



# **STRATEGIES FOR DEVELOPING THE USE OF "GREEN ENERGY" IN THE ENERGY INDUSTRY**

Saidov Mash'al Samadovich

Professor, Doctor of economics (DSc)

Rector of Shakhrisabz State Pedagogical Institute,

ORCID: 0009-0008-7814-3972

## **Abstract**

This article provides a scientific and practical analysis of strategies for developing the use of "green energy" in the energy sector. The study examines the role of renewable energy sources - solar, wind, hydropower and other resources in the national energy system, their economic and environmental efficiency. Based on statistical data for 2020-2024, the dynamics of growth in renewable energy capacities and electricity production volumes were analyzed. The issues of state support mechanisms, the importance of investment policy, the need to modernize electricity networks and institutional reforms were also considered. The article develops a comprehensive strategy for the effective introduction of "green energy", including practical recommendations on upgrading infrastructure, improving financial incentive mechanisms, introducing innovative technologies and strengthening the personnel training system.

**Keywords:** Green energy, renewable energy sources, solar energy, wind energy, energy security, decarbonization, energy efficiency, investment policy, sustainable development, energy strategy.

## **Introduction**

In the 21st century, energy resources have become one of the main strategic factors of the world economic system. The level of energy supply is directly related to the industrial potential of the country, its investment attractiveness and the well-being of the population. At the same time, the processes of energy production and consumption on a global scale have a serious impact on the



environment. Reliance on traditional fuels causes large amounts of carbon emissions into the atmosphere, which exacerbates problems such as climate change, desertification, depletion of water resources and loss of biodiversity.

World experience shows that a fundamental transformation of the energy sector is necessary to achieve sustainable development. This process is carried out through the “greening” of the energy system, that is, a gradual increase in the share of renewable energy sources, improving energy efficiency and transitioning to a carbon-neutral economy. Green energy not only mitigates environmental problems, but also allows the formation of new technological industries, increases competitiveness and develops an innovative economy.

The processes of modernization, diversification and digitalization of the energy system are inextricably linked with the development of "green energy". The modern energy concept involves the transition from centralized production to decentralized, intelligent and flexible systems. This requires the local introduction of small-scale solar and wind power plants, the use of energy storage technologies and the development of "smart grids". As a result, the stability of energy supply will increase, losses will be reduced and consumers will be actively involved in the energy market.

Another important aspect of green energy development is its socio-economic impact. Renewable energy projects create new jobs, stimulate local production and attract foreign investment. At the same time, reduced air pollution has a positive impact on public health, reducing medical costs and improving the quality of life.

Green energy also plays an important role in ensuring energy security. Diversification of energy sources reduces dependence on foreign markets, reduces the risk of price fluctuations, and strengthens the stability of the national economy. Especially in the context of instability in the global energy market, reliance on domestic renewable resources provides a strategic advantage.

Based on the above, it is an urgent task to develop strategies for the development of the use of "green energy" in the energy sector and analyze them on a scientific basis. This process requires a comprehensive approach, that is, combining institutional reforms, financial mechanisms, technological innovation and human resources.



Currently, the issue of developing "green energy" in the energy sector is emerging as a priority area of not only environmental, but also strategic economic and social importance. In the context of global climate change, limited natural resource reserves and instability in the energy market, reliance on traditional fuel sources cannot ensure sustainable development in the long term. The energy sector is the main source of greenhouse gases emitted into the atmosphere. Therefore, its decarbonization, that is, the transition to a "green economy" by reducing carbon emissions, has become an urgent task on a global scale.

In recent years, the global energy market has undergone dramatic changes. The decline in the cost of renewable energy technologies, the improvement of energy storage systems and the introduction of "smart grids" have made green energy a competitive source. As a result, many countries are adopting specific targeted programs in their national strategies aimed at increasing the share of renewable energy, reducing coal and oil consumption, and improving energy efficiency. These trends are also shaping new requirements in the context of global economic competition.

The relevance of this issue for Uzbekistan is explained by several factors. First, the demand for electricity in the country is increasing every year. The expansion of industrial sectors, the commissioning of new production capacities and population growth are increasing the pressure on energy supply. The main part of the existing energy production system relies on natural gas, which makes the issue of efficient allocation of resources and their rational use urgent.

Secondly, price fluctuations in the global energy market and geopolitical factors affect energy security. Diversification of energy sources, that is, increasing the share of renewable sources, can ensure stability in relation to external risks. This will strengthen the independence and stability of the country's economy.

Third, the growing environmental problems also increase the need to develop green energy. Atmospheric pollution, deterioration of air quality, and illegal or inefficient use of natural resources have a negative impact on public health. The introduction of renewable energy sources will reduce the emission of harmful substances into the air, which will contribute to increasing social well-being.

Fourth, green energy will diversify the economy and create new jobs. New specializations will be formed in the fields of production, installation and



maintenance of solar panels, wind turbines and energy storage equipment. This will serve to develop an innovative economy and improve the investment climate. The development of renewable energy sources is also relevant within the framework of international obligations and sustainable development goals. The country's active participation in global environmental initiatives requires adapting national energy policy to modern requirements.

Based on the above factors, the issue of developing the use of "green energy" in the energy sector is of strategic importance. In this direction, the development of scientifically based strategies, assessment of economic efficiency, and improvement of institutional mechanisms are important conditions for the long-term sustainable development of the country.

**Review of literature on the topic.** In foreign and domestic literature, the issue of developing "green energy" is mainly covered in three large blocks: the impact of renewable energy on climate and energy security; support policies (FIT, quota/RPS, auctions) and their effectiveness; technical integration (grid, balancing, energy storage), and a socially just transition.

The IPCC AR6 WGIII report identifies increasing the share of renewable energy sources as one of the main ways to decarbonize the energy system. However, the IPCC approach relies more on macro-scenarios: there is a risk of generalizing "small" but crucial factors such as institutional quality, network infrastructure, and cost of capital across countries. That is, the report shows well "what needs to be done", but the questions "how and in what order" require additional national analytical work for implementation.[1]

The IEA's Renewables 2024 report provides a clearer picture of the market and policy implications: it notes that climate and energy security policies in almost 140 countries have made renewable energy competitive with fossil fuels in many cases. However, because the IEA's projections are typically based on a "business as usual" scenario, small changes in legislation (tax incentives, auction rules, permitting processes) can quickly change the projection trajectory. In this sense, it is more appropriate to read the IEA's findings as a risk map rather than a "roadmap." [2]

IRENA reports emphasize technology costs and LCOE dynamics. These sources provide strong evidence to refute the stereotype that "green energy is expensive."



However, IRENA's global averages do not fully reflect the financing, currency risk, grid connection costs, and project development costs in each country.[3,4] Thus, IRENA data are "guidelines" for national strategies, but local cost breakdowns are required when setting tariffs/auction prices.

A classic debate in renewable energy policy is between "price-based" (feed-in tariff) and "quantity-based" (quota/RPS) mechanisms. Butler and Neuhoff compare the experiences of Germany (FIT) and the United Kingdom (tender/certificate) and show that FIT has yielded high adoption rates and relatively low consumer costs, and that the main obstacle is not "price competition" but rather finding a good site and permits. Their strength is that the analysis is based on the real behavior of project developers; their limitation is that the results depend on the specific institutional environment, and failure to take into account the differences in regulatory, grid and land relations when transferring it to another country can lead to erroneous conclusions.[5]

Dong uses multi-country panel data to statistically prove that FIT is more effective in increasing wind power than RPS. This has the advantage of being empirically tested; the disadvantage is that it assumes the same "design quality" and implementation discipline. In practice, however, both FIT and RPS may not be effective if poorly designed; therefore, a statistical "average effect" is not a sufficient rule for national strategy. [6]

Auctions have become increasingly popular in the last decade. IRENA's "Auctions: A Guide to Design" shows that auctions can be used to "identify" the need for subsidies through competition, but also openly discusses the risks of "underbidding", high transaction costs, qualification requirements and project portfolio abandonment. The conclusion is that auctions are not an automatic solution; their effectiveness depends heavily on design details (pre-qualification, penalties, indexation, currency risk sharing, grid connection guarantees). [6]

del Río (in his analysis of auctions) argues that auctions can work well in finding the "lowest price", but when broad objectives such as innovation, local industrial development, diversification (technology/region) are set, the auction rules become more complex, which can reduce the number of participants and weaken competition. Matthäus et al. also show that the level of competition, risk sharing and execution discipline are crucial for an "efficient auction". A critical point: most studies focus on price, but sometimes the macroeconomic effects of network



integration, balancing costs and construction delays are not sufficiently taken into account. [9]

In the design of FITs, Couture and co-authors have shown that investment can be accelerated by reducing risk: the more transparent and predictable the tariff model, the cheaper the financing. However, one of the main risks of FITs is that if the tariff is set incorrectly, “excess rent” and increased consumer costs can occur. For this reason, in practice, many countries are moving from FITs to auctions, but this transition also requires institutional preparation (project preparation market, transparent tendering, claims resolution mechanism). [8]

In the context of Uzbekistan, local and regional studies have primarily focused on measuring resource potential. Rakhimov, Sadullaeva, and co-authors, based on actinometric data, assess the solar resource in Uzbekistan and justify the importance of indicators such as GHI/DNI/DHI in planning photovoltaic generation. The strength of this work is its reliance on real measurements; the weakness is its limited connection to policy designs (tariff/auction/PPP), grid connectivity, and investment risks. That is, the presence of resources is a necessary but not sufficient condition for strategy. [14]

Zakhidov's article on wind resources is one of the first studies to address the feasibility and assessment issues of wind power plants in Uzbekistan. Later, Bahrami and co-authors add a technical and economic assessment (Weibull distribution, power factor, LCOE) and identify specific regions (e.g., the outskirts of Karakalpakstan) as promising. A critical point: many analyses are based on wind data at a height of 10 m and extrapolate to the turbine hub height; this can significantly change the result. [12]

In terms of grid impact, A. Mirzabaev and other authors show that the introduction of renewables changes the power flows along the power transmission lines. Work in this direction is very important for the strategy, since “building generation” and “fitting it into the system” are not the same task. However, large-scale scenario modeling (hourly balance, reserves, price signals, energy storage) is still rare in domestic research; filling this gap would increase the effectiveness of the strategy. [11]

The OECD/IEA report “Solar Energy Policy in Uzbekistan: A Roadmap” systematically lists the obstacles (grid, financing, regulations, PPPs) for Uzbekistan, and raises issues related to the possibility of revising the 2030 targets



and sector reforms. The strength of this source is that it provides recommendations that are close to the local context; its limitation is that it is also largely policy-regulatory, and does not delve into “local grid modeling” and regional grid nodes. In this context, the roadmap needs to be integrated with technical grid studies. [13]

International financial institutions (IFC/World Bank, ADB) documents show how auctions and PPPs work in practice through the first large-scale solar projects in Uzbekistan (Navoi, Scaling Solar). An important conclusion from them is that the factors that “ensure investor acceptance” are usually broader than price - payment guarantees, PPA terms, conversion/currency risk, grid connection and permit deadlines. If these aspects are not translated into clear mechanisms in the national strategy, projects may slow down, even if there is resource potential and political will. [14]

Finally, the UNECE document “Just Energy Transition Roadmap for Uzbekistan” brings forward the social aspect of the “green transition”: new jobs, retraining, mitigation of impacts across regions. A critical point: to avoid remaining declarative, the “just transition” needs to be linked to budget, labor market policy, and energy subsidy reform; otherwise, social resistance may slow down the strategy. [15]

### **Research methodology**

In the process of researching strategies for developing the use of "green energy" in the energy sector, comparative analysis and synthesis, induction and deduction, expert assessment, scientific abstraction, statistical grouping, correlation and regression analysis, and other methods were widely used.

### **Analysis and results**

Renewable energy sources - solar, wind, hydropower, biomass and geothermal resources - are naturally renewable and emit almost no greenhouse gases during their use. The reduction in the cost of technologies, the improvement of energy storage systems and the introduction of digital control tools are making green energy economically competitive. Therefore, many countries are identifying renewable energy sources as a priority in their national energy strategies and developing mechanisms for state support.

This direction is of strategic importance for Uzbekistan. The high share of industry and agriculture in the country's economy, the steady growth of the population and the acceleration of urbanization processes are increasing the demand for electricity every year. The existing energy system is formed mainly based on natural gas, which in the long term creates certain limitations in terms of resource efficiency and environmental sustainability. At the same time, the high level of solar radiation in the country's regions and the presence of wind resources in some regions create great potential for the widespread introduction of renewable energy sources.

**Table 1 Total renewable energy capacity (MW) in 2020-2023**

Years	Total QTEM capacity (MW)	Hydropower (MW)	Solar + Wind (MW)
2020	2025	2021	4
2021	2156	2152	4
2022	2478	2225	253
2023	2668	2415	253

**Source: IRENA Renewable Energy Capacity Statistics data used**

According to the data presented in the table, during 2020-2023, renewable energy capacity showed a significant increase in total: from 2,025 MW in 2020, it reached 2,668 MW in 2023, an increase of 643 MW. While the main share (hydropower) remains stable in the existing network, there is a clear increase in the ranking in the field of solar and wind energy. This indicates an acceleration in the construction of photovoltaic (PV) and wind power plants in Uzbekistan.

**Table 2 Electricity generation from renewable energy in 2022-2024 (million kWh)·hour)**

Years	Photovoltaic + Wind energy (million kWh)·hour)	All QTEM (million kWh)·hour)
2022	434	434
2023	576.9	576.9
2024	4860	4860

**Source: Data from the Ministry of Energy of the Republic of Uzbekistan**



According to the data presented in the table, in 2022, a total of 434 million kWh of solar and wind power will be installed. ·hours of electricity generated, in 2023 this figure will be 576.9 million kWh·hours. In 2024, all renewable energy sources (mainly solar and wind) will reach 4,860 million kWh·hours, with rapid growth. These indicators demonstrate the effectiveness of the strategy of rapid implementation of QTEM projects in Uzbekistan.

The development of the use of "green energy" is important for ensuring the stability, environmental safety and economic efficiency of the energy system. It is necessary to develop comprehensive and long-term strategies for the widespread introduction of renewable energy sources.

**1. Strategy for improving public policy and the legal framework.** State policy is crucial in the development of green energy. Therefore, it is important to improve legislation supporting renewable energy sources, create a favorable legal environment for investors, and simplify regulatory mechanisms. As part of this strategy, it is necessary to:

- simplify licensing and permitting processes for renewable energy projects;
- introduction of a system of state-guaranteed electricity procurement;
- Measures such as improving regulatory and legal documents regulating renewable energy projects can be implemented.

**2. Investment and financial support strategy.** The development of the renewable energy sector requires significant financial resources. Therefore, it is important to develop cooperation between the public and private sectors. This strategy includes:

- implementation of energy projects based on public-private partnerships (PPPs);
- attracting international financial institutions and investors;
- financing through green bonds and soft loans;
- introduction of tax incentives and subsidies.

These measures will increase the economic attractiveness of renewable energy projects.

**3. Energy infrastructure modernization strategy.** The increase in renewable energy sources will place new demands on electricity networks. Therefore, it is necessary to modernize the existing electricity transmission and distribution networks. As part of this strategy:



- digitalization of electricity networks and introduction of "smart grid" technologies;
- development of energy storage systems (battery storage);
- introduction of technologies aimed at reducing electricity losses;
- measures such as improving mechanisms for integrating renewable energy plants into the grid will be implemented.

**4. Strategy for the development of scientific research and innovation.** The introduction of innovative technologies in the green energy sector is important for increasing its efficiency. Therefore, it is necessary to support scientific research and innovative development. This strategy includes the following:

- developing research on renewable energy at universities and research centers;
- development of local technologies and their implementation;
- strengthen cooperation with foreign scientific centers;
- supporting innovative startups.

**5. Development strategy based on regional specialization.** Locating renewable energy projects based on each region's natural resources and climatic conditions will increase efficiency.

For example:

- construction of solar power plants in areas with high solar radiation;
- development of wind power plants in areas with high wind potential;
- construction of small hydroelectric power plants in mountainous areas.

This approach allows for maximum use of energy resources.

**6. Strategy for training personnel and increasing the ecological culture of the population.** Qualified personnel are essential for the development of green energy. Therefore, it is necessary to train specialists specializing in the field of renewable energy in the educational system. Within the framework of this strategy:

- development of "green energy" courses in higher education institutions;
- implementation of retraining and advanced training programs for specialists;
- intensify advocacy efforts to increase energy efficiency and environmental awareness among the population.



By implementing the above strategies in a comprehensive manner, it is possible to develop "green energy". This will ensure the stability of the energy system, environmental safety and economic development. The widespread introduction of renewable energy sources will serve as an important factor in strengthening the country's energy independence and achieving sustainable development in the future.

### **Conclusion**

The process of developing "green energy" in the energy sector of Uzbekistan is taking on a gradual but systematic character. The growth of renewable energy capacities and production volumes in 2020-2024 confirms that the priorities of the country's energy policy are changing. In particular, the increase in projects in the field of solar and wind energy is contributing to the diversification of electricity sources.

The results of the analysis showed that increasing the share of renewable energy solves three strategic tasks at once. The first is to ensure environmental sustainability. The transition to renewable energy sources reduces the amount of harmful gases emitted into the atmosphere, improves air quality and increases the national contribution to combating climate change. The second is to strengthen energy security. Diversification of energy sources reduces the country's dependence on changes in external markets. The third is to stimulate economic development. Investments in the renewable energy sector create new jobs, develop local industries and service sectors.

At the same time, practical analysis has shown that strategic planning needs to take into account a number of challenges and constraints. First, the growth of generation capacity requires the modernization of the grid infrastructure. Since renewable energy sources are inherently variable, energy storage systems, balancing capacities, and "smart grid" technologies must be introduced to effectively integrate them into the national electricity grid. Second, if the investment environment is not stable, the long-term effectiveness of projects may decrease. Therefore, legal guarantees, transparent auction mechanisms, and fair distribution of financial risks are of great importance.

The results of the study also showed that the development of renewable energy is not only a technical or economic issue. It also requires social and institutional



changes. Factors such as training personnel, supporting scientific research, and increasing the ecological culture of the population ensure long-term sustainability. In this context, strengthening cooperation between higher education institutions, research centers, and the private sector is of strategic importance.

In the future, it is appropriate to focus on the following priority areas to achieve the goals set by 2030:

1. In addition to increasing the share of renewable energy, comprehensively improve energy efficiency.
2. Modernization of electricity grids and widespread introduction of energy storage technologies.
3. Continue to improve public-private partnership mechanisms and attract investments.
4. Developing local technologies by encouraging research and innovation activities.
5. Effective use of resource potential based on territorial specialization.

In general, the development of "green energy" is a decisive factor in ensuring sustainable development, environmental safety and economic competitiveness of Uzbekistan. "Greening" the energy system through a comprehensive, scientifically based and institutionally sound strategy is fully consistent with the country's long-term national interests.

Thus, expanding the use of renewable energy sources should be considered not only a modern trend, but also a strategic direction of national development.

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