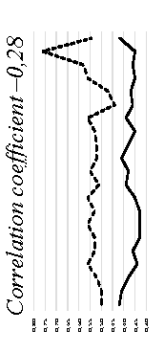
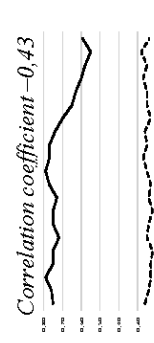
Fig. 9. The grouping of countries in the two-dimensional field of parameters – Energy Freedom Index (I_{ef}) and the share of imports of Russian energy resources in the structure of total consumption (I_{mrf})

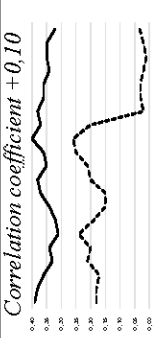
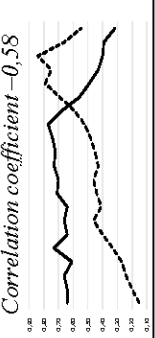
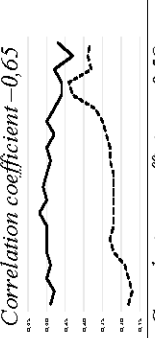
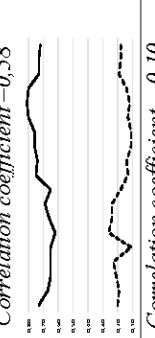

- in the high-risk zone (HR) were countries whose index is below average, and which have more than half of Russian energy resources in the structure of total consumption: $I_{ef} < 0,50$; $I_{mrf} > 0,50$ (Greece, Lithuania, Netherlands, Slovakia, Hungary);
- in the medium-risk zone (MR) were countries whose index is below average, but which have less than half of Russian energy resources in the structure of total consumption: $I_{ef} < 0,50$; $I_{mrf} < 0,50$ (Austria, Belgium, Estonia, Ireland, Spain, Italy, Cyprus, Luxembourg, Malta, Germany, Portugal, Croatia);
- in the low-risk zone (LR) were countries whose index is above average, and which have less than half of Russian energy resources in the structure of total consumption: $I_{ef} > 0,50$; $I_{mrf} < 0,50$ (Bulgaria, Denmark, Latvia, Poland, Romania, Slovenia, France, Czech Republic, Sweden).

Both of the abovementioned approaches to grouping do not take into account the measures taken by the countries to reduce dependence on energy imports from Russia (which in this case oppose risky measures), so they cannot be used to measure final risk and determine their readiness for the embargo. In addition, the country's readiness to implement the proposed EU embargo is largely determined by its political interests. To this end, the countries were analyzed in the context of a set of measures they took to eliminate Russian dependence and preparedness for the embargo.

To date (since the countries are in the process of making final decisions), four groups of countries can be identified (Table 3) according to the degree of their readiness to replace Russian energy sources and impose an embargo:






Table 3. Comparative analysis of European countries by groups of measures to eliminate dependence on Russian energy imports and readiness for embargo

Country	Dynamics of changes I_{ef} (solid line) and I_{mf} (dashed line)	Implemented actions on the embargo	Diversification	Use of clean energy	Reduction of energy intensity	Increasing own production and (or) construction of own LNG terminals
1	2	3	4	5	6	7
<i>Group 1</i>						
Bulgaria		Refusal to renew the contract after the expiration of this year	Agreement with Azerbaijan on increasing gas supplies.			Use of a new pipeline with Greece
Slovakia		Cessation of veto, but focus on embargo relief based on oil-based production from Russia	Searching for a solution			Development of strategies for the introduction of new technologies of other types of oil refining
Hungary		Refusal of the embargo. Ban on the supply of coal from Russia	Searching for a solution			
Czech Republic		Needs an extension or exemption from the oil embargo	Use of Shell's TAL oil pipeline			

1	2	3	4	5	6	7
<i>Group 2</i>						
Austria	 <i>Correlation coefficient +0,10</i>	Cessation of veto, refusal of the oil and gas company OMV to import oil from Russia				Production of shale gas by new methods
Netherlands	 <i>Correlation coefficient -0,58</i>	Cessation of veto, however, the focus on relief from the embargo is based on oil-based production from Russia				Changing oil refining technologies
Germany	 <i>Correlation coefficient -0,65</i>	Significant impact on the economy due to transportation conditions	Energy partnership agreements with Qatar			Use of LNG acceptance terminals from tankers
Romania	 <i>Correlation coefficient -0,58</i>	OMV Petrom's refusal to import oil		Strategic partnership between Romania, Hungary, Slovakia, and Poland on the development of hydrogen networks		Resumption of gas production on the Black Sea shelf
France	 <i>Correlation coefficient -0,10</i>	Readiness for the embargo				Resumption of NPP construction

1	2	3	4	5	6	7
Group 3						
Belgium	<p>Correlation coefficient +0,25</p>	Not interested in the energy embargo				Development of nuclear energy
Italy	<p>Correlation coefficient +0,53</p>	Significant dependence on fossil fuels from Russia, however, the embargo is maintained	Establishing cooperation with Algeria on fossil fuel imports			Cooperation with Spain on planning the construction of the pipeline
Lithuania	<p>Correlation coefficient +0,13</p>	Complete cessation of energy imports from Russia		Development of green energy		Import via LNG terminal in Klaipeda
Poland	<p>Correlation coefficient -0,85</p>	Full support for the embargo, a ban on coal imports, disconnection from gas supplies to Russia				Increasing own production
Finland	<p>Correlation coefficient +0,09</p>	Focus on joining NATO	Gas supply agreement with Estonia		Reduction of natural gas consumption	

1	2	3	4	5	6	7
<i>Group 4</i>						
Greece	Correlation coefficient +0,30 	Support for the embargo				Construction of LNG floating stations
Denmark	Correlation coefficient -0,65 	Support for the embargo		Focus on green energy		Resumption of the Baltic Pipe pipeline project from Norway to Poland
Estonia	Correlation coefficient - 0,79 	Refusal to import until the end of the year				Creation of receiving capacities in ports
Ireland	Correlation coefficient +0,94 	Full support for the abandonment of fossil fuels from Russia		Focus on the use of nuclear, wind and solar energy		
Spain	Correlation coefficient -0,39 	Support for the embargo, use of LNG regasification				Cooperation with Italy on planning the construction of the pipeline
Cyprus	Correlation coefficient -0,41 	Support for the embargo, concerns about declining profitability of shipping	Focus on gas supplies from the eastern Mediterranean			

1	2	3	4	5	6	7
Latvia	Correlation coefficient $-0,29$ 	Support for the embargo	Use of gas reserves. Focus on the use of Lithuanian terminals			
Luxembourg	Correlation coefficient $-0,36$ 	Agreement with the refusal of coal	Neutrality in imports of Russian gas and oil			
Malta	Correlation coefficient $+0,03$ 	Independence from the import of fuel resources from Russia	Focus on diversification of energy sources			
Portugal	Correlation coefficient $+0,49$ 	Support for the embargo		Focus on renewable energy sources		
Slovenia	Correlation coefficient $+0,10$ 	Support for the embargo	Focus on cooperation with Croatia on gas supplies			

- *Group 1* – countries for which the refusal to import fuel resources from Russia threatens the greatest losses in the economy, and which need and may receive a delay in the imposition of embargoes (Hungary, Czech Republic, Slovakia and Bulgaria);
- *Group 2* – countries that are heavily dependent on fuel imports from Russia, and at the beginning of the sixth package of sanctions have some controversy over the imposition of the embargo (Netherlands, Austria, Germany, Romania, France);
- *Group 3* – countries that have significant or moderate dependence on imports of fuel imports from Russia, but support the embargo (Lithuania, Belgium, Italy, Finland, Poland);
- *Group 4* – countries that have low dependence on fuel imports from Russia and support the embargo (Greece, Estonia, Ireland, Spain, Cyprus, Luxembourg, Malta, Portugal, Slovenia, Denmark, Latvia).

Measures envisaged by the strategy of elimination of EU dependence taken by certain countries (anti-risk measures) can be divided into four categories: diversification; use of clean energy; reduction of energy consumption; the increase of own energy production and (or) construction of own LNG terminals.

Group 1 — Bulgaria (LR), Czech Republic (LR), Slovakia (HR), Hungary (HR). This group of countries includes both high-risk and low-risk countries, which have low or not very high dependence on Russian energy imports. As can be seen from Table 3, all countries in this group have already increased their energy independence index in 2020 and reduced the share of Russian fuel imports. The analysis showed that for the countries of this group, the primary measure to reduce dependence is the diversification of fuel suppliers.

Bulgaria has the highest index and declining dynamics of imports from Russia, which is already taking measures to diversify — liquefied gas supplies from the US at lower prices than from Russia, supplies from Azerbaijan, and in the long run - LNG use through terminals in Greece and Turkey [24]. The Czech Republic, with fairly strong reserves of coal, oil and gas, is mainly focused on imports from Russia. The lack of differentiation policy in the past determines the urgent need for its implementation. In particular, the Czech company Mero acquired a stake in Shell's TAL oil pipeline [25]. In addition, the Czech Republic has a significant level of biogas production potential. These countries are quite capable of overcoming the risk that will arise as a result of the energy embargo from Russia.

Slovakia currently has a sufficient level of gas in its storage facilities to meet its needs, but it is completely dependent on oil imports from Russia due to the technological features of refineries. Hungary is heavily dependent on Russian fuel, especially oil, and has a low level of supply diversification. Receiving Russian gas in transit through Bulgaria, under the threat of its suspension, the country needs new sources of supply and changes in energy policy. However, for Hungary and Slovakia, the search for alternatives to Russian imports is a long one, and cannot be implemented quickly.

Group 2 — Netherlands (HR), Austria (MR), Germany (MR), Romania (LR), France (KR). This group includes countries with high, medium and low risk — those that at the beginning of the sixth package of EU sanctions had controversy over the imposition of embargo. In the countries of this group there is an inverse relationship between the increase in the level of Energy Freedom Index and the share of fuel imports from Russia in domestic consumption.

At the same time, the Energy Freedom Index in 2020 increased only in Germany and France, while in other countries it decreased. In Austria, when the share of fuel imports from Russia in domestic consumption decreased, the level of the Energy Freedom Index also decreased. This shows that the country's energy dependence is moderate. Austria has long had Kazakhstan, Libya and Iran as key oil suppliers, but high dependence on gas has caused the country to hesitate in deciding on an embargo. Germany, which has a developed industry, needs much more energy than it produces. The supply of fuel resources is limited by pipelines, which complicates the diversification process. The country is considering the supply of liquefied natural gas from Qatar, which will allow the gradual abandonment of Russian gas, for this purpose will be used terminals to receive gas from tankers. The partnership agreed with Qatar includes not only LNG supplies, but also the development of renewable energy sources, as well as energy efficiency measures [26]. Romania's measures are aimed at the development of foreign economic activity and gas production from the Black Sea shelf. However, these projects are long. The Netherlands is currently unable to completely cut off all fossil fuel supplies from Russia, but is refusing to transport it, and the country is focused on import diversification. To this end, floating regasification plants (LNG terminal) are being leased for future LNG gas uptake in Emshaven, Groningen [27]. France receives about 70% of its electricity from nuclear energy. The country has abandoned its previous government's policy of reducing the share of nuclear generation, and this year announced plans to build six new reactors and consider building eight more. This provides the country with a high level of energy security. Thus, the countries of this group have the opportunity to replace imported fossil fuels from Russia, so an embargo is possible. The threat of loss of energy independence that could occur in the event of further dependence on Russia can be eliminated (as shown in Table 3).

Group 3 — Lithuania (HR), Belgium (MR), Italy (MR), Finland (MR), Poland (LR). This group of countries includes high, medium and low risk countries - those that have supported or expressed the readiness to impose an embargo. With the exception of Lithuania, the countries of this group have a low level of dependence on Russian fossil fuels. The defining feature of the countries of this group is the growth of the Energy Freedom Index and the decline in the share of fuel imports from Russia in domestic consumption, which indicates an intensification of efforts in these areas. Poland is actively looking for opportunities to diversify supplies and increase its own production. With an expanded LNG terminal, the country is stepping up the commissioning of the Baltic Pipeline, which will provide it with gas connections with Lithuania and Slovakia [28]. Italy is focusing on diversification and finding new suppliers, and Algeria is currently being considered as such. In addition, the possibility of building a pipeline to supply gas from Spain is being discussed. Belgium has a strong nuclear power industry but is an importer of fuel resources. Although a fairly high proportion of them imported from Russia, the country has taken steps to diversify its sources of supply, importing oil from Iran and Saudi Arabia and gas from Qatar, the Netherlands and Norway. Lithuania's economy is heavily dependent on Russian fuel imports, but the country was one of the first to abandon it. Currently, the country is focused on imports through the LNG terminal in Klaipeda from other suppliers and the development of green energy. Finland is focusing on new gas import agreements, including an agreement with Estonia. A characteristic feature of Group 3 countries is the low level of LNG use.

Group 4 — Greece (HR), Estonia (MR), Ireland (MR), Spain (MR), Cyprus (MR), Luxembourg (MR), Malta (MR), Portugal (MR), Slovenia (MR), Denmark (MR), Latvia (MR). This group of countries includes countries with high, medium and low risk - those that have low dependence on imports of fuel resources from Russia and support the embargo, because they risk the least. The level of their energy independence is determined mainly by other factors. With the exception of Denmark, Estonia and Ireland, all countries in the group have seen an increase in the Energy Freedom Index in recent years. Latvia, which transported gas from Russia, is now relying on the supply of liquefied gas through the Klaipėdos Nafta terminal [29] and is stepping up its green energy policy. Luxembourg has the ability to quickly give up Russian coal but needs oil and gas. The Slovenian government, although it has not given up on Russian fuel, has expressed its readiness to support EU actions in this direction. The country is now focusing on obtaining liquefied natural gas from a terminal in Croatia. Estonia had a high level of gas supplies from Russia, but decided on a strategy of diversification, in particular, the ports will be set up to receive liquefied natural gas. Spain was still the largest importer of LNG from the United States — in 2021 its share rose to 65% [6; 8]. Almost all of Ireland's imports are to the UK, the country focuses on the development of renewable energy sources. Countries such as Cyprus, Greece, and Malta are located in warm natural climates, fossil fuels are used only for industrial purposes. However, the key industry of these countries is shipping, they are engaged in the transportation of oil by sea, and in the embargo see a certain threat of loss of traffic [30]. Greece is focused on the construction of new LNG floating stations. To this end, a project has been launched to build a floating liquefied natural gas terminal in Alexandroupolis [31]. The terminal is scheduled to be completed by the end of 2023, which will identify Greece as the center of EU gas reserves.

Risks and losses of Ukraine's energy as a result of the military invasion of the Russian Federation

In 2019, the Energy Freedom Index of Ukraine was 0,70 and ranked 49th out of 142 countries in the overall ranking [2]. Among the EU countries, only Romania and Denmark were ahead of it.

It should be noted that in 2020 Ukraine's Energy Freedom Index increased by 10% to 0,77 and the overall Ief and energy potential subindex surpassed all EU countries, and the energy balance subindex ranked 3rd. The high energy potential and the general trend of growing energy independence allowed Ukraine to develop an export-oriented energy policy. It had every prospect of becoming a competitive and full-fledged player in the European energy market.

At the same time, Ukraine depends on oil imports by about 83%, 33% on natural gas imports, and 50% on coal imports [32]. This situation is due to the lack of incentives for the development of own energy production, significant depletion of explored fields, and constant changes in government regulation on the rent for hydrocarbon production. Over the past few years, the state has paid more attention to eliminating dependence on gas imports. Therefore, in 2021, imports of oil and petroleum products from Belarus to Ukraine exceeded 2,86 billion dollars, and imports of these resources from Russia amounted to about 3,43 billion dollars [33].

Even before the beginning of the military aggression on February 24, 2022, Ukraine was actively implementing measures to reduce energy dependence on Russia. Such measures have received additional support from other countries. Thus, Energoatom and all its stations were transferred to the Paris Center of the World Association of Nuclear Operators (until now, Ukrainian nuclear power plants were part of the Moscow center WANO). All operating nuclear power plants are operating stably, despite losses. It was planned to build a storage facility for spent nuclear fuel. Ukraine has refused to purchase Russian nuclear fuel. Currently, fuel reserves for WWER-1000 reactors will be enough for two years. During this period, it is planned to equip one of the Ukrainian enterprises with a production line for assembling Westinghouse fuel assemblies.

The Ukrainian power system has finally disconnected from the power systems of Russia and Belarus and joined the European Network of Transmission System Operators for Electricity (ENTSO-E). Accession provides a bilateral advantage: on the one hand, it is an opportunity for European business to work in the energy market of Ukraine, on the other — the development of the European energy market by domestic companies.

Military action has halted the active development of renewable energy that has been observed in Ukraine in recent years. Solar energy suffers the most due to the large area of damaged industrial solar generation facilities. Thus, according to various estimates, 30–40% of solar power plants in the regions affected by the Russian invasion were affected (1120–1500 MW of installed capacity). More than two thirds of all wind power plants have been shut down. 10–15% of the installed capacity of bioenergy facilities was affected [34].

Gas imports from Europe are uninterrupted, in March 2022 the volume of imports amounted to 10 million cubic meters per day. Hungary provides the maximum volume of Ukraine daily imports (about 4,5 million cubic meters per day) [35]. The GTS operators of Slovakia and Poland also provided additional guaranteed capacity for gas imports to Ukraine.

Ukraine is also currently undergoing changes in the market for imports of oil and oil products, where Russia and Belarus used to be key suppliers. The search for new suppliers and the damage caused by hostilities at the largest domestic refineries, Kremenchuk and Shebelynsky, provoked a shortage in the market and a significant increase in product prices.

The outlined measures will increase the level of Ukraine's energy independence, as well as ensure full participation in the European electricity market in the postwar period. However, repairing the damage will require global financial support.

CONCLUSIONS

1. Analysis of the energy independence of the European Union, after the Russian military intervention in Ukraine, showed significant negative consequences. Unflexible and multi-vector energy policy of industrialized EU countries, and their underutilization of energy potential, including the development of renewable energy, and low energy balance have led to import dependence on one energy supplier, and limited opportunities to use their own energy sources. The consequence of such an imbalance is the economic dependence of countries with developed economies on the Russian Federation, which has a predominantly raw-materials-based economy.

2. For a long time, European countries have been increasing their dependence on Russia's fuel resources through slow implementation of reforms, differentiation of suppliers, and development of energy infrastructure, considering it economically feasible to use existing exporters and traditional transit infrastructure. The energy crisis of 2021 revealed the following problems of Europe's energy system:

- limited gas transportation capacity;
- inadequate geographical location or insufficient length of existing gas pipelines in the EU;
- lack of LNG terminals and seaports in some countries;
- failure of the existing level of developing renewable energy to meet energy needs.

3. In such circumstances, the implementation of the strategy of energy independence of European countries from the Russian Federation should focus on two basic areas:

- diversification of supplies;
- accelerated transition to the production and use of clean energy.

Studies have shown that both directions have significant limitations and could lead to a complete abandonment of Russian energy at best in 2030, which significantly complicates the imposition of a full embargo on energy imports from this country until 2030.

4. An alternative to a full embargo could be a sharp reduction in energy imports, imposing a 40% tariff on it, which would reduce imports by about 80%. This will reduce economic losses for the countries, which are most dependent on Russian energy. The economic effect of changing energy supply strategies for European countries will depend on the replacement and redistribution of energy between sectors.

5. The study of the level of energy independence of European countries provided an opportunity to identify four key groups of countries on this indicator:

- with a high level of energy independence and a low level of risk of its loss;
- with a sufficient level of energy independence and an acceptable level of risk of its loss;
- with an acceptable level of energy independence and an increased level of risk of its loss;
- with a low level of energy independence and a high level of risk of losing it.

The analysis showed that in the first and second groups of countries, there are those who have an increased risk of losing energy independence due to the embargo on energy from Russia. These risks must be minimized through the introduction and implementation of planned EU measures aimed at diversifying supplies and accelerating the transition to the production and use of clean energy.

6. Russia's full-scale military invasion of Ukraine has led to the irreparable destruction and destabilization of the country's energy system, which was previously closely integrated with the respective systems of Russia and Belarus. As a result of hostilities, the largest domestic refineries, Kremenchuk and Shebelynsky, were damaged. There were destabilized energy supply chains from Europe, which led to a significant deficit in the energy market and a significant increase in product prices. In response to all the devastating phenomena since February 24, 2022, Ukraine has joined the ENTSO-E integrated power system of continental Europe, disconnected from the energy systems of Russia and Belarus, and established supply chains for oil products from Europe. Despite the fighting and the capture

of the largest Zaporizhzhya nuclear power plant in Europe by Russian troops, Ukraine's energy system has been operating smoothly throughout the Russian aggression. These measures are gradually increasing the level of Ukraine's energy independence and should ensure its full participation in the European market in the postwar period. However, repairing large-scale damage will require global political and financial support.

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АНАЛІЗ ВПЛИВУ ВІЙСЬКОВОГО ВТОРГНЕННЯ РОСІЇ В УКРАЇНУ НА ЕНЕРГЕТИЧНУ НЕЗАЛЕЖНІСТЬ КРАЇН ЄВРОПИ / М.З. Згуровський, М.О. Кравченко, К.О. Бояринова, О.І. Іляш, К.О. Копішинська, І.О. Пишнограєв

Анотація. Подано аналіз проблем енергетичної незалежності та енергопостачання країн Європи з огляду на вплив повномасштабного воєнного вторгнення Росії в Україну. Наведений аналіз ґрунтується на розробленому авторами Індексі енергетичної незалежності (Energy Freedom Index – *Ief*), який агрегує субіндекси енергетичного потенціалу, енергетичного балансу та розвитку енергетики. Сформовано рейтинг 142 країн світу за значенням вказаного індексу та визначено місця країн Європейського Союзу і України у цьому рейтингу. Проаналізовано заходи, спрямовані на підвищення рівня енергетичної незалежності європейських країн та України. До головних заходів віднесено: диверсифікація постачань та прискорений перехід на чисту енергетику. Проведено кластеризацію країн Європи за рівнем утрат в економіці та безпеці внаслідок ембарго на російські енергоносії. Виділено чотири групи країн за ступенем їх готовності до заміни російських енергоносіїв та запровадження ембарго. Проаналізовано динаміку показників індексу енергетичної незалежності, їх залежності від російського імпорту та запропоновано заходи для зменшення цієї залежності.

Ключові слова: енергетична незалежність, індекс енергетичної незалежності, повномасштабне вторгнення Росії в Україну, залежність від російського викопного палива.