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## ENERGY SYSTEM OF UKRAINE: EUROPEAN INTEGRATION TRANSFORMATIONS AND ECONOMIC SECURITY

*This article examines the significance of the energy system for the functioning of the national economy and its impact on the level of the state's economic and overall security. Particular attention is paid to the energy system's ability to adapt to crisis conditions, particularly during a period of martial law, when the risks of losing generation, transmission and distribution capacity increase significantly. It is argued that the recovery and development of the sector require the modernisation of the technical infrastructure and a reorientation of resource provision in line*

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## ЕНЕРГЕТИЧНА СИСТЕМА УКРАЇНИ: ЄВРОІНТЕГРАЦІЙНІ ТРАНСФОРМАЦІЇ ТА ЕКОНОМІЧНА БЕЗПЕКА

*Розглянуто значення енергетичної системи для функціонування національної економіки та її вплив на рівень економічної і загальної безпеки держави. Особливу увагу приділено здатності енергосистеми адаптуватися до кризових умов, зокрема в період воєнного стану, коли суттєво зростають ризики втрати генеруючих, передавальних і розподільчих потужностей. Обґрунтовано, що відновлення та розвиток галузі потребують оновлення та розв'язок технічної бази й переорієнтації ресурсного забезпечення відповідно*



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with European approaches. The research hypothesis is that the deepening of Ukraine's integration into the European economic space creates conditions for the qualitative modernisation of the energy system, increases its resilience to external threats and contributes to strengthening the state's economic security. It is demonstrated that attracting international support and developing institutional investment mechanisms are important factors in the restoration of energy infrastructure. The theoretical basis of the study is the approach of enterprise economic security, which allows for a comprehensive assessment of the state and prospects of the energy system's development. The study employs general scientific methods, in particular analysis, synthesis and generalisation. It is generally accepted that the path towards European integration is crucial for enhancing the resilience of the energy system and creating the conditions for long-term economic growth.

**Keywords:** economic security, energy system, resilience, European integration, energy infrastructure, investment, development.

до європейських підходів. Дослідження ґрунтується на гіпотезі, що поглиблення інтеграції України до європейського економічного простору створює умови для якісної модернізації енергетичної системи, підвищує її стійкість до зовнішніх загроз і сприяє зміцненню економічної безпеки держави. Показано, що залучення міжнародної підтримки та розвиток інституційних механізмів інвестування є важливими чинниками відновлення енергетичної інфраструктури. Теоретичною основою дослідження є підхід економічної безпеки підприємства, що дозволяє комплексно оцінити стан і перспективи розвитку енергетичної системи. Використано загальнонаукові методи, зокрема аналіз, синтез і узагальнення. Зазначено, що євроінтеграційний вектор розвитку є визначальним для підвищення стійкості енергетичної системи та формування передумов довгострокового економічного зростання.

**Ключові слова:** економічна безпека, енергетична система, стійкість, європейська інтеграція, енергетична інфраструктура, інвестиції, розвиток.

**JEL Classification:** Q40, Q43, Q48, F15, H56, O13

## Introduction

The modern energy system is the most important component of Ukraine's economy, representing an optimally structured set of individual economic units whose activities are functionally interconnected within a unified complex for generating, distributing, and transmitting energy produced using relevant energy resources to the end consumer. The structural proportions, as well as the substance of all the system's components, have certain characteristics inherent to the national economy, macroeconomic management policies, inherited values, and accumulated technological potential.

The energy system and infrastructure were largely established in the previous century and inherited not only production assets and technologies but also the shortcomings of the command-and-administrative system, including paternalism in management, state regulation of tariffs for assessing activities, and so on. However, despite relative technological backwardness, an inertial approach to managing this part of the national economic complex, and numerous emergencies caused by shelling during martial law, a new paradigm for system management has effectively begun to emerge, thanks to the heroism of Ukrainian energy workers. This paradigm involves moving from symptomatic diagnosis to the development of analytical tools for identifying trends and directing the system's development on the basis of a new matrix of criteria, objectives, and implementation instruments. With the

support of partner countries, new technical equipment and technological configurations are being introduced into the system, modern requirements and quality standards are being established, and new mechanisms for and financial logistics are being applied. This provides grounds for asserting that Ukraine's energy system is moving towards European integration on the basis of profound internal transformations taking place alongside the restoration of its viability.

In other words, an evolutionary transformation of Ukraine's energy supply sector is underway. It is based on the principles of ensuring the economic security of each economic component and, by induction, of the system as a whole. This transformation is being implemented through crisis management tools and involves a transition to economic growth strategies aligned with the models of European countries and their approaches to assessing the relevant parameters.

The relevance of the study is determined by the need for a scientific understanding of the role of crisis management mechanisms in the activities of enterprises within Ukraine's energy sector under martial law in shaping and assessing their level of economic security according to the parameters of the European approach, establishing consistent comparability between metrics and criteria, and demonstrating the actual existence of these processes and the scale of their impact on the operational resilience of economic entities in the sector under these conditions.

A preliminary analysis of the activities of enterprises within Ukraine's energy sector indicates the fragmented application of strategic performance indicator planning, even less frequent consideration of risk factors, the absence of a comprehensive approach to determining the scope and functional interrelationships of the dominant management areas, and the assessment of factor burdens in correlation with fluctuations in indicators affected by changes in the external and internal environments.

The introduction of European experience in managing the integrated power system, which is being transferred to Ukraine as part of efforts to support its operation and enhance its resilience, is becoming a platform for reforming and modernizing the domestic management framework on the basis of security priorities and objectives aimed at improving the resilience, adaptability, and ability of the energy system to function effectively in the face of crisis challenges. This contributes to the digitalization of management, stronger coordination, risk forecasting, and a transition to a preventive model of energy security provision.

The purpose of the study is to substantiate approaches to developing an assessment model of the economic security of Ukraine's energy system under martial law and in the context of European integration, taking into account crisis management methods and European experience.

The hypothesis is that deeper integration of Ukraine into the European economic area creates conditions for the qualitative modernization of the energy system, increases its resilience to external threats, and contributes to strengthening the state's economic security.

The research methodology comprises a system of principles and methods for analysing the theoretical foundations of managing the processes through which systems attain a state of economic security by means of crisis response mechanisms, particularly under emergency operating conditions. It also involves systematizing established characteristics and interrelationships, identifying factors influencing their development, studying international experience and its current implementation in the operations of existing Ukrainian enterprises, and formulating relevant generalizations, conclusions, and proposals for their practical testing.

The scientific novelty lies in systematizing the main theoretical approaches to defining the concept of "economic security of an economic system," as well as the fundamental provisions of the organizational and methodological framework for its establishment and maintenance and the system of assessment criteria and standards. This has made it possible to unify the theoretical research model and determine the influence of sector-specific characteristics of economic activity on its underlying structure, particularly under martial law. Approaches to characterizing the state and main development trends of Ukraine's energy system as prerequisites for its integration into the European integration process have also been improved, and the factors influencing the intensity of this process have been identified.

The main body of the article consists of three sections. The first examines the prerequisites for developing the economic security potential of Ukraine's energy system in the process of European integration. The second presents a theoretical model for managing the process of achieving the target level of economic security in economic activity within Ukraine's energy system. The third substantiates the role of European integration within the system of strategic objectives and factors for strengthening its economic security potential.

### **1. Prerequisites for developing the economic security potential of Ukraine's energy system in the context of european integration**

This issue has been addressed in contemporary academic research highlighting key aspects of the functioning of Ukraine's energy system, particularly its technical potential, resilience to external threats, and management mechanisms for ensuring energy security. At the same time, further research is needed into management tools for enhancing the resilience of Ukraine's energy system, taking into account European experience and current security challenges. The relevance of the topic is not limited to the conditions of martial law in Ukraine, which significantly intensify the impact of destabilizing factors on the functioning of the energy system, but also encompasses the specific features of its operation and development in the pre-war period. Thus, Diachenko et al. (2025) characterize Ukraine's energy sector as of February 2022 as one of the most powerful in Europe, with its

potential preserved even during wartime. In terms of electricity generation capacity, Ukraine ranks among the top ten countries in Europe, while in terms of natural gas production, it ranks among the top three, possessing some of the largest gas storage capacities in Europe.

According to Bulakh (2023), Ukraine actively cooperates with neighbouring European countries in the transportation of gas, oil, and petroleum products, as well as in electricity transmission, and has one of the largest shares of carbon-neutral electricity generation in Europe. Approximately 70% of Ukraine's electricity production is provided by nuclear, hydropower, and renewable generation. At the same time, 75% of the coal used for electricity generation is of domestic origin. The level of self-sufficiency in natural gas is approximately 67%.

According to the author, the war crisis resulted in a 4% loss of electricity generation capacity in Ukraine due to destruction and a 35% loss due to the occupation of part of the country's territory. In particular, the occupation of the Zaporizhzhia Nuclear Power Plant, the largest nuclear power plant in Europe, reduced the total generation capacity of all nuclear power plants in Ukraine by 43% (Bulakh, 2023).

In the context of ensuring the sustainable operation and development of Ukraine's energy sector, Chuhunov et al. (2023) note that integrating the energy system into the European energy space strengthens its role in ensuring national security, particularly in the political and economic dimensions. At the same time, the authors emphasize the growing importance of investment in infrastructure modernization, the introduction of technological innovations, and reform of the resource provision framework. Expanding the integrated European economic space through the inclusion of neighbouring countries, particularly Ukraine, creates new approaches to financing, promotes the development of investment models and mechanisms, and creates new opportunities for integrating domestic economic entities into the unified European economic area. For Ukraine, for example, financial support for projects through the mechanisms of the European Green Deal and relevant financial institutions is becoming accessible. This will make it possible to reduce the carbon footprint, improve other resource efficiency indicators, and strengthen the competitive position of the Ukrainian economy.

The authors consider the introduction of debt-for-climate swaps and debt-for-nature swaps in Ukraine to be a realistic prospect, as these mechanisms would make it possible to reduce the debt burden and direct financial resources towards restoring the balance of the ecosystem.

The socio-economic aspect of the sustainable development of Ukraine's energy system is the focus of Ali A.H.S. (2021), who analyzes the impact of reforms in this sector of the economy on employment levels, public well-being, and the quality of energy supply, including through the provision of resources to producers using available logistics schemes and capacities. The author assesses the role of renewable energy sources as a factor in creating new jobs, developing scientific and technological progress, increasing direct investment attractiveness and the derived attractiveness for

consumers of energy resources produced using advanced technology. Ali A.H.S. argues that the use of clean energy contributed to a reduction in unemployment in Singapore from 14% to 2% as of 2021.

The processes of the functioning and development of energy systems, transformations in the public assessment of these processes, and their specific features within the European integration model are examined by Kvasnii et al. (2024). They formulate the problem of energy poverty, which emerged during the decarbonization process, when a significant proportion of households spent disproportionately large amounts of money on energy resources or had limited access to them. As a result, the state is forced to expand support programs, introduce preferential tariffs for vulnerable population groups, promote energy efficiency measures in the residential sector, use appropriate mechanisms, and so forth.

Particular emphasis is placed on the social adaptation of communities that have historically depended on traditional coal-based energy. Modern technological transformations of the energy system, as well as progressive practices and experience in its development in European countries, the United States, and developed Asian countries, create the need to change the priorities of the economic activities of business entities and the functioning of the energy system as a whole, both at the national level and at the integrated European level. This transformation should aim to ensure a socio-economic balance between the interests of businesses, the population, and the state. Therefore, innovative environmental rehabilitation programs that do not reduce the productive capacity of the country's economy as a whole will help lower unemployment, preserve the demographic potential of the country and its regions, and increase the value of human capital, in which investment will be made through retraining and training programs and the modernization of competency standards for small businesses. The authors substantiate the role of investment in the development of a "green" economy, which is "geared towards" the formation of new clusters of economic growth focused on environmentally safe technologies. In the authors' view, this creates opportunities for the development of local production based on reducing regional energy dependence through the extensive use of renewable energy sources. This will strengthen the competitive position of the national economy as a whole and, in the long term, build competitiveness potential with qualitatively new parameters, criteria, and mechanisms for its enhancement.

The authors also focus on Ukraine's European integration process, emphasizing the need to implement principles and forms of public participation in decision-making regarding the development of the energy system. In particular, this involves supporting local initiatives, establishing energy cooperatives (a new form for Ukraine), engaging citizens in energy resource management based on social responsibility and trust in state reforms, and fostering a culture of energy conservation and rational energy resource consumption, among other measures. The article concludes that

community engagement directly affects the development of the energy system in a region and the country as a whole, which, in turn, directly affects the quality of life of the population and the social cohesion of territorial communities. Thus, the prerequisites are created for simultaneously achieving energy, social, and economic objectives.

Regarding the modernization of the energy systems of territorial communities, the authors focus on the digitalization of business processes within optimal energy system management frameworks, using modern tools for monitoring, analysis, diagnostics, and control to ensure sufficient operational and management efficiency (Kvasnii et al., 2024). The authors also examine examples of the establishment of autonomous energy regions in EU countries—Denmark, France, and Germany—highlighting their impact on the sustainable development of communities that have achieved a high level of energy independence, employment, and local business success, and have established a brand and reputation for their community.

The experience of implementing effective energy-saving models is analyzed in the article by Skorokhod and Kostiuk (2021, pp. 147–153), which focuses on the implementation of intelligent energy systems in the context of the Smart Grid concept using Smart technologies. According to the data presented in the article, more than 40 cities worldwide obtain 100% of their electricity from solar power plants, wind power, hydropower facilities, and biofuels. Among these cities, the authors mention Burlington (USA), Basel (Switzerland), and Reykjavík (Iceland).

The state of development of methodological tools for the quantitative assessment of changes in indicators of economic growth, greenhouse gas emissions, and income distribution within the system is characterized in the article by Stojkoski et al. (2023), who analyze its implementation using mathematical matrices based on data on the geographical distribution of exports of energy system products, technology patents, and scientific publications in the relevant field.

Recommendations for changing the structure of Ukraine's fuel and energy balance in the context of expanding the use of local energy resources through increased local geological exploration activities are presented in the work by Petrovets (2023).

Kohut (2023), referring to the position of the previous author, notes that the process of reforming and developing the sector requires the establishment of a favourable investment climate and a focus on long-term planning, particularly the determination of operational safety parameters for business entities, the sector as a whole, and territorial communities. The author separately examines the impact of martial law in the country in terms of its material and psychological destructiveness, the maximization of risks for investors, and the impossibility of adequately insuring the implementation of investment projects and business activities. The article presents a PEST analysis matrix reflecting the realities of key factors affecting the activities and formation of the strategic potential of Ukraine's energy system.

The matrix metrics identify economic factors (1.147), political factors (0.847), which account for the European integration vector, and technological factors (0.553), including the impact of the decarbonization process in the energy sector, as the most influential. Sociocultural factors (0.537) have a relatively smaller impact; their assessment is based, in particular, on the significance of consumer preferences in the market for shaping the development priorities of the fuel and energy complex. The author links public health, air pollution levels, and public healthcare expenditure to the outcomes of restructuring energy supply systems in favour of energy decentralization and distributed generation. This approach will enable the population and businesses to exercise greater control over the quality and cost of energy consumption and strengthen their energy independence.

In assessing Ukraine's initial conditions for European integration, the author identifies Europe's high dependence on fossil fuels and the volatility of energy resource markets, as well as the pressure these factors exert on the competitiveness of economies. For Ukraine, which had lost a significant share of its generation capacity and infrastructure due to shelling, these issues are of critical importance, with losses amounting to USD 14.6 billion as of 2024. Fossil fuel-based energy generation sources have been affected: direct losses in thermal power generation amounted to USD 5.4 billion, while losses related to hydroelectric power plants and pumped-storage power plants amounted to USD 82.5 billion. Approximately 13% of solar generation capacity remained in occupied territories, while 8% was damaged or destroyed. As a result of destruction or loss in occupied territories, the wind power generation system lost up to 80% of its production assets (Kohut, 2023).

In June 2024, at the Ukraine Recovery Conference in Berlin, the following estimates were announced by Ukraine's energy system partners:

- United States of America – USD 824 million to support energy infrastructure;
- World Bank – an additional grant of USD 47 million for the procurement of heating equipment for Kharkiv, including 1,000 generators and solar panels;
- European Union – initiation of solar panel supplies;
- Germany – EUR 30 million to improve the reliability of the energy system (UkraineInvest, 2024).

The conference also presented a new strategy for the development of Ukraine's energy system through 2050, which envisages increasing wind power generation capacity to 140 GW, solar power generation capacity to 94 GW, energy storage capacity to 38 GW, nuclear power generation capacity to 30 GW, combined heat and power plants (CHP) and bioenergy capacity to 18 GW, and hydropower generation capacity to 9 GW. According to estimates based on the TIMES model, this programme requires USD 383 billion in direct capital investment (Ministry of Energy of Ukraine, 2023).

## **2. Theoretical model for managing the process of establishing the target level of economic security in economic activity within Ukraine's energy system**

The theoretical model for the formation and management of a system's state, taking into account the requirements for ensuring a certain level of economic security, is based on the conceptual consistency of definitions, indicators, and criteria in accordance with the currently accepted paradigm of managing financial and economic activities, both at the level of an individual business unit and that of integrated systemic entities.

By systematizing scholars' theoretical approaches to defining the essence of the concept of "economic security," common features of their academic positions can be identified. Thus, Kuzenko and Sablina (2020, p. 13) interpret economic security as a state of efficient resource utilization, defining it in terms of the level of effective use of financial and material assets, as well as market opportunities, which helps prevent internal and external threats and ensures stable market growth in accordance with established objectives. Zubko (2021, p. 17) adopts a similar position, considering the economic security of a business entity to be the systemic operation of a mechanism for the effective mobilization and management of a company's corporate assets, aimed at maximizing their utilization to ensure its stable operation and ability to counteract any negative factors that may affect the economic security of the business entity.

Melikhova (2018, p. 24) brings together approaches based on the criterion of "economic security as a state of protection," considering the economic security of an economic system to be a process-based substance. She characterizes the concept as the effective management of a security service with functions that guarantee the sustained security of operational activities and help preserve an organization's economic independence in the face of external challenges, ensure rapid adaptation to new market conditions, minimize undesirable consequences, and optimize the management of enterprise resources to achieve strategic objectives.

Alkema et al. (2019, p. 22) interpret economic security as a comprehensive, multi-stage hierarchical system with a complex structure that ensures the security of business processes through the efficient use of an enterprise's economic potential and is aimed at preventing internal and external threats. This system is implemented through a set of specialized legal, economic, and organizational measures. Marchenko (2022, p. 57) also emphasizes the systemic and process-based nature of economic security, viewing it as a set of management processes aimed at ensuring an enterprise's stability and protection from adverse internal and external environmental factors throughout its entire operational cycle. The author further specifies the concept as a comprehensive management process that ensures the continuous development of an enterprise and affects the efficiency of its economic activities in both the short and long term.

An in-depth definition of the essence of economic security as a state of comprehensive business activity is presented in the study by Sytnyk et al. (2019). The authors consider it a distinct function that is shaped by the influence of various factors and ensures stable development, financial reliability, the country's competitiveness, and public well-being. In subsequent studies, this approach is further specified with regard to the functioning of individual business entities.

In general, the above definitions consider economic security in terms of a set of means and mechanisms for ensuring a state of an economic system in which it meets established criteria for economic protection against the adverse effects of external and internal environmental factors. This state characterizes an economic system's ability to function stably and achieve established objectives under normal business conditions.

Different approaches share the fundamental characteristics of the state of economic security in business activity, namely, financial stability and an active investment position in pursuing development through innovative ideas for technological modernization and environmental sustainability, while taking into account the requirements of the regulatory environment at both the regional and national levels.

However, further discussion and development of this issue require the search for a universal theoretical construct and its adaptation to specific industry contexts. It is indisputable that the key consideration in this search is the understanding that the economic security of an economic system is not an end in itself; rather, it is a tool and a means of harmonizing the interests of all components involved in interactions with the external environment, including counterparties and business partners, local and national institutions, as well as those within the internal sphere, such as employees.

At the top of the pyramid of an economic system's interests are economic interests, which reflect efforts to achieve high product competitiveness and a secure market position, sustainable marketing prospects, an optimal pricing policy, rational expenditure, and a sufficient level of profitability with minimal risks.

The social interests of an economic system within the framework of security guarantees include providing jobs, ensuring that employees' competencies meet job requirements, maintaining a rational intensity of their utilization, establishing a justified level of remuneration while complying with social protection standards and ensuring high discipline in their implementation, providing a social benefits package, offering opportunities for professional growth, and so forth.

Political interests within the security framework of an economic system's activities are manifested in its alignment with the principles, methods, and business ideology of public administration in the country.

An important component of the spectrum of interests of a business entity and its interaction environment is environmental interests, which are

associated with the economic assessment of and issues related to environmental protection. These are addressed through autonomous investments, compensatory sanctions for pollution incidents, and other economic mechanisms within the modern management paradigm.

The range of interests of agents within the interaction environment of an entity, whether operating as an individual or a consolidated economic system, can be significantly expanded depending on the specific industry and subject area of its activities. These include, in particular, attributed, compulsory, global, and strategic interests, among others.

The nature, sources, and intensity of threats and hazards capable of impeding the realization of economic interests and undermining the stability of an economic system's functioning are identified in accordance with the substance of those interests.

This theoretical position reveals the multifaceted nature of the model for managing the establishment and maintenance of the stability of an economic system's economic security. Under the general approach, the model is structured into functional blocks that determine the specific features of the methodological basis for assessment and the instruments of influence. This approach to management organization makes it possible to rationalize expenditure significantly and improve the quality of decision implementation through greater performance and efficiency.

It is clear that the economic system's industry affiliation significantly modifies the content of these components while preserving the basic configuration of the overall structure and general assessments. The decomposition of the business entity's operational security system is presented in *Figure 1*:

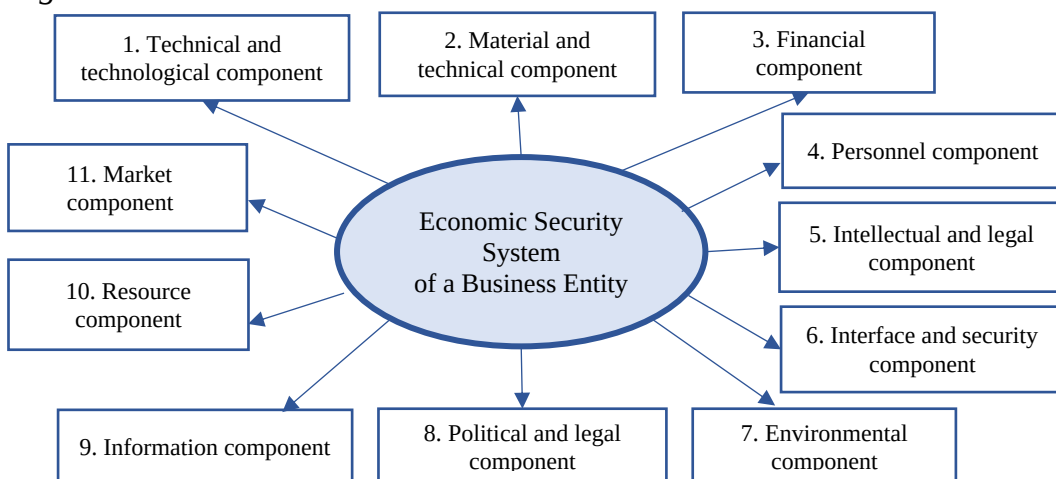


Figure 1. Components of the economic security system of a business entity

Source: compiled based on (Zubko, 2022, pp. 277–278).

The practice of managing the establishment and maintenance of economic security within accepted criteria is based on a generally recognized theoretical model for the scientific substantiation of relevant management

mechanisms, as well as on established methodological principles and methodological approaches to identifying and assessing its parameters.

At the current stage, scientific generalizations of various approaches are systematized into the following groups according to the similarity of the tools used for their implementation: indicator-based (threshold), resource-functional, program-target (comprehensive), risk-dependent, investment-profitability, and economic-mathematical approaches, which are used in assessment procedures based on the corresponding methods. The methodological toolkit for assessing an enterprise's level of economic security includes integral assessment methods, functional dependence methods, the indicator-based method, point-based assessment methods (the rating approach), hierarchical levels of economic security, the graphical method, and fuzzy logic theory.

The system of assessment parameters requires information support based on publicly available financial and statistical reporting (SRM, BAS ERP, IT-Enterprise, Debet Plus, Prozorro, Prozorro Market, YouControl). For internal analysis, management accounting data are used. The structuring and calculation of derived indicators depend on the assessment methodology adopted by the analyst, which is substantiated by the specific methodological approach.

The universality of theoretical generalizations and approaches to information support for the processes of managing the establishment of an economic security system, structured around dominant functional blocks, abstracts the analytical field from industry-specific characteristics. However, it makes it possible to account for the industry-specific features of an economic system in matrices of criteria and indicator weighting scales, and to influence them through operational interventions and adjustments to long-term objectives.

The theoretical model for managing the process of ensuring an appropriate level of economic security for an economic system is generally suitable for application under extraordinary operating conditions, which characterize the current situation in Ukraine as a result of the full-scale invasion by the Russian Federation. The specific features of this period require the inclusion of crisis management tools in the overall management response framework, reflecting changes in criteria, metrics for assessing parameters, resource support, and so forth. Under these conditions, the role of risk management, an optimization-based approach to resource provision management, personnel management, the integration of innovation into technological solutions, and an organizational and economic mechanism for responding promptly to crisis events becomes increasingly important.

It is under precisely these conditions that Ukraine's energy sector currently operates. As a result of intensive Russian shelling, it is no longer in a state of crisis but has reached a critical state characterized by property losses and a high probability of economic collapse. The severity of the situation is classified not according to the economic security criteria

applicable to the business entities integrated into the system, but according to the parameters of technical and, subsequently, economic survival, although these aspects constitute a single whole and are inextricably interdependent. Current assessments of the situation are framed in terms of energy security as a fundamental component of Ukraine's national security. In recent years, Ukraine has intensified its participation in the European integration process, combining efforts to restore capacity across all sectors of the energy industry with its reform, modernization, upgrading of resource provision, and alignment with the operational standards of the integrated European energy system according to comparable parameters of progressiveness and economic and technological security.

### **3. European integration within the system of strategic objectives and factors for strengthening the economic security potential of Ukraine's energy system**

The security of Ukraine's energy system is not an additive characteristic of its state, as it comprises not only the parameters of individual elements but also has a synergistic nature of formation, as well as macro-economic assessments and areas of intervention that involve a high degree of state regulation against the backdrop of achieving an energy balance and an independent level of energy resilience within the framework of national security strategy and policy. This approach is not exclusive; it is applicable not only to countries with advanced economies. During structural economic and political shifts toward integration, the initiators and implementers examine and ensure the comparability of project configurations both in terms of their individual components and as a whole, particularly in energy integration models.

This is precisely the task facing Ukraine in the process of European integration under the challenging conditions of almost four years of destruction of national assets, particularly in the energy sector.

An in-depth, comprehensive analysis of all the characteristics of Ukraine's energy system is carried out on an ongoing basis and incorporated into established model templates to ensure continuous monitoring of the system's economic security margin as it seeks to become part of the established European energy framework. This analysis covers structural features and the proportions of business entities of various legal forms and ownership types; the presence or absence of monopolistic distortions in different energy market sectors; the degree of market liberalization and efficiency; the state of market participants' market valuation, including their investment value; and the calculation of key indicators of the resilience of financial and economic activities at the level of individual enterprises and the integrated system. These processes are reflected in the conclusions and recommendations of A Competitiveness Strategy for Europe (2024), as well as in investment support plans for the development of green energy in Ukraine,

particularly solar and wind power, and for increasing renewable energy capacity while reducing the share of coal and other energy resources used in energy complexes that generate greenhouse gas emissions. For comparison, according to WindEurope (2024) and SolarPower Europe (2024), in 2023–2024, wind power accounted for approximately 17–18% of electricity generation in the European Union, while solar power accounted for approximately 9–10%, representing the highest growth rates among renewable energy sources. Hydropower accounted for only 12–13% of electricity generation, nuclear power for 22–23%, and other sources (bioenergy, coal, gas, oil, etc.) collectively accounted for approximately 27–30% of the integrated energy mix (Ember, 2024).

The differences between Ukraine's and the EU's approaches to energy balance formation are outlined in Investment Opportunities of the Energy Sector (*Figure 2*).

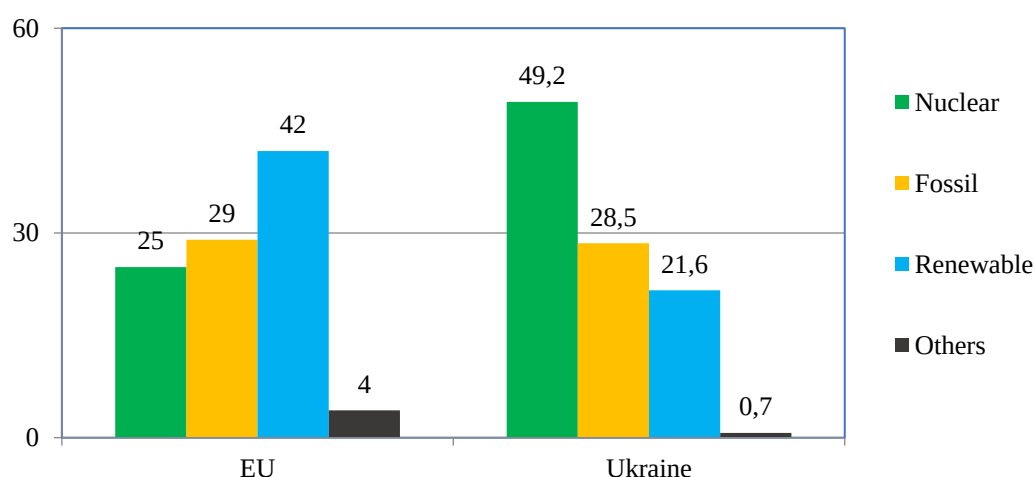


Figure 2. Energy sources in Europe and Ukraine, %, 2023

Source: compiled based on (Investment Opportunities of the Energy Sector, 2024).

While Ukraine continues to prioritize its dependence on nuclear power (49.2%), the EU is pursuing a strategy aimed at minimizing such dependence. At the time of the study, nuclear power accounted for 25% of the total energy sources. The use of fossil fuels in the systems being compared was almost identical: 29% in the EU and 28.5% in Ukraine. Moreover, the EU significantly outperformed Ukraine in the use of renewable energy sources, accounting for 42% compared with 21.6% in Ukraine. In Ukraine, other sources (0.7%) were not included among the actively utilized sources, whereas in the energy balance of the EU's integrated energy system, they accounted for 4%.

Clearly, Ukraine's European integration strategy should provide for the reform of the national energy system along development vectors aligned with the EU's development priorities and criteria for system compatibility, thereby enabling its full integration while preserving the resilience of the

established overall balance and the economic security margin of this complex integrated energy system.

In addition to technological analysis, a key component of studying the integration of Ukraine's energy system is the comparative analysis of the organizational and economic mechanisms governing its operation. Despite the similar broad structural composition of the EU and Ukrainian energy systems – comprising the generation, distribution, and supply of energy resources – their proportions in terms of activity volumes differ. Thus, according to Ember (2024), Eurostat, and the IEA, in 2024–2025, the EU electricity sector consisted of generation, accounting for 60% (€ 480–550 billion); distribution and transmission, accounting for 20% (€ 170–220 billion); and supply, accounting for 20% (€ 180–230 billion). In Ukraine, the corresponding proportions were 65% for generation (UAH 210–260 billion), 20% for transmission and distribution (UAH 70–95 billion), and 15% for supply (UAH 55–75 billion).

Among the factors influencing the achievement of system comparability, the structural characteristics of business entities' presence in the "energy resource production – supply" chain should be noted in terms of their legal and organizational forms and types of ownership. For example, according to Eurostat, ENTSO-E, and European Commission reports (2023–2024), in the EU, up to 65% of enterprises operating in electricity generation and supply are joint-stock companies, 25% are business companies, and 15% represent other forms of business organization, including specialized associations such as concerns, associations, and conglomerates established on a statutory or contractual basis. Thus, the overwhelming majority of the sector belongs to joint-stock and corporate structures, while state-owned or collective forms are less prevalent and often take the form of large national or transnational concerns. Ukraine is characterized by the significant market shares of major producers, with Energoatom accounting for 50%, and energy traders such as DTEK, accounting for 45%, which hold near-monopolistic positions in Ukraine's energy market. The remaining market participants (small private generators and renewable energy enterprises) account for only a limited share, approximately 10–15% of total electricity generation (IEA – Electricity Generation by Source, Ukraine, 2025). Thus, DTEK is effectively the largest private player in Ukraine's electricity market, alongside the state-owned Energoatom, which dominates the nuclear sector, accounting for approximately 50% of electricity generation.

Among the factors that have a decisive influence on the fundamental economic principles governing the activities of energy system enterprises are the mechanism of state regulation, the degree of liberalization of the energy market, and market players' freedom to choose the type and content of their pricing policies based on an assessment of interactions among the main market elements and market conditions along actual and projected trajectories of change.

The EU market is characterized by the formation of prices for energy products and services in accordance with objective trends in supply and demand, taking into account speculative market fluctuations. EU Member States address issues of social protection for the population without removing them from market mechanisms. In Ukraine, however, state regulation of energy resource prices for end consumers remains in place, while the performance of all system components is assessed according to the reverse principle. Existing cooperation with the EU energy system through critical energy imports has exacerbated this imbalance, creating a crisis situation for energy traders unless state support is provided or tariff scales for domestic energy consumption are adjusted (A Competitiveness Strategy for Europe, 2024; IEA – Electricity Market Report: Ukraine, 2024).

Green energy tariffs are not comparable. In Ukraine, they are the highest in Europe (until 2030), making the development of this energy source unattractive for business investment. In addition, a factor reducing the quality of Ukraine's energy system operations and development is relatively poor payment discipline at all stages of financial logistics. Extensive chains of non-payments are reflected in all parameters of the economic security models of market participants, further reducing assessments of the system's attractiveness for investment and its suitability for integration into the unified energy complex.

The assessment tools adopted in analytical practice for determining the level of economic security of a business entity or an integrated economic system are based on financial performance indicators and their dynamics over the period under study. These include indicators of solvency, business activity, financial independence, creditworthiness, and others, as well as the relationships between individual performance characteristics, particularly the rates of change in revenue and assets based on their market valuation.

The analytical framework also incorporates performance results relating to the production and technical, intellectual and human resources, and commercial components within the current and tactical reporting periods. The specific set of indicators is determined with due consideration of the strategic aspects of operations, namely market-related, social, and innovation and technology-related aspects. The comparability of indicators is ensured through the application of international accounting standards and management accounting models commonly used in Ukraine.

Despite substantial technical assistance not only in preserving, restoring, and developing Ukraine's energy system assets according to critical priorities and requirements, the European integration process will acquire a multifaceted scope and high intensity as the country achieves maximum comparability in its economic and organizational operating mechanisms, the technological base for energy product generation, and the delivery of energy products and services to end consumers, as well as consistency in approaches to assessing the level of economic security as a component of national security as a whole.

Achieving adequate values for the economic security indicators of Ukraine's energy system is a prerequisite for its European integration as a worthy member of the European energy community. Conversely, the European integration of Ukraine's energy system is a well-founded strategic decision and a means of strengthening its economic security potential.

### Conclusions

The study entitled "Economic Security of Ukraine's Energy System under Martial Law and European Integration" established that Ukraine's energy system is a key factor in ensuring economic and national security, while its level of resilience directly determines the stability of the national economy. It was also substantiated that European integration creates institutional and economic prerequisites for the recovery and modernization of the energy system on a modern technical and technological basis, while an increase in the level of economic security serves as a driver of integration processes.

It was demonstrated that, under martial law, energy system management is shifting towards crisis management, which requires the adaptation of methodological tools for assessing economic security. Despite infrastructure losses, Ukraine's energy system retains significant production potential and ensures gradual integration into the European energy space.

The study substantiated approaches to developing an assessment model of the economic security of the energy system, taking into account wartime challenges and European integration processes, as well as the expediency of applying crisis management methods and drawing on European experience.

The interdependence between the level of economic security of the energy system and the effectiveness of European integration was established: achieving appropriate security parameters is a prerequisite for integration, while integration is a factor in strengthening these parameters, thereby confirming the proposed hypothesis.

Prospects for further research are associated with the development of optimization models for ensuring the economic security of Ukraine's energy system, taking European standards into account and focusing on achieving a synergistic effect.

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