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ECONOMIC EFFICIENCY AND ENVIRONMENTAL BENEFITS OF THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES*

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ABSTRACT

The study aims to determine the economic and environmental advantages of renewable energy sources compared to conventional ones. The focus is on assessing the potential of renewable energy sources to reduce carbon emissions, promote sustainable development, and support economic progress. The impact of renewable energy sources on achieving energy independence, increasing energy efficiency, and reducing dependence on fossil fuels is assessed, and attention is paid to innovative technologies for converting solar, wind, water and biomass energy, ensuring environmentally friendly production. Key mechanisms of state support for the development of renewable energy sources are considered, including investment incentives, the introduction of "green" tariffs and ensuring regulatory framework. Study methodology. The analytical approach was applied based on data collection and analysis to assess the economic and environmental benefits of introducing renewable energy sources. The system approach made it possible to consider the development of renewable energy sources as an integrated system of interactions between the economy, ecology, society, and technologies. The scientific novelty of the study is the comprehensive approach to analyzing the economic and environmental efficiency of renewable energy sources. There were determined the impact of renewable energy sources on the reduction of greenhouse gas emissions and their contribution to the fight against global warming, which allows for a quantitative assessment of environmental efficiency in the context of achieving the goals of the Paris Agreement and national strategies for reducing the carbon footprint. The

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authors suggested recommendations for improving state policy to support and develop renewable energy sources, including analysis of current mechanisms for stimulating the production and use of renewable energy. A comparative analysis of the cost of energy production from different sources, their impact on the ecosystem and return on investment is carried out. Particular attention is paid to studying the experience of advanced countries in the implementation of renewable energy sources and adapting these practices to the current needs of the world economy. Scientific novelty lies in identifying the factors contributing to the constant growth of the share of renewable energy sources in the global energy balance. The prospects for using waste-to-energy technologies are described, as well as their role in minimizing environmental risks is analyzed and the socio-economic effect of RES integration is determined, including the creation of new jobs, increasing the level of social responsibility of business and the development of a "green" economy. The results of the study are of practical importance for the formation of strategies for state regulation of the energy sector, stimulating innovation in the field of renewable energy sources, as well as developing recommendations for businesses on adaptation to new environmental standards. The study contributes to the deepening of the understanding of the complex impact of renewable energy sources on the economy, ecology, and society, as well as to the expansion of the scientific base for the development of effective strategies for increasing the share of RES in the energy balance of countries.

Keywords: renewable energy, energy structure of the country, economic benefits, "green" energy sources, energy investments, environmental protection, environmental safety

JEL: F01, O32, Q20.

INTRODUCTION

Recently, the issues of climate change and environmental protection have attracted considerable attention and discussion among the global community, becoming a source of heated debate. Driven by rapid growth in global consumption of goods and services, global energy demand has increased significantly, from 8,461 Mtoe in 1990 to 13,978 Mtoe in 2022, a nearly 1.65-fold increase. However, energy consumption growth slowed to 0.6% in 2019, compared to an average growth rate of 2% per year between 2000 and 2022. Similarly, electricity consumption increased from 10,135 to 22,964 TW/h, or 2.3 times [15]. Slower economic growth and milder temperatures translate into growth of 0.7% in 2021, compared to an average of 3% per year between 2000 and 2023, maintaining an upward trend. Increasing energy consumption is confronting the depletion of readily available reserves of traditional energy sources, which has caused an increase in emissions of harmful substances such as CO_2 and methane into the atmosphere [41].

Today, energy production is responsible for approximately three-quarters of all global greenhouse gas emissions, becoming a significant driver of climate change. Meanwhile, the burning of fossil fuels and biomass causes great harm to human health, killing at least five million people every year due to air pollution. With the gradual depletion and rising cost of traditional energy sources such as oil and gas, the world is facing the challenge of transitioning to renewable energy, which includes low-carbon sources such as renewable technologies and nuclear power. In this context, world leaders have been actively working on

improving policies and mechanisms to stimulate the development of this sector during the last decades [42]. However, despite its growing popularity, renewable energy continues to cause debates requiring additional clarification of concepts and addressing current economic, environmental, and security challenges.

LITERATURE REVIEW

The current development model, focused on using renewable energy sources, is a leading global economic trend [1]. According to some scientists and experts from scientific research institutions, this approach to development aims to promote global economic progress while limiting the growth of energy demand, forcing the production of low-carbon products, and guaranteeing a reliable and affordable energy supply [2, 6].

Modern science makes a significant contribution to research in the field of sustainable development. In the works of many scientists [12, 25, 38], a special place is occupied by traditional energy as an integral part of the economic potential of the countries of the world, the issues of transformation of nature protection and ecological topics. You should especially note the works of some prominent economists and ecologists [26, 45], who define a leading economic model that combines efforts to reduce pollution, mitigate the effects of climate change and ensure sustainable development.

As indicated by some other scientists [4], already in the 21st century, an economy based on renewable energy sources involves finding harmony between population growth, economic progress, and environmental protection. It aims to minimize fossil fuel consumption and its associated negative environmental impact.

There are also the authors [16, 28], who state that the energy area of economic development is characterized by improving the efficiency of energy use and creating an energy system based on ecologically clean sources with the view of reducing energy consumption and limiting pollution and emissions. It aims to reduce greenhouse gas emissions compared to the traditional carbon economy and includes efforts to build inclusive institutions, support global engagement, and develop long-term innovations.

As noted by one scientist [22], the main goal of such an economy is to significantly reduce greenhouse gas emissions caused by humans and to mitigate the effects of climate change. An economy that is based on renewable energy sources is an innovative socio-economic development model focused on reducing greenhouse gas emissions. One can achieve it through technological innovation, changes in infrastructure and behaviour, and reducing the consumption and burning of carbon fuels without jeopardizing economic growth.

The analysis and classification of the literature indicate the relevance of the topic under study and the presence of specific gaps. Thus, in most cases, research devoted to the energy transition and “green” investment ignores traditional energy sources. In contrast, studies analyzing processes in the fuel and energy complex (FEC) either do not pay enough attention to low-carbon technologies and concentrate on indicators of economic efficiency or offer costly (in terms of personnel and financial resources) assessment models of sustainable social and environmental development. More studies must be devoted to a comprehensive and acceptable approach to ensuring the sustainable development of renewable energy sources.

The study aims to analyze the economic benefits and environmental impact associated with using renewable energy sources compared to traditional ones. It focuses on determining the potential of renewable energy sources to reduce carbon emissions, ensure sustainable development, and promote economic growth.

METHODS

The study uses an analytical research method, which consists of analyzing data and information to assess renewable energy sources' economic and environmental efficiency. This method makes it possible to determine the immediate effects of using such sources and assess their long-term impact on the economy and the environment.

The analytical approach involves the following stages:

1. Data collection. Data on the costs of installing and operating renewable energy sources, including solar panels, wind farms, hydroelectric plants, etc., including information on the amount of energy produced and its cost, are collected.
2. Analysis of economic efficiency. At this stage, a comparative analysis of economic indicators of renewable and traditional energy sources is necessary.
3. Analysis of environmental benefits. The impact of renewable energy sources on the environment is analyzed, including reducing greenhouse gas emissions, reducing fossil fuel use, and impacting biodiversity and ecosystems. Data from scientific studies and statistical reports of international organizations are used.

The study also uses the systematic research method, which makes it possible to consider the development of renewable energy sources as a complex system interacting with economic, ecological, social, and technical subsystems. This method provides an integrative approach to the analysis, considering the factors that affect the efficiency of using renewable energy sources and their impact on the environment and society.

The main components of the systematic method are as follows:

1. *Identification of the system and its subsystems.* Identifying key elements of a renewable energy development system, including energy production, transportation, storage, and consumption, as well as the relationships between economic efficiency, environmental benefits, social impact, and technological innovation.
2. *Analysis of relationships between subsystems*. Study of the relationships between different components of the system, such as the impact of reducing the cost of technology on economic availability, the relationship between the introduction of renewable sources and the reduction of greenhouse gas emissions, and the impact of political decisions on the development of the industry.
3. *Development of implementation strategies and recommendations*. Based on the systematic analysis, strategies and recommendations are formulated to optimize the use of renewable energy sources, increase their economic efficiency, and minimize environmental risks.

RESULTS

Modern Components of the Use of Renewable Energy Sources

Renewable energy is characterized by its purity and origin, which is exclusively from renewable sources, unlike fossil fuels, without harming the environment, which makes it more acceptable for sustainable development. Clean energy can be mistakenly confused with renewable energy, but the critical difference is that while all renewable are clean, not all clean energy sources are renewable. Nature provides renewable energy sources such as wind and sun, and they do not cause pollution, unlike clean energy sources, such as nuclear power and carbon neutralization technologies such as carbon capture and storage (CCS) [39].

The use of fossil fuels such as coal and oil causes enormous environmental damage that is often irreversible. However, some alternative or "green" energy sources may also have negative aspects, including nuclear power, especially given the risks of radiation contamination. The challenges of meeting growing energy needs and protecting nature face the problem of managing the increasing amount of waste generated by humans, including vast amounts of municipal solid waste, which, according to the World Bank, is expected to grow from 1.3 billion tons in 2010 to 2.2 billion tons by 2025. Waste can become a valuable energy resource, possibly converting 1 kg of waste into 300 to 1500 watts of thermal or electrical energy [10]. This correct use of waste ensures renewable energy production and contributes to their safe and harmonious disposal.

The waste-to-energy segment has already taken its place in the global economy and municipal governance, competing with recycling in the context of waste management strategies. Although recycling is more appropriate in many cases, not all types of waste are fully recyclable. Alternative energy involves using renewable and virtually inexhaustible resources for energy production while minimizing the negative impact on the environment [9] (Table 1).

Therefore, alternative energy is a sector of the energy industry that includes innovative methods of energy production from renewable or virtually unlimited resources while minimizing environmental risks. Electricity, along with transport and heating, is one of the three key components of the general energy supply.

Table 1. The main types of renewable energy and their characteristics [34]

Energy type	Source	Technology	Use area
Solar power	Sun	Photoelectric, solar thermal technologies	Electricity, heating, cooling
Wind power	Wind	Wind turbines	Electricity
Hydraulic or hydroelectric power	Water	Hydroelectric power plants	Electricity
Geothermal power	Earth	Surface geothermal systems and heat pumps	Electricity, heating, cooling
Biopower	Biomass	Biomass combustion, biogas plants, biofuel	Electricity, heating, cooling, transport
Wave power	Surface ocean waves	The kinetic energy produced by the oscillations of the ocean surface caused by the wind	Electricity
Hydrogen power	Hydrogen	Production of hydrogen in the process of electrolysis of water or by way of microbial fermentation of organic waste	Electricity, heating, cooling, transport

Analytical Substantiation of the Economic and Environmental Benefits of the Development of Renewable Energy Sources

The share of fossil fuels and low-carbon electricity has remained stable for many years. In the early 2000s, there was an increase in the use of fossil fuels. During this time, the share of nuclear power decreased, while the share of renewable energy sources increased, as shown in Figure 1. However, the reduction in the use of atomic power has levelled progress in the area of renewable energy sources; the decrease in nuclear power roughly matched the growth in the use of renewable energy sources.

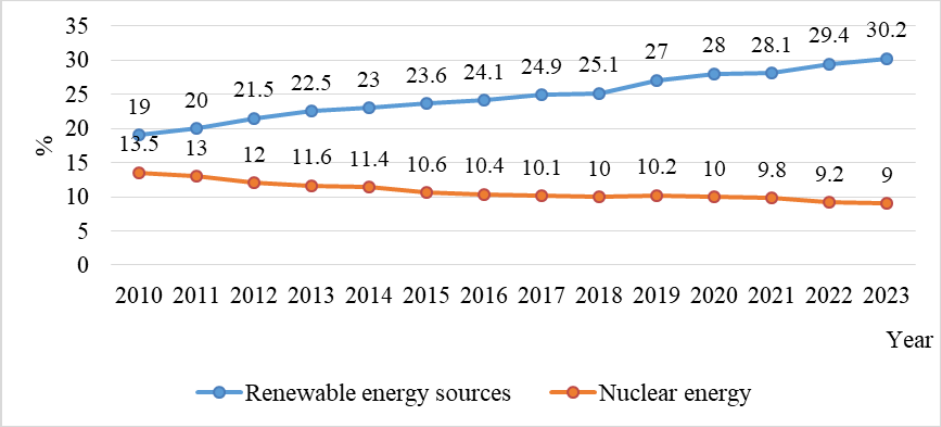

Figure 1. The share of renewable energy sources in the energy structure by world region in 2010-2023, % [33].

In 2023, the share of renewable sources in the total energy balance of the world increased by 1.5 % to 30.2%, which is 10% higher than in 2010. In countries with significant hydropower potential, such as Brazil, Colombia, Canada, New Zealand, Sweden, or Norway, producing more than two-thirds of electricity from renewable sources, the level of use of renewable energy is traditionally high. In other countries, ambitious energy policies and lower costs of wind and solar energy production have contributed to the growth of energy production from renewable sources, reflected in an increase in their share in the energy sector. In Europe, the share of renewable energy has increased by 18% since 2010, reaching 43%, with significant increases in the UK (+36% to 43%), the Netherlands (+30% to 40%), Germany (+27% to 44%), and Turkey (+15% to 42%). In Australia, the share of renewable sources increased by 22% to 31%, in Chile by 14% to 55%, in the USA by 12% to 22%, in China by 12% to 31%, in Japan by 12% to 22%, in Thailand by 12% to 18%, and in South Africa by 8% to 10%. According to the data, the share of renewable energy in the global energy portfolio shows growth in all regions during 2010-2022 [33] (Figure 2).

Alternative energy acts as a specialized branch of the energy industry that involves innovative methods of energy production from renewable or virtually infinite resources while minimizing environmental risks. Along with transportation and heating, electricity is one of three key components of general energy production. As mentioned earlier, the ratio between fossil fuels and low-carbon electricity has remained unchanged for many years. In the early 2000s, the use of fossil fuels even increased. During this time, the share of nuclear power has

decreased while the share of renewable energy sources has increased [3], as shown in Figure 3. However, the reduction in the use of nuclear power levelled progress in renewable energy sources. The decrease in atomic power roughly matched the growth in using renewable energy sources [35].

In 2022, solar PV power generation reached an unprecedented growth rate of 270 TWh, up 26% from the previous year, reaching nearly 1,300 TWh. This year was marked by the most significant increase in energy production from any renewable source, overtaking wind power production for the first time. Solar PV plants now provide 4.5% of the world's total electricity generation, ranking third in output among renewable sources after hydropower and wind power [19].

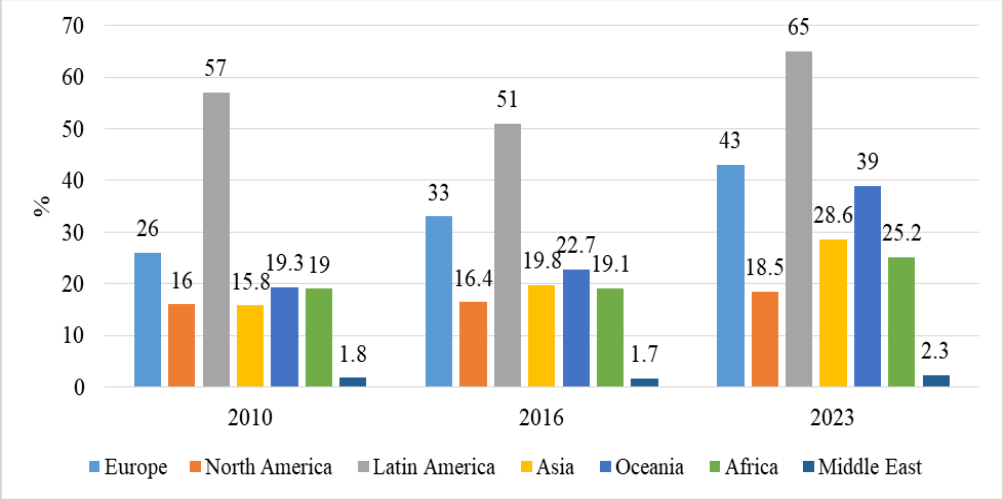

Figure 2. The share of renewable energy sources in the energy structure by world region in 2010-2023, % [33].

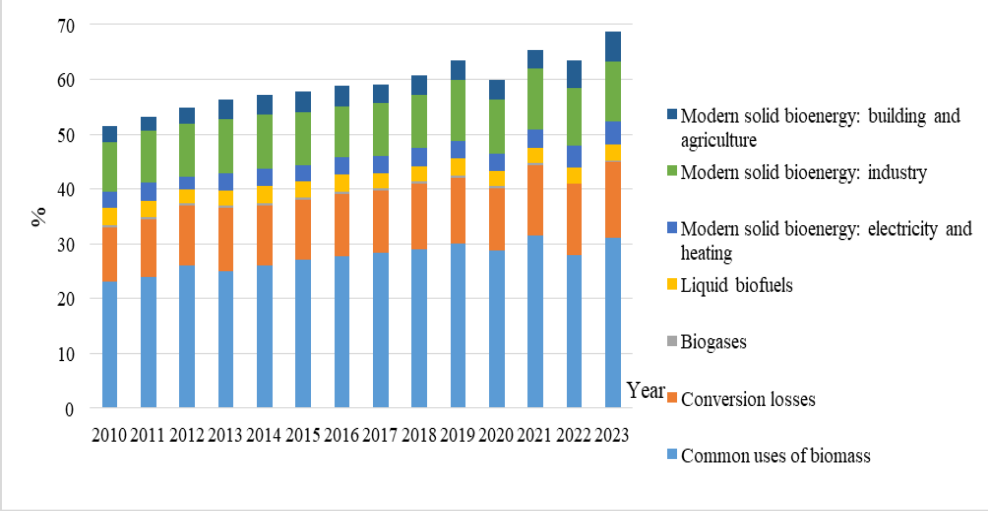

Figure 3. Biopower use by sector worldwide in the net-zero-emissions scenario during 2010-2022 and projection to 2030, EJ (1018 J) [30].

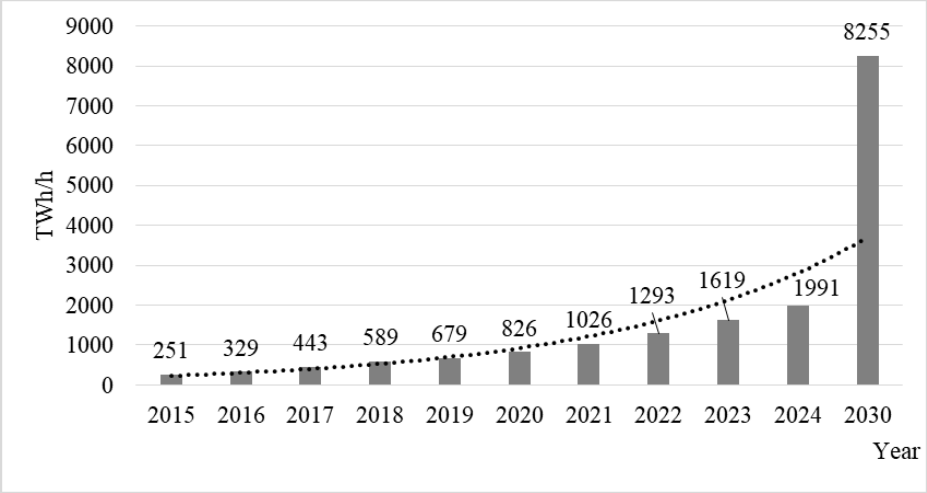

Figure 4. Solar PV power production in the net-zero-emissions scenario during 2015-2023 and projection to 2024 and 2030, TWh/h [43].

In 2022, about 38% of solar power production growth came from China, driven by significant capacity expansion. The European Union and the USA also demonstrated significant growth, accounting for 17% and 15%, respectively.

Despite high commodity prices and rising interest rates, solar PV power has shown resilience, helping to accelerate its production. China continues to lead the way in solar capacity additions, adding 100 GW in 2022, nearly 60% more than a year earlier. EU steps up solar installations, adding 38 GW of capacity, responding to the energy crisis. The USA plans to significantly expand solar production thanks to new funding under the Inflation Reduction Act. India has also made significant progress, with 18 GW of solar capacity added in 2022, and is planning to increase its capacity further. Brazil significantly increased its solar capacity in 2022, adding nearly 11 GW, double the growth rate in 2021. According to forecasts, this trend will continue at this level due to the stable demand for renewable energy from industry and retail electricity suppliers [33].

In the same year, wind power production reached a record growth rate of 265 TWh, a 14% increase compared to 2021, surpassing 2,100 TWh. It was the second-largest growth of any renewable energy source after solar power (Figure 4).

Below are the countries and regions that have demonstrated impressive results in wind power development. China continues to lead the pace of wind capacity additions, adding 37 GW in 2022, including 7 GW in offshore wind farms. The ambitious targets set in the 14-th five-year plan for developing renewable energy sources will stimulate the expansion of this industry in the coming years [43].

The European Union boosts wind capacity development, adding 13 GW in 2022, responding to the energy crisis. New policies and strategic objectives outlined in the REPowerEU plan and the Green Deal will help attract investment in wind energy. In the US, new funding for wind energy has been announced thanks to the 2022 Inflation Reduction Act. The first large-scale wind farms will appear on the country's eastern coast in 2023-2024. The UK installed almost 3 GW of offshore wind capacity in 2022, a significant achievement

compared to other countries except China. The government also signed a contract to build the first floating wind farm at the Contract for Difference auction [36] (Figure 5).

In 2022, one should note a significant increase in the share of wind and solar power in the total energy balance of Australia (more than 23%, an increase of 3.6%), Latin America (up to 13%, of which Chile has more than 26% and Brazil 16%), and Asia (12%, an increase of 1.5%). At the same time, in Africa (5%, including 6% in South Africa), the CIS countries (1%, in particular, less than 1% in Russia and 6% in Ukraine) and the Middle East (less than 2%, despite the growth of renewable generation in UAE) these indicators remain small [32].

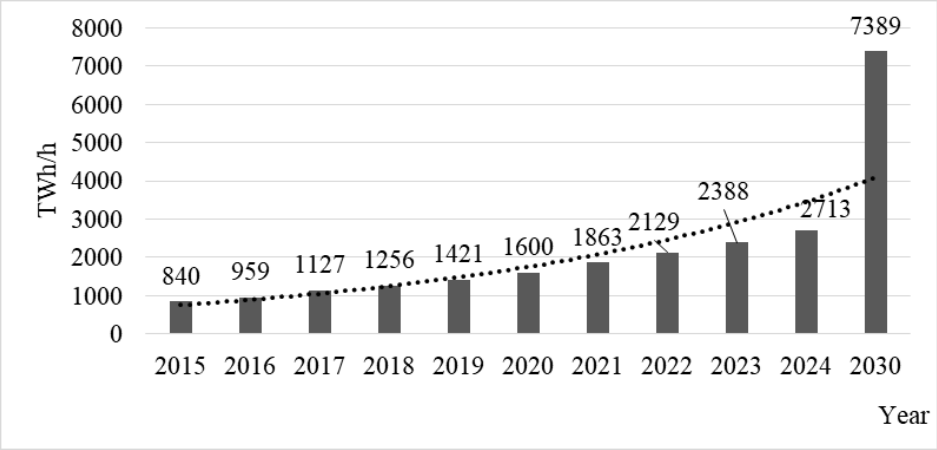

Figure 5. Wind power production in the net-zero-emissions scenario during 2015-2023 and projection to 2024 and 2030, TWh/h [43].

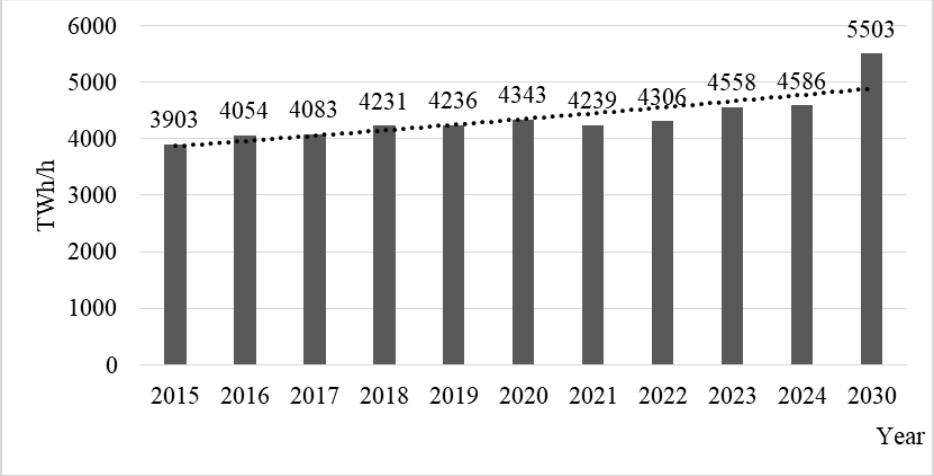

Figure 6. Hydropower production in the net-zero-emissions scenario during 2015-2023 and projection to 2024 and 2030, TWh/h [32].

In the same year, hydroelectricity production increased by almost 70 TWh (about 2%), reaching 4,300 TWh. The increase in production was possible due to the active commissioning of new capacity in 2021-2022. However, the global capacity utilization rate

remained below historical levels due to persistent droughts in countries with developed hydropower, such as Canada, China, Turkey, the USA, and Western Europe (Figure 6).

Despite this, hydropower remains the leading renewable energy source, surpassing all other types of renewable sources in production. However, the average annual growth rate over the past five years has been only a third of the required level, which indicates the need to intensify efforts, in particular, to simplify the process of issuing permits and ensure the sustainability of projects [27]. Hydropower plants should become a reliable centre of clean energy systems.

China, India, and Europe are among the countries that have made significant progress in hydropower development. China added 24 GW of capacity, which accounts for nearly three-quarters of all global hydropower growth. In India, several large projects will come online in the coming years. Europe added almost 2 GW of hydropower capacity, becoming a leader in integrating renewable energy sources [14].

So, summing up, you can state that electricity production from "green" sources is growing. States are interested in transitioning to renewable energy sources and implementing appropriate policies and incentives for developing this sector. However, renewable energy development causes some problems that require an urgent solution. The main issues faced by renewable energy are as follows:

1. Because renewable energy supply is variable, the energy storage problem remains relevant, requiring reliable solutions. Despite progress in the development of battery technologies, which reduce the cost of storage, sustainability issues and environmental expenses remain [21].

2. Economic and financial problems are also challenges for the sector, as a large-scale transition from traditional energy sources to renewables requires significant investments. The need to invest in developing innovations and new technologies often faces funding constraints, especially from large corporations and governments [7].

Despite these problems, alternative financing methods, such as crowdfunding, open up new opportunities for implementing projects in the field of renewable energy. However, to overcome challenges and accelerate the development of this industry, it is necessary to attract further investments in the research and development of environmentally friendly energy solutions (Figure 7).

Therefore, based on the presented data analysis, electricity production from renewable sources continues to increase. States demonstrate a growing interest in the transition to renewable energy sources, actively developing policies and incentives to develop this sector. At the same time, the renewable energy sector faces many challenges that require urgent solutions [23]. The main problems of the development of renewable energy include the following:

- Challenges related to efficient, affordable, and reliable energy storage. The variability of renewable energy supply requires a solution to the issue of energy storage. Despite significant progress in the development of battery technology, environmental expenses and the need to extract rare metals remain essential issues;

Main problems of the development of renewable energy
The problem of efficient, affordable, and reliable energy storage
Economic and financial problems
Political challenges
Infrastructure problems
Land use, industry
Technical problems
High initial installation cost
Monopoly of non-renewable energy sources
Lack of knowledge and information
Absence of policies, subsidies

Source: Developed by the authors.

Figure 7. Main problems of the development of renewable energy.

- Economic and financial problems facing the sector transitioning from fossil fuels to renewables. Significant investment is needed to develop new technologies and innovations, but financial support remains insufficient;
- Political challenges also play a crucial role, as political positioning and isolationism can hold back the development of this sector. It is essential to find a balance between rapid changes and the readiness of society to accept these changes [24];
- Infrastructure challenges are critical for the widespread use of renewable energy sources, and the lack of developed energy grids complicates a large-scale transition;
- The problem of land use also requires finding the optimal balance between energy production and other needs, especially when using agricultural land for energy purposes.

With record wind capacity growth in 2023, positive trends in China, Europe, and the USA are particularly notable despite supply chain challenges. Offshore wind energy growth, while not reaching levels of two years ago, points to continued investment in the industry.

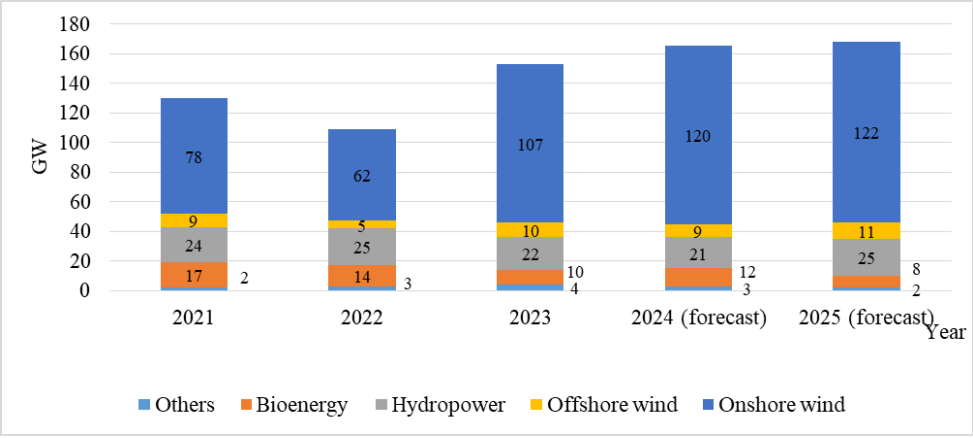

Figure 8. Growth of renewable electricity capacities by technologies in 2022-2023 and forecast for 2024, GW [31].

In 2024, further growth in the number of solar photovoltaic installations is expected despite the existing difficulties with expanding wind energy projects. Falling prices for PV modules, increased use of decentralized solar systems, and drive for mass adoption will promote increased numbers in key markets such as China, the EU, the USA, and India. On the other hand, without active political decisions, the global growth in the number of onshore wind farms in 2024 is expected to decrease by 5% compared to 2023. Despite China's wind power growth in 2024, it will be partially offset by problems with auctions and permitting delays in Europe. However, the situation may improve with the adoption of new laws. Overall, total global renewable energy capacity may exceed 4,500 GW by the end of 2024, equivalent to the combined power capacity of China and the USA.

Prospects and Challenges of Spreading Renewable Energy Sources

Under the optimistic scenario, the global increase in the capacity of renewable energy sources could reach 550 GW in 2024, which is 20% more than the baseline forecast, which is mainly due to the faster commissioning of home and commercial PV systems, based on the assumption of speedier implementation of the latest policies and incentives. The growth potential of coastal wind and solar photovoltaic projects depends mainly on the speed of obtaining permits, construction, and timely connection of the projects under development to the power grid [44].

During the study, the authors also created a table that describes the different types of renewable energy sources, their economic and environmental benefits, investment complexity, and available government support tools.

Table 2 provides an overview of the critical aspects of using different types of renewable energy sources, their economic and environmental benefits, and the potential challenges that may arise during the investment and implementation of such projects.

Table 2. Comparative analysis of renewable energy sources from the standpoint of economic and environmental benefits

Renewable energy source type	Economic implementation benefits	Environmental implementation benefits	Investment difficulty level	Government support tools
Solar power	Lower electricity expenses, high return on sunny days	No CO_2 emissions, pollution reduction	Medium	Subsidies, "green" tariffs
Wind power	Stable income from the sale of electricity, low operating costs	Clean energy, minimal environmental impact	High	Guaranteed electricity prices, tax benefits
Hydropower	Long-term production of electricity at low costs, high reliability	Renewable resource, minimization of environmental impact	High	Subsidies for construction, tax credits
Biopower	Energy production from waste, reducing dependence on imported resources	Reducing the amount of waste, producing energy from renewable sources	Medium	Financing of waste processing projects, tax benefits
Geothermal power	Low operating costs, stable energy production	Low level of CO_2 emissions, use of natural heat of the earth	High	Research grants, government loans

Source: Developed by the authors.

The conflict between Russia and Ukraine accelerated the integration of renewable energy sources in the European Union, forcing European countries to reduce their dependence on Russian natural gas urgently. As a result, in many EU countries, there were revised forecasts regarding the increase in the capacity of renewable energy sources by 40% compared to the indicators until 2022 during 2023-2024 [5]. The main driver of this revision was the growth in the use of distributed solar PV systems, which accounts for the lion's share of changes in forecasts, especially against the background of high electricity prices, which make solar energy more financially attractive. Also, this revision was possible due to increasing political support, especially in countries such as Germany, Italy, and the Netherlands [37].

New political decisions implemented in 2022 by the world's largest economies will support using renewable energy. The countries and regions that have made significant progress in the development of renewable energy sources include [17, 20]:

- *China.* This country continues to be at the forefront of increasing renewable energy capacity, adding 160 GW in 2022, nearly half of the global increase. Ambitious targets concerning renewable energy included in the 14-th five-year plan will stimulate investment in the sector;
- *The European Union*. It has accelerated the development of solar and wind energy, adding more than 50 GW in 2023, a 45% increase from the year before, thanks to new policies and targets set out in the REPowerEU plan and the Green Deal;
- *The USA*. This country announced new financing in 2023, which should contribute to the medium-term development of renewable energy sources and increased investments;
- *India.* This country reaffirmed its ambition to reach 500 GW of non-fossil energy capacity by 2030, announcing a plan to commission 50 GW of new capacity annually [40].

A detailed overview of renewable energy development policies in different countries was also presented (Table 3).

Table 3. The modern policy of the countries of the world regarding the development of renewable energy [8, 11]

Policy	Country	Year	Active/Inactive	Jurisdiction
Climate Law 2023	Israel	2030	Announced	National
New Zealand Energy Strategy	New Zealand	2024	Planned	National
Solar and Renewable Energy Fund	Lebanon	2023	Active	National
2023 incentives for decentralized renewable electricity production	Portugal	2023	Active	National
National budget for 2023 — development of renewable energy sources	Indonesia	2023	Active	National
Subsidies for large-scale solar PV systems in 2023. Large-scale solar PV auction scheme	Switzerland	2023	Active	National
650 GWh renewable energy auction with strike price guarantee	Estonia	2023	Active	National
Amendment to the Energy Conservation Act	Japan	2023	Active	National
Financing of new wind farms in 2023	Brazil	2023	Active	National
Carbon contracts for difference for energy-intensive industries	Germany	2023	Active	National

Following the introduction of Israel's historic 2022 climate law in February 2023, the Ministry of Environmental Protection presented an updated bill to achieve carbon neutrality by 2050. The bill sets a goal of reducing greenhouse gas emissions by 50% by 2030 compared to 2015 as a baseline.

New Zealand's energy policy, managed by the Department of Business, Innovation and Employment, aims to move to a zero-carbon economy by 2050 [13]. The policy focuses on ensuring energy availability, security of supply, and economic development support while reducing dependence on fossil fuels and increasing the share of renewable sources and low-emission alternatives. This strategy has two phases and will be developed by the end of 2024. It will examine potential future scenarios and identify ways to achieve the goals [18].

USAID, in partnership with the Ministries of Industry, Energy, Water Resources, and Environment of Lebanon, is implementing a $20 million solar energy development project through the Trade and Investment Facilitation Project and the Lebanon Investment Initiative. In 2023, the Portuguese government granted tax incentives for decentralized renewable energy production if used locally or sold via feed-back to the grid. In the 2023 budget, Indonesia allocated funds for developing photovoltaic panels on roofs in less developed regions and for developing solar street lighting [29]. On the threshold of 2024, the prospects for renewable energy sources look particularly encouraging. States are trying to innovate in the solar energy sector, making it easier for businesses and industries to transition to sustainable development. With the proper regulations, incentives, and the joint efforts of consumers and industry leaders, it is possible to contribute to a future based on clean and renewable energy, creating a healthier planet for generations to come [39].

DISCUSSION

The study may need more up-to-date, detailed, or specific data on the cost, efficiency, and environmental impact of particular renewable energy sources in different regions. The rapid development of technologies in renewable energy sources can make the study results obsolete shortly after publication. They may underestimate or oversimplify the environmental benefits of renewable energy sources without considering their implementation and operation's potential adverse environmental effects (e.g., impact on biodiversity and land use). High dependence on government support and political stability can affect the economic efficiency of renewable energy sources. There needs to be more attention to social aspects such as the impact on job creation, social acceptance of technology, and possible impact on local communities.

The study confirmed the potential of using technologies for converting organic and inorganic waste into energy to reduce the volume of municipal solid waste and reduce the environmental burden. Use of natural resources and reduce dependence on fossil fuels.

The study proved that the integration of renewable energy sources into the energy system requires increased government support, in particular through the introduction of innovative financial mechanisms energy. The results of the statistical analysis showed that an increase in the use of renewable energy sources is accompanied by a significant reduction in greenhouse gas emissions. Over the period 2015-2023, countries that actively implemented renewable energy reduced their emissions by 18% on average, which is a fundamental factor in the context of fulfilling the obligations of the Paris Agreement.

According to statistics, the largest increase in the use of renewable energy sources was recorded in the EU, China, and the USA, and solar energy in 2023 amounted to more than 55% of the global figure, confirming the country's leading position in the development of "green" energy. Analysis of economic indicators confirms the high profitability of investments in renewable energy sources. In countries with high potential for hydropower, such as Norway and Brazil, average payback rates are even higher, further attracting investment.

Prospects for further research may involve several vital areas aimed at in-depth study of the potential and challenges associated with renewable energy sources. They include:

1. Research on the latest technologies in the field of renewable energy sources, including improving the efficiency of photovoltaic panels, developing wind turbine technologies, as well as innovations in the fields of hydropower, geothermal energy, and biofuel production. Particular focus is on the analysis of the possibilities of reducing the cost and increasing the availability of these technologies;
2. A detailed study of the environmental impact of different types of renewable energy sources, including analysis of greenhouse gas emissions at the stages of production and operation, the effect on biodiversity and the landscape, as well as the potential risk of water and soil pollution;
3. Development of economic assessment models for the implementation of renewable energy sources, including analysis of cost, return on investment, impact on the labour market and macroeconomic consequences for different regions and countries.

CONCLUSION

The study has proven that renewable energy plays a significant role in transitioning to ecologically clean energy due to its minimal environmental impact. The implementation of renewable energy projects in the electricity sector, heating systems, and transport is a crucial element in helping to keep the increase in the average global temperature below 1.5°C. Within the "Net Zero Emissions by 2050" strategy, renewable energy sources provide an opportunity for almost complete decarbonisation of the electricity sector. Focusing on clean and safe renewable sources will bring many benefits: conservation of fossil resources, slowing of global warming, improvement of public health, creation of new enterprises and jobs in the field of renewable energy, and access to unlimited energy resources.

Despite the challenges in the wind energy sector, it has been proven that further growth in the number of solar PV systems is expected. Under an optimistic scenario, the total increase in renewable energy capacity could reach 550 GW in 2024, almost 20% more than the main forecast. The crisis caused by the Russian invasion of Ukraine stimulated the EU to implement renewable energy sources more actively. According to projections, renewable energy sources in the EU will grow by 40% during 2023-2024. China will increase its contribution to global renewable capacity growth to a record 55% in 2024, being a leader in developing new offshore and onshore wind energy projects and solar PV energy projects. A new policy introduced in 2022 in the world's largest economies will support using renewable energy. Countries like China, the EU, the USA, and India made progress in developing renewable energy sources. Both developed and developing countries are actively developing policies to support renewable energy.

REFERENCES

[1] Adam, D. H., Supriadi, Y. N., Ende, Siregar, Z. M. E. Green Manufacturing, Green Chemistry and Environmental Sustainability: A Review. *International Journal of Scientific & Technology Research*, 9(04), 2020, pp. 2209-2211.

[2] Andryeyeva, N., Khumarova, N., Nikolaychuk, T. Aligning the social, environmental, and economic interests of "green growth" of the Ukrainian nature reserve fund objects. *Environmental Economics*, 10(1), 2019, pp. 93-104. doi: 10.21511/ee.10(1).2019.07.

[3] Azzuni, A., Aghahosseini, A., Ram, M., Bogdanov, D., Caldera, U. and Reyer, C. Energy Security Analysis for a 1% Renewable Energy Transition in Jordan by 2. *Sustainability*, 12 (12), 2022. doi: 10.3390/su12124921.

[4] Bhunia, G. S., Shit, P. K., Sengupta, D. Free-open access geospatial data and tools for forest resources management. In: Spatial modelling in forest resources management: rural livelihood and sustainable development. *Springer*, *Chapter*, 2021, pp. 651–675. doi: 10.1007/978-3-030-56542-8_28.

[5] Collins, P. Green Energy: advantages, examples, and suppliers. *Climate Consulting*, 2022. Retrieved from: https://climate.selectra.com/en/environment/green-energy (Accessed 30 Sep. 2024).

[6] Dowling, Jacqueline A., Katherine, Z. Rinaldi, Tyler, H. Ruggles, Steven, J. Davis, Mengyao, Yuan, Fan Tong, Nathan, S. Lewis and en Caldeira. *Role of Long-Duration Energy Storage in Variable Renewable Electricity Systems.* Vol. 4 (9), 2022, pp. 1907–28. doi: 10.1016/j.joule.2020.07.007.

[7] Energy Mix. Explore global data on where our energy comes from, and how this is changing. 2023. Retrieved from: https://ourworldindata.org/energy-mix#renewables-how-much- of-our-energy-comes-from-renewables (Accessed 28 Sep. 2024).

[8] Energy Transition Investment Trends 2024. Tracking global investment in the low-carbon transition. 2024. Retrieved from: https://assets.bbhub.io/professional/sites/24/ Energy-Transition-Investment-Trends-2024.pdf (Accessed 22 Sep. 2024).

[9] Eze, Val & Edozie, Enerst & Umaru, Kalyankolo & Wisdom, Okafor & Chinyere, Ugwu & Ogenyi, Fabian. Overview of Renewable Energy Power Generation and Conversion (2015-2023). *Eurasian Journal of Science and Engineering*. Vol. 4, 2023, pp. 105-113.

[10] FiBL & IFOAM – Organics International. The World of Organic Agriculture. Statistics & emerging trends. 2022. Retrieved from: https://www.fibl.org/fileadmin/documents/shop/1344-organic-world-2022.pdf (Accessed 22 Sep. 2024).

[11] García, M. A., Gallagher, J., Rodríguez, J. A., McNabola, A. An economic and environmental optimization model for sizing a hybrid renewable energy and battery storage system in off-grid farms, *Renewable Energy*, Volume 220, 2024, 119588. doi: 10.1016/j.renene.2023.119588.

[12] Greim, Peter, Solomon, A. A. and Breyer, C. Assessment of Lithium Criticality in the Global Energy Transition and Addressing Policy APS in Transportation. *Nature Communications* 11 (1), 2020, 4570. doi: 10.1038/s41467-020-18402-y.

[13] Hund, Irsten, Daniele La Porta, Thao P. Fabregas, Tim Laing and John Drexhage. Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. World Bank. 2020. Retrieved from: https://pubdocs.worldbank.org/en/9617115888755

36384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf. (Accessed 22 Sep. 2024).

[14] ING. Energy Outlook 2024: High ambitions, steadier speeds. 2024. Retrieved from: https://think.ing.com/uploads/reports/Energy_Outlook_Jan_2024_%28ap%29.pdf (Accessed 28 Sep. 2024).

[15] International Renewable Energy Agency (IRENA). 2024. Retrieved from: http://www.irena.org/ (Accessed 30 Sep. 2024).

[16] Jaden, K., Panton, A. J. and Schwerhoff, G. 2024. Energy Security and The Green Transition. Retrieved from: https://www.imf.org/en/Publications/WP/Issues/2024/01/12/Energy-Security-and-The-Green-Transition-543806 (Accessed 22 Sep. 2024).

[17] Just the facts: renewable energy vs. nonrenewable energy. 2021. Retrieved from: https://justenergy.com/blog/just-the-facts-renewable-energy-vs-nonrenewable-energy (Accessed 30 Sep. 2024).

[18] Key Themes for the Global Energy Economy in 2024. Retrieved from: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2024/01/2024-Key-Themes-Global-Energy-Economy-in-2024.pdf (Accessed 29 Sep. 2024).

[19] Krishna, N. Ganesh, Deqing, Zhang, Scott, J. Miller, Kai, Rossen, Paul J. Chirik, Marisa C. Kozlowski, Julie, B. Zimmerman, Bryan, W. Brooks, Phillip, E. Savage, David, T. Allen and Adelina, M. Voutchkova-Kostal. *Green Chemistry: A Framework for a Sustainable Future Environmental Science & Technology*, 55(13), 2021, pp. 8459-8463. doi: 10.1021/acs.est.1c03762.

[20] Ladenburg, J., Kim, J., Zuch., Soytas, U. Taking the carbon capture and storage, wind power, PV or other renewable technology path to fight climate change? Exploring the acceptance of climate change mitigation technologies – A Danish national representative study, *Renewable Energy*, Volume 220, 2024, 119582. doi: 10.1016/j.renene.2023.119582.

[21] Lassara, C., Orero-Blat, V. and Ribeiro-Navarrete, S. The financial performance of listed companies in pursuit of the sustainable development goals (SDG). *Economic Research*, Vol. 1, 2021, pp. 139-145. doi: 10.1080/1331677X.2021.1877167.

[22] Longo, S., Cellura, M., Luu, Le Q., Nguyen, T. Q., Rincione, R., Guarino, F. Circular economy and life cycle thinking applied to the biomass supply chain: A review, *Renewable Energy*, Vol. 220, 2024, 119598. doi: 10.1016/j.renene.2023.119598.

[23] Makedon, V., Dzeveluk, A., Khaustova, Y., Bieliakova, O., Nazarenko, I. Enterprise multi-level energy efficiency management system development. *International Journal of Energy, Environment, and Economics*, 2021, Vol. 29, Is. 1, pp. 73-91.

[24] Makedon, V., Zaikina, H., Slusareva, L., Shumkova, O., Zhmaylova, O. Use of rebranding in marketing sphere of international entrepreneurship. *International Journal of Entrepreneurship*. Volume 24, Issue 1S, 2020. Retrieved from: https://www.abacademies.org/articles/use-of-rebranding-in-marketing-sphere-of-international-entrepreneurship-9325.html (Accessed 21 Sep. 2024).

[25] Manberger, André, and jörn Stenqvist. Global Metal Flows in the Renewable Energy Transition: Exploring the Effects of Substitutes, Technological Mix and Development. Energy Policy, 2018, Vol. 119 (August), pp. 226–241. doi: 10.1016/j.enpol.2018.04.056.

[26] Obukhov, S., Ibrahim, A., Tolba, M. A., M., El-Rifaie, A. Power balance management of an autonomous hybrid energy system based on the dual-energy storage. *Energies*, 20219, Vol. 12. doi: 10.3390/en12244690.

[27] Orsini, S., Padel, S., Lampkin, N. Labour Use on Organic Farms: a Review of Research since 2000. *Organic Farming*, 2018, Vol. 4, Is. 1, pp. 7–15. doi: 10.12924/of2018.04010007.

[28] Osman, A. I., Chen, L., Yang, M. et al. Cost, environmental impact, and resilience of renewable energy under a changing climate: a Review. *Environmental Chemistry Letters*, 2023, 21, pp. 741–764. doi: 10.1007/s10311-022-01532-8.

[29] Policy assessment: renewable energy development in Indonesia's power sector. 2024. Retrieved from: https://www.climate-transparency.org/wp-content/uploads/2024/01/Implementation-Check-Renewable-Energy-Development-in-Indonesia-2024.pdf (Accessed 22 Sep. 2024).

[30] Products. Energy, sustainability and innovation. Enel Group. 2023. Retrieved from: https://www.enel.com/company/services-and-products (Accessed 22 Sep. 2024).

[31] Renewables 2020: Analysis and forecast to 2025. Retrieved from: https://www.iea.org/reports/renewables-2020 (Accessed 12 Sep. 2024).

[32] Renewable energy consumption (% of total final energy consumption). World Bank. 2023. Retrieved from: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS. (Accessed 29 Sep. 2024).

[33] Renewable energy statistics 2023. International Renewable Energy Agency, Abu Dhabi. 2023. Retrieved from: https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Jul/IRENA_Renewable_energy_statistic s_2023.pdf?rev=7b2f44c294b84cad9a27fc24949d2134. (Accessed 28 Sep. 2024).

[34] Renewables. Latest findings. IEA. 2023. Retrieved from: https://www.iea.org/energy-system/renewables. (Accessed 29 Sep. 2024).

[35] Renewable power growth is surging – driven by the global energy crisis and policy momentum. IEA. 2023. Retrieved from: https://www.iea.org/energy-system/renewables (Accessed 30 Sep. 2024).

[36] RISE – Regulatory Indicators for Sustainable Energy. World Bank. 2023. Retrieved from: https://www.worldbank.org/en/topic/energy/publication/rise---regulatory-indicators-for-sustainable-energy (Accessed 30 Sep. 2024).

[37] Russo, M. A., Carvalho, D., Martins, N., Monteiro, A. Forecasting the inevitable: A review on the impacts of climate change on renewable energy resources. *Sustainable Energy Technology Assess*, 2022, 52, 102283. doi: 10.1016/j.seta.2022.102283.

[38] Santi, M., Sancineto, L., Nascimento, V., Azeredo, J. B., Orozco, E. V. M., Andrade, L. H., Gröger, H., Santi, C. Flow Biocatalysis: A Challenging Alternative for the Synthesis of APIs and Natural Compounds. *International Journal of Molecular Sciences*, 2021, 22(3), 990. doi: 10.3390/ijms22030990.

[39] Serhan, C. Climate Change and Energy Security: The Dilemma or Opportunity of the Century?" *IMF*. September 9, 2022. Retrieved from: https://www.imf.org/en/Publications/WP/Issues/2022/09/08/Climate-Change-and-Energy-Security-The-Dilemma-or-Opportunity-of-the-Century-523249. (Accessed 24 Sep. 2024).

[40] Subramani, Dr. Pragaspathy & Kasireddy, Idamakanti & Rao, R.V.D. & Vas, Vijetha & Chittala, Phani & Korlepara, Prakash. *International Conference on Smart and Sustainable Energy Systems (ICSSES 2024)*, 16-17.

[41] The big choices for oil and gas in navigating the energy transition. 2023. McKinsey & Company. Retrieved from: https://www.mckinsey.com/industries/oil-andgas/our-insights/the-big-choices-for-oil-and-gas-in-navigating-the-energytransition?cid=emlweb (Accessed 24 Sep. 2024).

[42] The Paris Agreement. What is the Paris Agreement? United Nations. 2023. Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement (Accessed 30 Sep. 2024).

[43] World Energy & Climate Statistics–Yearbook 2023. Retrieved from: https://yearbook.enerdata.net/electricity/world-electricity-production-statistics.html (Accessed 27 Sep. 2024).

[44] Yilma, Hasan Ümitcan, Steven O. Imbrough, Clemens, van Dinther, and Dogan, Eles. Power-to-Gas: Decarbonisation of the European Electricity System with Synthetic Methane. *Applied Energy*, 2022, 323 (October), 119538. doi: 10.1016/j.apenergy.2022.119538.

[45] Zhang, X., Yao, G., Vishwakarma, S., Musumba, M., Heyman. A. and Eric A., Davidson Quantitative assessment of agricultural sustainability reveals divergent priorities among nations. *One Earth*, 2021, Vol. 4, pp. 1262-1277. doi: 10.1016/j.oneear.2021.08.015.