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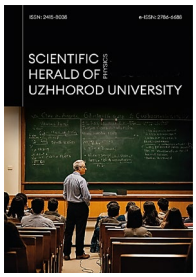

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Renewable energy and economic growth

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Abstract

Relevance. The relevance of the study is that energy conversion based on renewable sources can help accelerate economic growth, create millions of jobs, and improve people's living conditions.

Purpose. The aim of the research is to examine the present facets of renewable energy and its influence on economic development.

Methodology. The study employed comparative, functional, and system analysis approaches to assess the impact of renewable energy on economic growth. Comparative analysis examined varying conditions, functional analysis explored interdependencies between renewable energy elements, and system analysis modeled complex interactions between renewable energy and economic factors.

Results. The study found that renewable energy conversion can significantly accelerate economic growth by creating millions of jobs and improving living conditions. It revealed that renewable energy sources are more cost-effective compared to fossil fuels and nuclear energy, and they have the potential to reduce the incidence of air pollution-related deaths by 7 million annually. Technological advancements such as clean hydrogen and electrification in transportation and heating are pivotal in decarbonising hard-to-transition sectors.

Conclusions. Renewable energy not only addresses climate change but also serves as a catalyst for economic recovery and growth, particularly in times of crisis. The shift towards renewable sources presents a dual benefit: mitigating climate

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impact and providing economic stability through job creation and health improvements. The study underscores the importance of embracing renewable energy as a strategic response to both environmental and economic challenges.

Keywords: renewable energy; economic growth; crisis, climate; energy sources; jobs.

Introduction

Renewable energy encompasses various natural resources harnessed for power generation, such as sunlight, wind, water resources, Earth's heat, and biomass combustion. The conversion process of these renewable sources results in minimal greenhouse gas emissions, earning them the moniker "clean energy." Renewable energy can be utilized directly to produce electricity or heat for residential and industrial purposes [1-2].

Biogas energy is employed to generate electricity or heat, while biofuel energy finds application in the transportation sector. The significance of renewable energy sources lies in their pivotal role in attaining energy and climate objectives. Not only are they cost-effective, but they also present a competitive alternative to fossil fuel prices. As a result, these energy sources have the potential to render energy systems more affordable, reduce reliance on imported fossil fuels in developing nations, foster job creation, open new avenues for industries, and contribute to economic growth [3]. The phenomenon of economic transformation should be included in the forecasts of consumption of both primary energy and electricity. Although this phenomenon is qualitatively understandable, it is much more difficult to quantify it.

Currently, the European Union is a leader in the field of renewable energy sources and is taking significant steps to bring renewable energy technologies to the market more widely [4]. Ambitious policies, and also research, innovative projects, and significant investments contribute to strengthening the industrial base. This, in turn, has made certain renewable energy technologies more accessible to citizens. The widespread adoption of solar panels and wind turbines can be attributed primarily to the increased activity in the market. One significant factor contributing to this trend is the substantial reduction in the cost of solar energy production, which witnessed a 75% decline between 2009 and 2018.

In 2014, the energy generated by onshore wind turbines surpassed that produced by coal, gas, and nuclear energy sources [5]. Furthermore, in 2019, wind and solar energy production in the European Union exceeded coal production for the first time, indicating that wind and solar energy have become competitive and even cheaper than fossil fuels in many locations. As technology becomes more accessible, the role of citizens is also expanding, facilitating the emergence of energy communities engaged in the generation, storage, and sale of their own renewable energy in the modern world [6-8].

It is expected that in the next decade the share of renewable energy sources in energy consumption will continue to grow. For example, the growth of solar energy will be mainly conditioned by an increase in its own consumption and the growing popularity of solar panels installed on roofs. This will provide a competitive advantage, which is expressed in economic growth and the creation of new jobs. Developed countries undergoing a deep market transformation, due to the use of reserves of economic efficiency, can count on the growth of GDP without increasing the consumption of primary energy and electricity. The demand for primary energy for the electric power industry depends on the form of the structure of primary and final energy in the countries [9].

The assumptions of energy policy assume the stabilization of final energy consumption, which is justified in the light of the observed trends in the global economy and the specifics of countries in the process of transformation. It is projected that there will be a substantial decline in the proportion of coal and a considerable rise in the proportion of natural gas, aligning with global trends. The significant increase in the share of natural gas is seen as a desirable trend in both the composition of primary and final energy, particularly in terms of its utilization in the economy, as well as in the electricity generation and centralized heat sectors [10].

The objective of this study is to examine the present-day facets of renewable energy and assess its influence on economic growth. Additionally, it aims to explore how renewable energy contributes to job creation and improved living conditions.

Materials and Methods

The methodological basis of the study consisted of the following approaches: comparative, functional, and system analysis. The comparative method is presented within the experimental aspect. In fact, it is primarily a means of changing some of the conditions under which the phenomenon and function of renewable energy is investigated, including its impact on economic growth. In more technical terms, the approach is a means of controlling some independent variables by comparing observations made on certain conditions that differ in terms of various factors. In all these cases, the comparative method is based on a comparison between the conditions and the economic condition of a particular region. The comparative elements presented in this way appear as a category of methods that will always be integrated within the experimental method, understood in the strict sense of the word, which includes variations that are much more global and molar. The implementation of the current approach is quite simple and will not take much time. Moreover, it forms a solid basis for comparison and allows the assessment to be carried out synchronously with the real state of the accompanying factors affecting renewable energy.

The functional method refers to the relationship between two or more renewable energy elements, in which any change made to one causes a change in the other, or the others require adaptation on their part. It emphasises the interdependence that exists between the elements. In the same sense, the goal pursued in the functional approach is to come to the identification of the heaviest independent variable, that is, the one that has the greatest impact on the dependent variable. A dependent variable is a phenomenon that varies depending on one or several other phenomena, in the place of which it is located in a certain situation of dependence. Therefore, it needs to be explained, while the

independent variable is explanatory. While among the observed consequences there are functions that contribute to the adaptation or adjustment of the concepts of renewable energy and economic growth, on the other hand, there are dysfunctions that prevent the adaptation and adjustment of the phenomena under study. This approach is applicable to any complex situation that requires consideration of many factors when interacting with incoming and outgoing flows.

System analysis provides a methodological basis for modelling operations and provides answers to many questions about renewable energy and economic growth. A lot of internal and external interactions in a dynamic environment make it very difficult to understand the processes. Considering the object of study as a system facilitates diagnosis by integrating all variables that are interdependent. Observation of the complexity of the environment, scientific, and sociological progress have shown the need for a system concept that cannot be reduced to a structure concept. The need to integrate interactions and integrity into systems has become apparent. Consistency, which shows the complexity of certain processes, meets this expectation. The objects to be studied cannot be understood from the analysis of simple causal relationships. Relationships are most often cyclical; an action produces an effect that changes the environment, which, in turn, changes the underlying cause of the effect. Reality consists of constant interactions between elements, and their consideration emphasises the "living" aspect of the system.

Results and Discussion

Every economy needs cheap and publicly available energy, so the development of civilisation is inextricably linked with energy. Energy in the form of fossil fuels continues to be the main substrate for energy production. Consequently, the natural scarcity of energy resources and the growing demand for energy determine the need to search for new, unconventional, stable energy sources that are cost-effective and energy-efficient. Therefore, in the energy sector, all processes are constantly changing, from energy production to distribution to consumers. In this context, it is necessary to pay attention to electricity, which in the modern world is a fundamental factor affecting economic growth. This is directly related to the fact that the increase in electricity consumption is caused by industrialisation, urbanisation, an increase in the standard of living, its duration, and the constant growth of the world's population.

The interdependence of energy and economic growth, with particular emphasis on climate and energy policy, determines the impact of energy prices on GDP. And the challenges facing the sector in connection with current legislation and market trends, with particular emphasis on climate and energy policy. Renewable energy is recognized as a pathway to foster innovative economic development, providing a broader perspective on the potential for implementing innovative solutions not only in the energy sector but also across various industries.

Recently, there has been a growing interest in "green energy", which is not only very useful for the environment, but also brings many economic benefits. At the same time, it is possible to observe how sharply electricity prices are rising, which, in turn, affects the finances of energy recipients. Thus, "green energy" is especially interesting for those who want to take care of both the environment and the budget [11-12]. The existing technologies enabling the utilization of renewable energy sources such as wind, sea waves, geothermal energy, or local biomass have the capacity to provide six times more energy than the current global consumption [13].

Production methods of renewable energy ensure that carbon dioxide, a significant contributor to climate change, is not released during the generation of electricity and heat. One notable advantage of renewable energy sources is their infinite potential for utilization, unlike conventional fuels like coal. Their widespread adoption has a profound impact across multiple domains. As the market share of "green energy" expands, it enhances energy security. Thus, there are certain resources that do not carry the risk of exhaustion. It is important that access to renewable energy sources is everywhere, so there is no need to import fossil raw materials from other countries. This is very desirable energy independence since there has been an increase in electricity prices for many years.

It is important to highlight that the environmental impact of developing countries is significantly influenced by factors such as technological advancements, financial development, the utilization of renewable and non-renewable energy, and the influx of foreign direct investment [14]. The adoption of renewable energy sources, for instance, plays a vital role in mitigating environmental harm, as these sources are non-polluting and renewable. When examining European Union nations, it is worth noting that Bosnia and Herzegovina has a substantial proportion of renewable energy in its overall energy balance (48.8%), while Albania accounts for 39.5% according to the World Development Indicators (Table 1).

Both countries exhibit low levels of financial system development and technological innovation. However, Albania demonstrates a low ecological footprint, whereas Bosnia and Herzegovina ranks among the leaders in terms of environmental degradation. On the other hand, Azerbaijan has the lowest share of renewable energy in its energy mix (1.31%), along with low levels of financial development and technological innovation, and a moderate environmental footprint [15].

Table 1: Environmental impact and renewable energy adoption in developing countries

Country	Renewable Energy Share (%)	Financial and Technological Development	Environmental Footprint
Bosnia and Herzegovina	48.8	Low	Environmental Leader
Albania	39.5	Low	Low Ecological Footprint
Azerbaijan	1.31	Low	Moderate

Despite the abundance of studies examining the relationship between energy consumption and environmental degradation, limited information is available specifically on countries categorized as net oil importers or net oil exporters. However, it has been discovered that the impact of energy consumption is more pronounced in net oil exporting countries due to their heavy reliance on raw materials, limited development and utilization of renewable energy sources, and inefficient energy resource utilization. In contrast, net oil importing countries exhibit significant consumption of renewable energy sources, which aids in reducing the adverse environmental impact. This is evident through negative coefficients, indicating a decrease in environmental degradation. However, in net oil exporting countries, the value of this coefficient is insignificant, highlighting their low level of development and renewable energy consumption due to their heavy dependence on oil [16-17].

Continuous technological advancements necessitate the implementation of novel solutions that have not yet been employed in the domain of power grid management. Additionally, investments in renewable energy sources drive the growth of the industry responsible for manufacturing production equipment such as wind turbines, photovoltaic modules, solar collectors, and heat pumps. Consequently, this leads to the accelerated development of technologies for converting renewable energy into heat and electricity [18-19]. The increasing energy demand compels researchers to enhance the efficiency of production equipment and strive for minimizing energy production costs. Moreover, the utilization of distributed energy systems introduces various types of technological innovations associated with the use of electronic devices in households. All these factors contribute to the advancement of an innovative economy.

The current structure of energy production sources is the result of the history of the development of the electric power industry in the post-war period in an autarkic and centrally managed economy. The carbon structure of primary energy for the electric power industry, in addition to the known negative impact on the environment, also affects the efficiency of the process of generation and network transportation of electricity, where an important element is the loss of energy, electricity to cover the own needs of power plants and combined energy [20-21].

The future structure of electricity generation sources is the result of the structure of investments in replacement and development in a competitive electricity market. Investors in this area can make decisions based on an assessment of factors affecting the return on investment in the generation sector, primarily considering the ratio between primary energy prices, capital costs, and environmental protection fees. In the current conditions, when natural gas prices for industrial consumers are relatively inflated, while maintaining moderate environmental requirements, especially without climate charges for CO^2 emissions, there will be no significant changes in the structure of the power plant.

Since 2000, progress has been made in the areas of traditional emissions of pollutants into the atmosphere, fuel efficiency of transport, energy intensity, renewable energy sources, water consumption, waste management, and biodiversity protection. This is partly conditioned by the slowdown in economic activity after the economic crisis, but also conditioned by the use of tools to reduce the burden on the environment, such as tax rules that affect consumer behaviour and take into account environmental costs. Environmental issues are also increasingly being considered in development cooperation and research. However, many of these changes are still of secondary importance, and the regulations introduced are often not coordinated, which limits the effectiveness of efforts to reduce the negative impact on the environment.

According to the Energy Guidelines 2022, released by the National Energy Administration [22], it is projected that the proportion of renewable energy in overall energy consumption will reach approximately 17.3%. Additionally, new electricity will replace around 180 billion kWh of old electricity. Wind and solar energy are expected to contribute approximately 12.2% of the total electricity consumption in society. Consequently, the advancement of renewable energy emerges as a crucial priority for the future development of the energy industry, serving as a substantial component of non-power sources [23].

Countries continue to support the production and consumption of fossil fuels in various ways, and economic activity is still associated with carbon emissions and the irrational use of energy and other natural resources [24]. One of the main challenges in the future will be climate change and the impact of environmental degradation on health, on future development and growth. To solve these problems, especially during the period of return to economic growth, strict rules and access to reliable information will be required. The impact of air pollution on climate and human health remains a concern. This is partly conditioned by the slowdown in economic growth after the economic crisis, tighter climate regulation, and changing patterns of energy consumption. Under current policies, global CO2 emissions could be three times the thresholds needed to limit long-term global temperature increases to 2°C. Emissions of sulphur oxide and nitrogen oxide continue to decrease. This is the result of energy conservation, the spread of alternative fuels, pollution

control, and technological progress. The energy balance, which today is still based on coal, will develop towards an increase in the share of renewable energy sources, including offshore winds and photovoltaic installations, while reducing the share of carbon fuels [25-26].

To ensure reliable supply, renewable energy sources must be supported by low- and zero-emission sources, regardless of weather conditions [27]. The mixture during the transition period can be supplemented with the use of RDF – fuel, investments in hydrogen technologies, and battery storage of electricity [28]. Coal prices are formed at the expense of domestic production costs, which for many years have been higher than world market prices, demonstrating an upward trend with a fall in the costs of global players [29].

On the horizon of 2040, the demand for coal is likely to decrease as a result of climate policy, but will continue to depend on the growth of domestic production costs, while in the long term, developing countries will become recipients of world prices reflecting the global level of production costs. In the medium and long term, climate policy, the development of electric vehicles, hydrogen engines, and polymer processing will play an increasingly important role. Liberating economic growth to finally solve the problem of mass unemployment, which especially affects young people, and working for industrial revival to increase competitiveness in the world are the main priorities that complement each other and require an appropriate mutual balance across the continent [30-31].

H_2 is an energy vector that is actively considered as a promising alternative for micro-grid energy storage. It has a number of advantages, particularly noteworthy is the potential to produce hydrogen through the electrolysis of water in electrolysers, utilizing electricity derived from renewable sources. This approach enables the production of "green hydrogen," which is environmentally friendly, unlike the thermo-chemical production method that relies on fossil fuels. However, currently, electrolysis accounts for a mere 4% of global hydrogen production, while the remaining 96% is generated through thermochemical processes using fossil fuels. Natural gas, oil, and coal contribute to 48%, 30%, and 18% of the total production, respectively. Incorporating H2 in microgrid energy storage systems holds significant importance in scaling up the production of green hydrogen. This becomes especially relevant considering the widespread integration of renewable energy sources, as it helps to balance their variability and offers additional benefits such as load balancing and peak load reduction. Implementing H2-based energy storage systems not only fosters the development of energy infrastructure but also advances environmental sustainability by reducing reliance on fossil resources and transitioning towards cleaner energy sources [32-34].

To achieve economic growth, protect the environment, and reduce dependence on raw materials and energy, a profound transformation of existing production and consumption methods is imperative. This necessitates embracing the principles of a circular economy paradigm. The economic and ecological balance of individual territories and the whole planet is based on three steps consisting of optimising the processes of energy conversion, recycling, and waste treatment. Due to technology, it is possible to reduce the consumption of resources – energy, raw materials, water, and reduce or even completely eliminate emissions into the environment. However, the transition to a low-carbon economy is, first of all, a necessary condition for achieving energy independence, which is a key goal in times of geopolitical uncertainty.

In addition, industrial revival requires optimal use and recycling of the continent's limited resources: waste disposal should become the basis of any new economic model [35-40]. In the face of the gradual depletion of resources essential for the functioning of the modern economy, the concept of a closed-loop economy presents practical and effective solutions. By closing the loops of raw materials, water, and energy, this "new" model enables economic growth while simultaneously reducing emissions and environmental impacts. The circular economy is founded on a paradigm shift, as it transforms waste from one process into resources and raw materials for another [35; 41; 42]. This brings about a profound transformation of production chains and consumption patterns, effectively breaking the link between GDP growth rates and the environmental impact and consumption of natural resources.

Creativity and the ability to develop new economic models for cities will be essential so that more efficient resource management does not entail a new burden on public spending and for industrial enterprises, the quality of supply, and competitiveness of which must be guaranteed. States can support such changes, in particular, through an appropriate regulatory approach that encourages innovation and promotes initiatives to use alternative resources. Energy efficiency is the most optimal way to combine the decarbonisation of the economy and increase the level of energy security [43-46]. Energy efficiency goals should be fully integrated into all sectors of the economy.

The implementation of appropriate measures presents a significant opportunity to achieve a much larger reduction in fossil fuel consumption compared to simply replacing fossil fuel energy with renewable sources. Effective policies in this domain can also foster the emergence of new forms of economic activity within countries [47; 48]. These activities can manifest at the local level, in regions and cities, by creating sustainable jobs, driving growth, and reducing energy dependency. Regrettably, energy efficiency, which serves as a fundamental principle and a strategic tool, often receives inadequate attention from national policymakers [49-51]. In order to implement the appropriate solutions and achieve the desired results, the current goals must be presented within the framework of a properly conducted public policy. Installations running on renewable energy sources or regenerated energy still need financial support from government agencies to compensate for the usually high investment costs [36-37; 52].

All market participants need stable prices for CO_2, set at the right level, to create an autonomous positive mechanism that should gradually reduce the use of fossil fuels in favour of renewable fuels and waste, thereby reducing greenhouse gas emissions. The very principle of CO_2 pricing is crucial here. To achieve these goals, it is necessary to develop an economically acceptable way to fully utilise all types of recyclable waste. The transition to

more efficient economic models of resource use is one of the responses to the growing threat of fluctuations in commodity prices and their growing scarcity [52-54]. All these changes significantly affect the possibilities of effective planning of economic activity, investment planning, and the introduction of sustainable business models by the subjects of the industrial sector.

Despite the ongoing economic crisis, the sector of energy production from renewable sources remains one of the most dynamically developing sectors of the economy. The so-called "green energy" creates many more jobs than coal energy, and several times more than nuclear energy [55]. The dynamic development of renewable energy sources, supported by the spread of technologies that reduce energy consumption, is a response to the climate and economic crisis and the rising costs of energy production based on fossil fuels. Improving energy efficiency is the most profitable economic measure from an economic, social, and environmental standpoint [38; 56].

In 2020, hydropower contributed 16% to the global electricity production, and its share is projected to surpass that of fossil fuels by 2050. Norway heavily relies on hydropower as the primary source of electricity, accounting for 99% of its total production. China boasts the world's largest hydroelectric power plant, the Three Gorges Dam, with an impressive capacity of 22.5 gigawatts (GW) [39]. This facility generates approximately 100 terawatt hours (TWh) of electricity annually and serves the power needs of around 70-80 million households. Canada is also actively harnessing its water resources to generate clean, sustainable, reliable, and affordable electricity, with hydropower contributing to 60% of the country's total electricity production. Moreover, pumped-storage power plants not only generate electricity but also provide flood control, supply water for various purposes (industrial, agricultural, and domestic), and store electricity from water, even during periods of drought [40-41; 57].

Renewable energy sources are an important element of energy policy. In the long term, they will gradually receive more and more attention. This will not only contribute to the fight against climate change, but will ultimately reduce energy prices and increase the competitiveness of the economy. Renewable energy is still not impressive in its results, but there are countries and enterprises that have almost completely switched to this method of energy production. Investments in renewable energy sources are high [42; 58]. However, in the long term, the benefits of their implementation for the environment and health are such huge profits and quality that the use of fossil fuels seems completely unreasonable, including from an economic standpoint. For states, reliance on renewable energy is beneficial in terms of independence from fuel imports. In addition, reducing the environmental impact by minimising emissions of pollutants has a positive effect on the overall health of countries [59-61].

The ability to store such renewable energy significantly reduces transmission losses. In a broader sense, the development of such sources will contribute to the creation of new jobs, especially in agricultural regions, and will positively affect entrepreneurship and the competitiveness of the economy. Ultimately, renewable energy will develop at an increasingly rapid pace. According to experts, photovoltaic energy will be one of the most important sources of investment. This sector, due to the dynamic development of technologies and industrial potential in the field of creating devices and infrastructure for photovoltaic systems, has a chance to significantly increase the share in the production of renewable energy.

Despite the use of increasingly economical appliances and devices, the demand for electricity and, consequently, its consumption is growing [62]. This is the main driving force of economic development. However, in this quest for the future, it is necessary not to forget about the planet, which is beginning to lose in an unequal battle with man. The resources inside are limited, and their complete exhaustion is only a matter of time. Only a sustainable and responsible energy policy can compensate for the ever-increasing energy consumption [43; 63].

The share of renewable energy sources in it should increase to leave the planet in the best condition for future generations so that they can enjoy its benefits and breathe the cleanest possible air. The extent of positive changes resulting from the development of this sector will be determined by the resolutions implemented by the governments and parliaments, including the final form of the law on renewable energy sources. It is extremely important to form legal solutions regulating this area of the economy in such a way as to stimulate GDP growth, create jobs, and at the same time fulfil relevant obligations. One such promising area worth stimulating is projects related to the development of the scattered small-scale energy market [64; 65]. The examples of many Western countries show how dynamic this market is. In addition, the development of modern energy, developed at the local level, stimulating national industry, the service sector, ultimately affecting the quality of life, is of great importance.

Combining further economic growth with concern for the environment and future generations is one of the main challenges facing the world today [66-68]. The global economy requires a huge amount of energy to function efficiently, and obtaining it only from fossil fuels causes environmental pollution and, as a result, climate change. Using only fossil fuels also exposes them to the risk of gradual depletion [44; 69]. According to the analysis, the most cost-effective measure leading to the fulfilment of climate commitments is the support of consumer energy. This is conditioned by the fact that most of the energy produced from micro sources will be used for their own needs. To stimulate economic growth, it is necessary to unlock the potential, give an impulse to show initiative and innovation. The conventional factors determining growth rates are gradually being depleted.

Private consumption and domestic demand are falling. It is possible to revive the economy by focusing on renewable energy sources, producing locally, training, investing, and operating. The adoption of renewable energy sources is not limited to highly developed nations but extends to poorer yet rapidly advancing countries. These countries recognize that the development of renewable energy technologies not only enhances the well-being of their citizens but also presents genuine economic and business opportunities. China serves as a prominent example in recent years, driving over 40% of global electricity production growth.

Central Asian regions are also making strides in energy transition, albeit not at an optimal pace, considering their relatively high energy consumption and CO2 emissions. The countries within this region exhibit significant variations in the current share of renewable energy sources in their total electricity production and the speed of industry development over the past decade [45; 70; 71]. Achieving a transition to renewable energy sources entails addressing numerous challenges, which necessitates the establishment of permanent and transparent mechanisms to support investment efforts. Ensuring energy supply reliability emerges as a crucial concern. This requires substantial investments in transmission and distribution infrastructure and ensuring the availability of conventional energy sources during periods of reduced activity from renewable energy installations. Energy transition incurs substantial costs, coupled with extensive and costly support mechanisms, which implies that electricity prices will inevitably continue to rise [46; 72]. Restructuring the energy model of countries also entails ensuring socially just transformations in coal regions [73; 74].

Based on an evolutionary transformation scenario, assuming that public policies, technology advancements, and societal preferences will change at a similar pace as in the recent past, global energy demand is expected to increase by approximately one-third by 2040, driven by rising living standards, particularly in India, China, and Asia. Around 75% of the total increase in energy demand will stem from industry and infrastructure, while the growth in energy demand for transportation will significantly slow down due to improved vehicle efficiency. Renewable energy sources and natural gas will provide 85% of the increase in energy supply, with renewable energy sources projected to become the largest source of energy generation worldwide by 2040 [47-48].

Conclusions

Thus, renewable energy sources are gaining their place in the global energy and economic systems faster than any other fuel in history. The rapid pace of change in energy systems around the world indicates that in the near future it will be necessary to solve the difficult task of increasing energy supply while reducing emissions. Various forms of energy will play a role in solving this problem. Predicting the progress of energy conversion is a huge and complex task. Renewable energy sources and natural gas together will make up the vast majority of the increase in the supply of primary energy.

In the evolutionary transformation scenario, 85% of the new energy will be produced using low-carbon technologies. International trade stimulates economic growth and allows countries to diversify their energy sources. The leaders of the energy industry are changing the emphasis in their movement, shifting them to renewable energy sources such as wind and solar. They use location-based technologies to drive profitable investments in the new energy landscape by analysing cost data and information such as wind speed and sunshine. Support for renewable energy sources is one of the goals of the national energy policy.

The term "green economy" is currently one of the key slogans when it comes to global trends and economic development. The "green economy" is a sustainable economy in which goals related to economic development are accompanied by concern for the state of the environment, preservation of its potential and values. It is important to note that this is not a model that belittles the essence of the functioning of the economy as such. This refers to the implementation of measures that, by stimulating income and employment growth, contribute to reducing CO2 emissions and environmental pollution. Even with the economic downturn caused by COVID-19, industry experts predict a good future for the renewable energy sector.

Renewable energy sources benefit the economy by providing the development of innovative sectors, such as engineering and information technology, and electrical and electronic, chemical, and mechanical engineering industries. This will enable the countries to sustain the progressive advancement of renewable energy sources and foster the creation of innovative projects. The suggested solutions will further enhance the positive influence of renewable energy sources on the overall resilience of the energy system.

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Conflict of Interest

None.

References

[1] Dogan E, Seker F. Determinants of CO2 emissions in the European Union: The role of renewable and non-renewable energy. *En Renew.* 2019;58(3):4976-4980.
[2] Imaaduddiin MH, Utama W, Jasikur C, Lestari W, Aini AN. Potential for renewable energy generation from water sources in the Batang River area. *Env Res Eng Man.* 2023;79(1):80-89.
[3] Zambrano-Monserrate MA, Carvajal LC, Urgiles-Sanchez R. Is there an inverted U-shaped curve? Empirical analysis of the Environmental Kuznets Curve in Singapore. *Asia-Pac J Acc Econ.* 2018;25(2):145-162.
[4] Li L, Leung GCK. The relationship between energy prices, economic growth, and renewable energy consumption: Evidence from Europe. *En Rep.* 2021;7:1712-1719.
[5] Parimala PVSSA, Sharma D, Mathew R. A comprehensive review on the advances in renewable wind power technology. *Wind Eng.* 2023;47(2):442-463.
[6] Dincer H, Yuksel S. Multidimensional evaluation of global investments in renewable energy with the integrated fuzzy decision-making model under the hesitancy. *Int J En Res.* 2019;43(5):4578-4595.
[7] Khobai H, Le Roux P. Does renewable energy consumption drive economic growth: Evidence from Granger-causality technic. *Int J En Econ Pol.* 2018;8(5):1-8.

[8] Aydın E, Brounen D, Ergün A. The rebound effect of solar panel adoption: Evidence from Dutch households. *En Econ.* 2023;120:106593.

[9] Schultz F. Analyzing the correlation between Sino-Japanese monthly trade and conflict values (2006-2014) with vector autoregression (VAR). *Econ Eff Pol Shocks Sino-Jap Rel.* 2020;57–72.

[10] Zeren F, Akkuş HT. The relationship between renewable energy consumption and trade openness: new evidence from emerging economies. *Renew En.* 2020;147(1):322-329.

[11] Smiech S, Papiez M. Energy consumption and economic growth in the light of meeting the targets of energy policy in the EU. *En Pol.* 2018;71(4):118–129.

[12] Miłek D, Nowak P, Latosińska J. The development of renewable energy sources in the European Union in the light of the European Green Deal. *Energies.* 2022;15(15):5576.

[13] Ryland M, He W. Domestic thermal energy storage applications: What parameters should they focus on? *J En Stor.* 2023;60:106685.

[14] Wang R, Usman M, Radulescu M, Cifuentes-Faura J, Balsalobre-Lorente D. Achieving ecological sustainability through technological innovations, financial development, foreign direct investment, and energy consumption in developing European countries. *Gondwana Res.* 2023;119:138-152.

[15] Tan Y, Uprasen U. The effect of foreign direct investment on renewable energy consumption subject to the moderating effect of environmental regulation: Evidence from the BRICS countries. *Renew En.* 2022;201:135-149.

[16] Adekoya OB, Oliyide JA, Fasanya IO. Renewable and non-renewable energy consumption – ecological footprint nexus in net-oil exporting and net-oil importing countries: Policy implications for a sustainable environment. *Renew En.* 2022;189:524-534.

[17] Ogunrinde O, Shittu E. Efficiency and productivity of renewable energy technologies: Evidence from U.S. investor-owned utilities across regional markets. *Util Pol.* 2023;82:101506.

[18] Phillips PB, Perron P. Testing for unit roots in time series regression. *Biometrika.* 2019;75(2):335-346.

[19] Fraser T, Chapman AJ, Shigetomi Y. Leapfrogging or lagging? Drivers of social equity from renewable energy transitions globally. *En Res Soc Sci.* 2023;98:103006.

[20] Menegaki AN. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *En Econ.* 2019;33(2):257-263.

[21] Ocal O, Aslan A. Renewable energy consumption-economic growth nexus in Turkey. *Renew Sust En Rev.* 2020;28:494-499.

[22] World Energy System Transformation Forecast 2022. 2022. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Mar/IRENA_WETO_Summary_2022_RU.pdf?rev=83f2688ad482470eb5a2e771b1a3787a&hash=B8A932E455B7C27799C954E41683CB04.

[23] Taghizadeh-Hesary F, Dong K, Zhao C, Phoumin H. Can financial and economic means accelerate renewable energy growth in the climate change era? The case of China. *Econ An Pol.* 2023;78:730-743.

[24] Johansen S. Statistical analysis of integration vectors. *J Econ Dyn Cont.* 1988;12(2):231-254.

[25] García-Afonso Ó, González-Díaz B. Effectiveness of zero tailpipe vehicles to reduce CO2 emissions in isolated power systems, a realistic perspective: Tenerife island test case. *Energy.* 2023;273:127173.

[26] Somoye OA, Seraj M, Ozdeser H, Mar'I M. Quantile relationship between financial development, income, price, CO2 emissions and renewable energy consumption: Evidence from Nigeria. *Lett Spat Res Sci.* 2023;16(1):45-60.

[27] Fotourehchi Z. Renewable energy consumption and economic growth: A case study for developing countries. *J Soc Econ Dev.* 2019;23(2):34-49.

[28] Nasrullah N, Husnain MI, Khan MA. The dynamic impact of renewable energy consumption, trade, and financial development on carbon emissions in low-, middle-, and high-income countries. *Env Sci Poll Res.* 2023;30(19):56759-56773.

[29] Rangarajan A, Foley S, Trück S. Assessing the impact of battery storage on Australian electricity markets. *En Econ.* 2023;120:106601.

[30] Amri F. The relationship amongst energy consumption, foreign direct investment and output in developed and developing countries. *Renew Sust En Rev.* 2019;64:694-702.

[31] Choudhury S. Review of energy storage system technologies integration to microgrid: Types, control strategies, issues, and future prospects. *J En Stor.* 2022;48:104171.

[32] Diaz IU, de Queiróz Lamas W, Lotero RC. Development of an optimization model for the feasibility analysis of hydrogen application as energy storage system in microgrids. *Int J Hydrogen En.* 2023;48(43):16159-16175.

[33] Cruz-Soto JD, Azkona-Bedia I, Velazquez-Limon N, Romero-Castanon T. A techno-economic study for a hydrogen storage system in a microgrid located in baja california, mexico. levelized cost of energy for power to gas to power scenarios. *Int J Hydrogen En.* 2022;47(70):30050-30061.

[34] Langer J, Quist J, Blok K. Review of renewable energy potentials in indonesia and their contribution to a 100% renewable electricity system. *Energies.* 2021;14(21):7033.

[35] Karl TR, Trenberth KE. Modern global climate change. *Science.* 2020;327(5965):1-7.

[36] Rahman MM, Velayutham E. Renewable and non-renewable energy consumption–economic growth nexus: new evidence from Asia. *Renew En.* 2020;147(1):399-408.

[37] Eren BM, Taspinar N, Gokmenoglu KK. The impact of financial development and economic growth on renewable energy consumption. *Sci Tot Env.* 2019;663:189-197.

[38] Dhayal KS, Giri AK, Esposito L, Agrawal S. Mapping the significance of green venture capital for sustainable development: A systematic review and future research agenda. *J Clean Prod.* 2023;396:136266.
[39] Li C, Solangi YA, Ali S. Evaluating the factors of green finance to achieve carbon peak and carbon neutrality targets in china: A delphi and fuzzy AHP approach. *Sustainability.* 2023;15(3):2721.
[40] Agu OS, Tabil LG, Mupondwa E. Actualization and adoption of renewable energy usage in remote communities in canada by 2050: A review. *Energies.* 2023;16(8):3601.
[41] Liu R, Solangi YA. An analysis of renewable energy sources for developing a sustainable and low-carbon hydrogen economy in china. *Processes.* 2023;11(4):1225.
[42] Xie F, Liu C, Chen H. Threshold effects of new energy consumption transformation on economic growth. *Sustainability.* 2018;10(11):4124.
[43] Arthur WB. Increasing returns and path dependence in the economy. Ann Arbor: University of Michigan Press. 2020.
[44] Ozturk IA. Literature survey on energy-growth nexus. *En Pol.* 2020;64:261-270.
[45] Can M, Gozgor G. Effects of export product diversification on quality upgrading: an empirical study. *J Int Trade Econ Dev.* 2018;27(3):293-313.
[46] Wang J, Li W, Haq SU, Shahbaz P. Adoption of renewable energy technology on farms for sustainable and efficient production: Exploring the role of entrepreneurial orientation, farmer perception and government policies. *Sustainability.* 2023;15(7):5611.
[47] Campbell JY, Perron P. Pitfalls and opportunities: What macroeconomists should know about unit roots. Macroeconomics Annual. Cambridge: MIT Press; 2019.
[48] Orlova S, Mezeckis N, Vasudev VPK. Compression of hydrogen gas for energy storage: A review. *Latv J Phys Tech Sci.* 2023;60(2):4-16.
[49] Lamp S. Sunspots that matter: The effect of weather on solar technology adoption. *Env Res Econ.* 2023;84(4):1179-1219.
[50] Duroha JC, Macht GA. Solar installation occupational risks: A systematic review. *Saf Sci.* 2023;160:105014.
[51] Metaksa G, Moldabaeva G, Alisheva Z. Obtaining preset properties in the hydrogenation process by controlling the state of phase boundary. *E3S Web Conf.* 2018;56:03028.
[52] Oringojin ES, Moldabayeva GJ. Foundations of chemical recovery of metals from leaching solutions through electrical action. *Int J Chem Sci.* 2012;10(2):751–767.
[53] Bagasharova ZT, Abdelmaksoud AS, Abdugaliyeva GY, Sabirova LB, Moldabayeva GZ. Recovery of water aquifers after the impact of in-situ leaching of Uranium. *Int Multidiscipl Sci GeoConf Surv Geol Min Ecol Manag, SGEM.* 2015;1(4):19-26.
[54] Petrov EG, Gorbach VV, Ragulya AV, Lyubchik A, Lyubchik S. Gate-tunable electroluminescence in Aviram-Ratner-type molecules: Kinetic description. *J Chem Phys.* 2020;153(8):18574.
[55] Subhoni, M., Kholmurodov, K., Doroshkevich, A., Asgerov, E., Yamamoto, T., Lyubchyk, A., Almasan, V., Madadzada A. Density functional theory calculations of the water interactions with ZrO2 nanoparticles Y2O3 doped. *J Phys: Conf Ser.* 2018;994(1):012013.
[56] Doroshkevich AS, Lyubchyk AI, Islamov AK, Turchenko VA, Glazunova VA, Zelenyak TY et al. Nonequilibrium chemo-electronic conversion of water on the nanosized YSZ: Experiment and Molecular Dynamics modelling problem formulation. *J Phys: Conf Ser.* 2017;848(1):012021. doi: 10.1088/1742-6596/848/1/012021
[57] Sharyi V, Supriaha O, Kalinichenko B. Resolution of investment conflicts between the state and foreign companies in the context of crisis prevention. *Soc Leg Stud.* 2023;6(4):200–207. doi: 10.32518/sals4.2023.200
[58] Kim S-C, Han K-S, Kim H-W, Jeong M-J, Chung J-K. John Milton's view on the True Church. *Astra Salvens.* 2022;2022(1):151–167.
[59] Messina A, Fogliani AM. Valproate in conversion disorder: A case report. *Case Rep Med.* 2010;2010:205702.
[60] Messina A, Concerto C, Rodolico A, Petralia A, Caraci F, Signorelli MS. Is it time for a paradigm shift in the treatment of schizophrenia? the use of inflammation-reducing and neuroprotective Drugs—A review. *Brain Sci.* 2023;13(6):957.
[61] Dobrovanov O, Králinský K. Sonographic screening of congenital kidney malformations in Slovakia. *Lek Obz.* 2018;67(12):426–429.
[62] Dobrovanov OY. Efficacy and sensitivity of prenatal and postnatal ultrasound screening of congenital developmental anomalies of kidneys in slovakia. *Wiad Lek.* 2021;74(3 cz 1):450–454.
[63] Zholdasbekova A, Biyashev KB, Biyashev BK, Sarybaeva DA, Zhumanov KT. Method for producing attenuated Salmonella strain. *J Pharm Sci Res.* 2018;10(1):162-163.
[64] Zhumanov KT, Biyashev KB, Biyashev BK, Sansyzbai AR, Valdovska A. Application of polyvalent hyperimmune serum against mastitis in beef cattle. *Biol Med.* 2015;7(5):BM-154-15.
[65] Moldabayeva GZ, Suleimenova RT, Bimagambetov KB, Logvinenko A, Tuzelbayeva SR. Experimental studies of chemical and technological characteristics of cross-linked polymer systems applied in flow-diversion technologies. *News Nation Acad Sci Republ Kazakhstan, Ser Geol Techn Sci.* 2021;4(448):50-58.
[66] Moldabayeva G, Abileva S. Study and determination of regularities in variability of oil rheological properties to enhance oil recovery. *Period Engin Natur Sci.* 2021;9(4):44–60.

[67] Gimranova R, Aimagambetov Y, Nevmatulina K, Garipova A, Mazhitova S, Kudaybergenova S. Transformation of Human Capital as a Driver of Innovative Economy. *Acad J Interdiscipl Stud.* 2023;12(6):203–220. doi: 10.36941/ajis-2023-0164

[68] Bongiovanni A, Parisi GF, Scuderi MG, Licari A, Brambilla I, Marseglia GL, Leonardi S. Gastroesophageal reflux and respiratory diseases: Does a real link exist? *Minerva Pediatr.* 2019;71(6):515–523.

[69] Yaremchuk NI, Oshurko AP, Oliinyk IY. Age assessment of the dynamics of morphological rearrangement of bone tissue of the articular processes of the human lower jaw depending on the loss of the masticatory teeth. *Pol Merkur Lek.* 2023;51(2):120–127.

[70] Zhakupova AA, Biyashev KB, Biyashev BK, Ermagambetova SE, Nurgozhayeva GM. Performance test of the drug enterocol. *J Pharm Sci Res.* 2017;9(10):1941-1942.

[71] Biyashev KB, Biyashev BK, Saribayeva DA. Persistence of the Escherichia coli 64G-Probiotic Strain in the Intestine of Calves. *Biol Med.* 2016;8(2):2-3.

[72] Spytska L. Prospects for the legalization of cryptocurrency in Ukraine, based on the experience of other countries. *Soc Leg Stud.* 2023;6(4):226–232.

[73] Spytska L. Prohibition in the USA, the USSR, and the UAE: Ideological and Procedural Differences, Causes of Failures or Successes. *Nov Jus.* 2023;17(3):67–92.

[74] Spytska L. Global practice of reducing the level of tobacco consumption through legislative regulation. *Med Law.* 2023;42(2):407–422.

Відновлювана енергія та економічне зростання

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Анотація

Актуальність. Актуальність дослідження полягає в тому, що перетворення енергії на основі відновлюваних джерел може допомогти прискорити економічне зростання, створити мільйони робочих місць і покращити умови життя людей.

Мета. Метою дослідження є вивчення сучасних аспектів відновлюваної енергії та її впливу на економічний розвиток.

Методологія. У дослідженні використовувалися порівняльний, функціональний та системний підходи до аналізу впливу відновлюваної енергії на економічне зростання. Порівняльний аналіз досліджував різні умови, функціональний аналіз розглядав взаємозалежності між елементами відновлюваної енергії, а системний аналіз моделював складні взаємодії між відновлюваною енергією та економічними факторами.

Результати. Дослідження показало, що перетворення відновлюваної енергії може значно прискорити економічне зростання, створюючи мільйони робочих місць та покращуючи умови життя. Виявлено, що відновлювані джерела енергії є більш економічно вигідними порівняно з викопним паливом та ядерною енергією, і вони мають потенціал знизити кількість смертей, пов’язаних із забрудненням повітря, на 7 мільйонів щорічно. Технологічні досягнення, такі як чистий водень та електрифікація в транспорті та опаленні, є ключовими у декарбонізації важкоперехідних секторів.

Висновки. Відновлювана енергія не тільки вирішує проблему зміни клімату, але й служить каталізатором економічного відновлення та зростання, особливо в часи криз. Перехід до відновлюваних джерел представляє подвійну користь: зменшення впливу на клімат і забезпечення економічної стабільності через створення робочих місць та покращення здоров'я. Дослідження підкреслює важливість впровадження відновлюваної енергії як стратегічної відповіді на екологічні та економічні виклики.

Ключові слова: відновлювана енергія; економічне зростання; криза; клімат; джерела енергії; робочі місця.