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Harnessing Renewable Energy for Sustainable Economic Growth and Environmental Resilience

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Abstract

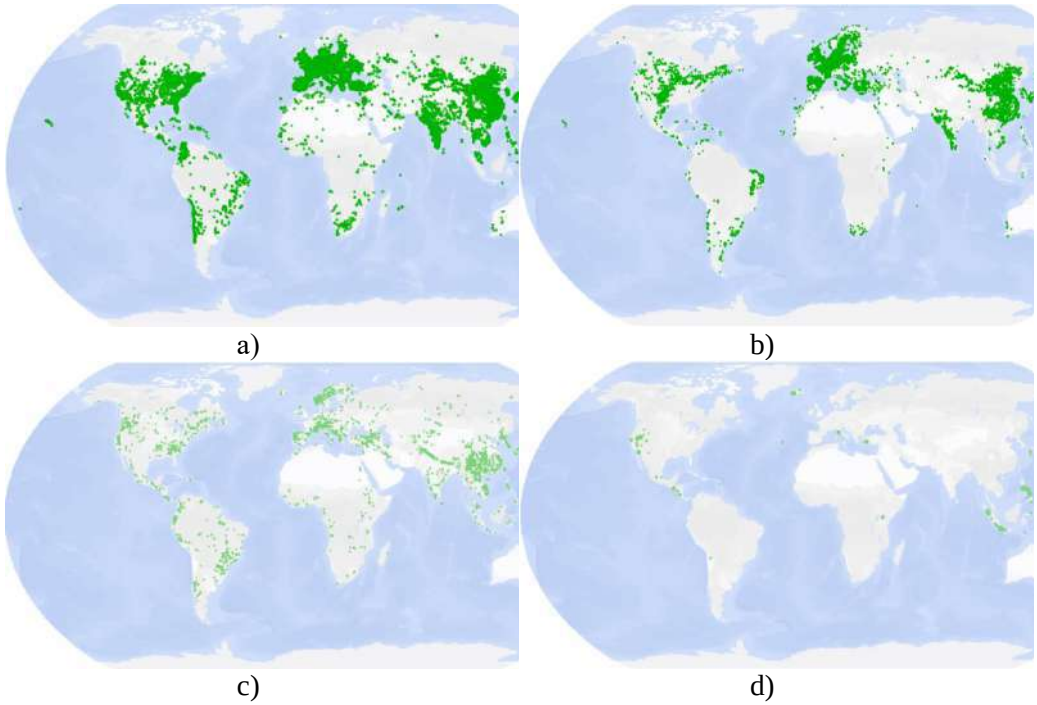
Renewable energy sources are a crucial element of the overall sustainable global economic development system due to climate change, depletion of fossil fuel sources, and the need to reduce the negative impact on the environment. Additionally, in modern geopolitical challenges, escalating economic pressures, and regional disparities in renewable energy development further complicate the global transition to sustainable energy. This article aims to define the role of renewable energy sources in ensuring sustainable economic development and analyze the influence of key factors on their implementation in sustainable development. We analyzed literature sources, and statistical data, followed by comparative analysis, systematization, and generalization, to identify the key factors influencing the implementation of renewable energy sources. The expert assessment method revealed the impact of internal and external factors on the development of the energy sector. These factors include Politics (P), Economy (E), Social sphere (S), Technology (T), Ecology (E) and Law (L) pillars that influence the implementation of renewable energy sources in ensuring sustainable economic development. The findings suggest that political instability (P1 - -2.7) and the destruction of energy infrastructure (P2 - -3.0), as well as economic factors (Total E - 5.05 / -8.33), are currently the main negative factors affecting the renewable energy sector in Ukraine. Additionally, social (Total S - 4.63 / -8.67) and environmental aspects (Total E - 3.9 / -8.125) still lack adequate management by the government and public perception, negatively impacting the further development of renewable energy sources. At the same time, technological innovations (Total T - 9.1 / -9.1) and the legal environment (Total L - 9.16 / -9.16) show potential for further sectoral development. The implementation of alternative energy sources and the overall support of the energy sector mainly depend on balanced policies in the electricity sector, the sector's investment attractiveness, social support, and the availability of technological innovations.

Keywords

Waste; Fiscal policy; Macro-financial stability; Renewable energy sources; Alternative energy sources

Introduction

Renewable energy sources (RES) are currently an alternative to traditional energy systems, allowing the avoidance of natural resource shortages and the reduction of adverse environmental impacts. Using renewable energy sources, such as solar, wind, geothermal, hydro, and bioenergy, reduces greenhouse gas emissions, decreases dependence on fossil fuels, and increases countries' energy security. Globally, 36,469 solar photovoltaic farms (Global Energy Monitor, 2024c), 17,292 wind farms (Global Energy Monitor, 2024d), 2,689 hydroelectric power stations (Global Energy Monitor, 2024b), and 353 geothermal stations (Global Energy Monitor, 2024a) are currently in operation (Figure 1). It should be noted that renewable energy sources are expected to account for more than 42% of global electricity production by 2028, with the share of wind and solar photovoltaic energy doubling to 25% (IEA50, 2024). However, it should be noted that the current development of RES is accompanied by uneven technological advancement in this area across different countries and geographical regions of the world. For example, such disparity is illustrated by the significant gap between Western European countries, such as Germany, Denmark, and Austria, which are leaders in the implementation of wind and solar technologies, and developing countries, particularly in Africa or Southeast Asia, where the field of renewable energy sources is developing much more slowly. The reasons for this gap primarily include different levels of economic development, the availability of investments, political support, and the existence of the necessary infrastructure to integrate renewable energy sources into national energy systems.



a) b)

c) d)

Figure 1: Global renewable energy infrastructure status showing a) map of operating solar photovoltaic farms; b) map of operating wind power plants; c) map of operating hydroelectric power plants; and d) map of geothermal energy use
Source: Global Energy Monitor (2024a; 2024b; 2024c; 2024d)

Among the European Union (EU) member states, Germany is making significant efforts to implement renewable energy sources (RES), mainly through the Energiewende programme, which aims to transition to a low-carbon, environmentally responsible, reliable, and economical energy supply. A balanced policy results in the shift from nuclear energy to green energy, reducing CO_2 emissions and gradually eliminating dependence on imported resources. Renewable energy accounts for 49% of Germany's electricity, leading to a high concentration of new projects in the solar energy sector. Therefore, Germany is one of the leading EU countries actively contributing to enhancing energy security, improving energy efficiency, and decarbonizing the economy (Edo, 2023). Denmark's case is like Germany's but more market-oriented and decentralized. Denmark has successfully reduced its high dependence on imported fossil fuels to partial self-sufficiency due to its high share of RES, which accounted for 68.4% of domestic electricity production in 2018 (Wang, Moreno-Casas and Huerta de Soto, 2021). Austria is also advanced regarding RES, with its climate policy, based on the "Mission 2030" strategy, aimed at significantly reducing greenhouse gas emissions by 36% by 2030 compared to 2005 levels. The combination of Austria's strategic initiatives primarily directs investments into the energy sector, in line with Austria's broader decarburization goals, demonstrating its commitment to global environmental sustainability, which has led to an increase in the number of solar photovoltaic and wind energy systems in the country (da Silva *et al.*, 2024).

In contrast, in Nigeria, the focus is not on the widespread adoption of RES, although the country has a plan for further integration under the Renewable Energy Master Plan (REMP). Instead, it is on rural electrification, where most areas do not have access to electricity. Given Nigeria's economic problems, political instability, and dependence on the oil industry, it is essential to develop measures and ensure coordination between the government, industry, civil society, and international partners to move forward and realize Nigeria's clean energy ambitions (Idoko *et al.*, 2024; Oduro, Simpa and Ekechukwu, 2024). An analogous situation is observed in South Sudan, where the population has the lowest access to electricity due to security risks and political instability — only 7.7% as of 2021; over 90% of rural areas do not have electricity. This situation prompts the government to develop policies to implement RES but also hinders investment opportunities in this area (Thiak and Hira, 2024).

Another example of insufficient RES development is Ukraine's energy sector amid Russia's full-scale invasion. However, despite Ukraine's macroeconomic, geopolitical problems, and supply chain challenges, global investments in energy transition technologies, including RES and energy efficiency, reached USD 1.3 trillion in 2022 (Polyanska *et al.*, 2023). For Ukraine, the prospects of using RES are primarily concerned with ensuring energy security and independence in the context of Russia's destruction of energy infrastructure and a significant electricity deficit caused by the war.

Thus, the relevance of studying the prospects for using RES to ensure the sustainable development of economies in different geographical regions of the world is determined by the opportunities to reduce dependence on fossil fuels, decrease greenhouse gas emissions, and ensure energy security. Additionally, the study allows for considering regional characteristics, including natural and climatic conditions, economic

development, and political will, in assessing the effectiveness of RES implementation, which is a determining factor in the global transition to sustainable development and combating climate change.

The aim of authoring the scientific article is to determine the role of RES in ensuring sustainable economic development. The article aims to analyze current trends in the development of the energy sector in countries with various levels of development. The study of political, economic, social, technological, environmental, and legal factors influencing the implementation of RES in ensuring sustainable economic development allowed for an analysis of Ukraine's potential as a developing country to expand its renewable energy capacity, create new and restore destroyed energy infrastructure amid the ongoing Russia-Ukraine war and political instability.

Literature Review

Currently, the issue of developing renewable energy sources in the context of ensuring environmental sustainability and economic growth is particularly pressing, considering the depletion of fossil fuels and climate change, which can be mitigated through green energy and the rational use of energy (Sotnyk *et al.*, 2023). Sustainable development involves conserving natural resources, reducing the negative impact on the environment, and ensuring economic growth through environmentally safe solutions (Mikhno *et al.*, 2021). In this context, green energy, based on renewable sources such as solar, wind, hydro, geothermal, and bioenergy, allows a transition to an energy-efficient economy by reducing dependence on fossil fuels (Kansongue, Njuguna and Vertigans, 2023). The implementation and efficient use of renewable energy sources contribute to the reduction of greenhouse gas emissions (Al-Ghouti *et al.*, 2021), improvement of air quality (Do Thi *et al.*, 2021), and enhancement of energy security (Thiak and Hira, 2024). According to the International Energy Agency (IEA), the deployment of renewables in the power, heat and transport sectors is one of the main enablers of keeping the rise in average global temperatures below 1.5°C. In the Net Zero Emissions by 2050 scenario, renewables allow electricity generation to be almost completely decarbonized. Meanwhile, renewable transport fuels and renewable heat contribute to significant emissions reductions in transport, buildings and industry (IEA50, 2024).

It is essential to consider the current scientific discourse on the circular economy and environmental transformation concept to determine the critical trends in developing renewable energy sources to ensure sustainable economic development. For example, Koval *et al.* (2023) argue that the potential for transitioning to a circular economy and promoting sustainable consumption contributes to the conservation of natural resources and increased energy efficiency. In this context, implementing and developing renewable energy sources, as one of the components of the circular economy, also positively affects the national economy, including reducing the use of fossil fuels and promoting environmentally responsible consumer behaviour (Yakovenko, 2023). At the same time, the need to use circular management models to achieve a sustainable business process, as discussed by Arsawan *et al.* (2024), is related to the need to increase the resilience of enterprises in the context of their adaptation to climate change, optimization of natural resource use, and potential transition to renewable energy sources.

Furthermore, for many countries, the issue of reducing the gap in access to and the quality of energy resources across different regions remains relevant (Igliński *et al.*, 2016). Moreover, to support the renewable energy sector and, as a result, ensure sustainable economic development, a balanced investment policy in the energy sector is necessary. This promotes the implementation of next-generation technologies and reduces environmental risks (Nikonenko *et al.*, 2022); the introduction of an environmental risk system based on sustainable development principles (Sumets *et al.*, 2022); and the eco-transformation of energy services to support the low-carbon transition (Kovalko, Eutukhova and Novoseltsev, 2022).

Methodology

The following methods were employed in the research:

Literature Review: Literature was used to study current trends in the development of renewable energy sources for sustainable economic development, a literature review was conducted, drawing from a wide range of sources. Of these, 25 scientific articles of the most scientifically significant articles published in the period from 2021 to 2024 were selected for inclusion in the analysis. Reports from the International Energy Agency (IEA), the Global Energy Monitor, and peer-reviewed journals such as Renewable and Sustainable Energy Reviews were also analyzed to obtain statistical data to support the identified trends. This body of literature provided insights into the adoption of RES technologies across the solar, wind, hydro, and geothermal energy sectors.

Statistical Analysis: Data from 2024 Global Energy Monitor and IEA reports were used to determine the state of the global renewable energy infrastructure. During the study, 4 data sets covering the number of operating solar photovoltaic power plants, wind turbines, hydroelectric power stations, and geothermal energy were analyzed to assess the global infrastructure of renewable energy, emphasizing the trends of their development in different regions and countries.

Comparative and Systematic Analysis: Comparative analysis was used to compare strategies and the level of RES development in different countries. In particular, the sample included documents, energy strategies, such as Germany's Energiewende, and investment reports from 2005 to 2024 from countries such as Germany, Denmark, Austria, Nigeria, and Ukraine. This method is used to study international experience in the development of the alternative energy sector and to identify the uneven development of technological solutions in this area across different countries and geographical regions of the world. Using the systematization method, the previously identified factors contributing to the development of renewable energy are classified by analyzing relevant government reports, climate strategies, and scientific studies published in the period 2021–2024. Thus, we have outlined the politics (P), economy (E), social sphere (S), technology (T), ecology (E), and law (L) factors influencing the implementation of renewable energy sources in ensuring sustainable economic development. The degree of influence of each factor on implementing renewable energy sources was determined using expert assessments on a ten-point scale. The study involved 25 researchers conducting ecology, sustainable development, and environmental management studies. A high score indicates a strong impact and a serious threat, while a low score indicates

no impact or threat. For each factor, the weight score was calculated by multiplying its importance by the degree of influence. The result of the analysis is the calculation of the total weighted score (Total), which allowed for assessing the impact of individual factors on the economic security of the regions. Additionally, the values assigned to the relevant factors were determined by experts based on their experience and the contextual relevance of each factor to the development of renewable energy sources. Positive values (+) indicate opportunities, while negative values (-) reflect threats arising from the impact of the specified factors on this process. Instead, the generalization method was used to formulate the features of the factors and their manifestation by synthesizing data from more than 25 sources of literature, including climate strategies, Reports from the International Energy Agency (IEA), the Global Energy Monitor, etc. This allowed us to draw comprehensive conclusions about the role of renewable energy in ensuring sustainable development.

Expert Evaluation and Assessment: The expert assessment method is applied to investigate the impact of internal and external environmental factors on implementing renewable energy sources in ensuring sustainable economic development. The criteria for expert selection included academic qualifications (PhD or equivalent in ecology, energy management, or related fields) and professional experience in renewable energy. Selection criteria that emphasize academic and professional expertise were necessary to ensure that the assessments are expert, although experiences and areas of specialization may skew the assessment towards certain factors (e.g., political or technological factors) over others. As a rule, priority was given to experts with the highest number of publications among others and who are involved in national or international environmental and energy initiatives. Instead, the criteria for conducting the research included several political, economic, social, technological, environmental, and legal factors related to the sector's development. The study involved 25 researchers, 7 of whom are professors aged 40 to 60 who focus their research on developing preventive measures to overcome threats to the energy sector's development; 8 are professors aged 45 to 55 who, in their scientific work, develop strategies and measures to ensure sustainable economic development; and 10 are lecturers in the departments of ecology and environmental management. Based on the data obtained, a weighted assessment of each factor was calculated, reflecting the extent of their influence on the development of Ukraine's energy sector in the context of Russia's full-scale invasion of Ukraine, the destruction of critical infrastructure, including the energy infrastructure of the country, and political instability.

Thus, the outlined methods provided a solid basis for further research for assessing the current state of renewable energy development and its potential for sustainable economic growth. In this context, the analysis of relevant scientific sources, the analysis of secondary statistical data, and the comparative analysis of various state development strategies contributed to the efficiency and objectivity of developing our system of factors influencing the introduction of renewable energy sources in ensuring sustainable economic development, which is discussed in the next section.

Results

Implementing renewable energy sources (RES) plays a crucial role in sustainable development, primarily by reducing dependence on coal and other non-renewable energy sources, which increases the country's energy security and reduces its vulnerability to price fluctuations and supply disruptions. Given that many countries are still directly dependent on fossil fuels (coal, oil, natural gas), there is a need for a gradual and measured transition to RES to ensure the resilience of the energy system through risk distribution and energy source diversification (Oduro, Simpa and Ekechukwu, 2024). To achieve zero fossil fuel use by 2050, renewable energy production needs to increase 6 to 8 times if energy demand remains constant or increases by 50% from the 2020 energy demand level. In this context, the aggressive application of energy-saving policies, including land use and taxation, could reduce global energy consumption by 10% or more by 2050. The likelihood of achieving independence from fossil fuels also increased by limiting global energy demand growth by 25% by 2050 compared to 2020 (Holechek *et al.*, 2022).

The market orientation and decentralized nature of renewable energy sources—solar, wind, geothermal, hydro, and bioenergy — minimize energy losses during transportation, contributing to the efficient use of resources. The opportunity to transition to green energy encourages many businesses to develop and implement eco-efficiency, green production, and environmentally friendly management practices to reduce their environmental impact. To maintain public interest in green production and consumption, governments of various countries are working to make renewable energy more accessible and efficient by developing a new conceptual model primarily based on a network of distributed energy systems (Gawusu *et al.*, 2022).

Moreover, the implementation of RES offers broad opportunities to reduce carbon dioxide (CO_2) emissions and other pollutants, resulting in improved air quality and reduced negative impacts on climate change. Dependence on unstable energy resources and global air quality deterioration is driven by dirty coal and oil products. In contrast, implementing renewable energy sources in this context effectively reduces emissions and the amount of solid waste (ash and slag from coal processing), oil waste, and waste from burning fossil fuels. This reduces pollution and enhances energy security (Al-Ghouti *et al.*, 2021).

Table 1 presents the main factors influencing the implementation of renewable energy sources in ensuring sustainable economic development. An impact assessment of individual parameters was conducted using a PESTEL analysis to assess the significance of the identified factors.

The first factor influencing the implementation of renewable energy sources is the political factor (P), which includes political instability, the consequences of military actions, and state regulation of the energy sector. Table 2 presents the results of assessing the impact of political factors on the implementation of renewable energy sources.

Table 1: Factors influencing the implementation of renewable energy sources in ensuring sustainable economic development

Group of factors	*Factors with the most significant impact*	*Features and their manifestation*
Politics (P)	Political instability (P1)	Uncoordinated political decisions on the development of the renewable energy sector
	Destruction or neglect of energy infrastructure (P2)	Destruction of energy facilities, including power plants, substations, and networks, which hinders energy supply and integration of renewable energy sources
	Availability of a state strategy for the development of renewable energy sources (P3)	Clarity and effectiveness or inconsistency of renewable energy policies
	State support for the development of renewable energy sources (P4)	Implementation of feed-in tariffs, grants, grant programs and subsidies for renewable energy projects
Economy (E)	Impact on the sustainable development of the national economy (E1)	Level of dependence of the energy sector on fossil fuel imports
	The volume of attraction and general availability of investments in renewable energy sources (E2)	Clear rules and facilitation of financing of renewable energy projects by public and private investors
	Cost of alternative energy production (E3)	High cost of renewable energy technologies, their implementation and provision of appropriate infrastructure
	Level of availability of the latest technologies (E4)	High cost or lack of access to new technologies
Social sphere (S)	Environmental awareness of the population (S1)	Low level of interest and awareness of the benefits of implementing renewable energy sources
	New jobs in the renewable energy sector (S2)	Insufficient development of the industry, which may limit job creation, and the availability and quality of educational training programs
	Availability of alternative energy in rural and remote areas (S3)	Lack of access to electricity in remote regions or high cost for residents of rural areas
	Impact of renewable energy sources on the quality of life and health of the population (S4)	Spread of chronic diseases among the population due to air, water and soil pollution from traditional energy sources
Technology (T)	Level of technological infrastructure (T1)	Lack of or outdated grid and systems for integrating renewable energy sources

Group of factors	*Factors with the most significant impact*	*Features and their manifestation*
	Level of maintenance and management of energy systems (T2)	Low efficiency of management and control of new energy systems
	Integration of decentralized systems into the national energy grid (T3)	Difficulties with the integration of decentralized energy solutions due to lack of appropriate infrastructure
Ecology (E)	Impact on greenhouse gas emissions (E1)	Reduction of CO2 and other greenhouse gas emissions
	Impact on biodiversity (E2)	Loss of natural environment due to the construction of new energy facilities
	Impact on waste management (E3)	Level of control over industrial waste
	Impact on water consumption (E4)	Impact of hydropower plants on water resources and ecosystems
	Impact on land use (E5)	Impact of renewable energy infrastructure construction on agricultural land and natural landscapes
Law (L)	Efficiency of the legal and regulatory framework for renewable energy sources (L1)	Existence or absence of institutions, laws and regulatory instruments that support the development of renewable energy sources
	Efficiency of state regulation of renewable energy sources (L2)	Establishment of clear rules and requirements for certification, licensing, and compliance of renewable energy technologies
	Availability of international environmental agreements (L3)	Speed and quality of implementation of international climate and environmental agreements

Table 2: Assessing political factors on renewable energy sources implementation

Events/factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
P1	-	0.3	9	-2.70
P2	-	0.3	10	-3.00
P3	+ / -	0.25 / 0.25	8	+2.00 / -2.00
P4	+	0.15	7	+1.05
Total P	2 (+) / 3 (-)	1	34 of 40	+3.05 / -7.70

Political factors impact the implementation of renewable energy sources to ensure sustainable economic development. In particular, the consequences of the full-scale invasion include political instability (P1 = -2.7) and Russia's destruction of energy infrastructure (P2 = -3.0), which cause chaotic decision-making and inconsistency in the

actions of governing institutions regarding the development of the energy sector under conditions of the destruction of crucial energy infrastructure facilities. The need for a clear strategy for developing the renewable energy sector (P3 = 2.0 / -2.0) is due to the importance of effectively integrating sustainable development principles to eliminate inconsistencies in policy related to alternative energy sources. A positive factor influencing the implementation of renewable energy is the possibility of state support for the sector (P4 = 1.05) by introducing green tariffs, subsidies, grant programs, and funding.

Economic factors (E) include the cost of securing essential resources and the technological and investment attractiveness of introducing renewable energy sources into the country's energy sector. Table 3 presents an assessment of the impact of this group of factors.

Table 3: Assessing economic factors on renewable energy sources implementation

Events/ factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
E1	+ / -	0.25 / 0.27	9	+2.25 / -2.43
E2	+ / -	0.28 / 0.26	10	+2.8 / -2.60
E3	-	0.24	8	-1.92
E4	-	0.23	6	-1.38
Total E	2 (+) / 4 (-)	1	33 of 40	+5.05 / -8.33

Expanding renewable energy sources (E1 = 2.25 / -2.43) reduces the national economy's dependence on fossil fuel imports. However, it is essential to ensure the investment attractiveness of the sector (E2 = 2.8 / -2.6) to cover the high costs of production technologies (E4 = -1.92) and the construction and provision of appropriate infrastructure (E3 = -1.38) as negative influencing factors. Table 4 presents an assessment of the impact of social factors on the implementation of renewable energy sources.

Table 4: Assessing social factors on renewable energy sources implementation

Events/ factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
S1	+ / -	0.3 / 0.32	9	+2.70 / -2.88
S2	+ / -	0.27 / 0.25	7	+1.89 / -1.75
S3	-	0.22	9	-1.98
S4	-	0.21	10	-2.10
Total S	2 (+) / 4 (-)	1	35 of 40	+4.63 / -8.67

The assessment of the impact of social factors on the implementation of renewable energy sources showed that the most significant factors for sustainable economic development are the increase in eco-consciousness among the population (S1 = 2.7 / -2.88) and the creation of new jobs in the alternative energy sector (S2 = 1.89 / -1.75). However, the inefficiency of related measures may hurt the further implementation of

environmental initiatives in the country's energy sector. Additionally, it is essential to ensure the availability of alternative energy in rural and remote areas (S3 = -1.98) and to improve the population's quality of life and health (S4 = -2.1), as currently, no practical results have been achieved in these areas. The results of the evaluation of the impact of technological factors on economic security are presented in table 5.

Table 5: Assessing technological factors on renewable energy sources implementation

Events/factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
T1	+ / -	0.29 / 0.3	8	+2.32 / -2.40
T2	+ / -	0.32 / 0.3	9	+2.88 / -2.70
T3	+ / -	0.39 / 0.4	10	+3.90 / -4.00
Total T	3 (+) / 3 (-)	1	27 of 30	+9.10 / -9.10

Technological factors in the current conditions are a negative phenomenon that requires improvements to the energy grid and systems for the integration of renewable energy sources (T1 = 2.32 / -2.4), increasing the efficiency of management and control over new energy systems (T2 = 2.88 / -2.7), and the systemic integration of decentralized systems into the national energy grid (T3 = 3.9 / -4.0). This will contribute to optimizing technological infrastructure, improving maintenance and management, and eliminating integration challenges due to the lack of appropriate infrastructure. In turn, the results of calculating the degrees of influence of environmental factors on the implementation of renewable energy sources are presented in table 6.

Table 6: Assessing environmental impact on renewable energy sources implementation

Events/factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
E1	-	0.2	8	-1.60
E2	-	0.15	6	-0.90
E3	-	0.25	10	-2.50
E4	+ / -	0.2 / 0.2	7	+1.40 / -1.40
E5	-	0.2	9	-1.80
Total E	1 (+) / 5 (-)	1	40 of 50	+8.20 / -8.20

The most significant negative impact on the implementation of renewable energy sources currently comes from the significant volumes of greenhouse gas emissions (E1 = -1.6), excessive consumption of water resources (E4 = -2.5), destruction of natural habitats (E2 = -0.9), agricultural lands, and natural landscapes (E5 = -1.80). These existing threats can be overcome by improving the efficiency of the waste management system (E3 = 1.4 / -1.4), which will ensure the sustainable development of the energy sector and the economy. In addition, it is essential to highlight the impact of legal factors on implementing renewable energy, as shown in table 7.

Table 7: Assessing legal factors' impact on renewable energy sources implementation

Events/factors	*Threats (-) / Opportunities (+)*	*Manifestation capability*	*Significance*	*Impact on the renewable energy sector*
L1	+ / -	0.37 / 0,36	10	+3.70 / -3.60
L2	+ / -	0.35 / 0,36	10	+3.50 / -3.60
L3	-	0.28	7	-1.96
Total L	2 (+) / 3 (-)	1	27 of 30	+9.16 / -9.16

The presence of a regulatory and legal framework (L1 = 3.7 / -3.6) and state regulatory instruments (L2 = 3.5 / -3.6) regarding renewable energy sources creates favourable opportunities for the sector's development and ensures the sustainable development of the economy. However, the absence or non-fulfilment of conditions in international environmental agreements (L3 = -1.96) hinders the development of the country's energy sector and the potential for attracting foreign investments, expertise, and technologies.

As a result of assessing the impact of various aspects of the internal and external environment on implementing renewable energy sources to ensure sustainable economic development, cumulative weighted assessments (Total) were calculated for each factor. The summarized results for each impact factor are presented in figure 2.

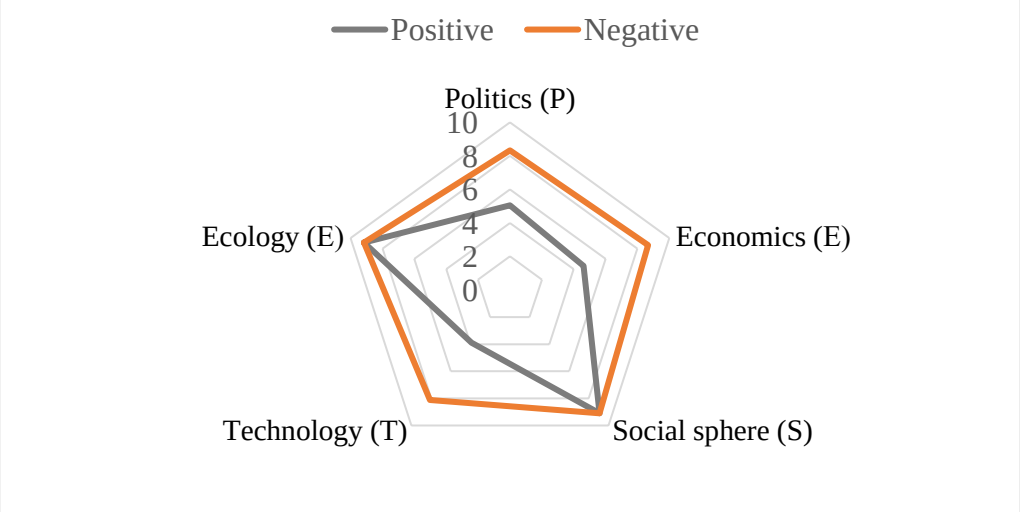


Figure 2. General assessment of factors influencing the implementation of renewable energy sources in sustainable economic development

Thus, the overall impact of political factors indicates that their negative influence (Total P = -7.70) significantly outweighs the positive opportunities (Total P = 3.05), due to political instability and the destruction of energy infrastructure. Additionally, economic factors (Total E = 5.05 / -8.33) hurt the development of the renewable energy sector, including the prohibitive costs of implementing renewable energy sources and the difficulty of accessing financial resources, which significantly limits the growth of this sector. In turn, low public awareness, and insufficient public support (Total S = -8.67) are the main barriers to the effective implementation of renewable energy, despite

positive social attitudes in some regions (Total S = 4.63). Technological factors demonstrated a balance between opportunities and threats (Total T = 9.1 / -9.1), as they can have both positive and negative consequences in the case of insufficient technological capacity. The main environmental threat to implementing renewable energy sources (Total E = 3.9 / -8.125) is the increased pressure on ecosystems due to inefficient management systems. The most significant favourable influence on the implementation of renewable energy comes from legal factors (Total L = 9.16 / -9.16), as a clear legislative framework creates stable conditions for the sustainable development of the national economy. Therefore, the slowdown in the development of renewable energy sources is caused by political instability and economic and social barriers. In contrast, technological innovations and balanced legal policies are critical tools for reducing negative impacts and stimulating further growth in the energy sector.

Discussion

The present study analyzed the influence of external and internal environmental factors on adopting renewable energy sources to achieve sustainable economic development, employing PESTEL analysis supported by expert assessments. Nonetheless, the study possesses certain limitations. Social factors, specifically public awareness of renewable energy sources, exhibit significant variations across regions, which were not captured in the study and may have an impact on the interpretation of social perception factors. However, this avoids significant fragmentation of the results and allows for a focus on more general trends and challenges. The study has a certain time frame (2021-2024), which may limit the applicability of the results in the long term if socioeconomic conditions, technological advances, or political situations change. Also, the focus on certain countries (e.g. Germany, Denmark, Austria, Nigeria, Ukraine) may limit the generalizability of the study's findings to other regions. This approach distinguishes our study from others. For instance, Igliński *et al*. (2016) conducted a PEST analysis of renewable energy sources in the Łódź Voivodeship, Poland, which primarily relied on a literature review without integrating statistical or empirical data. Similarly, Kansongue, Njuguna and Vertigans (2023) examined internal and external factors in renewable energy development in Togo, based on framework approaches, including PESTEL and SWOT analysis. Although this study includes current statistical data on the functionality of renewable energy sources, it does not assess the opportunities and threats to their development. Compared to prior studies, such as Igliński *et al*. (2016) and Kansongue, Njuguna and Vertigans (2023), our research integrates both expert assessments and statistical insights, providing a multifaceted perspective on the barriers and enablers of renewable energy adoption. Unlike Do Thi *et al.* (2021), which is based on applying PESTLE analysis, multi-criteria decision analysis, and life cycle assessment (LCA) methods for comparing desalination technologies using renewable energy sources, our study uniquely combines PESTEL analysis with expert input to highlight actionable recommendations. Their study presented a scientific discussion on fossil fuels and alternative energy sources by processing a large amount of statistical data from Saudi Arabia and creating a normalized decision matrix. However, the results of our study on the factors influencing the implementation of renewable energy sources in ensuring sustainable economic development are based on the collection of expert assessments, which provide unique results regarding political, economic, social, technological, legal, and environmental factors. Thus, recommendations for stakeholders based on: identified

policy challenges (Total P = 3.05 / -7.70) include ensuring coordination and consistency of strategies and strengthening government support for the renewable energy sector through clear incentives (green tariffs, subsidies, etc.); economic challenges (Total E = 5.05 / -8.33), which involves the implementation of measures to increase investments in renewable energy sources by intensifying public-private partnerships and simplifying bureaucratic barriers; social issues (Total S = 4.63 / -8.67) that can be addressed by expanding training programs for green jobs and increasing public awareness and confidence in renewable energy; technological barriers (Total T = 9.1 / -9.1), which require increasing the availability of renewable energy in rural and remote regions with the help of decentralized local government systems; environmental problems (Total E = 3.9 / -8.125), which require qualitative regulation of the impact of RES infrastructure on the environment; legal barriers (Total L = 9.16 / -9.16) require authorities to regulate the legal framework to facilitate the certification and licensing of RES infrastructure. Moreover, a large amount of scientific literature was analyzed, and our conclusions were made regarding the role of alternative energy in ensuring sustainable economic development. This study was also adapted to the conditions of the current Russia-Ukraine war and the need to restore energy infrastructure. However, future research should explore the integration of digital innovations, such as blockchain and IoT, into renewable energy systems to address technological and operational inefficiencies.

Conclusion

The modern concept of the energy sector, based on the use of alternative energy sources, aims to reduce dependence on fossil fuels, minimize greenhouse gas emissions, and improve air quality. At the same time, creating favourable conditions for the development of renewable energy sources stimulates innovation, energy efficiency, and sustainable consumption and generates new economic opportunities. In addition, collaboration between governments, private entities, and local communities is essential to overcoming sectoral barriers and realizing the full potential of renewable energy technologies. However, the effectiveness of implementing renewable energy sources is directly dependent on several political, economic, social, technological, environmental, and legal factors that determine the development of this sector and present potential risks. Given the current geopolitical tensions and energy crises, renewable energy adoption is more critical than ever to ensure energy security and environmental sustainability. Thus, renewable energy sources play a crucial role in ensuring the economy's sustainable development, combining sustainability principles with the country's overall economic growth. With continued investment and innovation, renewable energy can serve as a cornerstone for global climate action and energy independence, fostering resilience in the face of future challenges.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	No	Yes	Yes	Yes
Collected the data	Yes	No	Yes	No	No
Contributed to data analysis and interpretation	Yes	Yes	No	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes
Critical revision of the article/paper	No	Yes	No	Yes	No
Editing of the article/paper	No	Yes	Yes	No	Yes
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Overall Contribution Proportion (%)	20	20	20	20	20

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Research involving human bodies or organs or tissues (Helsinki Declaration)
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