



GENERAL PROBLEMS OF THE MODERN RESEARCH AND INNOVATION POLICY

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ASSESSMENT OF THE FUEL SECURITY OF THE EUROPEAN COUNTRIES AND THE THREAT OF UKRAINE'S FALL INTO THE TRAP OF FUEL DEPENDENCE

Introduction. Fuel security is critical for the stability of every country. Advanced oil-deficit economies pay considerable attention to fuel security by developing motor fuel production.

Problem Statement. Because of the declining petroleum production and refining and limited opportunities to import petroleum and motor fuels, Ukraine has gradually turned into a country with a critically low fuel security.

Purpose. The purpose is to determine the level of fuel security of European countries and Ukraine based on the methodological approach that involves the calculation of local fuel security indicators by components and levels.

Materials and Methods. The information source of the study is Eurostat database. Using large-scale modeling of big-data in Microsoft Power BI software, we have made an integrated assessment of fuel security of European countries in the regional space and its dynamics.

Results. It has been determined that among European countries, those that produce crude hydrocarbons sustainably and develop petroleum refinery through low-concentration imports of raw materials have strong positions in terms of fuel security in the general European fuel security rating, in particular, Norway (77%), Spain (48%), and Lithuania (47%). The level of Ukraine's fuel security fell from 35% (13th place in the ranking based on the assessment results), in 2001, to 31% (24th place in the ranking), in 2021. The destruction of production facilities as a result of Russian aggression has resulted in its drop almost to zero. It has been proved that strengthening Ukraine's fuel security by restoring production from crude hydrocarbons is impossible because of the decline in their production and limited import opportunities.

Conclusions. The research proposes a methodological approach to assessing the country's fuel security based on the four security components: accessibility, availability, acceptability, and affordability. This makes it possible

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to determine it by the levels of primary, final, and overall fuel security. The solution to this problem has been proposed by developing the production of synthetic motor fuel from coal. The results can be used in revising the Energy Strategy of Ukraine.

Keywords: fuel security, petroleum refinery, crude hydrocarbons, synthetic motor fuel, and dependency trap.

Formulating the energy security problem as a separate field of research and development is directly related to the oil crisis of 1973, when for the first time the Arab countries embargoed petroleum supplies to Europe and the USA [1–3]. From that time until today, this issue is in the center of attention of both researchers [4–7] and international organizations [8–10]. Currently, out of over 46,000 publications indexed in the Web of Science database, more than 7,000 publications deal with energy security [11]. The philosophical analysis of the essence of the energy security concept has allowed the authors [12] to give the following empirical definition, “the state of the energy system that ensures its existence and development, guarantees the satisfaction of the energy interests of its elements, as well as the actions aimed at its achievement”. Our study is based on this definition.

Against the background of the energy crisis caused by Russia’s invasion of Ukraine, ensuring energy and fuel security has come to the forefront of the economic and political agenda in Europe. Different energy needs determine different areas of assessing fuel security that is considered, in particular, by the area of production and use of motor fuel: from the extraction of crude hydrocarbons to the consumption of finished motor fuel. This issue, due to its relevance, has been taking an important place in scholarly research for many years. In 1993–2023, the Web of Science database indexed 6,854 publications in the field of fuel security, with a noticeable increase in the number of publications on since 2006 [11]. In 2023, researchers focused their particular attention towards dependence on Russia. In particular, in [13] the authors stated that the Organization of the Petroleum Exporting Countries (OPEC) used petroleum as a weapon against Western countries who supported Israel in the Yom Kippur War of 1973. In 2021, Russia used a similar strategy, proving that energy was a

weapon to pressure sovereign states. The authors of [14] have concluded that European countries should get rid of dependence on Russian oil and gas in the long term.

Ukraine inherited from the USSR a well-developed motor fuel production sector that consisted of 6 petroleum refineries and 1 gas processing plant. In 2000–2021, this sector suffered a devastating destruction: the production of motor fuel at 4 large enterprises was suspended. As a result, the production of motor fuel decreased by 85%, in 2021, as compared with 2005. At the same time, the production of crude liquid hydrocarbons (petroleum and gas condensate) in Ukraine dropped rapidly, both because of the depletion of active deposits in the conditions of limited and difficult access to explored oil potential and because of the occupation of part of the territories of the Black Sea-Crimean and Dnipro-Donetsk petroleum and gas-bearing regions. In 2021, the total production of liquid hydrocarbons amounted to 2.4 million tons, which was 36% less than in 2000. The destruction of the last operating capacities as a result of Russian attacks on petroleum refineries has reduced its level to almost zero, turning Ukraine into a net importer of motor fuel, which has no resource cycle of its production. Unless this extremely negative situation changes, Ukraine will not be able to ensure its fuel/energy and national security.

The above proves the high relevance and objective necessity of researching fuel security issues both for Europe as a whole and for Ukraine in particular. In today’s conditions, it is necessary to identify the most pressing problems in this area and the ways to solve them in order to prevent Ukraine from falling into the trap of fuel dependence.

The diversity of research on energy security has determined the diversity of approaches to its assessment by components and local indicators. In

this study, special attention has been paid to the 4A concept for long-term security of energy supply, which was proposed in 2007 [15]. It is based on such security components as: availability (geological component), affordability (economic component), acceptability (geopolitical component), and accessibility (ecological and social component). Although this approach has become one of the fundamentals in energy security research, there is confusion about the content of these components. Some researchers take into account all 4 components [16], while others consider only individual ones [17, 18] or expand their composition when building their own energy security indicator [19].

Thus, the authors [16] have singled out its 16 local indicators, some of which generally refer to the entire energy sector, while others directly refer to the petroleum sector, without dividing it by chains of the resource cycle. Separately, they add an indicator of political stability. Also, the authors of [20] have suggested evaluating energy security by 4 components, with 13 indicators, combining the qualitative metrics of the fuel and energy balance (9 indicators) with the petroleum sector (3 indicators) and economic development (1 indicator). Such approaches reflect the subjective opinion of the authors on the content of the energy security indicator, rather than fuel security.

Having analyzed the 4A concept, the authors [17] concluded that it should provide answers to the 3 basic questions: who should be secured; which values should be secured; what are the threats against which security is necessary. They have noted that in most cases, these components are not clearly disclosed in the studies. Such ambiguity arises from the authors because they do not clearly separate these issues by security components.

The researchers [18] have taken into account only the 3 components: availability, affordability, and acceptability, trying to develop a universal approach to the assessment of energy security, which would be suitable for each energy system. They have considered energy security from the standpoint of a process approach, highlighting refining, transportation, and storage. Such an ap-

proach is considered objective for a general understanding of energy security issues, it does not take into account the specifics of individual spheres of the energy industry, which does not allow a clear interpretation of risks and resilience for each of them.

The author of [19] has singled out 20 security components, among which there are only 3 components that correspond to the 4A concept: affordability, accessibility, and availability. This approach is one of the most thorough for understanding energy security in general, but one of the most difficult for modeling, including in the fields of energy management, dynamics, and regional space.

In [21], the 4 components of energy security have been studied in terms of 24 local indicators in order to build a general index of energy security, given the economic and political components of energy sector management. However, the proposed approach significantly complicates building the energy security index, making its assessment generalized and subjective.

The researchers [22] have supposed that such components as availability and accessibility constitute a classical approach to energy security, while affordability and acceptability are associated with modern environmental problems such as climate change, socio-political problems, and fuel poverty. They have noted that the 4A concept is insufficient for a comprehensive definition of energy security and add to it the components of technological development, management, and unconventional threats. Thus, their perception of energy security is related to the provision of sustainable development, rather than to the classical understanding of energy security as risks and resiliencies with respect to energy supply failures, as stated in [8].

The author of [23] has defined the modern concept of energy security from the 7 basic components: accessibility, affordability, environmental impact, social impact, geopolitical relations, government efficiency, and technological development. Thus, the study combines the 4A concept with other components of economic and national security.

In [24], while considering the 4A concept of energy security, the authors have suggested replacing the availability component with applicability. They have developed an approach to assessing national energy security based on 19 indicators that combine different areas of the energy industry, among which only 2 indicators relate to the petroleum sector.

Having analyzed the security components, the authors of [25] decided to replace the “availability” component with “accountability”. However, the content of this component in their understanding includes both the replaced component and accessibility.

The conventional approach to the study of energy security has been presented in [26]. It takes into consideration 4 components of energy security. The authors propose 21 energy security indicators. However, the main attention in this approach is paid to electric energy, while the petroleum sphere is represented by only 1 indicator that is petroleum import.

Therefore, there remains the problem of the confusion of security components and their relation to local indicators. The concepts being so close to each other, therefore first we use the Cambridge Dictionary [27] to get the definition of each component:

- ◆ availability means the quality or state of being easily reached or obtained;
- ◆ accessibility means the quality or state of being bought, used or obtained as far as possible;
- ◆ acceptability means the quality or state of being satisfactory and acceptable or agreeable;
- ◆ affordability means the quality or state of having a cost that is not too high.

Thus, these components sequentially and inter-relatedly explore the chains of different systems by sequentially connecting with each other. Given this, due to its logic, reasonableness and conventional simplicity in terms of perception and application, it is the 4A concept that is considered appropriate by the authors for the study of fuel security.

Another component of the problem of energy security research is its generalized or hybrid as-

essment in various spheres of the energy industry. In this study, we have determined only a separate component of it, which is the resource cycle of motor fuel from the extraction of primary hydrocarbons to the production of motor fuel. Other areas should be researched and estimated separately and thereafter integrated into the overall energy security indicator.

The purpose of the study is to assess the fuel security of European countries and Ukraine, based on the methodical approach that involves the calculation of local indicators of fuel security by components and levels. This provides an opportunity to determine the state of fuel security of countries in the regional space and Ukraine, in particular, to identify the risks for Ukraine and ways to prevent it from falling into the trap of fuel dependence.

The main research hypotheses are as follows:

- 1) advanced oil-deficit economies of Europe pay considerable attention to the development of domestic production of motor fuel;
- 2) Ukraine’s fuel security is at a critically low level due to the rash steps in the industrial policy regarding the development of this sector;
- 3) the potential for strengthening Ukraine’s fuel security should be sought among unconventional ways of developing motor fuel production in Ukraine.

The research on fuel security is proposed to be based on the resource cycle of motor fuel, which includes chains from the production of crude liquid hydrocarbons to the consumption of finished liquid motor fuel (Fig. 1).

The information base of the research is Eurostat data for 2000–2021 [29]. The use of Microsoft Power BI software (USA) [30] makes it possible to assess fuel security based on large-scale modeling of large data sets in regional space and dynamics.

The 4A concept components enable assessing fuel security in terms of security components and levels of the resource cycle of motor fuel (Fig. 2).

The calculations of some proposed local indicators of fuel security by components are given in Table 1.

The individual components of fuel security in this study have been calculated according to the minimum-maximum method [28], given the equal importance of each, which corresponds to the system approach [12].

The first chain of the fuel cycle is natural reserves, i.e. deposits of crude oil and natural gas liquids. The assessment of the security component by this chain is reduced to the assessment of accessibility of natural reserves of crude hydro-

Table 1. The Local Indicators of Fuel Security by the Components and the Specific Features of Their Calculation

Indicator	Formula for calculation
Accessibility of crude hydrocarbons for indigenous production, years (AC_{IP})	$AC_{IP} = \frac{NR_{O\&NGLs}}{IP_{O\&NGLs}},$ <p>where $NR_{O\&NGLs}$ is the proven natural reserves of crude oil and natural gas liquids, thousand tons; $IP_{O\&NGLs}$ is the indigenous production of crude oil and natural gas liquids, thousand tons</p>
Accessibility of crude hydrocarbons for petroleum refining, years (AC_R)	$AC_R = \frac{NR_{O\&NGLs}}{TI_{O\&NGLs}},$ <p>where $TI_{O\&NGLs}$ is the transformation inputs of crude oil and natural gas liquids by the petroleum refining complex, thousand tons</p>
Availability of crude hydrocarbons for petroleum refining, % (AV_R)	$AV_R = \frac{IP_{O\&NGLs}}{TI_{O\&NGLs}} \cdot 100\%$
Availability of motor fuel for final consumption, % (AV_{FC})	$AV_{FC} = \frac{TO_{MF}}{FC_{MF}} \cdot 100\%,$ <p>where TO_{MF} is the production of motor fuel (total of gasoline, diesel fuel, liquefied petroleum gas), thousand tons; FC_{MF} is the final consumption of motor fuel, thousand tons</p>
Acceptability of crude oil in raw materials for petroleum refining, % (ACC_O)	$ACC_O = \frac{TI_O}{TI_{CH}} \cdot 100\%,$ <p>where TI_O is the transformation input of crude oil by petroleum refineries, thousand tons; TI_{CH} is the total transformation input of crude hydrocarbons, thousand tons</p>
Acceptability of motor fuel in the output of petroleum refining, % (ACC_{MF})	$ACC_{MF} = \frac{TO_{MF}}{TI_{O\&NGLs}} \cdot 100\%$
Affordability of crude hydrocarbons import, % (AF_{CH})	$AF_{CH} = \frac{I_{O\&NGLs} - E_{O\&NGLs}}{TI_{O\&NGLs}} \cdot HHI_{O\&NGLs} \cdot 100\%,$ <p>where $I_{O\&NGLs}$ is the import of crude oil and natural gas liquids, thousand tons; $E_{O\&NGLs}$ is the export of crude oil and natural gas liquids, thousand tons; $HHI_{O\&NGLs}$ is the Herfindahl-Hirschman index of crude oil and natural gas liquid import</p>
Affordability of motor fuel import, % (AF_{MF})	$AF_{MF} = \frac{I_{MF} - E_{MF}}{FC_{MF}} \cdot HHI_{MF} \cdot 100\%,$ <p>where I_{MF} is the motor fuel import, thousand tons; E_{MF} is the motor fuel export, thousand tons; HHI_{MF} is the Herfindahl-Hirschman index for motor fuel import</p>

Source: prepared by the authors.

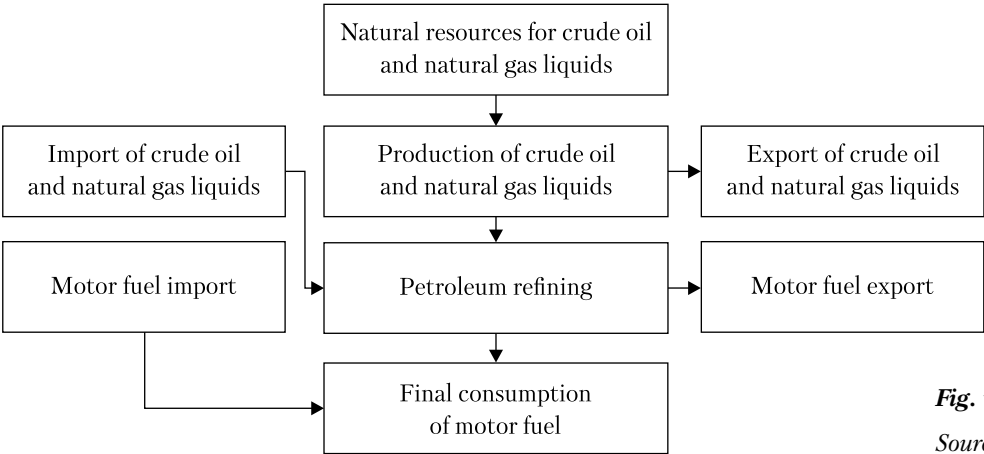


Fig. 1. Motor fuel resource cycle
Source: prepared by the authors.

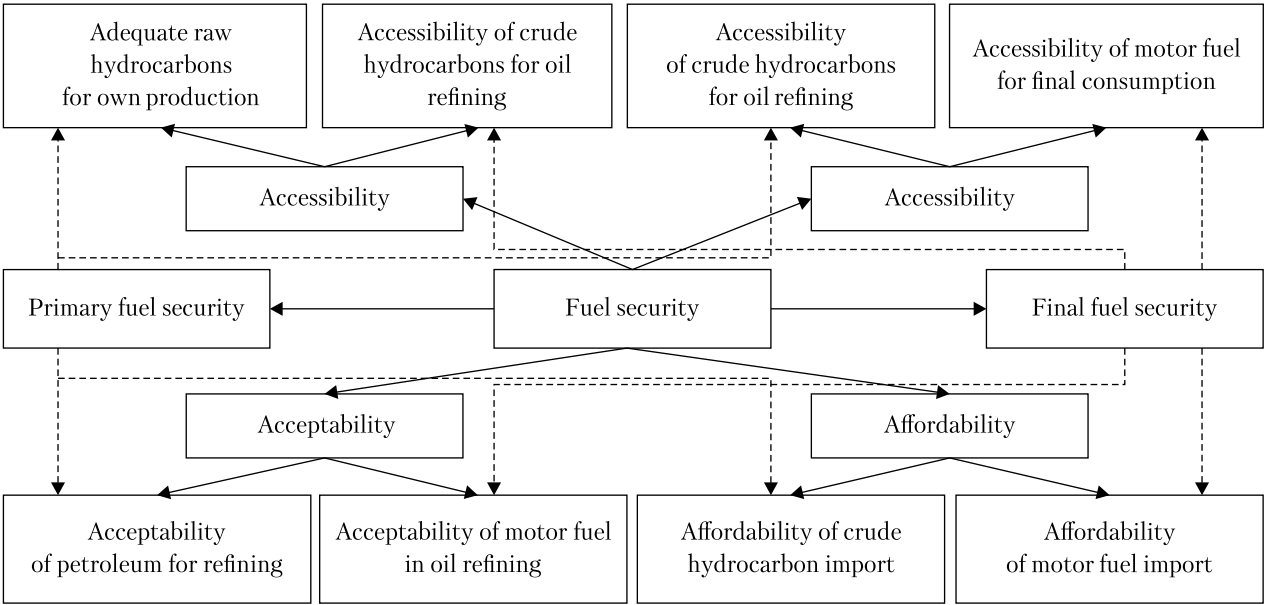


Fig. 2. Conceptual scheme of fuel security assessment
Source: prepared by the authors.

carbons for indigenous production and refinery inputs. This makes it possible to determine the natural potential of each country, to follow its qualitative dynamics and to distribute countries according to their contribution in the regional space. Figure 3 presents the comparative dynamics of the accessibility of crude hydrocarbon reserves in Ukraine and the EU in 2000–2021.

On average, in the EU, the accessibility of natural reserves for production was 29 years in 2021, but these reserves would be enough for as few as 1 year to fully cover the needs of the petroleum refining industry. As compared with 2000, the accessibility of reserves for extraction in the EU increased by 17 years, but for refining, as before, they remained at an extremely low level. There-

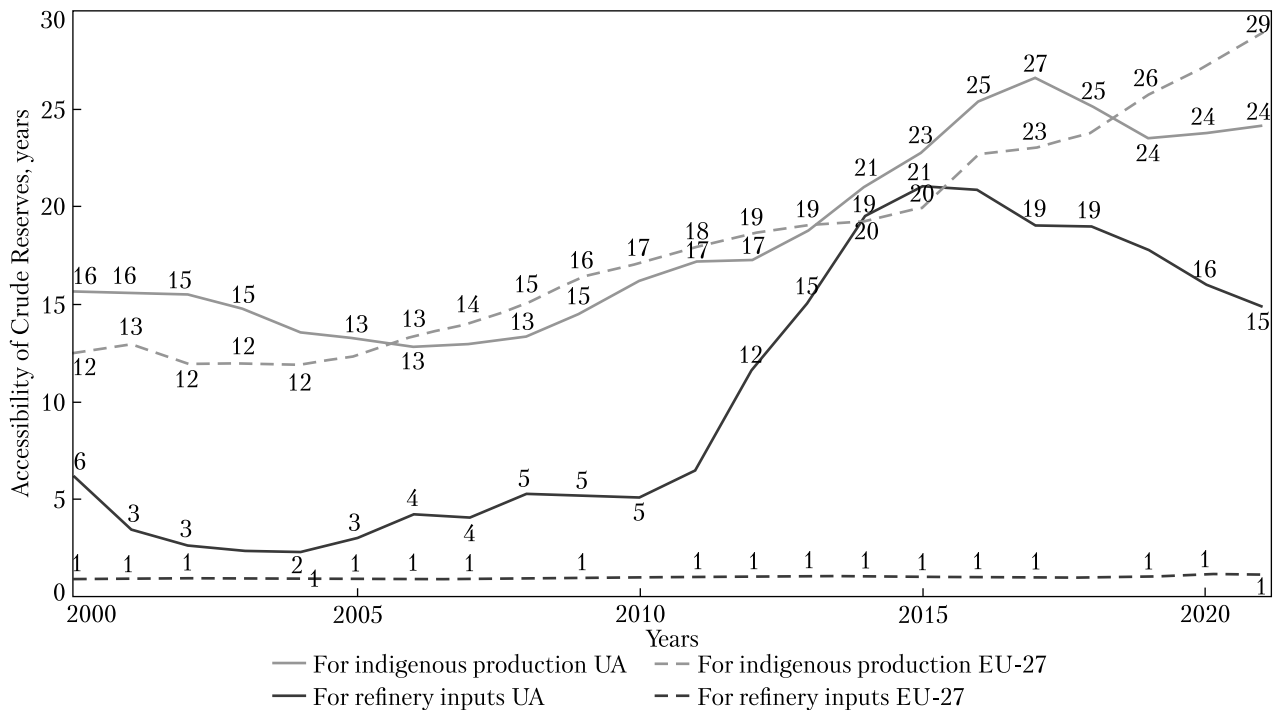


Fig. 3. Dynamics of accessibility of crude hydrocarbons reserves in Ukraine and the EU in 2000–2021

Source: calculated by the authors based on Eurostat data [30].

fore, having small deposits of liquid hydrocarbons, the EU intensively reduced their production, while maintaining the appropriate level of refining of crude hydrocarbons.

Ukraine had a relatively weaker position in terms of the accessibility of natural reserves for extraction as compared with the EU. They amounted to 24 years, in 2021, with the volume of crude oil and natural gas liquids production reaching 2.4 million tons. The active Ukrainian deposits are depleted and flooded, which has complicated their development and caused a drop in production. The accessibility of reserves for production in Ukraine increased by 6 years, in 2000–2021. The accessibility of natural reserves for petroleum refining depended on the stability of the operation of industrial enterprises in Ukraine. In 2004, the crude oil and natural gas liquids consumption amounted to 25.5 million tons. Under the conditions of a complete reorientation to Ukrainian raw materials, these reserves would be

enough for as few as 2 years. However, the gradual closure of enterprises of certain types of activities led to a drop in the consumption of crude hydrocarbons to 3.8 million tons annually, in 2021. Under such conditions, the reserves will be sufficient for 15 years. That is, as compared with the EU, Ukraine had a weaker position in terms of the accessibility of reserves for extraction, but stronger in terms of the accessibility of reserves for petroleum refining. However, the causes of the latter were negative and related to the deindustrialization of the Ukrainian economy.

The largest accessible reserves of crude hydrocarbons for production were reported in Spain, as it intensively reduced the development of small deposits. However, these reserves were clearly not enough to meet the needs of petroleum refining. Norway had the most significant reserves for petroleum refining, which it extensively mined, which made these reserves insufficient in terms of production. Croatia and Greece had rather large

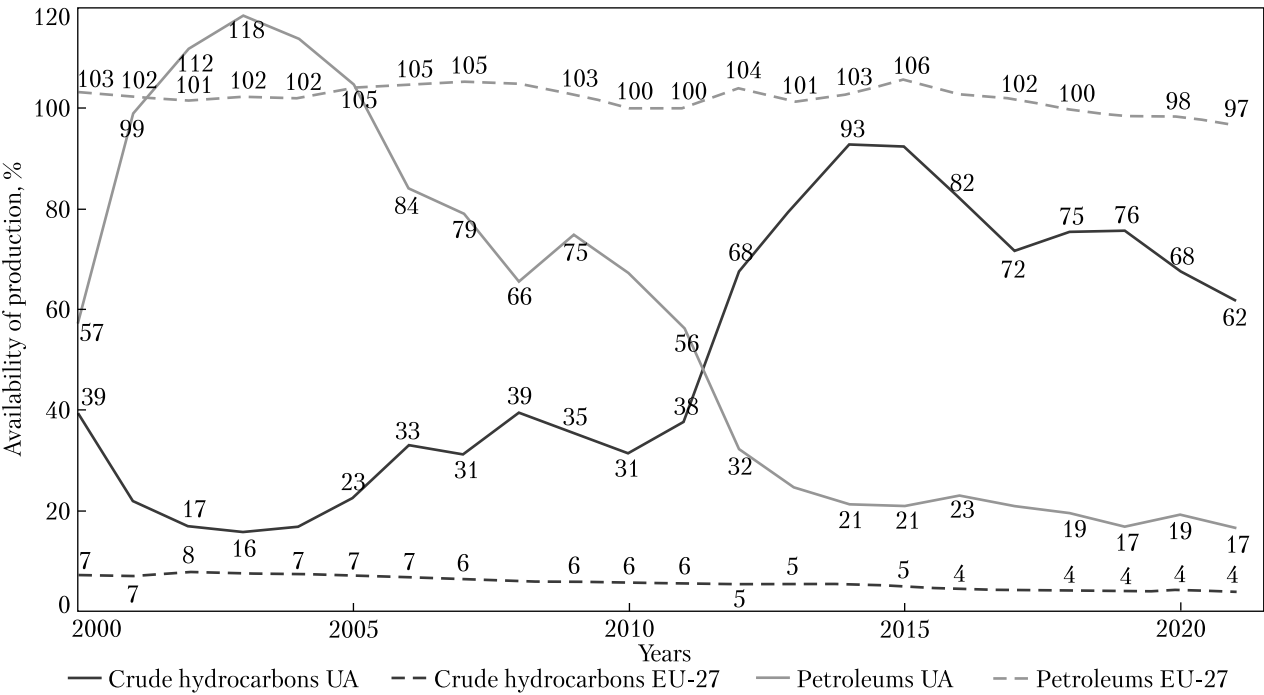


Fig. 4. Dynamics of availability of crude hydrocarbons and motor fuel in Ukraine and in the EU, in 2000–2021

Source: generalized by the authors based on Eurostat data [29].

reserves for production, but these reserves were not enough for the needs of petroleum refining. The rest of the European countries could be considered oil-deficient in terms of natural reserves of crude oil and natural gas liquids, since the accessibility of reserves for petroleum refining did not exceed 5 years. Ukraine in the European space had a fairly strong position in terms of the accessibility of reserves both for production and for petroleum refining needs. However, this level was reached due to a drop both in indigenous production of crude hydrocarbons and in petroleum refining.

Thus, in terms of the 1st security component (accessibility of natural reserves), Ukraine in the European space took a rather strong position. It had moderate deposits of crude oil and natural gas liquids and did not develop its own petroleum refining.

The second security component is related to the conversion of natural resources into final products, i.e. petroleum refining. It is proposed to

evaluate it based on the availability of indigenous production of crude hydrocarbons for petroleum refining and availability of petroleum refining for final consumption. Figure 4 presents the dynamics of petroleum refining availability in Ukraine and the EU, in 2000–2021.

According to Fig. 4, the availability of crude oil and natural gas liquids for petroleum refining in the EU was at a low level. In addition, it decreased from 7%, in 2000, to 4%, in 2021, in particular, from 7% to 4%, for crude oil, and from 59% to 16%, for natural gas liquids. At the same time, the petroleum refining for the final consumption of motor fuel in the EU was always at a high level, and as recently as in 2020–2021, it has fell under 100%.

In Ukraine, as a result of the drop in petroleum refining, the availability of crude hydrocarbons for petroleum refining, on the contrary, increased. The lowest level of availability for indigenous production at the level of 16–17% was reported during the national petroleum refining industry

renaissance in 2003–2005 when all 6 large enterprises of the sector were operating in Ukraine. This indicator reached its peak in 2012–2014 and amounted to 68–93%, as a result of the shutdown of a number of enterprises in the industry and the reduction of petroleum refining volumes by others. After 2015, there was a reduction in the availability of crude oil and natural gas liquids for petroleum refining from 92%, in 2015, to 62%, in 2021. This reduction was caused, among others, by the fact that Ukraine lost access to crude hydrocarbon production facilities in the Black Sea and Crimea oil and gas-bearing region.

The growth of petroleum refining in Ukraine in 2001–2005 led to an increase in the availability of motor fuel for the domestic market needs. During this period this increase ranged within 99–118%. The growth of prosperity and revival of Ukraine's economy in 2006–2009 stimulated an increase in the final consumption of motor fuel and, accordingly, a decrease in the availability of domestic production for final consumption from 84% to 75%. In 2010–2014, as a result of the degradation of the petroleum refining sector of Ukraine (the shutdown of the Odesa Refinery, in 2010, and the Lysychansk Refinery, in 2012, as well as the transformation of the Nadvirna and Drohobych refineries into petroleum product terminals), the availability of motor fuel production declined from 67% to 21%. In 2015–2021, only the Kremenchug Refinery and the Shebelino Gas Processing Plant were actually operating, but the availability of their refinery output gradually decreased from 23%, in 2015, to 17%, in 2021, because of petroleum supply problems.

Only in Norway, the existing production of crude hydrocarbons covers the needs of petroleum refining, and petroleum refining satisfies the final consumption of motor fuel. Only Denmark, Romania, Croatia, and Serbia may be considered to have significant presence of crude oil and natural gas liquids production for petroleum refining, while in the rest of the countries this indicator does not exceed 20%. In 12 EU countries, the availability of petroleum refining for final consumption exceeds 100%. Lith-

uania, the Netherlands, and Greece have the highest values (over 200%), while in 18 countries its level is insufficient. The lowest values are reported for France and Ireland (below 50%).

In terms of the 2nd security component (availability of petroleum refining), Ukraine in the European space can be considered an outlier, since, having a significant availability in terms of crude oil and natural gas liquids production, it has a critically low availability of petroleum refining for final consumption.

The third security component determines the quality of the conversion of primary resources into final products and can be characterized as the acceptability of petroleum refining. It is evaluated by acceptability of crude oil and acceptability of refinery outputs. At the same time, in most countries, there has been a trend that the replacement of crude oil with other raw materials (natural gas liquids, refinery feedstocks, and other hydrocarbons) leads to an increase in the output of motor fuel.

Figure 5 presents the dynamics of the acceptability of petroleum refining in Ukraine and the EU, in 2000–2021. As the data show, in the EU, the acceptability of crude oil for the needs of petroleum refining was always above 90% and decreased by 3%, in 2021 as compared with 2000. The acceptability of motor fuel in the EU exceeded 60% and increased by 7%, in 2021, against 2000.

In Ukraine, the acceptability of crude oil for petroleum refining needs increased from 87% to 97%, in 2000–2006, while the acceptability of motor fuel fluctuated in the range of 46–67%. The extensive exploitation of petroleum refineries by Russian owners on high-sulfur Urals oil fell on this period. In 2007–2011, the acceptability of crude oil and petroleum derivatives was at a relatively stable level of 84–87% and 67–71%, respectively. The shutdown of major refineries led to a decline in crude oil acceptability to 70–74%, in 2012–2021, except for 2017 and 2018, and a drop in the acceptability of petroleum products from 74%, in 2012, to 43%, in 2021. Such a swift drop in the acceptability of petroleum products is also associated with the increasing share of

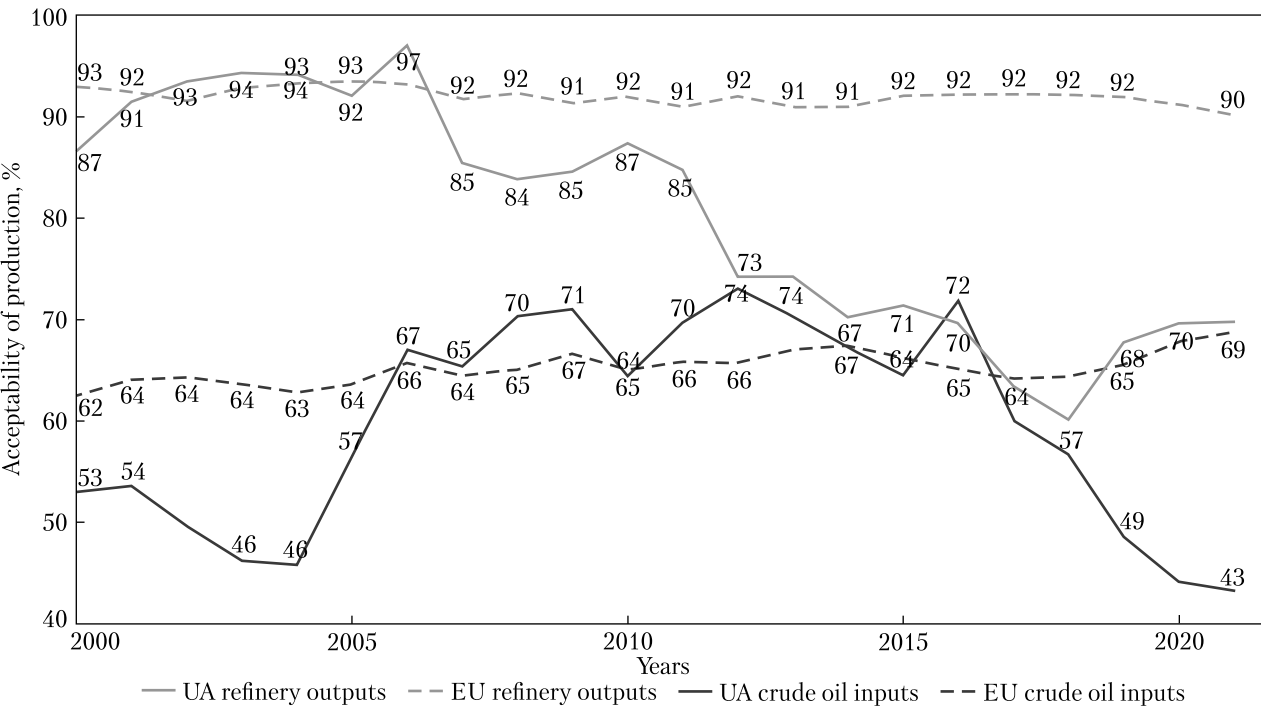


Fig. 5. Dynamics of acceptability of production of crude hydrocarbons and motor fuel in Ukraine and the EU, in 2000–2021
Source: generalized by the authors based on Eurostat data [29].

petroleum product production by low-efficiency mini-refineries. Therefore, as compared with the EU, Ukraine did not pay enough attention to the development of this sector of industry.

In most European countries, except for Croatia and Greece, the acceptability of crude oil exceeded 80%, while the acceptability of petroleum products came to 60%, except for the Netherlands and Ireland. Croatia, Norway, and Finland had the highest acceptability of petroleum products and the lowest acceptability of crude oil. These countries were intensively developing refinery feedstocks.

So, in terms of the 3rd security component (acceptability of production), Ukraine should be considered an outlier in the European space, since after 2012, it had one of the lowest acceptability values in Europe.

The fourth security component is the affordability of import crude hydrocarbons and motor fuel, which helps to develop one's own petroleum refining using high-quality and cheap raw materi-

als and supply cheap and high-quality petroleum products to the domestic market. It is proposed to evaluate this component using the indicator of import dependence weighted by the Herfindahl-Hirschman concentration index. It is assumed that the higher its value, the more open the access to world markets and the lower the risk of supply interruptions.

Figure 6 presents the dynamics of the affordability of import crude hydrocarbons and motor fuel in Ukraine and the EU, in 2000–2021.

Figure 6 shows that the EU has moderate affordability of crude hydrocarbons, due to the fact that it has an extensive geography of supplies. Their main importers were Russia (31%), Norway (8%), Saudi Arabia and Kazakhstan (7% each), as well as Nigeria and Iraq (6% each). The concentration of import of crude hydrocarbons in the EU gradually decreased from 1516, in 2010, to 1124, in 2021, and therefore their affordability increased, despite the high import dependence of

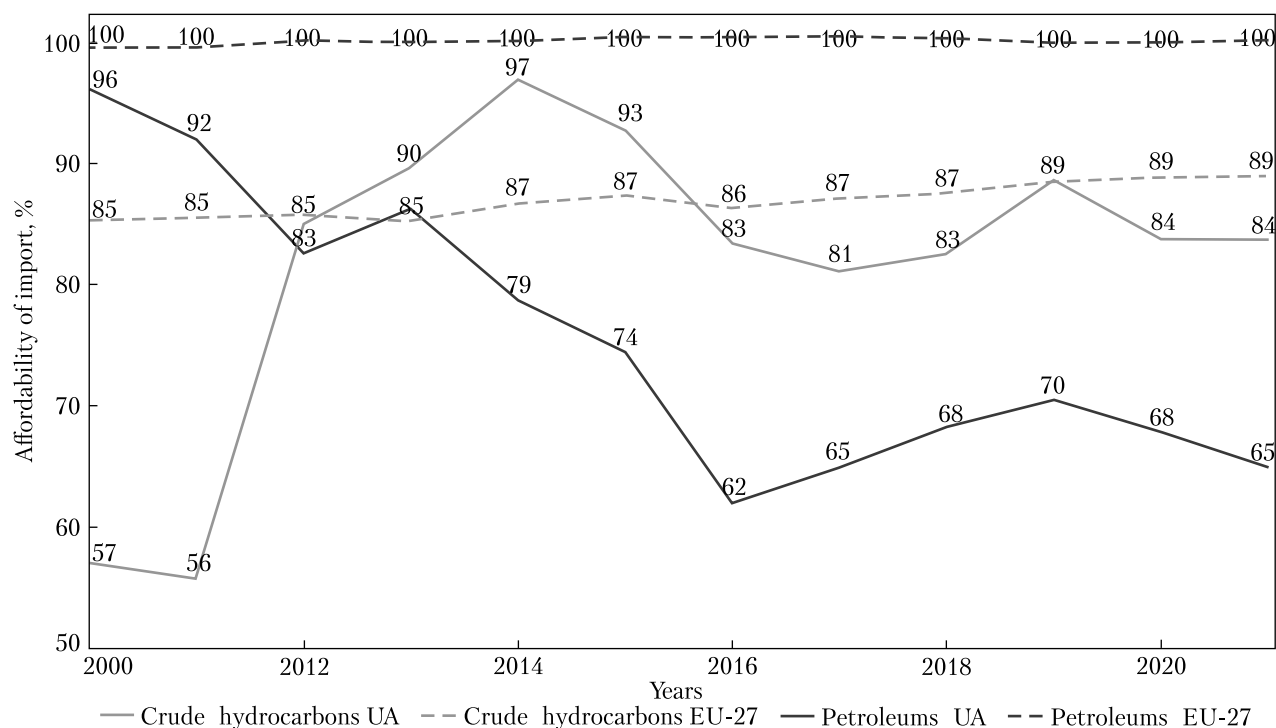


Fig. 6. Dynamics of the affordability of import crude hydrocarbons and motor fuel in Ukraine and the EU, in 2000–2021

Source: prepared by the authors based on Eurostat data [29].

the EU in terms of crude hydrocarbons. Also, despite the fact that in general the EU is self-sufficient in terms of motor fuel, there were reported significant external and internal flows of its import into the EU. The main exporters were Russia (17%), the Netherlands (13%), Belgium (9%), the USA (7%), and the United Kingdom (6%). The concentration of imported motor fuel was at a low level, varying within 666–705 units. Therefore, in terms of the affordability of motor fuel, the EU can be considered completely open, which allows us to suggest no risks of fuel supply failures.

In 2010–2011, Ukraine experienced low affordability of crude hydrocarbons because of high import dependence and high concentration. The main importers of crude hydrocarbons to Ukraine were Russia (74%), Azerbaijan (14%), and Kazakhstan (11%). In 2012–2014, as a result of the decline in the domestic petroleum refining in Ukraine, there was a sharp increase in the affor-

dability of crude hydrocarbons import that, like before, mainly consisted of Russian raw materials. In 2016–2021, there was an import reorientation from Russia to Central Asian. The main importers were Azerbaijan (50%), Russia (25%), USA (9%), and Kazakhstan (7%). So, the affordability of crude hydrocarbons for Ukraine got stabilized at the level of 81–83%. However, it should be noted that there was also a reorientation from pipeline supplies to sea transportation that was limited by the capacities of ports, which led to a reduction in the imports to Ukraine. In addition to the high concentration of import of crude hydrocarbons, there was a high concentration of import of finished petroleum products in Ukraine, so the import dependence was growing. This led to the fact that the affordability of import motor fuel was significantly lower than in the EU and ranged from 62 to 70%. In 2016–2021, the main importers of petroleum derivatives to Ukraine

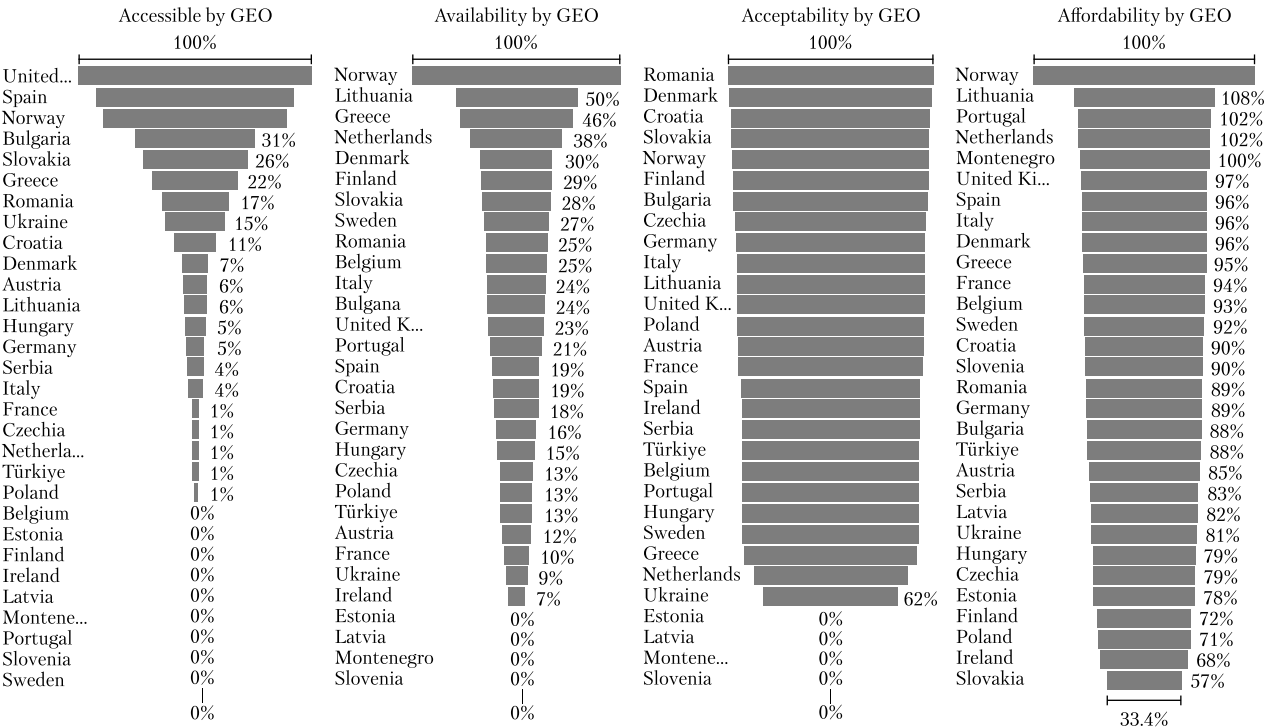


Fig. 7. Assessment of fuel security components of European countries based on the 4A concept, in 2017–2021

Source: prepared by the authors.

were Belarus (44%), Russia (31%), and Lithuania (9%). Thus, Ukraine had limited affordability of both crude hydrocarbons and finished motor fuel, focusing mainly on the post-Soviet markets. This provoked risks of disruptions in their supply and market manipulations.

The lowest affordability of crude hydrocarbons was in the countries focused on the import of Russian oil: the Czech Republic, Slovakia, Bulgaria, Lithuania, and Finland. Whereas countries with developed sea routes had the highest affordability: Spain, Italy, France, the Netherlands, Belgium, and Portugal. Ukraine, like many other continental European countries (such as Austria, Poland, etc.), had limited access to both crude hydrocarbons and finished petroleum products. However, access to the Black Sea allowed Ukraine to carry out minor diversification of crude hydrocarbon and petroleum product supplies, in particular crude hydrocarbons from Asian co-

untries through Russian ports or American petroleum through the Bosphorus Strait.

Therefore, in terms of the 4th security component (affordability of import of crude hydrocarbons and motor fuel), Ukraine had a satisfactory position in the import of raw materials and a weak position in the import of finished products. However, such positions were achieved due to a developed system of oil pipelines and a favorable geographical location.

Calculating the individual security components makes it possible to approach the problem of evaluating the general level of fuel security by normalizing the determined local indicators using the minimum-maximum method.

Figure 7 gives an integral assessment of the fuel security components based on the 4A concept (a 5-year time range is chosen to eliminate the impact of certain non-permanent factors, such as the COVID-19 pandemic or recovery after it).

Figure 7 shows that the United Kingdom, Spain, and Norway take the strongest positions in terms of accessibility. The United Kingdom and Norway thanked to significant deposits of crude oil and natural gas liquids in European terms, while Spain was among the leaders due to the frugal use of insignificant crude hydrocarbon deposits. In addition to Spain, Bulgaria, Slovakia, and Greece were frugally developing minor deposits, where crude hydrocarbon reserves for production exceeded 100 years, while their accessibility for refining did not exceed 1 year.

Ukraine took the 8th place in the European space, as it extensively mined proven reserves. Ukraine was preceded by Romania that having almost 3 times more deposits of crude oil and natural gas liquids, produced them moderately and provided a significant share of its own petroleum refineries with them. Germany and Italy have larger deposits of crude oil and natural gas liquids than Ukraine. These reserves are also extensively developed by them for the needs of their own petroleum refineries. The eleven European countries have small deposits of crude hydrocarbons, and their accessibility is negligible for both production and refining. The nine countries have absolutely no proven reserves, so their accessibility is 0%.

In terms of the security component “availability of petroleum refineries”, the 5 countries have its value above 100%, these are: Norway, Lithuania, Greece, the Netherlands, and Denmark. Among these countries, only Norway has available production of crude hydrocarbons covering the needs of petroleum refineries, while in the rest of the countries, high values of availability are ensured by excess production of motor fuel for domestic final consumption. The United Kingdom is characterized by high values of both indicators of availability, which allows it to take 6th place by this component in the fuel security rating. Estonia, Latvia, Montenegro, and Slovenia stand out, as they have neither production of crude hydrocarbons nor refineries for their conversion into motor fuel. These are the so-called countries with a zero resource cycle of motor fuel: import

of motor fuel – consumption of motor fuel. These countries are preceded by Ireland and Ukraine: the former has undeveloped production and petroleum refining (0% and 37%, respectively, in 2017–2021), while the latter has its own production and practically none petroleum refineries (70% and 18%, in 2017–2021).

Romania, Denmark, Croatia, Norway, and Finland (over 90%) were the leaders in terms of security component “acceptability of production”. These countries had a developed petroleum refining sector with motor fuel acceptability in the range of 85–89%, oriented towards crude oil refining (80–96%). In most European countries, the acceptability of production exceeded 80%, and only in the Netherlands its level was 71%, because of the low acceptability of motor fuel production at the level of 46% with the acceptability of crude oil at 88%. Ukraine preceded the group of countries with a zero resource cycle of motor fuel (defined by the 2nd component), as it had a limited acceptability of crude oil at the level of 60%. The declining petroleum production, complicated logistics and lack of access to world markets forced it to look for an alternative to crude oil, such as natural gas liquids or refinery feedstocks. The low acceptability of motor fuel production in Ukraine was estimated at 50% (because of closure of large progressive enterprises of the sector and reorientation to mini-refineries without deep petroleum refining).

In terms of the security component “affordability of import”, the first places in the ranking were taken by the net exporters of petroleum products: Norway, Lithuania, the Netherlands, and Greece. Portugal, whose share of net exports is insignificant (35%), also ranks among the leaders. The country produces motor fuel from imported raw materials (98%), but uses its advantageous geographical position in terms of access to world markets (*HHI* = 909). Italy and Spain also use an advantageous geographical position. The Czech Republic, Poland, and Slovakia are among the outsiders of the rating for this security component. These countries are partially import-dependent for mo-

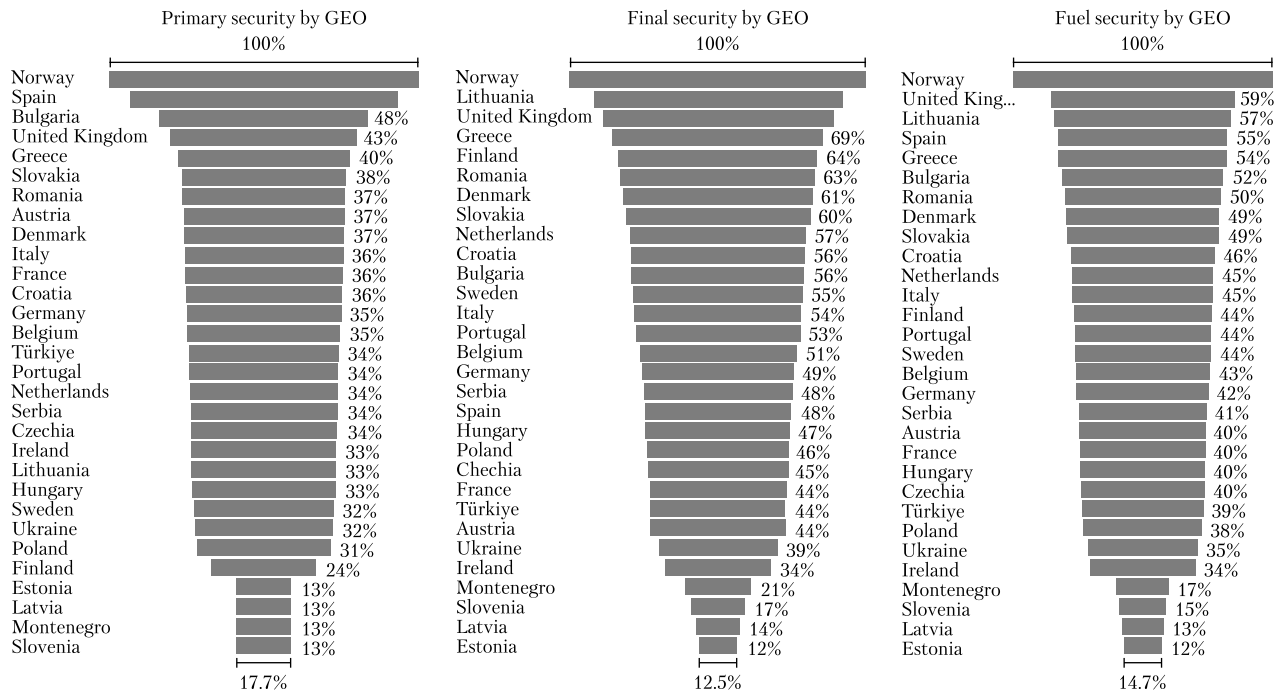


Fig. 8. Assessment of fuel security of the European countries in 2017–2021

Source: prepared by the authors.

tor fuel, completely import-dependent for crude hydrocarbons and have a highly concentrated structure of their imports oriented towards Russian oil. Also among the outsiders there are some countries with a zero resource cycle of motor fuel: Estonia, Latvia, and Ireland, which have a highly concentrated structure of their imports. In contrast, Slovenia, despite its zero resource cycle, has a low concentration of motor fuel import, which allows it to hold the 19th place in the ranking by this component. In this rating, Ukraine took 24th place because of high import dependence for motor fuel with a moderately high concentration of supplies. At the same time, the affordability of import of crude hydrocarbons in the country was at a high level because of the decline in the petroleum refining industry. The import dependence on them was at a moderately low level, while the concentration was at a moderate level.

Figure 8 shows the assessment of the fuel security of European countries by levels in 2017–

2021: the primary fuel security that concerns only crude hydrocarbons; the final fuel security that applies exclusively to motor fuel; overall fuel security (generalized indicators of both levels).

Based on Fig. 8, the leaders in terms of the primary fuel security were the countries that had available reserves of crude hydrocarbons, such as Norway, the United Kingdom, and Romania, as well as the countries that had industrial production of them, such as Spain, Bulgaria, and Greece. The outsiders were the countries that did not have proven reserves and had a zero resource cycle of motor fuel (Estonia, Latvia, Montenegro, and Slovenia), as well as the countries that were highly dependent on highly concentrated imports (Poland and Finland). Ukraine ranked 7th from the bottom, as it had moderate proven reserves that covered most of the declining petroleum refining industry. The structure of Ukrainian import was moderately concentrated, as there was a reorientation from Russian oil to Central Asian oil, in 2017–2021.

The leaders in terms of final fuel security were the countries that had excessive capacity of the petroleum refining complex: Norway, Lithuania, the United Kingdom, Greece, Finland, and Romania. Ukraine took the 6th place from the bottom, ahead of Ireland that has an underdeveloped petroleum refining complex, as well as the countries with a zero resource cycle (Montenegro, Slovenia, Latvia, and Estonia).

The above-mentioned components and levels of fuel security have determined the following overall level of fuel security of European countries: Norway, the United Kingdom, Lithuania, Spain, Greece, Bulgaria, and Romania have the highest level of fuel security. Among them, only Norway, the United Kingdom, and Romania have significant petroleum deposits. At the same time, the absence of these deposits in the other above-mentioned countries allows them to achieve a high level of fuel security thanks to the development of a highly efficient petroleum refining complex based on low-concentration import of crude hydrocarbons. The countries with a zero resource cycle of motor fuel have the lowest level of fuel security: Montenegro, Slovenia, Latvia, and Estonia. Ukraine and Ireland precede these outsiders because they have not paid attention to the development of their own production of motor fuel. Above them, there are the countries that have insufficient capacities of the petroleum refining complex oriented on the import of Russian oil: Hungary, the Czech Republic, Turkey, and Poland.

Thus, in the period before the full-scale war with Russia, Ukraine had a weak position in fuel security, gradually turning into a country with a zero resource cycle of motor fuel. The destruction of the last major petroleum refineries actually drives it into a dependency trap.

Among the expected forecast alternatives for the development of the fuel sector in Ukraine, there are clearly distinguished the two scenarios:

1) to join the group of European countries with a zero resource cycle of motor fuel;

2) to refuse from import of finished motor fuel, to restore the petroleum refining industry, and to increase its own production.

It is obvious that the strengthening of Ukraine's fuel security involves the implementation of the second scenario. However, under such a scenario, Ukraine faces challenges unforeseen by European practice.

First, the strengthening of fuel security by maximizing indigenous production of crude hydrocarbons is practically impossible, since [31]:

- ◆ over a 30-year period, the volume of hard-to-mine reserves in Ukraine has almost tripled (currently, about 68–70% of all deposits belong to this category);
- ◆ 88% of oil fields have reserves of less than 1 million tons and belong to “very small”, according to the modern classification;
- ◆ about 71% of Ukrainian crude oil production reserves belong to the “C” category, while as few as 29% of the oil reserves, the vast majority of which were produced in the Eastern region, belong to the higher “A” and “B” categories;
- ◆ the average value of the petroleum extraction coefficient in Ukraine is approaching 30% versus the design level of 36.5%, while the world indicator in the corresponding conditions is 40–50%;
- ◆ the existing well fund has been worn out and been operating less than for 10%; less than 10% of wells have been productive;
- ◆ the absolute majority of the oil fields of Ukraine have entered the late stage of development.

The diversification of crude hydrocarbon supplies for the needs of Ukraine's petroleum refineries is also a scenario that is difficult to implement. Before the beginning of Russia's military aggression in Ukraine, there were the three logistical routes for supplies [31]:

1) the Russian direction — pipeline transport through the *Druzhba* oil pipeline and other international interconnectors from the Russian Federation;

2) the Caspian route — sea transport through the Black Sea from the ports of Batumi, Supsa,

Novorossiysk, by Ukrainian oil pipelines from the sea ports of Odesa and Kherson, and then by trunk oil pipelines of Ukraine or railway transport to Ukraine's refineries;

3) international direction — by sea transport through the Turkish Bosphorus and Dardanelles Straits to sea ports.

Out of the listed, only the 3rd direction remains promising, however, in this case, the supply volumes are limited by the throughput through the Turkish gulfs, which does not allow us to consider it the main one.

The scarcity of proven oil reserves and limited opportunities for the diversification of crude hydrocarbon supplies to Ukraine necessitate the development of the national resource cycle of motor fuel based on unconventional ways of its production. This is possible due to the maximization of the use of one's own energy potential to ensure the production of motor fuel (in particular, with coal-to-liquids (CTL) or gas-to-liquids (GTL) technologies). Priority is given to CTL technology, since Ukraine has large reserves of both hard and brown coal.

Therefore, the production of synthetic motor fuel from coal is considered one of the most promising applications of Ukraine's coal potential. The production of synthetic motor fuel should be considered a strategic direction for restoring the resource cycle of motor fuel in Ukraine, which is capable of meeting the motor fuel needs of the national economy and protecting from the influence of external and internal political and economic shocks.

CONCLUSIONS

The proposed methodical approach to the assessment of fuel security has made it possible to solve the tasks, to prove the proposed hypotheses, and to obtain the following conclusions:

1. The resource cycle of motor fuel provides a comparison of fuel security by chains of input resources based on output needs, which, unlike the existing ones, allows to thoroughly determine the

qualitative local indicators. Based on the calculated local indicators of Ukraine's fuel security in the European space, in 2021, Ukraine may be considered an outlier. Having a relatively high accessibility of reserves for production (24 years) and consumption (15 years), availability of crude hydrocarbons for petroleum refineries (62%), affordability of import of crude hydrocarbons (84%), Ukraine did not pay due attention to its own production of motor fuel. In particular, the availability of motor fuel production (17%), the acceptability of petroleum for refineries (69%), the acceptability of motor fuel production (43%) were at a critical level;

2. The assessment of fuel security involves determining it in terms of the components of availability, accessibility, acceptability, and affordability, as well as the levels of primary, final, and overall fuel security. This, unlike the existing approaches, allows us to identify the risks and resilience of each country in the regional space. In particular, it has been established that Ukraine in the European space had critically low values of fuel security both in terms of the security components (the accessibility is 15%, the availability is 9%, the acceptability is 62%, and the affordability is 81%) and its levels (the primary is 32%, the final is 39%, and the overall is 35%). This proves its place among the outsiders in the European space, ahead of the countries with a zero resource cycle of motor fuel (Ireland, Latvia, Estonia, and Montenegro);

3. To strengthen the fuel security and to drive Ukraine out of fuel dependence trap are impossible unless to use nonconventional ways for restoring the resource cycle of motor fuel. The Russian aggression in Ukraine has resulted in the destruction of the remaining petroleum refineries and prevented its access to the global and, in particular, the Central Asian markets of crude hydrocarbons, which leads to Ukraine's falling into the trap of dependence on the import of motor fuel. It is impossible to solve the problem of strengthening the fuel security by the traditional scenarios of restoring the pet-

roleum refining complex due to the problems with crude hydrocarbons supplies, both due to the drop in their indigenous production and the unfavorable geographical border with the Russian Federation, which limits access to their import. Under these conditions, the restoration of fuel resource cycle in Ukraine is impossible unless we use the existing large coal potential and launch the production of synthetic motor fuel based on it.

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ОЦІНКА ПАЛИВНОЇ БЕЗПЕКИ КРАЇН У ЄВРОПЕЙСЬКОМУ ПРОСТОРІ ТА ЗАГРОЗИ ПОТРАПЛЯННЯ УКРАЇНИ У ПАСТКУ ПАЛИВНОЇ ЗАЛЕЖНОСТІ

Вступ. Формування паливної безпеки є важливим для стабільності держави. Високо розвинуті нафтодефіцитні країни цьому питанню приділяють значну увагу шляхом розвитку виробництва моторного палива.

Проблематика. Через падіння нафтовидобутку, занепаду нафтопереробки та обмежених можливостей щодо імпорту нафти та моторного палива Україна поступово перетворювалася на країну із критично низьким рівнем паливної безпеки.

Мета. Визначення рівня паливної безпеки країн та України зокрема в Європейському просторі на основі методичного підходу, що передбачає розрахунок локальних індикаторів паливної безпеки за компонентами та рівнями.

Матеріали й методи. Інформаційною базою слугували дані Євростату. За допомогою широкомасштабного моделювання великих масивів у програмному забезпеченні *Microsoft Power BI* було проведено інтегральну оцінку паливної безпеки європейських країн у регіональному просторі та у динаміці.

Результати. Визначено, що міцні позиції з паливної безпеки мають країни, які ощадливо видобувають сирі вуглеводні та розвивають нафтопереробку шляхом низькоконцентрованого імпорту сировини (Норвегія — 77 %, Іспанія — 48 % та Литва — 47 % у загальноєвропейському рейтингу паливної безпеки, сформованому за результатами оцінки). Рівень паливної безпеки України скоротився з 35 % (13 місце) до 31 % (24 місце), а руйнація виробничих потужностей через російську агресію зводить його майже до нуля. Зміцнення паливної безпеки України шляхом відбудови виробництва на сирих вуглеводнях неможливе через падіння їх видобутку та обмежені можливості імпорту.

Висновки. Запропоновано методичний підхід до оцінки паливної безпеки країн, що будується на чотирьох безпечових компонентах: достатність, наявність, прийнятність, доступність. Це дозволяє визначити її за рівнями первинної, кінцевої та загальної паливної безпеки. Вирішення проблеми можливе через розбудову виробництва синтетичного моторного палива із вугілля. Отримані результати можуть бути використані при перегляді Енергетичної стратегії України.

Ключові слова: паливна безпека, нафтопереробка, первинні вуглеводні, синтетичне моторне паливо, пастка залежності.