

DEVELOPMENT OF RENEWABLE ENERGY SOURCES IN UKRAINE: OPPORTUNITIES, BARRIERS AND PROSPECTS

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Abstract. The article is devoted to the study of the development of renewable energy sources in Ukraine, with an emphasis on the opportunities, barriers and prospects of this process. In the context of current energy security challenges, in particular due to the country's dependence on imported energy resources and the need to ensure stable energy supply in the context of global changes, renewable energy is becoming particularly important. Ukraine has significant potential for the development of energy sources such as solar, wind, hydropower, and biomass. Thanks to favorable natural conditions, including high levels of insolation and wind resources, Ukraine has the potential to build large-scale solar and wind power plants. However, in order to realize these opportunities, it is necessary to improve the legislative and regulatory framework, as well as to stimulate the development of investment attractiveness in the renewable energy sector. According to the data, the share of renewable energy sources in Ukraine's energy system in 2023 was 22%, which is a significant achievement, although this figure still lags behind the European average. However, the development of renewable energy faces challenges, in particular, due to the lack of effective market pricing mechanisms and technical difficulties. The article pays special attention to legislative initiatives that promote the development of renewable energy sources, in particular the "green tariff" and amendments to the laws of Ukraine in recent years. In particular, the Law of Ukraine "On Amendments to Certain Laws of Ukraine on Restoration and Green Transformation of the Energy System of Ukraine" is an important step in the market transformation of the sector, meeting European standards and creating conditions for sustainable development of renewable energy. These measures are expected to contribute to the country's energy independence and ensure compliance with international sustainable development goals, in particular, achieving carbon

neutrality by 2060. The article emphasizes the importance of formulating state plans for the development of renewable energy sources, which will increase the share of energy from renewable sources to 27% by 2030 and ensure the long-term development of this sector in Ukraine.

Keywords: renewable energy sources, energy security, green tariffs, energy investments, legislative framework, international standards.

Problem statement. The current energy landscape of Ukraine reflects an important transformation caused by the need to move towards sustainable development and reduce dependence on traditional energy sources, in particular coal and gas. Renewable energy sources (RES) play an important role in this transformation, as they not only ensure energy security, but also contribute to reducing greenhouse gas emissions and preserving the environment. In recent years, Ukraine has made significant progress in expanding its renewable energy infrastructure, particularly solar and wind power, which opens up new opportunities for economic growth and the development of innovative technologies. However, despite these achievements, the country faces a number of challenges, such as the need to modernize energy grids, political and economic barriers, and restrictions on financing renewable energy projects. In view of these factors, the development of renewable energy sources in Ukraine requires a comprehensive approach, including improving public policy, attracting investment, and developing infrastructure.

An analysis of recent research and publications on the development of RES in Ukraine demonstrates the importance of scientific developments in this area. In this context, L. Kvasniy, I. Drozd, and S. Voloshanska argue that the use of RES and modern innovative technologies allows not only to optimize costs but also to minimize environmental impact. Building an energy-efficient economy requires the combined efforts of government agencies, the business environment, and civil society. According to scientists, rising energy efficiency standards not only pose new challenges but also open up ample opportunities to implement innovative solutions and stimulate progress. At the same time, investing in research, development of advanced technologies and popularization of energy-saving practices contributes to the formation of an environmentally safe and sustainable world focused on the well-being of future generations [1, p. 357]. At the same time, K. Prieb emphasizes that in order to increase investment in the development of RES in Ukraine, it is necessary to introduce various forms and methods of attracting financing. This includes active participation in international programs of grant, technical and other specialized support, the use of state and municipal budgetary assistance, the development of energy service companies, the creation of specialized loan products in the energy sector, the issuance of green bonds, and the promotion of self-financing by energy consumers. An important step to ensure a stable investment flow is to improve the state policy in the field of RES, which should be aimed at creating favorable conditions for investors, increasing their motivation and ensuring the stability of their activities [2, p. 115]. For his part, P. Pucenteilo notes that the development of renewable energy sources is a key element of the modern energy strategy, which

aims to ensure long-term stability, energy independence and environmental sustainability. The use of such energy sources contributes to the diversification of energy supplies, reduces vulnerability to economic and political crises, and opens up new opportunities for the growth of national economies. For Ukraine, this direction is strategically important and can become the basis for modernization of the energy infrastructure and integration into the European energy community [3, p. 68]. A team of scientists, in particular O. Yara, O. Artemenko, Y. Zhuravel and N. Lytvyn, emphasize that the development of energy-saving technologies and RES will help improve environmental performance, reduce environmental damage and reduce emissions. Therefore, it is important to implement an effective energy policy, improve the regulatory framework and attract investments in these areas [4].

The purpose of the article is to study the development of RES in Ukraine with a focus on the opportunities, barriers and prospects of this process.

The main material is presented. The development of RES in Ukraine is of particular relevance in the context of current energy security challenges. The country's dependence on imported energy resources and the need to ensure a stable energy supply in the context of global economic and political changes increase the importance of transition to alternative energy sources. Renewable energy sources, such as wind, solar, river flow, biomass, and geothermal energy, can significantly reduce dependence on traditional energy resources and reduce the negative impact on the environment. In particular, Ukraine has favorable conditions for the development of wind and solar energy due to its large areas with high insolation and wind resources, which allows for the installation of powerful solar and wind power plants. At the same time, realizing these potentials requires the development and improvement of the legislative and regulatory framework, promotion of investment attractiveness, and support for relevant technological innovations.

According to UkraineInvest [5], before the full-scale invasion, the share of renewables in Ukraine's energy system was 8.1%, and the country was a world leader in the development of this sector. In 2019, Ukraine was among the top ten leaders in terms of renewable energy growth and ranked sixth in terms of investment attractiveness in the green energy sector. Over the past ten years, more than USD 12 billion has been attracted to the Ukrainian renewable energy sector. As of 2023, the share of renewables in Ukraine's electricity production, including large hydroelectric power plants, reached 22%, while in Europe this figure is 42%. Before the war, the installed capacity of RES reached 9.9 GW, including 2 GW of wind energy, 6 GW of solar energy, and 0.2 GW of biomass. At the beginning of 2024, this figure was 8.7 GW. Despite the challenges of the war, more than 1400 new RES facilities were connected in 2023, 182.3 MW of wind and about 500 MW of solar power plants were commissioned. Ukrainian businesses have invested about \$150 million in solar energy development. It stipulates that Ukraine's long-term goals are to reduce greenhouse gas emissions by 35% from 1990 levels and achieve carbon neutrality by 2060 by replacing coal energy with renewable sources. Since 2009, a "green tariff" has been in place to encourage private owners to install their own power generating facilities to sell electricity to the state. The feed-in tariff rate in 2024

is EUR 0.117 per 1 kWh. Private companies are actively deploying solar panels, wind turbines, and small hydro plants, contributing to the sustainable development of the energy sector.

In view of these achievements, it is important to note that the period from 2014 to 2023 was characterized by an active growth in the volume of installed capacity and electricity production from renewable sources. This was made possible by government incentives, such as the feed-in tariff model introduced in accordance with the Law of Ukraine "On Alternative Energy Sources" [6]. However, the support system had its limitations, in particular due to the lack of market-based pricing mechanisms and feedback. This has led to a number of economic and technical problems that require policy improvements and the introduction of new market instruments to stimulate the development of renewable energy sources in Ukraine.

Given these challenges, it is important to note that the Law of Ukraine "On Alternative Energy Sources" [6] is one of the most important legal acts that defines the legal framework for the development of alternative and renewable energy sources in Ukraine. This legislation is of strategic importance for the country, as it establishes the legal, economic and social framework for promoting the use of renewable energy sources such as solar, wind, hydro, biomass and geothermal energy. According to this law, the state provides legal protection for investors in renewable energy by offering incentives in the form of tax breaks, state subsidies and compensation to companies operating in this sector. One of the main goals is to reduce Ukraine's dependence on traditional energy sources and reduce the negative impact on the environment by reducing greenhouse gas emissions. The law also provides for the development and implementation of state programs and projects aimed at developing renewable energy sources in different regions of the country. This allows optimizing the energy infrastructure and using environmentally friendly sources for electricity and heat production. Despite the numerous achievements in the RES sector in Ukraine, the realities and challenges faced by this sector require immediate resolution. Insufficient funding, technical difficulties, and other obstacles create a need for further optimization of the legal framework to stimulate faster development of renewable energy.

In response to these challenges, a Memorandum of Understanding was signed to resolve problematic issues in the renewable energy sector in Ukraine [7]. It provided for a reduction in feed-in tariffs by investors, as well as state guarantees for the stability of payments and debt repayment. These agreements were enshrined in 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" No. 810-IX [8], which came into force in 2020.

In 2023, the Verkhovna Rada of Ukraine adopted Law No. 3220-IX "On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine" [9], which became an important step in improving the conditions for the development of renewable energy sources. The law laid the groundwork for a market-based transformation of the sector that meets European standards and provides for the creation of conditions for further

sustainable growth of renewable energy. The main provisions of the law are aimed at stimulating the use of innovative mechanisms in the renewable energy sector. In particular, it introduces the development of a system of direct contracts between renewable electricity producers and consumers, creates a register of guarantees of energy origin, and introduces new support mechanisms, such as the Net billing model for active consumers. These steps are aimed at ensuring transparency and competitiveness of the renewable electricity market. An important innovation was the identification of new market participants, including active consumers and aggregators, as well as the possibility for renewable electricity producers to leave the balancing group of the guaranteed buyer, which allows them to sell electricity independently and receive a market premium. To ensure the sustainability of the sector, the legislation has been adapted to the best international practices, including the flexibility of auction models for supporting energy producers that take into account load profiles, specific hours of the day for support, and the possibility of combined construction of renewable energy facilities with energy storage. These measures create the preconditions for the integration of innovative technologies and the effective functioning of the green energy market, which is an important step towards Ukraine's energy independence and compliance with global sustainable development goals.

The Law of Ukraine "On Amendments to Certain Laws of Ukraine on Restoration and Green Transformation of the Energy System of Ukraine" [9] is part of a broader strategy that includes the implementation of the National Renewable Energy Action Plan until 2030 [10]. For its part, the Action Plan and the measures envisaged in it should become the basis for achieving sustainable development of the RES sector in Ukraine. The expected results of its implementation are crucial for consolidating long-term growth trends and ensuring energy independence in the face of global changes. Thus, the implementation of these provisions will help strengthen the country's energy independence and security, as well as the decarbonization of the energy sector, industry, and transport, which will have a positive impact on the overall environmental situation. Among the important tasks is the formation of medium-term state plans for the development of renewable energy, which will determine the scale of technology implementation, the need for investment, and create a favorable legal environment. In particular, the implementation of European legislation in this area will be the basis for optimizing regulatory frameworks and increasing the share of renewable energy in total consumption to at least 27% by 2030. An important component is to attract investments, the latest technologies and intellectual resources for the development of the industry, which will help create new jobs, increase the competitiveness of the national economy and ensure a balanced fuel and energy structure. Another priority is the development of sustainable renewable energy that does not harm biodiversity and natural ecosystems. Taken together, these measures create the preconditions for Ukraine's long-term sustainable development, laying down strategic guidelines for improving energy efficiency, environmental responsibility and economic stability of the country.

The National Renewable Energy Action Plan until 2030 [10] and the measures envisaged therein should become the basis for ensuring the sustainable development of the RES sector in Ukraine, as their implementation will create the basis for long-term growth trends in the energy sector and increase the country's energy independence in the face of global changes. In this context, RES development programs at various levels play an important role, actively promoting the growth of this sector by ensuring the integration of innovative technologies and attracting investments. They also help to reduce environmental risks, which is an important step towards preserving natural resources and achieving the sustainable development goals set at the national level.

For example, at the local level, such programs often include initiatives for the introduction of small and medium-sized renewable energy sources, which allows communities to reduce energy dependence and improve the environment by reducing greenhouse gas emissions. For example, such programs can encourage the installation of solar panels or wind turbines, which stimulates the development of green energy at the local level. At the national level, government programs can include feed-in tariffs, financial incentives for businesses investing in renewable energy, and the creation of infrastructure to integrate these technologies into the country's overall energy grid. In Ukraine, for example, "green" tariffs were introduced, which significantly contributed to the growth of investments in solar and wind energy as part of the strategy to achieve energy security and reduce CO₂ emissions. At the same time, the international level includes multilateral agreements and commitments, such as the Paris Agreement [11] (ratified by Ukraine in 2016), which encourage countries to switch to RES. In view of the above, RES development programs at various levels create the necessary legal and financial framework to ensure sustainable growth of renewable energy, ensuring more efficient use of natural resources and reducing the negative impact on the environment.

Summarizing the above, we should highlight the prospects for the development of renewable energy, noting that in Ukraine this process has great potential in the context of martial law and growing pressure on the country's energy infrastructure. Given the strategic importance of energy security and stability of energy supply in the face of global and local challenges, the development of RES in Ukraine can be a key factor in reducing dependence on imported energy resources and ensuring energy independence.

For example, we note that Ukraine has significant potential for wind and solar energy development due to its natural resources - high levels of insolation and favorable wind conditions, which allow for the installation of powerful solar and wind power plants. The development of these energy sources should become part of the country's energy security strategy, as they can not only reduce environmental impact but also mitigate the risks associated with traditional energy resources.

Over the past decade, Ukraine has already seen an active increase in installed renewable energy capacity, in particular through instruments such as the feed-in tariff. However, further development requires improvement of the legal and regulatory framework, in particular through the development of new market-based

pricing mechanisms and the integration of innovative technologies. Implementation of new market instruments, such as a system of direct contracts between producers and consumers of renewable energy, as well as the use of the Net billing model, will increase the efficiency and competitiveness of the RES market.

The laws adopted in 2020-2023, including Law of Ukraine No. 3220-IX on the Green Transition of the Energy System, laid the foundation for market transformations in the RES sector and are in line with European standards. They provide for attracting investments, supporting technological innovations and developing new energy market models that should contribute to the growth of RES by 2030.

The prospects for RES development in the context of the national strategy also envisage achieving energy independence and sustainable development through the integration of European legislation and increasing the share of RES in total energy consumption to 27% by 2030. The strategic development of this industry provides not only economic benefits but also environmental benefits, as it ensures decarbonization of the energy, transport and industry sectors, which, in turn, will improve the environmental situation in the country.

Conclusions. Thus, we note that the development of RES in Ukraine is becoming increasingly important in the context of current energy security challenges, in particular due to dependence on imported energy resources and the need to ensure stable energy supply. Ukraine has a significant potential for wind and solar energy development due to favorable natural conditions, but realizing this potential requires improvement of legislative and investment policies. In recent years, there has been an active growth in the volume of installed renewable energy capacity, but there is a need to improve market mechanisms and further support investment in the sector. Legislative initiatives, such as the feed-in tariff, stimulate the development of renewable sources, but they have limitations that require further optimization. Government steps, including memorandums and new legislative initiatives, are aimed at creating conditions for market transformation of the sector and integration of innovative technologies. In particular, the introduction of new support mechanisms and the adaptation of legislation to European standards have significant potential to ensure the sustainable development of Ukraine's energy system and achieve energy independence.

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