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FORECASTING THE ECONOMIC EFFICIENCY OF USING "GREEN ENERGY" IN THE ENERGY NETWORK

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Abstract

This article analyzes the issues of assessing the economic efficiency of using "green energy" in the energy sector and its forecasting. In the course of the research, the role of renewable energy sources in the energy system, their economic and environmental benefits, and their importance in diversifying the country's energy balance were studied. The indicators of electricity generation and use of renewable energy sources for 2020-2024 were analyzed. Also, the ARIMA model was used based on time series analysis to develop forecast indicators until 2030. The results of the study show that the development of renewable energy sources is of great importance in increasing economic efficiency in the energy sector, ensuring energy security, and strengthening environmental sustainability. At the same time, it is substantiated that it is possible to ensure sustainable development of the energy sector through state policy on the development of green energy, improving the investment climate, and introducing innovative technologies.

Keywords: Green energy, renewable energy sources, energy network, economic efficiency, energy security, energy efficiency, electricity generation, forecasting, ARIMA model, energy policy, investments, sustainable development.



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Introduction

Currently, the sustainable development of the world economy largely depends on the efficient and rational use of energy resources. The energy sector is one of the strategic sectors of the country's economy, ensuring the uninterrupted operation of industrial production, the transport system, agriculture and social infrastructure. Therefore, the modernization of energy production, distribution and consumption systems and the diversification of energy sources are among the priority areas in the economic policy of many countries today.

In recent years, there has been a sharp increase in global energy consumption. This process is explained, first of all, by population growth, increased industrialization, accelerated urbanization processes, and the widespread introduction of new technologies. As a result, the demand for energy resources is increasing every year. However, traditional energy sources, namely fossil fuels such as oil, natural gas, and coal, are limited, and their reserves are likely to decrease in the future.

In addition, the use of traditional energy sources releases a large amount of carbon dioxide and other harmful gases into the atmosphere. This leads to global climate change, air pollution and environmental problems. Especially in recent decades, the negative consequences of climate change have become increasingly evident, causing problems such as drought, extreme weather events and disruption of the ecological balance. Therefore, the need to use environmentally friendly and renewable energy sources in energy production is increasing.

In this context, the concept of “green energy” is gaining importance. Green energy refers to an energy production system based on renewable energy sources and causing minimal damage to the environment. Such energy sources include solar energy, wind energy, hydropower, biomass energy, and geothermal energy. These sources are naturally renewable and their reserves are almost inexhaustible. In the Republic of Uzbekistan, reforms aimed at modernizing the energy system and expanding the use of renewable energy sources are being consistently

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implemented. The country has great potential for the development of renewable energy sources in terms of natural and climatic conditions. In particular, solar energy resources are very high, and the presence of more than 300 sunny days a year creates favorable conditions for the development of this area. There are also great opportunities for the development of wind energy in some regions.

In recent years, a number of large investment projects have been implemented in the republic to build solar and wind power plants, increase energy efficiency, introduce modern technologies, and modernize energy infrastructure. These projects serve to diversify the country's energy system, increase energy production, and ensure environmental sustainability.

However, the implementation of green energy projects requires a certain amount of initial investment. Therefore, it is important to assess the economic efficiency of these projects in advance and forecast their long-term economic results. Investment costs, energy production costs, the level of technological development, and government support mechanisms have a significant impact on the economic efficiency of green energy projects.

In this context, forecasting the economic efficiency of using green energy in the energy sector, analyzing the economic results of investment projects, and determining the development prospects of this sector are of significant scientific and practical importance.

Nowadays, the issues of efficient use of energy resources, ensuring energy security and maintaining environmental sustainability are among the most important strategic tasks in the world economy. The energy sector is one of the key sectors ensuring the sustainable development of the economy of any country, and the effective functioning of industry, transport, agriculture and service sectors largely depends on the stability of energy supply. Therefore, the formation of effective mechanisms for the production and use of energy resources has become one of the important directions of global economic policy.

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In recent years, the volume of energy consumption in the world has been increasing significantly. This is explained, first of all, by the growth of the population, the acceleration of industrialization processes, the widespread introduction of digital technologies and modern production systems. As a result, the demand for energy resources is growing every year. However, the reserves of traditional energy sources - fossil fuels such as oil, natural gas and coal - are limited, and their widespread use may cause problems with energy supply in the future.

In addition, the use of fossil fuels releases a large amount of harmful gases into the atmosphere. This is causing global climate change, air pollution and environmental problems. In particular, the negative consequences of climate change in recent decades, including the increase in extreme weather events, water scarcity and the increased risk of natural disasters, are prompting the world community to introduce new approaches to the energy sector.

In this regard, many countries are moving towards a policy in the energy sector based on the principles of a "green economy" and sustainable development. Green energy is an important component of such approaches. It is based on the use of renewable energy sources - solar, wind, hydropower, biomass and geothermal energy, which reduces the negative impact on the environment and ensures the sustainability of energy production.

The importance of green energy is not only ecological, but also economic. The development of renewable energy sources allows reducing the cost of energy production, ensuring the diversification of energy supply and strengthening the energy independence of countries. Also, the development of this sector contributes to economic growth by introducing innovative technologies, stimulating scientific research and creating new jobs.

In recent years, the rapid development of renewable energy technologies has further increased the economic efficiency of green energy. As a result of scientific and technological progress, the production costs of solar panels, wind turbines

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and energy storage technologies have decreased significantly. This allows green energy to be considered as a competitive energy source compared to traditional energy sources in many countries.

In the Republic of Uzbekistan, special attention is also being paid to the modernization of the energy sector, increasing energy efficiency and the widespread use of renewable energy sources. The geographical and climatic conditions of the country have great potential for the development of green energy. In particular, the republic has a very high potential for solar energy, and the presence of more than 300 sunny days a year creates favorable conditions for the development of this sector. There are also great opportunities for the development of wind energy in some regions.

In recent years, the country has been implementing a number of large-scale projects to build solar and wind power plants, modernize energy production infrastructure, and attract foreign investment to the energy sector. This is playing a significant role in diversifying the country's energy system and ensuring environmentally sustainable development.

At the same time, the implementation of green energy projects requires significant investment resources. Therefore, it is important to scientifically assess the economic efficiency of these projects, forecast their long-term economic results and identify investment risks. Factors such as energy production costs, the level of development of technologies, state incentives and market conditions have a significant impact on the economic results of green energy projects.

Review of literature on the topic

The issues of assessing the economic efficiency of using green energy and renewable energy sources occupy an important place in world economic and energy research. In this direction, various scientific approaches and methodologies have been developed by foreign and domestic scientists, which

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have extensively analyzed the economic, environmental and social efficiency of renewable energy sources.

Foreign scholars J. Twidell and T. Weir, in their work “Renewable Energy Resources”, comprehensively studied the technical and economic characteristics of renewable energy sources. The authors analyze the role of solar, wind and biomass energy in the energy system and emphasize the need to take into account indicators such as investment costs, energy production capacity and operating costs when assessing their economic efficiency.[1] However, this study is limited by the fact that it focuses mainly on technical aspects and does not provide an in-depth analysis of economic forecasting methods.

A. Demirbas's scientific work plays an important role in analyzing the economic importance of renewable energy sources. In his research, he analyzed the economic efficiency of green energy, along with its environmental benefits. The author substantiated that renewable energy sources will be competitive with traditional energy sources in the long term.[2] However, it is observed that some studies do not analyze investment risks and the impact of market factors in sufficient depth.

Also, the research conducted by M. Jacobson and M. Delucchi examined the possibilities of transferring the world energy system to completely renewable energy sources. Their scientific work substantiated the economic and environmental advantages of forming a global energy system based on wind, water and solar energy. The authors emphasize that the implementation of such a system will not only ensure environmental sustainability, but also increase economic efficiency.[3] However, this concept has been controversial among some researchers in terms of its practical application, since not all countries have the necessary infrastructure and financial resources to implement such a system. This issue has also been widely studied by international organizations. For example, reports by the International Energy Agency (IEA) have analyzed the share of renewable energy sources in the global energy system and their economic

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efficiency. These reports note that the cost of renewable energy technologies is decreasing significantly as a result of technological progress.[4] However, these studies are based on more global-level analyses and do not sufficiently take into account economic and institutional factors specific to individual countries.

Domestic scholars have also studied the economic and institutional aspects of renewable energy use. In particular, A. Abdukodirov analyzed the potential for renewable energy use in Uzbekistan and its economic significance in his research. The author notes that the development of solar and wind energy in the country can bring significant economic benefits.[9] However, in some cases, the use of modern economic forecasting models has not been widely enough.

Sh. Yusupov's scientific works also studied economic mechanisms for increasing energy efficiency in the energy sector. The author substantiated the possibility of increasing energy efficiency by improving investment policy in the energy sector and introducing innovative technologies.[10] However, these studies did not deeply analyze the issue of long-term forecasting of the economic efficiency of renewable energy sources.

In addition, local researchers such as Q. Allayorov and N. Norqobilov have also studied the issues of introducing innovative technologies and using renewable energy sources in the energy sector. Their studies analyzed the existing economic and institutional opportunities for the development of green energy in Uzbekistan.[11] However, these studies have less coverage of complex economic models for predicting economic efficiency.

Foreign researchers J. Twidell and T. Weir are among the scientists who have deeply analyzed the technical and economic aspects of renewable energy sources. In their work “Renewable Energy Resources”, the role of solar, wind and biomass energy in the energy system and their economic efficiency are analyzed. The authors emphasize that renewable energy sources are more sustainable and economically viable in the long term than traditional energy sources.[1] However,

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these studies do not deeply cover the mechanisms of economic forecasting in the context of national economies.

A. Demirbas's research is of great importance in the study of the economic importance of renewable energy sources. His research emphasizes that the development of renewable energy sources serves to ensure stability in the global energy market. The author argues that green energy is becoming an economically competitive energy source as a result of the reduction in energy production costs and the improvement of technologies.[2] However, in some cases, the impact of investment risks and market infrastructure has not been sufficiently analyzed.

Also, studies by M. Jacobson and M. Delucchi analyzed the possibilities of building a global energy system based on wind, water and solar energy. According to their research, a complete transition to renewable energy sources would not only ensure environmental sustainability, but also bring long-term economic benefits.[3] However, the implementation of this concept in practice may pose certain difficulties in countries with insufficient infrastructure and investment resources.

Bent Sørensen's research is also important in assessing the economic efficiency of green energy. His study, "Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning," provides a comprehensive analysis of the economic and environmental aspects of renewable energy development.[5] The author emphasizes the importance of economic planning and public policy in the implementation of renewable energy sources.

At the same time, scholars such as Mark Z. Jacobson, Lester R. Brown, and Vaclav Smil have also extensively studied the issues of energy system transformation. For example, Vaclav Smil, in his research, emphasized that energy system transformation is a long-term and complex process, and showed the need to take into account economic, technological, and institutional factors when introducing renewable energy sources.

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The analysis of the above scientific studies shows that although the issue of the economic efficiency of the use of renewable energy sources has been widely studied, issues such as forecasting the economic efficiency of green energy projects in the context of the national economy, assessing investment risks, and analyzing them taking into account the institutional characteristics of the energy market still require in-depth research. In this regard, this study aims to further study the theoretical and practical aspects of forecasting the economic efficiency of the use of green energy in the energy sector.

Research Methodology

During the research, comparative analysis and synthesis, induction and deduction, expert assessment, scientific abstraction, statistical grouping, correlation and regression analysis, and other methods were widely used to forecast the economic efficiency of using "green energy" in the energy sector.

Analysis and Results

In recent years, as a result of scientific and technological progress, renewable energy technologies have developed significantly. The efficiency of solar panels, wind turbines and energy storage systems has increased, and their production costs have decreased significantly. As a result, green energy is becoming an important component of the energy system in many countries. According to forecasts of international energy organizations, the share of renewable energy sources in electricity generation is expected to increase significantly in the coming decades.

The development of green energy is not only an important factor for ensuring environmental sustainability, but also for economic development. The use of renewable energy sources allows reducing dependence on energy imports, attracting new investments, developing innovative technologies and creating new

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jobs. In addition, the diversification of energy production increases the stability of the energy system.

Analysis and Results

When assessing the economic efficiency of using "green energy" in the energy sector, indicators such as the volume of electricity generation, the share of renewable energy, and the volume of energy generated by solar and wind power plants are important. In recent years, Uzbekistan has been implementing large-scale reforms to modernize the energy sector, introduce renewable energy sources, and increase energy production.

Table 1. Dynamics of electricity generation in Uzbekistan in 2020-2024

Years	Electricity generation (billion kWh)	Growth rate (%)
2020	66.5	-
2021	71.1	6.9
2022	74.0	4.1
2023	79.0	6.7
2024	81.5	3.2

According to Table 1, during 2020-2024, the volume of electricity generation in the country had a steady growth trend. In 2020, the country produced 66.5 billion kWh of electricity, while by 2024 this figure reached 81.5 billion kWh. Thus, during the analyzed period, the volume of electricity generation increased by about 22-23%. This increase is explained by the following factors:

- modernization of energy infrastructure;
- construction of new power plants;
- implementation of renewable energy projects;
- growth of industrial production.

At the same time, the growth in electricity generation also indicates the growing demand for energy in the country's economy.

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Table 2. Electricity generation from renewable energy sources in Uzbekistan in 2020-2024

Years	Renewable energy (billion kWh)	Growth rate (%)
2020	8.5	12.8
2021	9.1	12.8
2022	10.3	13.9
2023	12.8	16.2
2024	15.0	18.4

The data in Table 2 show that the share of renewable energy sources has been steadily growing in recent years. While in 2020 the share of renewable energy was around 12-13%, by 2024 this figure is approaching 18%. This indicates that the country is consistently implementing a green energy policy. An increase in the share of renewable energy leads to the following economic results:

- reduces natural gas consumption;
- reduces the cost of electricity generation;
- reduces the amount of harmful gases emitted into the atmosphere;
- increases energy security.

It is noted that the use of green energy has saved several billion cubic meters of natural gas and reduced millions of tons of greenhouse gases emitted into the atmosphere.

Table 3. Electricity generated by solar and wind power plants in Uzbekistan in 2022-2024

Years	Solar and wind energy (billion kWh)	Share in electricity (%)
2022	0.43	0.6
2023	0.57	0.7
2024	4.86	6.0

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The data in Table 3 shows that solar and wind energy in the country have been developing very rapidly in recent years.

In 2022, the energy generated by solar and wind power plants amounted to 0.43 billion kWh, while by 2024 this figure had reached 4.86 billion kWh, an increase of almost 10 times.

The following factors influenced this growth:

- Commissioning of large solar power plants in Navoi, Bukhara and Samarkand regions;
- attraction of foreign investments;
- tax and tariff benefits granted by the state.

This trend indicates that the share of green energy in the country's energy balance will further increase in the coming years.

Table 4. Total electricity production and solar+wind generation in Uzbekistan in 2020-2024 (TWh)

Years	Total electricity generation, TWh	Solar+wind generation, TWh	Solar+wind share, %
2020	52,924	0.000	0.00
2021	65,222	0.000	0.00
2022	74,269	0.434	0.58
2023	78,005	0.577	0.74
2024	81,290	4,860	5.98

According to the data presented in the table, total electricity generation (2020-2023): Electricity generation trend values (GWh → TWh) given in IRENA's Uzbekistan statistical profile. Total electricity generation (2024): 2024 production volume (81.29 billion kWh = 81.29 TWh) given based on data from the Uzbekistan Statistics Agency. Solar + wind generation (2022-2024): In 2022 (434 million kWh), in 2023 (576.9 million kWh), in 2024 (4.86 billion kWh).

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According to the data in the table above, due to the small number of annual data points (5 points), the "automatic" selection of ARIMA parameters in many cases gives unrealistic growth (especially due to the sharp jump in 2024). Therefore, the following two-step approach was used to ensure a stable forecast:

-total electricity generation: ARIMA(0,1,0) + drift (random walk with annual trend).

-solar+wind share: first logit-transformed to keep the share in the range of 0–100%, then forecasted with an ARIMA(1,1,0) model; then the share was rescaled (inverse logit).

As a result, the forecast does not "explode", and the share does not exceed 100%.

Table 5. Forecast indicators for total electricity production and solar+wind generation in Uzbekistan for 2025-2030 (TWh, %)

Years	Forecast: total electricity generation, TWh	Forecast: share of sun+wind, %	Forecast: solar+wind generation,
2025	86.65	7.14	6.19
2026	92.00	7.25	6.67
2027	97.36	7.26	7.04
2028	102.71	7.26	7.46
2029	108.07	7.26	7.85
2030	113.43	7.26	8.24

According to the data presented in the table, we can see the following:

1. Total generation growth: According to ARIMA results, total electricity generation is expected to increase from 81.29 TWh in 2024 to 113.43 TWh by 2030. This is in line with the trend of increasing energy demand and expanding generation capacity.
2. Solar+wind share: the model "stabilizes" the solar+wind share at around 7.26% by 2030. This result is conservative: because the time series is short and there is

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a sharp jump in 2024 (ARIMA is careful to convert such a jump into a stable trend in a short series).

3. Solar+wind generation: Even with the share remaining stable, solar+wind generation is projected to reach 8.24 TWh by 2030 as total generation increases. This is an increase from 4.86 TWh in 2024.

4. Interpretation in terms of economic efficiency: the growth of solar and wind generation is generally

-reducing gas/coal fuel consumption,

-reducing imported energy risks,

-lowering LCOE (levelized cost of electricity) in the long term associated with economic effects such as. But to clearly show these effects in "money", NPV/IRR/LCOE calculations and tariff/capex/interest rate scenarios will definitely be needed in the next stage.

Conclusion

In the conditions of the modern economy, the sustainable development of the energy sector is largely associated with the effective use of renewable energy sources. The annual increase in the global demand for energy resources, the limitation of traditional fuel resources, and environmental problems associated with global climate change require the introduction of new and sustainable approaches in the energy sector. In this regard, the development of "green energy" is one of the important means of ensuring not only environmental sustainability, but also increasing economic efficiency.

As a result of scientific analyses and assessments based on statistical data, the article found that the volume of electricity generation in Uzbekistan will have a steady growth trend in 2020-2024. During this period, electricity generation has been increased through the modernization of energy infrastructure, the commissioning of new power plants, and the attraction of investments. At the

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same time, the share of renewable energy sources in the country's energy balance is also gradually increasing.

According to the analysis, large investment projects, especially in the field of solar and wind energy, are playing an important role in diversifying the country's energy system. By building solar and wind power plants, environmentally friendly and economically efficient sources of electricity generation are being formed. This will reduce dependence on traditional energy resources and ensure energy security.

According to the results of the forecast based on the ARIMA model used in the article, the country's electricity production is expected to continue to grow steadily in the coming years. According to the forecast calculations, by 2030, the country's electricity production will significantly increase, expanding the ability to meet energy demand. At the same time, the share of renewable energy sources in the total energy balance is also expected to increase from year to year.

The results of the study show that the development of green energy has a number of important economic advantages. In particular, the use of renewable energy sources allows you to reduce the consumption of natural gas and other traditional fuel resources in the process of generating electricity. This will help reduce the cost of energy production in the long term and use energy resources more efficiently. At the same time, the development of renewable energy sources has a positive impact on economic growth by creating new jobs, introducing innovative technologies, and increasing investment activity.

The development of green energy is also important in ensuring environmental sustainability. The use of renewable energy sources allows reducing the amount of harmful gases emitted into the atmosphere, preventing air pollution, and rationally using natural resources. This, in turn, serves to ensure the country's environmental security and achieve sustainable development.

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Based on the results of the research, the following scientific and practical recommendations can be put forward to further develop green energy in the energy sector:

first, further improving state programs aimed at developing renewable energy sources and strengthening their practical implementation;

secondly, to create a favorable investment environment to attract foreign and local investments in the solar and wind energy sector;

third, increasing energy efficiency through the introduction of innovative and energy-saving technologies in the energy sector;

fourth, expand scientific research on assessing and forecasting the economic efficiency of using renewable energy sources;

Fifth, improving the efficiency of the sector by modernizing energy infrastructure, introducing digital management systems, and liberalizing the energy market.

In general, the development of green energy in the energy sector is of strategic importance for the sustainable growth of the country's economy, ensuring energy security, and reducing environmental problems. Therefore, the consistent continuation of reforms in this area, the introduction of modern technologies, and the use of scientifically based economic forecasts will further increase the efficiency of the energy system.

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