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Article

Analysis and forecast of renewable energy production and investment development in the Republic of Kazakhstan

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ABSTRACT

This study examines the structural, financial, and policy dimensions of renewable energy development in the Republic of Kazakhstan between 2022 and 2024, offering projections through 2030. Drawing on national legislation, statistical datasets, international benchmarks, and qualitative field insights, it evaluates production dynamics across solar, wind, hydro, and bioenergy systems. Quantitative analysis reveals a 42.8% increase in renewable electricity output over the three-year period, reaching a 6.43% share of total electricity generation by the end of 2024, yet still below the nationally mandated targets for 2030 and 2050. The paper examines the evolving legal framework that supports both utility-scale and distributed energy initiatives, highlighting incentives such as auction-based feed-in pricing, tax exemptions, extended power purchase agreements, and individual producer rights. It identifies systemic barriers, including tariff indexation delays, currency risks, limited access to concessional finance, and infrastructure bottlenecks. Financing structures dominated by debt instruments and international capital flows are mapped through institutional profiles. Comparative policy analysis and stakeholder feedback from events like Qazag Green Fest inform a set of integrated recommendations, including expanding energy storage systems, modernizing grid infrastructure, deploying green taxonomies and investor safeguards, and scaling technical education and public awareness campaigns. The findings underscore Kazakhstan's pivotal opportunity to transition toward energy sovereignty and climate resilience through coordinated public–private strategies, regulatory clarity, and robust investment mechanisms.

1. Introduction

Renewable energy is energy obtained from natural sources (sunlight, wind, etc.) that are replenished at a rate exceeding their consumption. Renewable energy sources provide a large amount of energy and are associated with much lower emissions. Currently, renewable energy sources are a cheaper alternative in many countries than fossil fuels (coal, oil, and gas). Renewable resources include solar energy, wind energy, geothermal energy, ocean energy, and bioenergy. The sustainable development of the global economy is closely tied to the effective utilization of the advantages of renewable energy. Renewable energy sources have become a magnet for innovation and investment. Most developed countries have included principles for the development of renewable energy sources in their national development strategies. Annual investments exceeding $750 billion have proven the profitability of the future sector. The rapid growth of solar, wind, and other types of renewable energy has positively affected the sustainability triad: economy, social sphere, and ecology. This allows us to consider this phenomenon as a factor in creating a new energy system and future economy. Just three decades ago, the global community considered achieving 10% electricity production from renewable energy sources in the total energy balance to be an excellent result. At present, this is no longer sufficient to ensure energy security and conserve financial resources at the macro level. The goal of our research is to analyze and assess the level of development and production of renewable energy in the Republic of Kazakhstan. Based on this goal, the following research tasks have been addressed in this article:

- An analysis of the production and development of renewable energy in Kazakhstan over the past three years has been conducted.

- Issues of state support and investment in the development of renewable energy in the Republic of Kazakhstan have been examined.
- A forecast of further development of renewable energy sources (RES) in Kazakhstan until 2030 has been provided.

Currently, the entire world is facing the challenge of climate change, which is one of the most important issues for the energy sector. Renewable energy is becoming a viable alternative, driven by the growing trend of decreasing construction costs for renewable energy stations, which is fueled by increased investor demand. The main growth drivers are the new strategy, according to Kazakhstan's Concept for Transition to a Green Economy:

- 10% share of renewable energy sources in total electricity production by 2030
- 50% share of alternative and renewable energy sources in total electricity production by 2030 [1]

In matters of government policy on production and financial support for the Republic of Kazakhstan, the experience of leading countries such as China and Türkiye is noteworthy. The relevance of this study is confirmed by the analysis, forecasts, and strategic perspectives for developing renewable energy production and promoting investments from both the public and private sectors. According to the international consulting company PwC, investment in renewable energy sources is especially significant for the oil and gas and energy sectors. Studying the foreign experience of countries using renewable energy sources, in the UK, over five years, investments in the green economy yielded 75% annual returns, while at the same time, fossil fuels yielded 8.8%, and in the USA, the figures were 200% and 97.2%, respectively [2]. Thus, it is relevant to involve all necessary participants in implementing green energy projects, particularly small-scale renewable energy projects. This study provides a comprehensive analysis and assessment of the development level and production of renewable energy in the Republic of Kazakhstan. The study methodically examines the sector's recent performance and future potential, providing a clear and evidence-based outlook. The primary research objectives addressed in this article are:

- To analyze the production and development of renewable energy in Kazakhstan over the past three years.
- To examine the key issues of state support and investment in Kazakhstan's renewable energy sector.
- To provide a quantitative forecast for the development of RES in Kazakhstan through 2030.

The relevance of this study is underscored by the global challenge of climate change and the increasing economic viability of renewable energy projects. By analyzing recent data, evaluating government policy, and forecasting future growth, this research offers strategic insights for public and private sector stakeholders. The findings contribute to the broader discourse on green energy transitions in resource-rich nations and provide a crucial framework for accelerating the implementation of sustainable energy projects in Kazakhstan.

2. Literature review

The issues of development prospects, government support, investment, and financing of projects in the renewable energy sector have been studied by well-known foreign scholars [3-13]. In the Republic of Kazakhstan, several articles have been published in recent years on the challenges of developing renewable energy [14,15], including analyses of policy and governance hurdles [16-18], financial and investment processes impacting renewable projects [19], and scenario planning for coal exit and renewable energy transitions [20]. Additional studies have explored multi-criteria decision-making systems for spatial renewable energy development in Kazakhstan [21] and evaluated renewable versus nuclear resources for electricity generation [22]. In determining the stage of emergence and development of renewable energy in Kazakhstan, as well as in assessing the world experience of leading countries in the use of renewable energy, the works of American and European scientists were considered. For instance, references [3, 4, 6] examine the development of renewable energy and mechanisms for stimulating its growth in the USA. Features of targeted innovative stimulation of renewable energy use in European countries are considered in reference [5].

Several researchers emphasized the importance of financial support mechanisms for stimulating investment in renewable energy. One of the key financial support mechanisms is the use of preferential tariffs, tax benefits, and tradable "green" certificates [23]. These mechanisms provide financial incentives for the development of renewable energy sources and help to offset the higher costs associated with renewable energy technologies [10]. Recent reviews highlight additional innovative financing models, such as concessional finance, blended finance, and auctions, which mitigate risks and enhance the attractiveness of renewable projects in developing countries [24,25]. Policy insights from comparative studies in Brazil and Nigeria further underscore the role of targeted incentives in overcoming barriers to renewable energy financing [26]. Additionally, financial investments from both the public and private sectors are crucial for expanding renewable energy production capacity [9]. Such investments help fund research and development, infrastructure development, and the implementation of renewable energy projects. Empirical evidence from global samples suggests that green bonds, a form of green finance, significantly enhance renewable energy production by providing dedicated capital flows [27].

The role of financial markets in supporting renewable energy projects is also significant. Financial market investors, including pension funds, insurance companies, and mutual funds, utilize renewable energy stock indices to evaluate and manage their investments. These indices provide information on the financial performance and potential risks associated with renewable energy projects, enabling investors to make informed decisions [11]. Green finance influences the investment behavior of renewable energy enterprises, facilitating better capital allocation and risk management [28]. Studies on renewable energy investment and green economies show that green finance enhances firm-level investments, particularly in Asia [29]. Furthermore, the creation of a "green" financial system is essential for financing green energy projects [12]. The green financial system ensures that funds are directed toward sustainable and environmentally friendly projects, including renewable energy. Such a system can help reduce environmental degradation and facilitate investments in clean technologies

for renewable energy projects. Research demonstrates that green finance not only supports renewable energy development but also contributes to climate change mitigation by reducing emissions [30,31]. Bibliometric analyses reveal evolving trends in energy transitions and green finance, emphasizing their interconnected roles in sustainable development [32]. The success of renewable energy projects depends not only on financial indicators but also on non-financial performance measures, such as environmental impact, social benefits, and long-term sustainability. Assessing these non-financial indicators alongside financial ones allows for a more comprehensive evaluation of the success and viability of renewable energy projects. Critical reviews of competitiveness indicators for energy projects stress the need for multi-disciplinary key performance indicators (KPIs) that encompass environmental, social, and governance factors beyond economics [33]. Empirical studies confirm that non-financial measures, such as community engagement and ecological footprints, significantly influence project outcomes [13]. Financial support systems are crucial for the development and implementation of renewable energy projects. Mechanisms such as preferential tariffs, tax benefits, and tradable green certificates provide financial incentives for the development of renewable energy sources. To expand renewable energy production capacity, financial investments are required from both the public and private sectors [9]. The role of financial markets in managing investments in renewable energy is significant. Additionally, the development of a green financial system and the consideration of non-financial performance measures are crucial to the success of renewable energy projects. For instance, segmentation analysis of support mechanisms for green hydrogen highlights the efficacy of offtake support and infrastructure funding in reducing investment risks [34]. Studying the strategies of global leaders in the application of renewable energy and in-depth research by prominent scholars will help formulate recommendations for adapting foreign experience to the development of Kazakhstan's green economy.

3. Methodology

3.1 Research design

This study utilizes a mixed-methods research design, combining both qualitative and quantitative approaches. This design is most suitable for providing a data-driven and factual analysis of the multi-level impact of renewable energy on Kazakhstan's economy, foreign policy, and energy security. The methodology is specifically structured to answer the central research question: How can Kazakhstan enhance its capabilities in developing renewable energy? It is also designed to test the guiding hypothesis that Kazakhstan's efforts to introduce renewable energy can become a strategic turn that will enhance its national influence and security.

3.2 Data collection and sampling

Data was gathered using a combination of primary and secondary research tools to ensure a comprehensive and triangulated perspective.

Primary data:

- Expert interviews: We interviewed specialists, such as government officials, energy company executives, and researchers. These interviews helped us understand what influences Kazakhstan's renewable energy plans and how diplomacy attracts investment.
- Surveys: A structured questionnaire was distributed to a sample of stakeholders in the energy sector. A purposive sampling strategy was employed to target individuals with direct experience in renewable energy projects. The survey aimed to collect quantitative data on perceived investment risks, policy effectiveness, and growth prospects.

Secondary data:

- Statistical data: National statistics on energy production and investment were collected from official government sources of the Republic of Kazakhstan.
- Document analysis: Policy documents, legal acts, and reports from international organizations like IRENA were systematically reviewed to provide context and quantitative benchmarks.

3.3 Data analysis

The collected data were analyzed as follows:

- Qualitative analysis: Thematic analysis was the method used to analyze data from expert interviews and policy papers. This process involved identifying, coding, and understanding recurring ideas and trends related to Kazakhstan's energy diplomacy, foreign relations, and its utilization of renewable energy in its policies.
- Quantitative analysis: The study used descriptive statistics like frequencies, means, and percentages to analyze survey responses and national data. Trend analysis was also applied. This quantitative method helped find key patterns in renewable energy growth and supported the qualitative results with statistical backing.

By integrating the findings from both qualitative and quantitative analyses, this study provides a robust and multifaceted response to the research question.

4. Analysis and discussion

The pathways and prospects for developing renewable energy sources in the Republic of Kazakhstan are defined by the Ministry of Energy of the Republic of Kazakhstan. The Law of the Republic of Kazakhstan on the Support of Renewable Energy Sources provides definitions and types of renewable energy sources. Renewable energy sources (RES) are sources of energy that are continuously renewed by naturally occurring processes. They include the following types: solar radiation energy, wind energy, hydrodynamic energy of water, geothermal energy (heat from soil, underground water, rivers, and reservoirs), and anthropogenic sources of primary energy resources, such as biomass, biogas, and other fuels derived from organic waste used for producing electricity and/or heat. The legislative acts of Kazakhstan play a significant role in the development of renewable energy sources. The existing legislation is attractive for investors, including private investors and international financial institutions. However, to stimulate the electricity market, it is necessary to consider several additional recommendations and proposals from experts and scientists. To achieve the goals set under the Paris Agreement by 2050, the installed capacity of renewable energy facilities must increase by a factor of 10. This is the forecast provided by the International Renewable Energy Agency (IRENA). Despite commitments made by countries to limit the rise in global average

temperature, current investments in construction and development of green technologies may be insufficient to reach stated objectives. An indispensable part of a country's green ecosystem is its green taxonomy. The green taxonomy has several priority tasks, as highlighted in the UNDP Information Package for implementing small-scale renewable energy projects in Kazakhstan. Figure 1 illustrates these main objectives [2].

Renewable energy projects are included in the list of priority investment projects. Previously established investment preferences have been supplemented with benefits, including exemptions from the following taxes: land tax, property tax, and corporate income tax. In Kazakhstan, the duration of contracts for guaranteed electricity buyback by the RES operator has been extended to 20 years. A comprehensive analysis of Kazakhstan's renewable energy market was performed, drawing on research by the international auditing firm PwC. Project-level evaluations indicate that the predominant financing structure for renewable energy projects in Kazakhstan follows a 70/30 split, with 70% of costs funded through debt financing, primarily loans. Development banks play a pivotal role in financing these projects, as detailed in Table 1. Banks Involved in Renewable Energy Financing, which outlines the key financial institutions supporting the sector's growth. Despite the active development of the RES market in the Republic of Kazakhstan and strong legislative support, renewable energy still faces many challenges that restrict sector growth. One of the key limiting factors is investment risk. Several major reasons that hinder investment growth in the sector have been identified. The most critical among them are shown in Figure 2. This study examined how investment in Kazakhstan's renewable energy sector affects electricity production from renewable sources. The renewable energy facilities in Kazakhstan include wind (WPP), solar (SPP), small hydro (HPP), and biofuel power plants (BioPP). Table 2 shows data on electricity production from renewable energy sources in Kazakhstan.

Table 1. Banks involved in renewable energy financing

Bank	Amount (billion KZT)
EBRD (European Bank for Reconstruction and Development)	162
DBK (Development Bank of Kazakhstan)	67
China Development Bank	29
DBK Leasing	22
ADB (Asian Development Bank)	21
GCF (Green Climate Fund)	10
EDB (Eurasian Development Bank)	15
AIIB (Asian Infrastructure Investment Bank)	14
Green Climate Fund	10
ICBC	6

From Table 2, it can be seen that by the end of 2024, the share of electricity generated from RES in Kazakhstan's total production was 6.43%. The growth in RES share compared to 2022 was 42.8%. If such growth rates are maintained, the 2030 target is achievable. Electricity production from RES in Kazakhstan is generated by small hydro plants, wind farms, solar farms, and biogas installations. Detailed breakdown by source is provided in Table 3.

Table 2. RES electricity production in Kazakhstan, 2022–2024 [16]

Year	Total RES Production	Share of RES in Energy Structure (%)
2022	5,110.7	4.5
2023	6,675.5	5.92
2024	7,581.33	6.43

Figure 1. The main objectives of the "green" taxonomy [2]

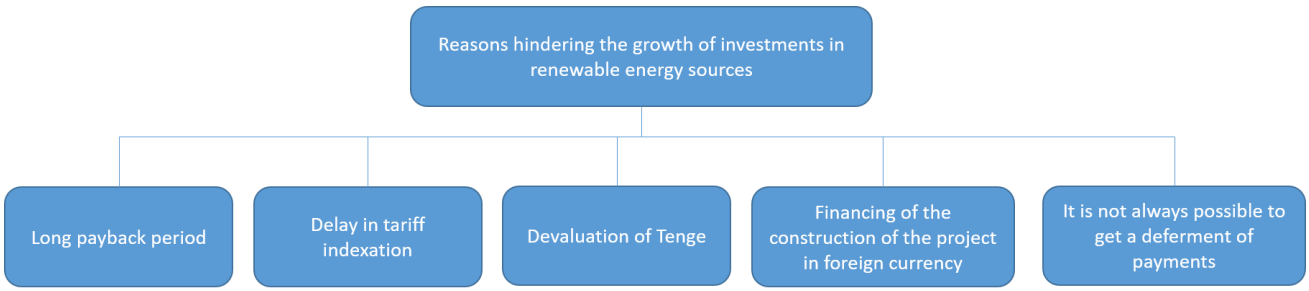

Figure 2. Reasons Hindering Investment Growth in RES [1]

According to Table 3, Kazakhstan had 148 RES installations by the end of 2024, with a combined capacity of 3,032.11 million kWh. This includes:

- 59 wind energy facilities with 1,520.05 million kWh capacity
- 46 solar energy facilities with 1,222.61 million kWh capacity
- 40 small hydro facilities with 287.68 million kWh capacity
- 3 bioenergy facilities with 1.77 million kWh capacity

In 2024, amendments were made to the Law of the Republic of Kazakhstan regarding support for the use of renewable energy sources and energy. According to this law, the population, farming households, and small and medium-sized enterprises are now allowed to generate electricity independently and sell it. Every citizen of Kazakhstan is permitted to install renewable energy systems with a capacity of up to 200 kilowatts and sell any surplus electricity generated by these systems. When evaluating the profitability of installing such renewable energy systems, several factors are essential:

- Location for solar panels (intensity of solar radiation and number of sunny days per year)
- Location for wind turbines (wind availability and speed)
- Cost of the renewable energy installation
- Household electricity consumption patterns

All of these factors determine how much surplus electricity can be supplied to the grid. Based on Kazakhstan's legislative acts and academic research, we identified the following additional recommended support measures for RES:

- Mandatory connection of renewable energy installations to transmission or distribution grids
- Priority and compulsory transmission of electricity generated from RES
- Mandatory purchase of electricity produced using RES by individual consumers through the Unified Settlement Center
- Exemption of RES producers from paying transmission taxes and elimination of licensing requirements for electricity production

Table 3. Electricity Production by RES Type in Kazakhstan (2022–2024) (millions of kWh) [16]

Year	Small HPP	#	WPP	#	SPP	#	BioPP	#
2022	260,00	37	948,00	46	1148,00	44	1.77	3
2023	269.61	39	1394.6	57	1202,60	45	1.77	3
2024	287.68	40	1520,05	59	1222.61	46	1.77	3

Practices from developed countries for supporting RES could be adapted and implemented in Kazakhstan. However, this requires a comprehensive approach:

- Evaluation of energy output from RES and associated costs
- Development of subsidy mechanisms and investment attraction strategies for sector development, considering the country's limited resources
- Creation of special investment funds to support subsidies

In Kazakhstan's case, the low energy efficiency of many buildings and the aging energy infrastructure, much of it from the Soviet era, must be considered, as it requires modernization. Therefore, evaluating locations where active use of small RES installations by individuals and their electricity contributions to the grid would not overload the system is crucial.

To effectively use small-scale RES installations, individuals need basic technical knowledge. Thus, RES distribution programs should include training and awareness initiatives on the operational features of such energy systems. Kazakhstan's RES sector receives active government support. Currently, government support includes:

- Guaranteed electricity buyback at auction price
- Annual indexation of tariffs
- Exemption from grid fees
- Investment preferences

These policies foster a favorable investment climate, support the development of new projects, and ensure the sustained growth of green energy in the country's overall energy balance. To enhance government support for RES projects, a scientific approach is needed in their implementation and development. A transparent and predictable tariff policy is essential, as is creating conditions for broader private-sector participation in RES construction and operation. Kazakhstan's government has stressed the inadmissibility of administrative barriers that deter investors and hinder project realization. Kazakhstan has committed to achieving a 15% share of electricity production from RES by 2030 and increasing that share to 50% by 2050. The country has a vast territory, it's the ninth largest in the world, and possesses 77% of Central Asia's solar energy potential and 90% of the region's wind energy potential. However, much of this potential remains underutilized, as Kazakhstan still relies heavily on Soviet-era energy infrastructure geared toward fossil fuels. For example, in 2024, the country's electricity was generated as follows:

- 66% from coal
- 21% from natural gas
- 6.6% from hydroelectric power
- Only 6.4% from RES

This scenario demands substantial investment in RES development and modernization of the grid infrastructure. Several Kazakh researchers emphasize the importance of developing renewable energy, as RES plays a crucial role in addressing global challenges—such as energy, environmental, and food security [3,5-8]. RES project support systems are essential for successful development and implementation. These include:

- Banking initiatives: energy loans and project financing
- The role of financial institutions and investment companies in backing RES
- Public-private partnerships in RES financing
- Challenges and opportunities for financial support of RES enterprises

Kazakhstan's commitment to using renewable energy sources is reinforced through the National Action Plan for Renewable Energy Development. This comprehensive strategy outlines ambitious targets and policy frameworks to facilitate RES deployment. Preferential tariffs and other incentive schemes have attracted investment and created a supportive environment for renewable energy projects. Furthermore, regulatory frameworks shed light on government investments and subsidies that drive sector growth.

Securing financial support is the cornerstone of renewable energy projects. Banks were the first to offer energy loans and project financing options, aiding RES implementation. Financial institutions and investment companies now collaborate to provide innovative funding models. Public-private partnerships have emerged as a viable pathway, highlighting the collaborative approach needed for a sustainable energy transition. Nevertheless, challenges in securing financial backing remain, necessitating strategic solutions for overall sector development.

5. Project financing, foreign investment, and risk mitigation

In Kazakhstan, the primary financing scheme comprises approximately 70% debt financing. In terms of the number of projects, nearly two-thirds are implemented by Kazakhstani investors. However, around 60% of all installed RES capacity is financed by foreign investors, since they tend to be more interested in undertaking large-scale projects. Kazakhstan is actively developing international cooperation and attracting investments in the RES sector, particularly in solar and wind energy projects. This supports the successful implementation of large-scale RES projects across various regions of the country. Currently, the main investors in RES projects in Kazakhstan are development banks and foreign investors. Foreign investors aim to stabilize the legislative framework and contractual conditions as they stood at the time investment obligations were undertaken. Such stability allows them to clearly understand and confidently assess their future commitments, responsibilities, and risks. RES projects in the Republic of Kazakhstan frequently utilize project finance structures, which combine debt and equity financing. This enables investors to share risks and participate effectively in the implementation of projects. Renewable energy projects require significant upfront investment. Because most of these projects are financed through loans from international organizations in foreign currency, currency fluctuations can result in substantial cost increases in the local currency, the Tenge (KZT). This is precisely why the tariff indexation mechanism was introduced to make projects more attractive to investors. However, there remains a risk of delayed tariff indexation, which may result in losses for investors, particularly if production costs rise and the tariff remains unchanged after project launch.

RES projects often have long payback periods, which raise risks for investors, especially in volatile economic conditions. Project financing is vulnerable to political interference. Additionally, legislative changes may significantly affect a project's financial outlook. Therefore, investors need to account for political risk before committing to obligations. Such factors represent serious challenges for investors, especially when planning and implementing renewable energy projects. In general, Kazakhstan's renewable energy sector presents several unique features and opportunities that make it attractive for project financing.

6. Proposals and recommendations

Analysis of actual data for the years 2022–2024 and forecast analysis through 2030 has shown that there are several problems and challenges in implementing and developing RES in the Republic of Kazakhstan:

- Dependence on weather conditions
- Legislative framework
- Generation instability
- Outdated coal-fired power plants
- Shortage of professional specialists
- Financial risks for investors

Restraining factors in the development of RES in Kazakhstan's energy market were thoroughly discussed at the 3rd International Business Festival (Qazag Green Fest). As a result of this forum, a number of recommendations were provided, which we also support:

- Review and adopt a Strategy for the development of the electricity sector in Kazakhstan through 2030
- Expand joint training and retraining programs with foreign universities for specialists in the energy sector
- Develop markets for bilateral renewable energy contracts
- Promote further incentives for small-scale RES
- Improve the tariff indexation mechanism for RES projects
- Strengthen informational support for RES development
- Exclude RES installations from the list of terrorist-vulnerable facilities

In our view, possible solutions for advancing production and investment in the renewable energy sector include:

i. Development of energy storage capacities and systems: To stabilize the energy system, energy storage systems should be developed and implemented. These systems will accumulate excess electricity generated by RES and release it into the grid during peak consumption periods.

ii. Regulatory mechanisms: Introduce step-by-step regulatory mechanisms governing the integration of new RES installations into the national energy system and determine the priority order for electricity transmission from various generation sources during peak loads and demand drops.

iii. Infrastructure and technology development: In order to make RES a competitive sector of the economy, it is necessary to have not only natural resources and sales markets. Development of related industries, such as manufacturing, transportation, and electricity sales, is also crucial. Attention should be given to creating industrial clusters that provide a full cycle: from design and component manufacturing to recycling of decommissioned RES equipment. Developing domestic infrastructure and technologies for solar and wind generation will help reduce dependence on imports, lower production costs through scale effects, reduce electricity tariffs, and make RES more accessible, while also creating new jobs and contributing to Kazakhstan's economic growth.

iv. Investor protection mechanisms: To protect investors from risks (e.g. delayed indexation, electricity price drops, or increases in capital and operating costs during RES project implementation), there is a need to create government-backed or private guarantee systems.

v. Implementation and expansion of educational programs and specialist training in the RES sector: Introducing relevant educational programs and training a sufficient number of RES specialists is a key task for industry development. Such specialists include solar and wind energy designers, operations engineers, and meteorological energy analysts.
Currently, Kazakhstan's Ministry of Science and Higher Education funds 18 programs in energy and energy efficiency. Eight of these programs are specifically focused on the development of renewable energy. Promoting green energy disciplines among young people will foster the development of renewable energy in Kazakhstan and help achieve global goals related to climate change and environmental protection.

7. Conclusion

We have presented information about various financial support systems available for renewable energy projects in Kazakhstan. With a clear understanding of these support mechanisms, potential investors can make informed decisions, contributing significantly to the country's goals in renewable energy and a sustainable future. Although challenges remain, the future of renewable energy in Kazakhstan is optimistic. By addressing regulatory difficulties, investing in research and development, and improving financial support mechanisms, Kazakhstan can overcome its obstacles and continue progressing toward a sustainable energy future. Through collective efforts of government bodies, private enterprises, and the public, the republic can not only achieve its renewable energy targets but also become one of the leading countries in the RES sector, paving the way for a greener and more sustainable future. The article reviewed the development system of production and investment support for renewable energy sources in Kazakhstan. Several key findings and recommendations were made that underscore the pivotal role of renewable energy sources. Investment support programs for RES development have significantly boosted the growth of solar and wind energy projects. These efforts not only reduce CO_2 emissions but also stimulate economic growth, create jobs, and enhance the country's energy security. Regulatory challenges, technological limitations, and financial barriers must be addressed through coordinated efforts involving government agencies, businesses, and research institutions. Government bodies play a central role in shaping the future of renewable energy. Clear and consistent policies, streamlined regulatory processes, and incentives for research and innovation are imperative. Government authorities should also focus on raising public awareness, promoting environmental responsibility, and cultivating a culture of energy efficiency. Companies can contribute to investments and growth in the RES sector. Investing in research and development is especially important. Collaborating with international partners and participating in public-private partnerships can accelerate the adoption of advanced renewable energy solutions. Moreover, companies should actively engage with the public, informing communities about the benefits of RES and sustainable practices. Involving communities in dialogue, addressing concerns, and highlighting the tangible benefits of RES projects fosters a sense of ownership and pride.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

The manuscript contains all the data. However, more data will be available upon request from the authors.

Conflict of interest

The authors declare no potential conflict of interest.

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