
РОЗДІЛ 3.
ІНФОРМАЦІЙНО-ТЕХНОЛОГІЧНІ ВЕКТОРИ ТРАНСФОРМАЦІЇ
БІЗНЕСУ В УМОВАХ ЦИФРОВОЇ ЕКОНОМІКИ ТА СТАЛОГО
РОЗВИТКУ

3.1. Sustainable development of the Ukrainian energy system under the European integration: socio-economic aspects

Ganushchak Tetiana,

*PhD in Economics, Assistant Professor,
State University of Trade and Economics,*

Sova Olena,

*PhD in Economics, Assistant Professor,
Institute for Demography and Life Quality Problems of the
National Academy of Sciences of Ukraine*

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The process of Ukraine's European integration necessitates the transformation of the national energy system in accordance with the principles of sustainable development, which require a balance between economic feasibility, social equity, and environmental security. The conditions of the modern energy transition are shaped by numerous challenges, the most significant of which include the need to reduce dependence on fossil fuels, enhance energy efficiency, and integrate Ukraine into the European energy market.

Since the beginning of armed aggression in eastern Ukraine in 2014, the domestic energy system has undergone significant changes and has become the target of numerous attacks. However, this process became particularly critical following Russia's full-scale invasion in February 2022. The consequences of the war for Ukraine's electricity sector include infrastructure destruction, reduced generation capacity, fuel shortages, and disruptions in traditional energy supply chains. At the same time, due to the necessity of maintaining the country's vital functions amid military operations, measures have been implemented to ensure the continued operation of the energy system. These measures include the diversification of energy sources, modernization of existing energy infrastructure facilities, integration into the European energy grid, and increased use of renewable energy sources. A crucial task remains the reconstruction of fuel and energy complex facilities that have been partially or completely destroyed.

These challenges underscore the critical need for an accelerated transformation of Ukraine's energy system in line with European standards and global sustainable development trends. Strategic decisions in the field of energy security should not only guarantee the stability of energy supply but also lay the foundation for post-war economic recovery and the dynamic attraction of investments. In this context, the research topic is of utmost relevance, as it allows for an assessment of the current opportunities, risks, and prospects on Ukraine's path to energy independence.

As of February 2022, Ukraine's energy sector was among the most powerful in Europe and remains so despite significant damage caused by the Russian invasion. Ukraine ranks among the top-10 European countries in terms of installed electricity generation capacity and is among the top-3 natural gas producers [1, p. 83]. Additionally, the country possesses the largest underground gas storage facilities in Europe. A well-developed and reliable system for transporting gas, oil, petroleum products, and electricity transmission links Ukraine with neighboring countries, reinforcing its role as a key player in the regional energy landscape. Ukraine also boasts one of the highest shares of carbon-neutral electricity generation in Europe, with approximately 70% of its electricity produced from nuclear, hydro, and renewable sources. The country's energy security is further strengthened by its extensive underground gas storage facilities. Prior to the full-scale invasion in February 2022, Ukraine was able to meet 75% of its domestic coal demand with its own resources. In the gas sector, the country covered 67% of its needs through domestic production, while the remainder was imported from a diversified range of suppliers within the European Union. However, the war has inflicted severe damage on Ukraine's energy infrastructure. Approximately 4% of its total generating capacity has been destroyed due to hostilities, while an additional 35% remains under occupation. This includes the Zaporizhzhia Nuclear Power Plant – the largest nuclear facility in Europe – which alone accounts for 43% of Ukraine's total nuclear generation capacity [2].

Ensuring the sustainable operation and development of Ukraine's electricity sector within the framework of European integration is a critical aspect of national security from both political and economic perspectives. The economic dimension is particularly tied to the increasing role of investment in modernizing infrastructure, implementing energy-efficient technologies, and expanding energy sources. Integration into the European Union opens up opportunities for Ukraine to access financial support for energy projects through mechanisms such as the European Green Deal and international financial institutions. This, in turn, will contribute to reducing the country's carbon footprint and enhancing the competitiveness of the Ukrainian economy. A particularly promising strategy for Ukraine is the implementation of «debt-for-climate swaps» and «debt-for-nature swaps». These mechanisms allow for

the reduction of a debtor country's financial obligations in exchange for directing resources toward ecosystem restoration, thereby balancing financial sustainability with environmental commitments [3].

The creation of a «green» bond market is an important step for Ukraine on the way to implementation European standards for the development of a «green» economy and environmental protection. A promising financial instrument that meets the requirements of the global capital market will allow accumulating and concentrating financial flows for the development and resource provision of domestic projects for environmental post-war reconstruction [4, p. 99].

The energy sector accounts for 8% of Ukraine's GDP, and in terms of consumption, Ukraine ranks 28th in the world. Approximately 7% of foreign direct investment in Ukraine is directed towards electricity supply, underscoring the sector's importance for economic development. Almost 450000 people are employed in the Ukrainian energy sector, which currently represents 1,2% of the total population. The loss of labor resources due to military actions and the emigration of the working-age population has a significant negative impact on the industry. 7,6% of Ukraine's budget was provided by the energy sector in 2023 [5].

The socio-economic aspect of sustainable energy development in Ukraine encompasses the impact of fuel and energy sector reforms on employment, population well-being, and energy resource accessibility. The transition to renewable energy sources contributes to job creation, technological potential development, and an improved investment climate. For example, the adoption of clean energy practices in Singapore led to a decrease in the unemployment rate from 14% to 2% following the implementation of projects in this sector [6].

In the process of decarbonization, the issue of energy poverty becomes particularly significant, where a large proportion of households spends disproportionately high amounts on energy resources or has limited access to them. This necessitates the expansion of state support programs, including the introduction of preferential tariffs for vulnerable populations and the promotion of energy efficiency measures in the housing sector.

A particular challenge is the social adaptation of communities historically dependent on traditional energy industries, especially coal mining. The decarbonization process requires society to develop alternative economic activities that will help reduce unemployment and maintain the demographic potential of the regions. In this context, reskilling programs, small business development, and investment in «green» economy projects are crucial, leading to the formation of new economic growth clusters focused on environmentally sustainable technologies. This opens up opportunities for the development of local industries utilizing renewable energy

sources, reducing regional energy dependence, and enhancing the competitiveness of the national economy in the long term.

European integration also stimulates the implementation of public participation principles in decision-making regarding energy development. Supporting local initiatives, creating energy cooperatives, and involving citizens in energy resource management contribute to strengthening social responsibility and increasing public trust in government reforms. The development of an energy-saving culture and conscious energy consumption is an essential step towards ensuring the long-term sustainability of the energy system. Thus, the development of the energy system directly impacts the quality of life and social cohesion of Ukraine's territorial communities.

One of the key areas for modernizing the energy systems of territorial communities is the digitalization of business processes, which involves the implementation of modern digital technologies for automating and optimizing energy system management. This includes the use of monitoring systems, data analytics, artificial intelligence, and other tools for continuous control and management of energy consumption, allowing for cost reductions and productivity improvements [7].

There are numerous examples of autonomous energy regions being established in EU countries. Successfully implemented projects in Denmark, France, and Germany have positively impacted community sustainability, energy independence, employment rates, local business activity, and the branding and reputation of these communities [8]. More and more countries are actively implementing smart energy systems, developed within the Smart Grid concept and utilizing Smart technologies to ensure an efficient energy-saving model. Over 40 cities worldwide receive 100% of their electricity from solar, wind, hydro, and biomass energy. Among them are Burlington (USA), Basel (Switzerland), and Reykjavik (Iceland) [9, p. 151]. Studies have already been conducted explaining changes in economic growth, income inequality, and greenhouse gas emissions through mathematical matrices using data on export geography by products, technology patents, and scientific publications in research fields [10].

To change the structure of Ukraine's regional fuel and energy balance increased use of local energy resources and expanded geological exploration activities could be applied [11]. This requires a stable investment climate, long-term planning, and security guarantees for enterprises and communities. However, under current wartime conditions, the implementation of such initiatives is significantly complicated by infrastructure destruction, investor risks, and the inability to fully develop energy projects. Therefore, achieving peace is a critical prerequisite for the effective transformation of the energy sector.

The PEST analysis of Ukraine's energy sector has revealed the significant impact of key factors on its strategic potential [12, p. 411]. Economic factors have the greatest influence (1,147), emphasizing the importance of the energy sector for the national economy. Political factors (0,847) rank second, particularly due to Ukraine's European integration trajectory. Technological factors (0,553) confirm the commitment to decarbonizing the energy sector.

Socio-cultural factors (0,537) have a somewhat lower impact; however, they reflect the importance of consumer preferences in the development of the fuel and energy complex. Reducing air pollution contributes to improving public health, which, in turn, lowers healthcare costs. Energy decentralization and the implementation of distributed generation allow citizens and businesses to gain more control over energy consumption and increase their level of energy independence.

Currently, Europe's high dependence on fossil fuels and the instability of energy markets have become some of the biggest challenges to its competitiveness. For Ukraine, which has lost a significant portion of its energy infrastructure, this issue is of critical importance. As of November 2024, the losses in Ukraine's energy sector amount to \$14,6 billion. Due to attacks, the Kakhovka and Dnipro hydroelectric power plants, as well as the Trypillia and Zmiiv thermal power plants, have been completely destroyed. Other generating facilities, high-voltage substations, and oil and gas infrastructure objects have also suffered significant damage. The current direct losses in thermal power generation are estimated at \$5,4 billion, while those for hydroelectric and pumped storage power plants amount to \$2,5 billion. Approximately 13% of solar generation capacity is located in occupied territories, while 8% has been damaged or destroyed. Around 80% of wind power generation is under occupation, with some facilities damaged due to shelling [13].

In June 2024, at the Ukraine Recovery Conference in Berlin, several significant international agreements were concluded in the energy sector [5]:

- United States – \$824 million to support energy infrastructure;
- World Bank – an additional grant of \$47 million for the procurement of thermal equipment for Kharkiv, including 1000 generators and solar panels;
- European Union – initiation of solar panel supplies;
- Germany – €30 million to enhance the reliability of the energy system.

According to the new Ukraine's Energy Strategy until 2050, the country has the potential to expand wind generation capacity to 140 GW, solar power to 94 GW, energy storage to 38 GW, nuclear power to 30 GW, thermal and bioenergy capacity to 18 GW, and hydropower to 9 GW [14]. Based on the TIMES economic-mathematical model, building new power generation facilities will require \$383 billion in investments.

M. Draghi suggests investing in renewable energy, expanding interregional energy networks, and implementing innovative energy-saving technologies. For Ukraine, this presents an opportunity to attract European investments into «green» energy projects, particularly solar and wind energy. Restoring energy independence should become a key element not only of national security but also of economic development. Ukraine has the potential to become a regional leader in renewable energy deployment, leveraging its natural resources and European investment capital [15].

In recent years, many countries have made efforts to reduce their dependence on coal and other energy sources that contribute to high greenhouse gas emissions. In the first half of 2024, wind and solar power generation in the EU reached a historic high, accounting for 30% of electricity production compared to 27% from fossil fuels. The remaining 43% came from hydropower, nuclear energy, and other sources [16].

Figure 1 illustrates the energy sources in the EU and Ukraine.

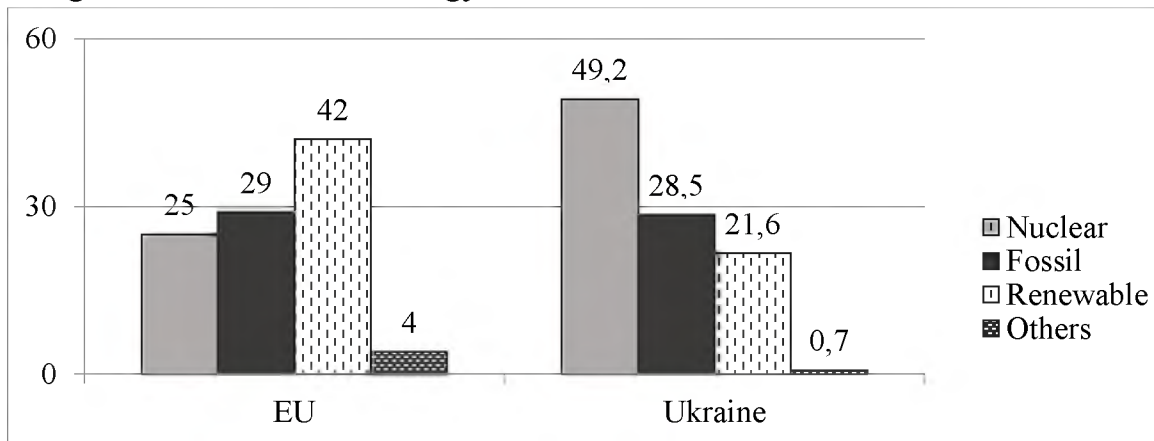


Fig. 1. – Energy sources the EU and Ukraine, 2023, % [5].

The data indicate significant differences in the approach to energy balance formation. Ukraine exhibits a high dependence on nuclear energy, with its share accounting for 49,2%, whereas in the EU, this figure is significantly lower at only 25%. Meanwhile, the use of fossil fuels (coal and gas) is nearly identical: 28,5% in Ukraine and 29% in the European Union. The most notable difference is observed in the renewable energy sector (sun, wind, water, biomass). In the EU, renewables constitute 42% of the energy mix, nearly twice as much as in Ukraine, where the share stands at only 21,6%. The «other sources» category plays a minor role in the energy balance of both systems; however, in the EU, it reaches 4%, whereas in Ukraine, it is only 0,7%.

Overall, these data illustrate the key differences in energy system structures: while the European Union actively develops renewable energy, Ukraine, despite some progress in this area, still relies heavily on nuclear generation. In 2024 JSC NAEC «Energoatom» launched the construction of power units №5 and №6 at the

Khmelnitsky nuclear power plant, using AP1000 technology from Westinghouse [17, p. 113]. However, nuclear reactors require vast amounts of water for cooling – on average, 75000 liters per minute – while renewable energy technologies are rapidly decreasing in cost and are already the most economically efficient alternatives available.

The European Union and Ukraine, as a candidate country, have made a significant contribution to the global energy transition, achieving remarkable progress in energy sector reforms. Further deepening of cooperation will facilitate the increased use of underground gas storage facilities by European enterprises, the expansion of electricity export potential, and the advancement of scientific research in nuclear energy. Above all, strengthening energy security remains a key factor in the country's socio-economic stability.

Reliable energy supply not only fosters well-being but also creates the necessary conditions for the return of migrants and internally displaced persons by ensuring access to essential services, employment opportunities, and comfortable living conditions in Ukraine. Investments in sustainable energy infrastructure and the development of renewable energy sources enhance public confidence in the country's reconstruction prospects and stimulate the recovery of regions affected by military actions.

To ensure effective integration into the European energy market, Ukraine must align its legislation with EU requirements, establish a transparent energy market, and enhance the competitiveness of enterprises. A crucial area of focus is the expansion of hydrogen production and exports, the promotion of eco-friendly transportation, and the implementation of energy-efficient technologies in industries. Innovations in the energy sector will help reduce dependence on fossil fuels, decrease resource consumption and energy costs, lower greenhouse gas emissions, and improve environmental conditions. A swift transition from outdated fossil fuel-based energy technologies – responsible for 86% of global CO₂ emissions over the past decade – to clean renewable energy should be a priority for all democratic nations facing the dual threats of climate change and security risks [17, p. 124].

It is essential to intensify foreign investment attraction and participation in grant programs to support the modernization of energy infrastructure and the expansion of clean energy use. The construction and maintenance of transitional energy networks will facilitate electricity exchange between countries, ensuring a balance between supply and demand in the energy market.

Ukraine's EU membership will benefit both the country and its European partners by strengthening regional energy security and ensuring the sustainable development of the energy system. Thus, achieving this goal in Ukraine amid European

integration requires a comprehensive approach that includes stimulating investments in renewable energy, increasing energy efficiency, enhancing social support for the population, and fostering the development of innovative technologies. The implementation of these measures will contribute to the formation of an energy-secure, economically stable, and socially responsible model of Ukraine's energy development.

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3.2. Стратегічні орієнтири трансформації газового сектору енергетики України в повоєнний період

*Дзьоба О.Г.,
доктор економічних наук, професор,
професор кафедри підприємництва та маркетингу,
Слободян Н. Б.,
докторант,
Гараздюк В. В.,
здобувач PhD,*

Івано-Франківський національний технічний університет нафти і газу

Ключові слова: стратегія, інноваційна трансформація, відновлення, сталий розвиток, енергетична галузь, потенціал.

Газова галузь економіки України є однією із провідних у вирішенні завдання енергетичного забезпечення потреб господарського комплексу країни та важливою складовою її національної безпеки. Впродовж усього періоду розбудови економіки незалежної Української держави її газова галузь відіграла важливу роль у вирішенні питань внутрішнього енергозабезпечення та слугувала, завдяки своїй розвинутій газотранспортній системі, надійним транспортним коридором для постачання природного газу в низку країн Європи. Стратегічне значення газової галузі в економіці характеризується часткою