POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2024 ✦ Volume 27 ✦ Issue 4 ✦ 133–154

DOI: 10.33223/epj/190485

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# Energy security management in the context of current challenges and international experience

Abstract: The research relevance is determined by the constant changes in the global energy landscape and the negative impact of the Russian-Ukrainian war on the energy market. The study aims to formulate recommendations for optimising national strategies and policies in the field of energy security based on the analysis of global experience as well as Ukraine's specific challenges and practices in managing this area. The study used analytical, functional, statistical, synthesis, and other methods. The study of energy security has become key to understanding current challenges and promoting the resilience of national energy systems. This study examines the practice of other countries in the field of energy conservation. The use of renewable energy sources in the energy systems of some countries was assessed. The findings point to the need to focus on the development of renewable energy sources and regulatory policies to ensure market stability. International cooperation is identified as a key success factor in energy security management. The study emphasizes the need for continuous monitoring and adaptation of strategies to effectively respond to growing energy challenges. A detailed analysis of best practices shows the need to implement

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strategies that include the development of renewable energy sources, infrastructure modernization, and the search for innovative solutions. Implementation of the proposed measures will help to increase the resilience of the country's energy system, reduce dependence on imports, and promote sustainable economic development. The results of the study can be used to develop and optimize energy security management strategies, contributing to the country's resilience, competitiveness, and sustainable development.

Keywords: energy security, governance, challenges, renewable energy sources, Russian-Ukrainian war, sustainable development

## Introduction

Today's challenges necessitate effective energy security management, especially in the context of Russia's war against Ukraine and its impact on the energy market. Ukraine's fuel and energy complex is a dynamic system with interconnections between sectors, combining the electricity and fuel industries, including coal, peat, shale, oil, and gas. When developing energy security management strategies, it is important to understand the organization of Ukraine's fuel and energy sector, consider its potential, and identify possible risks. Understanding the principles of energy security management plays an important role in guaranteeing the security of energy supply, reducing dependence on external sources, and addressing environmental and economic challenges. The study of this topic will not only broaden the understanding of the problems of the modern energy sector but also provide specific tools for improving energy security management strategies at different levels (national and global).

The study is driven by the need to adapt current strategies to changing energy conditions and several challenges. Observations of the global energy market, the diversity of energy sources, technological innovations, and challenges for the energy system identify issues that require careful scientific analysis. The tasks to ensure the efficient functioning of the energy system include the introduction of renewable energy sources, balanced use of various sources, improvement of energy efficiency, and ensuring the stability of energy supply in the context of geopolitical instability. The study aims to address these issues to develop effective management strategies that incorporate current trends and requirements of the modern energy sector.

Effective energy security management is based on several key principles. First, diversifying energy sources by increasing the use of renewable energy sources such as solar, wind and bioenergy reduces dependence on fossil fuels, contributing to sustainable development. Second, international cooperation through technology sharing and joint projects allows countries to jointly address global energy challenges, particularly climate change. Third, regulatory policies are crucial to ensure market transparency and competitiveness and encourage investment in new technologies and infrastructure modernization. Finally, continuous monitoring and adaptable strategies ensure a proactive response to the changing global energy landscape and emerging

challenges. Together, these principles strengthen energy security by enhancing resilience, stability, and global cooperation in energy governance.

Improving energy security management strategies implies the use of special tools adapted to different levels of governance. At the national level, this includes the introduction of renewable energy technologies, energy efficiency improvements, and innovative methods of energy production and storage. The modernization of energy infrastructure and the introduction of smart grid technologies are also necessary, along with the development of demand response programs and flexible electricity pricing for efficient consumption management. Active public involvement in strategy development and implementation facilitates broader support and participation. At the international level, countries are improving energy security by participating in initiatives such as those of the International Energy Agency, cooperating in joint technology transfer projects, and harmonising standards and regulations. Alignment with global agreements, such as the Paris Agreement on climate change, also ensures the coordination of efforts to promote sustainable energy practices. At all levels, investment in research and the development of new energy technologies, the use of data analytics and modern ICT systems for effective management, and contingency planning for disaster resilience are critical. Diversifying sources of supply and building robust energy trading partnerships further strengthen comprehensive energy security strategies.

According to the results of recent studies, Shchurov (2022) emphasizes that the instability of the global energy landscape poses significant challenges for energy security management. In particular, there is a constant need to adapt energy systems to changing conditions and ensure their effective functioning. However, it is worth noting that the study does not consider the impact of cyber threats, which are becoming significant in the current technological environment and may affect energy security. Vashchenko and Pobochenko (2022) highlight the importance of promoting renewable energy sources and improving infrastructure to increase the productivity of energy systems. The authors emphasize the need for strategic planning and innovative technologies in these areas. However, the authors limit themselves to aspects of technical development without considering the social and economic dimensions of energy security management, which may affect overall strategic effectiveness.

Prokhorova (2023) identified the analytical method as a key tool for analysing energy security management strategies. The author highlights the importance of this method in considering and formulating effective strategies to ensure the sustainability of energy systems. It is worth noting that this study does not consider the role of the public and civil society in shaping energy strategies, which may affect their adoption and implementation. Lunyov (2023) emphasizes the effect of geopolitical instability when developing strategies to ensure energy sustainability. Analysis of the political environment is a necessary element in managing energy security and formulating appropriate measures. However, it should be noted that the researcher ignores the impact of climate change on energy security, which is an important aspect, especially in the context of growing environmental concerns, increased attention to the development of renewable energy sources, and reduced dependence on coal and other polluting sources, which is becoming increasingly important in the context of global climate change and its consequences for the energy system.

Kraus et al. (2023) emphasize that energy solutions require not only a focus on innovative technologies but also the consideration of the impact of geopolitical conflicts on energy security and the development of strategies to overcome them to ensure the sustainability and efficiency of the energy sector. However, it should be noted that the paper does not address the importance of the international community joining forces to jointly address energy challenges. Samoilyk et al. (2022) consider the implementation of integrated strategies as a way to ensure a stable and efficient energy supply. The combination of different approaches and coordination of different aspects of the energy system can help to optimize and improve its performance. However, this study does not address the regulatory and legal environment in the context of implementing integrated energy security management strategies, which may determine their success.

In the context of studying the global experience of energy security management, we note that, Honcharov et al. (2023) analyze the level of innovativeness of world economies and Ukraine's position in international rankings. The authors propose a scientific and methodological approach to forecasting the innovativeness of economic development and argue that to increase the level of innovation of the national economy and strengthen its competitive position, it is necessary to significantly intensify innovation activities in Ukraine. The publication of M. Dykha and V. Dykha (2023) investigated the problems of the energy sector functioning in the context of war and outlined the measures necessary to ensure Ukraine's energy security.

The study aims to address Ukraine-centric issues by analysing global best practices and formulating tailored recommendations to develop effective, adaptive management strategies. These can incorporate current energy trends while being appropriately customised to Ukraine's unique wartime requirements of restoring damaged infrastructure, securing energy independence, and reactivating economic growth on a sustainable footing.

## 1. Materials and methods

The analytical method was used to scrutinize energy trends, identify key factors affecting energy security, and scrutinize sector development strategies. It involved decomposing complex issues into component parts, examining the nature, role, and interdependence of each part through deconstructive reasoning. This systemic analysis allowed us to draw valid conclusions and formulate recommendations to address the multifaceted challenges of energy security management, efficiency and long-term sustainability of energy systems. Statistical methods provided objective quantitative data and numerical indicators, which facilitated a detailed study of energy efficiency indicators and the identification of patterns in energy consumption and production profiles in different sectors and regions.

Statistical methods such as regression analysis, forecasting, and probability distribution models were applied to historical data sets. This empirical analysis helped to quantify the impact of various energy policies and technology interventions aimed at improving energy security. It also

allowed for the development of optimal strategies for the efficient use of available energy resources based on predictive modeling. The method of induction involves the study of case studies and examples to derive general principles of the behaviour and functioning of energy systems. By analysing the results of different policies, technological implementations, and management approaches adopted in different contexts, the method of induction reveals fundamental relationships and natural patterns. The insights gained from such bottom-up reasoning contributed to the formulation of general guidelines for energy security management strategies and helped to anticipate potential system-level impacts.

Deduction played a supporting role in extrapolating specific recommendations and future scenarios based on overarching theories, general principles, and empirical data on energy system dynamics. Through logical reasoning based on comprehensive conceptual frameworks and analysis of real-world observations, this top-down approach helped to identify the root causes underlying energy security challenges and develop targeted measures to effectively address them. The functional method systematically examined the objectives and main functions that energy systems are designed to fulfill. It identifies the various components, their roles, and the mechanisms governing their integration to achieve desired outcomes, such as meeting energy demand reliably and efficiently. Using this approach allowed the identification of areas requiring strategic intervention and the development of holistic solutions optimised for the overarching functional requirements of energy security.

The benchmarking method allowed the comparison of strategies, policies, and on-the-ground results related to energy security management in different countries and contexts. It involved structured cross-comparisons based on relevant variables such as energy mix, regulations, technology deployment, and socio-economic factors. This benchmarking of international best practices provided insight into what works well and what does not work well in different contexts. The comparative assessment served as a basis for developing specific recommendations that take into account Ukraine's specific national realities. Finally, the synthesis method combined the results obtained through the above methods into a coherent, multifaceted strategy to strengthen Ukraine's capacity to manage energy security. It combined complementary solutions on technological, regulatory, economic, and institutional aspects into a holistic, coordinated model to maximize their synergistic impact. The synthesis ensured that the proposed strategy comprehensively addressed the interrelated aspects of energy security, from renewable energy deployment and grid modernization to market reforms and international cooperation. The annual reports of the European Electricity Review (2024), which provide detailed sectoral data on renewable energy trends in the EU, were used as inputs, and also the Order of the Cabinet of Ministers of Ukraine No. 373-R "On the approval of the Energy Strategy of Ukraine for the period up to 2050" (2023) which provides new strategy at restoring Ukraine's energy sector. These authoritative sources enabled comparative analysis and benchmarking of Ukraine's energy landscape against global developments.

## 2. Results

In today's world of growing population, changing climatic conditions, and increasing energy dependence, the development of an effective and sustainable energy strategy is becoming a priority for countries. Ukraine, like many other countries, faces an urgent need to implement new strategies aimed at ensuring energy security, conserving resources, and reducing the negative impact on the environment. Given the constant Russian missile and drone attacks targeting Ukraine's energy infrastructure, there is an urgent need to develop robust strategies for restoring and sustaining the energy sector's supply capabilities.

The Order of the Cabinet of Ministers of Ukraine No. 373-R "On the approval of the Energy Strategy of Ukraine for the period up to 2050" (2023) replaced the outdated strategy. This step demonstrates the importance of adapting to modern challenges and needs. The new strategy defines comprehensive measures aimed at restoring Ukraine's energy sector. It envisages the development of renewable energy sources, energy efficiency, infrastructure modernization and the development of energy technologies. One of the key aspects of the new strategy is the ability to adapt to rapidly changing conditions in the international energy market. Ukraine seeks to maintain its competitiveness by developing modern technologies and attracting investments in the energy sector. The strategy also addresses the need to ensure the country's energy security. Reducing dependence on imported energy resources and developing domestic energy sources will help Ukraine ensure stability and independence in the energy sector.

The outbreak of the Russian full-scale invasion of Ukraine had geopolitical consequences and significant changes in the country's energy sector. The challenges posed by the war have brought about important changes in energy strategies and structures and identified new opportunities for Ukraine (Matiychuk 2023). One of the main transformations has been Ukraine's desire for energy self-sufficiency and independence from Russian supplies. Various measures, such as expanding the use of renewable energy sources, improving energy efficiency, and diversifying sources of supply, have become priorities. Ukraine is actively developing its domestic energy potential, including gas production and nuclear energy development. However, the war has also caused great stress on the energy infrastructure. Damage to energy facilities and infrastructure has posed a major challenge to restoring and modernising systems. However, these difficulties have also contributed to the wider adoption of new technologies and increased resilience of energy networks. The development of energy scenarios in wartime requires active cooperation with international partners and the introduction of transformational policies. In particular, Ukraine is cooperating with the EU to integrate its energy space and adapt to European standards and regulations.

In March 2022, a historic event took place for Ukraine, with the synchronization of its power system with the European Energy Association ENTSO-E (Integration into the European… 2022). This step defined a new stage for the country's energy sector, recognised as a strategic step to strengthen energy independence and increase system resilience. The transition to physical interconnection with ENTSO-E was an important step for Ukraine for several key reasons. It al-

lows the country to integrate into European energy markets, creating opportunities for mutually beneficial energy exchange and increased resource efficiency. Reducing energy isolation will increase the security of supply and reduce vulnerability to possible disruptions in domestic production. Synchronization allows Ukraine to actively participate in European energy policy and standardization, contributing to the quality and security of its energy supply. Alignment with European norms requires improvements in the infrastructure and management of the power system, which in turn contributes to modernization and competitiveness. The physical interconnection of Ukraine's power system with ENTSO-E underscores the country's choice to take an active role in Europe's common energy space and confirms its commitment to the values and standards adopted by its European partners.

In a time of war, the role of energy is not only determined by the supply of electricity but also by the key factor for national security and sustainable development. Ukraine is proving to be a dynamic player, actively adapting to new conditions, and developing strategies to effectively manage its energy future. At the current stage of the evolution of the EU energy sector, there is a significant dependence on energy imports due to a limited number of large suppliers, fluctuations in energy prices, and an increased risk of energy supply security (Rodriguez-Fernandez et al. 2022). The economic state of countries and the welfare of their populations are closely linked to the availability of fuel and energy resources and the efficiency of their use. Each country is looking for ways to overcome energy challenges by introducing significant changes in the structure of its energy base by reorienting to alternative sources. Figure 1 summarizes the key indicators of long-term energy strategies in some countries around the world. Following their official strategies, this forecast shows how the share of renewable energy sources in gross final energy consumption may change over time in different countries from 2005 to 2028.

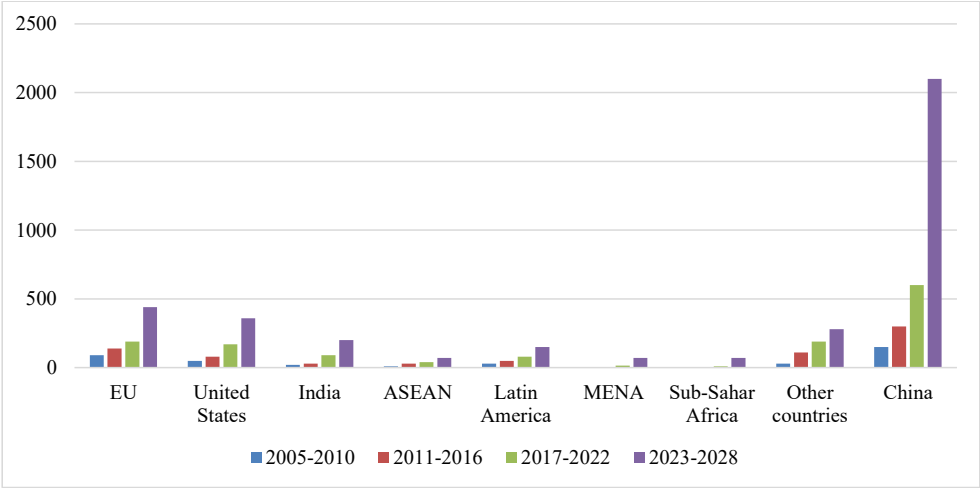


Fig. 1. Share of renewable energy sources in total final energy consumption in several countries
Source: compiled by the authors based on Renewables 2023: Analysis and forecasts to 2028 (2024)

Rys. 1. Udział odnawialnych źródeł energii w całkowitym końcowym zużyciu energii w poszczególnych krajach

European Electricity Review (2024) has published its annual report on the state of the EU electricity industry. This report reflects the latest trends and achievements in the development of the EU electricity sector, in particular regarding the increasing share of renewable energy sources. energy sources, reducing greenhouse gas emissions, and achieving energy efficiency goals. Such an analysis of the EU electricity sector is important for understanding energy trends and developing strategies for further development of the energy sector in the EU. Information on the share of European countries in the global energy system is presented in Figure 2.

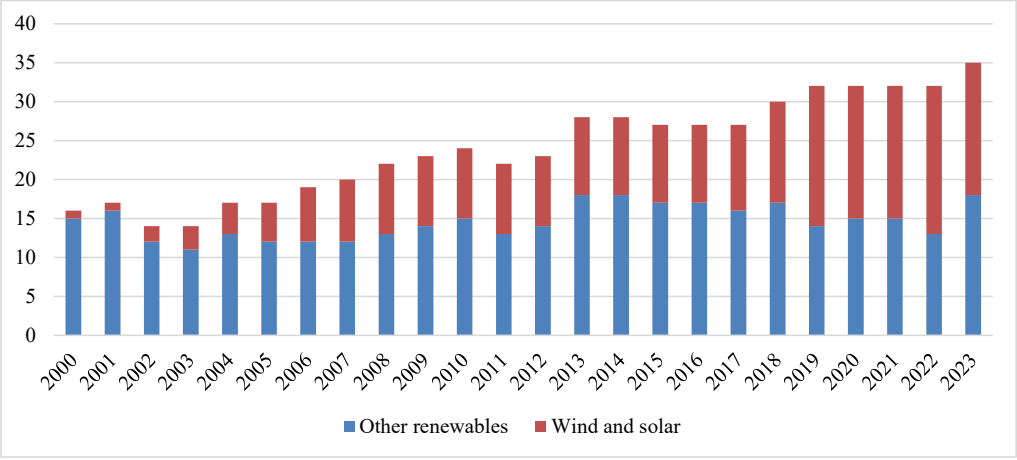


Fig. 2. Share of renewable energy sources in gross final energy consumption in some European countries
Source: compiled by the authors based on European Electricity Review (2024)

Rys. 2. Udział odnawialnych źródeł energii w końcowym zużyciu energii brutto w wybranych krajach europejskich

The distribution of primary energy use is determined by the balance between traditional and innovative sources, as well as economic and environmental factors. Ensuring a sustainable and efficient distribution requires a comprehensive approach that combines technological innovation, renewable energy development, and international cooperation to achieve energy sustainability and balanced development. Significant improvements in energy efficiency and energy conservation mean that the EU's projected energy demand is expected to decrease by around 40% by 2050. Total energy consumption is measured in millions of tons of oil equivalent (Fig. 3).

Energy security management is one of the key components of modern global governance, as energy determines the development of countries and international relations (Dzhejula 2022). Today, the world is facing various challenges that require comprehensive management strategies based on international experience and cooperation. These challenges range from climate change to geopolitical tensions. However, thanks to the experience gained and innovations in energy security governance, it is possible to find effective solutions that promote sustainable development and energy security. One of the main challenges facing energy security management is the need to reduce dependence on hydrocarbons and other non-renewable energy sources. Climate

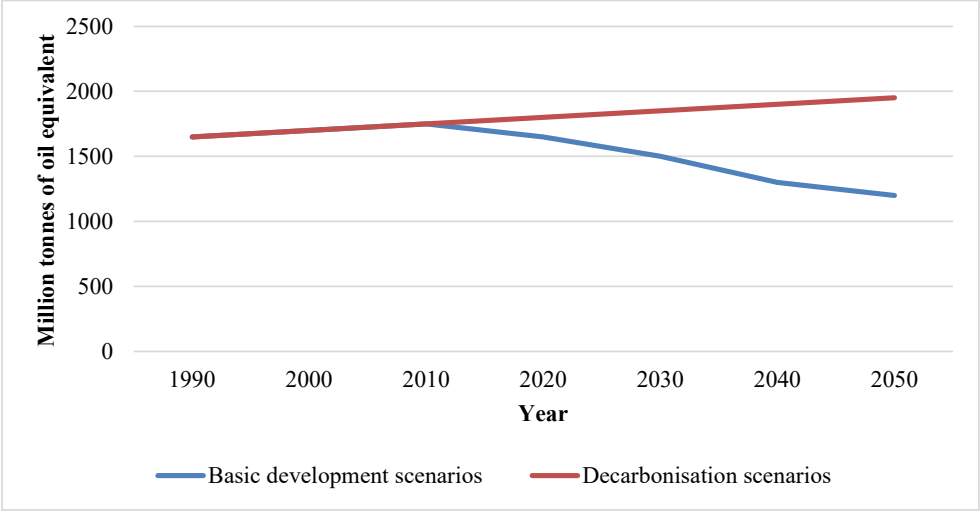


Fig. 3. Dynamics of total energy consumption in the EU, considering the Energy Development Plan until 2050 proposed by the European Commission

Source: Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions (2011)

Rys. 3. Dynamika całkowitego zużycia energii w UE na podstawie Planu Rozwoju Energetycznego do roku 2050 zaproponowanego przez Komisję Europejską

change has become one of the most pressing issues of our time, and the development of alternative energy sources, such as solar, wind and hydropower, is becoming an urgent necessity. International experience shows that countries that invest heavily in renewable energy and energy efficiency ensure more sustainable economic and energy development. Another important challenge is geopolitical instability, which can be an obstacle to energy supplies. Conflicts in regions rich in energy resources can lead to supply disruptions and higher energy costs. To ensure energy security, countries should actively cooperate in developing strategies to diversify supply sources and develop alternative routes for energy delivery.

The application of international experience in energy security management allows for the development of effective strategies and mechanisms for responding to challenges. For example, the integration of countries into international energy communities, such as the International Energy Agency (IEA), allows for the exchange of experience and information on best practices in energy security management. In addition, international treaties, and agreements, such as the Paris Agreement on Climate Change, encourage countries to work together to reduce greenhouse gas emissions and develop green energy. Managing energy security in the modern world requires a comprehensive approach based on international experience and cooperation between countries. The development of alternative energy sources, diversification of supply sources, and joint efforts to reduce the impact of energy on climate change are key elements of effective energy security management.

In countries with developed industries, the bulk of electricity (approximately 80%) is generated by thermal power plants (TPPs). TPPs and nuclear power plants (NPPs) operate as base-load power plants, which ensures a stable load on the power system. Oil and natural gas play a significant role in the energy complex of most EU countries, which are mainly imported but also partially produced in the region (North Sea). TPPs play an important role in electricity generation and are one of the key elements of the energy infrastructure, and their technical and economic aspects should be carefully considered. TPPs in Ukraine and abroad have several advantages that support their efficiency in electricity generation (Bandura et al. 2023). Ukraine has a well-developed thermal power sector, which ensures a steady supply of electricity. One of the key advantages of thermal power plants is their high efficiency in converting thermal energy into electricity. This provides efficient use of various fuels, making TPPs versatile and adaptable to different operating conditions. For instance, thermal power plants are an important element of the energy systems of countries such as China, the United States and India. In China, which is the world's largest electricity producer, TPPs play a key role in ensuring energy stability and peak load balancing. In the United States and India, where a large share of electricity is generated using coal, TPPs are an important element of the energy security strategy and the resilience of the energy networks. This distribution demonstrates the versatility of TPPs in different countries, where they are used for a variety of tasks, contributing to efficient electricity generation and ensuring the reliable operation of energy systems.

A nuclear power plant is a technologically complex energy facility that uses nuclear fuel to generate thermal energy, which is then converted into electricity. The main element of a nuclear power plant is a nuclear reactor, where a controlled atomic fission reaction takes place, resulting in a significant amount of heat. Nuclear energy is essential in the context of efficiency and sustainability. Nuclear power plants define the energy landscape of several countries that make good use of nuclear energy (Dzhezhula and Finik 2022). In the United States, the use of nuclear power is of strategic importance, and the large number of operating nuclear power plants plays a key role in ensuring the resilience of the energy system. China, by expanding its use of nuclear power, aims to ensure a sustainable energy supply for its economy and reduce greenhouse gas emissions. These examples emphasize the importance of NPPs in energy security and sustainable development strategies around the world. Thus, NPPs are an important component of the modern energy sector, providing highly efficient and environmentally friendly electricity generation.

Ukraine could use nuclear energy as a significant resource to ensure stability and independence in the energy sector. It should be emphasised that nuclear energy in Ukraine could increase generation, but several critical aspects should be considered, including the occupation of the Zaporizhzhia NPP at the beginning of the Russian full-scale invasion of Ukraine and its mining, as reported by official institutions in the media. Given the challenges and risks, it is important to look at the prospects of modern mini-nuclear power plants in the development of nuclear energy in Ukraine. Their advantages include high mobility and the ability to generate energy in different regions. This creates the potential to ensure the sustainability of the country's energy market. Modern mini-nuclear power plants, due to their compactness and high mobility, make it possible to locate them in different parts of the country, which allows for dispersed sources of

electricity and, accordingly, reduces the potential risks associated with the use of large nuclear power plants. The use of highly efficient systems and mechanisms will maximize the benefits of nuclear energy while ensuring the sustainability and safety of the energy system.

Modern mini-nuclear power plants (MNPPs) offer a transformational approach to nuclear energy development, especially in countries like Ukraine. These compact and mobile units are designed for efficient and flexible power generation, addressing the unique geographic and economic challenges facing the country. One of the key advantages of MAES is that they can be deployed in different regions, providing a decentralised energy solution. This flexibility not only increases the resilience of the power system but also reduces the risks associated with traditional large-scale nuclear power plants, such as potential catastrophic failures and the need for extensive infrastructure.

The compactness and advanced technological design of modern nuclear power plants contribute to their efficiency and safety. Using the latest systems and mechanisms, these plants can maximize nuclear power generation while minimising environmental and operational risks. Their deployment can provide a stable supply of electricity even to remote or low-income areas, supporting economic development and stability. In addition, the mobility of these plants allows them to respond quickly to energy needs and emergencies, further strengthening Ukraine's energy security. The introduction of modern IGPPs represents a strategic step towards a more sustainable, stable, and secure energy future for Ukraine.

It is worth noting that technologies to increase resource efficiency and reduce emissions are important. Wind power plants are an innovative method of electricity generation that uses wind energy to drive special turbines. In this process, the kinetic energy of the wind is converted into mechanical energy and then into electricity by generators (Stoliarov 2024). Wind power plants in Ukraine and abroad have several significant advantages that make them an important element of the modern energy landscape. By developing wind power, Ukraine actively contributes to environmental protection by reducing greenhouse gas and other pollutant emissions. This helps to achieve clean energy production and reduce environmental impact. At the same time, wind farms in Ukraine contribute to the diversification of the energy mix and the inclusion of renewable energy sources in the country's energy portfolio. This approach contributes to the sustainability of the energy system. The use of wind energy also reduces dependence on fossil fuel imports, making the country more energy self-sufficient. This is especially important in the context of strategic instability in the global energy market.

Wind farms harness wind energy to generate electricity using wind turbines that convert the kinetic energy of the wind into mechanical energy that drives generators. By utilising this renewable energy source available domestically, countries can reduce their dependence on importing fossil fuels such as oil, natural gas, or coal to generate electricity (Skuro 2018). Developing domestic wind energy resources allows countries to diversify their energy mix and increase the share of local energy sources in their total consumption. This reduces the need to import fossil fuels from other countries, increasing energy independence. Wind farms can make a significant contribution to a country's electricity needs through clean energy generated within its borders. Because wind is a renewable resource, wind energy expansion can provide a sustainable path to

greater self-sufficiency, reducing dependence on imports, which poses an energy security risk due to geopolitical instability or supply disruptions. Wind energy development is an important strategy for countries seeking to increase their energy self-sufficiency and insulate themselves from fluctuations in global fossil fuel markets.

Considering the global experience, where wind power plants are already recognised as an effective means of energy production, Germany and Denmark are examples of countries that have successfully integrated wind energy into their energy systems. Germany is a leader in the use of wind energy, and the large number of wind farms contributes to a balanced and sustainable energy supply. Denmark also has a high share of wind energy in its energy mix, improving technology and developing highly efficient wind turbines. These examples demonstrate successful strategies for implementing wind power to achieve a sustainable and diversified energy future. Overall, wind farms embody modern approaches to creating a sustainable and efficient energy system, providing clean and continuous electricity generation.

The combination of different renewable energy sources, such as wind, solar, and bioenergy, with conventional sources (gas, coal, nuclear generation) can create a diversified and sustainable energy portfolio, reducing dependence on fossil fuels and contributing to sustainable development (Sikorska et al. 2024). Supporting and creating incentives for investment in renewables should be a key element of the strategy. The introduction of technologies to improve the efficiency of energy production and consumption, such as smart grids and energy-efficient buildings, should be a priority for investment and development. The development and modernization of transport and energy infrastructure and the improvement of networks to ensure efficient and reliable energy distribution are an integral part of the energy security management strategy. Active cooperation with European partners and participation in European energy initiatives will contribute to stability and development. Participation in joint projects and technology exchange with EU countries will help improve the standards and efficiency of the energy sector.

The creation of a stable and transparent regulatory system, flexibility, and openness in interaction with businesses and other stakeholders will guarantee the efficiency and competitiveness of the market. Thus, energy security governance is a complex task, and countries must constantly adapt their strategies to new challenges and opportunities in the energy sector. The international exchange of experience and effective cooperation can contribute to the creation of stable and effective energy security management systems.

## 3. Discussion

The study highlights the need to regularly update and improve energy security management strategies as the energy landscape is constantly changing. The introduction of high-performance technologies and active exchange of experience at the international level are becoming important factors in addressing emerging energy challenges. These actions aim to ensure that strategies are

adaptable and flexible to effectively respond to the growing demands and new realities of the energy sector. International cooperation is proving to be crucial for sharing technological and strategic solutions to overcome global challenges such as climate change and geopolitical instability. Cooperation between countries in the energy sector allows for effective innovation and reduced environmental impact. Regulatory policy plays an important role in shaping transparent, competitive, and sustainable energy markets (Botnarenko and Kryzhna 2023). Establishing clear rules and standards promotes stability and attracts investment in new technologies and infrastructure.

The introduction of renewable energy sources should be emphasised, as it not only reduces emissions but also opens up new prospects for the development of modern technologies and the formation of new market sectors. The introduction of renewable energy sources contributes to the implementation of the principles of sustainable development, reduction of environmental impact, and reduction of dependence on traditional fuels. At the same time, new opportunities are created for the development and implementation of innovative technologies, as well as the development of new markets in the areas related to energy production, storage, and distribution. The integration of renewable energy sources is a key element in ensuring sustainable development and the transition to a clean energy landscape, contributing to economic growth and reducing negative environmental impact.

The modernization of energy infrastructure is crucial for several reasons. First, it helps ensure the security and reliability of the energy supply by replacing aging and outdated equipment with new, more efficient, and resilient systems. Obsolete infrastructure is more prone to breakdowns, energy losses, and vulnerability to disruptions or extreme weather events. Modernising the grid, pipelines, storage facilities, etc., reduces these risks. Second, infrastructure upgrades enable better integration of renewable energy sources like wind and solar into the energy mix. This involves enhancing grid flexibility, installing smart meters, implementing energy storage solutions, etc., to accommodate the variable nature of renewable generation. Up-to-date infrastructure is vital for transitioning to a more sustainable energy future.

Third, modernization improves overall energy efficiency by minimising transmission and distribution losses, enabling better demand management, and allowing for the deployment of energy-saving technologies across the system. This reduces wastage and the need for additional energy production capacity. Fourth, it facilitates the adoption of cutting-edge technologies like smart grids, Internet of Things sensors, analytics, and automation that optimize energy management through better monitoring, control, and predictive maintenance capabilities. Continuous infrastructure modernization enhances energy security, incorporates renewable sources, boosts efficiency and productivity, reduces environmental impact, and future-proofs energy systems to keep pace with technological innovations – making it an essential long-term priority (Volkov et al. 2023).

According to recent research by Maqbool and Jowett (2023), an overview of international renewable energy development reflects a general trend towards a shift from traditional energy sources to more sustainable and environmentally friendly alternatives. Countries around the world are considering the development of renewable energy as a strategic initiative to reduce

their dependence on fossil fuels, as well as to reduce greenhouse gas emissions and conserve natural resources. National governments and businesses are investing significant efforts in the implementation of renewable energy sources, such as solar and wind energy, hydroelectric power plants, and others. This contributes to the development of new technologies and the competitiveness of these energy sources. However, despite the positive trends, several challenges arise, such as production volatility and the need to expand energy infrastructure and develop efficient energy storage systems. It is worth noting that the review of international renewable energy development reflects a general trend toward a shift from traditional energy sources to more sustainable and environmentally friendly alternatives. Countries around the world are considering the development of renewable energy as a strategic initiative to reduce their dependence on fossil fuels, as well as to reduce greenhouse gas emissions and conserve natural resources (Ismayilov et al. 2023). The international perspective on renewable energy development is not only driven by environmental concerns but also by economic and social benefits. The transition to renewable energy can create new jobs, foster innovation, and improve energy security. It is important to bear in mind that this process requires global coordination and cooperation to achieve the common goals of sustainable development and preservation of the planet's ecosystem. In addition, M. Dykha and V. Dykha (2023) note that the cost of electricity from renewable energy sources is constantly decreasing while the cost of electricity from conventional generation is increasing.

Referring to the definition of Ivanovski and Marinucci (2021), political uncertainty can play a key role in shaping global energy transitions and influencing renewable energy development strategies. Policy uncertainty, especially in the context of hydrocarbon regulation and energy policy decision-making, can lead to instability and unpredictability for renewable energy industries. Political decisions and legislation may influence the degree of support for renewable energy and, therefore, determine the scale and pace of global change in the energy sector. The environmental risks associated with renewable energy are important to consider in the context of global efforts to combat climate change. The development of renewable energy should be accompanied by due consideration of environmental impacts and the development of energy project management strategies to minimize negative environmental impacts and preserve biodiversity. Ensuring energy security should be based not only on political and economic decisions but also on a balanced approach to the environmental aspects of renewable energy (Vyshnevska et al. 2022). The study results confirm that uncertainty can cause fluctuations in global energy markets, influence decisions on investments in new energy technologies, and limit countries' ability to secure sustainable energy supplies. Global political uncertainty can also result in increased geopolitical risks associated with countries' dependence on energy resources.

Qiu et al. (2023) determined that energy security and energy management are of particular importance in the face of the growing threat of extreme natural events. Climate change is leading to an increase in the frequency and intensity of events such as hurricanes, floods, earthquakes, and other natural disasters. These phenomena can have a large-scale impact on existing energy systems and energy supply. Extreme natural events can lead to accidents and damage to energy infrastructure, including power grids, gas pipelines, and other facilities. This can lead to interruptions in electricity supply and emergencies and is an important aspect of energy security

strategies. Developing and implementing emergency plans, modeling possible consequences, and improving and upgrading infrastructure to increase its resilience to extreme conditions are important tasks of energy security management. An important aspect is the integration of the latest technologies and innovations into energy management systems to ensure more efficient use of resources and rapid recovery of energy infrastructure after emergencies (Orfanova 2023). Smart grids, data analytics, and the use of modern technologies in power system management can greatly facilitate the response to challenges posed by extreme natural events.

Lee et al. (2022) demonstrated that information and communication technologies (ICTs) play an important role in modern energy systems and have an impact on their security. Today, an increase in the use of these technologies can be observed to ensure effective management and monitoring of energy processes. One of the most important aspects is the introduction of modern electricity distribution management systems based on digital technologies. This enables power grid operators to effectively manage and monitor the system in real-time. The use of modern analytical tools to process the vast amounts of data generated in energy processes is another important component. Data analysis helps identify anomalies and predict possible problems in system operation, which is important for accident prevention and safety. In the context of international relations, ICT enables countries to cooperate effectively in the energy sector. Shared platforms, data exchange systems and technology transfer promote innovation and enhance energy security at the international level. At the same time, however, new cybersecurity challenges are emerging as energy system infrastructure is becoming subject to increasing cyberattacks.

As noted by Berdysheva and Ikonnikova (2021), the energy transition in the modern world is defined by dramatic changes in the use of fossil fuels and a gradual shift to renewable energy sources. This process has a profound impact on international energy trade and energy security dynamics. On the one hand, the growing demand for renewable energy is fueling the development of new technologies and production, which may affect the allocation of international markets and trade flows. However, the energy transition also poses challenges for countries that have traditionally specialised in the production and export of fossil fuels. The decline in demand for these types of energy may affect their economies and force them to rethink their strategies and diversify their industries. International energy trade plays an important role in this process. Changes in the structure of energy production and consumption can lead to revised agreements, contracts with external suppliers, and new strategies for the development of energy markets. This can also have an impact on geopolitical relations and the distribution of influence in the world.

Ostergaard et al. (2021) determined that ensuring energy security through demand response is becoming an increasingly important task in the face of growing energy demand and energy market instability. Demand response means the ability of energy consumers to respond effectively to changes in energy prices and availability. It is becoming a key element in energy supply and energy system management strategies. The benefits of demand flexibility are evident in the face of fluctuating energy market prices and changes in supply conditions. Consumers who can effectively regulate their demand can save money by responding to periods of lower prices or supply constraints. It also helps avoid the risks associated with possible supply disruptions. Demand response contributes to the resilience of the energy system as a whole. It allows for more

efficient use of existing resources, reduces the need to build additional capacity, and helps to support environmentally sustainable energy production. In the context of the growing challenge of climate change and the volatility of the global energy market, demand response is becoming a strategic reserve for maintaining energy security and stability. The development of smart energy technologies and demand-side management systems defines a new stage in the evolution of energy systems aimed to maximize the flexibility and efficiency of energy use (Makedon et al. 2021).

In today's world, where energy security is a key component of sustainable development and resilience, the optimization of national strategies and policies in this area is an integral part of effective energy management. Given the global and Ukrainian experience in this regard, several recommendations can be made to improve and optimize national energy security strategies. It is important to adapt and implement best practices that have proven themselves in developed countries. In particular, the introduction of renewable energy technologies, energy efficiency, and innovative methods of energy production, storage, and distribution can significantly improve the sustainability of national energy systems (Zakharova 2023). In the context of the Russian invasion of Ukraine, it is worth noting the analysis of possible mechanisms for restoring Ukraine's economy, including the modernization of the energy sector and the role of the international community in this process, as described in the publication. National strategies should actively promote international cooperation and partnerships in the energy sector. Exchange of experience, technological innovations, and joint projects can significantly improve the sustainability of energy systems and ensure resource efficiency. In the context of Russia's war against Ukraine, we draw attention to the analysis of possible mechanisms for the recovery of Ukraine's economy, including the modernization of the energy industry, as well as the role of the international community in this process, which is described in the publication (Kocherov et al. 2023).

It is necessary to emphasize global trends in the energy sector and adapt strategies to the challenges and opportunities they generate. Developing flexible and adaptive strategies will allow the country to respond effectively to changes in the global energy landscape. Active public involvement in the development and implementation of energy security strategies is vital. Broad public support and participation can help address key issues and introduce innovative approaches. Managing energy security in Ukraine requires a comprehensive approach and carefully developed mechanisms to address current challenges. Firstly, it is necessary to focus on diversifying energy sources by switching to renewable sources and investing in the latest technologies. This will contribute to sustainable development, reducing dependence on traditional sources and $CO_2$ emissions. Modernization of energy infrastructure is also crucial. Introducing financial incentives to upgrade and improve infrastructure will help ensure the security of supply and reduce losses in the energy system. The development of energy efficiency is of great importance. Integrating energy efficiency programs and standards for businesses and households will help reduce costs and ensure the resilience of the energy system.

Energy storage and distribution are equally important. The development of technologies for energy storage and flexible distribution smooths out load peaks and ensures grid resilience. Stimulating innovation through tax credits and support for research and the implementation of

innovative energy technologies will improve the state of the energy system. Flexible tariffs that incentivize consumers to use electricity during periods of lower load are an important element for regulating consumption and improving the functioning of the energy system. However, only a small proportion of consumers currently take advantage of such opportunities. These recommendations create the preconditions for achieving resilience and sustainable development of the energy sector in Ukraine.

## Conclusions

Energy security research highlights the need to systematically analyze and actively adapt management strategies as the energy landscape is constantly changing. It is necessary to consider global challenges, such as climate change and geopolitical instability, and to develop strategies that can effectively respond to these trends. Effective energy security management is a complex task that requires joint efforts of the state, business, and the public. The implementation of best practices and achievements of global partners determines the achievement of positive results. At the same time, national peculiarities and analysis of our experience are crucial for creating an effective energy security management system in Ukraine. In the future, the country's stability in the face of global challenges in the energy sector will be determined by the development and improvement of such a system. International cooperation is a key factor in solving problems that require collective attention. The exchange of technologies and strategic solutions allows countries to work together to create efficient energy systems that address global challenges and ensure sustainability.

Regulatory policies that focus on market transparency and competitiveness are an important element in creating sustainable energy systems. It sets the conditions for the development of new technologies and stimulates investment in the energy sector. The introduction of renewable energy sources not only reduces emissions but also opens up new opportunities for innovation and the creation of new markets. It promotes the development of modern technologies and ensures the sustainable development of the energy sector. All these aspects highlight the need to constantly monitor, update, and adapt energy security management strategies to ensure sustainable development, competitiveness, and resilience of energy systems in the current global environment.

The Authors have no conflicts of interest to declare.

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# Zarządzanie bezpieczeństwem energetycznym w kontekście bieżących wyzwań i międzynarodowego doświadczenia

## Streszczenie

Znaczenie prowadzonych badań jest zdeterminowane przez ciągłe zmiany w globalnym krajobrazie energetycznym oraz negatywny wpływ wojny rosyjsko-ukraińskiej na rynek energetyczny. Opracowanie ma na celu sformułowanie zaleceń dotyczących optymalizacji krajowych strategii i polityk w dziedzinie bezpieczeństwa energetycznego w oparciu o analizę światowych doświadczeń, a także specyficznych wyzwań i praktyk Ukrainy w zarządzaniu tym obszarem.

W analizie wykorzystano metody analityczne, funkcjonalne, statystyczne, syntezy i itp. Badanie bezpieczeństwa energetycznego stało się kluczem do zrozumienia obecnych wyzwań i promowania odporności krajowych systemów energetycznych. Niniejsze opracowanie analizuje praktykę innych krajów

w dziedzinie oszczędzania energii. Oceniono wykorzystanie odnawialnych źródeł energii w w systemach energetycznych niektórych państw. Ustalenia wskazują na potrzebę skupienia się na rozwoju odnawialnych źródeł energii i polityk regulacyjnych w celu zapewnienia stabilności rynku. Współpraca międzynarodowa została uznana za kluczowy czynnik sukcesu w zarządzaniu bezpieczeństwem energetycznym. Wyniki analizy podkreślają potrzebę ciągłego monitorowania i dostosowywania strategii, aby skutecznie reagować na rosnące wyzwania energetyczne.

Szczegółowa analiza najlepszych praktyk wskazuje na potrzebę wdrożenia strategii obejmujących rozwój odnawialnych źródeł energii, modernizację infrastruktury oraz poszukiwanie innowacyjnych rozwiązań. Wdrożenie proponowanych działań pomoże zwiększyć systemu energetycznego kraju, zmniejszyć zależność od importu i promować zrównoważony rozwój gospodarczy. Wyniki badania mogą zostać wykorzystane do opracowania i optymalizacji strategii zarządzania bezpieczeństwem energetycznym, przyczyniając się do odporności, konkurencyjności i zrównoważonego rozwoju państwa.

Słowa kluczowe: bezpieczeństwo energetyczne, zarządzanie, wyzwania, odnawialne źródła energii, dywersyfikacja, zrównoważony rozwój