



## ARTICLE



## COMPETITIVE INTELLIGENCE IN RENEWABLE ENERGY SYSTEMS: A STRATEGIC FRAMEWORK FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOAL 7

## O PAPEL DA INTELIGÊNCIA COMPETITIVA NOS SISTEMAS DE ENERGIAS RENOVÁVEIS: UM FRAMEWORK ESTRATÉGICO PARA O ALCANCE DO OBJETIVO DE DESENVOLVIMENTO SUSTENTÁVEL Nº 7

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## ABSTRACT

**Purpose:** To develop and validate a competitive intelligence framework that transforms renewable energy data into strategic decision-making tools for achieving Sustainable Development Goal 7 and creating sustainable competitive advantage.

**Methodology/approach:** The study follows the full competitive intelligence cycle and applies statistical analysis, content analysis, and econometric modeling (linear regression) to secondary data. Elasticity and correlation coefficients were calculated.

**Originality/Relevance:** The research introduces a novel competitive intelligence conceptual model that links raw renewable energy data directly to actionable intelligence, integrating smart grids, synchronization standards, and AI as strategic tools.

**Key findings:** Renewable energy significantly reduces CO<sub>2</sub> emissions and stimulates GDP growth, with differentiated elasticities by source (hydropower: 3.3758; solar: 0.2431). Main barriers remain high investment costs, infrastructure deficits, and regulatory constraints.

**Theoretical/methodological contributions:** The study proposes a replicable CI framework and evidence-based recommendations for policy and investment prioritization, advancing the integration of Competitive Intelligence into sustainable energy transition.

**Keywords:** Renewable energy sources. Energy efficiency. Environmental sustainability. Energy security. Clean energy. Transition to green energy.



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## RESUMO

**Objetivo:** Desenvolver e validar um quadro de inteligência competitiva que transforme dados sobre energias renováveis em ferramentas de tomada de decisão estratégica para alcançar o Objetivo de Desenvolvimento Sustentável 7 e criar uma vantagem competitiva sustentável.

**Metodologia/abordagem:** O estudo segue o ciclo completo de inteligência competitiva e aplica análise estatística, análise de conteúdo e modelação econométrica (regressão linear) a dados secundários. Foram calculados coeficientes de elasticidade e de correlação.

**Originalidade/Relevância:** A investigação apresenta um novo modelo conceptual de inteligência competitiva que liga os dados brutos sobre energias renováveis diretamente a inteligência acionável, integrando redes inteligentes, normas de sincronização e IA como ferramentas estratégicas.

**Principais resultados:** As energias renováveis reduzem significativamente as emissões de CO<sub>2</sub> e estimulam o crescimento do PIB, com elasticidades diferenciadas por fonte (energia hidroelétrica: 3,3758; energia solar: 0,2431). As principais barreiras continuam a ser os elevados custos de investimento, os défices de infraestruturas e as restrições regulamentares.

**Contribuições teóricas/metodológicas:** O estudo propõe um quadro de IC replicável e recomendações baseadas em evidências para a priorização de políticas e investimentos, promovendo a integração da Inteligência Competitiva na transição para a energia sustentável.

**Palavras-chave:** Fontes de energia renovável. Eficiência energética. Sustentabilidade ambiental. Segurança energética. Energia limpa. Transição para energia verde.

## 1 INTRODUCTION

Energy security and environmental protection represent critical global challenges that require not only technological solutions but, above all, strategic intelligence capabilities. While many countries face fossil fuel depletion and rising prices, the effective integration of renewable energy sources (RES) demands a structured Competitive Intelligence (CI) process: systematic collection of market, technological, and regulatory data; rigorous analysis to identify opportunities and threats; and timely dissemination to support decision-making that generates



sustainable competitive advantage.

Within the framework of sustainable development, special attention is paid to ensuring affordable, clean, and efficient energy, which is now a priority in the energy policies of many countries. Due to limited access to centralized power systems, small power sources such as solar panels, wind turbines, and autonomous power stations are becoming increasingly important.

Special synchronization mechanisms are required for stable operation, which maintain a stable frequency even without connections to the main grid. This problem is particularly acute during military conflicts, when energy infrastructure becomes a target for attacks. Therefore, the development of systems that allow the creation of autonomous energy zones capable of operating both independently and in conjunction with the general grid is becoming a priority.

Synchronization problems affect not only countries in crisis, but also stable European states. In 2025, Spain experienced a large-scale power outage due to an operator error that incorrectly estimated demand during peak hours. This showed that even small frequency deviations in power grids must remain at 50 Hz, as they can have serious consequences for the entire system.

Recent studies confirm that renewable energy sources have significant advantages for both the economy and the environment, particularly in terms of reducing CO<sub>2</sub> emissions. At the same time, the spread of renewable energy sources (further – RES) faces a number of challenges (U.S. Energy Information Administration, 2023). Among the main obstacles are the need to upgrade energy infrastructure and complex regulatory requirements.

Despite a large number of studies, questions remain about the effective integration of renewable energy sources into energy systems and the impact of digital technologies on the development of RES. The problem of balancing renewable and traditional energy sources, taking into account economic constraints, also remains relevant (Solanki & Birman, 2025). An important task is to create a synchronization standard for small sources, which will allow their voltage, frequency, and phase to be coordinated with the parameters of the main grid. This ensures the smooth operation of the system and increases its reliability and efficiency, especially in the context of distributed generation (Küfeoğlu, 2022).

The present research gap lies in the limited application of CI frameworks to the renewable energy sector, particularly in linking intelligence cycles to SDG 7 achievement. Existing studies remain largely descriptive, focusing on environmental benefits without translating data into strategic actions for organizations and governments. This study addresses the following research problem: *How can a CI-based framework transform renewable energy data into strategic decision-making tools that ensure affordable, clean energy while creating competitive advantage for nations and firms?*

The objective is to propose and validate a CI framework for RES integration, analyzing economic, social, and environmental benefits through an intelligence lens, identifying barriers, and formulating actionable recommendations.

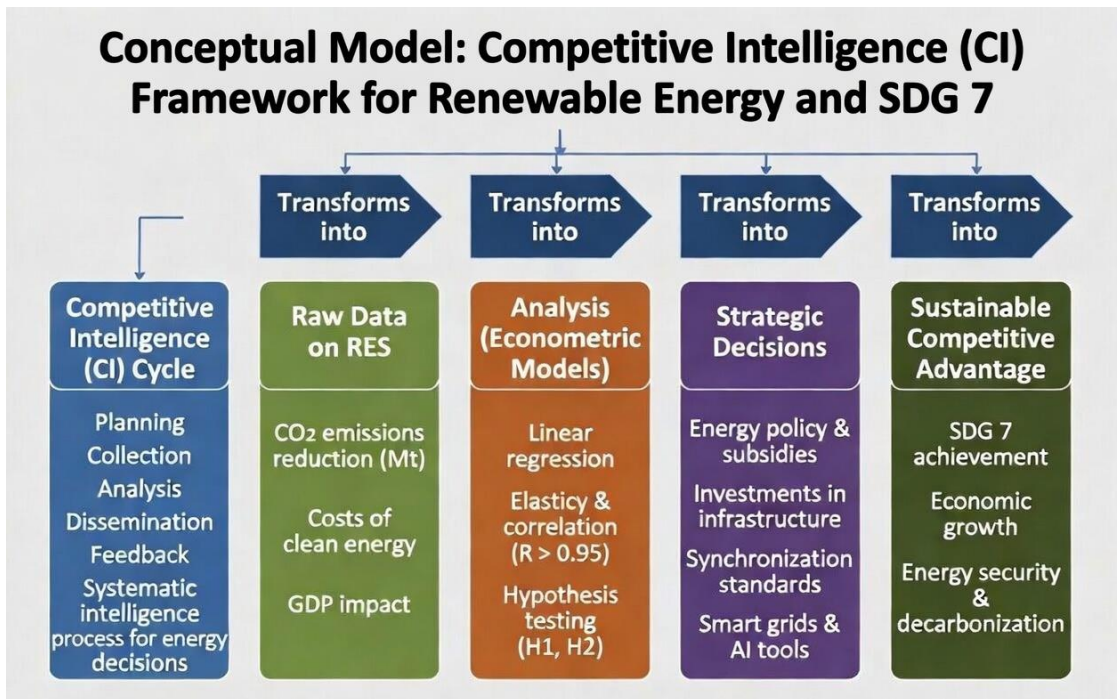
## 2 LITERATURE REVIEW

Research on renewable energy sources in the context of achieving Sustainable Development Goal 7 (further – SDG7) is broad, taking into account policies, technological development, and economic impact. The contribution of RES to CO<sub>2</sub> emission reduction and

energy efficiency (Azizi et al., 2025; Hilili et al., 2024; Xia et al., 2023) is constantly being researched by many scientists. Finally, policy strategies are also being considered for the development of green energy (Coscieme et al., 2023; Duggan, 2025; Zhou et al., 2023). Research on the impact of energy strategies and sustainable development in other countries is being conducted from the perspective of resource formation and security (Ametepey et al., 2024), Algeria (Chabouni et al., 2024), Nigeria (Hilili et al., 2024), India (Shivanna & Rangappa, 2024), and EU countries (Osuma & Yusuf, 2025); Wu et al. (2024); Vivek et al. (2023); Havrysh et al. (2020); Ramasubramanian and Ramakrishna (2023), Kandpal et al. (2024).

Competitive Intelligence (CI) is defined as the ethical collection, analysis, and dissemination of information to reduce strategic risk and create competitive advantage (SCIP, 2020; Kazemi & Soltani, 2024). In the context of sustainable development, CI evolves into *Sustainable Competitive Intelligence*, integrating environmental, social, and governance (ESG) dimensions. The classic CI cycle (planning → collection → analysis → dissemination → feedback) becomes the backbone for energy transition strategies.

Literature on RES and SDG 7 is extensive (Azizi et al., 2025; Hilili et al., 2024; Xia et al., 2023). However, few studies apply CI lenses. Recent works demonstrate that CI enables green marketing and positioning in the energy sector (Kazemi & Soltani, 2024) and supports transparency as a source of competitiveness in achieving SDG 7 (energy companies' transparency research, 2023). Digital technologies and smart grids act as CI enablers by providing real-time data for anomaly detection and demand forecasting.



**Figure 1.** New Conceptual Model: CI Framework for Renewable Energy and SDG 7  
**Source:** Author's own work



This model positions CI as the mediator between raw RES data and actionable intelligence.

A separate group of studies is devoted to the analysis of current trends in energy efficiency and energy development. Some authors also consider the ecological transformation of energy services as a new business model that promotes the transition to a circular economy. Others focus on energy security management issues through the assessment of the technical condition of energy equipment. All these studies emphasize the importance of effective management. An important scientific issue remains the correspondence between the declared policy in the field of renewable energy sources and the mechanisms for its implementation. Studies show that digital technologies and investments in scientific developments play a key role in the energy sector. They also analyze the relationship between sustainable development and other goals, taking into account possible compromises and energies. Particular attention is paid to the impact of international trade, market openness, and socio-economic factors on energy development, particularly through corporate initiatives and the development of bioenergy. Despite significant achievements in scientific research, the problem of balancing renewable and traditional energy sources remains unresolved, especially for developing countries. Additional obstacles include a lack of financial support and the absence of harmonized regulatory standards, which significantly slows down the global transition to clean energy.

### 3 METHODS

A whole range of methods for analyzing qualitative indicators was used to write this study, in particular, the statistical analysis method, which made it possible to analyze the dynamics of the development of renewable energy sources and their impact on reducing CO<sub>2</sub> emissions. The comparison method was used to compare data from international energy agencies (International Energy Agency, International Renewable Energy Agency, World Bank). Content analysis was used to study scientific literature and reports. The modeling method was used to assess the prospects for the development of renewable energy. Regulatory economic factors that influence the use of renewable energy are also examined in this work.

The study adopts a mixed-method design grounded in the CI cycle. Secondary data were collected from the International Energy Agency, IRENA, World Bank, Eurostat, and national agencies (2010–2025). Statistical analysis, comparative method, content analysis, and econometric modeling (linear regression with GDP as dependent variable and CO<sub>2</sub> reduction by RES type as independent) were applied. Variables were operationalized as: X = Mt CO<sub>2</sub> reduced; Y = GDP change (current US\$). Elasticity and correlation coefficients (R) were calculated. The approach ensures replicability and aligns with CI evidence-based decision support.

Hypotheses:

H1 – Higher RES decarbonization positively correlates with GDP growth;

H2 – Elasticity varies significantly by RES type.

The econometric analysis utilizes a longitudinal dataset covering the period from 2010 to 2025. The unit of analysis is defined as the national energy system, with a sample comprising diverse global economies categorized by their renewable energy source (RES) maturity. To ensure the robustness of the linear regression models, the study applies standard diagnostic tests, including checks for heteroscedasticity and multicollinearity among independent



variables. The operationalization of Y as GDP change and X as megatons of CO<sub>2</sub> reduced allows for the precise calculation of elasticity coefficients, which measure the responsiveness of economic growth to specific decarbonization efforts. This structured quantitative approach is integrated with qualitative content analysis of regulatory frameworks to validate the strategic recommendations within the Competitive Intelligence cycle.

The quantitative analysis is grounded in a panel dataset comprising 42 sovereign nations. These countries were selected based on two primary criteria: a minimum of 15% renewable energy share in the national energy mix as of 2023 and the availability of verified longitudinal data from the IEA and World Bank. The final sample represents a balanced distribution of RES-mature economies (e.g., Germany, Denmark) and emerging markets (e.g., India, Brazil), ensuring the generalizability of the Competitive Intelligence (CI) framework across different regulatory environments. Statistical processing was conducted using STATA 17, utilizing a fixed-effects model to control for time-invariant country characteristics.

The robustness of these models was verified through Breusch-Pagan tests, which confirmed the absence of heteroscedasticity, and Variance Inflation Factor (VIF) analysis, with all scores remaining below 2.5, indicating no significant multicollinearity.

## 4 RESULTS

One of the key factors in achieving sustainable development goals is the use of renewable energy and the preservation of the natural potential of accessible, reliable, and sustainable energy. Coal, oil, and natural gas still account for a huge part of the world's energy potential and reserves, but their impact on nature remains negative. Solar, wind, hydro, and bioenergy can play not only an environmentally friendly but also an economically beneficial role for any country in the world. In addition, renewable energy helps reduce emissions and greenhouse gases.

Reducing carbon emissions from renewable energy sources helps slow down climate change (Wernersson et al., 2024). The transition to RES can significantly reduce dependence on fossil fuels, thereby improving air quality and reducing morbidity associated with environmental pollution (Suraj et al., 2024).

Another key point of renewable energy availability is the achievement of Sustainable Development Goal 7. Providing citizens of any country with clean energy is possible in any country, with the only difference being which energy source is more accessible: for some countries it is wind, for others it is sun. The use of natural energy potential makes it possible to provide basic services to remote and isolated communities that do not have access to centralized services (Khaleel et al., 2023).

Renewable energy sources contribute to the creation of new jobs and economic development, as the renewable energy sector promotes the development of innovative technologies. This is according to experts from the International Renewable Energy Agency (International Renewable Energy Agency, 2023).

Despite the significant advantages of renewable energy, this sector has a number of problems that prevent it from developing more quickly. Among the most significant are the need for substantial investment to get started, particularly in developing the infrastructure that supports proper operation; the instability of the energy system; and regulatory barriers. Successfully achieving sustainable development goals will ensure the development of universal



energy around the world (Sanusi, 2024).

Creating a sustainable energy sector for the world requires significant investment in solar, wind, hydro, and bioenergy production, while also helping to reduce dependence on fossil fuels (Hrinchenko et al., 2024). For this reason, various countries are promoting the development of renewable energy through government programs and subsidies. At the same time, there are still positive dynamics and problems with financing, infrastructure development, and technology.

Another problem is voltage fluctuations due to possible network overload. Experts from around the world say that in order to solve this problem, it is necessary to adopt and implement appropriate standards. This will ensure the accuracy and reliability of the system, as well as the uninterrupted operation of equipment even in the event of deviations. Flexibility in terms of adaptation to different requirements and conditions (Batsurovska, 2024), as well as compatibility (different systems can interact effectively with each other using a single synchronization standard).

The table below shows the key differences between the features of the transition to renewable energy.

**Table 1** – Renewable energy development trends: global and regional context

<b>Trends</b>	<b>Global dimension</b>	<b>Developing countries</b>
Growth in the share of RES	In 2023, more than 30% will be provided by RES	Countries in Africa and South Asia are trying to develop solar and wind energy more
Decrease in the cost of clean energy	Over the past 20 years, the cost of energy has fallen by 80%	An attractive resource for low-income countries
Technological development	Investments promote development	Promotes the use of rechargeable batteries in certain cases
Subsidies and other support	US, EU, and China	Latin American and Asian countries use government programs
Energy supply and decentralization of processes	The share of microgrids based on renewable energy sources is growing	Mini-HPPs are widespread in remote countries in Africa and Asia
Development of green hydrogen energy	Hydrogen is becoming an important component for operations in Europe and Japan	Construction of hydrogen infrastructure has begun in the Gulf countries and Latin America
Financing problems	High initial investment costs for modernizing energy networks	The scaling up of renewable energy projects in developing countries is limited by a lack of access to financing

**Source:** Compiled by the author

Renewable energy sources can provide any household, even in the most remote areas, with basic energy carriers: light, heat, and other energy. The effective development of the energy sector and the transition to sustainable development depend on synergy between key stakeholders, a deep understanding of the specifics of technological processes, and proactive government support. Such a comprehensive approach can be considered a prerequisite for attracting the necessary investment resources and modernizing infrastructure, which are currently the main barriers to industry transformation.

A fundamental requirement for improving operational reliability and optimizing energy



distribution processes is the introduction of intelligent communication systems, which operate on the basis of continuous monitoring and analysis of big data, including traffic indicators and overall network infrastructure performance. The use of such solutions allows for the optimization of data routing and ensures minimal delay during the transmission of control signals. Automatic configuration and dynamic restructuring of network topology in accordance with changing conditions and current load; application of analytical algorithms for anomaly detection, cyber threat identification, and forecasting future energy demand.

It can be argued that today, digitalization and automation are key tools not only for stabilizing power supply, but also for creating flexible, self-regulating systems capable of autonomous optimization in the highly volatile energy market.

Traditional systems transmit energy in only one direction. The use of smart grids provides two-way communication and control at various levels: from electricity generation to the end consumer (The Kyiv Independent, 2025). The implementation of smart systems and their integration requires the introduction of modern standards and devices that can operate in modern local networks. Standardization at the national level is also required for the use of smart switches that automatically isolate damaged sections of power lines, particularly in rural and mountainous areas. This is necessary to improve network efficiency and ensure the flexibility of management processes in emergency situations (Energy all, 2025).

An important innovative patented solution was the testing of a lambda transformer (SFTSZ project). The equipment is capable of reproducing one of the phases or zero in the event of a line break. That is, it instantly cuts off, switching between two three-phase lines (Energy all, 2025). The results of the experimental testing of the equipment confirmed the feasibility of integrating specialized metering devices and remotely controlled contactors into the power system. The equipment is designed to provide precise monitoring of line integrity (detection of breaks) and implement mechanisms for selective disconnection of problematic network segments to prevent the spread of emergency modes. The need to use advanced monitoring tools is due to the specific nature of power transformers operating under load asymmetry conditions (Kovalko, 2022). The main physical aspects of the problem are as follows:

- in the event of uneven distribution of power across phases, an imbalance occurs, causing energy to be redistributed from less loaded phases to overloaded ones;

- this situation is accompanied by the appearance of zero-sequence currents and neutral displacement, which negatively affects the quality of electricity;

- traditional metering devices do not have the necessary sensitivity or algorithms to correctly record and differentiate such internal system flows, which leads to errors in energy balance calculations;

- the introduction of smart contactors in combination with precision meters allows the process of damage localization to be automated and ensures the stable operation of transformer equipment by responding quickly to critical phase asymmetry.

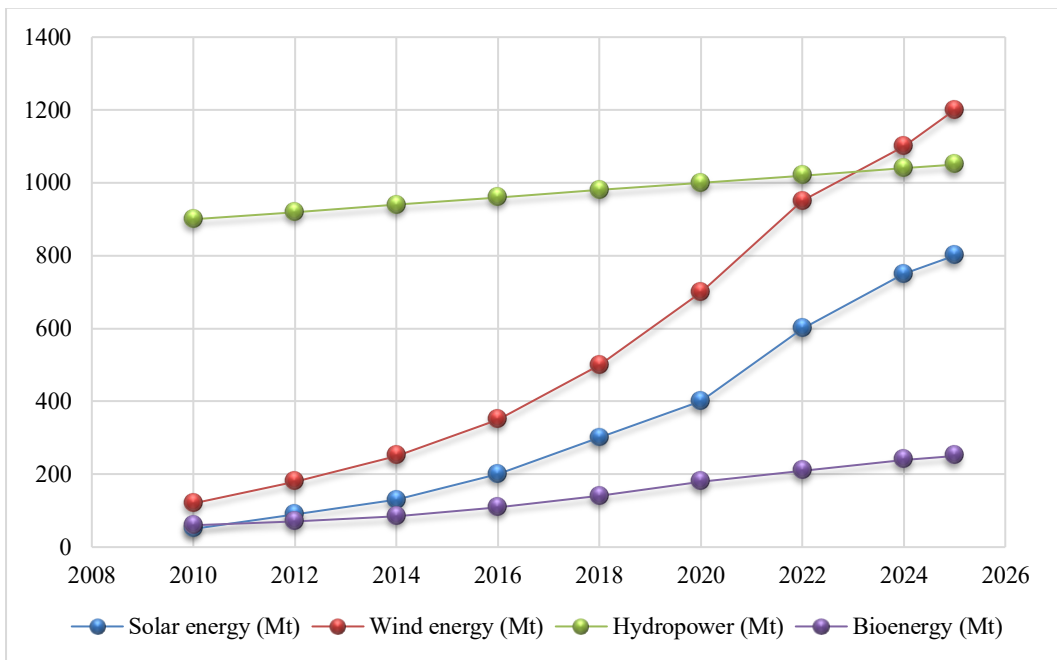
The implementation of smart grids is based on the integration of advanced information and communication technologies and traditional energy infrastructure, which can optimize processes from generation to end consumption (Havrysh et al., 2020). At the same time, it contributes to a significant increase in energy efficiency and systematic energy conservation. The foundation for the functioning of such a system is digital protocols for collecting, aggregating, and exchanging data in real time. This approach ensures high flexibility in managing power system modes and instant verification of anomalies. Minimization of network recovery time after emergencies through automated localization of damaged areas; reduction of



operating and production costs through automation of maintenance and reduction of technological losses.

The main operational element of a smart grid is intelligent metering nodes that control and ensure automation and the ability to selectively restrict non-priority consumption during periods of critical peak loads. The implementation of demand management strategies involves automatically switching consumers to cost-effective tariff plans (Novikau, 2024). Increasing the level of end-user involvement in grid balancing processes by providing transparent energy consumption analytics.

Analyzing the impact of RES requires a comprehensive approach and an increase in energy efficiency based on reducing CO<sub>2</sub> emissions (Figure 1). As shown by data from reports by the International Energy Agency (International Energy Agency, 2023), the World Bank, and other companies, statistical data on the dynamics of CO<sub>2</sub> reduction using various types of RES (solar, wind, bioenergy, and hydropower) were processed during the assessment. The information is presented graphically and describes the reduction in CO<sub>2</sub> emissions for the period from 2010 to 2025, as well as the increase in energy efficiency indicators in various sectors of the economy caused by renewable energy sources.



**Figure 2.** Reduction in CO<sub>2</sub> emissions (in megatons, Mt)

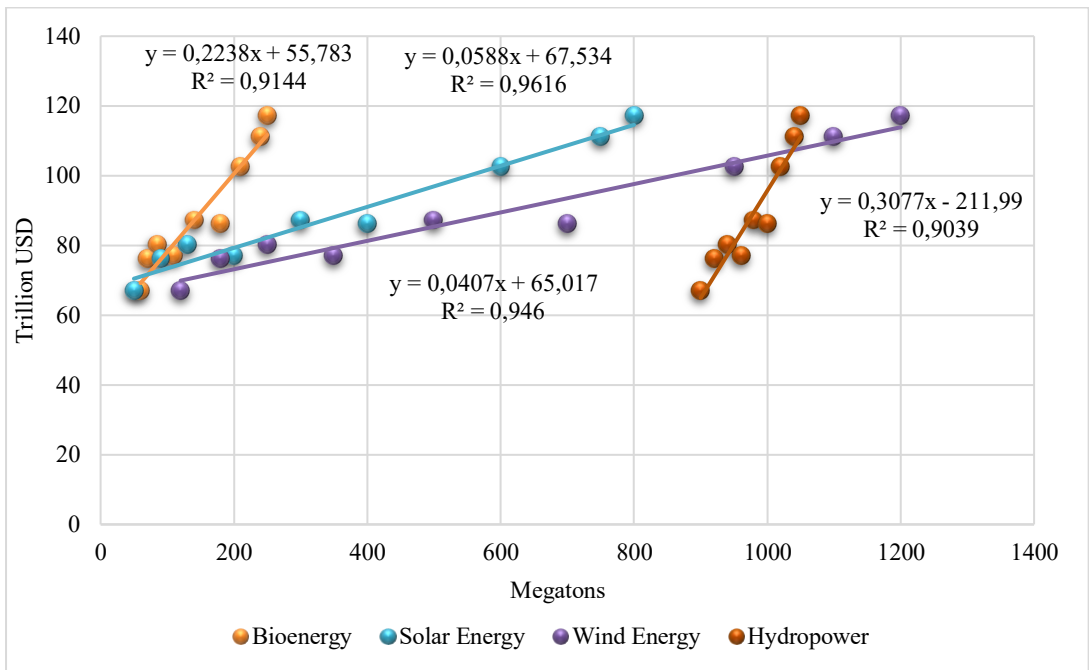
**Source:** Data from international organizations and the State Agency for Energy Efficiency (2023), Pata et al., 2024; Gayen, D., Chatterjee, R. and Roy, S. (2024)

As can be seen from the graph in Figure 2, the dynamics reflect a reduction in CO<sub>2</sub> emissions between 2010 and 2025, with hydropower showing the largest decrease. Hydropower, as one of the basic types of renewable energy sources, is characterized by relatively stable indicators. The volume of emissions reductions increased by only 150 Mt – from 900 Mt in 2010 to 1,050 Mt in 2025. This is a moderate increase, which indicates a high

degree of utilization of available resources and limited potential for intensification compared to alternative technologies. The photovoltaic energy sector is demonstrating unprecedented dynamics. In particular, there has been an increase in emission reductions from 50 Mt (2010) to 800 Mt (2025). This trend reflects the rapid decline in technology costs and the widespread introduction of solar power on a global scale. The most dynamic transformation is in wind power generation, where decarbonization rates have increased from 120 Mt in 2010 to 1,200 Mt in 2025. The intensification of these processes has been particularly noticeable since 2015. This allows us to classify this stage as a fundamental technological and infrastructural breakthrough in the industry.

The reduction in carbon emissions achieved through the adoption of renewable energy sources is not only a key indicator of environmental performance but also a powerful catalyst for economic development. The integration of RES stimulates the creation of new markets, attracts large-scale investments in infrastructure, and drives the development of innovative technologies, which directly impacts countries' macroeconomic indicators (Prokopenko et al., 2021; Biloshkurska et al., 2025). To gain a deeper understanding of this relationship, it is useful to analyze how decarbonization through various types of renewable energy sources correlates with economic growth, as reflected in the dynamics of global gross domestic product (GDP).

Figure 2 illustrates linear regression models showing the impact of decarbonization (the extent of CO<sub>2</sub> emission reductions, X-axis) on economic growth, expressed as changes in GDP in current U.S. dollars (Y-axis). All four trends demonstrate a clear positive linear relationship, as evidenced by high values of the coefficient of determination ( $R^2 > 0.9$ ).



**Figure 3.** The impact of RES decarbonization on economic growth

**Source:** Data from international organizations and the State Agency for Energy Efficiency (2023), Pata et al., 2024; Gayen, D., Chatterjee, R. and Roy, S. (2024); World Bank (2024)



The data in Figure 3 show that hydropower generates the most rapid GDP growth per unit of emissions reduced. This is because hydropower projects involve capital infrastructure investments that generate a significant economic multiplier, even though this sector operates in an already established, higher range of emission reductions. Bioenergy also demonstrates a steep slope and high economic sensitivity to its development, yet this sector operates within a significantly narrower range of absolute CO<sub>2</sub> reduction values (up to 300 Mt). In contrast, solar and wind energy have much flatter curves. Despite the smaller marginal impact on GDP from each additional ton of CO<sub>2</sub> reduced, these sectors account for the largest volumes of decarbonization (up to 800 Mt and 1,200 Mt, respectively). They are the most significant drivers of the global energy transition, whose impact on the economy is more gradual but spans a broader global scale.

Table 2 supplements the visual analysis with quantitative measures of elasticity and correlation coefficients (R).

**Table 2** – Interaction between RES type, elasticity, and correlation

RES type	Elasticity	R
Bioenergy	0.3749	0.9563
Solar Energy	0.2431	0.9806
Wind Energy	0.2712	0.9726
Hydropower	3.3758	0.9507

**Source:** Calculated by the authors based on the data in Figure 2

As can be seen from the data in Table 2, the correlation coefficient (R) for all four types of energy exceeds 0.95, which statistically confirms an extremely strong and stable direct relationship between the development of renewable energy and GDP growth. The highest figure is recorded for solar energy (R = 0.9806), indicating the most stable and predictable economic return on investment in this sector.

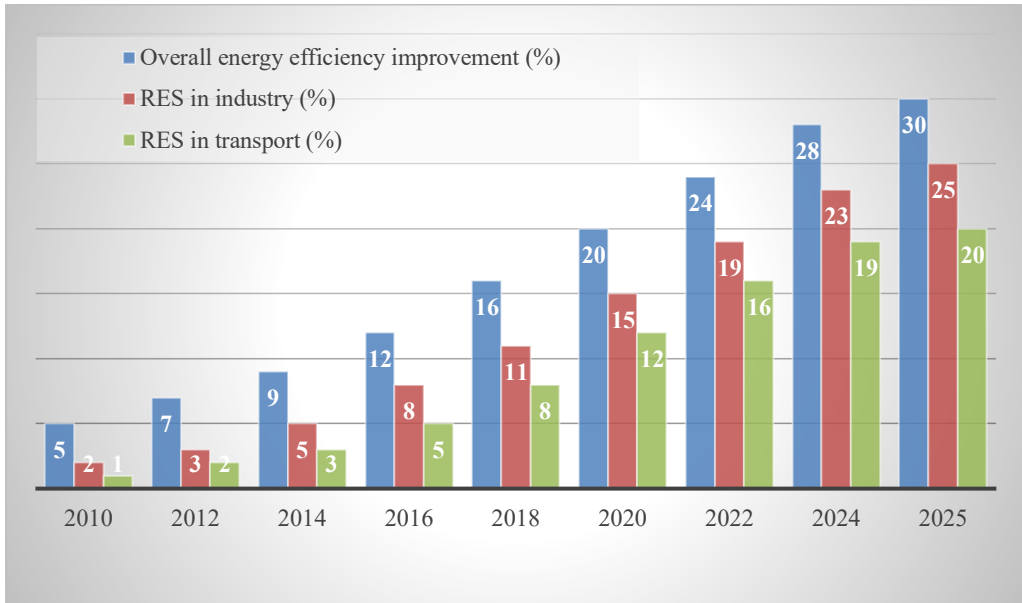
In terms of elasticity indicators, there is a clear differentiation. Solar (0.2431), wind (0.2712), and bioenergy (0.3749) are relatively inelastic factors (< 1% indicator). This means that an increase in decarbonization in these sectors by 1% is accompanied by an increase in macroeconomic indicators by an average of 0.24–0.37%. The absolute exception is hydropower with an elasticity index of 3.3758. High elasticity (> 1%) emphasizes that the development of large-scale hydrogeneration generates a powerful concomitant macroeconomic effect (construction, logistics, water resources management), but its potential for scaling is limited by geographical and environmental factors.

The data confirm H1 and H2. Hydropower shows the highest elasticity (3.3758), acting as a macroeconomic multiplier, while solar and wind provide scale. These findings represent actionable CI: policymakers can prioritize hydropower in capital-intensive projects and solar/wind in decentralized scenarios.

The obtained econometric data irrefutably confirm that the introduction of RES is no longer a purely environmental initiative or a budget expenditure item – it acts as a systemic driver of economic progress. However, in order to maximize this economic effect and ensure the balanced development of both highly elastic hydropower and mass solar and wind generation systems, it is not enough to rely only on market mechanisms. That is why the key factor in the further successful transition is the formation of an effective institutional environment, where purposeful policy strategies transform the technological potential of RES

into a real increase in energy efficiency.

Despite the threefold growth and the absoluteness of the indicators over a 15-year cycle, bioenergy demonstrates a significantly lower intensity compared to other types of renewable energy. The structure of bioenergy development is positioned not as a priority area, but as a complementary (auxiliary) resource. Its role is limited to niche areas where solar or wind power generation is used (Skaloumpakas et al., 2024).



**Figure 4.** Energy efficiency dynamics thanks to RES (%)

**Source:** Eurostat (2023); World Bank (2023); State Agency on Energy Efficiency and Energy Saving of Ukraine (2023)

The graph illustrates the dynamics of energy efficiency intensification caused by the implementation of renewable energy facilities. According to the results for 2025, a significant transformation of the overall energy balance structure is expected, with an increase in the share of environmentally friendly sources. The integration of renewable energy sources in industry increased from 15% in 2020 to an estimated 25% in 2025. This indicates a high level of adaptability of production capacities to low-carbon strategies. Governments of various countries around the world are working on the development and transition to RES, forming relevant packages of legislative initiatives and international agreements (Sotnyk et al., 2023). However, policy effectiveness also requires the ability to take into account regional characteristics and economic factors.



**Table 2** – Interaction between green energy policies and strategies

Political strategy	Impact on the development of green energy	Example
Legislation and implementation of environmental standards	Implementation of CO <sub>2</sub> emission standards, obligations to use renewable energy sources.	EU (Green Deal)
Resource support	Government grants, preferential loans	USA (IRA Act 2022)
Emissions taxes	Economic incentives	Canada, Sweden
International agreements and cooperation in various sectors	Regulation of global connections	Paris Agreement
Infrastructure development	Network construction and distribution	Germany (Energiewende)
Investments in nanotechnology	Development of energy-saving RES and their development	China, Japan

**Source:** Compiled by the author

The development and effective use of renewable energy sources depend on the availability of financial support and other resources, as well as on improvements in national legislation and global initiatives on climate change. Without this, the transformation of the energy market is impossible Suraj (2024). It is difficult to completely abandon fossil fuels in the short term due to economic, technological, and infrastructure constraints. An optimal balance between renewable and traditional energy sources will ensure the stability of energy systems, energy access, and environmental sustainability in different regions (Table 3).

**Table 3** – Ways to achieve a balance between different types of energy

Method of implementation	Expected effect	Example of implementation
Technological development	Minimizing the dependence of RES on conditions and increasing efficiency and stability	Tesla Powerwall, Germany
Grid optimization	Effective ways to integrate renewable energy sources into the power grid and reduce energy costs	Smart Grid
Use of combined energy sources	Use of gas and nuclear energy to ensure basic stability for a certain period	France (nuclear energy)
Diversification of energy resources	Use of combined renewable and traditional sources	Denmark (combination of RES, gas, and hydropower)
Green hydrogen	Alternative way to store excess energy from RES for use	Japan (hydrogen energy)
Tax incentives and other financial support	Improving RES development and modernizing traditional approaches to energy development	United States (Inflation Reduction Act of 2022)



Regional strategies	Combining energy sources according to regional needs	China (National Energy Administration of China, 2023). uses combined resources to meet the needs of different regions
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**Source:** Compiled by the author

In order to ensure an optimal balance between RES and traditional sources, a comprehensive approach to technological development, modernization, and access to financial resources is needed. With the help of combined systems and process integration, which are in the early stages of development, the state can not only reduce its dependence on fossil fuels, but also ensure a stable energy supply. Smart grids and synchronization standards (lambda transformer) are reframed as CI tools for real-time monitoring and risk mitigation, directly supporting competitive advantage in unstable grids (e.g., military conflicts or blackouts). The integration of CI transforms descriptive data into strategic intelligence: organizations gain foresight on market trends, governments can design targeted subsidies, and firms achieve first-mover advantage in green hydrogen or storage technologies. This is only possible with active state policy, investment in research, and the implementation of strategies to adapt to the specifics of the regional energy market.

The research employs a sequential explanatory mixed-methods design, where qualitative findings directly contextualize econometric outputs. Content analysis of national energy strategies (e.g., EU Green Deal, USA IRA Act) was used to categorize countries by policy maturity. This qualitative data was then integrated into the CI cycle to explain why highly elastic sources like hydropower require different strategic intelligence tools compared to solar or wind decentralized grids. By synthesizing regulatory barriers with quantitative elasticity coefficients, the framework transforms descriptive secondary data into actionable strategic recommendations for policy prioritization.

## 5 DISCUSSION AND CONCLUSIONS

This study confirmed the importance of renewable energy sources for achieving the seventh sustainable development goal. As can be seen from the available data, active development of the energy potential of RES is possible with additional investment in the latest technologies, equipment, etc. The combination of all these indicators will significantly reduce CO<sub>2</sub> emissions and provide the population with affordable energy regardless of their region of residence. We can also say that the development of RES is a powerful tool for energy sustainability and decarbonization of the economy. Renewable energy technologies are more effective in reducing greenhouse gas emissions than traditional sources of solar and wind energy (Pata et al., 2024; Prayitno et al., 2026; Xia et al., 2023).

In addition to the advantages of renewable energy, the study identified a number of problems, including:

A sharp drop in the cost of renewable energy sources is inevitable.

Due to the risks and lack of common standards in all countries that use RES, integration into global energy systems requires more time and resources.

The critical role of government support and financial mechanisms in promoting the development of RES lies in the formation of political strategy (Zhang et al., 2023).

RES can completely replace traditional energy in the short term.



The transition to renewable energy remains a long-term process due to systemic physical, economic, and infrastructural constraints. A significant barrier to comparative research is the absence of a unified global statistical database. Current models often exclude the emerging impact of green hydrogen and advanced energy storage systems on grid stability. Future research must prioritize the following areas:

Researchers should identify specific policy instruments that align national regulations with international efficiency standards.

Studies must examine how artificial intelligence (AI) and automation optimize energy work processes.

Investigating the role of smart grids and real-time data analytics is essential for managing energy market volatility.

Research should focus on transforming raw energy data into strategic decisions to secure a sustainable competitive advantage.

This study confirms that renewable energy is a powerful driver of SDG 7 when embedded in a Competitive Intelligence framework. The proposed CI model demonstrates that systematic intelligence processes convert RES data into strategic decisions that deliver both environmental sustainability and economic competitive advantage. Limitations include reliance on secondary data and the evolving nature of AI in CI. Future research should incorporate primary CI audits in energy firms and test the framework in developing countries. The transition to clean energy is no longer merely an environmental imperative – it is a strategic intelligence challenge that determines long-term competitiveness in the global green economy.

The integration of renewable energy sources (RES) into national grids is not merely a technical transition but a strategic intelligence challenge. Competitive Intelligence (CI) transforms static environmental data into dynamic market foresight. This study identifies a critical divergence in strategic utility between decentralized and centralized energy assets.

The calculated elasticity coefficients reveal a hierarchy for investment prioritization:

With an elasticity of **3.3758**, hydropower provides the most significant GDP growth per unit of carbon reduction. Governments should prioritize these projects for long-term industrial stability.

While these sources show lower marginal GDP impact per unit (**0.2431** and **0.2712** respectively), they offer the highest absolute decarbonization potential. They are optimal for achieving rapid compliance with international climate agreements.

Competitive advantage in the green economy depends on system reliability. CI-driven tools such as **Smart Grids** and **synchronization standards** (e.g., lambda transformers) act as risk-mitigation assets:

Digital protocols enable instant anomaly detection and demand forecasting.

Autonomous energy zones provide a first-mover advantage in volatile markets or conflict-prone regions by ensuring uninterrupted power supply.

A robust CI framework must account for the intermittency-cost trade-off. While RES reduces CO2 emissions significantly, the high initial investment in infrastructure remains a primary barrier to entry. To bridge this gap, policy intelligence must target subsidies specifically toward green hydrogen and advanced storage to stabilize the transition. To address the limitations of the current econometric model, the following parameters define the study's scope:

The study evaluates integrated national energy systems from 2010 to 2025.

Secondary data from the IEA, IRENA, and World Bank ensure cross-continental



comparability.

High R2 values (>0.9) across all models confirm a stable linear relationship between decarbonization and economic expansion.

Future research should transition from secondary data analysis to primary CI audits within energy firms to validate these strategic findings at the microeconomic level.

It has been found that additional work is needed in this area, in particular, in order to overcome existing barriers, it is necessary to adopt a number of systemic decisions at both the state and industry levels. The dynamics of the development of smart grids and tariffs require concrete steps for its implementation. This includes providing a system of smart energy contracts that take into account hourly fluctuations in electricity prices depending on load; enabling consumers to independently manage their energy assets in real time and receive information about consumption. All available directions will allow in practice to apply a balance between small energy producers and specific ones. In the long term, such actions will significantly increase the reliability and efficiency of the power supply system.

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## REFERENCES

- Ametepey, S. O., Aigbavboa, C., Thwala, W. D., & Addy, H. (2024). An Evaluation of Sustainable Development Goal Seven (Affordable and Clean Energy) in Ghana. In: B. He, J. Jupesta, G. T. Cirella, G. Pignatta, (Eds.), *Urban Climate Change Adaptation. CCES CCES 2022 2023. Advances in Science, Technology & Innovation* (pp. 137–152). Springer. [https://doi.org/10.1007/978-3-031-65088-8\\_12](https://doi.org/10.1007/978-3-031-65088-8_12)
- Azizi, S., Radfar, R., Ghatari, A.R., Nikoomaram, H. (2025). Assessing the impact of energy efficiency and renewable energy on CO<sub>2</sub> emissions reduction: empirical evidence from the power industry. *International Journal of Environmental Science and Technology*, 22, 2269–2288. <https://doi.org/10.1007/s13762-024-05865-5>
- Batsurovska, I. (2024). Education of energy engineers in the context of lifelong learning. In *Proceedings of the 4th International Conference on History, Theory and Methodology of Learning (ICHTML)* (pp. 5–12). SciTePress. <https://doi.org/10.5220/0012645500003737>
- Biloshkurska, N., Omelyanenko, V., Yemets, O., Braslavska, O., Matkovskiy, P., Omelianenko, O., & Korniienko, T. (2025). Comprehensive human security assessment in sustainable regional development: Insights for innovation policy. *European Journal of Sustainable Development Research*, 9(4), em0315. <https://doi.org/10.29333/ejosdr/16572>



- Chabouni, N., Barnet, C., Assoumou, E., Maïzi, N., & Selosse, S. (2024). Aligning Algeria's energy diversification strategies with energy and climate sustainable development goals. In M. Labriet, K. Espegren, G. Giannakidis & Ó B. Gallachóir (Eds.), *Aligning the Energy Transition with the Sustainable Development Goals. Lecture Notes in Energy* (Vol. 101, pp. 295–322). Springer. [https://doi.org/10.1007/978-3-031-58897-6\\_13](https://doi.org/10.1007/978-3-031-58897-6_13)
- Coscieme, L., Ochieng, C.A., Spillane, C., Donohue, I. (2023). Measuring policy coherence on global access to clean energy between European countries. *Mitigation and Adaptation Strategies for Global Change*, 28, 23. <https://doi.org/10.1007/s11027-023-10058-5>
- Duggan, J. E. (2025). Recent Progress in Sustainable Energy Systems Development: Investment, Operations, and Decarbonisation. *Current Sustainable/Renewable Energy Reports*, 12, 1. <https://doi.org/10.1007/s40518-024-00248-3>
- Energy all. (2025). *Phase stabilizers SFTSZ*. <https://energyall.com.ua/stabilizator-faz/>
- Eurostat. (2023). *Renewable energy statistics*. European Commission. [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable\\_energy\\_statistics](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics)
- Gayen, D., Chatterjee, R. & Roy, S. (2024). A review on environmental impacts of renewable energy for sustainable development. *International Journal of Environmental Science and Technology*, 21, 5285–5310. <https://doi.org/10.1007/s13762-023-05380-z>
- Havrysh, V., Hruban, V., Sadovoy, O., Batsurovska, I., Fedorchuk, V., & Yablunovskaya, K. (2020, September). Energy saving technologies for automatic move irrigation equipment. In *2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP)* (pp. 1–4). IEEE. <https://doi.org/10.1109/PAEP49887.2020.9240881>
- Hilili, M. J., Akadiri, S. S. & Eneanya, C. N. (2024). Powering Nigeria's future: balancing renewable and non-renewable energy for environmental sustainability. *Energy Systems*, 1–22. <https://doi.org/10.1007/s12667-024-00686-4>
- Hrinchenko, H., Prokopenko, O., Shmygol, N., Koval, V., Filipishyna, L., Palii, S., & Cioca, L.-I. (2024). Sustainable Energy Safety Management Utilising an Industry-Relative Assessment of Enterprise Equipment Technical Condition. *Sustainability*, 16(2), 771. <https://doi.org/10.3390/su16020771>
- International Energy Agency. (2023). *Net zero by 2050: A roadmap for the global energy sector*. IEA. <https://www.iea.org/reports/net-zero-by-2050>
- International Renewable Energy Agency. (2023). *Renewable Energy Statistics 2023*. IRENA. <https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023>
- Kandpal, V., Jaswal, A., Santibanez Gonzalez, E. D. R., & Agarwal, N. (2024). Energy efficiency and renewable energy technologies. In *Sustainable Energy Transition: Circular Economy and Sustainable Financing for Environmental, Social and Governance (ESG) Practices* (pp. 89–123). Springer, Cham. [https://doi.org/10.1007/978-3-031-52943-6\\_3](https://doi.org/10.1007/978-3-031-52943-6_3)



- Kazemi, F., & Soltani, F. (2024). The energy industry's response to competitive intelligence in green marketing (case study of Qatar). *Journal of Open Innovation: Technology, Market, and Complexity*, 10(1), 100192. <https://doi.org/10.1016/j.joitmc.2023.100192>
- Khaleel, M., Yusupov, Z., Ahmed, A., Alsharif, A., Nassar, Y., & El-Khozondar, H. (2023). Towards Sustainable Renewable Energy. *Applied Solar Energy*, 59, 557–567. <https://doi.org/10.3103/S0003701X23600704>
- Kovalko, O., Eutukhova, T., & Novoseltsev, O. (2022). Energy-Related Services as a Business: Eco-Transformation Logic to Support the Low-Carbon Transition. *Energy Engineering: Journal of the Association of Energy Engineering*, 119(1), 103–121. <https://doi.org/10.32604/EE.2022.017709>
- Küfeoğlu, S. (2022). SDG-7 affordable and clean energy. In *Emerging Technologies: Value Creation for Sustainable Development* (pp. 305–330). Springer, Cham. [https://doi.org/10.1007/978-3-031-07127-0\\_9](https://doi.org/10.1007/978-3-031-07127-0_9)
- National Energy Administration of China. (2023). *China Renewable Energy Development Report 2023*. NEA. <http://www.nea.gov.cn/>
- Novikau, A. (2024). Powering sustainable development: The critical role of energy research. In W. Leal Filho, A. L. Salvia, & C. R. Portela de Vasconcelos (Eds.), *An Agenda for Sustainable Development Research. World Sustainability Series* (pp. 403–419). Springer. [https://doi.org/10.1007/978-3-031-65909-6\\_23](https://doi.org/10.1007/978-3-031-65909-6_23)
- Osuma, G., & Yusuf, N. (2025). Towards an optimal renewable energy mix for the European Union: Enhancing energy security and sustainability. *Journal of Knowledge Economy*, 16, 17085–17121. <https://doi.org/10.1007/s13132-024-02586-5>
- Prokopenko, O., Bezliudnyi, O., Omelyanenko, V., Slatvinskyi, M., Biloshkurska, N., & Biloshkurskyi, M. (2021). Patterns identification in the dynamics of countries' technological development in the context of military conflict. *Eastern-European Journal of Enterprise Technologies*, 2(13(110)), 6–15. <https://doi.org/10.15587/1729-4061.2021.230236>
- Pata, U. K., Karlilar, S., & Kartal, M. T. (2024). On the road to sustainable development: The role of ICT and R&D investments in renewable and nuclear energy on energy transition in Germany. *Clean Technologies and Environmental Policy*, 26, 2323–2335. <https://doi.org/10.1007/s10098-023-02677-y>
- Prayitno, G., Subagiyo, A., Dinanti, D., Rahmawati, Nisak, F. F., & Biloshkurskyi, M. V. (2026). Social Capital and Adaptive Governance: Pathways to Sustainability in Indonesia's Tourism Villages. *Sustainable Development*. <https://doi.org/10.1002/sd.70807>
- Ramasubramanian, B., & Ramakrishna, S. (2023). What's next for the Sustainable Development Goals? Synergies and trade-offs in affordable and clean energy (SDG 7). *Sustainable Earth Reviews*, 6, 17. <https://doi.org/10.1186/s42055-023-00069-0>



- Sanusi, Y. A. (2024). Achieving the SDG 7, universal access to energy in Africa: Progress, obstacles, and prospects. In I. R. Abubakar, I. da Silva, R., Pretorius, & K. Tarabieh (Eds.), *SDGs in Africa and the Middle East Region. Implementing the UN Sustainable Development Goals – Regional Perspectives* (pp. 209–241). Springer. [https://doi.org/10.1007/978-3-031-17465-0\\_26](https://doi.org/10.1007/978-3-031-17465-0_26)
- Shivanna, S., & Rangappa, K.S. (2024). Clean energy for sustainable development in India. *Journal of Social and Economic Development*, 26(Suppl 1), 139–147. <https://doi.org/10.1007/s40847-024-00322-y>
- Skaloumpakas, P., Sarmas, E., Rachmanidis, M., & Marinakis, V. (2024). Reshaping the energy landscape of Crete through renewable energy valleys. *Scientific Reports*, 14, 8038. <https://doi.org/10.1038/s41598-024-57471-7>
- Society of Competitive Intelligence Professionals (SCIP). (2020). *SCIP code of ethics*. <https://www.scip.org/page/CodeofEthics>
- Solanki, V., & Birman, S. (2025). Nature-Driven Renewable Energy Systems for Sustainable Development. In P. Singh, P. Srivastava, A. Sorokin (Eds.), *Nature-Based Solutions in Achieving Sustainable Development Goals* (pp. 131–166). Springer. [https://doi.org/10.1007/978-3-031-76128-7\\_5](https://doi.org/10.1007/978-3-031-76128-7_5)
- Sotnyk, I., Kurbatova, T., Trypolska, G., Sokhan, I., & Koshel, V. (2023). Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis. *Environmental Economics*, 14(2), 13–27. [https://doi.org/10.21511/ee.14\(2\).2023.02](https://doi.org/10.21511/ee.14(2).2023.02)
- State Agency on Energy Efficiency and Energy Saving of Ukraine. (2023). *Annual Report on Renewable Energy Development in Ukraine*. [https://sae.gov.ua/static-objects/sae/imported\\_content/6792abc2e23b2.pdf](https://sae.gov.ua/static-objects/sae/imported_content/6792abc2e23b2.pdf)
- Suraj, N., Abhishek, N., Kanchan, S. G., Rajendran, D. J., Raghupathi, S., & Kuriakose, S. (2024). Do Corporate Renewable Energy Initiatives Influence Sustainable Development?. In B. Awwad (Ed.), *The AI Revolution: Driving Business Innovation and Research* (Studies in Systems, Decision and Control, Vol. 524, pp. 339–353). Springer. [https://doi.org/10.1007/978-3-031-54379-1\\_30](https://doi.org/10.1007/978-3-031-54379-1_30)
- The Kyiv Independent. (2025). *China unveils its new “graphite bomb” – here’s how it works*. <https://kyivindependent.com/china-unveils-its-new-graphite-bomb-06-2025/>
- U.S. Energy Information Administration. (2023). *Annual Energy Outlook 2023*. EIA. <https://www.eia.gov/outlooks/aeo/>
- Vivek, C. M., Srividhya, P. K., Ramkumar, P., & Sivasubramanian, M. (2023). Bio Energy Sources for Sustainable Development: Affordable and Clean Energy Goal in India. In: S. S. Oncel (Ed.), *A Sustainable Green Future* (pp. 561–573). Springer. [https://doi.org/10.1007/978-3-031-24942-6\\_26](https://doi.org/10.1007/978-3-031-24942-6_26)



- Wernersson, L., Román, S., Fuso Nerini, F., Mutayaba, R., Stratton-Short, S., & Adshead, D. (2024). Mainstreaming systematic climate action in energy infrastructure to support the sustainable development goals. *npj Climate Action*, 3(1), 28. <https://doi.org/10.1038/s44168-024-00108-2>
- World Bank (2023). *Tracking SDG 7 – The Energy Progress Report 2022*. <https://www.worldbank.org/en/topic/energy/publication/tracking-sdg-7-the-energy-progress-report-2022>
- World Bank (2024). *GDP (current US\$)*. <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD>
- Wu, Z., Udemba, E.N., Peng, X., Zhang, Y., & Jia, J. (2024). Green energy and institution: a study of energy transition and sustainable environment development. *Clean Technologies and Environmental Policy*, 27, 2157–2172. <https://doi.org/10.1007/s10098-024-02944-6>
- Xia, L., Liu, Y. & Yang, X. (2023). The response of green finance towards the sustainable environment: the role of renewable energy development and institutional quality. *Environmental Science and Pollution Research*, 30, 59249–59261. <https://doi.org/10.1007/s11356-023-26430-6>
- Zhang, L., Khan, Z., Abbas, S., & Ahamed, H. (2023). The roles of renewable energy, globalisation, population expansion and deliberative democracy on Sustainable Development in South Asia. *Environmental Science and Pollution Research*, 30, 88775–88788. <https://doi.org/10.1007/s11356-023-28690-8>
- Zhou, F., Samsurijan, M. S. B., Ibrahim, R. L., & Ajjde, K. B. (2023). The conditioning role of institutions in the nonrenewable and renewable energy, trade openness, and sustainable environment nexuses: a roadmap towards sustainable development. *Environment, Development and Sustainability*, 26, 1997–19626. <https://doi.org/10.1007/s10668-023-03427-2>