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GEOGRAPHICAL AND ECONOMIC ASPECTS OF RENEWABLE ENERGY DEVELOPMENT IN UKRAINE AMID MILITARY THREATS

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ABSTRACT
Purpose: The article describes the primary renewable energy sources and their geographical use, which is dictated by energy policy.
Design/Methodology/Approach: The research strategy combines qualitative and quantitative methods to analyse Ukraine's renewable energy sector during wartime disruptions and post-war recovery. A combination of theoretical and empirical methods, such as analysis, synthesis, theoretical modelling, and generalising materials from the scientific literature, must be used to solve the task set. The article analysed 38 sources published between 2012 and 2024, which were searched in 16 databases and search engines: CINAHL, ClinicalTrials.gov, Cochrane Library, EbscoHost, Embase, ERIC, Google Scholar, LILACS, ProQuest, PsycINFO, PubMed, ScienceDirect, Scopus, SportDiscus, TRID and Web of Science.
Finding: The main challenges for developing the energy sector in Ukraine include growing demand for energy resources against the backdrop of declining reserves of traditional energy resources, rising prices, and growing dependence on energy imports.
Research Limitation: A major limitation is the focus on Ukraine's unique geopolitical and economic context, so the results cannot be directly generalised to countries without similar circumstances, such as ongoing conflicts or dependence on external energy resources.
Practical Implication: This study allowed us to identify the main factors influencing the solution of energy supply and energy consumption problems as conditions for sustainable and proportional development of regional economies.
Social Implication: The study offers relevant solutions to meet society's needs, including recommendations on energy security, job creation, and environmental preservation. This would improve citizens' quality of life and ensure long-term energy stability.
Originality/ Value: The study is novel because it contributes to the field of renewable energy. It addresses the intersection of energy security and economic efficiency in times of crisis. It offers a new framework for sustainable energy policy in the regions of Ukraine during the war.
Keywords: *energy policy. gas market. geographical dimension. renewable energy. threats*

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INTRODUCTION

The impact of Russian aggression is significantly impeding renewable energy projects and the sector as a whole, causing a substantial setback compared to its status before the war in Ukraine. As of September 2022, a quarter of the existing renewable energy capacity was out of operation, including the large majority of power generation from wind. The number of projects destroyed, damaged, and under enemy occupation is increasing rapidly.

According to the Statistical Review of World Energy 2024 data, the world's proven oil reserves reached 239.8 billion tons (1700.1 billion barrels) at the end of 2023. This is enough for approximately 52 years of global production (R/P), considering the constant growth of global energy consumption. The world's proven gas reserves at the end of 2023 totalled 186.9 trillion cubic meters, ensuring 55 years of global production. In 2023, the world's coal reserves were 892 billion tons, which is enough to ensure 114 years of global output, and today, it has the largest reserves of all fossil fuels. Therefore, alternative energy is the key to solving the issues of resource depletion (Kovalskyi et al., 2024; Ma et al., 2018).

One of the areas of geothermal energy is using low-potential energy from the earth, featuring low source temperatures (3-30 °C) (Redko et al., 2019). This energy cannot be used directly in power supply systems. Such energy can be utilised by devices called heat pumps. In other countries, heat pumps are becoming more widely used in residential heating systems. In Canada and the United States, heat pumps comprise 45% of the market for heating systems (Pearce & Sommerfeldt, 2021). The European Union plans to provide more than 50% of its heat supply through heat pumps in the coming years (Marina et al., 2021).

The ability of matter atoms to absorb electromagnetic radiation ensures solar energy conversion into thermal energy. In this case, the energy of electromagnetic radiation is converted into the kinetic energy of atoms and molecules of matter, i.e., thermal energy. As can be seen from Figure 1, the intensive use of concentrated solar radiation began in the second decade of this century. The installed load of this type of power plant worldwide was 4.8 GW at the end of 2016.

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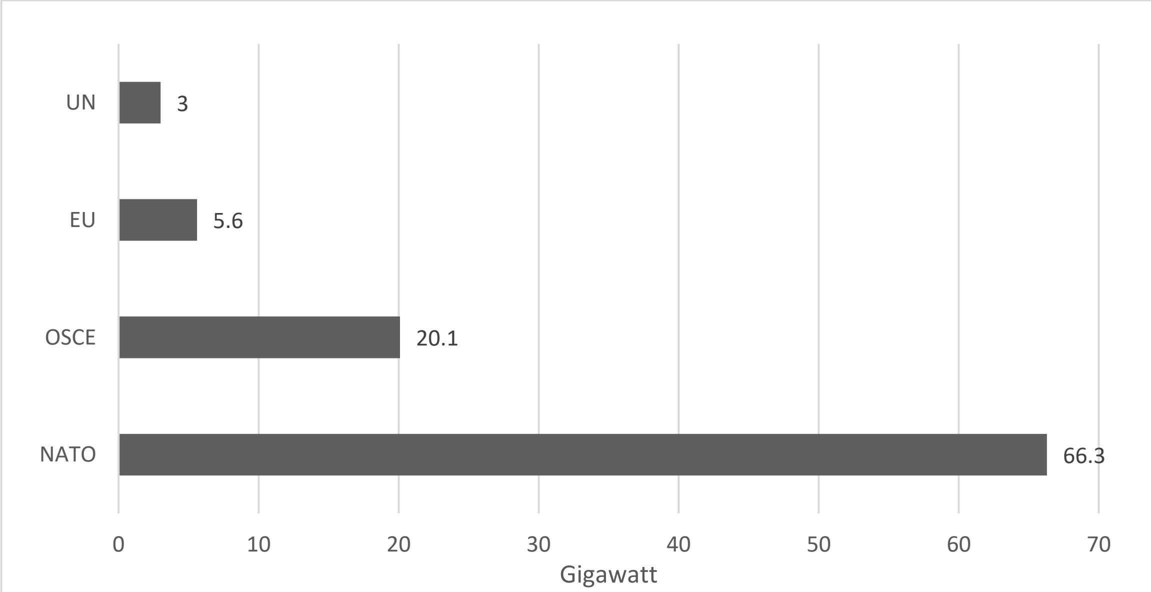

Figure 1: Dynamics of using concentrated solar radiation globally
Source: Ma et al. (2018)

The advantage of heating using solar rays is the high speed of the process, exceeding 1000 K/s. The molten material is not contaminated with foreign inclusions, as the narrow beam melts it in the form of the same material. An oxidising or reducing atmosphere can be created in the working chamber. Several dozen solar furnaces have been built worldwide. They are in the USA, France, Japan, Algeria, Uzbekistan, Armenia, and other countries. The capacity of the installations varies from 5-10 kW to 1000-5500 kW. The largest solar concentrator in the world was built in Uzbekistan near Tashkent, as shown in Figure 2. The mirror area is 1840 m^2 (12090 mirrors). The maximum temperature in the working zone is 2000°C.

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Figure 2: General view of the world's largest solar concentrator (Uzbekistan)
Source: Ang et al. (2022)

In addition to visualising the state of the development of alternative energy sources (in general and by type), the corresponding features of the regions can be obtained based on either relative or synthetic indicators (Sáez-Martínez et al., 2016; Ang et al., 2022). Regional profiles can be formed by any set of indicators selected for analysis. The choice of the best value with subsequent comparison with regional indicators will allow for comparing the selected indicators and ranking regions based on these estimates.

LITERATURE REVIEW

The development of renewable energy sources in Ukraine is determined by the geographical diversity of renewable energy sources, such as solar, wind, biomass and hydropower (Zaichenko et al., 2024; Kovalskyi et al., 2024), which remain underutilised due to infrastructural economic and political barriers (Lukashevych et al., 2024; Zinchenko & Yakovenko, 2024). In particular, Kostenko et al. (2024) note Ukraine’s strategic advantage for solar energy production, especially in the southern regions, despite the challenges associated with military activities that disrupt the operation of installations and grid connections.

In contrast, the economic aspects of renewable energy, highlighted in the works of Sokhan et al. (2024), Ikevuje et al. (2024), and Kukharets et al. (2024), focus on its ability to increase energy independence and reduce dependence on imported fuels. In particular, as Rokicki et al. (2023) and Ilie et al. (2023), the issue of the dependence of EU member states and Ukraine on energy imports from Russia becomes increasingly critical in wartime. However, Hlushko (2024) notes that Ukrainian resources remain underutilised, accompanied by infrastructure vulnerabilities and economic constraints exacerbated by prolonged hostilities.

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Therefore, it should be noted that hydrogen energy has significant potential. The global hydrogen energy market could reach $2 billion annually by 2025. Burning hydrogen produces lower greenhouse gas emissions (50 % less than petrol-powered cars). When hydrogen is produced from renewable raw materials, it has a high energy density and generates only water as the primary emission source (Kovalskyi et al., 2024; Khoja et al., 2020; Mehrjerdi, 2020). However, hydrogen is highly explosive, has a low liquefaction temperature, and low density in its gaseous state, which causes several issues related to its storage and accumulation. The achievement of the set goals is planned by creating and implementing state support measures in the fields of hydrogen production, storage, transportation, and storage (Ahmed et al., 2020).

The combustion of biomass for energy production has been practised for a long time. However, this process causes environmental pollution and is not very efficient, as the full potential of biomass as an energy source is not utilised (Yang et al., 2015; Xia et al., 2022). Currently, biomass meets only about 10% of global energy demand, which allows hydrogen to be one of the leaders among all renewable energy sources (Ampah et al., 2022). Large-scale industrial hydrogen production is carried out through natural gas reforming (via conversion into synthesis gas) with an efficiency of about 70-75% or through coal gasification, which has an efficiency of about 45-65% with a concomitantly high level of CO_2 emissions (Mazhar et al., 2021).

Hydrogen technologies do not compete with traditional methods of generating electricity and heat but rather with decarbonisation systems of the energy system: carbon capture and storage, bioenergy, and heat pumps (Abbasi et al., 2020; Rej et al., 2022). Hydrogen has proven itself well in specific niches; for example, serial production of cars that run on alternative engine sources is already underway. Storage and transportation of hydrogen in cylinders is associated with increased danger due to its high volatility and explosiveness when in contact with air (Amrouche et al., 2016). This explains the extremely high material intensity of such transportation methods – a container weighing approximately 20 kg for every 1 kg of transported hydrogen, negatively affecting transportation costs.

METHODOLOGY

To solve the tasks set, a combination of theoretical and empirical methods is and will be used, including theoretical methods such as analysis to determine the aspects of existing concepts of the development of renewable energy sources and their integration into the economy; the synthesis was applied to the development of comprehensive strategies for the energy development of Ukraine; theoretical modelling is used to predict possible scenarios for the implementation of renewable energy technologies; and generalisation of materials from scientific literature on the researched issue contributed to the formation of objective conclusions. Instead, empirical methods of interpretation include: the analysis was used to

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study the current state of development of renewable energy sources in Ukraine; the synthesis was applied to combine the results of various studies on the concept of the development of renewable energy sources in the context of post-war reconstruction; and the systematisation of the obtained data was used to form the characteristics of the efficiency of various energy systems.

The search engines analysed in this study represent common resources in frequently cited systematic reviews and meta-analyses in recent years. The article analysed 38 sources published between 2012 and 2024, which were searched in 16 databases and search engines: CINAHL, ClinicalTrials.gov, Cochrane Library, EbscoHost, Embase, ERIC, Google Scholar, LILACS, ProQuest, PsycINFO, PubMed, ScienceDirect, Scopus, SportDiscus, TRID and Web of Science. Although most of the mentioned search systems contain closed databases, the emphasis was therefore on open-access publications available for collecting empirical data on renewable energy implementation, evaluating legislative and institutional frameworks, and applying comparative analysis with international practices to propose tailored strategies for Ukraine's sustainable energy transition.

RESULTS AND DISCUSSION

The war has inflicted significant damage upon Ukraine's renewable energy sector, abruptly halting its prewar momentum and plunging it into a state of profound disruption. This grim reality underscores the urgent imperative to prioritise the sector's revitalisation as a cornerstone of Ukraine's post-war economic and environmental reconstruction. While renewables present a beacon of hope in this bleak landscape, their resurgence hinges upon establishing critical regulatory, institutional, and financial preconditions, unlocking their full potential to drive Ukraine's sustainable and prosperous future.

Alternative energy sources include geothermal, hydrothermal, aerothermal energy, biomass energy, biogases (gas from organic waste, sewage treatment plants), and secondary energy resources, which contain blast furnace and coke oven gases, coal seam degasification, and the conversion of waste energy potential from technological processes (Salem et al., 2022). The research of legal, economic, organisational, and technical problems related to using alternative energy sources is reflected in the studies by both Ukrainian and foreign scholars. Anwar et al. (2021) described the efficiency of photovoltaic converters, which ranges from 12% to 24%, depending on the design and semiconductor materials used.

Zappa et al. (2019) claimed that in 2016, the total capacity of photovoltaic installations worldwide reached 303 GW, sufficient to cover 1% of the world's total electricity demand. China, Germany, and Japan took the leading positions in the global arena of solar energy

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production at that time (Annual Energy Outlook, 2012; China 2030, 2012; Australian Energy Resource Assessment, 2014).

Having subjected seaweed to fermentation, Parrado et al. (2016) obtained ethanol. Seaweed can also be composted to produce biogas, dried, and burned for energy.

Adams et al. (2018) list four main methods of converting wave energy into electricity:

– the principle of "oscillating water column" (OWC);
– attenuators;
– the principle of "body oscillation" (point absorber);
– the principle of "overflow" (overtopping).

At present, systems for energy storage from renewable sources using fuel cells have been developed (Ikegami & Wang, 2016) and are being implemented. As shown in Figure 3, electrical energy generated by solar panels (or wind turbines) is used to produce hydrogen (via electrolysis), which is stored in special containers and supplied to fuel cells to generate electrical energy during periods of peak energy consumption (or at night when solar radiation is absent).

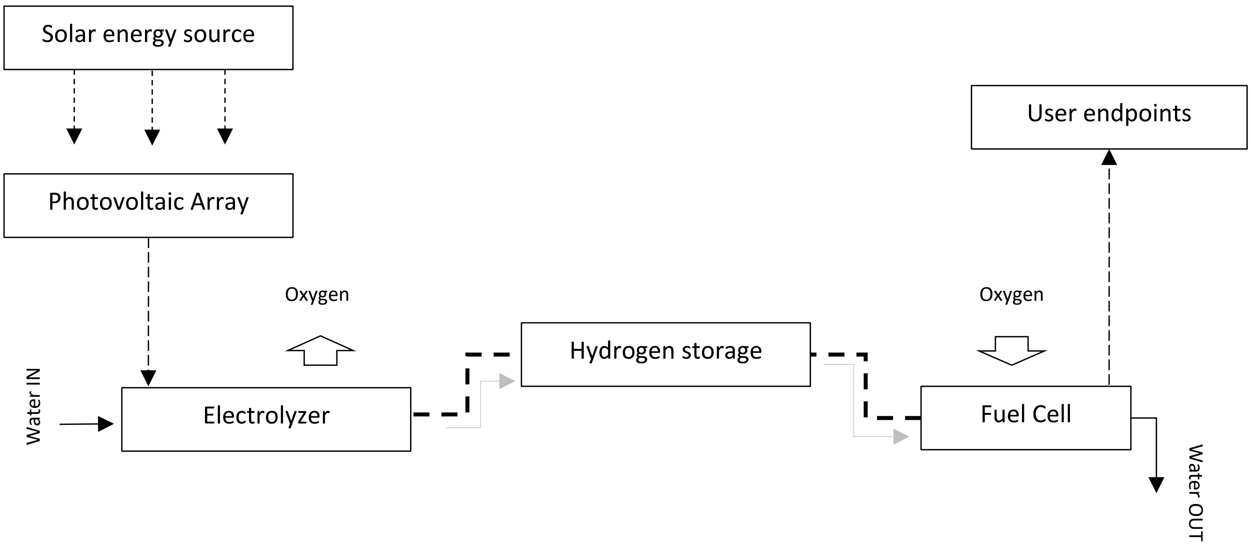

Figure 3: Principle of Accumulation and Use of Solar Energy: photovoltaic array; hydrogen storage; oxygen; fuel cell
Source: Ikegami & Wang (2016)

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This study aims to analyse the use of renewable energy sources and justify the prospects for developing them. The paper also analyses engineering and technical approaches to implementing an energy policy strategy.

At present, the following types of organic biofuels are used for transportation:

– bioethanol (mainly made from sugarcane and corn);
– bio-methanol (from marine phytoplankton);
– biobutanol ($C_4H_{10}O$ - butyl alcohol from sugarcane, beets, corn, wheat, etc.);
– dimethyl ether (from coal, natural gas, cellulose-paper production waste, and biomass).
– biodiesel (made from animal, vegetable, and microbial fats, as well as products of their esterification (rapeseed, soybean, palm, coconut oil) (Doppalapudi et al., 2021; Doppalapudi et al., 2023).
– second-generation biofuel (different fuels obtained by biomass pyrolysis, algae, etc.).

Biodiesel–methyl ester, which possesses fuel properties and is obtained due to a chemical reaction from plant fats, finds the broadest application in many countries (Sotnyk et al., 2023). In the world (2021), 185 trillion litres of biofuel were produced, of which about 125 trillion litres account for fuel ethanol (74%). The leading world producers of biofuels are the USA and Brazil.

Swiss company Clean Hydrogen Producers (CHP) has developed a technology for hydrogen production from water using parabolic solar concentrators. The area of the installation's mirrors is 93 m². At the concentrator's focus, the temperature reaches 2200°C. Water begins to split into hydrogen and oxygen at temperatures above 1700°C. Hydrogen production amounts to 3800 kg per year (about 10.4 kg per day). According to the information resource of the International Network of Renewable Energy (REN21), the contribution of Renewable Energy Sources (RES) to gross energy consumption is 21.5%. The largest share is traditional biomass utilisation (7.8%) (Ziegler et al., 2019).

The share of RES in global electricity consumption is somewhat higher, at 24.5%. The maximum contribution to electricity consumption comes from hydropower (16.6%). As of 2023, China, the United States, and Germany have the largest installed RES capacity. The intensive development of renewable energy in China in recent years and wind and solar energy in Germany is worth noting. Germany ranks first globally because it consumes much less per capita than China.

Significant achievements in the development of renewable energy are evident in the countries of the European Union (300 GW of installed capacity). When considering the percentage contribution of RES to the energy consumption of EU countries, significant achievements of Scandinavian countries and Latvia can be noted. State support and incentives for using RES

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drive Europe's success in this field. From the long-term perspective of world energy development, by 2100, the consumption of hydrocarbon energy is planned to be reduced by 30-35% by replacing it with renewable energy sources.

Despite its high cost, renewable power has matured sufficiently to outperform non-renewable energy with accumulated practical experience. Even so, unconventional energy sources encounter numerous impediments when utilised in a standalone fashion. WT and PV rely on the environment to produce electricity, whereas FC requires hydrogen-rich fuel. In this context, Figure 4 shows how non-conventional energy will change the world by 2040.

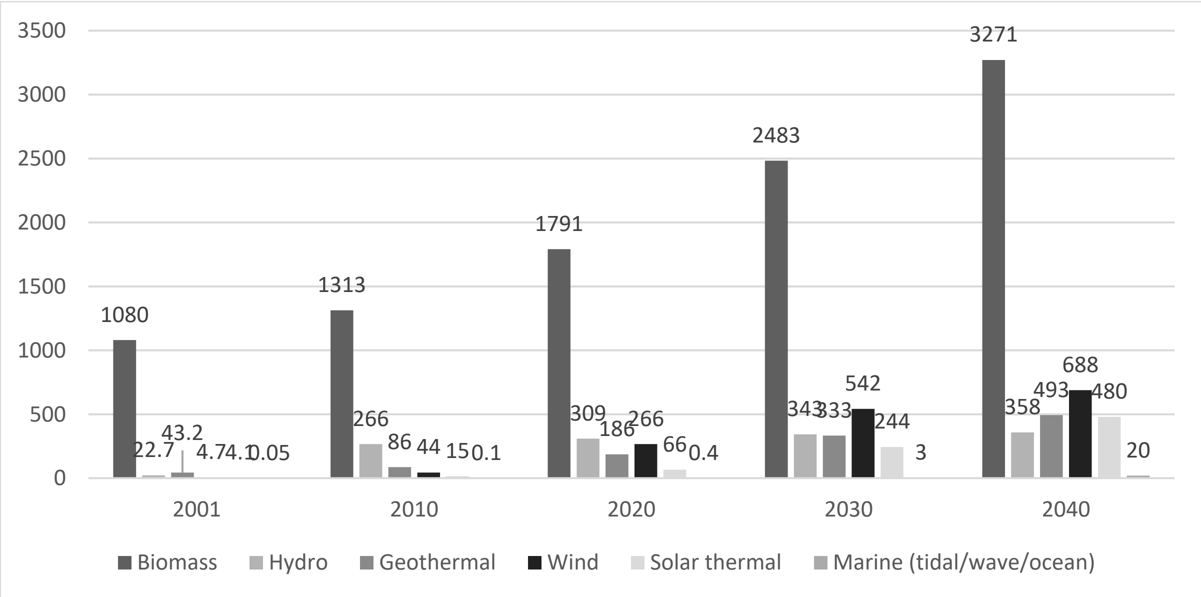

Figure 4: Scenario of the World Energy Development
Source: Jain & Sawle (2021)

In Ukraine, as in the rest of the world, the largest contribution to renewable energy comes from wood fuel sources (firewood, wood chips, wood waste). The country has recently commissioned new photovoltaic, wind, and hydroelectric power plants in recent years. In particular, according to a study by the International Energy Agency in 2023, the most important indicators are solar and wind energy to achieve zero net emissions by 2050 (GW), as indicated in Figure 5.

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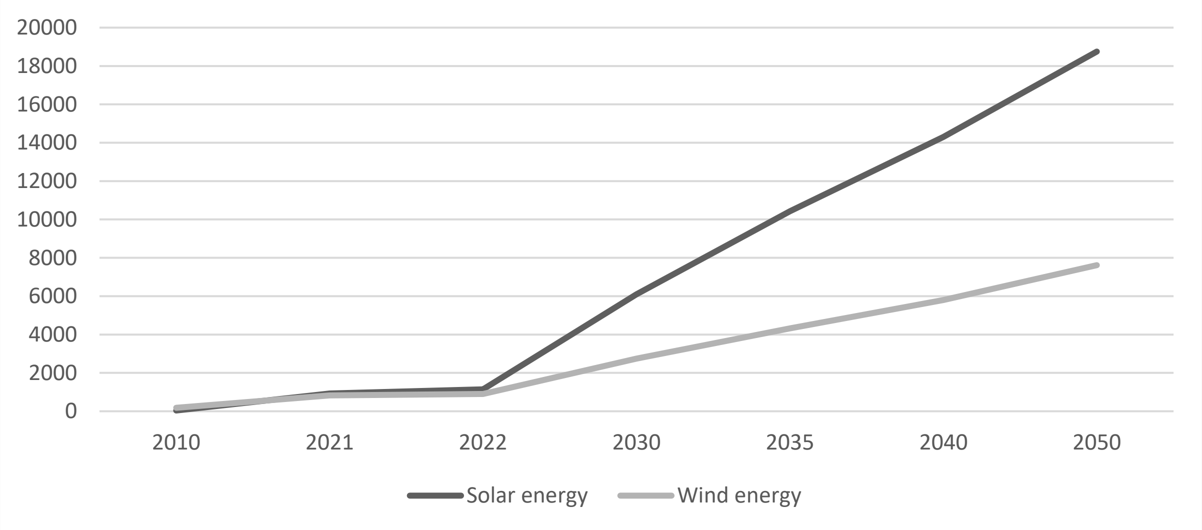

Figure 5: Solar and Wind required to meet Net Zero Emissions by 2050 (GW)
Source: developed by the authors based on IEA (2023)

Given the continued European integration processes even during hostilities, in May 2022, the European Commission presented the REPowerEU strategic plan. The proposed REPowerEU plan consists of four interconnected blocks: energy saving, diversification of energy imports, replacing fossil fuels, accelerating the EU country's transition to clean energy, and smart investment.

The document proposes comprehensive measures to reduce the consumption of oil, oil products and natural gas and the active introduction of renewable energy sources. Initiatives within the framework of REPowerEU are called to respond to the modern challenges of the global energy crisis by increasing energy efficiency, diversifying energy supplies and accelerating the transition to renewable resources (EEAS, 2022). Adherence to the course of European integration, which provides for the observance of measures to improve environmental conditions, will provide Ukraine with a gradual replacement of fossil fuels in various sectors - household, industrial, and electricity generation. Therefore, this plan serves as a means to guarantee the energy security of the populace, thereby enhancing their rights and liberties while simultaneously promoting the principles of sustainable development.

In addition, Ukraine's most important task currently is mitigating the energy crisis that arose due to abandoning Russian energy sources. The decision to abandon Russian energy sources is also made in the European Union member states, and it is included in the REPowerEU strategic plan.

As a crucial component of this decision, it is imperative to consider diverse economic factors to implement appropriate measures to alleviate the ramifications of the energy crisis and avert

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a further expansion of the energy deficit, which may soon surpass 4 GW. Therefore, the economic aspects of the development of renewable energy in Ukraine in the context of military threats encompass several crucial areas:

– Increasing energy independence by abandoning external (primarily Russian) energy resources and switching to own renewable energy sources;
– Attracting international investments to support energy projects considers international standards and environmental sustainability requirements;
– Reducing energy costs is due to reducing the burden on the state budget and diversifying resources for defence and social needs;
– Supporting economic sustainability at the local level, which involves the creation of new jobs and the development of infrastructure, stimulates the economy and stabilises local communities;
– Ensure long-term energy stability by advancing local resources and innovative methods for generating sustainable energy.

In order to effectively overcome the energy crisis in Ukraine and stabilise the energy system, it is necessary to implement several strategic measures to ensure long-term energy stability and independence. Development of renewable energy infrastructure, including the accelerated construction and modernisation of solar, wind and bioenergy facilities, is critical. This will reduce the dependence on imported energy sources and establish a solid foundation for meeting energy requirements. Securing the modernisation of existing energy facilities, maximising energy usage, and minimising energy losses are some of the complex measures necessary.

Another important step is strengthening international cooperation, in particular within the framework of the partnership with the EU countries. This includes both the involvement of technologies and financial support for projects focused on energy restoration.
In addition, it is important to promote the development of scientific research initiatives and innovative technologies that can increase the efficiency of using renewable energy sources and create innovative solutions to strengthen the state's energy independence.

Institutional support and improving legal regulation are significant in this context. A stable regulatory environment contributes to creating favourable conditions for attracting investors. Creating tax incentives and other support tools for companies specialising in producing clean energy is necessary to integrate renewable energy into national energy policy effectively.

Discussion

In the context of the formulated results of regional energy policy, it is necessary to focus on the accelerating rates of economic growth in regions and the growth of energy efficiency in regions compared to the primary energy resource consumption rates (Gurieiev et al., 2020).

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The factor of energy security of the region through alternative energy sources is one of the most important characteristics of their development. The choice of appropriate assessment criteria and their quantitative values will allow for creating appropriate scorecards of alternative energy potential and the degree of its development (Atstaja et al., 2022).

Suppose solar radiation in the Sahara was used by 10%. It would be possible to produce the current world energy demand in approximately 700 km by 700 km, as shown in Figure 6. However, with the current state of technology and engineering, it is impossible to transmit energy to consumers worldwide cost-effectively. Regarding geographic latitude, solar radiation in Ukraine is much lower than in the Sahara: the country receives up to 1200 kWh/m^2 of radiation per year. This corresponds to the amount of energy contained in 60 litres of oil. In general, the annual solar radiation throughout the territory of Ukraine represents an amount of energy that exceeds the gas requirement for energy production by 15 times.

Along with industrial electricity production, solar modules have been used in recent years to create new environmentally friendly vehicles (hybrid cars, aeroplanes, dirigibles, etc.). As can be seen, wind power is on the rise globally. The total installed capacity of wind power in 2021 reached 487 GW. The highest growth rate is observed in China (+23%). The top 5 countries in wind energy development include China, the United States, Germany, India, and Spain. Considering the size of the countries, Germany has the most tremendous success in developing wind energy (Azad et al., 2015; Azad et al., 2019).

Figure 6: The potential for solar energy use in the Sahara Desert
Source: Azad et al. (2015)

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The largest solar power plant is in Morocco (Sahara Desert), as shown in Figure 7. Its capacity equals 500 MW.

Figure 7: Overview of the largest solar power plant (Morocco)
Source: Azad et al. (2019)

Geothermal power plants can be effectively used for both heating and electricity generation. As can be seen, geothermal power plants are most widely used in the United States, the Philippines, and Indonesia. For example, in the United States, the registered capacity of geothermal power plants is more than 3.5 GW. Global hydropower generation in 2022 reached 1064 GW. As can be seen, the top 10 countries of the world's hydropower producers include China (about 28% of global production), Brazil, the United States, Canada, and other countries. Incineration of municipal solid waste - this technology is used in many European countries. For example, on the outskirts of Vienna (Austria), four thermal power plants have been set up that run on industrial and municipal waste (including toxic and medical waste) and provide thermal energy to the city.

One progressive and still unexplored alternative energy source is tidal energy, which occurs in shallow waters, ranging from 1-3 TW. The technical potential of tidal currents is 48 TWh/year (0.17 EJ) in Europe and 30 TWh/year (0.11 EJ/year) in China. Ocean currents also have significant energy potential. For example, the Gulf Stream has a technical potential for generating 25 GW of energy equivalent. Ocean thermal energy potential is 44,000 TWh/year (159 EJ/year) as shown in Figure 8. As shown in the figure, this type of energy has the maximum value in equatorial regions.

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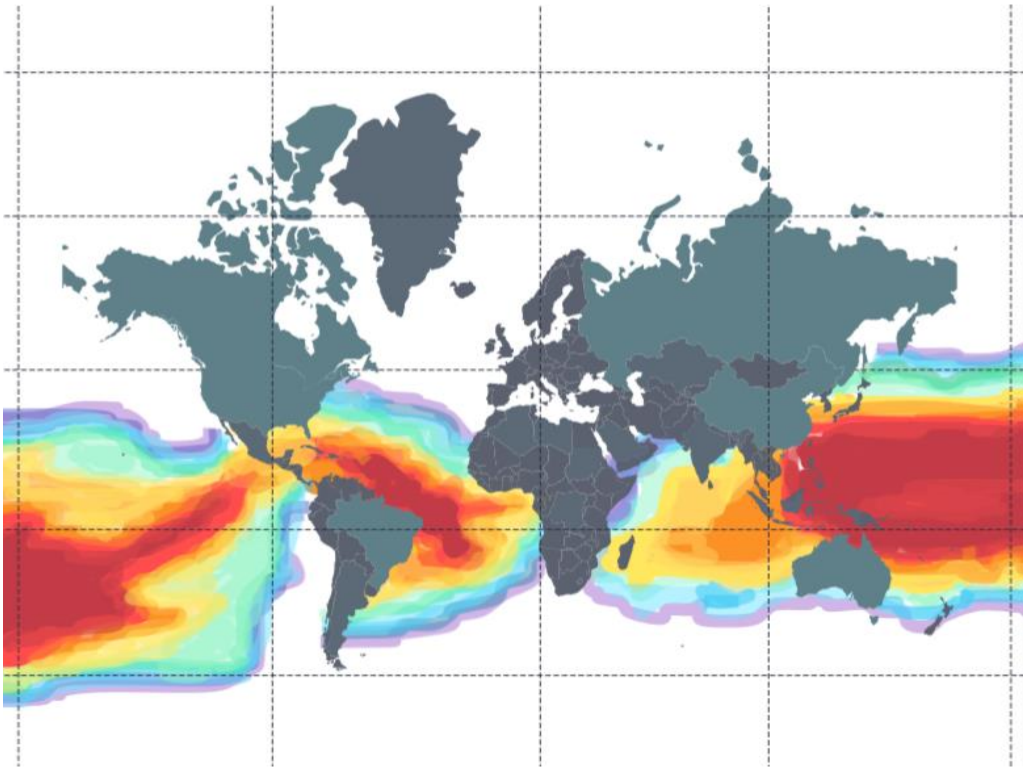

Figure 8: Global distribution of oceans' thermal energy
Source: Gurieiev et al. (2020)

The peculiarity of the political orientation in solving optimisation problems based on smart networks includes the application of artificial intelligence and neural network elements. The latter are used to search for the most optimal solutions to the problems using previous experience of similar issues and the experience of leading experts in energy policy. It should be noted that decision-making using "smart grids" can be carried out online, using all modern operational types of communication (Internet, cellular, and radio communications).

CONCLUSION

The main challenges for the development of the energy sector in Ukraine compared to the European countries are as follows: growing demand for energy resources against the backdrop of declining reserves of traditional energy resources and rising prices; growing dependence on energy imports; the need to protect the environment; and the need for significant investments in the energy sector.

The priority areas of energy development in our country include improvement and diversification of the fuel and energy balance; maximum involvement of domestic energy

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resources, including renewable, unconventional, and secondary energy sources; reconstruction and modernisation of existing facilities and replacement of retired facilities with the introduction of new scientifically based energy efficient technologies; and reduction of fuel consumption for electricity and heat generation.

Practical implications include actionable recommendations for developing renewable energy infrastructure, fostering international cooperation, and strengthening institutional frameworks. The study advocates for energy independence, economic stability, and environmental sustainability as crucial factors in rebuilding resilient communities on a social level. The study's unique contribution to energy policy strategy is the integration of war-specific challenges into energy policy strategy.

REFERENCES

Abbasi, K., Kangjuan, L., Nadeem, M. A., Khan, A., & Shaheen, R. (2020). Agricultural and manufacturing sector determinants of electricity consumption, price, and real GDP from Pakistan. *North American Academic Research, 3,* 21–44. https://doi.org/10.5281/zenodo.3604943

Adams, S., Klobodu, E. K. M., & Apio, A. (2018). Renewable and non-renewable energy, regime type and economic growth. *Renew Energy, 125,* 755–767. https://doi.org/10.1016/j.renene.2018.02.135

Ahmed, K., Farrok, O., Rahman, M. M., Ali, M. S., Haque, M. M., & Azad, A. K. (2020). Proton Exchange Membrane Hydrogen Fuel Cell as the Grid Connected Power Generator. *Energies, 13,* 6679. https://doi.org/10.3390/en13246679

Ampah, J. D., Afrane, S., Agyekum, E. B., Adun, H., Yusuf, A. A., & Bamisile, O. (2022). Electric vehicles development in Sub-Saharan Africa: Performance assessment of standalone renewable energy systems for hydrogen refueling and electricity charging stations (HRECS). *Journal of Cleaner Production, 376,* 134–238. https://doi.org/10.1016/j.jclepro.2022.134238

Amrouche, S. O., Rekioua, D., Rekioua, T., & Bacha, S. (2016). Overview of energy storage in renewable energy systems. *International Journal of Hydrogen Energy, 41,* 20914–20927. https://doi.org/10.1016/j.ijhydene.2016.06.243

Ang, T., Salem, M., Kamarol, M., Das, H. Sh., Nazari, M. A., & Prabaharan, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy Strategy Reviews, 43,* 100939. https://doi.org/10.1016/j.esr.2022.100939

Annual Energy Outlook (2012). Energy Information Administration, Office of Integrated Analysis and Forecasting. U. S. Department of Energy.

Anwar, A., Siddique, M., Eyup, D., & Sharif, A. (2021). The moderating role of renewable and non-renewable energy in environment income nexus for ASEAN countries: evidence

ISSN: 2408-7920

from Method of Moments Quantile Regression. *Renewable Energy*, *164*, 956–967. https://doi.org/10.1016/j.renene.2020.09.128

Atstaja, D., Koval, V., Grasis, J., Kalina, I., Kryshtal, H., & Mikhno, I. (2022). Sharing model in circular economy towards rational use in sustainable production. *Energies*, *15*(3). https://doi.org/10.3390/en15030939

Australian Energy Resource Assessment (2014). GeoScience_Australia. https://arena.gov.au/assets/2018/08/australian-energy-resource-assessment.pdf

Azad, A., Rasul, M., Islam, R., & Shishir, I. R. (2015). Analysis of Wind Energy Prospect for Power Generation by Three Weibull Distribution Methods. *Energy Procedia, 75,* 722–727. https://doi.org/10.1016/j.egypro.2015.07.499

Azad, K., Rasul, M., Halder, P., & Sutariya, J. (2019). Assessment of Wind Energy Prospect by Weibull Distribution for Prospective Wind Sites in Australia. *Energy Procedia*, *160,* 348–355. https://doi.org/10.1016/j.egypro.2019.02.167

China 2030 (2012). *Building a Modern, Harmonious, i Creative High-Income Society*. World Bank, Development Research Center of State Council, The People's Republic of China.

Doppalapudi, A., Azad, A., & Khan, M. (2021). Combustion chamber modifications to improve diesel engine performance and reduce emissions: A review. *Renewable and Sustainable Energy Reviews, 152,* 111683. https://doi.org/10.1016/j.rser.2021.111683

Doppalapudi, A., Azad, A., & Khan, M. (2023). Advanced strategies to reduce harmful nitrogen-oxide emissions from biodiesel fueled engine. *Renewable and Sustainable Energy Reviews, 174,* 113123. https://doi.org/10.1016/j.rser.2022.113123

EEAS (2022). REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. *European Union*. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3131

Gurieiev, V., Kutsan, Y., Iatsyshyn, A., (...), Artemchuk, V., & Popov, O. (2020). Simulating systems for advanced training and professional development of energy specialists in power sector. *CEUR Workshop Proceedings, 2732,* 693–708. https://doi.org/10.31812/123456789/4456

Hlushko, A. D. (2024). Strengthening energy security of Ukraine. *Economy and Region*, 3(94), 157-163. https://journals.nupp.edu.ua/eir/article/view/3501

IEA (2023). Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach. *International Energy Agency*. 226 p. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

Ikegami, M., & Wang, Z. (2016). The long-run causal relationship between electricity consumption and real GDP: evidence from Japan and Germany. *Journal of Policy Modeling, 38*(5), 767–784. https://doi.org/10.1016/j.jpolmod.2016.10.007

Ikevuje, A. H., Kwakye, J. M., Ekechukwu, D. E., Ogundipe, O. B., & Esiri, A. E. (2024). Optimizing the energy mix: Strategies for reducing energy dependence. *Open Access Research Journal of Multidisciplinary Studies*, 8(1), 94-104. https://doi.org/10.53022/oarjms.2024.8.1.0051

African Journal of Applied Research
Vol. 11, No. 1 (2025), pp. 115-133
http://www.ajaronline.com
https://doi.org/10.26437/ajar.v11i1.
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Ilie, A. G., Zlatea, M. L. E., Negreanu, C., Dumitriu, D., & Pentescu, A. (2023). Reliance on Russian Federation Energy Imports and Renewable Energy in the European Union. *Amfiteatru Economic*, 25(64), 780-797. https://www.ceeol.com/search/article-detail?id=1161380

Jain, S., & Sawle, Y. (2021). Optimization and comparative economic analysis of standalone and grid-connected hybrid renewable energy system for remote location. *Frontiers in Energy Research, 9,* 724162. https://doi.org/10.3389/fenrg.2021.724162

Khoja, A., Azad, A., Saleem, F., Khan, B., Naqvi, S., Mehran, M., & Amin, N. (2020). Hydrogen Production from Methane Cracking in Dielectric Barrier Discharge Catalytic Plasma Reactor Using a Nanocatalyst. *Energies, 13,* 5921. https://doi.org/10.3390/en13225921Kostenko, G. P., Zaporozhets, A. O., Zaporozhets, N. V., & Verpeta, V. O. (2024). Aspects of integration of renewable distributed generation into the energy supply system of Ukraine. *Problemy Ekonomiky*, (2), 83-93. https://doi.org/10.32983/2222-0712-2024-2-83-93

Kovalskyi, M., Duczmal, W., Oleksiuk, M., Skomorovskyi, A., & Berezivskyy, Z. (2024). Renewable Energy Sources in The Context of Emissions Reduction: Geographical Aspects And Challenges for Sustainable Development. African Journal of Applied Research, 10(1), 374-386.

Kukharets, V., Hutsol, T., Kukharets, S., Glowacki, S., Nurek, T., & Sorokin, D. (2023). European Green Deal: The impact of the level of renewable energy source and gross domestic product per capita on energy import dependency. *Sustainability*, 15(15), 11817. https://doi.org/10.3390/su151511817

Lukashevych, Y., Evdokimov, V., Polukhin, A., Maksymova, I., & Tsvilii, D. (2024). Innovation In The Energy Sector: The Transition To Renewable Sources As A Strategic Step Towards Sustainable Development. African Journal of Applied Research, 10(1), 43-56.

Marina, A., Spoelstra, S., Zondag, H. A., & Wemmers, A. K. (2021). An estimation of the European industrial heat pump market potential. Renewable and Sustainable Energy Reviews, 139, 110545. https://doi.org/10.1016/j.rser.2020.110545

Ma, Y., Zhang, J., Huang, Y., & Cao, J. (2018). A novel process combined with flue-gas desulfurisation technology to reduce lead dioxide from spent lead-acid batteries. *Hydrometallurgy, 178,* 146–150. https://doi.org/10.1016/j.hydromet.2018.04.006

Mazhar, A., Khoja, A., Azad, A., Mushtaq, F., Naqvi, S., Shakir, S., Hassan, M., Liaquat, R., & Anwar, M. (2021). Performance Analysis of TiO2-Modified Co/MgAl2O4 Catalyst for Dry Reforming of Methane in a Fixed Bed Reactor for Syngas (H2, CO) Production. *Energies, 14,* 5921. https://doi.org/10.3390/en14113347

Mehrjerdi, H. (2020). Modeling and optimisation of an island water-energy nexus powered by a hybrid solar-wind renewable system. *Energy, 197,* 117–217. https://doi.org/10.1016/j.energy.2020.117217

Parrado, C., Girard, A., Simon, F., & Fuentealba, E. (2016). 2050 LCOE (Levelized Cost of Energy) projection for a hybrid PV (photovoltaic)-CSP (concentrated solar power) plant in the Atacama Desert, Chile. *Energy, 94,* 422–430. https://doi.org/10.1016/j.energy.2015.11.015

Pearce, J. M., & Sommerfeldt, N. (2021). Economics of grid-tied solar photovoltaic systems coupled to heat pumps: The case of northern climates of the US and Canada. Energies, 14(4), 834. https://doi.org/10.3390/en14040834

Redko, A., Redko, O., & DiPippo, R. (2019). Low-temperature energy systems with applications of renewable energy. Academic Press, 1-373. https://books.google.com.ua/books?hl=uk&lr=&id=fsC4DwAAQBAJ&oi=fnd&pg=PP1&dq=low-potential+energy+from+the+earth,+featuring+low+source+temperatures+(3-30+%C2%B0C).+&ots=Wo-vXXzOeB&sig=aA-SvajRR_5sl4H_V_UZiT1_MfA&redir_esc=y#v=onepage&q&f=false

Rej, S., Bandyopadhyay, A., Murshed, M., Mahmood, H., & Razzaq, A. (2022). Pathways to decarbonisation in India: the role of environmentally friendly tourism development. *Environmental Science and Pollution Research, 29,* 50281–50302. https://doi.org/10.1007/s11356-022-19239-2Rokicki, T., Bórawski, P., & Szeberényi, A. (2023). The impact of the 2020–2022 crises on eu countries' independence from energy imports, particularly from russia. *Energies*, 16(18), 6629. https://doi.org/10.3390/en16186629

Sáez-Martínez, F. J., Lefebvre, G., Hernández, J. J., & Clark, J. H. (2016). Drivers of sustainable cleaner production and sustainable energy options. *Journal of Cleaner Production, 138,* 1, 1–7. https://doi.org/10.1016/j.jclepro.2016.08.094

Sokhan, I., Luzan, Ye., & Zapadenko, V. (2024). The Role of Strategic Management in the Adaptation of Companies to the Conditions of the Energy Crisis in Ukraine. *Successes and achievements in science*, 8(8), 520-535. https://doi.org/10.52058/3041-1254-2024-8(8)-520-535

Sotnyk, I., Kurbatova, T., Trypolska, G., Sokhan, I., & Koshel, V. (2023). Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis. *Environmental Economics, 14*(2), 13–27. http://doi.org/10.21511/ee.14(2).2023.02

Xia, W., Apergis, N., Bashir, M., Ghosh, S., Do˘gan, B., & Shahzad, U. (2022). Investigating the role of globalisation, and energy consumption for environmental externalities: Empirical evidence from developed and developing economies. *Renewable Energy, 183,* 219–228. https://doi.org/10.1016/j.renene.2021.10.084

Yang, H., He, J., & Chen, S. (2015). The fragility of the environmental Kuznets curve: revisiting the hypothesis with Chinese data via an "extreme bound analysis". *Ecological Economics*, *109,* 41–58. https://doi.org/10.1016/j.ecolecon.2014.10.023

Zappa, W., Junginger, M., & van den Broek, M. (2019). Is a 100% renewable European power system feasible by 2050? *Applied Energy, 233-234,* 1027–1050. https://doi.org/10.1016/j.apenergy.2018.08.109

African Journal of Applied Research
Vol. 11, No. 1 (2025), pp. 115-133
http://www.ajaronline.com
https://doi.org/10.26437/ajar.v11i1.
Received: August 5, 2024
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Revised: December 13, 2024
Published: January 2025

Zaichenko, S., Derevianko, D., Trachuk, A., & Jukova, N. (2024). Evaluation of complex indicators of forecasting the strategic development of renewable energy sources of Ukraine in the structure of renewable national energy of Ukraine. *Power Engineering: Economics, Technique, Ecology*, 3(77), 138-146. https://doi.org/10.20535/1813-5420.3.2024.314624

Ziegler, M. S., Mueller, J. M., Pereira, G. D., Song, J., Ferrara, M., Chiang, Y.-M., & Trancik, J. E. (2019). Storage Requirements and Costs of Shaping Renewable Energy Toward Grid Decarbonization. *Joule*, *3*(9), 2134–2153. https://doi.org/10.1016/j.joule.2019.06.012

Zinchenko, O., & Yakovenko, V. (2024). Diagnostics of the green investment market potential: approaches and principles in the realities of Ukraine. In Transforming the practice of managing the innovative development of socio-economic systems: a collective monograph. *National University of Kyiv-Mohyla Academy*, 510-521. https://ekmair.ukma.edu.ua/handle/123456789/29570

ISSN: 2408-7920