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Impacts of renewable energy on Ukraine's energy sustainability

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ABSTRACT: In the face of the rapid advancement of energy systems and the requirements of modern society, analyzing the impact of alternative energy sources on the sustainability of these systems is a significant issue for countries, with Ukraine being no exception. This paper meticulously examines alternative energy sources' technical and engineering aspects, weighing their advantages and limitations in sustainable development. The objective is to identify the most effective strategies to bolster sustainable energy development in Ukraine, taking into account economic, environmental, and social aspects. The research adopts a comprehensive analytical approach, utilizing a mix of qualitative and quantitative methods, to assess the implications of alternative energy sources on the sustainability of energy systems within the context of Ukraine's sustainable development. It reviews policy documents and international agreements to gain insights into the regulatory and economic landscape. It also analyzes trends in energy production, consumption, and investment in alternative energy projects in Ukraine, comparing them with traditional energy sources. However, this sector's sustainable development hinges on providing adequate government support and creating a favorable business environment. The research underscores that one of the primary responsibilities of the Ukrainian government is to protect investors in RES and create the conditions for their continued operations.
Keywords: sustainable development; alternative energy sources; energy efficiency; economic growth.

Impactos das energias renováveis na sustentabilidade energética da Ucrânia

RESUMO: Dado o rápido desenvolvimento dos sistemas energéticos e as necessidades da sociedade moderna, a análise do impacto das fontes alternativas de energia na sustentabilidade destes sistemas é uma questão importante para os países, especialmente a Ucrânia. Este artigo fornece uma análise aprofundada dos aspectos técnicos e de engenharia, das fontes alternativas de energia, e, avalia suas vantagens e limitações no desenvolvimento sustentável. Nesse sentido, o objetivo é identificar as melhores estratégias para apoiar o desenvolvimento energético sustentável na Ucrânia, considerando aspectos econômicos, ambientais e sociais. Adota-se uma abordagem analítica abrangente para avaliar as implicações das fontes alternativas de energia na sustentabilidade dos sistemas energéticos no contexto do desenvolvimento sustentável da Ucrânia. Foram revisados documentos políticos e acordos internacionais para compreender o panorama regulamentar e econômico. Foram analisadas tendências na produção, consumo e investimento de energia em projetos de energia alternativa na Ucrânia e comparadas com as fontes de energia tradicionais. No entanto, o desenvolvimento sustentável deste setor requer apoio governamental adequado e um ambiente empresarial favorável. Destaca-se que uma das principais tarefas do governo ucraniano nesse sentor, é proteger os investidores em RES e criar as condições para as suas futuras atividades.
Palavras-chave: desenvolvimento sustentável; fontes de energia alternativa; eficiência energética; crescimento econômico.

1. INTRODUCTION

According to a resolution adopted in 2012 by the UN General Assembly, economic progress, which is currently leading to the rapid accumulation of material and human resources, is coming at the expense of excessive depletion and degradation of natural resources, which is deepening inequality among people (REDKO et al., 2022). Modern energy sources are divided into traditional and alternative. Traditional ones, such as oil, gas, and coal, have a serious drawback: they cannot be renewed. Sometimes, the reserves of these resources will be exhausted, so it is necessary to turn to other energy sources. This problem determines the need to research and develop alternative energy sources (MOLDOVANOV, 2020; PAVLYK, 2020).

Another problematic aspect is the negative impact on the environment. Using traditional sources leads to greenhouse gas emissions that affect the climate. Recently, these changes have become more noticeable: an increase in floods,

hurricanes, droughts, and other weather events that cannot be controlled (ZAPOTOTSKA; SKLIAROV, 2019; LYULYOV et al., 2021).

One of the ways to reduce the negative impact on the climate is to switch to alternative energy sources, such as wind, hydro, solar, and biogas. They are environmentally friendly and renewable. The urgency of the energy balance problem is becoming apparent in the modern world. The community faces an energy crisis when the electricity demand is several times higher than its production - about 27-30 trillion kilowatt-hours annually. The development of society is indirectly linked to the energy resources used to create new products. Humanity's increasing material and spiritual needs lead to an increase in energy demand (PAVLYK, 2020; SOTNYK et al., 2021).

The media often promote new energy generation methods, promising a cleaner future. But why is the share of these sources in energy production growing so slowly? The main problem is that no energy source competitive with traditional methods has yet been identified. Currently, 80% of energy is produced through the combustion of coal, oil, gas, and other natural resources that will be exhaustible in a few centuries (GNANGOIN et al., 2022). As Sembiyeva et al. (2023) note, investments in green technologies play a key role in energy security and sustainable development. One way to transition to greener energy sources is to adopt national and international regulatory laws limiting fuel resource extraction. However, many countries, particularly the Gulf states, do not limit production for reasons of economic viability (RENA, 2023).

Therefore, North American and European countries already bear the brunt of energy conservation. A growing number of researchers are looking for more efficient energy sources using renewable resources. Among the promising energy sources are flowing water and wind, ocean tides, heat from the earth's interior, and solar energy. Active research is also underway to reproduce thermonuclear processes similar to those on stars (VOUMIK et al., 2023).

Energy is conceptualized as the ability to perform work using physical forces. According to Efayena et al. (2022), energy is a critical resource from which individuals can derive electricity and heat. The authors point out that the energy potential of a river varies when its flow speed relative to the ground changes compared to its speed relative to a motorboat. They emphasize the need to develop and use alternative energy sources to meet the increasing global demand for energy. These sources are categorized according to their origin, technological processes and the natural environment, with a primary distinction between renewable (such as solar, wind, hydro and biomass) and non-renewable sources. Renewable sources are described as using solar panels to convert sunlight into electricity, wind turbines to convert kinetic energy, hydroelectric dams to convert water flow and biomass to convert organic materials into energy.

Although renewable energy sources are becoming increasingly popular, there are still viable non-renewable alternatives. Nuclear power generates substantial energy output through nuclear reactions but requires careful management of radioactive materials. Geothermal energy harnesses heat from the Earth's core, while tidal energy produces electricity through the movement of water. This categorization allows exploring diverse energy sources to meet societal demands, mitigate environmental impact, and advance sustainable development. However, further advancements in science and technology are necessary to optimize the efficient utilization of these resources.

2. LITERATURE REVIEW

2.1. Evaluating solar and wind energy for global sustainable power challenges

There has been considerable interest in the use of solar energy recently. Most of the energy that comes to the Earth is of solar origin, but a significant portion is dissipated in the atmosphere and hydrosphere (CROSS BORDER BUSINESS LAW AG, 2023).

The possibilities for direct use of solar energy are great. The use of 0.0125% of total solar energy would fully satisfy the current energy needs of mankind, and the use of 0.5% would ensure them forever (provided that the world's population does not exceed 20 billion people) (CROSS BORDER BUSINESS LAW AG, 2023). Unfortunately, these are only theoretical possibilities. Even under the best weather conditions, the energy density of a sunbeam does not exceed 250 W m^{-2}. Let's say that to collect this amount of energy in a year, it is necessary to place collectors in an area of 130,000 km^2! In addition, to produce such a large number of collectors, 1.3*109 tonnes of aluminum would be needed. The world's aluminum reserves are estimated to be approximately the same (CROSS BORDER BUSINESS LAW AG, 2023).

There are numerous limitations to the use of solar energy. In addition to the cost and large volume of resources, the problem is the lack of free space. For example, if in 2100, humanity plans to fully meet its energy needs from solar resources, the area of collectors will be between 1 and 3 million km^2. The use of solar radiation will require significant human resources (CROSS BORDER BUSINESS LAW AG, 2023). So, it is too early to talk about the massive use of solar energy. Although solar power plants can be useful in areas remote from the grid and in resorts, the overall contribution of solar energy is still low. Why build collectors when nature has larger and more powerful resources such as the atmosphere and hydrosphere (CROSS BORDER BUSINESS LAW AG, 2023)?

The energy in moving air masses is hundreds of times greater than the capacity of all the hydroelectric power stations on Earth's rivers. The wind constantly blows over the earth, from small splashes to strong storms. These unexpected air currents can satisfy all the needs of humanity. However, the share of electricity generated by wind is only 0.1%. Why is there such a limit to the promising and environmentally friendly use of wind energy? Humankind has been harnessing wind power for more than 5,000 years. First, the wind was used to propel boats, grind grain and pump water. Nowadays, wind power is used to generate electricity. Even though the cost of electricity from wind is currently relatively low at 4 cents per kilowatt-hour, new wind power projects often do not pay off for a long time. The most successful project was the installation of wind turbines on the Hawaiian island of Ohio. A giant turbine with a blade diameter of 122 meters generates more than 6,200 kW at a 47 km h^{-1} wind speed. The steady rise in energy prices will make such projects even more profitable, and the share of wind energy may increase over time (CROSS BORDER BUSINESS LAW AG, 2023) (Figure 1).

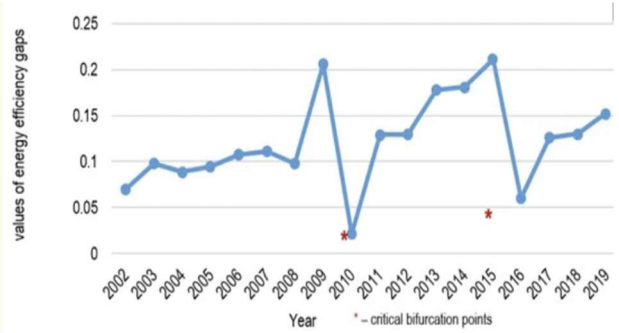

Figure 1. Assessment results of the energy efficiency gaps in Ukraine in 2002-2019. (Source: VASYLIEVA et al., 2021)
Figura 1. Avaliação das lacunas de eficiência energética na Ucrânia em 2002-2019 (VASYLIEVA et al., 2021).

2.2. Renewable energy sources and their impact on economic growth in Ukraine

Hydropower, deriving from the kinetic energy of river water, stands as a notable renewable energy source. This technique harnesses the flow of water to produce electrical energy, facilitated by hydropower plants equipped with turbines that convert water movement into electricity. Various methods of tapping into river flow for energy production possess distinct advantages. They are considered clean and renewable energy sources that do not emit harmful substances into the atmosphere. Hydropower plants can be of different sizes - from small to large mega-projects - depending on the river flow volume. However, the use of river energy has its limitations. Special structures, such as dams, are often required to store water and create the flow needed for power generation. This can affect river ecosystems and natural landscapes, creating serious problems (RAZUMKOV CENTRE, 2019).

Despite this, hydropower remains one of the most efficient methods of electricity generation, providing a steady stream of energy with relatively low carbon emissions. Development and research in this area aim to reduce the negative impact on the natural environment and improve technologies to maximize the efficient use of this important energy source (GHOBAKHLOO & FATHI, 2021).

2.3. Geothermal and marine energy dynamics

Since ancient times, people have known about a huge source of energy hidden deep in the Earth's crust. The power of even the smallest volcanoes exceeds the capabilities of any artificial power plant by hundreds of times. Although humanity has not yet developed a way to harness the energy of volcanoes directly, Iceland is already an excellent example of the rational use of this underground resource. This country is fully self-sufficient in the heat with the help of hot fountains that operate with incredible precision (CROSS BORDER BUSINESS LAW AG, 2023). The initial experiments using geysers did not take place in Iceland. The ancient Romans tried to use the heat of geysers for their baths in Caracalla (CROSS BORDER BUSINESS LAW AG, 2023). Energy from the depths of the earth is used not only for heating. Some power plants use hot underground resources and have been operating for a long time. The first such plant was built in 1904. Today, there is a 500-kilowatt geothermal power plant near the city of San Francisco. However, hot springs are not everywhere on earth. Although geysers are a great energy source, their location complicates any attempts to use these resources globally (CROSS BORDER BUSINESS LAW AG, 2023).

Ocean energy, or marine power, uses the various forms of energy found in seawater to create electricity. This energy source includes tides, waves, ocean currents, and the temperature difference between the surface and the ocean's depths. One method of harnessing marine energy is tidal power, which uses the natural movement of water caused by tides to drive turbines. Wave energy is another method where generators convert wave vibrations into electricity. Electricity also turns turbines that operate according to the water flow. Some technologies use the temperature difference between the surface and the ocean's depth to create electricity (Shedding light on energy - 2023 edition - Eurostat, n.d.). Marine energy can be an important source of renewable energy. It is very environmentally friendly and does not emit carbon into the atmosphere. However, technological development, production costs, and the impact on marine ecosystems remain challenges in this area. Innovations and research aim to reduce costs and negative environmental impacts to optimize this energy source's potential (Shedding Light on Energy - 2023 edition - Eurostat, n.d.; KUROK et al., 2023).

The state of the Ukrainian economy regarding energy production and use is at a critical juncture, and the government needs to introduce appropriate policies. Therefore, it is necessary to analyze the link between energy efficiency and development to assess its impact in the future. The results of this study have important implications for policy-making in Ukraine and promoting optimal growth. The study focuses on the relationship between energy efficiency and economic growth in Ukraine, which is important for policymakers, economists, and academics to ensure sustainable development, strategic energy strategy, and environmental protection. Understanding this relationship's dynamics helps identify opportunities to promote economic growth and implement efficient and responsible energy use.

2.4. Research Objectives

The primary aim of this study is to explore the relationship between energy efficiency and economic development in Ukraine. This investigation aims to answer two key questions:

1. What is the relationship between energy efficiency and economic growth in Ukraine during its transition period?
2. How does energy efficiency affect economic growth?

3. METHODOLOGY

This study adopts a comprehensive analytical approach to assess the implications of alternative energy sources on the sustainability of energy systems within the context of Ukraine's sustainable development.

3.1. General Background

The investigation commences by outlining the evolution and present state of global energy systems, with a particular emphasis on Ukraine. Given Ukraine's distinct geopolitical and environmental circumstances, notably the ongoing conflict and its pursuit of sustainable development, the research is contextualized within these parameters. This approach lays the groundwork for comprehending the

pivotal role of alternative energy in realizing sustainability objectives.

3.2. Data Collection

Data were systematically gathered from various sources, including government reports, energy sector analyses, and academic journals. These sources offered insights into the technical characteristics, efficiency, and environmental impacts of various alternative energy technologies (wind, solar, hydro, and biomass) and their implementation in Ukraine. Policy documents and international agreements were also reviewed to understand the regulatory and economic landscape.

2.3. Data Analysis

Trends in energy production, consumption, and investment in alternative energy projects in Ukraine were analyzed, compared to traditional energy sources, and assessed to assess their impact on sustainability indicators such as carbon emissions, energy security, and economic viability.

3.4. Methodological Challenges

The study acknowledges the complexity of accurately predicting the long-term impacts of alternative energy adoption, considering the fluctuating geopolitical situation, technological advancements, and global energy markets. The research adopts scenario analysis to mitigate these uncertainties, exploring various future paths based on different levels of alternative energy integration into Ukraine's energy mix.

Through this methodological framework, the study aims to provide a holistic understanding of how alternative energy sources can contribute to the sustainability of Ukraine's energy systems. The findings are intended to inform policymakers, stakeholders, and researchers about the strategic direction for energy development in Ukraine, emphasizing the balance between economic growth, environmental protection, and social equity.

4. RESULTS

4.1. Renewable energy sector in Ukraine in 2021

In 2021, the Ukrainian energy sector is in a critical position to determine the strategic direction of its further development. This is especially true for the renewable energy sector (RES). On the one hand, the government has begun to gradually fulfill the obligations set out in the Memorandum of Understanding on the Resolution of Problematic Issues in the Renewable Energy Sector of Ukraine, which was signed in June 2020 with the mediation of the Energy Community. This led to the start of debt repayment to renewable energy producers, which positively impacted the market. However, at the same time, there were attempts at the state level to turn feed-in tariffs into illegal state aid or an illegally applied measure. At the initiative of the Antimonopoly League, there have been attempts to recognize feed-in tariffs as illegal or unconstitutionally applied. Nevertheless, the President of Ukraine made an international commitment to end domestic coal consumption by 2035 and phase out the use of thermal energy from 2022 by signing the Global Energy Declaration on Wind Turbines at COP26 (OGARENKO; ALIYEVA, 2017; THE CABINET OF MINISTERS OF UKRAINE, 2017; SKOROKHOD; KOSTIUK, 2021).

On the other hand, the government continues focusing on maintaining the outdated nuclear infrastructure. It approves the state program for developing the nuclear industrial complex until 2026. Contradictory actions and commitments raise concerns about the country's future energy development strategy (SOTNYK, 2021).

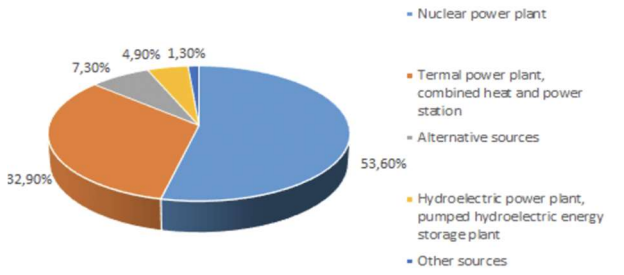

Figure 2. Composition of Ukraine's Electricity Generation and Trade in the First Half of 2020. (Source: Bushovska, 2021)
Figura 2. Composição da geração e comércio de eletricidade da Ucrânia no primeiro semestre de 2020. (Fonte: Bushovska, 2021)

5. DISCUSSION

Numerous studies confirm the correlation between energy use and a country's economic progress (BUZUGBE, 2023).

In 2019, Ukraine was ranked among the top 10 countries worldwide for the rapid development of renewable energy, and in 2020 - among the top 5 countries in Europe for the active expansion of solar energy. According to the Climate-scope analysis by Bloomberg New Energy Finance, in 2019, Ukraine ranked 8th out of 104 countries in terms of investment attractiveness in low-carbon energy sources and the formation of a green economy. However, in 2021, the country ranked 48th in terms of overall investment potential among 136 countries, according to Bloomberg NEF (KONECHENKOV, 2022).

Since 2019, investments in new renewable energy projects in Ukraine have consistently exceeded investments in fossil fuel projects. Over the past ten years, domestic and international investors have invested more than $12 billion in FDI in renewable energy in Ukraine's economy. At the end of 2021, about 35% of the installed capacity in the renewable energy sector was owned by foreign investors, which demonstrates the competitiveness and openness of the Ukrainian renewable energy market (Production of "green" energy by facilities and the number of "green" tariffs, n.d.).

BUSHOVSKA (2021) critically examines the Ukrainian government's inadequate efforts in promoting renewable energy sources. According to data presented in Figure 2 of the article, the primary sources of Ukraine's electricity generation in the first half of 2020 were nuclear, thermal, and hydroelectric power. The country produced 73,431 million kWh of electricity during this period, exporting 2,676.4 million kWh and importing 1,756.6 million kWh.

This analysis underscores the critical need for a strategic shift towards more sustainable and renewable energy sources, highlighting the gap in government support and the potential for policy enhancement to foster a more renewable-centric energy sector.

During this period, the list of the largest international lenders and investors in the renewable energy sector of Ukraine included the European Bank for Reconstruction and

Development, the Black Sea Trade and Development Bank, the US International Development Finance Corporation (DFC), the Bavarian Federal Bank (BayernLB), the Investment Fund of Nations (IFU), the Nordic Environment Finance Corporation (NEFCO) and other organizations. Investments in constructing power plants using this renewable energy source are represented by organizations and individual investors from many countries in Europe and Asia (KONECHENKOV, 2022).

Data from the National Energy and Utilities Regulatory Commission (NEURC) show that the installed capacity in Ukraine's renewable energy sector reached 9,655.9 megawatts as of 31 December 2021 (MINISTRY OF ENERGY OF UKRAINE, 2023).

It is important to note that significant development in this area is accounted for by domestic SPPs, which account for 37% of RES capacity (KONECHENKOV, 2022).

According to the data, the total installed capacity of home solar power systems reached 1205.1 MW at the end of 2021. Industrial solar has seen a steady decline over the same period. The industrial solar generation capacity increase in 2021 was only 305.5 MW or 26.1% of the total new RES capacity commissioned in 2021. Less than 818.1 MW, which is 3.6 times less than in 2020 (1123.6 MW). Thus, the total installed solar energy capacity at the end of 2021 is 7586.3 MW, including households. As for wind power, it remains the second-largest installed capacity in the renewable energy sector in Ukraine. However, the wind energy sector added the newest capacity to the country's green energy mix in 2021. The share of commissioned wind capacity in 2021 was 30.6% or 358.8 MW. This is 2.5 times higher than the capacity of new wind farms commissioned in 2020 (144.2 MW). Thus, the total installed capacity of wind power at the end of 2021 is 1672.9 MW. Before the conflict, 34 wind farms or 699 wind turbines with an average unit capacity of 3.5 MW, were built in Ukraine (KONECHENKOV, 2022).

In 2021, bioenergy in Ukraine proved to be a promising sector, especially in the gas crisis that emerged in late 2021 and early 2022. This sector has the potential to partially compensate for the shortage of natural gas through heat and electricity production. During this period, 21 MW of biogas plants were commissioned, accounting for 1.79% of the total capacity, twice as much as in 2020. Also, 43.1 MW of biomass power plants were launched, an increase of 3.68% compared to the previous year (SYCH et al., 2023).

The share of small hydropower plants commissioned in 2021 is 1.24% or 14.6 MW. This indicates a certain increase in this renewable energy segment, although the figures are lower than for other types of bioenergy (SYCH et al., 2023) (Figure 3).

This trend in increasing renewable energy capacity, especially in bioenergy, indicates the prospects and development of alternative energy sources in Ukraine. This could be an important step in reducing dependence on imported natural gas (KONECHENKOV, 2022).

5.1. Renewable Energy Sector of Ukraine 2022

According to the Ukrainian Wind Energy Association (UWEA), during the martial law in Ukraine, the production of "green" energy by wind and solar power plants decreased by 80% and 30%, respectively. In a letter dated 28 September 2022, the Minister of Energy of Ukraine and the NEURC were asked to support Draft Law No. 8191, extending the agreement term with the "Green" project until 31 December 2024. This will allow for the completion of the construction of 300 to 500 MW of green power plants and meet the requirements for ensuring origin and operation developed in Directive 2009/28/EC and Directive (EC) 2018/2001 (SKOROBOGATOVA et al., 2022; MINISTRY OF ENERGY OF UKRAINE, 2024).

Figure 3. Wind farms in Ukraine as of the end of 2021 (Source: Konechenkov, 2022).
Figura 3. Parques eólicos na Ucrânia no final de 2021 (Fonte: Konechenkov, 2022)

1. Bonus wind turbine, Kyiv region
2. Staryi Sambir 1 WPP, Lviv region
3. Staryi Sambir 2 WPP, Lviv region
4. Zborivska WPP, Ternopil region
5. Bioenergoproduct WPP, Ternopil region
6. Shevchenkove-1 wind farm (first stage), Ivano-Frankivsk region
7. Ovid Wind Wind Farm, Odesa region
8. Dniester wind farm, Odesa region
9. Yuzhne Energy WPP, Odesa region
10. Ochakivskyi wind farm, Mykolaiv region
11. Blagodatny Wind Park, Mykolaiv region
12. Prychornomorsky Wind Park, Mykolaiv region
13. Pivdennyi Wind Park, Mykolaiv region
14. Shchaslyvyi Wind Park, Mykolaiv region
15. Shvydkyi Wind Park, Mykolaiv region
16. WPP "Sinha Energy LLC", Mykolaiv region
17. Novorossiysk wind farm, Kherson region
18. Stavky wind farm, Kherson region
19. Berehova wind farm, Kherson region
20. Novotroitska WPP, Kherson region
21. Overianivska WPP, Kherson region
22. Myrnenska WPP, Kherson region
23. Syvash WPP (2006), Kherson region
24. Syvash Wind Farm (2019), Kherson region
25. Botievo WPP, Zaporizhzhia region
26. Prymorska 1 wind farm, Zaporizhzhia region
27. Prymorska 2 wind farm, Zaporizhzhya region
28. Orlivska WPP, Zaporizhzhia region
29. Zaporizhzhia WPP, Zaporizhzhia region
30. Kramatorsk WPP, Donetsk region
31. Vetroenergoprom, Donetsk region
32. Novoazovsk Wind Park, Donetsk region
33. Krasnodon Wind Park, Luhansk region
34. Lutuginsky wind farm, Luhansk region

In July 2022, the Ministry of Energy reported that about 30% of solar power plants in Ukraine were damaged or destroyed. The martial law increased the demand for domestic renewable energy power plants by ten times for households and 4-5 times for industrial enterprises. On 13 December 2022, Ukraine signed a two-year cooperation program with the International Energy Agency (IEA) to restore the power system after the destruction. Key areas include energy system security, energy efficiency, low-carbon

hydrogen, renewable energy, biogas, and data analysis and statistics. According to the World Energy Outlook 2022 study of 6 December 2022, the IEA forecasts significant growth in renewable energy in other countries and considers three development scenarios: public policy (STEPS), announced commitment (APS), and net zero emissions by 2050 (SKOROBOGATOVA; DESNA, 2022).

As of 6 December 2022, low-carbon energy accounted for approximately 40% of electricity generation (30% from renewables and 10% from nuclear). According to the STEPS scenario, renewable energy will account for 45% of total electricity production by 2030 and 60% in the APS scenario. The European Union supports onshore and offshore energy systems, accounting for more than 40% of total electricity production by 2050 under the STEPS scenario and more than 50% under the APS and NZE scenarios. According to the NZE scenario, renewable energy will become the backbone of the world's economies (SKOROBOGATOVA; DESNA, 2022).

5.2. Renewable energy sector of Ukraine 2023

According to the State Enterprise Guaranteed Buyer, UAH 0.46 billion was paid for electricity from renewable energy sources (RES) in 2022, and UAH 10 billion was paid for five months of 2023. As of 1 June, 99% of the debt for 2021, 53.9% for 2022 and 57.6% for 2023 has been repaid. Of these, the payment for April 2023 is 56.3%, and for May - 50.3%. NPC Ukrenergo's debt to Guaranteed Buyer totalled UAH 18.56 billion. From 1 January to 1 June 2023, Guaranteed Buyers purchased 2,923 thousand MWh of renewable electricity from producers. Of this volume, 64% was solar, 18% was wind, 14% was bioenergy, and 5% was hydropower (Actual information on settlements with electricity producers, n.d.; KONECHENKOV, 2022).

4.3. Exports

Shortly after exports to Slovakia resumed on April 17, 2023, they were halted again at the request of Slovakia. This brief resumption underscores the absence of significant connectivity or system stability issues and highlights the importance of compliance with European rules, including the implementation of synchronized bilateral auctions. In late April, discussions between the European Commission, the Energy Community, Slovak regulators, and the Ukrainian and Slovak gas transmission system (GTS) operators, led by NPC Ukrenergo Development, resulted in an agreement to streamline the coordination of export contracts between the two countries' GTS operators, subject to further approval by the Ukrainian authorities (DLF ATTORNEYS-AT-LAW, 2023).

4.4. Import

This seems to be a difficult situation for the electricity market in Ukraine. The NEURC is currently discussing tariff changes that could improve the situation of market participants. This could reduce budgetary expenditures on energy support and make market entry more attractive. However, several factors influence this need for change.

Currently, the current price of electricity does not correspond to the actual energy price, which leads to the fact that the state budget compensates for the difference between the price and the actual cost of electricity. However, the budget does not currently have any sources of capital that could be used for this purpose (DLF ATTORNEYS-AT-LAW, MAY 19, 2023). Approval of the new tariffs will allow market participants to operate without incurring large losses. This is important, especially given the damage to the energy infrastructure.

In addition, prices set on the market are lower than in neighboring countries. For example, the Ukrainian price during peak periods is around EUR 100, while the average price in the Slovak market is EUR 102 (excluding delivery and distribution costs). In this situation, importing electricity for commercial purposes does not make sense if it does not bring commercial benefits. However, additional financial resources are needed to compensate for the domestic production and import deficit, which can be covered by consumer dollars or the budget (DLF attorneys-at-law (May 19, 2023). Therefore, price changes and electricity market rules are needed to prepare for the heating season and possibly compensate for the lack of domestic energy production through imports (DLF attorneys-at-law (May 19, 2023).

5.5. Future Development of the VDE Sector

These strategies and documents, developed before the conflict, significantly define the role of renewable energy sources (RES) in Ukraine's development. The Energy Strategy until 2035 focuses on the development of renewable energy sources to achieve 25% of the total primary energy supply by 2035 from these sources. This strategy envisages renewables developing most dynamically compared to other types of production. It also envisages the development of distributed generation from RES and the introduction of smart grids (KYRYLENKO et al., 2021).

The Economic Strategy 2030 also identifies decarbonization, RES development, and circular economy as the priority areas for developing the national economy. It aims to increase the share of RES to 25% of total electricity production by 2030 (CABINET OF MINISTERS OF UKRAINE, 2021). It also focuses on expanding storage facilities, hydrogen production, and supporting local renewable energy production (KONECHENKOV, 2022).

These strategies reflect Ukraine's desire to implement initiatives to reduce carbon dioxide emissions, improve energy efficiency, and increase the use of renewable energy sources in line with European standards and principles of green development (DIACHYK et al., 2017). The Green Energy Concept of Ukraine until 2050, launched by the government in 2020, states that by 2050, the country could reach a 70% share of renewable energy sources (RES) in electricity production. Also important are targets of up to 15% from solar energy. It can be provided by plants installed on the roofs of private homes and commercial complexes (Production of "green" energy by facilities and the number of "green" tariffs, n.d.). The RES targets are also reflected in the National Low-Carbon Development Strategy until 2050 and contribute to the Paris Agreement (Konechenkov, 2022).

However, in the context of a large-scale war with the Russian Federation, it is necessary to focus on implementing the 2032 Recovery Plan for Ukraine, presented by the Government at the international donor conference in Lugano in 2019. According to this plan, developing the renewable energy sector will be a priority. The plan envisages the construction of new solar and wind power plants to increase export capacity, renewable energy plants to produce

hydrogen from renewable sources, hydroelectric power plants, and pumped hydroelectric power plants. It is also planned to commission new modern facilities, batteries, and electrolysis plants over the next ten years. Preliminary estimates of investments in the Energy Independence and Green Path program amount to $130 billion (SELIKHOVA, 2022).

Specific targets for RES development do not cover all potential opportunities. For example, according to the Ukrainian Wind Energy Association, at least 7 GW of new wind farms could be added by 2030. This is due to the availability of permits for the construction of new facilities with a capacity of 4 GW and an increase in the average capacity of wind turbines to 6 MW or more, which makes achieving this goal a reality (KONECHENKOV, 2022).

Ukraine's bioenergy potential is also impressive. Biomass and biofuels can replace natural gas. Biomethane is predicted to meet up to 30-40% of the EU's gas needs by 2050. Ukraine can produce up to 10 billion m3 of biomethane annually, mainly from agricultural waste. It is possible to achieve biogas/biomethane production of up to 6 billion m3 per year, some of which can be exported. The country has enough resources to replace up to 4 billion cubic meters of natural gas annually by 2030 (KONECHENKOV, 2022).

The development of solar energy is also important. In Ukraine, installing photovoltaic systems on rooftops and homes attracts attention (APERGIS et al., 2023). It is important to note that Ukraine's recovery plan until 2032 does not have specific targets related to offshore wind energy. However, according to the World Bank, Ukraine has a high technical potential for developing this industry, especially in the Black Sea, where the theoretical potential of offshore wind farms is 250 GW, of which Ukraine has (APERGIS et al., 2023). Ukraine's Renewal Plan until 2032 defines the strategic direction of renewable hydrogen energy development in line with the European Hydrogen Strategy. Recognized by the EU as a priority partner in the hydrogen transition, Ukraine plans to create 10 GW of renewable hydrogen production capacity by 2030, 75% of which can be exported to Europe, including Germany. Even after the war, these projects remain relevant, and Ukraine has launched several renewable hydrogen projects (VERKHOVNA RADA OF UKRAINE, 2021).

The occupation of the Zaporizhzhia nuclear power plant and attempts to disconnect it from the grid, as well as the control of most coal and gas mines, demonstrate the need to move away from fossil fuels. These developments and pressure on Russian oil and gas reveal the hidden costs of conventional energy. Therefore, renewable energy associations in Europe and Ukraine believe that the post-war reconstruction of Ukraine should be based on renewable energy sources (RES). These associations are convinced that by 2030, Ukraine could reach a 50% share of renewables in its total electricity mix. This is important to ensure energy security, upgrade Ukraine's energy infrastructure, and compensate for losses from closing outdated coal-fired power plants (OGARENKO; ALIYEVA, 2017). It is also worth noting that an important event occurred in the Ukrainian energy sector this year: Ukraine became a member of the European Network for Transmission of Electricity for Europe (ENTSO-E). This association brings together 42 network managers from 35 European countries.

In 2017, Ukraine signed an agreement to synchronize its power system with the European one, which envisages the start of synchronization of the Ukrainian system with the European one in 2023. However, events have changed this schedule, making it more urgent than a year earlier. The cost of integration is estimated at UAH 11 billion, but the annual economic effect of synchronization could reach UAH 40 billion. Interestingly, even before the invasion, 96% of Ukraine's power systems were technically connected to the occupying countries and Moldova, while only 4% were synchronized with European countries (TYMOSHENKO et al., 2023).

Among the benefits of interconnecting the Ukrainian power system with the European one is a reduction in the cost of energy production through more efficient use of production capacities. In addition, the opportunities for exporting Ukrainian and importing foreign electricity are improving, as are the opportunities for attracting foreign investors. One of the positive effects of this integration is the development of renewable energy sources through special programmers (TYMOSHENKO et al., 2023).

6. CONCLUSIONS

A shift to renewable energy sources (RES) could eliminate the possibility of political or military pressure from one country on another over energy sources. Many past conflicts have involved battles over energy resources such as oil, gas, or coal. For example, Ukraine is a victim of constant energy pressure and blackmail from Russia, which affects the supply of heat and electricity to Ukrainian consumers. Using renewables can eliminate this political influence because these energy sources are available to everyone, and there is no need for war. It is important to note that renewables can ensure society's safety and health. For example, events such as the Chornobyl disaster and the occupation of the Zaporizhzhia NPP demonstrate the risks of nuclear energy and its potential for misuse in personal interests. On the other hand, wind energy is safe and does not threaten life and health. Increasing nuclear energy in Ukraine's recovery plan could increase the country's vulnerability to such “nuclear terrorism” and maintain its dependence on nuclear fuel imports. However, operations in this area require attention and caution, especially about public safety.

It is worth emphasizing that renewable energy sources, such as wind power, can make societies independent in many areas, including electricity and decarbonization of the economy. These technologies can be key to helping countries become independent of oil imports and reduce their corresponding dependence.

The development of renewable energy sources brings obvious economic and social benefits. However, sustainable development of this sector requires appropriate government support and favorable business conditions. One of the main tasks of the Ukrainian government is to protect investors in renewable energy and create the necessary conditions for their further activities.

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