“Implementation of innovative technologies in Kazakhstan: A case of the energy sector”

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IMPLEMENTATION OF INNOVATIVE TECHNOLOGIES IN KAZAKHSTAN: A CASE OF THE ENERGY SECTOR

Abstract

The implementation of innovative renewable energy projects is designed to meet the growing electricity demand and reduce carbon dioxide emissions into the atmosphere. In order to avoid resource dependence of the economy and meet the demand for electricity in remote areas of Kazakhstan, the development of renewable energy sources is urgent. The purpose of this study is to analyze the effectiveness of the implementation of existing mechanisms for the implementation of innovative renewable energy projects through auctions. Moreover, it identifies their shortcomings and offers proposals for improvement. The analysis uses data from the Kazakhstan Bureau of National Statistics on renewable energy sources, namely alternative energy sources such as solar and wind power plants, excluding biogas. The methodology provides for the assessment of projects implemented through auctions for 2018–2021, taking into account such indicators as the dynamics of the number of wind and solar energy projects, their capacity, the percentage of auction price reduction for a specific year. The paper discusses the mechanism for conducting auctions of solar and wind electricity, which, through the auction organizer, connects authorized bodies and investors. The main indicators of auctions for individual years are noted, and the main shortcomings of this mechanism are identified. The analysis of barriers to innovative renewable energy project implementation revealed the presence of contradictions in the price regulation of renewable electricity, the lack of market pricing mechanisms, and the unpreparedness of the energy infrastructure for integration with renewable sources.

Keywords renewable energy, innovation technologies, technology implementation, energy policy, auctions, barriers

JEL Classification O13, O14, O32, Q42

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INTRODUCTION

In most developed and developing countries, there is a steady increase in interest in alternative energy sources. With the development of industry, more and more hydrocarbon raw materials are required, the reserves of which are limited, and production requires increasing costs. In this regard, the needs of production can be met by renewable energy sources. Such sources have an inexhaustible resource, ensure the environment's safety, and help minimize negative climate change in the future.

Historically, in Kazakhstan, industries use mineral raw materials. This is primarily due to an ample oil, gas, and coal supply in the republic's territory. At the beginning of the twentieth century, the richest mineral deposits were identified and began to be developed. This contributed to the development of extractive industries – oil, coal, and non-ferrous metallurgy. These industries currently dominate the economy of Kazakhstan, determining its raw material character. About 80% of thermal and electrical energy is generated in the country from coal and its derivatives, negatively affecting the climate and the environment. Most coal power plants are outdated and require major upgrades to efficiently generate power.

The increase in the cost of mining mineral raw materials and the negative impact of mining on the climate led to increased attention to renewable energy sources and the possibility of their widespread use in the energy sector of the republic. Due to its geographical location and large territory, Kazakhstan has great potential for using renewable energy sources for electricity generation. Solar and wind power can most effectively provide electricity in remote rural areas.

In Kazakhstan, the policy in the sphere of renewable energy began to take shape in the mid-2000s (Mouraviev, 2021) with the adoption of several legislative acts. In 2013, the Concept for the transition to a green economy and the Environmental Code were adopted (Minazhova et al., 2023). Innovative renewable energy projects began to be considered to reduce the economy's dependence on traditional energy sources, such as oil, gas, and coal, which currently prevail (Karatayev et al., 2016). Thus, the development of small-scale energy, the transition to alternative energy, resource-saving, and energy efficiency, biofuel, waste processing, as well as the introduction of waste-free and low-waste production into the industry can become promising areas of innovative green economy in the country (Upushev & Esenkulova, 2015).

The development of a green economy in Kazakhstan requires the implementation of innovative projects in the energy sector, which will make it possible to get away from the resource dependence of the economy and reduce environmental risks in the long term. Also, the development of alternative energy will contribute to building a diversified innovative economy (Sitenko, 2011), which is one of the national priorities of the National Development Plan until 2025.

The implementation of green energy projects requires the creation of an effective market mechanism in which investors can not only make a profit but also contribute to the renewal of energy infrastructure. Therefore, analyzing the experience of implementing renewable energy projects through the auction mechanism is necessary.

1. LITERATURE REVIEW

In recent years, interest in innovative renewable energy projects and their implementation has been growing (Twidell, 2021; Huseynli, 2023). This is due to the growing consumption of energy resources, their high cost, as well as the need to combat greenhouse gas emissions. Chow et al. (2003) and Rogner (2012) discussed the availability and consumption of energy resources and their role in the global energy system. Research notes the dependence of the world industry on combustible fuels, which contributed to the growth of production and economic progress. At the same time, there is concern that the growth in consumption of traditional fuels leads to increased environmental risks during their extraction and further combustion (Mudarissov & Lee, 2014).

Studies devoted to Kazakhstan emphasize the need to introduce innovative technologies in traditional industries, which will contribute to the recovery of the national economy (Tasmaganbetov et al., 2020; Zhunussova et al., 2020). Kazakhstan has all the necessary natural, climatic, and economic conditions to introduce innovative renewable energy projects (Kalikov et al., 2020). In recent years, the country has increasingly developed a transition policy to a green economy and alternative energy sources, which will allow moving away from the economy's dependence on raw materials (Karatayev et al., 2016; Mouraviev, 2021). Also, the growth in the share of alternative energy sources will contribute to the implementation of the obligations of the Kyoto Protocol taken by Kazakhstan in 1999 to reduce greenhouse gas emissions (Karatayev & Clarke, 2016; Laldjebaev et al., 2021).

Among renewable energy sources, much attention in the literature sources is paid to hydroelectric power plants, as well as alternative sources of electricity – solar, wind, and biogas (Karatayev & Clarke, 2014; Koshim et al., 2018). Hydroelectric power plants have been operating in Kazakhstan for a long time, producing about 13% of the to-

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tal energy; however, solar and wind power projects have been developed only in the last decade (Diyar et al., 2014; Raihan & Tuspekova, 2022). There are ongoing discussions about the economic feasibility of introducing renewable energy sources in various territories (Collins & Bekenova, 2017; Nurlankyzy et al., 2016). Experts agree that small power sources such as solar panels or small wind farms can bring economic benefits and will be effective in regions remote from large cities (Pacesila et al., 2016; Laldjebaev et al., 2022).

Upushev and Esenkulova (2015) and Minazhova et al. (2023) considered state policy's features in the electric power industry and the implementation of innovative renewable energy projects. Kozhukhova et al. (2019) and Kurbanov et al. (2020) note that the government creates regulatory and legal conditions for the introduction of alternative energy sources, both by domestic companies and with the attraction of foreign investment. At the same time, the risks of administrative restrictions in the pricing of electricity from renewable sources should be considered, which may lead to a decrease in market regulation in the industry.

Kurbanov et al. (2020) and Yessengeldin et al. (2016) considered organizational and economic mechanisms through which innovative technologies can be introduced in the energy sector. Generally, the mechanisms used are based on cross-country cooperation (Steblyakova et al., 2022; Niyazbekova et al., 2022), public-private partnerships, and attracting investment through auctions. Babazhanova et al. (2017) and Bulin (2021) discuss the theoretical foundations of the auction trading mechanism and the prospects for its application. However, there is no analysis in the literature of the practical application of this mechanism in recent years, and the barriers that prevent the implementation of alternative energy projects in Kazakhstan have not been studied.

Therefore, the purpose of this study is to examine the current stage of development of innovative renewable energy projects in Kazakhstan, as well as to analyze the implementation of the mechanism of innovative renewable energy projects through auctions.

2. METHOD

The dynamics of wind and solar energy production and the share of innovative renewable energy projects in total electricity production were determined with the help of statistical analysis. A functional-logical method was used for a visual representation of the interaction scheme between the participants in the innovative renewable energy auctions, according to the current legislation in this area. The performance of the innovative renewable energy auctions for 2018–2021 was assessed using statistical and comparative methods. Content analyses of government documents (laws, state programs, and strategies) relevant to the introduction of innovative renewable energy projects, as well as guidelines for private investors and other participants in the sphere of renewables, were used.

To determine the price of electricity for consumers and the price cap, the following calculation methodology was used:

$$PEC = PC + PEPC, \tag{1}$$

where *PEC* – the price of electricity for consumers; *PC* – the price cap for electric power; *PEPC* – the price for electric power capacity.

Price caps are indexed once a year on October 1, considering the inflation rate. So, for projects in national currency (tenge), indexed auction price (T_{t+1}) will be:

$$T_{t+1} = T_t \cdot CPI, \tag{2}$$

where T_t – auction price taking into account previously carried out indexation, if such indexation was previously carried out; *CPI* – consumer price index, accumulated for the twelve months preceding October 1 of the year of indexation. *CPI* is determined by the submissions of the Bureau of National Statistics.

For projects with a loan in foreign currency:

$$T_{t+1} = T_t \cdot \left(1 + 0.3 \frac{(CPI_t - 100\%)}{100\%} + 0.7 \cdot \frac{USD_{t+1} - USD_t}{USD_t} \right), \tag{3}$$

where CPI_t – consumer price index accumulated over the twelve months preceding October 1 of the year of indexation, determined by the submission of the authorized body in the field of state statistics; USD_{t+1} – current exchange rate of tenge to the US dollar as of October 1 of the year of indexation (submitted by the National Bank of Kazakhstan); USD_t – the average exchange rate of the tenge to the US dollar, calculated for twelve months preceding the indexation date (submitted by the National Bank of Kazakhstan).

The study uses statistical data and analytical indicators of the Bureau of National Statistics of the Republic of Kazakhstan, International Renewable Energy Agency, reports on the development of renewable energy sources of the International Energy Agency, KazEnergy (National energy reports), and Samruk Energo. To evaluate the results of the innovative renewable energy auctions, the study used analytical materials and reports from KOREM JSC (Kazakhstan Electricity and Capacity Market Operator) and the US Agency for International Development.

3. RESULTS AND DISCUSSION

The Concept of transition to a green economy was accepted in Kazakhstan in 2013. The need to create and implement this Concept was the inefficient use of resources in all industries. According to experts, this will lead to lost profits of 4-8 billion US dollars per year for the republic's economy, and by 2030 may amount to 14 billion US dollars. The problem of environmental degradation is also progressing, which affects erosion and the loss of agricultural land, the lack of water resources, air pollution in large industrial cities, etc.

The Concept sets itself the achievement of the following target indicators:

- share of renewables (solar and wind sources): at least 3% by 2020;
- innovative renewable energy in total electricity generation – 30% by 2030.

The share of innovative renewable energy was 11% in 2020, showing even a decrease compared to 2016–2017, so reaching 30% remains a rather ambitious task. Concerning innovative renewable energy projects with 35 kWh and more, excluding large hydroelectric power plants, their share was 3.69% in 2021, demonstrating rapid growth over the last 2-3 years.

The Bureau of National Statistics collects data on renewable energy sources in the following sections: hydroelectric power plants, solar (SPP), wind power plants (WPP), and power plants using biogas. This paper considers only alternative energy sources, such as solar and wind power plants, without considering biogas because the share of electricity from biogas is insignificant (only 0.3% according to 2020 data).

The volume of electricity production through solar and wind sources is 2.1% of the country's total electricity production. Nevertheless, the dynamics of electricity production by these types of resources are positive (Figure 1).

Figure 1 shows that the growth in electricity generation by solar and wind energy is noted at the level of 2019 when the amount of generated solar energy increased by 2.6 times compared to the previous year, and wind energy – by 1.6 times. This resulted from measures taken by the government to develop alternative energy technologies, particularly the innovative renewable energy auction mechanism.

The legislation on the alternative electric power industry was developed by adopting the law "On supporting the use of renewable energy sources" in 2009. The law defines the basic concepts of innovative renewable energy projects, development goals, as well as the mechanism of state support of innovative renewable energy implementation for electricity and heat (Minazhova et al., 2023). This mechanism was based on a centralized guaranteed purchase by the authorized body of all electricity produced by renewables at fixed tariffs (KOREM JSC, 2021).

The development of a legislative framework for the development of innovative renewable energy projects did not lead to a significant increase in the implemented innovative renewable energy projects, and the amount of electricity produced in

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Source: IRENA (2023).

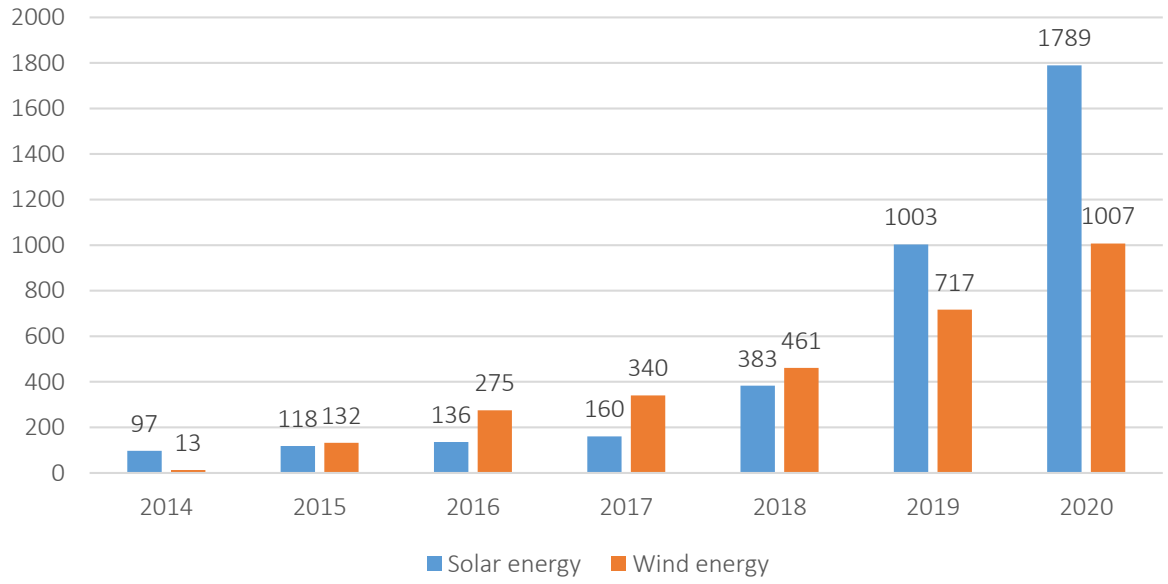

Figure 1. Dynamics of electricity generation (GWh)

the framework of alternative energy in 2016–2017 barely exceeded 1% of the republic total volume of electricity.

At the same time, private investors showed interest in innovative renewable energy facilities in the republic. This was facilitated by reducing costs for the technical construction of alternative energy facilities and reducing the cost of the necessary components. In this regard, it was necessary to change the legislation to attract investment capital to the industry and increase the generated electricity capacity (Kozhukhova et al., 2019).

In July 2017, the law "On amendments and additions to certain legislative acts on electricity issues" was adopted. The new changes provided an opportunity for auctions to select renewable energy projects. This mechanism was borrowed from world practice and was innovative for Kazakhstan. Investors could participate in auctions for all innovative renewable energy sources (wind, solar, hydro, and biological power plants). At the same time, investors were provided with competitive auction price limits for renewable energy technologies (Bulin, 2021; Babazhanova et al., 2017). The auction itself is held online on an independent trading platform, ensuring transparency in selecting projects and prices. The auction mechanism is shown in Figure 2.

With the change in legislation and the introduction of the auction model, there has been a significant increase in the amount of electricity produced through renewable energy sources (Table 1). Thus, according to the Ministry of Energy for 2022, electricity generation by renewable facilities amounted to 5,110 million kilowatts (Ministry of Energy of the Republic of Kazakhstan, 2023).

According to the results of the auctions in 2021, the maximum reduction in price for wind energy projects was 34.6%, solar energy – 56.64%. This indicates that auctions provide price reductions and allow determining market prices for electricity from renewable energy facilities (KOREM JSC, 2021).

The implementation of renewable energy projects is based on the own or borrowed funds of investors. The state does not provide direct financing; however, through a single center, the state purchases the entire volume of renewable energy electricity produced. At the same time, investors are provided with investment preferences and zero payment rates for the transportation of electricity from renewables.

The following vital projects were implemented through auctions:

1. Solar power plant in the Karaganda region in the central part of Kazakhstan by company

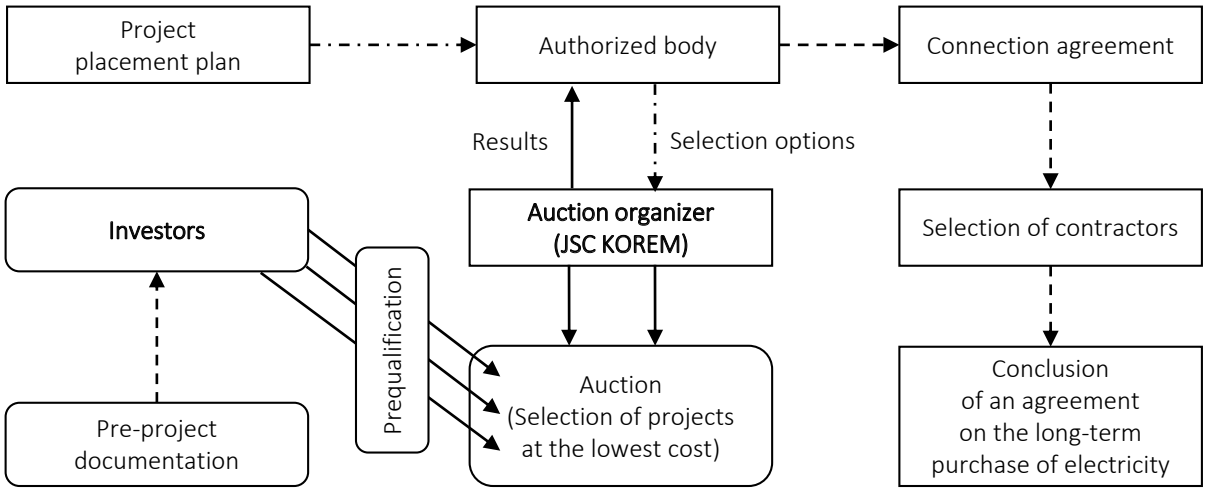

Figure 2. Renewable energy projects' auction scheme

Table 1. Results of auctions for wind and solar energy projects in 2018–2021

Year	Projects selected			Capacity auctioned (MW)			Percent of price descending by auction	
	Wind	Solar	Total	Wind	Solar	Total	Wind	Solar
2018	16	12	28	500.85	270	770.85	23.3	48
2019	5	3	8	108.99	86.5	195.49	14.96	56.64
2020	3	4	7	64.95	60	124.95	26.7	14.09
2021	1	1	2	50	20	70	34.6	24.12

KazSolar 50 LLP, Germany (winner of the auction in 2019). The project's installed capacity is 26 MW, and the auction price is 16.97 tenge/kWh (without VAT). The total design cost of the station amounted to 5.6 billion tenge.

2. Wind power plant in the vicinity of the Aktogay village in the Ayagoz district (winner of the auction in 2018). The project's installed capacity is 50 MW, and the auction price is 17.49 tenge/kWh (without VAT).

3. Wind power plant Arm Wind in the Akmola region (winner of the auction in 2019). The investor is Arm Wind LLP (Italy). In the first stage, the WPP capacity will be 48 MW, possibly increasing to more than 100 MW; the auction price is 19.27 tenge/kWh (without VAT). The total design cost of the station will be 50 billion tenge.

Since 2019, conducting a new type of auction has become possible – auctions with documentation. For this, changes were made to the Rules for holding auctions (Order dated June 27, 2019, No. 228). This type of auction involves participation in the auction of projects, for which all possible investors are provided in advance with complete information that covers the main parameters of the project. This includes a marketing plan for constructing a new power generation facility, environmental and social impact assessment, technical conditions for connection, etc. As world practice shows, such auctions contribute to offering a lower electricity price.

In 2019, the first auction with documentation for a 50 MW solar power plant was held. Seven companies from six countries were allowed to participate in the auction: Kazakhstan, Russia, Germany, China, Italy, and the Netherlands. The auction participants submitted 95 price proposals; as a result, the starting auction price of 29 tenge/kWh decreased by 2.3 times and amounted to 12.49 tenge/kWh. The winner was Arm Wind LLP (project for the Shaulder solar power plant construction in the Shaulder village, Turkestan region). The power plant will avoid greenhouse gas emissions of more than 1.2 million tons of CO_2 equivalent over the entire power plant service life.

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The development of renewable energy projects in Kazakhstan demonstrates steady growth; however, there are several constraining factors for the full implementation of alternative energy projects in the economy. According to Karatayev and Clarke (2014), in the first place, the introduction of innovative renewable energy projects is hindered by a lack of understanding of their opportunities. The country's economy depends on traditional energy sources, and a quick transition to renewable energy is difficult (Niyazbekova et al., 2022). Training technical personnel in renewables infrastructure and state financial support for overcoming the high initial capital requirements for developing such projects is essential.

The power transmission infrastructure in the Republic of Kazakhstan (operated by KEGOC at the national level) is characterized by high wear and tear (65% on average) and high losses in regional power network companies. Electricity losses are associated with the large extent of the territory of Kazakhstan and can reach more than 10%. Thus, in 2020, electricity losses during transmission in the KEGOC networks amounted to 2767.86 million kWh (5.7%), and in the regional power network companies networks – 4739.5 (10.9%). The renewal of electrical grids is proceeding slowly despite the annual investment of energy companies (about 30% of the required revenue), according to the National Energy Report 2021 (KAZENERGY Association, 2021).

The pricing policy in the electric power industry has undergone repeated changes over the past ten years. Since 2009, a system of price caps for electric power has been applied, making it possible to modernize fixed assets quickly (Tasmaganbetov et al., 2020). Each power plant could invest money in fixed assets in exchange for a higher price cap. Thus, this mechanism attracted investments of USD 6.8 billion to reconstruct and modernize existing equipment from 2009 to 2015.

For the development of renewable energy projects, the electric capacity market was supposed to be launched in 2016, but in fact it was launched only in 2019. The price of electricity for consumers consists of two components: the price cap for electric power by groups of organizations (tariff for electric power) and the price for electric power capacity (services of maintaining the capacity ready to generate). At the same time, the Ministry of Energy set the capacity price individually, which led to the actual absence of market mechanisms for the selection and determination of the capacity price for modernized and expanded power plants.

From 2021, the cost of purchasing electric power produced by renewable energy projects has been deducted from the price caps of traditional power plants' electricity. Their allowance was allocated as a separate component of the cost of electric power, which was an additional financial burden on traditional power plants. Thus, government price regulation in the electricity sector has decreased opportunities to attract investment in infrastructure.

The lack of personnel (engineers) in the alternative energy sector can also deter the large-scale implementation of renewables (Laldjebaev et al., 2022). Today, the training of specialists in electric power engineering specialization at the levels of bachelor, master, and Ph.D. is carried out in six universities in the country. At the same time, there are no specialties for training in renewable sources. Separate disciplines in renewable energy are studied only in 3 out of 6 universities (Zhunussova et al., 2020). Below there are presented the main constraining factors for implementing renewable energy projects in the republic:

1) in legal and regulatory framework sphere – the framework is developed more slowly than the declared strategic goals in the renewable energy sphere; there is no regulation of technical specifications; the current framework is better designed to support traditional energy sources;

2) in infrastructure sphere – the need to develop ways to transport electricity from the place of production through the transmission system to consumers; the need to develop technical requirements for the integration of alternative energy infrastructure into the energy network;

3) in financing sphere – high capital costs for technical support of renewable energy projects; inconsistent price regulation in the electric power sector;

4) in research and staff training sphere – low level of funding for scientific research in the renewable energy sphere; lack of qualified personnel to work at renewable energy facilities at all stages of construction and operation.

The elimination of existing barriers will contribute to the technological and innovative development of the electric power industry and the growth of renewables in the total volume of electric energy. Initiated mechanisms in the field of renewable energy need to be consistent. The decrease in the auction price (positive effect) was also accompanied by a decrease in the volume of auction capacity, which does not correspond to the long-term goals of the previously adopted Concept for the transition to a green economy (the share of wind and solar energy by 2030 is 10%, the share of all alternative sources by 2050 is 50%). It is also necessary to form a long-term plan for holding auctions to attract more investors.

CONCLUSION

The paper aims to examine the current stage of development of renewable energy projects in Kazakhstan, as well as to analyze the implementation of the mechanism of innovative renewable energy projects through auctions. The goal of achieving the share of renewables (solar and wind sources 3%) was completed. The auction mechanism developed in 2017 has proven to be effective. For 2018–2021, more than 40 innovative wind and solar energy projects have been approved in the republic, most of which have completed the construction phase and reached their design capacity.

To evaluate projects implemented through auctions for 2018–2021, indicators such as the dynamics of the number of wind and solar energy projects, their capacity, and the percentage reduction in the auction price for a particular year were considered. Among the positive effects of auctions, a significant reduction in the auction price (up to 57%) for each type of renewable energy source was noted. A negative factor is the decrease in the number of projects implemented through auctions, which indicates inconsistent government policy in this area.

Among the limiting factors for developing renewable energy sources in the republic are imperfections in the legislative framework in green electricity, deteriorated infrastructure, the high initial cost of renewable energy projects, and the lack of highly qualified personnel. As for green electricity staff, it is necessary to pay attention to the training of specialists in the universities of the republic with specializations in solar and wind electricity.

Future research should analyze the performance indicators of ongoing solar and wind electricity projects. An updated mechanism for implementing renewable energy projects may also be studied based on the results of expected changes in legislation in the electric and heat power field.

AUTHOR CONTRIBUTIONS

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Investigation: Ali Sabyrzhan.
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Visualization: Elmira Syzdykova.
Writing – original draft: Diana Sitenko, Yelena Gordeyeva.
Writing – review & editing: Diana Sitenko, Elmira Syzdykova.

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