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INTRODUCTION OF ALTERNATIVE (RENEWABLE) ENERGY IN UKRAINE AS A STRATEGIC RESPONSE TO ECONOMIC CHALLENGES IN A SPECIAL PERIOD

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Abstract. *Purpose of the article.* This research article highlights the key areas of green energy implementation in Ukraine as a strategic response to current military and economic challenges. The main focus is on the analysis of the potential of renewable energy sources and their impact on energy security and sustainable development of the country. *Object of the article.* The article examines the processes of integration of renewable energy into the national energy system. The subject of the analysis is the introduction of "green" energy as a basis for ensuring Ukraine's energy independence. *Methodology.* The research methods include a systematic approach to analysing the potential of renewable energy sources, comparative legal analysis to assess regulatory initiatives, and modelling the economic impact of renewable energy integration. An important role is also played by statistical analysis and forecasting methods, which allow to assess future developments in the energy sector. *Practical implications.* Strengthening national security by reducing dependence on imported energy resources and increasing the share of renewable energy in the country's energy balance. *Value / Originality.* The study contributes to the understanding of the importance of green energy as a strategic response to the challenges of a special period. The paper offers specific recommendations on policies and mechanisms for implementing effective renewable energy solutions. *Results.* It is determined that the introduction of green energy should include strategic planning and the use of innovative technologies for efficient resource management. Significant investments are required from the state budget of Ukraine, local budgets and the private sector. At the same time, strategic resource management should take into account the interests of all parties, ensuring the stability and reliability of critical infrastructure.

Keywords: green energy, renewable energy sources, energy security, energy independence, sustainable development, strategic planning.

JEL Classification: O13, Q01

Introduction

The development of alternative renewable energy in Ukraine is of particular relevance in the context of ongoing Russia's aggression, as it contributes to reducing dependence on imported energy resources and ensuring the country's energy independence. In the context of ongoing military operations and political instability, the development of domestic, environmentally friendly energy sources has become a critical priority for ensuring energy security. Ukraine, facing a challenging attack and the need for rapid adaptation to changing wartime conditions, has identified the development of alternative energy as a strategic direction for restoring the national economy. This includes the large-scale deployment of solar and wind power plants, which can help reduce environmental impact and increase energy resilience. Integration with European energy systems in response to military action not only increases opportunities for clean energy exports, but also plays an important role in attracting investment. This strategy allows Ukraine to move towards sustainable development, and investments in renewable energy stimulate technological development and modernisation of the energy system (Bohdana, Kuzmenko, Chorna, 2023). The restoration and expansion of energy capacities, as well

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as the development of new technologies, such as smart grids and energy storage systems, are a response to the need to adapt to changing energy conditions during martial law. Efforts to introduce European standards and improve legal regulation in Ukraine's energy sector should form the basis for further integration of Ukraine into the European energy market. These measures should include the creation of favourable conditions for foreign and domestic investors, infrastructure development and increased reliability of energy supply. The recovery of Ukraine's economy should be underpinned by a sustainable development strategy, with the objective of attracting investment in alternative energy, including renewable energy projects. Furthermore, it is of paramount importance to develop and implement a national renewable energy strategy that considers not only the requirements of the domestic market but also global energy trends. Such a strategy would enable Ukraine to enhance its status as an energy exporter and to markedly diminish its reliance on external energy sources, particularly in light of the prevailing security concerns and economic volatility.

1. Research Methodology

1.1. Scientific and Theoretical Substantiation of the Implementation of Alternative (Renewable) Energy as an Economic Component of Postwar Ukraine's Development

The subject of integrating green energy into Ukraine's strategic response to military and economic challenges during a special period is becoming increasingly relevant and attracting greater attention from academic researchers. This topic is explored in the works of notable scientists such as I. V. Stadnyuk, O. P. Kravchenko, M. L. Lysenko, S. I. Solovyova, O. B. Shevchenko, and others. I. V. Stadnyuk is engaged in the integration of renewable energy sources into the national energy system, with a particular focus on strategic and political aspects. O. P. Kravchenko's research concerns the economic efficiency of renewable energy, with a particular focus on the impact of green energy on economic stability and development. M. L. Lysenko's research is centred on the environmental implications of renewable energy implementation, with a particular focus on the impact on the natural environment and climate change. These researchers make a significant contribution to the understanding of a wide range of renewable energy issues, from technological innovation to legal regulation. Ukraine's renewable energy legal framework is dynamic and adaptive, but requires continuous improvement and harmonisation with European standards. Relevant laws and regulations, such as the Law of Ukraine "On Alternative Energy Sources", are designed to regulate the use, promotion and control of energy production from alternative sources. The practice of management in the field of renewable energy in Ukraine demonstrates notable advancement in the implementation of contemporary technologies and the formulation of strategies that not only align with the country's internal requirements but also adhere to the principles of European energy policy. This encompasses the formulation of economic recovery programmes, with the advancement of green energy representing a principal objective. It is of paramount importance that governmental and non-governmental organisations play a pivotal role in this process, as they are instrumental in financing, regulating and monitoring the implementation of relevant programmes and projects. It is imperative that the public and private sectors establish effective interaction in order to ensure the successful implementation of renewable energy policy and achieve energy independence.

1.2. Methodological Features of the Study of the Alternative (Renewable) Energy Implementation as an Economic Component of Postwar Ukraine's Development

The methodological basis of the article is the use of various scientific methods that provide a comprehensive study of the impact of green energy on the economic and military security of the country in times of war. The main tools include the dialectical method for analysing the dynamics of development and internal contradictions in the field of green energy. The grouping method was employed for the classification of renewable energy sources, thereby facilitating the identification of principal trends and differences. The comparative method was employed to evaluate the efficacy of disparate approaches to green energy at the international level, thereby facilitating the identification of the most efficacious strategies that can be adapted to Ukrainian conditions. A systems analysis was employed to evaluate the comprehensive impact of renewable sources on national security and economic stability. The case study method played a pivotal role in the study, as it focuses on particular instances of green energy implementation, elucidating the pragmatic aspects of implementation and the challenges encountered by authorities and businesses. Furthermore, project analysis was employed as a supplementary method to evaluate the prospective economic and social advantages of green energy initiatives. The aforementioned methods assist in identifying the most optimal means of developing the energy sector, ensuring national security and compliance with European standards, and facilitating long-term economic recovery.

2. Development of Alternative (Renewable) Energy in Ukraine: Response to Modern Challenges

2.1. Consequences of Military Aggression for Ukraine's Economic Sectors

The war and the economic crisis caused by military actions on the territory of Ukraine have had a profound impact on the country's energy sector, with the main consequence being the significant destruction of critical infrastructure. This has resulted in significant disruptions to the electricity supply and substantial economic losses. As of May 2024, the direct losses incurred by Ukraine's energy sector were estimated to exceed 16.1 billion USD. The greatest losses, amounting to 8.5 billion USD, were caused by the destruction of electricity generation facilities, 2.1 billion USD in losses due to damage to high-voltage transmission lines, and 3.3 billion USD in losses to the oil and gas infrastructure. Restoration of destroyed and damaged infrastructure requires significant investment: the total reconstruction needs are estimated at 50.5 billion USD. This amount includes 48.5 billion USD for reconstruction of destroyed infrastructure and 2 billion USD to meet the liquidity needs of energy companies due to the loss of revenues as a result of the war. According to official data, 27 medium and large power plants are occupied in Ukraine. It is notable that a number of critical facilities, including the Zaporizhzhia NPP, the Luhansk TPP, and the Vuhlehirsk TPP, are situated in territories that have been temporarily occupied. In addition to these facilities, there are numerous other critical infrastructure sites that have sustained significant damage. In excess of 18 GW of electricity generation capacity was appropriated during the invasion, including the largest nuclear power plant in Europe, the Zaporizhzhia NPP. In addition, Kakhovka Dam and Dniprovska Dam, as well as Zmiivska and Trypilska TPPs, were completely destroyed (Chornyi, 2022). Additionally, high-voltage transmission substations sustained considerable damage. The data demonstrate the extent of the losses and costs incurred as a result of the conflict, emphasising the crucial necessity for the reconstruction and modernisation of Ukraine's energy infrastructure in order to guarantee the country's energy security amidst persistent threats. In the context of martial law in Ukraine, the reorientation of state regulation of the energy market assumes a new significance. The primary objectives are to guarantee the resilience of social and macroeconomic infrastructure and to initiate structural transformations in energy that are adapted to emergency conditions. This reorientation is taking place against the backdrop of significant wartime destruction and the need for a dynamic economic recovery. Significant direct losses in the energy sector, exceeding 16.1 billion USD, and critical damage to power plants and transmission lines are prompting a review of traditional approaches to managing the sector. Given the large reconstruction needs, the total investment required to rebuild the infrastructure is estimated at 50.5 billion USD, which requires efficient use of limited resources and optimisation of institutional performance (The Great War: energy losses and damages estimated at $56 billion, 2024).

2.2. European Integration and International Support for Ukraine's Economic Sectors

In this context, the focus is on improving the competitiveness of the energy sector, increasing electricity exports, which could become one of the key factors in macroeconomic stabilisation, and improving the functioning of regulatory institutions. During the war, the country has made significant progress towards integration into the European energy system, successfully synchronising its power system with ENTSO-E. By integrating into the ENTSO-E European energy system, Ukraine not only ensured more stable conditions for the operation of its power system during the war, but also created the preconditions for future electricity exports to the EU, which could become a significant source of revenue and further development of the national economy. It is also important to highlight the significance of the development of the energy sector in the European Union and its integration with the Ukrainian energy system for Ukraine. European initiatives, such as the Fourth Energy Package, are designed to provide support for the development of renewable energy sources and to increase energy efficiency. This has the effect of reducing Ukraine's dependence on imported energy resources, particularly from Russia. Furthermore, this has the additional benefit of reducing the energy influence of the aggressor on Ukraine and increasing its political and economic resilience. In addition, the EU's support for energy sector reforms and financial investments through various grant programmes have contributed to the restoration and modernisation of Ukraine's infrastructure, particularly in the renewable energy sector. This helps the country not only to rebuild destroyed facilities but also to develop new, more sustainable forms of energy production. Today, Ukraine is also facing the need to adapt to changing geopolitical realities, including diversification of energy sources and integration into the European energy market, which requires a significant revision of the national energy policy. Ensuring energy security in the context of limited resources and a constant military threat is becoming a priority, requiring not only the restoration of destroyed infrastructure but also strategic planning based on the latest

technological and managerial solutions. The European experience of reforming the energy sector, including deregulation of electricity markets and vertical disintegration of companies, is a useful example for Ukraine. The principle of separating energy companies by type of activity (generation, distribution, transmission and sales) allows for more transparent monitoring of their activities and the application of appropriate regulatory measures. Simultaneously, the creation of balancing groups, which minimise costs by balancing the market in real time, is an important tool for stabilising supply in the face of resource shortages. The war has stimulated transformational processes in Ukraine's energy sector, especially in the context of the transition to renewable energy sources such as wind and solar power plants. Such a transition is becoming strategically necessary, especially given that the green energy sector was actively developing before the war, making Ukraine a leader in terms of solar energy growth. However, military actions have resulted in considerable damage to infrastructure, which has had a detrimental impact on the sector's potential. Investments in the renewable energy sector can ensure not only a stable energy supply but also a significant increase in the country's energy independence from traditional sources, such as fossil fuels. The endeavours to reinstate and further develop solar and wind generation are in accordance with the European reform trajectory, which aims to liberalise energy markets and enhance the competitiveness of energy companies. In light of the considerable damage already incurred and the pivotal role green energy plays in Ukraine's economic and security landscape, the advancement of this sector represents a pivotal objective in the reconstruction of energy infrastructure and the assurance of a sustainable energy supply to consumers. This should also become the basis for further recovery of the national economy, contributing to the creation of new jobs and reducing the impact of the energy crisis caused by the military operations. It should be noted that energy sources are divided into two types: traditional and alternative. The former include fossil fuels (gas, oil, coal), while the latter include all alternative fuels (sun, water, wind). The key difference lies in their renewability in nature. Traditional sources are exhaustible, meaning that sooner or later this resource will become unavailable, while alternative sources are inexhaustible. Alternative energy sources are also referred to as 'renewable energy sources' or 'regenerative energy sources' and are used to produce energy using exclusively primary sources that do not contain CO_2, such as wind, water and solar energy. This group also includes biomass and geothermal energy. In fact, the concept of renewable energy sources includes all inexhaustible energy sources. The scientific community understands renewable energy as the use of energy from sources that are considered to be inexhaustible on the scale of human time. As defined by the International Energy Agency (IEA), renewable or regenerative energy is energy derived from natural sources such as the sun, wind, geothermal, hydropower and ocean resources, as well as solid biomass, biogas and liquid biofuels. It is distinct from energy derived from municipal or industrial waste, which can be either renewable or non-renewable. In many cases, however, both categories of waste are treated together, but the IEA does not classify them as renewable energy sources (Melnychuk, Dubrovyn, 2012).

2.3. Concept and Features of Alternative (Renewable) Energy

In Ukraine, the concept of renewable energy is employed in a more expansive manner and is frequently utilized as a synonym for alternative or non-traditional energy. This encompasses sources such as peat, low-potential geothermal energy (heat pumps), and secondary energy sources, including waste heat and household and industrial waste. In some instances, alternative energy sources encompass mine methane, natural gas derived from modest-scale fields, and other non-renewable fuels that necessitate the development of innovative technologies to facilitate their acquisition. The term "alternative energy sources" is utilised within the context of Ukrainian legislation. According to the Law of Ukraine "On Alternative Energy Sources" No. 555-IV of February 20, 2003, renewable energy sources are defined as solar, wind, geothermal, wave and tidal energy, hydropower, biomass energy, gas from organic waste, gas from treatment facilities, biogas, as well as secondary energy resources, including blast furnace and coke oven gases, mine (mine) gas, coal mine gas (methane), and waste energy potential (Article 1). It is noted that energy generated from alternative sources is electrical, thermal and mechanical energy produced at alternative energy facilities and may be a commodity intended for sale and purchase (The Law of Ukraine "On Alternative Energy Sources", 2003). Accordingly, the notion of "alternative energy" encompasses not only renewable energy sources but also any other means of replacing traditional fossil fuels. These include low-potential earth heat (utilised in heat pumps), secondary energy sources such as waste heat, household and industrial waste (which may be either renewable or non-renewable), blast furnace gas pressure and natural gas pressure during transportation, mine methane, natural gas from small fields, peat, and other potential sources (Kuzminskyi, Holub, Shchurska, 2009). As for the EU, there is no single approach to the content and types of alternative energy. Initially, according to Regulation 2039/82/EEC, alternative energy sources included liquefaction and gasification of solid fuels, exploitation

of geothermal fields and use of solar energy. This first document provided financial support for projects aimed at using alternative energy sources (Council Regulation (EEC) 2039/82).

The policy was further developed with the adoption of Directive 2001/77/EC, which aimed to stimulate the production of electricity from renewable energy sources and integrate it into the European internal electricity market. This document mentions such alternative sources as wind, solar, hydro and geothermal energy.

Directive 2009/28/EC, adopted on 23 April 2009, introduced significant changes by expanding the list of renewable energy sources. The list includes aerothermal, geothermal, biomass, organic waste gas, gas from sewage treatment plants, biogas and others. This directive has become a fundamental document for shaping renewable energy policy in the EU (Kuzmina, 2013).

The International Renewable Energy Agency (IRENA), established to promote the use of renewable energy sources worldwide, also plays an important role in this area. According to its charter, IRENA defines renewable energy as all forms of energy that are continuously produced from renewable sources. This includes not only traditional sources, but also innovative ones, such as tidal and wave energy and ocean thermal energy (Statute of the International Renewable Energy Agency, 2024).

The International Energy Agency (IEA) distinguishes the following types of renewable energy sources: biomass energy, geothermal energy, hydropower, ocean energy, solar energy and wind energy.

Renewable energy thus includes solar, wind, geothermal and hydroelectric power. It also covers ocean energy, including tidal and wave energy, ocean thermal energy, bioenergy, organic waste gas, waste water treatment plant gas, biogas and others.

Renewable resources, like traditional mineral energy sources, have their advantages and disadvantages. The advantages include their ubiquity, inexhaustibility and environmental friendliness. In addition, the operating costs of using such energy sources are relatively low, as the energy they produce is free.

The disadvantages of renewable energy are low energy density (specific power) and its variability over time. These factors necessitate the creation of large areas for energy installations that "capture" the energy flow (solar panels, wind turbines, tidal power plants, etc.). This leads to a high material intensity of such devices and increases the specific capital investment compared to traditional power plants. However, the higher capital investment can be offset by low operating costs, but at the initial stage it has a significant impact on the financial costs of those wishing to use renewable energy sources.

3. Types and Features of Alternative (Renewable) Energy

Consider the types of alternative (renewable) energy. Solar energy involves the conversion of solar radiation into heat and electricity, depending on the type of installation. In the national economy, solar energy is usually converted into electricity (directly or indirectly). For this purpose, the following types of solar power plants exist:

1. Photovoltaic power plants.
2. Helio-thermal power plants.
3. Thermo-air power plants.
4. Solar aerostat power plants.

Photovoltaic and geothermal power plants are currently used on an industrial scale. They are environmentally friendly and can be used for billions of years. Solar energy is also used to heat homes and provide hot water through solar collectors. The main constraint to the development of solar energy is its high cost compared to the price of energy from organic sources such as gas, oil and coal. The high level of solar energy prices is due to the expensive production of panels and the long payback period. The factors limiting the use of solar energy include the uneven distribution of sunlight in different parts of the planet, the need for large land areas for powerful power plants, and the inability to generate energy at night. The latter problem requires the use of batteries (Tsyhanok, Cherep, 2018).

Wind energy is specialised in harnessing the kinetic energy of the wind to produce any other type of energy needed by humanity. Wind is a modified form of solar energy, which is why it is also considered an alternative renewable energy. The advantages of wind power include its completely environmentally friendly production, significant savings, accessibility and practical inexhaustibility. Industrial enterprises can use small wind turbines to cover all or part of their electricity consumption. According to the World Wind Energy Association, wind energy is used in more than 70 countries. Among the countries that have achieved high results in the use of wind energy are the United States, Germany, Denmark, Spain and China. Currently, wind power accounts for about 1% of global electricity production. The wind energy market is developing quite dynamically, with its capacity increasing almost tenfold since 1998 (Alternative energy resources in the Ukrainian Black Sea region, 2021).

Hydropower is the use of the potential and kinetic energy of water to convert it into electricity. Today, it is the most developed among other unconventional sources. The potential of small rivers, tributaries and water supply systems provides energy independence for some remote areas and settlements. Unfortunately, Ukraine's modern hydropower industry has faced serious challenges in the run-up to the autumn-winter

period due to the destruction of about 45% of its capacity by Russia's forces. According to Ukrhydroenergo, published on their official Telegram page and shared with ExPro, since the beginning of the full-scale invasion, hydroelectric power plants have been hit by 118 missile strikes. The company is not deterred by these challenges and is actively planning the restoration and further development of its energy infrastructure. In the short term, Ukrhydroenergo plans to intensively restore 1000 MW of capacity to ensure stable operation during the autumn and winter period. Long-term plans include the construction of 2500 MW of new capacity, including the completion of the Dniester PSPP and Kaniv PSPP. The restoration of the Kakhovka HPP is also an important project. Other ongoing projects, such as the completion of the Dniester HPP, which is still under construction, are also worth noting. In January this year, the government allocated land plots for the construction of power lines to the plant, where three new units are being built (Hydropower of Ukraine is preparing for the autumn-winter period despite challenges, 2022; Claudia Aradau, 2010).

Geothermal energy is an environmentally friendly energy produced by the Earth's interior through radioactive decay and the cycle of formation of the Earth's crustal layers. This source is thermal, released in the form of steam or hot water. Geothermal energy is widely used in industry, road construction, heating houses/greenhouses/soil, drying agricultural products and the tourism sector.

Biofuels are organic fuels derived from plant, animal, agricultural or industrial waste. It is a renewable resource that is absolutely safe for the environment (Alternative energy sources, 2024). Biofuels include biogas, landfill gas, biodiesel, pellets, briquettes from biomass, firewood and wood waste, straw and crop stalks, municipal solid waste, as well as biogas that can be produced from manure and animal waste, etc. The share of biomass in total consumption in Ukraine is less than 1%. Currently, the use of biomass as a fuel in Ukraine is about 1 million tonnes of fuel equivalent per year, mainly firewood and wood waste (Zhownir, Oliinyk, Chaplyhin, 2007). At the international and national levels, some countries often have specific legal regulations for biofuels. For example, Directive 2009/28/EC (Renewable Energy Directive (RED)) sets specific targets for biofuels. There is also a dedicated EU Biofuels Strategy and international biofuel organisations (European Biofuels Technology Platform, European Industrial Bioenergy Initiative). The separation of this type of source is mainly due to the fact that it is a fuel for transport; very different raw materials can be used as a basis for biomass, which leads to different legal consequences associated with the use of this raw material. For example, the utilisation of specially cultivated plants, food crops, peat and wood as feedstocks is controversial in terms of its environmental impact. Biofuels are classified into first generation (bioethanol – from sugar cane and cereals, biodiesel – from vegetable oils (rapeseed, soya, sunflower) and fats, biogas (from methane, carbon dioxide and anaerobic decomposition of various types of waste and waste water)); second generation (from non-food plants and their parts, such as cellulose); third generation (from algae or synthetic substances). For use in standard internal combustion engines, bioethanol is blended with carbon fuel, and biodiesel can be used directly (Bilotskyi, 2017).

Biofuels can replace traditional fuels. Enterprises that use their production waste can get environmentally friendly fuel for their needs.

In Ukraine, the energy plant miscanthus, also known as elephant grass, is gaining popularity. This reed-like plant grows well on soils with low rainfall. Miscanthus is a perennial plant capable of producing stable yields for 20-25 years in one place.

The energy value of one ton of dry miscanthus is equivalent to:

- 400 kg of crude oil;
- 1.7 tons of wood;
- 515 cubic meters of natural gas;
- 620 kg of coal.

It is worth noting that miscanthus is recognised as an environmentally friendly fuel and contributes to improving the natural balance. Its use is supported by various international funds and grant programmes aimed at improving the global environmental situation.

Solar energy is the undisputed leader among alternative energy sources in Ukraine. As of the end of 2022, the total capacity of renewable energy sources was 3634.4 MW, of which 72.65% was accounted for by solar power plants with a total capacity of 2640.4 MW. Wind power plants ranked second with a significant margin of 21.37% (776.6 MW), followed by biomass and biogas with 3.24% (117.7 MW). Small hydropower plants are the least popular – 2.75% (99.8 MW) (Melnychuk, Dubrovyn, Myronenko, Hryhoryuk, 2012).

4. Legal Regulation of Alternative (Renewable) Energy in Ukraine During a Special Period

In recent years, Ukraine has seen active legislative regulation of the renewable energy sector, which has helped to adapt to the changing geopolitical context and economic challenges. One of the key legislative initiatives is to amend the legislation governing the green tariff. In particular, the Law of Ukraine "On Amendments to Certain Laws of Ukraine on Improving the Conditions for Supporting the Production of Electricity from Alternative Energy Sources", adopted in 2020, aims to stimulate the development of alternative energy through financial

incentives for renewable energy producers, increasing their competitiveness in the energy market.

In addition, the decision of the National Security and Defence Council of Ukraine, enacted by Presidential Decree No. 695/2023 of October 17, 2023, is aimed at ensuring the security of critical infrastructure and the energy system in wartime, which affects the stability of energy supply.

The Resolutions of the Cabinet of Ministers of Ukraine of June and July 2024 (No. 673 and No. 784) establish mechanisms for financial support for individuals who install generating units in their households that produce electricity from alternative sources, reduce dependence on imported energy resources and increase the country's energy independence.

The Cabinet of Ministers' Order No. 587-p dated June 25, 2024, which approved the National Energy and Climate Plan until 2030, aims to implement strategic directions for the development of renewable energy, in particular, to stimulate the introduction of innovative technologies and the expansion of green energy that meets European standards.

At the same time, the green tariff in Ukraine is an economic incentive to invest in renewable energy sources. The resolution of the National Commission for State Regulation of Energy and Public Utilities of June 28, 2024, No. 1237, focuses on specific support mechanisms for private households using renewable energy sources, in particular solar panels.

The resolution introduces a differentiated tariff structure for generating units of varying capacities that were commissioned at different times. This approach considers changes in technology costs and market conditions, thereby facilitating a gradual transition to a more sustainable energy model. It is also noteworthy that the "green" tariff provides a stable and predictable income for the owners of home power plants that utilise solar and wind energy.

In accordance with the resolution, augmented rates have been implemented for micro-installations utilising solar and wind energy situated on the roofs and facades of buildings. Such conditions encourage citizens to utilise every available metre of their property for the generation of clean energy, thereby markedly reducing the country's reliance on imported energy resources and reducing the overall load on the energy system.

Furthermore, the green tariff encourages technological advancement and the dissemination of sophisticated energy management techniques within the domestic sphere. Those who own solar panels or wind turbines are not only able to sell any excess energy they generate, but they can also utilise energy storage systems to optimise their consumption, thereby meeting their needs during peak periods.

The structure of the "green" tariffs is reflective of the national strategy of reducing the carbon footprint and contributes to the achievement of global climate change goals. The implementation of such initiatives at the national level is consistent with Ukraine's international commitments, particularly in relation to the Paris Agreement. It also serves to illustrate the country's leadership in adopting a responsible approach to the utilisation of natural resources.

Together, these measures form a new legal framework that allows Ukraine to effectively adapt to wartime challenges, ensure energy security and promote the sustainable development of alternative energy based on innovative and environmentally friendly technologies.

4.1 Issues of Implementation of EU Legal Norms and Requirements in National Legislation

The integration of Ukraine's energy system into the European Union involves the harmonisation of national legislation with European directives and regulations. However, this process faces a number of challenges, including legal uncertainty and frequent changes in legislation, which complicate the planning and implementation of long-term projects in the sector. Addressing these challenges is crucial for attracting investment and developing renewable energy sources.

The implementation of European norms in Ukraine has been facilitated by the adoption of the Law "On the Electricity Market" on 13 April 2017 (The Law of Ukraine "On Electricity Market", 2017). This legislation incorporates the principal provisions of Directive 2009/72/EC on the unification of rules for the internal electricity market, as well as Regulation (EC) 714/2009, which establishes the conditions for access to the network for cross-border electricity exchanges. Furthermore, the legislation takes into account the stipulations set forth in Directive 2005/89/EC, which are designed to guarantee the security of investments in the electricity infrastructure.

An additional crucial element of the implementation process is Ukraine's incorporation of provisions designed to guarantee the security and reliability of the energy infrastructure. This is particularly pertinent in light of the growing proportion of renewable energy sources and the necessity to integrate these sources into the national energy system.

4.2 Legal Regulation of the Implementation of the "Green Tariff" in Ukraine as an Economic Incentive for the Development of Renewable Energy

The "green" tariff is a special tariff at which electricity produced at power facilities from alternative

energy sources, such as solar, wind, biomass, and hydropower, is purchased. The principal objective of this system is to stimulate the production and utilisation of renewable energy sources by establishing financially attractive conditions for investors and consumers.

The green tariff is defined by the National Commission for State Regulation of Energy and Public Utilities as the price of electricity generated at power facilities, including the construction phases of power plants that have been commissioned. This stipulation is set forth in paragraph 1 of Article 9-1 of the Law of Ukraine "On Alternative Energy Sources" (The Law of Ukraine "On Alternative Energy Sources", 2003).

The tariff system allows for the sale of electricity generated from alternative sources on the wholesale electricity market in Ukraine, through contractual agreements with consumers or electricity suppliers. In particular, electricity suppliers are required to purchase electricity generated by small hydropower plants, wind and solar power plants, and power plants utilising biomass as fuel.

The green tariff is a price paid by electricity suppliers for electricity produced from solar radiation energy by power facilities (generating units) of private households. This stipulation pertains to households with an installed capacity not exceeding 30 kW. The production of electricity from solar radiation by private households is conducted without the necessity of a corresponding licence, thereby facilitating the process of market entry for individuals.

The procedure for the sale and accounting for such electricity, as well as the settlement of transactions related to it, has been approved by the National Commission for State Regulation of Energy. Household consumers who have installed generating units based on solar or wind energy are entitled to sell the electricity produced by these units in accordance with the rules governing the retail electricity market.

The universal service provider has no right to refuse the consumer to purchase electricity at the green tariff if all the requirements of the Electricity Retail Market Rules are met. In order to sell electricity at the green tariff, the household consumer submits to the universal service provider an application for notification of the installation of the generating unit and provides the necessary documentation.

After receiving the complete set of documents, the supplier registers the notification application, which serves as the basis for further purchases and sales of electricity. The green tariff rates are approved by the regulator and applied by the universal service provider according to the date of submission and registration of the notification application.

The relevance of introducing artificial intelligence into the calculation of energy consumption in order to reduce excess generation lies in several key aspects: 1) efficient use of resources (by analysing data and predicting energy consumption patterns using artificial intelligence, it is possible to optimise the operation of the power system, ensuring efficient use of energy resources and avoiding excessive electricity generation); 2) reduction of losses (artificial intelligence can help identify and eliminate problematic segments in power systems, which will lead to a reduction in energy losses during transportation and distribution); 3) consumption forecasting (artificial intelligence can predict and respond to peaks in energy consumption, ensuring the stability of energy supply and avoiding overloading power systems); 4) resource saving and emission reduction (efficient energy management using artificial intelligence can lead to a reduction in fuel consumption and greenhouse gas emissions, which will contribute to more sustainable and environmentally friendly development).

Artificial intelligence is a branch of computer science that deals with the creation of programmes and systems that can perform tasks that would normally require human intellectual abilities. These systems can demonstrate cognitive functions such as image recognition, speech understanding, decision-making, self-learning and planning. Artificial intelligence uses methods and techniques from computer science, mathematics, linguistics, philosophy and other fields to design and implement intelligent systems (Kuzmenko, Chorna, Kozhura, 2024).

As of 2024, the green tariff in Ukraine has been approved for a number of categories of producers, including private households that utilise solar panels or wind generators. The tariffs are set for different periods and vary depending on the type of installation, the date of commissioning of the equipment, and its capacity.

For solar plants commissioned between 2013 and 2014, the tariff is approximately 15.65 UAH / kWh. This tariff has been gradually decreasing, and from 2024 it will be around 6.39 UAH / kWh. Wind turbines commissioned between 2015 and 2019 have a tariff of approximately 5.08 UAH / kWh, which will also decrease by 2024 (The Resolution of the National Commission for State Regulation of Energy and Public Utilities "On the Establishment of 'Green' Tariffs for Electricity Generated by Private Households", 2024).

A significant advantage of the green tariff is its positive impact on the economic viability of investments in renewable energy sources. This encourages individuals and companies to invest in the installation of generating units, as such an investment can become not only environmentally beneficial but also economically profitable due to the sale of produced energy at increased tariffs.

Furthermore, the green tariff serves to diminish Ukraine's reliance on imported energy resources,

thereby enhancing the country's energy security through the promotion of local and renewable energy sources. In this regard, the government is implementing measures to enhance the efficacy of this instrument. It is developing novel legislative proposals to buttress the advancement of green energy in the context of climate change and energy-related challenges.

4.2 Issues of Implementation of Alternative (Renewable) Energy in Ukraine in a Special Period

The implementation of green energy in Ukraine, despite the existence of significant potential and state-level support, is confronted with a number of economic challenges, particularly in the context of martial law and economic instability. The analysis of these issues and the formulation of effective strategies to overcome them will facilitate the stimulation of renewable energy sources. The following text will examine each of these issues in detail.

Primarily, a significant obstacle to the introduction of alternative energy sources is the high cost of initial investment, which limits the availability of such technologies to a wide range of consumers. According to the authors, several key government initiatives can reduce the financial burden on investors and consumers. Firstly, the state can introduce direct grants or subsidies to help cover part of the cost of purchasing and installing equipment. This will reduce the entry barrier for new entrants to the renewable energy market.

In addition, tax incentives, such as tax credits and VAT exemptions for renewable energy equipment, can make investments more attractive. EU experience shows that such measures are more effective when combined with long-term financial instruments such as green bonds. Issuing green bonds can attract additional resources from private and institutional investors interested in sustainable investments.

Given the challenges that private investors may face due to high risks, government loan guarantees can also be an important factor. Such guarantees would reduce barriers for banks and financial institutions to lend to renewable energy projects.

Moreover, it is important to develop training and certification programmes to prepare qualified professionals capable of effectively implementing alternative energy projects. This approach not only promotes better technology adoption, but also increases the overall acceptance of renewable energy among the population.

Finally, the creation of a stable and predictable regulatory environment will be key to the long-term investment attractiveness of the renewable energy sector, ensuring long-term interest and support from both domestic and international investors.

Secondly, the dependence on imported renewable energy equipment increases overall costs and reduces the competitiveness of the sector in the domestic market. This dependence makes Ukraine vulnerable to external economic shocks and currency fluctuations, which can lead to volatility in equipment prices and, as a result, to higher production costs.

According to the authors, supporting domestic producers and developing local production of renewable energy components can be key steps in overcoming these challenges. Stimulating domestic production could include tax breaks for companies investing in the production of relevant equipment, as well as government grants and investment incentives for start-ups and research institutions developing new technologies in this area.

In addition, the development and implementation of a national programme called the "Programme for Stimulating Electricity Production from Renewable Energy Sources in Ukraine until 2030", which would direct resources to research and development in the renewable energy sector, could significantly improve the quality and efficiency of domestic technologies.

The further development and use of locally produced high-tech equipment will allow Ukraine not only to meet its domestic renewable energy needs, but also to effectively export its technological solutions, stimulating economic development and technological progress in the country. All of this could contribute to a significant economic breakthrough, making Ukraine less dependent on external suppliers and strengthening its position in the international renewable energy market.

Thirdly, the limited funding of state programmes for the development of renewable energy in Ukraine due to economic difficulties and martial law threatens the achievement of national goals in this area. According to the authors, alternative sources of funding should be sought to expand the possibilities of implementing such projects. In particular, international grants can play a significant role in this process, providing not only the necessary funding but also the transfer of modern technologies and practices.

Alternatively, private investment can make a significant contribution to the development of renewable energy. Investor attraction can be stimulated by tax incentives and the reduction of administrative barriers to the implementation of projects in this area. Public-private partnerships, where the state and private companies jointly finance and implement energy projects, can also be an effective tool for attracting investment.

Cooperation with international financial institutions, such as the World Bank and the European Bank for Reconstruction and Development, can also provide significant funds for the development of renewable energy infrastructure. These organisations often offer

special support programmes for developing countries to promote sustainable development and reduce carbon emissions.

Fourth, legal uncertainty and frequent changes in legislation create challenges for the planning and implementation of long-term renewable energy projects in Ukraine. This increases risks for investors and may hinder the development of the sector. To address this issue, the adoption and maintenance of stable, transparent and predictable legislation that supports renewable energy investments is critical.

In the authors' experience, the involvement of international consultants and experts in the development of legislative initiatives can significantly improve the quality and stability of the legislative framework. This will ensure the adaptation of the best international practices and standards and help avoid potential mistakes in legislative innovations.

It is also necessary to intensify outreach to the public and key stakeholders to ensure broad support for legislative initiatives. Open discussion of draft laws and their public examination can reduce uncertainty and increase trust in legislative acts.

Another step could be to introduce long-term rules for investment projects in the renewable energy sector, such as guarantees of unchanged investment conditions over a certain period (e.g., 10-15 years), which would allow investors to plan their investments with a greater degree of certainty.

Fifthly, the limited domestic market and high cost of energy from alternative sources make it difficult to widely deploy and use renewable energy sources in Ukraine. This reduces the profitability of projects and limits the interest of investors and consumers. The market can be expanded by creating incentives that will help reduce the cost of energy for the end user and increase interest in its use.

In particular, information campaigns aimed at raising awareness of the benefits of using renewable energy sources among the public and businesses can be an effective step. It is important to provide clear and accessible information on the economic and environmental benefits of such technologies, as well as on the possibilities of obtaining state and local subsidies and benefits.

It is also advisable to introduce financial incentives for consumers who decide to install renewable energy sources. These could include tax cuts, tax credits or direct subsidies for the purchase and installation of equipment. Such measures will help reduce initial costs and make renewable energy more accessible to a wider range of people.

At the same time, the development of programmes aimed at reducing the final cost of renewable energy products could attract more consumers. Programmes may include support for innovation in component manufacturing, optimisation of logistics and production chains, which in turn will reduce the overall cost of production.

Conclusions

The restoration of Ukraine's energy sector following the war is of paramount importance for the country's economic recovery and the strengthening of its energy security, both at the national level and for the wider European region. Specific focus is directed towards the advancement of alternative energy sources, which have the potential to become a pivotal element in attaining climate neutrality objectives by 2050 and transforming Ukraine into a prominent energy hub within the region.

It is posited that Ukraine's potential for alternative energy sources is considerable, with significant opportunities for the development of wind, solar, bioenergy, and hydropower. In accordance with the Energy Strategy of Ukraine, the objective is to increase wind generation capacity to 140 GW and solar generation to 94 GW by 2050. This will necessitate the installation of a considerable number of energy storage systems to stabilise the grid.

It is also important to note that the development of nuclear and hydropower generation are vital components of the strategy. With plans to reach 30 GW of nuclear generation capacity and 9 GW of hydropower generation, Ukraine will be able to meet not only domestic needs but also export energy to the EU.

It is worth emphasising that in order to attract investment and stimulate the development of the sector, Ukraine is working to improve corporate governance and transparency in energy markets. This includes legislative initiatives aimed at protecting investors and ensuring fair market transactions.

International support, in particular from the G7+ countries, should play a key role in the restoration and modernisation of Ukraine's energy sector, providing the necessary financing for the implementation of large-scale projects. This includes investments in the development of clean energy technologies, infrastructure modernisation, and enhanced energy security, which are the basis for Ukraine's sustainable economic growth in the future.

The prospects for Ukraine lie in the rehabilitation and expansion of energy capacities, as well as in the development of new technologies such as smart grids and energy storage systems. Ukraine will need to introduce innovative and efficient technologies such as smart grids, microgrids and vehicle-to-grid systems in the distribution sector. It is important to create the conditions for the widespread use of these technologies, which will optimise energy production and consumption, increase the overall efficiency of the energy system and significantly reduce the country's energy footprint.

References:

Chornyi, V. (2022). Impact of the war on the energy system of Ukraine. *Bulletin of Khmelnytskyi National University,* No. 2, Vol. 2, p. 196–202.

The Great War: energy losses and damages estimated at $56 billion. Available at: https://skilky-skilky.info/velyka-viyna-zbytky-ta-vtraty-enerhetyky-otsiniuiutsia-v-56-mlrd/

Melnychuk, M. D., Dubrovyn, V. O., Myronenko, V. H., Hryhoryuk, I. P., Polishchuk, V. M., Holub, H. A., Targonya, V. S., Dragnev, S. V., Svystunova, I. V., & Kukharets, S. M. (2012). Alternative Energy: [textbook for higher education students]. Kyiv: "Ahrar Media Group", 244 p.

The Law of Ukraine "On Alternative Energy Sources" of February 20, 2003, No. 555-IV. *The Official Bulletin of the Verkhovna Rada of Ukraine.* 2003. No. 24. Art. 155.

Kuzminskyi, Ye. V., Holub, N. B., & Shchurska, K. O. (2009). State, problems, and prospects of bioenergy in Ukraine. *Renewable Energy*, Vol. 4, p. 70–80.

Council Regulation (EEC) 2039/82 of 19 July 1982 amending Regulation (EEC) 726/79 as regards the granting of financial support for projects to exploit alternative energy sources // Official Journal. L 219. 28/07/1982. P. 9.

Kuzmina, M. M. (2013). Concept and types of energy from alternative sources. *Bulletin of the National University "Yaroslav the Wise Law Academy of Ukraine"*, Vol. 3 (14), p. 134–141.

Statute of the International Renewable Energy Agency. Available at: http://www.irena.org/documents/uploadDocuments/Statute/Statute_

Tsyhanok, K. O., & Cherep, A. V. (2018). Alternative energy sources as a means of resource efficiency. *Global and National Economic Problems*, Vol. 22, p. 688–691.

Alternative energy resources in the Ukrainian Black Sea region / National Institute for Strategic Studies. Available at: http://www.niss.gov.ua/articles/288/

Hydropower of Ukraine is preparing for the autumn-winter period despite challenges. Available at: https://expro.com.ua/novini/gdroenergetika-ukrani-gotutsya-do-osnno-zimovogo-perodu-popri-vikliki

Alternative energy sources. Available at: https://soncedim.com.ua/blog/alternativni-dzherela-energiyi

Zhownir, M., Oliinyk, Ye., & Chaplyhin, S. (2007). Straw will heat the villages. *Green Energy*, Vol. 5, p. 28.

Bilotskyi, S. D. (2012). Theoretical problems of international legal regulation of alternative energy. Alternative energy and energy security in international and national law: collection of materials of the International Scientific Conference "The role of international law in the development of ecological alternatives to modern energy", April 25, 2012, Kyiv University named after T. Shevchenko / ed. by O. V. Zadorozhnyi; V. I. Oleshchenko. Kyiv: Phoenix, 297 p.

The Law of Ukraine "On Electricity Market" of 13.04.2017 No. 2019-VIII. Available at: http://zakon3.rada.gov.ua/laws/show/ru/2019-19/page

The Resolution of the National Commission for State Regulation of Energy and Public Utilities "On the Establishment of 'Green' Tariffs for Electricity Generated by Private Households" of June 28, 2024, No. 1237. Available at: https://zakon.rada.gov.ua/rada/show/v1237874-24#n21

Kuzmenko, O., Chorna, V., & Kozhura, L. (2024). Implementation of artificial intelligence in energy consumption calculations to reduce excess generation in the context of Ukraine's recovery. *Baltic Journal of Economic Studies*, Vol. *10*(1), p. 153–162. DOI: https://doi.org/10.30525/2256-0742/2024-10-1-153-162

Bohdana, B., Kuzmenko, O., & Chorna, V. (2023). Economic measures for managing critical infrastructure facilities in Ukraine. *Baltic Journal of Economic Studies*, Vol. *9*(3), p. 22–32. DOI: https://doi.org/10.30525/2256-0742/2023-9-3-22-32

Claudia Aradau Security That Matters: Critical Infrastructure and Objects of Protection. *Security Dialogue*. Vol. 41, No. 5 (October 2010), p. 491–514.

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