European Journal of Sustainable Development Research
2026, 10(3), em0395
e-ISSN: 2542-4742
https://www.ejosdr.com/

MODESTUM

Research Article

OPEN ACCESS

An environmentally oriented economy and clean energy sources as the basis for sustainable progress and energy stability

Liudmyla Horbach [1*], Serhiy Kyrylenko [2], Vitaliy Zapukhlyak [2], Oksana Yermolenko [3], Myhaylo Grod [4]

[1] Vyacheslav Lipinski Institute of Volyn, JSC "Interregional Academy of Personnel Management", UKRAINE
[2] West Ukrainian National University, UKRAINE
[3] Simon Kuznets Kharkiv National University of Economics, UKRAINE
[4] National Academy of Statistics, Accounting and Audit, UKRAINE
***Corresponding Author:** gorbachl@ujis.in.ua

Citation: Horbach, L., Kyrylenko, S., Yermolenko, O., & Grod, M. (2026). An environmentally oriented economy and clean energy sources as the basis for sustainable progress and energy stability. *European Journal of Sustainable Development Research, 10*(3), em0395. https://doi.org/10.29333/ejosdr/18317

ARTICLE INFO

Received: 14 Oct 2025
Accepted: 28 Feb 2026

ABSTRACT

Amid increasing climate risks, growing geo-energy instability, and the urgent need for effective national strategies, the development of alternative renewable energy technologies is crucial for ensuring energy security at global, regional, and national levels. This study examines the role of the green economy and renewable energy as key drivers of sustainable development and energy stability in the context of global economic transformation. Using benchmarking, statistical and correlation analyses, and graphical visualization, the research highlights the strategic importance of renewable energy in achieving climate neutrality, sustainable development, and energy security. Benchmarking results indicate that successful energy transitions are strongly linked to institutional capacity, innovation environment, and investment, with a robust correlation between financing and production growth (R = 0.99). The study also identifies a shift from hydropower to solar and wind energy, reflecting technological breakthroughs and high adaptability. Integrating circular economy principles, digital technologies, and social inclusion, this synergy establishes a new energy paradigm—sustainable, flexible, and focused on human and ecosystem security.

Keywords: renewables, energy security, green energy, investment, circular economy

INTRODUCTION

In the twenty-first century, globalization has become a determining factor in the transformation of the world economic, technological and energy order. Modern global transformations are accompanied by growing interdependence between states, which contributes to the acceleration of the exchange of innovations and at the same time exacerbates environmental problems that have long gone beyond national borders (Gavkalova et al., 2024; Orujov, 2025). Climate change is a particular threat, which actualizes the search for new development models that can combine environmental sustainability, economic efficiency and social justice.

In this context, the transition to a green economy is seen as a global paradigm that integrates economic growth with environmental responsibility. Renewable energy is a key element of this transformation, as it contributes to reducing dependence on fossil fuels, reducing greenhouse gas emissions, increasing energy sustainability and creating new market opportunities. According to the International Renewable Energy Agency (IRENA), the energy transition has the potential to create millions of new jobs and ensure dynamic infrastructure renewal in all regions of the world (IRENA & ILO, 2024).

Globalization processes are shaping a new architecture of energy security, in which traditional geo-economic models are gradually losing relevance, giving way to decentralized and innovation-oriented resource management systems (Dunchev, 2025; Ryzhakova et al., 2023). This is of particular importance for countries that are in the post-conflict recovery stage or have limited access to traditional energy sources. In such a situation, the development of renewable energy and the implementation of green economy principles become not only a matter of time, but also an effective tool for strengthening national resilience to external – both economic and security – challenges (Gielen et al., 2019). For Ukraine, these issues are of particular relevance. In the post-war period, against the backdrop of large-scale destruction of energy infrastructure, growing challenges of climate adaptation and active European integration, the formation of a new energy paradigm has acquired strategic importance (Zavidna et al., 2025; Zvarych & Masna, 2023). At the same time, integration into a single European green space requires policy harmonization,

modernization of the energy sector, increased investment in "green" projects, and the creation of an effective mechanism for managing transformation processes (Mitryasova, 2025).

In view of the above, the study of the relationship between the development of the green economy, the increased use of renewable energy, and the improvement of energy security in the context of globalization is not only relevant but also extremely necessary. It allows to formulate sound recommendations for public policy, identify barriers and drivers of sustainable development, and help strengthen the adaptive capacity of national economies to global changes.

LITERATURE REVIEW

Over the past twenty years, the concept of a green economy has gained global recognition in response to the current challenges of climate change, resource depletion and energy instability. According to the definition of the United Nations Environment Programmer (UNEP), a "green economy" is a type of economy that contributes to improving human well-being and ensuring social justice, while significantly reducing environmental risks and the scarcity of natural resources (GCF, 2015). Within the framework of this approach, special importance is attached to the development of renewable energy as a key factor in the ecological transformation of national economic systems. In recent years, scientific discourse has increasingly paid attention to the relationship between the transition to a green economy, structural modernization of the energy sector, and ensuring long-term energy security (Pokhodenko, 2023; Shi & Zhao, 2023; Zeng et al., 2024).

Among the current publications exploring this link, it is worth noting analytical reviews that show a positive correlation between the expansion of the share of renewables in the energy balance of countries and strengthening energy security, in particular by reducing dependence on imported energy and increasing resilience to external shocks (Filho et al., 2022). Particular attention is paid to the role of decentralized energy, green investments, and technological innovations in ensuring sustainable development (Agbakwuru et al., 2024; Ferris, 2025; Mavlutova et al., 2025). According to the IEA and IRENA, in 2023, global investment in renewable energy exceeded USD 500 billion for the first time, indicating a strengthening of the global decarbonization trend (IEA, 2024b).

A significant contribution was made to the development of the theoretical and methodological framework for the development of the green economy. The analysis of the relationships between key concepts in the field of "green" transformation has allowed us to identify seven main scientific areas of research, including: sustainable development, financial constraints, "green" bonds, "green" credit policies, growth and recovery of the "green" economy (Krause et al., 2024). Within the framework of this research, integrated models were proposed that describe the relationship between "green" infrastructure, financial instruments and energy transition policies (Desyatnyuk et al., 2025; Mikropoulos et al., 2025). Scientists emphasize the need for an interdisciplinary approach to assessing the effectiveness of the "green" economy, taking into account environmental, energy, social and economic factors (Del Duca et al., 2024). In particular, the application of bibliometric analysis to publications in the scientific journals Energy Procedia and Society and Economy has made it possible to systematize the approaches and key concepts used in energy transformation research (Chou et al., 2023; Schürmann et al., 2019; Segura, 2024).

Foreign experience confirms the high variability of strategies for transitioning to a "green" economy depending on the national context. Thus, the countries of the European Union are focused on complete decarbonization by 2050 within the framework of the European Green Deal, paying special attention to the development of hydrogen energy, increasing energy efficiency and actively involving "green" financing (Fetting, 2020).

India, on the other hand, relies on large-scale production of green hydrogen as a component of energy independence (Raizada, 2025). Research shows that countries that have systematically integrated renewable energy into their national development strategy demonstrate higher energy resilience and less vulnerability to external threats (Guarascio et al., 2025; Monie et al., 2025; Saputra & Lutfiana Rakhman, 2025).

Along with positive trends, scientists note the threats and challenges of our time, in particular, the instability of renewable energy production, the complexity of integration into general energy grids, the lack of qualified personnel and the imperfection of the regulatory environment remain factors that hinder the full-scale implementation of green energy (Emin, 2023; Regen Power, 2025; Stepanenko et al., 2022). Therefore, the urgent issue is to improve regulatory support, stimulate research and development, create conditions for the effective functioning of the green bond market, carbon offsetting mechanisms, and climate change adaptation (EC, 2021; Wu & Yu, 2025).

For Ukraine, the green economy and renewable energy policy is of particular importance due to the need for energy recovery after the destruction caused by the full-scale war, as well as in the context of the implementation of the EU acquis, which is binding on member states and candidates for accession in the field of environment and energy (DiXi Group, 2024; EEAS, 2025). Ukraine has a strategic potential for the development of renewables, in particular wind and solar energy, as confirmed by recent reports by the European Commission and ENTSO-E (UFP, 2024). Building institutional capacity in this area, introducing a national green finance system and integrating into the European energy market should be key guidelines for the state policy of sustainable development (EBRD, 2025). Scientific studies emphasize that the effectiveness of state regulation of investment activities in the agricultural sector, in particular through financial incentives and support for raw material processing, can become an important factor in the formation of a green economy and increasing the energy security of Ukraine (Kniaz et al., 2023).

Thus, the reviewed scientific publications and official sources show that there is a theoretical and methodological basis for further study of the relationship between the development of a green economy, renewable energy and energy security in the context of global economic

transformation. Further study of the issues in this area should focus on the regional specifics of the introduction of green technologies, assessment of their effectiveness and formation of institutional conditions for accelerating the energy transition.

The gaps in research lie in the insufficient consideration of regional specifics in the implementation of renewable technologies, the assessment of their effectiveness, and the formation of institutional conditions for accelerated energy transformation. The novelty of the article lies in a comprehensive analysis of the interrelationship between the green economy, the development of renewable energy, and the strengthening of energy security, taking into account global transformations, international experience, and national sustainable development strategies.

The purpose of the article is to conduct a comprehensive study of the relationship between the development of the green economy, the introduction of renewable energy sources, and the strengthening of energy security, taking into account regional specifics, assessing the effectiveness of green technologies, and creating institutional conditions for accelerated energy transformation, integrating international experience and strategic approaches to national development.

MATERIALS AND METHODS

The study uses a comprehensive interdisciplinary approach, with quantitative methods of analysis and qualitative interpretation of data from the perspective of current global trends in renewable energy development. The methodological basis of the study is the concept of sustainable development, the theory of energy transition, as well as approaches to assessing the institutional capacity of different countries in the implementation of green strategies.

The selection of countries in the study was made taking into account the scale of installed renewable energy capacity, energy sector management models, natural and technological potential, economic and political diversity, and the availability of reliable international data (Enerdata, 2024; IEA, 2024a; IRENA, 2025). China and the US represent countries with high absolute volumes and dynamic growth in renewable energy, Germany and the EU countries demonstrate integrated regulated models, India and Brazil demonstrate specific natural and technological potential, and Ukraine demonstrates a unique combination of energy infrastructure renewal and European integration aspirations. This selection ensures the representativeness of global trends, allows for comparison of the effectiveness of different strategies, and enables assessment of the relationship between investments and the development of renewables. The study used a peer-reviewed methodology based on the analysis of secondary data from reliable scientific sources, including the Scopus and Web of Science databases, as well as official reports from international institutions such as the European Commission (EC), the National Research Council (NRC), and the International Renewable Energy Agency (IRENA). The results were systematized and presented in the form of analytical tables and graphics that clearly demonstrate both the structural features and dynamic shifts occurring in the process of global energy transformation. This approach allows for a holistic assessment of current trends and the identification of key areas for further change.

To collect reliable statistical data, the authors consulted official databases of international organizations, as well as analytical reports prepared at both the regional and national levels (EC, NRC, UNECE). These sources ensured the representativeness of the information and its relevance in the context of comparative analysis. In order to objectively assess the dynamics of the development of renewable energy in an inter-country context, a sample of six countries was formed, covering significant geographical, economic and political diversity. This sample included China, the United States of America, India, Germany, Brazil and Ukraine - countries representing different types of energy systems and strategies for the transition to renewable energy sources. The criteria for inclusion in the sample were: The scale of the implementation of renewable energy sources (RES), the specifics of the national energy policy, the level of technological development, the availability of institutional support and the general model of energy sector management. This approach made it possible not only to identify common features and differences between countries, but also to assess their ability to adapt in response to the challenges of the energy transition on a global scale.

RESULTS

In the current context of global climate change, increasing resource vulnerability and gradual transformation of energy systems, renewable energy is becoming increasingly important as one of the key areas of implementation of the sustainable development strategy. Over the past decade, there has been not only a dynamic growth in renewable energy capacities, but also a profound rethinking of its role in shaping the energy security system, maintaining ecological balance and strengthening socio-economic stability (Conde & Takano-Rojas, 2025; Liu et al., 2022). Renewable energy is increasingly viewed not only as a technological or environmental solution, but as a comprehensive component of a new model of sustainable development at the global level.

The development of this sector involves the application of a multi-component approach to energy consumption, encompassing low-carbon, energy-efficient and decentralized models (Mia et al., 2022). It is stimulated by the active transfer of innovative technologies, the emergence of new financial instruments (in particular, “green” bonds and target investment funds), as well as the expansion of cross-border cooperation. In this context, an analytical review of global trends in the development of renewable energy becomes not only a scientifically sound step, but also a necessary prerequisite for the formation of effective strategies for “green” growth and ensuring the sustainable inclusion of national economies in the transformed global energy architecture. In order to conduct a comprehensive analysis of the current state and prospects for the development of renewable energy in the global context, a representative sample of countries was formed, reflecting different scales, structural characteristics, geographical diversification and political conditions for the implementation of renewable

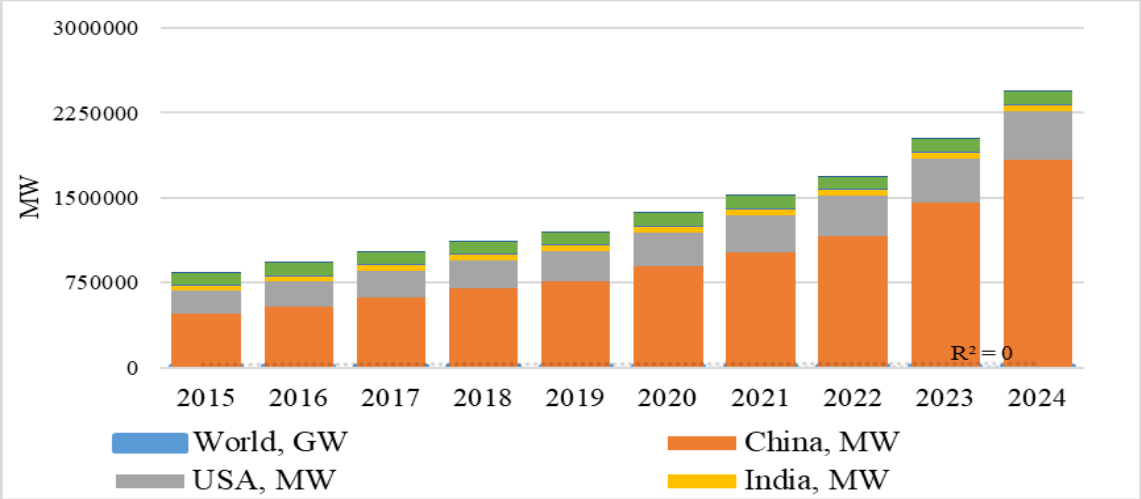

Figure 1. Amount of energy produced from renewable sources (2015-2024) (IRENA, 2025)

energy sources. The sample includes China, the United States, India, Germany, Brazil, and Ukraine — countries that demonstrate different approaches to energy sector development, which are determined by their economic structure, natural resource potential, institutional capacity, and geopolitical priorities (**Figure 1**).

The study identified China as the world leader in terms of installed renewable energy capacity. This choice is due not only to the technical scale of renewable energy deployment, but also to the high effectiveness of state policy, which combines centralized strategic planning with active industrialization of "green" generation. Thanks to government support, a favorable investment climate and the development of national technologies, China demonstrates an example of a systematic and long-term approach to energy transformation. This model was made possible by the integration of innovative policies, institutional stability and effective resource management, which ensured the dynamic growth of the renewable sector.

The United States has a well-developed decentralized energy model, where innovations are being intensively implemented, particularly in the private sector. The country ranks second in the world in terms of total renewable energy capacity (Tran, 2025). India has a significant potential for scaling up solar energy. The experience of individual countries is extremely valuable for understanding both the constraints and incentives for the development of renewable energy, especially in conditions of limited resources (Gandhi et al., 2022). In the European context, a striking example is Germany, which has become a pioneer in the implementation of green transformations. Its energy system is characterized by a high level of integration of renewable energy sources, effective balancing and a developed storage infrastructure, which indicates the maturity of the industry (FMEAE, 2014).

Among the southern countries, the example of Brazil is particularly indicative - hydropower dominates the structure of renewable energy, which is largely due to favorable natural conditions and regional specificities. This allows us to identify unique features of the development of "green" energy in countries with large natural potential (Catolico et al., 2021; Iequer et al., 2023).

Ukraine, in turn, is considered a country with significant resource potential for the development of renewable energy, which, however, has suffered large-scale destruction of energy infrastructure as a result of armed aggression. The domestic experience is unique in the global context - it combines the challenges of energy security, the need to restore critical facilities and the desire to integrate into the European Green Space, which is taking place in parallel with the transition to sustainable energy (Bandura & Romanishyn, 2025).

Therefore, involving different countries with different political contexts, levels of economic development and technological approaches in the analysis allows us to form a comprehensive picture of global trends in the field of energy transformations.

The analysis of the dynamics of the total installed capacity of Renewables in the world for the period 2015-2024 shows a gradual growth of this sector, which is confirmed by the trend line approximation coefficient R^2 = 0.948. According to Enerdata (2024), in 2024, the global total capacity of Renewables reached about 4,448 GW, with the largest annual increase in the last twenty years (+ 585 GW). This expansion indicates a steady trend of strategic reorientation of global energy systems towards the use of renewable resources.

Particular attention is drawn to the leading role of China, which provided more than 64% of the global renewable energy growth in 2024 - about 373 GW, bringing the total installed capacity in the country to 1,878 GW (IRENA, 2025). These dynamics are driven by industrial capacity and active government subsidy policies, export-oriented technologies, and accelerated deployment of offshore and distributed systems.

In order to better understand how financial support affects the development of renewable energy, a correlation analysis was conducted to trace the relationship between the volume of investments in this area and the actual growth of energy production from renewable sources (**Figure 2**).

The data obtained show an almost perfect linear correlation (R = 0.99) between the volume of investment in renewable energy and the growth in its production, which underscores the key role of financial support for accelerated energy transformation (**Table 1**).

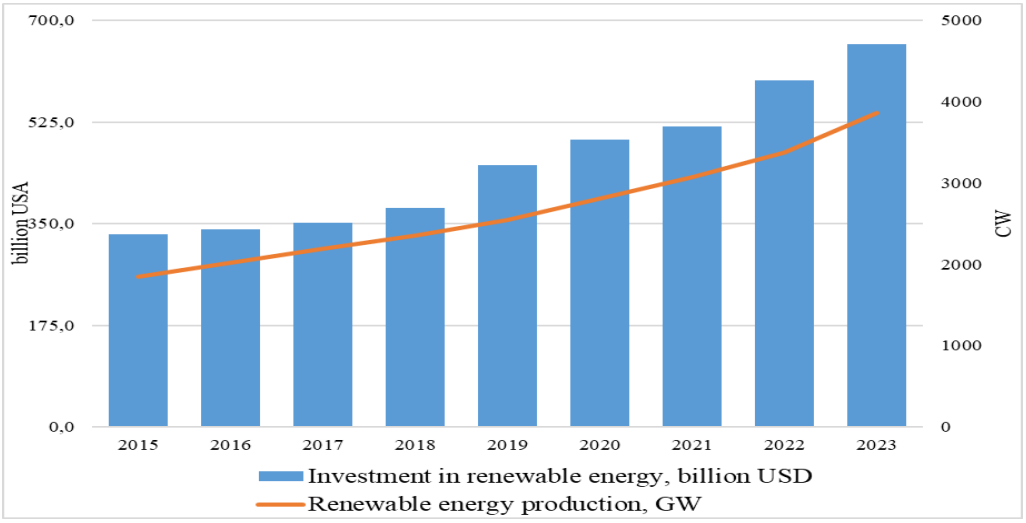

Figure 2. Relationship between the volume of renewable energy production and the amount of investment in Renewables, (2015-2023) (Source: IRENA, 2025; IEA, 2024a)

Table 1. Matrix of correlation between renewable energy production and investment in renewables

	Investment in renewable energy, billion USD	Renewable energy production, GW
Investment in renewable energy, billion USA	1	
Renewable energy production, GW	0,99011459	1

Such a high correlation indicates that investments directly stimulate capacity scaling, the introduction of new technologies, and the modernization of energy infrastructure. In addition, the results confirm the importance of coordinating public policy and market mechanisms: Countries that effectively integrate investment flows into national renewable energy development strategies demonstrate greater energy efficiency, resilience to external shocks, and faster adaptation to global decarbonization trends. These findings are consistent with international studies showing that financial instruments, such as green bonds and targeted investment funds, are critical to ensuring the stable growth of renewable energy production and the implementation of national green economy strategies.

An important trend today is the diversification of renewables, including the use of decentralized energy supply models, such as rooftop solar installations for the private sector and small businesses. According to the forecast (IEA, 2024b), the number of such systems in the world may reach hundreds of millions by 2030, which will significantly change the traditional hierarchy of the energy market. Let's consider the dynamics of changes in the structure of renewable energy sources in the world over time (**Figure 3**).

An analysis of the structure of global renewable energy generation for the period 2015–2024 shows significant changes in the ratio of key technologies. The share of hydropower has decreased from 59.7% in 2015 to 30.3% in 2024, reflecting the saturation of the sector, technical and environmental constraints on the construction of new large hydropower plants, and the relatively rapid growth of other sources. Wind energy shows gradual growth from 20.5% to a maximum of 25% in 2021, after which it stabilizes at 24–25%, indicating stable development and high technological potential in this sector. The most dynamic growth is observed

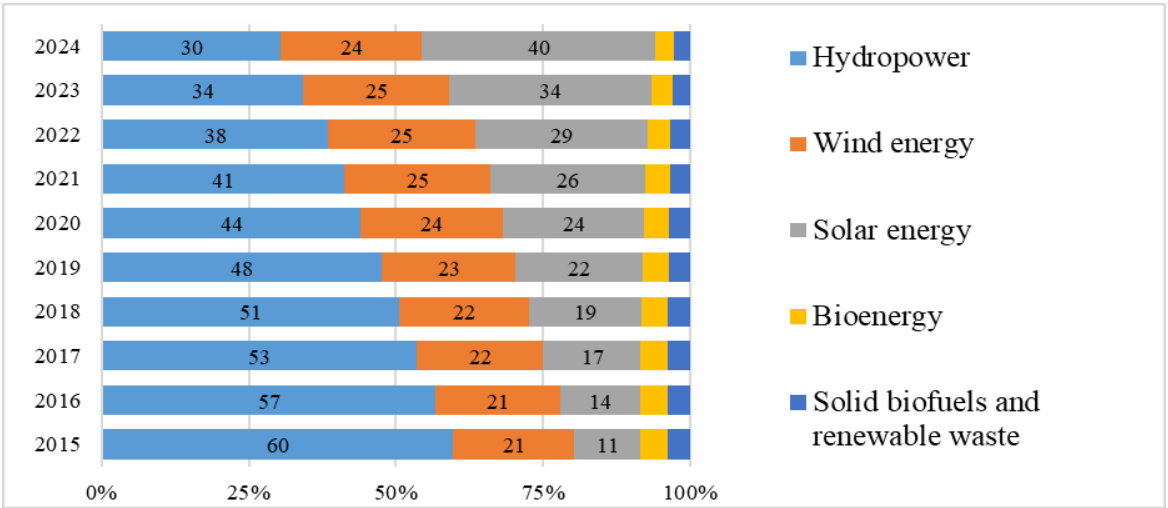

Figure 3. Structure of Renewables generation sources in the world, % (2015-2024) (IRENA, 2025)

Table 2. Typology of state policy in the field of green economy and renewable energy: international experience

Country / Region	Strategic initiative	Key instruments	Features of the model
EU (27 countries)	European Green Deal	EU ETS, Horizon Europe, green taxonomy	Institutional integration, just transition
South Korea	Korean Green New Deal	Hydrogen, digital energy, renewable energy subsidies	Centralized, export-oriented
Canada	Healthy Environment & Economy	CO_2 price, investment funds, energy efficiency	Federal model, adaptive policy
Scandinavian countries (Denmark, Norway, Sweden, Finland)	National sustainable development strategies	High level of CO_2- taxation, electrification, urbanization	High level of trust, innovation ecosystem

Source: (EC, 2023, 2025; NER, 2025; NRC, 2025; Susta, 2020; Thompson, 2022)

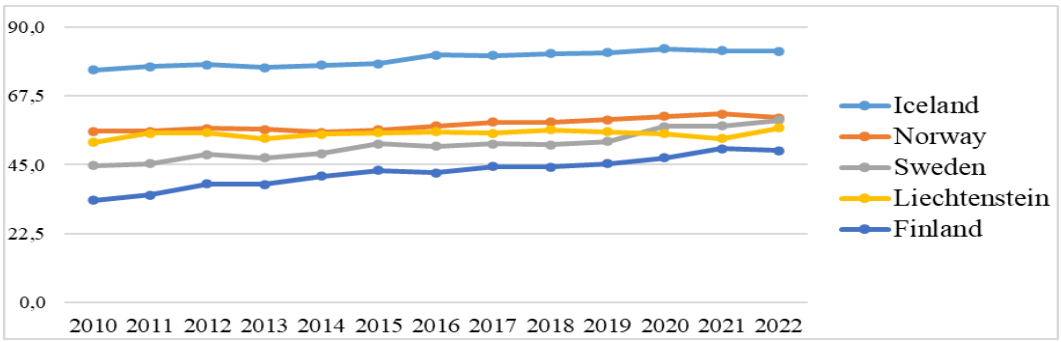

Figure 4. Top 5 countries with the highest share of renewable energy in total final energy consumption, % (2010-2022) (Source: UNECE, 2025)

in solar energy, whose share has increased from 11.2% in 2015 to 39.7% in 2024 due to the reduction in the cost of photovoltaic systems, the large-scale introduction of solar stations, and the support of state investment programs. Currently, solar and wind energy dominate the growth structure of renewable energy sources, accounting for over 90% of new power plants in 2024, with 452 GW of solar and 113 GW of wind energy. This confirms the long-term technological shift towards clean, low-carbon energy sources, which have high potential for scaling up and reducing the cost per unit of energy produced.

A comparative analysis of international experience shows significant differences in the practice of implementing a green economy and renewable energy development depending on the political model, economic structure, and level of institutional maturity of countries (**Table 2**).

In particular, the Scandinavian countries demonstrate the highest share of renewables in total energy consumption (over 50%) under conditions of active public participation and high level of trust in government policies (Multiconsult, 2018; NER, 2018, 2025). The European Union, in the context of regional coordination, ensures a steady increase in the share of renewables (EC, 2023, 2025), combining economic incentives with climate regulation. South Korea and Canada demonstrate different but effective models: The former through technological modernization and centralized management (Lee & Woo, 2020), the latter through market mechanisms and regional flexibility (NRC, 2025). In all cases, there is a close relationship between the scale of investment in renewables and the success of national green transformation strategies (Kniaz et al., 2023).

Let's consider global trends in renewable energy development by visualizing the ranking of countries with the highest share of renewables in the structure of final energy consumption (**Figure 4**). This approach allows us to identify the leaders of the sustainable energy transition and compare the results of their national strategies in the long term.

The data sample shows the dynamics of the growth of the share of renewable energy in total final energy consumption in the five leading countries of the world for the period 2010-2022. The presented data demonstrate a steady positive trend, especially in countries with mature sustainable development policies, such as Norway, Iceland and Sweden. This indicates the effectiveness of long-term strategies and systemic support for the RES sector as a basis for the energy transition.

Thus, a comprehensive comparison of the qualitative and quantitative parameters of green energy policy implementation at the international level suggests that the countries with the highest share of renewables in final energy consumption (in particular, Norway, Iceland, Sweden) are also among the leaders in terms of institutional sustainability, investment levels and regulatory efficiency, as shown in the table. This coincidence of quantitative and qualitative characteristics indicates the existence of a systemic approach that combines political will, institutional coherence, and strategic investment in renewable energy.

The example of the Scandinavian countries, as well as leaders with a high share of renewables, shows a mutually reinforcing effect: Active government support stimulates investment growth, which in turn contributes to increased clean energy production and reduced CO_2 emissions. These findings emphasize the importance of a comprehensive approach to formulating national energy transition strategies, in which economic, environmental and social indicators complement each other.

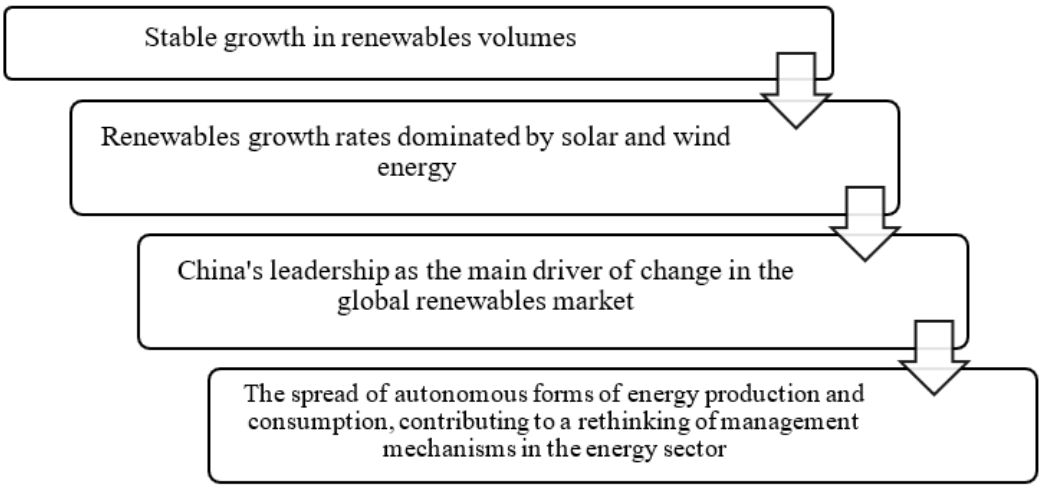

Figure 5. Key trends in the formation of Renewables at the global level (Source: Authors' own elaboration)

DISCUSSION

The results of the study confirm the growing role of the green economy and renewable energy as determinants of the global transformation of economic systems. In the context of the environmental crisis, geopolitical instability, and growing energy vulnerability, these approaches are the main factors in ensuring long-term sustainability, economic autonomy, and the transition to low-carbon development (Renewable energy and jobs: Annual review 2024). Thus, it is possible to identify the key trends in the formation of Renewables at the global level (**Figure 5**).

The above transformations in the green economy demonstrate the need for adaptation to climate change and reflect a deep structural restructuring of the global energy sector towards sustainable and inclusive development.

The optimized model for integrating the green economy and energy security encompasses six interrelated levels:

1) Strategic,
2) Technological and infrastructural,
3) Institutional and political,
4) Economic,
5) Socio-environmental, and
6) Synergistic.

At the strategic level, the key components are globalization, climate risks, international initiatives, and green financial instruments, which shape the need to transition to renewable energy sources as the basis for energy sustainability. The technological and infrastructural level involves increasing RES capacity, decentralisation, innovation and network modernisation to ensure reliability, flexibility and energy independence. The institutional and political level includes national strategies, regulatory incentives, market transparency, and policy alignment with EU standards, which contributes to effective management and investment attraction. The economic level focuses on reducing import dependence, developing green industry, creating new jobs and markets, and increasing economic stability and competitiveness. The socio-environmental level aims to reduce environmental pressure, improve quality of life, and increase communities' resilience to climate risks. The synergistic level reflects the integration of all components: the green economy stimulates the development of RES, RES ensure energy security, and stable energy markets support sustainable development and increased national resilience. In the context of the formation of the principles of circularity, inclusiveness and technological transformation, an attempt is made to build a generalized model of the interaction between the green economy and energy security (**Figure 6**).

The model is built through the prism of a systemic vision of the green economy as a multicomponent platform that combines environmental rationality, energy sustainability, innovative technologies, and social justice. The dominant element of interaction is renewable energy, which combines economic feasibility, environmental efficiency, and the ability to provide energy autonomy. This approach is in line with the current transformational paradigms defined in the EU's Climate Neutrality Strategy, the Sustainable Development Goals (SDGs), and research by international think tanks (IRENA, 2025; WB, 2025).

The circular economy is gradually becoming the basis for a new model of resource use in the energy sector. It involves replacing linear resource consumption with cyclical flows – through the introduction of closed material and energy chains, minimizing losses and extending the life cycle of products (EMAF, 2021; Ryzhakova et al., 2022). This necessitates:

- Stimulating the remanufacturing, reuse and recycling of materials;
- Reducing the environmental footprint of energy technologies at all stages of the life cycle – from raw material extraction to disposal (Gavkalova et al., 2025; Kalkanis et al., 2024).

An important social component of green transformation is the concept of Just Transition, which provides for equal rights and opportunities in access to green energy for all segments of the population, including:

- Guaranteed access to energy services regardless of geographic location, income or social status;
- Support for the re-profiling of labor resources in regions where fossil fuels are being abandoned (Dobrotková et al., 2024);

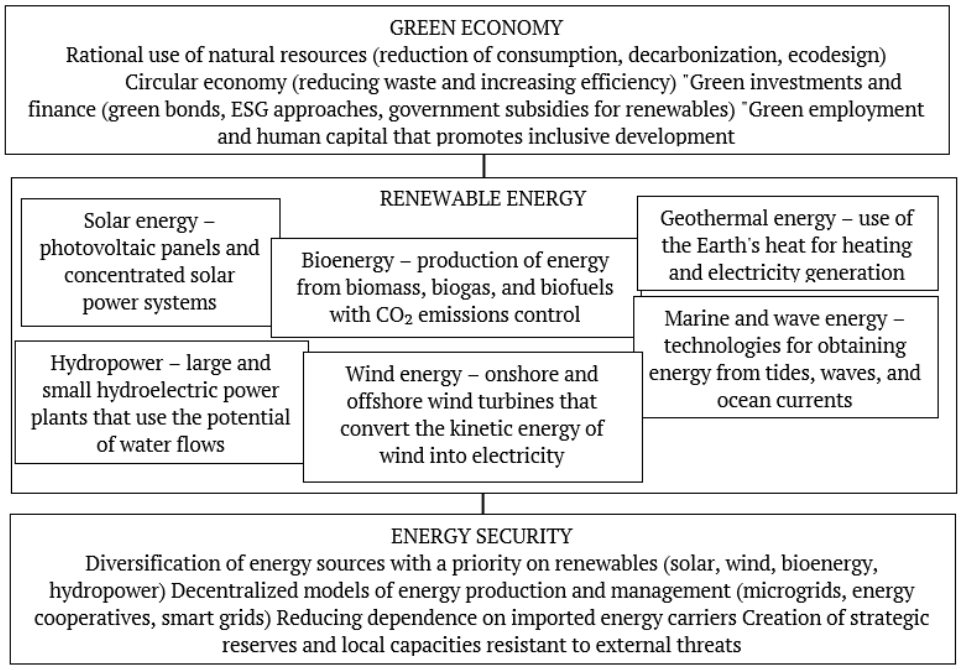

Figure 6. Key trends in the formation of Renewables at the global level (Source: Compiled by the authors)

- Expanding community participation in decision-making on energy management.

Intensive development of Renewables is achieved through the transfer of technological innovations in energy storage, hydrogen generation, smart grids, and digital demand management (IEA, 2024b, 2024c; IRENA & ILO, 2024; IRENA, 2025). The main ways in this direction:

- Active financial (venture capital source) support for research and development;
- Aintegration of renewables into important sectors of the economy (Dirma et al., 2024; Maradin et al., 2017; Zhang et al., 2024)
- The use of artificial intelligence and a large database of information helps to optimize energy generation and consumption.

The complex combination of these three factors requires effective institutional and political synergy:

- Balanced national and regional policies that successfully combine climate, energy, and socio-economic goals (EC, 2020);
- Formation of a national governance system–integration of state regulation, market factors and the public) (Busch, et al., 2023);
- Implementation of a monitoring system using a number of Renewables assessment indicators (Faraji Abdolmaleki & Bello Bugallo, 2025; Otundo Richard, 2024).

Green economy policies in developing countries require a comprehensive approach that combines institutional, financial, technological, and social instruments to accelerate environmental modernization, improve energy efficiency, and reduce dependence on fossil fuels. Priorities include interagency coordination, green budgeting, stimulating private investment through renewable energy funds, tax incentives, and green procurement programs. The development of renewable energy should be based on decentralized generation, energy cooperatives, localization of clean technologies, and circular economy principles. The social dimension is ensured by a just transition program, retraining of personnel, subsidies for low-income households, and ensuring access to clean energy in rural communities. Key factors include national green technology centers, support for environmental innovation, digital monitoring of energy consumption, and international cooperation with UNEP, IRENA, the Green Climate Fund, and financial institutions. The development of environmental education and a culture of sustainable consumption forms the basis for sustainable development, energy security, and increased competitiveness.

Thus, the future of energy transformation lies in the integration of circular, socially just and innovative approaches that can ensure not only decarbonization, but also increase social sustainability and economic efficiency.

CONCLUSION

A comprehensive analysis of the development of renewable energy in the global and national contexts over the past decade demonstrates the importance of this sector in ensuring sustainable development, climate neutrality and energy security. The benchmarking analysis of the experience of different countries shows the success of national renewable energy policies in close correlation with the level of institutional capacity, innovation potential and the amount of investment. A strong direct correlation between the amount of financing and the growth of production capacity ($R = 0.99$) was found, which emphasizes the crucial role of targeted financial support in the transformation of energy systems.

The structure of renewable energy sources has undergone significant changes: While hydropower remained the priority

in 2015, solar and wind generation took the leading positions in 2024. Such dynamics indicate a deep technological breakthrough and the ability of energy systems to quickly integrate innovations. Similar results were achieved primarily in countries where integrated models of sustainable development have been implemented - such as Norway, Sweden and Iceland. These states are distinguished by a high share of renewable energy in the structure of energy consumption, consistency of long-term strategies and a high level of trust in state institutions. Thus, the potential for the development of renewable energy is closely related to the integration of the principles of the circular economy, digital transformation and social justice. It is the combination of environmental efficiency, inclusiveness, and innovation that forms the basis for a new energy model – sustainable, adaptive, and focused not only on technical and economic indicators, but primarily on human well-being and the safety of the planet.

Author contributions: LH: conceptualization, methodology, data collection, writing – original draft, project administration; **SK:** supervision, formal analysis, validation, writing – review & editing; **VZ:** data analysis, visualization, interpretation; **OY:** literature review, theoretical framework, writing — review & editing; **MG:** software, resources, writing – review & editing. All authors agreed with the results and conclusions.

Funding: Authors declare that this research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical statement: The authors stated that the research was conducted in accordance with accepted academic and ethical standards. The study does not involve human or animal subjects and therefore did not require approval from an institutional ethics committee.

AI statement: The authors stated that generative AI and AI-based tools were used only to assist with language editing, text structuring, and improving the clarity of the manuscript. All scientific content, analysis, interpretations, and conclusions were developed and verified by the authors. The authors take full responsibility for the originality, accuracy, and integrity of the final submitted work.

Declaration of interest: The authors declare that they have no competing interests of any kind, including financial, commercial, political, or personal relationships that could have influenced the work reported in this paper.

Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

REFERENCES

Agbakwuru, V., Obidi, P. O., Salihu, O. S., & MaryJane, O. C. (2024). The role of renewable energy in achieving sustainable development goals. *International Journal of Engineering Research Updates, 7*(2), 13-27. https://doi.org/10.53430/ijeru.2024.7.2.0046

Bandura, R., & Romanishyn, A. (2025). Striving for access, security, and sustainability: Ukraine's transition to a modern and decentralized energy system. *CSIS* https://www.csis.org/analysis/striving-access-security-and-sustainability

Busch, S., Kasdorp, R., Koolen, D., Mercier, A., & Spooner M. (2023). *The development of renewable energy in the electricity market*. European Economy. https://economy-finance.ec.europa.eu/system/files/2023-06/dp187_en_energy%20markets.pdf

Catolico, A. C. C., Maestrini, M., Strauch, J. C. M., Giusti, F., & Hunt, J. (2021). Socioeconomic impacts of large hydroelectric power plants in Brazil: A synthetic control assessment of Estreito hydropower plant. *Renewable and Sustainable Energy Reviews, 151*, Article 111508. https://doi.org/10.1016/j.rser.2021.111508

Chou, C.-H., Ngo, S. L., & Tran, P. P. (2023). Renewable energy integration for sustainable economic growth: Insights and challenges via bibliometric analysis. *Sustainability, 15*(20), Article 15030. https://doi.org/10.3390/su152015030

Conde, J. J., & Takano-Rojas, H. (2025). Rethinking energy transition: Approaches from social representations theory. *Energy Research & Social Science, 122*, Article 104001. https://doi.org/10.1016/j.erss.2025.104001

Del Duca, V., Ponsiglione, C., Primario, S., & Strazzullo, S. (2024). Towards economic, environmental, and societal sustainable world: Reviewing the interplay of methodologies, variables, and impacts in energy transition models. *Journal of Cleaner Production, 479,* Article 144074. https://doi.org/10.1016/j.jclepro.2024.144074

Desyatnyuk, O., Krysovatyy, A., Ptashchenko, O., & Kyrylenko, O. (2025). The role of financial inclusion in fostering eco-entrepreneurship within the digital economy. *International Journal of Ecosystems and Ecology Science, 15*(1), 77-86. https://doi.org/10.31407/ijees15.109

Dirma, V., Neverauskienė, L. O., Tvaronavičienė, M., Danilevičienė, I., & Tamošiūnienė, R. (2024). The impact of renewable energy development on economic growth. *Energies, 17*(24), Article 6328. https://doi.org/10.3390/en17246328

DiXi Group. (2024). *European green deal: Impact on Ukraine's energy, climate and environment policies and legislation*. DiXi Group. https://dixigroup.org/en/analytic/european-green-deal-impact-on-ukraines-energy-climate-and-environment-policies-and-legislation/

Dobrotková, Z., Pargal, S., & Fichaux, N. (2024). *Jobs for a livable planet. Job creation potential of the clean energy transition*. Public Disclosure Authorized. https://documents1.worldbank.org/curated/en/099012324075618467/pdf/P17643810e6ae80901a66b1c56cb14b2a36.pdf

Dunchev, D. M. (2025). Renewable energy sources: The key for sustainable future. *Agricultural Sciences, 17*(44), 160-167. https://doi.org/10.22620/agrisci.2025.44.017

EBRD. (2025). *EBRD, the EU and partners announce plan to boost renewables in Ukraine*. Home. https://www.ebrd.com/home/news-and-events/news/2025/renewables-risk-mitigation-platform.html

EC. (2020). *The national energy and climate plan for 2021-2030. Objectives and targets, and policies and measures.* Ministry of National Assets. https://energy.ec.europa.eu/system/files/2020-08/pl_final_necp_part_1_3_en_0.pdf

EC. (2021). *Communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions empty. Strategy for financing the transition to a sustainable economy*. European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021DC0390

EC. (2023). European Green Deal: EU and Republic of Korea launch green partnership to deepen cooperation on climate action, clean energy and environmental protection. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2816

EC. (2025). *Towards a greener and more sustainable Europe*. European Union. https://european-union.europa.eu/priorities-and-actions/actions-topic/environment_en

EEAS. (2025). *The EU boosts its support towards a greener, resilient and competitive economy for Ukrainian citizens*. https://www.eeas.europa.eu/delegations/ukraine/eu-boosts-its-support-towards-greener-resilient-and-competitive-economy-ukrainian-citizens_en

EMAF. (2021). *Completing the picture: How the circular economy tackles climate change*. Ellen MacArthur Foundation. https://surl.li/tyuili

Emin, Z. (2023). *The complexity of renewables, Part 1*. PSC Specialists Grouph. https://www.pscconsulting.com/the-complexity-of-renewables-part-1/

Enerdata. (2024). *Global energy trends. Annual report, based on exclusive statistics on energy and CO_2 emissions*. https://www.enerdata.net/publications/reports-presentations/world-energy-trends.html

Faraji Abdolmaleki, S., & Bello Bugallo, P. M. (2025). Advancing sustainability assessment of renewable energy: A study on indicator-to-framework methods and associated rule mining. *Sustainable Development, 33*(3), 4393-4427. https://doi.org/10.1002/sd.3331

Ferris, T. (2025). *Assessing the regulatory process in a rapidly changing world*. IIEA.

Fetting, C. (2020). *The European Green Deal*. ESDN Office. https://www.esdn.eu/fileadmin/ESDN_Reports/ESDN_Report_2_2020.pdf

Filho, W., Balogun, A.-L., Surroop, D., Salvia, A., Narula, K., Li, C., Hunt, J., Gatto, A., Sharifi, A., Feng, H., Tsani, S., & Azadi, H. (2022). Realising the potential of renewable energy as a tool for energy security in small island developing states. *Sustainability, 14*(9). https://doi.org/10.3390/su14094965

FMEAE. (2014). *An electricity market for Germany's energy transition. Discussion Paper of the Federal Ministry for Economic Affairs and Energy (Green Paper)*. https://www.bundeswirtschaftsministerium.de/Redaktion/EN/Publikationen/gruenbuch.pdf?__blob=publicationFile&v=1

Gandhi, H. H., Hoex, B., & Hallam, B. J. (2022). Strategic investment risks threatening India's renewable energy ambition. *Energy Strategy Reviews, 43*, Article 100921. https://doi.org/10.1016/j.esr.2022.100921

Gavkalova, N., Smereka, S., Kadyrus, I., Kyrylenko, S., & Kasatkina, M. (2025). Energy-saving technologies and innovations: Driving competitiveness in contemporary business. *Grassroots Journal of Natural Resources, 8*(1), 138-162. https://doi.org/10.33002/nr2581.6853.080105

Gavkalova, N., Smereka, S., Kadyrus, I., Kyrylenko, S., & Kasatkina, M. (2024). Using innovation and energy efficiency technologies to drive business competitiveness. *Grassroots Journal of Natural Resources, 7*(3),s212-s229. https://doi.org/10.33002/nr2581.6853.0703ukr11

GCF. (2015). *United Nations Environment Programme. Green Climate Fund*. https://www.greenclimate.fund/ae/unep

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews, 24*, 38-50. https://doi.org/10.1016/j.esr.2019.01.006

Guarascio, D., Reljic, J., & Zezza, F. (2025). Energy vulnerability and resilience in the EU: Concepts, empirics and policy. *Journal of Industrial and Business Economics, 52* 683-726. https://doi.org/10.1007/s40812-025-00340-9

IEA. (2024a). World energy investment 2024 datafile. IEA. https://www.iea.org/data-and-statistics/data-product/world-energy-investment-2024-datafile

IEA. (2024b). *Global investment in clean energy and fossil fuels, 2015-2024*. https://www.iea.org/data-and-statistics/charts/global-investment-in-clean-energy-and-fossil-fuels-2015-2024

IEA. (2024c). *Renewables 2024*. IEA. https://www.iea.org/reports/renewables-2024

Iequer, P. H. N., Borgas, G. P., Simões, A. F., & Domingues, M. S. (2023). The expansion of renewable energy in Brazil: Opportunities and barriers within the context of energy transition and climate change mitigation. *Cuadernos de Educación y Desarrollo, 15*(3), 2535-2563. https://doi.org/10.55905/cuadv15n3-028

IRENA, & ILO. (2024). *Renewable energy and jobs: Annual review 2024*. International Renewable Energy Agency, Abu Dhabi, and International Labour Organization, Geneva.

IRENA. (2025). *Renewable capacity statistics 2025*. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2025/Mar/IRENA_DAT_RE_Capacity_Statistics_2025.pdf

Kalkanis, K., Bourtsalas, A., & Psomopoulos, C. S. (2024). Life cycle assessment applied to waste-to-energy technologies. In *Waste Valorization for Bioenergy and Bioproducts* (pp. 527-543). Elsevier. https://doi.org/10.1016/b978-0-443-19171-8.00014-6

Kniaz, S., Podolchak, N., Dziurakh, Y., Karkovska, V., & Kucher, A. (2023). Development of government regulation on investment activities in agriculture of Ukraine. *Ikonomicheski Izsledvania, 32*(2), 136-150. https://doi.org/10.13140/RG.2.2.12289.53600

Krause, J., Myroshnychenko, I., Tiutiunyk, S., & Latysh, D. (2024). Financial instruments of the green energy transition: Research landscape analysis. *Financial Markets, Institutions and Risks, 8*(2), 198-212. https://doi.org/10.61093/fmir.8(2).198-212.2024

Lee, J.-H., & Woo, J. (2020). Green new deal policy of South Korea: Policy innovation for a sustainability transition. *Sustainability, 12*(23), Article 10191. https://doi.org/10.3390/su122310191

Liu, H., Khan, I., Zakari, A., & Alharthi, M. (2022). Roles of trilemma in the world energy sector and transition towards sustainable energy: A study of economic growth and the environment. *Energy Policy, 170*, Article 113238. https://doi.org/10.1016/j.enpol.2022.113238

Maradin, D., Cerović, L., & Mjeda, T. (2017). Economic effects of renewable energy technologies. *Naše gospodarstvo/Our economy, 63*(2), 49-59. https://doi.org/10.1515/ngoe-2017-0012

Mavlutova, I., Spilbergs, A., Romanova, I., Kuzmina, J., Fomins, A., Verdenhofs, A., & Natrins, A. (2025). The role of green digital investments in promoting sustainable development goals and green energy consumption. *Journal of Open Innovation: Technology, Market, and Complexity*, *11*(2), Article 100518. https://doi.org/10.1016/j.joitmc.2025.100518

Mia, M. M., Rizwan, S., Zayed, N. M., Nitsenko, V., Miroshnyk, O., Kryshtal, H., & Ostapenko, R. (2022). The impact of green entrepreneurship on social change and factors influencing AMO. *Theory Systems, 10*(5), Article 132, https://doi.org/10.3390/systems10050132

Mikropoulos, E., Roelfsema, M., Chen, H.-H., Staffell, I., Oreggioni, G., Hdidouan, D., Thellufsen, J. Z., Chang, M. A., Fragkos, P., Giannousakis, A., Chatterjee, S., Ürge-Vorsatz, D., Pfenninger, S., Pickering, B., Victoria, M., Brown, T., & van Vuuren, D. P. (2025). Examining pathways for a climate neutral Europe by 2050; A model comparison analysis including integrated assessment models and energy system models. *Energy, 319,* Article 134809. https://doi.org/10.1016/j.energy.2025.134809

Mitryasova, O. (2025). *European green dimensions: Fundamental, applied, and industrial aspects: Monograph*. UWE.

Monie, S. W., Gustafsson, M., Önnered, S., & Guruvita, K. (2025). Renewable and integrated energy system resilience – A review and generic resilience index. *Renewable and Sustainable Energy Reviews, 215*, Article 115554. https://doi.org/10.1016/j.rser.2025.115554

Nordic Energy Research (NER). (2025). Selection of best practices and exemplary initiatives within energy efficiency in the Nordics. *Nordic Energy Research*. https://pub.norden.org/nordicenergyresearch2025-01/6-selection-of-best-practices-and-exemplary-initiatives-within-energy-efficiency-in-the-nordics.html

Nordic Energy Research (NER). (2018, December 5). *New report: Nordic renewable energy companies ready for developing countries*. https://www.nordicenergy.org/news/new-report-nordic-renewable-energy-companies-ready-for-developing-countries/

NRC. (2025) *Canada's green future*. Natural Resources Canada. https://natural-resources.canada.ca/climate-change/canadas-green-future

Orujov, E. (2025). Evolving dynamics of globalization in the 21st century: Technological, cultural and sustainable development. У *Economic Transformation in the Context of Global Challenges* (pp. 219-221). Baltija Publishing. https://doi.org/10.30525/978-9934-26-529-7-61

Otundo Richard, M. (2024). Monitoring and evaluation practices in renewable energy projects: A study of their impact on sustainable development in Kenya's marginalized regions. *SSRN Electronic Journal,* 107-130. https://doi.org/10.2139/ssrn.4993197

Pokhodenko, B. (2023). Review and comparative analysis of energy security concepts of the European Union and Ukraine. *The Journal of V. N. Karazin Kharkiv National University. Series: International Relations. Economics. Country Studies. Tourism,* 17, 56-79. https://doi.org/10.26565/2310-9513-2023-17-06

Raizada, A. (2025). *India's green hydrogen strategy in action policy actions. Market insights, and global opportunities*. https://www.ifri.org/sites/default/files/2025-05/ifri_raizada-india-green-hydrogen_2025_0.pdf

Regen Power. (2025). *What are the problems faced by renewable energy?* Regen Power. https://regenpower.com/what-are-the-problems-faced-by-renewable-energy/

Ryzhakova, G., Honcharenko, T., Predun, K., Petrukha, N., Malykhina, O., & Khomenko, O. (2023). Using fuzzy logic for risk assessment of construction enterprise management system. In *2023 IEEE International Conference on Smart Information Systems and Technologies* (pp. 208-213). Astana IT University. https://doi.org/10.1109/SIST58284.2023.10223560

Ryzhakova, G., Petrukha, S., Petrukha, N., Krupelnytska, O., & Hudenko, O. (2022). Ahroprodovol′chi lantsyuhy dodanoyi vartosti: metodolohiya, tekhnika ta arkhitektura [Agro-food value added chains: Methodology, technique and architecture]. *Financial and Credit Activity: Problems of Theory and Practice, 4*(45), 385-395. https://doi.org/10.55643/fcaptp.4.45.2022.3809

Saputra, G. T., & Lutfiana Rakhman, R. (2025). Reframing renewable energy reliability as a national security threat: Strategic foresight and institutional challenges in Indonesia's energy transition. *Journal Transnational Universal Studies, 3*(6), 49-68. https://doi.org/10.58631/jtus.v3i6.175

Schürmann, K., Ernst, A., Schumann, D., & Hake, J.-F. (2019). Transformation of energy systems as common projects: An integration of different scientific approaches to address real-world challenges. *Energy Procedia, 158*, 3534-3540. https://doi.org/10.1016/j.egypro.2019.01.915

Segura, K. G. L. (2024). Energy transitions research: An assessment methodology. *Society and Economy, 46*(3), 275-287. https://doi.org/10.1556/204.2023.00027

Shi, Y., & Zhao, Y. (2023). The contribution of green finance to energy security in the construction of new energy system: Empirical research from China. *Journal of Cleaner Production, 429,* Article 139480. https://doi.org/10.1016/j.jclepro.2023.139480

Stepanenko, V., Zamulko, A., Veremiichuk, Y., & Nakhodov, V. (2022). Ocinka rizikiv pri integraciji vidnovlyuvanih dzherel energiyi do sistemi elektropostachannya [Assessment of risk for the integration of renewable energy sources into the electricity supply system]. *Power Engineering: Economics, Technique, Ecology,* 2, Article 68. https://doi.org/10.20535/1813-5420.2.2022.261372

Susta, G. (2020). *European Union policies for a green economy: Analysis and objectives towards 2020*. Institute of European Democrats. https://www.iedonline.eu/download/2014/research_paper__european_union_policies_for_a_green_economy.pdf

Thompson, S. (2022). Green renewable power and policy in Canada: A just energy transition to net-zero. *Journal of Geoscience and Environment Protection, 10*(03), 1-12. https://doi.org/10.4236/gep.2022.103001

Tran, B. (2025). *Top countries leading the green energy transition (Renewable Power Stats)*. PatentPC. https://patentpc.com/blog/top-countries-leading-the-green-energy-transition-renewable-power-stats

UFP. (2024). *Ukraine Plan 2024 – 2027*. Ukraine-Facility-Plan. https://www.ukrainefacility.me.gov.ua/wp-content/uploads/2024/03/ukraine-facility-plan.pdf

UNECE. (2025). *Renewable energy share in the total final energy consumption*. UNECE Statistical database. https://w3.unece.org/SDG/en/Indicator?id=23

WB. (2025). *Tracking SDG 7 – The energy progress report 2025*. https://www.worldbank.org/en/topic/energy/publication/tracking-sdg-7-the-energy-progress-report-2025?intcid=ecr_hp_sidekick2_en_ext

Wu, J., & Yu, Z. (2025). The impact of market-based environmental regulation on carbon emission intensity: An analysis based on policy texts. *Sustainability, 17*(2), Article 465. https://doi.org/10.3390/su17020465

Zavidna, L., Kolesnikova, K., Barna, M., Shelemetieva, T., & Lanytsia, I. (2025). Integrated strategic models for the post-war recovery of Ukraine's hospitality and tourism industry. *International Journal of Sustainable Development, 18*(10), 29-40. https://oidaijsd.com/wp-content/uploads/2025/06/18-01-02-07-IJSD-UR2-25.pdf

Zeng, Q., Li, C., & Magazzino, C. (2024). Impact of green energy production for sustainable economic growth and green economic recovery. *Heliyon, 10*(17), Article e36643. https://doi.org/10.1016/j.heliyon.2024.e36643

Zhang, X., Feng, D., Wang, J., & Sui, A. (2024). Integrating renewable energy systems: Assessing financial innovation, renewable energy generation intensity, energy transition and environmental regulation with renewable energy sources. *Energy Strategy Reviews, 56,* Article 101567. https://doi.org/10.1016/j.esr.2024.101567

Zvarych, R., & Masna, O. (2023). Green energy transition in the concept of post-war reconstruction of Ukraine. *Herald of Economics,* 3, Article 170. https://doi.org/10.35774/visnyk2023.03.170