eISSN: 2229-3213 pISSN: 2229-3205
The Journal of Applied Science and Social Science
Volume 16,Issue 02 February, 2026

UDK: 620.91:330.341.1

METHODOLOGY FOR INCREASING THE EFFICIENCY OF RENEWABLE ENERGY SOURCES IN AN INNOVATIVE ECONOMY

Qodirov Bakhodirjon Tursunovich
University bussines and science
Senior lecturer of the Department of “Green Economy”, PhD
qodirovbahodir0175@gmail.com
Orcid iD:0009-0001-9363-5667

Abstract

This article analyzes the role of renewable energy sources in the innovative economy of the Republic of Uzbekistan and the methodology for increasing their efficiency. The study studied the dynamics of energy production in 2016–2024 based on international (IEA, IRENA, World Bank) and national (Ministry of Energy) data. The economic efficiency of renewable energy sources was assessed using LCOE (levelized cost of ownership), CF (capacity utilization factor) and scenario modeling methods. According to the results, by 2030, renewable energy capacity is expected to reach 25 GW, and the volume of "green" energy production is expected to reach 64 billion kWh. The article provides an in-depth analysis of investment activity, technological development and socio-economic impacts within the framework of the "Green Economy" strategy.

Key words

renewable energy, LCOE, CF, “green economy”, energy efficiency, scenario modeling.

Annotatsiya

Ushbu maqolada O‘zbekiston Respublikasida qayta tiklanuvchi energiya manbalarining innovatsion iqtisodiyotdagi o‘rni va ularning samaradorligini oshirish metodologiyasi tahlil qilingan. Tadqiqotda xalqaro (IEA, IRENA, World Bank) hamda milliy (Energetika vazirligi) ma’lumotlar asosida 2016–2024-yillardagi energiya ishlab chiqarish dinamikasi o‘rganildi. LCOE (darajalangan tannarx), CF (quvvatdan foydalanish koeffitsiyenti) va ssenariy modellashtirish usullari orqali qayta tiklanuvchi energiya manbalarining iqtisodiy samaradorligi baholandi. Natijalarga ko‘ra, 2030-yilgacha qayta tiklanuvchi energiya quvvati 25 GBтga, “yashil” energiya ishlab chiqarish hajmi esa 64 mlrd kVt·soatga yetishi kutilmoqda. Maqolada “Yashil iqtisodiyot” strategiyasi doirasida investitsion faollik, texnologik rivojlanish va ijtimoiy-iqtisodiy ta’sirlar chuqur tahlil etilgan.

Kalit so‘zlar

qayta tiklanuvchi energiya, LCOE, CF, “yashil iqtisodiyot”, energiya samaradorligi, ssenariy modellashtirish.

Аннотация

В данной статье анализируется роль возобновляемых источников энергии в инновационной экономике Республики Узбекистан и методология повышения их эффективности.отация: В данной статье анализируется роль возобновляемых источников энергии в инновационной экономике Республики Узбекистан и методология повышения их эффективности. Вннотация: В данной статье анализируется роль возобновляемых источников энергии в инновационной экномике Республики Узбекистан и методология повышения их эффективности. В исследовании изучалась динамика производства энергии в 2016-2024 годах на основе международных (МЭА, IRENA, World Bank) и национальных (Министерство энергетики) данных. Экономическая эффективность возобновляемых

источников энергии оценивалась с помощью методов LCOE (оцененная стоимость), CF (коэффициент использования мощности) и сценариев моделирования. Согласно результатам, ожидается, что к 2030 году мощность возобновляемых источников энергии достигнет 25 ГВт, а производство “зеленой” энергии достигнет 64 млрд кВт·ч.ласно результатам, ожидается, что к 2030 году мощность возобновляемых источников энергии достигнет 25 ГВт.

Ключевые слова

возобновляемые источники энергии, LCOE, CF, “зеленая экономика”, энергоэффективность, сценарное моделирование.

Introduction: In the 21st century, one of the most important directions of sustainable development in the world economy is the efficient use of energy resources and the introduction of renewable energy sources. The increase in global energy demand, the increase in carbon emissions, and the environmental risks associated with climate change have created the need for countries to transition from traditional energy models to innovative, “green” economic systems. In an innovative economy, energy efficiency is not only the main driver of economic growth, but also an important factor ensuring sustainable social development and environmental safety. Therefore, the widespread use of renewable energy sources - solar, wind, hydro and biomass technologies - is gaining strategic importance for every country.

The Republic of Uzbekistan, not remaining aloof from this global trend, has been pursuing a consistent policy in recent years to gradually implement the principles of a “green economy” and develop renewable energy sources. The country is implementing large-scale reforms, such as the construction of solar and wind power plants, the introduction of energy-saving technologies, the digitalization of energy infrastructure, and the reduction of losses in electricity networks. The legal basis for these reforms is set out in the “Strategy of the Republic of Uzbekistan for the Transition to a “Green Economy” for 2019–2030”, approved by the Presidential Decree. This strategy includes long-term national goals for the development of renewable energy sources, increasing energy efficiency, reducing carbon emissions, and ensuring environmental sustainability.[1]

According to the strategy, the following results are aimed to be achieved by 2030:

- Reduce greenhouse gas emissions per unit of gross domestic product by 35 percent compared to 2010 levels;
- increasing the share of renewable sources in electricity generation to at least 25 percent;
- doubling energy efficiency in the energy sector;
- significantly reduce the amount of harmful substances released into the environment.

These goals are fully aligned with the UN Sustainable Development Goals (SDG-7: Affordable and Clean Energy) and also serve as the basis for Uzbekistan's Nationally Determined Contribution (NDC) commitments under the Paris Agreement. The NDC sets a target of reducing greenhouse gas emissions by at least 35 percent per unit of GDP by 2030 (UNFCCC, 2021).[2]

Methodology: The main methodological basis is the theory of innovative economics, the energy sustainability model and the concept of "green economy". The theoretical foundation of the study was formed on the basis of the following scientific concepts:

- Sustainable development paradigm (UN, 1987; OECD, 2001)
- Green Economy Concept (UNEP, 2011)
- Energy Efficiency Model (IEA, 2023)
- Renewable Energy Transformation Theory (IRENA, 2022)

These theoretical foundations are inextricably linked to Uzbekistan's strategy for transitioning to a “Green Economy” and serve to harmonize national policy with international experiences.[3]

The analysis was carried out using the following methods:

1. Statistical analysis method - assessment of energy production and consumption dynamics based on data from the Ministry of Energy, IEA, IRENA, and the World Bank.

2. Comparative analysis method - comparing Uzbekistan's renewable energy performance with Central Asian countries.

3. Trend Analysis (Time Series Analysis) – Determining energy production rates between 2016 and 2024.[4]

4. CAGR (Compound Annual Growth Rate) – calculation of the average annual growth rate.

5. SWOT analysis – identifying strengths, weaknesses, opportunities and threats.

6. Scenario modeling - forecasting the growth of energy production and the share of "green" energy by 2030.

The country's production balance is 80–85% thermal power plants (mainly natural gas, partly coal), 16% "green" energy (of which 10–12% hydro, 4–6% solar and wind). This composition has been diversifying in recent years: 4 GW of new alternative capacities have been commissioned, and the share of "green" energy has reached 16%.[5]

Two directions are shaping this dynamic:

(i) New generation – launch of large solar and wind projects;

(ii) Demand side – expansion of household-scale solar panel installation (over 60,000 households).

The aging of the electricity transmission and distribution infrastructure (many networks are 30–40 years old) has kept losses high. However, losses, which were 18% in 2019, have fallen to 14% in 2024 (a relative reduction of ≈22%). The goal is to reduce losses to 8–9% by 2030.[6]

At the project level, renewables are becoming increasingly economically competitive: the price of 1 kWh of electricity in thermal plants is 5–6 cents, and in solar and wind it is on average around ≈3 cents. This demonstrates the cost advantage of "green" energy.

The main drivers of dynamic growth are:

Political priority: The transition to a “green economy” is included in strategic plans and aligned with the UN SDG-7 agenda.

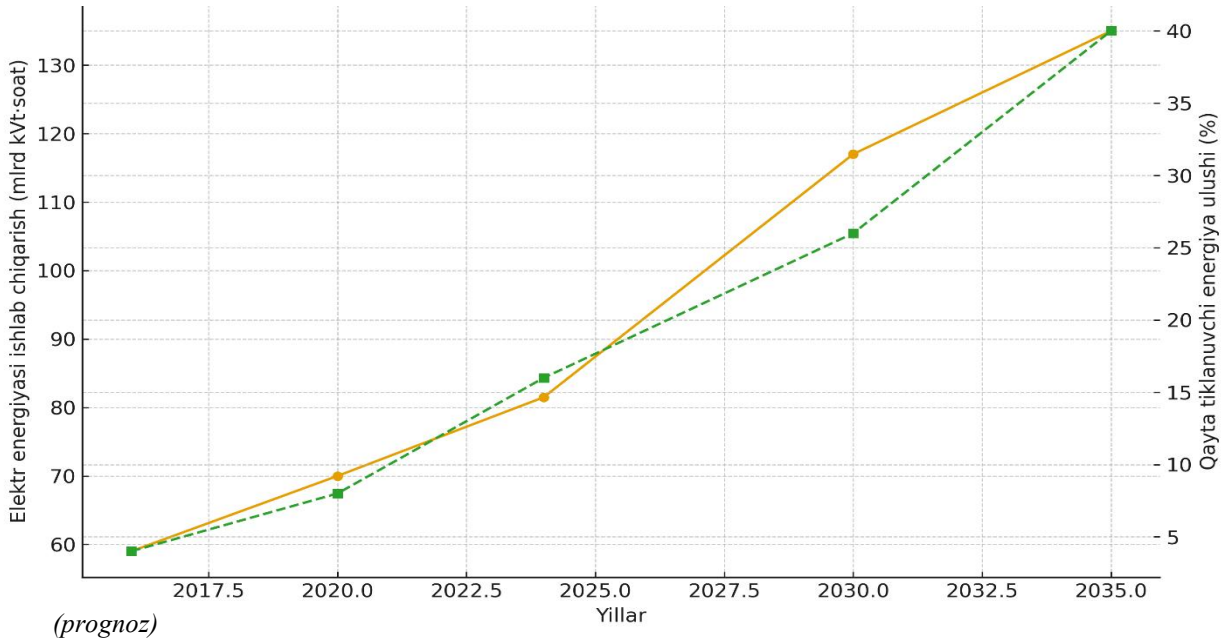
Investment projects: In the period 2025–2030, it is planned to increase the share of renewable energy in production to 26% and in total generation capacity to 40% by commissioning large solar and wind power plants (4.5 GW), installing 785 MW of photovoltaic panels, and building 225 MW of hydroelectric power plants.

Strategic goals: to increase the capacity of renewable energy sources to 25 GW by 2030, increase annual “green” energy production to 64 billion kWh, and increase the share of RE in total generation to 54%. This will allow reducing harmful gas emissions by ≈16 million tons annually.

National investment programs mandate that 15% of all new projects will include “green components” starting in 2025, 30% in 2027, and 55% in 2030. This will strengthen portfolio discipline and ensure stable financial flows.

1-Picture. Dynamics of renewable energy sources in Uzbekistan (scientific analysis)

Figure 1 shows the dynamics of changes in Uzbekistan's electricity generation and the share of renewable energy sources in 2016–2035. As can be seen from the graph, the total generation is



expected to grow from 59 billion kWh in 2016 to 135 billion kWh in 2035, i.e., a 2.3-fold increase. At the same time, the share of renewable energy sources (solar, wind, hydro) is expected to increase from around 4% in 2016 to 40% by 2035. This trend indicates the gradual implementation of the "green economy" strategy in Uzbekistan. As a result of the steady growth of dynamics, it is planned that by 2030 the renewable energy generation capacity will reach 25 GW, and the "green" energy produced will amount to 64 billion kWh per year. These indicators indicate the acceleration of the processes of environmental sustainability, resource efficiency, and the introduction of innovative technologies in the country's energy system.

Discussion: Investment activity in Uzbekistan’s renewable energy sector has increased significantly in recent years. The number of large projects financed by the World Bank, the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), and the Global Green Growth Institute (GGGI) is increasing. Between 2020 and 2024, the country will commission 4 GW of new renewable energy facilities, of which 2.6 GW of solar, 1.1 GW of wind, and 0.3 GW of hydropower. The total volume of foreign investments attracted for these projects amounted to more than 3.8 billion US dollars.

Also, within the framework of the “Green Energy Investment Program” for 2023–2030, cooperation has been established with more than 25 international investors on the basis of Power Purchase Agreement (PPA). This system provides a stable source of income for investors and has a positive impact on Uzbekistan's credit rating. In order to encourage investments in the country, tax incentives, a free customs regime, and a 15–25-year guaranteed tariff system have been introduced. In addition, opportunities for financing renewable energy projects through the “green bonds” mechanism are expanding. In cooperation with international institutions, grants and preferential loans are being attracted from organizations such as the EBRD, the World Bank, and GGGI, which stabilizes the flow of “green” projects.[7]

In recent years, the private sector has been rapidly increasing its share in renewable energy projects. Large companies such as Masdar (UAE), ACWA Power (Saudi Arabia), Total Eren (France) and Voltalia (France) are building solar and wind power plants in Uzbekistan. For example, projects such as the Zarafshan wind power plant (500 MW) and the Navoi solar power

plant (100 MW) are considered the largest "green" generation facilities in the region. The number of such facilities is expected to exceed 30 by 2030.

In the local industry, steps are also being taken to establish the production and service of energy equipment. In 2024, the Nur Energy Components plant launched the production of metal frames and inverter parts for solar panels. This serves to increase the share of local added value through an "import substitution" policy. By 2030, it is planned to attract a total of 10-12 billion US dollars in investment in the renewable energy sector in Uzbekistan. Of this, 60% will be covered by foreign and 40% by local sources.[8]

According to strategic goals:

The share of "green" energy will be increased to 26% in production and 40% in total generation;

25 GW of renewable energy will be built;

≈16 million tons of CO_2 emissions will be reduced annually;

More than 25,000 new jobs will be created in the renewable energy sector. These goals are fully consistent with Uzbekistan's "Green Economy Strategy" (PQ-4477, 2019) and the "Uzbekistan-2030" concept, aimed at sharply reducing the carbon intensity of the economy.

Renewable energy sources not only increase the stability of the energy system - but also create new economic sectors. According to IRENA (2024), the RE sector worldwide created more than 14 million jobs in 2023; in Uzbekistan, 25-30 thousand new jobs are expected to be created by 2030. These jobs are mainly in the installation of solar panels and wind turbines; maintenance and operation systems; local production of components (frames, inverters, networks).

The greatest social impact in terms of territory is observed in the regions of Kashkadarya, Bukhara, Navoi, Surkhandarya and Karakalpakstan, which are regions with the highest natural resource potential and solar radiation levels. Therefore, renewable energy projects serve as a factor in ensuring regional economic equality and reducing migration.

Since 80–85% of Uzbekistan's energy system is based on thermal power plants, carbon emissions remain high. According to the Green Economy Strategy, by 2030, when the share of renewable sources reaches 54%, 16 million tons of CO_2 emissions will be reduced annually. In addition, solar and wind energy production will reduce NO_x and SO_2 emissions by 30–40%, which will reduce the economic burden on the health system. According to the World Bank (2024) analysis, Uzbekistan will receive positive social benefits of 0.4–0.5% of GDP per year through reduced air pollution.

From the point of view of energy security, renewable sources also provide diversification of production - dependence on fuel imports is decreasing by 1.2 billion m^3 of gas per year. It is planned to establish the export of "green electricity" through new power transmission lines (Surkhandarya-Tajikistan, Karakalpakstan-Kazakhstan) by 2030. This export potential is associated with the seasonal excess capacity of RE plants, the formation of the CAREC regional electricity market and the "Green Power Hub Central Asia" initiative. By 2030, there is a possibility of exporting 1.5–2 billion kWh of "green electricity" per year, which will provide foreign exchange earnings of 150–200 million US dollars.

Uzbekistan's renewable energy strategy is fully aligned with the UN Sustainable Development Goals — in particular, it is directly linked to SDG-7 (Affordable and Clean Energy), SDG-9 (Industry, Innovation and Infrastructure), and SDG-13 (Climate Action). Renewable energy sources expand access to energy; develop innovative technologies; accelerate the transition to a carbon-neutral economy. By 2035, Uzbekistan will begin implementing a national action plan to achieve carbon neutrality within the framework of the Paris Agreement. In this regard, renewable energy sources are seen as the country's main driver.[9]

Conclusion: According to calculations and modeling results, Uzbekistan's renewable energy sector has entered a phase of steady growth in recent years. The fact that electricity

production increased by 38% between 2016 and 2024, and the share of renewable sources in total generation reached 16%, demonstrates the effectiveness of systemic reforms in this area. A new model based on the principles of energy efficiency and a “green economy” is taking center stage in the country's long-term economic strategy.

According to the results of the LCOE and CF models used to assess the economic efficiency of renewable energy sources, the cost of electricity generated at solar and wind power plants is 50–60 percent cheaper than at thermal power plants. At the same time, technical and economic analyses show the possibility of increasing the capacity of renewable sources to 25 GW and the production volume to 64 billion kWh by 2030. This forecast, while ensuring a 54 percent “green” share, has the potential to reduce emissions of harmful gases by up to 16 million tons annually.

The results of the scenario modeling show that if the “accelerated scenario” is implemented in the energy system of Uzbekistan between 2030 and 2035, almost half of the electricity will be generated from renewable sources. Such an outcome will be an important factor in strengthening energy security, reducing fuel imports and reducing the carbon footprint of the national economy. At the same time, it is noted that in the “restricted scenario” - technical, financial or management delays - may slow down the growth of the sector.

Socially, renewable energy projects play a major role in creating new jobs, strengthening interregional economic equality, and forming an ecologically healthy environment. According to estimates, by 2030, about 25-30 thousand new jobs will be created in this direction. At the same time, the need to develop a system for training qualified specialists in "green technologies" is also growing.

The sustainable development of the renewable energy sector for Uzbekistan is closely linked to the following factors:

Improving the investment climate and strengthening cooperation with international financial institutions;

Digitalization of energy generation, transmission and distribution infrastructure;

Development of local technologies through science and innovation centers;

Designation of regional "solar and wind zones" and formation of a cluster system in them;

Introduction of tax and subsidy incentives to improve energy efficiency.

From the perspective of sustainable development strategy, renewable energy sources are emerging as a key driver in Uzbekistan’s transition to a carbon-neutral economy. In line with the UN Sustainable Development Goals (SDG-7, SDG-9, SDG-13), expanding “green” projects will strengthen the country’s international image and increase its competitiveness in the regional energy market.

In conclusion, it is worth noting that renewable energy sources will become one of the main components of Uzbekistan's innovative economy, serving as a foundation for ensuring a balance between economic growth, environmental sustainability and social well-being.[10] In this direction, a combination of scientifically based policy decisions, financial mechanisms and technology transfers is expected to further strengthen the country's energy independence and international position in the coming decade.

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