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KAZAKHSTAN ENERGY POLICY: TRANSITION TO RENEWABLE ENERGY SOURCES AND DEVELOPMENT PROSPECTS

The article analyzes the status, potential, and development prospects of renewable energy sources (RES) in Kazakhstan in the context of the global transition to carbon neutrality. Kazakhstan, traditionally focused on the use of hydrocarbons, is faced with the challenge of diversifying its energy balance and reducing carbon dioxide emissions. The article examines in detail the main types of RES available in the country, including solar, wind, hydro, and bioenergy. It analyzes how the natural and climatic conditions of Kazakhstan contribute to the development of these areas: the wind resources of the northern and central regions, the abundance of solar radiation in the south, and significant biomass reserves open broad opportunities for generating clean energy. Particular attention is paid to state policy and legislative measures to support RES, including the transition to an auction system for capacity distribution, introduced in 2018. This system has increased transparency, competitiveness, and attracted international investment. The article notes the important role of international cooperation: such organizations as the European Bank for Reconstruction and Development (EBRD), the United Nations Development Programme (UNDP) and the United States Agency for International Development (USAID) actively support Kazakhstan's initiatives to develop renewable energy sources, providing both technical and financial assistance. At the same time, the article highlights the existing barriers to the development of the renewable energy sector. These include high costs of equipment and infrastructure, difficult logistical conditions, extreme climatic factors and the need to adapt technologies. These obstacles must be addressed to achieve the goals set by the government, including to meet international commitments to reduce the carbon footprint.

Key words: renewable energy, energy potential, solar energy, wind energy, hydropower, bioenergy, carbon neutrality, auction system, green economy, international cooperation.

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Қазақстанның энергетикалық саясаты: жаңартылатын энергия көздеріне көшу және олардың даму перспективалары

Мақала көміртегі бейтараптығына жаһандық көшу жағдайында Қазақстандағы жаңартылатын энергия көздерін (ЖЭК) дамытудың жай-күйін, әлеуетін және перспективаларын талдауға арналған. Көмірсутектерді пайдалануға дәстүрлі түрде бағдарланған Қазақстанның алдында энергетикалық балансты әртараптандыру және көмірқышқыл газының шығарындыларын азайту міндеті тұр. Мақалада елде бар жаңартылатын энергия көздерінің негізгі түрлері, соның ішінде күн, жел, су және биоэнергетика егжей-тегжейлі қарастырылады. Қазақстанның табиғи-климаттық жағдайлары осы бағыттардың дамуына қалай ықпал ететіні талданады: солтүстік және орталық аймақтардың жел ресурстары, оңтүстіктегі күн радиациясының көптігі және биомассаның айтарлықтай қоры экологиялық таза энергия өндіруге кең мүмкіндіктер ашады. 2018 жылы енгізілген қуаттарды бөлудің аукциондық жүйесіне көшуді қоса алғанда, жаңартылатын энергия көздерін қолдау жөніндегі мемлекеттік саясат пен заңнамалық шараларға ерекше назар аударылады. Бұл жүйе ашықтықты, бәсекеге қабілеттілікті арттырып, халықаралық инвестицияларды тартты. Мақалада халықаралық ынтымақтастықтың маңызды рөлі атап өтілген: Еуропалық қайта құру және даму банкі (ЕҚДБ), Біріккен Ұлттар Ұйымының Даму Бағдарламасы (БҰҰДБ) және Америка Құрама Штаттарының Халықаралық Даму Агенттігі (USAID) сияқты ұйымдар техникалық және қаржылық көмек көрсету арқылы Қазақстанның жаңартылатын энергия көздерін дамыту жөніндегі бастамаларын белсенді түрде қолдайды. Сонымен бірге, мақалада жаңартылатын энергия секторын дамытудағы кедергілер атап өтілген. Оларға жоғары жабдық пен инфрақұрылымдық шығындар, күрделі логистикалық жағдайлар, экстремалды климаттық

және технологияны бейімдеу қажеттілігі жатады. Бұл кедергілер үкіметтің қойылған мақсаттарына жету, соның ішінде көміртегі ізін азайту жөніндегі халықаралық міндеттемелерді орындау үшін шешімдерді талап етеді.

Түйін сөздер: жаңартылатын энергия, энергетикалық әлеует, күн энергиясы, жел энергиясы, су энергетикасы, биоэнергетика, көміртегі бейтараптығы, аукцион жүйесі, жасыл экономика, халықаралық ынтымақтастық.

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Казахстанская энергетическая политика: переход на ВИЭ и перспективы их развития

Статья посвящена анализу состояния, потенциала и перспектив развития возобновляемой энергетики (ВИЭ) в Казахстане в условиях глобального перехода к углеродной нейтральности. Казахстан, традиционно ориентированный на использование углеводородов, сталкивается с задачей диверсификации своего энергетического баланса и снижения выбросов углекислого газа. В статье подробно рассматриваются основные виды ВИЭ, доступные в стране, включая солнечную, ветровую, гидро- и биоэнергетику. Анализируется, как природные и климатические условия Казахстана способствуют развитию этих направлений: ветровые ресурсы северных и центральных регионов, обилие солнечной радиации на юге и значительные запасы биомассы открывают широкие возможности для генерации экологически чистой энергии. Отдельное внимание уделено государственной политике и законодательным мерам по поддержке ВИЭ, включая переход на аукционную систему распределения мощностей, введенную в 2018 году. Эта система позволила повысить прозрачность, конкурентоспособность и привлечь международные инвестиции. Статья отмечает важную роль международного сотрудничества: такие организации, как Европейский банк реконструкции и развития (ЕБРР), Программа развития ООН (ПРООН) и Агентство США по международному развитию (USAID), активно поддерживают инициативы Казахстана по развитию ВИЭ, предоставляя как техническую, так и финансовую помощь.

Вместе с тем статья подчеркивает существующие барьеры для развития сектора ВИЭ. К ним относятся высокие затраты на оборудование и инфраструктуру, сложные логистические условия, экстремальные климатические факторы и потребность в адаптации технологий. Эти препятствия требуют решения для достижения поставленных правительством целей, в том числе для выполнения международных обязательств по снижению углеродного следа.

Ключевые слова: возобновляемая энергетика, энергетический потенциал, солнечная энергия, ветровая энергия, гидроэнергетика, биоэнергетика, углеродная нейтральность, аукционная система, зеленая экономика, международное сотрудничество.

Introduction

In the context of the global transition toward sustainable development, Kazakhstan is actively striving to reduce its reliance on carbon-intensive energy sources and diversify its economy through the advancement of renewable energy. Despite possessing substantial reserves of oil, gas, and coal, the nation faces pressing environmental challenges. These include elevated levels of greenhouse gas emissions, significant environmental degradation of natural resources, and mounting risks linked to climate change. As a result, the shift to renewable energy sources (RES) represents a strategically critical priority for state policy, aimed at achieving carbon neutrality by 2060 and fulfilling the country's commitments under the Paris Agreement.

Kazakhstan's renewable energy development is bolstered by governmental initiatives and targeted investments in infrastructure and technology. The nation's natural conditions are highly conducive to the exploitation of various RES, such as solar, wind, hydro, and bioenergy. The expansive steppe and mountainous regions provide stable solar radiation levels and consistent wind flows, while the agricultural sector generates substantial biomass resources suitable for bioenergy production. However, realizing this potential requires addressing a range of systemic barriers, including high initial capital costs, limited technical expertise, insufficient access to advanced technologies, logistical constraints, and a lack of requisite infrastructure.

This study aims to analyze the current state, opportunities, and challenges associated with renewable energy development in Kazakhstan, while assessing the role of governmental policies and international support mechanisms in establishing a sustainable energy system. The objectives of the

study include: (1) evaluating Kazakhstan's natural and technological resources for RES development, with a focus on wind, solar, hydro, and bioenergy; (2) identifying factors impeding sectoral growth; and (3) formulating recommendations to attract investment and enhance international cooperation in the field.

The findings of this research position Kazakhstan as a promising player in the green energy market of Central Asia. Furthermore, the study highlights key areas for improving the efficiency and sustainability of the nation's energy system, thereby contributing to its strategic objectives in transitioning toward a low-carbon economy.

Methodology and research methods

This research employs a combination of methodological approaches to examine the current status and prospects of renewable energy development in Kazakhstan. The primary methods utilized are as follows:

Analytical Method. This method involves the systematic analysis of statistical data, official reports, and scientific literature. The study incorporates data on renewable energy capacity, electricity generation volumes, and carbon dioxide emissions. By analyzing these datasets, the research identifies key performance indicators of the renewable energy sector and assesses its growth dynamics.

Expert Assessment. The study integrates expert forecasts and opinions from authoritative organizations, such as the International Energy Agency (IEA), the European Bank for Reconstruction and Development (EBRD), and leading Kazakhstani energy specialists. These expert evaluations provide a nuanced understanding of the prospects and challenges facing Kazakhstan's renewable energy sector within both national and international contexts.

Historical and Logical Method. This method is applied to trace the evolution of Kazakhstan's renewable energy policies. The research examines legislative and regulatory developments since the adoption of the first renewable energy laws, thereby evaluating the progression of state regulation and the strategic planning initiatives undertaken in this domain.

Forecasting Method. Based on an analysis of current trends and strategic objectives–such as the government's plans to increase the share of RES in Kazakhstan's energy balance–this method enables projections about the sector's future trajectory. These forecasts account for the economic and environmental goals outlined in national strategies, offering insights into the long-term outlook for renewable energy development.

The methodology of this research is grounded in a systematic and comprehensive approach to assessing the renewable energy landscape in Kazakhstan. Both quantitative and qualitative indicators are incorporated to ensure a robust analysis. The systematic collection and interpretation of statistical data provide a factual basis for understanding the current state and potential of renewable energy sources, while expert opinions and forecasts enrich the analysis by contextualizing it within broader economic and policy frameworks.

This study employs an interdisciplinary approach that integrates economic, environmental, technical, political, and social dimensions influencing renewable energy development. By adopting such a multifaceted perspective, the research aims to provide an objective and holistic understanding of the opportunities and challenges within Kazakhstan's renewable energy sector. Additionally, the findings will support the formulation of evidence-based recommendations for enhancing energy policy, fostering international collaboration, and mobilizing investment to ensure the sustainable growth of this critical sector.

Literature review

The development of renewable energy in Kazakhstan has become a significant area of inquiry for both domestic and international researchers, reflecting the global shift toward sustainable energy systems. Among Kazakhstani scholars, the works of Zhunussova et al. (2020) are particularly noteworthy. These researchers explore various dimensions of renewable energy development, including the availability of natural resources, infrastructural challenges, and the influence of government policies on sectoral growth. Their studies provide valuable insights into how policy frameworks and governance mechanisms can either promote or impede the expansion of renewable energy initiatives in the country (Zhunussova et al., 2020).

Further contributions to the literature include the collaborative study by Akhmetov et al. (2011), titled "Wind Power Development in Kazakhstan: Potential and Obstacles." This research delves into the specific challenges facing wind energy in Kazakhstan, such as technological barriers, economic constraints, and the absence of advanced grid infra-

structure to support large-scale wind power generation. The authors also examine the interplay between local climatic conditions and wind energy potential, providing a nuanced understanding of the feasibility of wind power deployment in various regions of Kazakhstan (Akhmetov et al., 2011).

A broader analysis of Kazakhstan's energy sector is provided by Dulambayeva et al. (2013), who examine its current state and long-term development prospects. Their comprehensive study evaluates the structural and institutional aspects of the energy sector, offering an overview of existing energy resources and infrastructure (Dulambayeva et al., 2013). Similarly, Өміртай et al. (2023) explore Kazakhstan's role in the global energy market, addressing issues such as geopolitical dynamics, price volatility, and competition among energy-exporting nations. Глазачев (2023) places Kazakhstan's energy development in a regional context, identifying opportunities for cooperation and shared challenges among Central Asian states.

In addition to domestic research, international scholars have made valuable contributions to understanding Kazakhstan's renewable energy potential. Tskhay (2019) and Cochran (2016) provide critical evaluations of renewable energy sources in Kazakhstan. These studies emphasize the untapped potential of solar, wind, hydro, and bioenergy resources, as well as the technical and policy measures required to harness them effectively. By integrating renewable energy within the broader framework of energy security and climate change mitigation, these works underscore the strategic importance of diversifying Kazakhstan's energy portfolio (Tskhay, 2019; Cochran, 2016).

Reports from international organizations, including the International Energy Agency (IEA), the European Bank for Reconstruction and Development (EBRD), World Bank (WB), and United States Agency for International Development (USAID), also play a crucial role in the literature. These reports offer up-to-date data, policy recommendations, and comparative analyses that position Kazakhstan's renewable energy development within a global context. They highlight Kazakhstan's potential to align its energy transition efforts with international best practices, thereby enhancing its competitiveness in the global energy market. Moreover, these reports emphasize the importance of international collaboration and financing mechanisms in overcoming the economic and technological barriers to renewable energy expansion (IEA, 2022; EBRD, 2019; World Bank, 2021; USAID, 2022).

However, despite the extensive body of research, certain gaps remain unaddressed in the existing literature. One such gap concerns the adaptation of renewable energy technologies to Kazakhstan's extreme climatic conditions, which include severe temperature fluctuations, high winds, and varying levels of solar radiation. These conditions pose unique challenges to the deployment and maintenance of renewable energy systems. Another critical issue is the long-term sustainability of renewable energy projects, particularly in terms of financial viability, technological innovation, and environmental impact. These gaps highlight the necessity for interdisciplinary research that integrates technical, economic, and policy perspectives to formulate comprehensive strategies for the sustainable development of Kazakhstan's renewable energy sector.

In conclusion, while the existing literature provides a robust foundation for understanding the challenges and opportunities of renewable energy development in Kazakhstan, further research is needed to address the identified gaps. A more integrated and multidimensional approach would not only deepen our understanding of the sector but also contribute to the formulation of practical recommendations for policymakers and stakeholders. By bridging these gaps, future studies can support Kazakhstan's transition to a sustainable and resilient energy system that aligns with global trends and domestic priorities.

Results and discussion

Kazakhstan's energy policy prioritizes the establishment of a decentralized, environmentally sustainable, and balanced energy supply system that integrates renewable energy sources. This policy direction is supported by the country's dual advantages: significant reserves of traditional fossil fuels and favourable natural conditions for renewable energy deployment (European Bank for Reconstruction and Development, 2019: 4). However, the extensive reliance on oil, gas, and coal has had detrimental environmental impacts, including substantial contributions to global climate change. The intensification of international efforts to reduce carbon dioxide emissions further underscores the growing importance of renewable energy as a viable alternative to fossil fuels.

Kazakhstan's rising energy demand, fuelled by economic growth, highlights the critical need for investments in clean energy solutions. Redirecting a portion of revenues generated from oil and gas ex-

ports toward the development of renewable energy infrastructure could diversify the economy and establish a foundation for long-term energy sustainability. This strategic shift would enable Kazakhstan to assume a leadership position in renewable energy within the Central Asian region, where energy demand is projected to grow significantly (Cohran, 2016).

The country possesses considerable potential for the development of hydro, wind, and solar energy, according to expert assessments. However, the practical utilization of these resources remains limited due to several barriers, including high capital costs, inadequate infrastructure, and limited technological capacity. Despite these challenges, renewable energy development presents significant opportunities, particularly for enhancing local electricity generation and addressing distributed energy needs in remote regions. As emphasized by energy expert Zh. Khairushev, transitioning away from coal and gas-fired power plants is essential to reduce harmful emissions. "Current trends underscore the necessity of formulating a comprehensive, long-term strategy for the development of Kazakhstan's electric power sector, targeting carbon neutrality and sustainable development by 2050. This strategy would benefit from close cooperation with international partners to achieve its goals" (Жанадилова et al., 2022: 60).

Kazakhstan has demonstrated a commitment to international climate agreements, beginning with its accession to the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and subsequent ratification of the Kyoto Protocol in 2009. In 2016, the country further strengthened its climate commitments by ratifying the Paris Agreement, under which it pledged to reduce greenhouse gas emissions by 15% from 1990 levels by 2030, with a potential increase to 25% contingent on international support (Astana International Financial Centre, 2023). The enactment of the 2021 Environmental Code further obligates government institutions to support these objectives. Despite these measures, the energy intensity of Kazakhstan's economy remains significantly higher than the global average–by nearly 70%–due to its reliance on energy-intensive industries and coal as a primary energy source.

According to Kazakhstan's report to the UNFCCC, the energy sector accounted for approximately 80% of the nation's greenhouse gas emissions in 2020, with 90% of these emissions stemming from fuel combustion (International Energy Agency, 2022: 15). Recognizing the urgency of mitigating climate change, President K.K. Tokayev has committed the country to achieving carbon neutrality by 2060. The approval of the Carbon Neutrality Strategy in 2023 has further solidified Kazakhstan's climate policy framework (Стратегия достижения углеродной нейтральности Республики Казахстан до 2060 года, 2023).

It is noteworthy that Kazakhstan was the first among the post-Soviet states to introduce an emissions trading system (ETS). However, the effectiveness of this system has been limited by issues such as excess quotas and high emission coefficients for coal-fired power plants. In addition, emissions from other sectors, such as transportation and housing, continue to rise while policies and measures to reduce emissions from these sectors have yet to be developed (International Energy Agency, 2022).

Kazakhstan is actively taking steps to reduce greenhouse gas emissions, which contributes to the transition to a sustainable, green economy. These measures include the introduction of "clean" technologies aimed at increasing resource efficiency and optimizing emissions at an economically viable level. An important component is the implementation of comprehensive technology audits at 50 of the largest polluting enterprises, as well as achieving full implementation of best available technologies (BAT) by 2025 (Лим et al., 2021:16).

"According to British experts, 60% of Kazakhstan's territory has significant potential for the development of alternative energy sources, which can significantly contribute to meeting the country's energy needs. Moreover, expanding the use of renewable sources can support oil and gas exports, creating significant revenues in the context of expected growth in world hydrocarbon prices" (Dulambayeva, 2013: 971).

Kazakhstan has extensive reserves of renewable energy sources, including hydropower, solar and wind energy (Dulambayeva, 2013: 12). The hydropower potential is estimated at 170 billion kWh, while it is technically possible to use 62 billion kWh, of which 27 billion kWh are considered economically feasible (International Trade Administration, 2021: 5). However, the share of hydropower in the country's total electricity production is only 2%, despite the installed capacity of 12.3%. Most of the hydropower resources are concentrated in the east and south of Kazakhstan, along the Irtysh, Ili and Syr Darya rivers, accounting for 73% of the total hydropower capacity. Among the large hydroelectric power plants are the Bukhtyrminskaya, Shulbinskaya and Ust-Kamenogorsk on the Irtysh River, Kap-

shagayskaya on the Ili River and Shardarinskaya on the Syr Darya River (Самрук Қазына, 2018). There are 15 large hydroelectric power plants in the country with a capacity of more than 50 MW, with a total capacity of 2.25 GW, which is up to 13% of the country's total generating capacity. These stations generate about 8 TWh of electricity per year, which corresponds to approximately 8% of the total electricity production (Исполнение поручений Президента: в Казахстане разработана Концепция развития электроэнергетической отрасли страны до 2035 г., 2022).

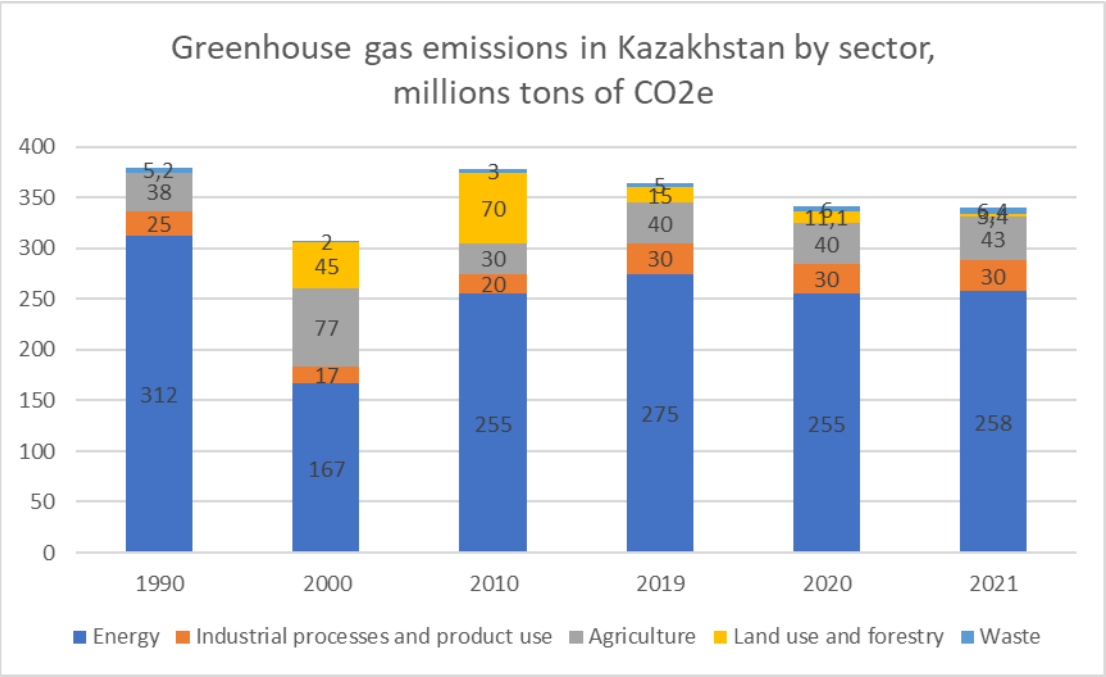

Figure 1 – Greenhouse gas emissions in Kazakhstan by sector, millions tons of CO2e
*Note – Compiled from source (Astana International Financial Centre, 2023: 3)

The Minister of Energy of the Republic of Kazakhstan B. Akchulakov emphasizes that the energy sector is the basis for the country's economic development. Ensuring energy security and accelerated development of the industry to meet the needs of the economy are considered priority tasks (Концепция развития топливно-энергетического комплекса Республики Казахстан на 2023–2029 годы, 2023). According to the Concept for the Development of the Fuel and Energy Sector of the Republic of Kazakhstan for 2023-2029 (2023), as of January 1, 2023, there were 130 renewable energy facilities with a total capacity of 2388 MW operating in the country. Among them are 46 wind power plants with a capacity of 957.5 MW, 44 solar power plants with a capacity of 1149 MW, 37 hydroelectric power plants with a capacity of 280 MW and 3 bioenergy facilities with a capacity of 1.8 MW. (Figure 2).

Data analysis shows that wind and solar power plants make the largest contribution, providing about 88% of the renewable energy capacity, confirming the high potential of these sources. At the same time, hydro and bioenergy occupy a relatively smaller share, indicating opportunities for their further development. As for the share of electricity generated from renewable sources in general, by the end of 2022 it reached 4.53%, indicating stable growth compared to 2020 (3.05%) and 2021 (3.67%). In 2022, the share of electricity from renewable (sources, excluding large hydroelectric power plants, amounted to 4.4% (according to other data – 4.53%) (Концепция развития топливно-энергетического комплекса Республики Казахстан на 2023–2029 годы, 2023). (Figure 3).

This growth reflects the country's efforts to transition to more sustainable energy sources and meet environmental commitments, but further investment and infrastructure support are needed to achieve the goals.

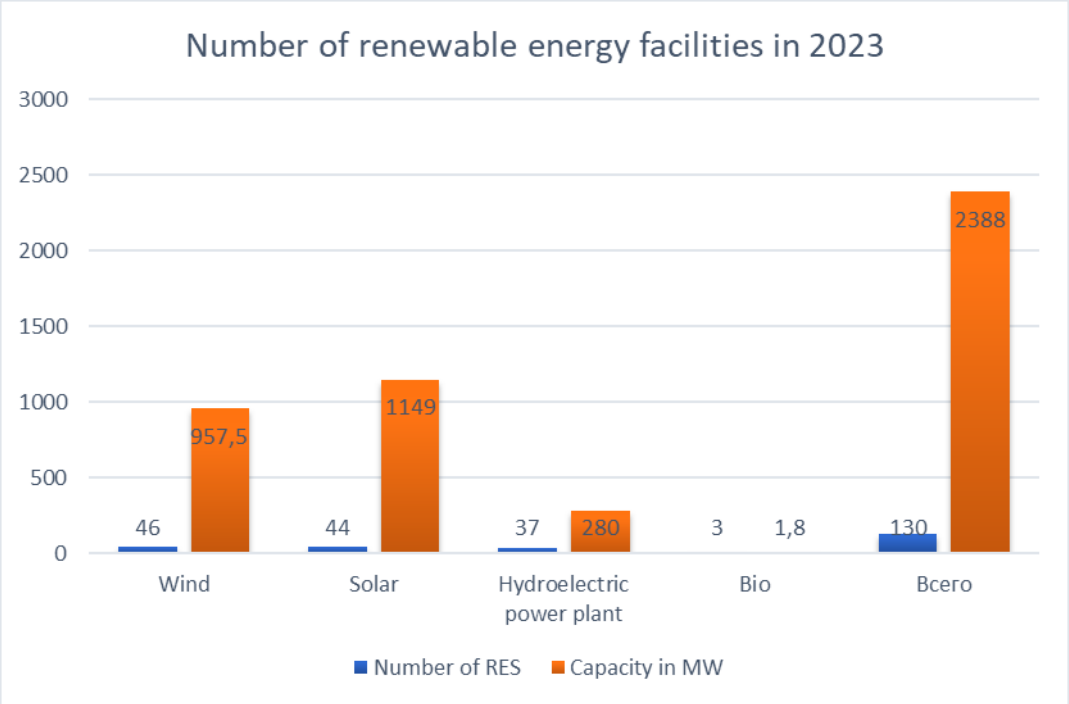

Figure 2 – Number of renewable energy facilities on January 1, 2023
*Note – Compiled from source (Концепция развития топливно-энергетического комплекса Республики Казахстан на 2023–2029 годы, 2023)

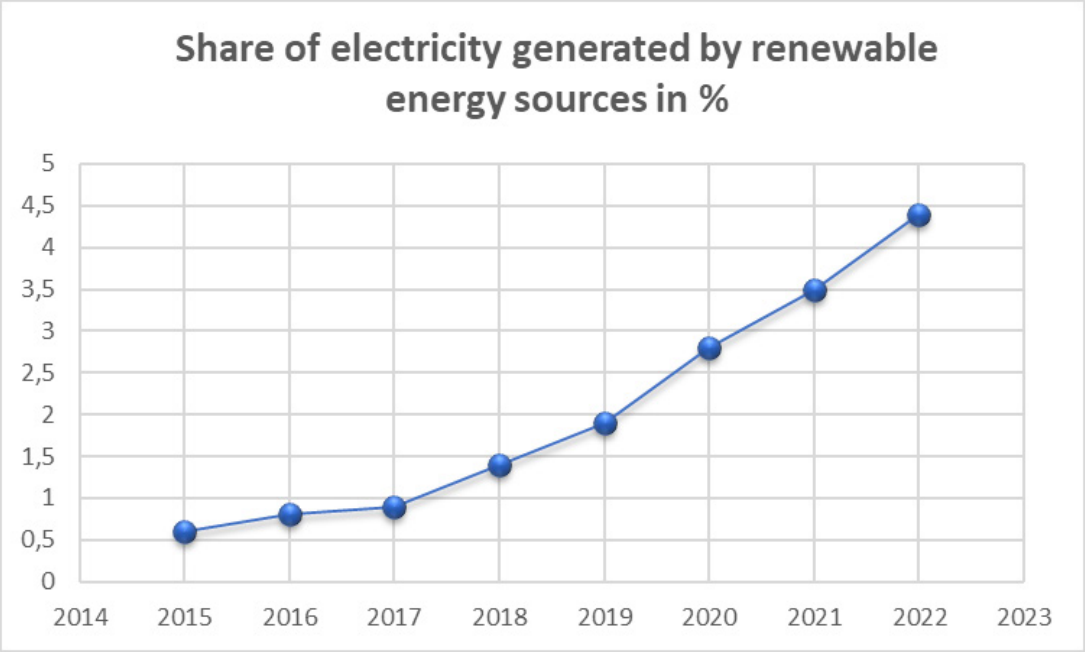

Figure 3 – Share of electricity generated by renewable energy sources
*excluding large hydroelectric power plants
*Note – Compiled from source (Бюро Национальной статистики Агенства по Стратегическому планированию и реформам Республики Казахстан).

However, it should be noted that total electricity production (as of October 16, 2023), including exports, reached 86.9 billion kWh, while consumption amounted to 86.8 billion kWh, which represents a decrease of 1.4% compared to 2022 figures. Energy Minister B. Akchulakov explained this decrease by measures to combat illegal activities in the field of digital mining, taken to maintain the load on the power grid below 16.1 GW in the autumn-winter period of 2022-2023.

The Ministry of Energy has also developed a plan for the development of the electric power industry until 2035, which provides for systemic measures, including reforming the electricity market and transitioning to a new operating model based on centralized purchases and sales of electricity. In order to reduce the wear and tear of generating capacities by 15% by 2035, it is planned to introduce a new tariff policy "Tariff in exchange for investments", which assumes a threefold increase in annual investments. Within the framework of this strategy, it is recommended to strengthen the role of owners of energy producing organizations, to provide measures for investing their own funds in modernization projects. The maximum amount of funds for the return of investments in the amount of 32 billion tenge has been set in the electric power market, with a requirement to increase this amount to 100 billion tenge. Among the priority areas, the implementation of 14 large projects for a total of more than 9 trillion tenge has been identified, which requires the involvement of foreign sources of financing and modern technologies (Исполнение поручений Президента: в Казахстане разработана Концепция развития электроэнергетической отрасли страны до 2035 г., 2022).

In 2018–2019, the Government of Kazakhstan, with the support of USAID, organized 28 auctions for a total capacity of 1,255 MW, which resulted in the selection of projects with a total capacity of 1,070.82 MW (including wind power plants – 609.84 MW, solar power plants – 356.5 MW, hydroelectric power plants – 89.08 MW, biogas plants – 15.4 MW). 145 companies from 12 countries participated in the auctions, and the reduction in prices for solar energy in the second year amounted to 63%. 30 companies entered into power purchase agreements for 15 years, and another 12 are in the process (World Bank, 2021). From 2020 to 2022, additional auctions resulted in the selection of 83 out of 1,746 declared projects, which attracted $400 million in investments.

Table 1 – Results of the selection of renewable energy projects

Types of RES	2018	2019	2020	2021	2022	Total
Capacity offered at auctions (MW)						
Wind	620	100	65	50	400	1235/
Solar	290	80	55	20	60	505
Hydro	75	65	120	120	220	600
Bio	15	10	10	10	10	55
Total	1000	255	250	200	690	2395
Selected in auctions (MW)/number of projects						
Wind	501/6	109/5	65/3	50/1	400/8	1125/33
Solar	270/12	87/3	60/4	20/1	40/2	476/22
Hydro	82/7	7/2	23/9	12/4	-	124/22
Bio	5/1	10/3	-	5/2	-	21/6
Total	858/36	213/13/	148/16	87/8	440/10	1746/83

*Note – Compiled from source (Astana International Financial Centre, 2023)

In general, the main investors in recent years have been European, Chinese and, less frequently, Russian companies (primarily Rosatom) (Глазачев, 2023). It should be noted that financing of renewable energy projects in Kazakhstan is most often carried out by Development Banks. (Figure 4).

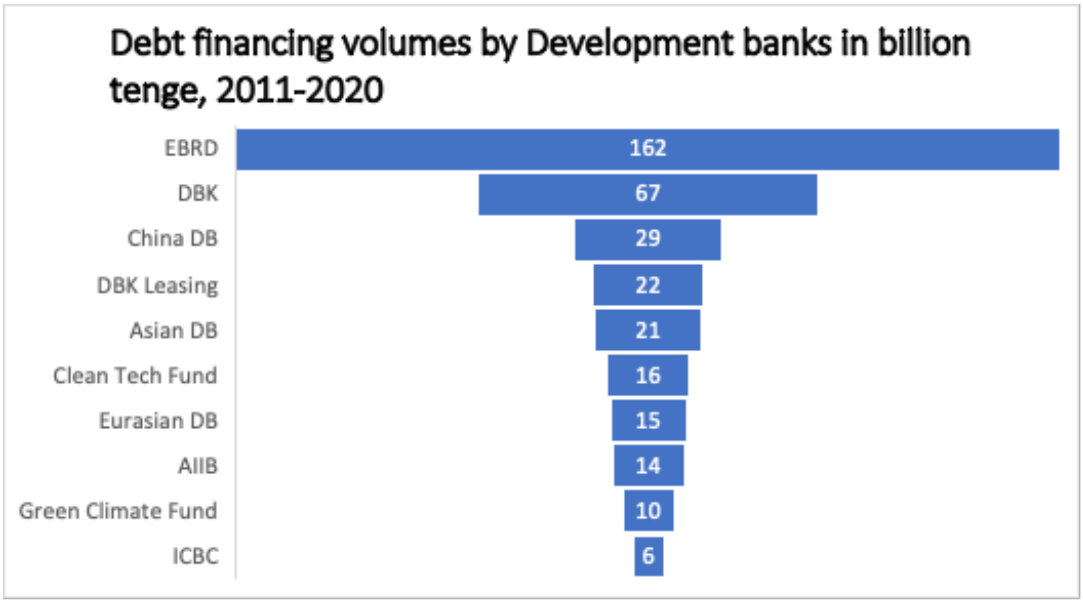

Figure 4 – Volume of renewable energy financing by Development Banks
*Note – Note – Compiled from source (World Bank, 2021)

In addition, data analysis showed that the main investors in the renewable energy sector of Kazakhstan are companies from the power and oil and gas sectors, mainly subsidiaries specializing in renewable energy sources and manufacturers of relevant equipment.

Even though the law on support for renewable energy was adopted in Kazakhstan back in 2009 (Закон РК О поддержке использования возобновляемых источников энергии от 4 июля 2009 г., 2023), significant growth in the sector began only after amendments were made between 2013 and 2017. State support measures have proven effective: since then, about 90 new renewable energy projects have been initiated, providing an average annual growth rate of 24% (Lim et al., 2021).

Between 2011 and 2020, about 628.5 billion tenge were invested in renewable energy projects. Local investors initiated 63% of projects, but their share in the total capacity of projects decreased by more than 20%. The attraction of foreign investors, especially from China, Germany, Italy, as well as joint ventures between Kazakhstan and Great Britain, increased from 13% (by number of facilities) to 40% (by installed capacity), which indicates the interest of foreign partners in large projects in Kazakhstan. (Figures 5,6).

According to the International Energy Agency, despite the significant potential of renewable energy sources (RES) in Kazakhstan, their share in the energy balance remains low due to abundant hydrocarbon resources, which hinder the development of RES (International Energy Agency, 2022). Experts believe that the country's strong dependence on cheap energy sources, especially coal, may hinder the implementation of energy-efficient and environmentally friendly solutions, hindering the use of the full potential of RES (Лим et al., 2021). Nevertheless, the government of Kazakhstan actively supports the development of RES and attracting investment in this sector. The largest funding in the field of renewable energy is directed to solar and wind energy, as well as to the construction of large power plants. The main contribution to the development of RES in the country is carried out mainly through investments in solar and wind projects, which demonstrate the greatest potential and growth prospects. (Figure 7).

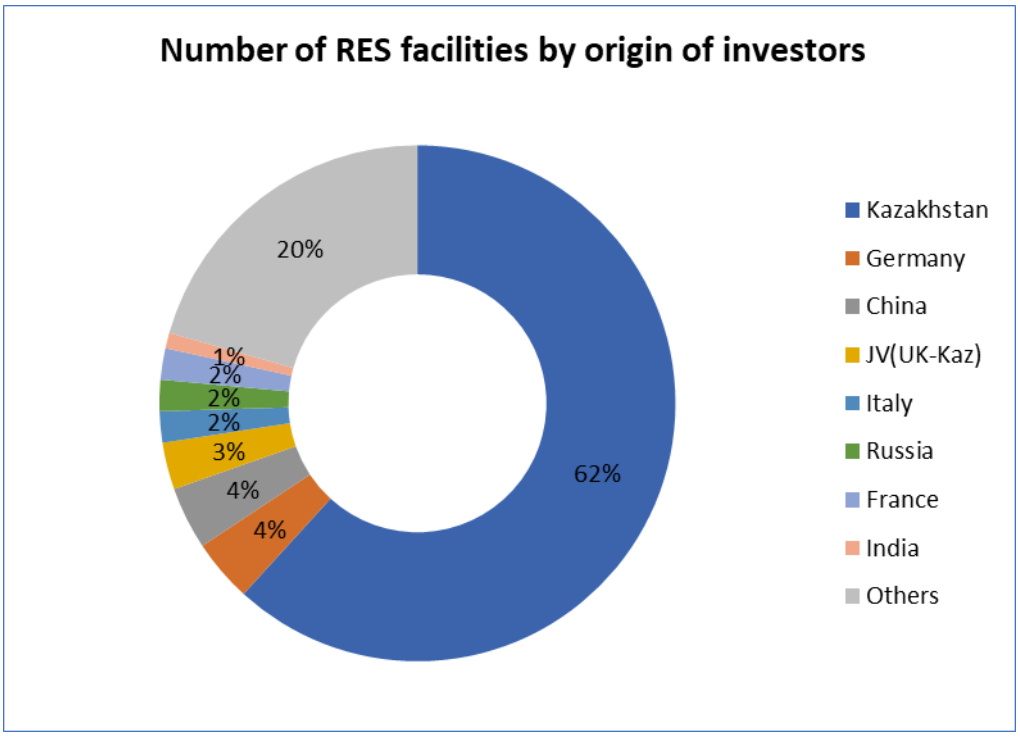

Figure 5 – Number of Renewable Energy Facilities by origin of investors, 2011-2020
*Note – Compiled from source (Lim et al., 2021).

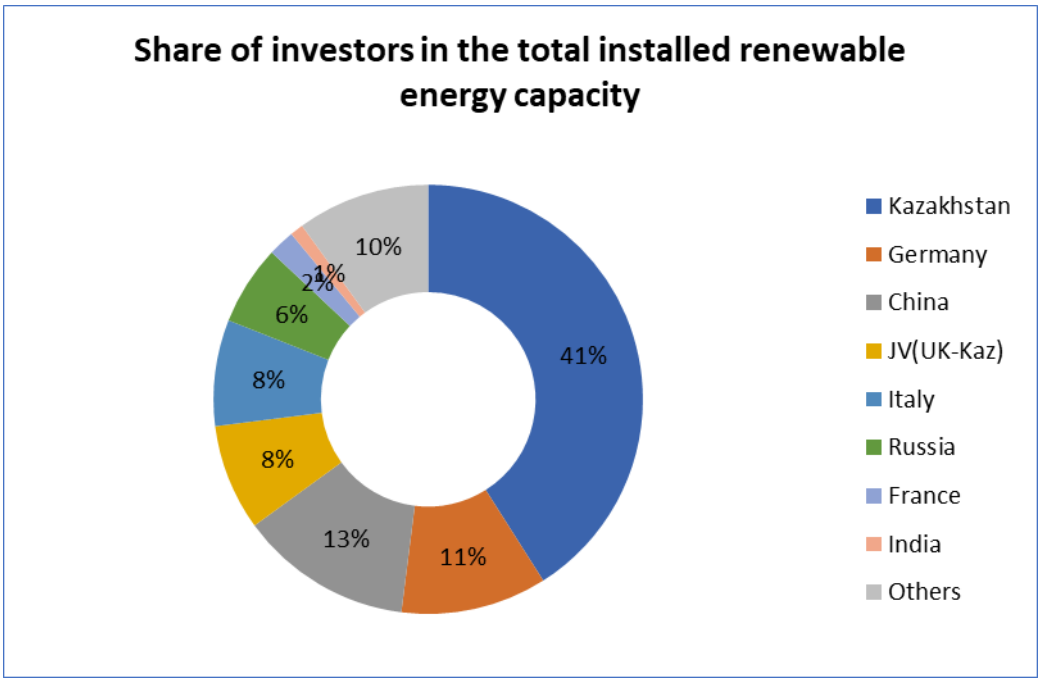

Figure 6 – Share of Investors in Total Installed Renewable Energy Capacity (2011-2020)
* Note – Compiled from source (Lim et al., 2021).

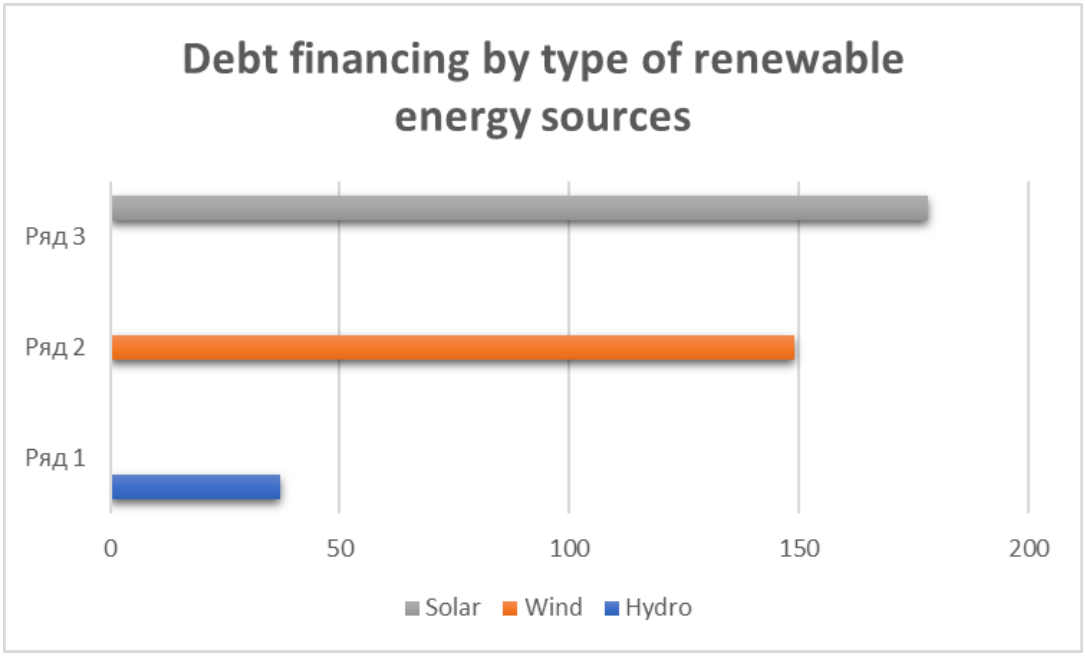

Figure 7 – Financing by type of renewable energy sources, billion tenge, 2011-2020
*Note – Compiled from source (Lim et al., 2021: 21).

Moreover, the country has achieved the goal of generating 3% of its electricity from renewable energy sources by 2020 (International Energy Agency, 2022: 14) and has set a goal to increase this share to 10% by 2030 and 50% by 2050 (Chikanayev and Abdukhalykova, 2021; USAID, 2022). Currently, there are more than 130 renewable energy facilities in Kazakhstan with a total capacity of over 2 GW, including solar, wind and large hydroelectric power plants, which significantly exceeds the 2011 figures.

Since January 1, 2018, Kazakhstan has switched from fixed "green" tariffs to an auction system for renewable energy projects. This step has increased the transparency and efficiency of project allocation, supporting economically sound initiatives (Chikanayev and Abdukhalykova, 2021: 106). From 2018 to 2021, the country held auctions for more than 1,700 MW, which led to the implementation of 75 projects (International Energy Agency, 2022: 14). Kazakhstan was the first in Central Asia to use auctions to distribute contracts for renewable energy projects, which helped attract investment and support the concept of a "green economy" (USAID, 2022). The concept is being implemented in three stages: 1) 2013–2020: optimization of resource use and creation of green infrastructure; 2) 2020–2030: economic transformation with an emphasis on water resources management and energy efficiency; 3) 2030–2050: transition to the Third Industrial Revolution with a focus on sustainable resources (Concept for transition of the Republic of Kazakhstan to Green Economy, 2013: 50).

Features of Wind Energy

The extensive steppe regions of Kazakhstan possess considerable potential for the development of wind energy. Approximately half of the country's territory experiences an average wind speed of 4 to 6 m/s, creating optimal conditions for electricity generation. These favorable wind conditions are particularly prominent in the northern and central regions, as well as along the Caspian Sea coast.

Despite this potential, the development of wind energy in Kazakhstan faces several technological and logistical challenges. The vast geographic size of the country, combined with its lack of direct access to the sea and underdeveloped internal transportation infrastructure, complicates the delivery and installation of large wind turbines. Additionally, the equipment must be adapted to extreme climatic conditions, characterized by temperature fluctuations ranging from +50°C to -50°C. These factors increase the costs of wind energy deployment compared to countries with more moderate climates.

In an effort to advance the wind energy sector, Kazakhstan has sought international support since the early 2000s. A significant initiative in this regard was the Wind Energy Development Programme,

implemented jointly by the United Nations Development Programme (UNDP), the Government of Kazakhstan, and supported by the Global Environment Facility (GEF). This program aimed to reduce greenhouse gas emissions while fostering the sustainable growth of the wind energy market. One of the program's key achievements was the development of the Wind Atlas of Kazakhstan, which has served as a foundational resource for investment decisions and regional energy planning (European Bank for Reconstruction and Development, 2019).

In prospects, Kazakhstan intends to further strengthen its wind energy initiatives, particularly in southern regions with high wind energy potential. These efforts will also include the integration of solar thermal power plants, contributing to a broader strategy of reducing dependence on coal and positioning the country as a regional exporter of environmentally sustainable energy (Tskhay, 2019).

Features of Solar Energy

Kazakhstan's continental climate, characterized by abundant solar radiation, provides an excellent foundation for the development of solar energy. Solar activity in the country averages between 2,200 and 3,000 hours annually, with radiation levels ranging from 1,300 to 1,800 kWh/m² per year. These favorable climatic conditions contribute to an estimated solar energy potential of approximately 1 trillion kWh annually, placing Kazakhstan among the countries with substantial untapped solar energy resources. The southern regions of Kazakhstan are identified as having the most advantageous conditions for solar energy generation due to their higher solar radiation levels and longer periods of sunshine (Akhmetov et al., 2011).

Recognizing its potential, solar energy has been designated as a priority sector for "green" investments in Kazakhstan, attracting significant attention from both public and private stakeholders. This has spurred the development of solar power infrastructure across the country. A notable achievement in this sector is the commissioning of a 100 MW solar power plant in the city of Saran, located in central Kazakhstan. This facility, the largest of its kind in Central Asia, symbolizes Kazakhstan's commitment to advancing renewable energy technologies and transitioning toward a low-carbon economy (Tskhay, 2019).

In addition to the Saran facility, six solar photovoltaic power plants with a combined capacity of 59 MW operate in the southern regions of the country. Among these, the Burnoye Solar Power Plant in the Zhambyl region stands out as a landmark project. Commissioned in 2015, this facility was financed by the European Bank for Reconstruction and Development (EBRD) and represents a key milestone in the development of Kazakhstan's renewable energy sector. The success of such projects underscores the importance of international financing and collaboration in driving renewable energy initiatives.

While the solar energy sector experienced substantial growth up until 2015, its progress was temporarily hindered during 2015–2016 due to a decline in electricity demand, which affected the economic viability of new investments. By 2017, the installed capacity of solar power plants had stagnated at the levels achieved earlier. However, renewed growth is anticipated, supported by national energy policies and international partnerships aimed at increasing renewable energy capacity. Plans for the construction of new facilities indicate a resurgence in solar energy development, with expectations for significant contributions to the country's energy mix in the near future (Самрұқ Қазына, 2018).

Looking ahead, the integration of solar energy into Kazakhstan's energy system holds immense potential for reducing dependency on fossil fuels, mitigating greenhouse gas emissions, and fostering regional energy security. The strategic development of solar power plants, coupled with supportive policies and international investment, positions Kazakhstan to become a regional leader in renewable energy and contribute meaningfully to global efforts in combating climate change.

Bioenergy potential

Kazakhstan, as a leading agricultural producer in Central Asia, generates substantial volumes of agricultural waste, which holds significant potential as a source of bioenergy. While a portion of this waste is traditionally utilized for mulching, fertilization, and livestock farming, a considerable volume remains underutilized. This surplus could be effectively converted into energy for heating, cooking, and electricity generation. At present, however, the country lacks adequate infrastructure for the large-scale conversion of agricultural waste into bioenergy, except for a limited number of biomass boiler facilities. Nevertheless, the integration of renewable energy sources, including bioenergy, is a critical component of Kazakhstan's green economy strategy. The transformation of unused agricultural residues into bioenergy could substantially increase the share of renewable energy in the country's overall energy balance (Andrukonyte, 2019: 2).

According to a study by the European Bank for Reconstruction and Development (2017) titled

"Bioenergy Opportunities in the Kazakh Agribusiness Sector," Kazakhstan produces over 5 million tonnes of plant residues annually that are suitable for energy conversion, with wheat and sugar beet accounting for 54% and 30%, respectively. Additionally, livestock waste, primarily in the form of manure, generates approximately 1.5 million tonnes of dry matter annually European Bank for Reconstruction and Development (European Bank for Reconstruction and Development, 2017).

In contrast to Kazakhstan, European countries have been actively converting agricultural waste into bioenergy for over two decades. Within the European Union (EU), biomass constitutes up to 60% of the renewable energy portfolio, with approximately 75% of bioenergy utilized in the heating and cooling sector through advanced methods such as direct combustion, pyrolysis, gasification, and biogas production.

Currently, Kazakhstan's bioenergy development remains in its nascent stage, employing basic technologies such as burning crop residues and producing biogas for thermal energy. These methods are designed to be technically feasible and adaptable to the country's local climatic conditions.

Experts highlight several advantages of bioenergy utilization. First, the conversion of agricultural waste provides valuable thermal energy for both industrial and domestic applications, with the potential for electricity generation. Residues from anaerobic decomposition in biogas plants can be repurposed as high-quality fertilizers, contributing to improved agricultural productivity. Additionally, bioenergy technologies play a critical role in mitigating surface and groundwater pollution by enhancing waste management practices across farms and industries. These benefits align closely with the objectives of the United Nations Sustainable Development Goals (SDGs), particularly those related to sustainable energy and environmental stewardship.

The application of bioenergy technologies in agriculture is especially important as it addresses waste disposal challenges and reduces environmental burdens. However, several obstacles hinder the broader implementation of bioenergy in Kazakhstan. Variability in the types and volumes of agricultural waste, as well as differences in disposal practices, necessitate tailored solutions for specific regions and enterprises. Moreover, the economic viability of bioenergy production is often constrained by the high costs associated with additional waste processing and transportation, which are required to ensure efficiency and sustainability. The lack of infrastructure and advanced technologies for effective waste collection and conversion further complicates the adoption of bioenergy solutions (Andrukonyte, 2019).

To fully realize the potential of bioenergy in Kazakhstan, it is essential to focus on the development and deployment of advanced technologies that account for the unique characteristics of different regions. Strategic investments in infrastructure, coupled with region-specific solutions, will play a pivotal role in overcoming existing challenges and promoting the sustainable growth of the bioenergy sector.

Conclusion

Kazakhstan, with its substantial reserves of hydrocarbon resources, acknowledges the imperative need to transition toward sustainable energy sources to mitigate its carbon footprint and achieve its environmental objectives. The development of renewable energy–encompassing solar, wind, hydro, and bioenergy–has been designated as a central priority within the nation's transition strategy toward a "green" economy. In recent years, Kazakhstan has made considerable progress in fostering favorable conditions for renewable energy development through legislative reforms, attracting foreign investment, and advancing infrastructure. These efforts have also positioned the country to fulfill its international climate commitments effectively.

Based on the findings of this study, the following key conclusions can be drawn:

Significant Renewable Energy Potential. Kazakhstan's geographical and climatic characteristics provide substantial opportunities for renewable energy development. The concentration of wind resources in the northern and central regions, combined with abundant solar radiation in the southern parts of the country, supports the adoption of environmentally sustainable energy solutions. Additionally, the availability of hydropower and bioenergy potential contributes to the diversification of Kazakhstan's energy portfolio, enhancing the resilience of its energy system.

Government Support and International Cooperation. The introduction of the auction-based capacity allocation system in 2018 marked a critical step in increasing transparency and competitiveness within Kazakhstan's renewable energy market. Collaborative efforts with international organizations, such as the United Nations Development Programme (UNDP), the European Bank for Reconstruction and Development (EBRD), and USAID, have played a pivotal role in attracting foreign investment and in-

tegrating advanced technologies. These partnerships are instrumental in fostering the sustainable growth of the renewable energy sector.

Barriers and Challenges. Despite its high renewable energy potential, Kazakhstan encounters several challenges, including the substantial capital costs associated with the installation and maintenance of renewable energy equipment, the necessity of adapting technologies to the country's extreme climatic conditions, and the inadequacy of infrastructure to support equipment transportation and installation. These issues present significant constraints on the growth of the sector and necessitate a comprehensive approach to address them.

Need for Technological and Infrastructural Advancements. The study underscores the importance of enhancing Kazakhstan's technological and infrastructural capacities to facilitate the effective development of renewable energy. The adaptation of technologies to local climatic and environmental conditions, coupled with the implementation of robust monitoring and project management systems, will be essential for minimizing operational costs and ensuring the long-term sustainability of the country's energy system.

Future Prospects. Kazakhstan's commitment to increasing the share of renewable energy in its overall energy mix is aligned with its goal of achieving carbon neutrality by 2060. The further advancement of the renewable energy sector holds the potential to significantly improve the nation's environmental quality, strengthen energy security, and create new employment opportunities within the framework of the "green" economy.

To sum up, while Kazakhstan has made notable strides toward integrating renewable energy into its energy system, a concerted effort is required to overcome existing barriers. The attraction of investments, the development of sustainable infrastructure, and the implementation of innovative technologies are critical to realizing the country's renewable energy potential. By addressing these challenges, Kazakhstan can establish itself as a regional leader in renewable energy and contribute meaningfully to global initiatives aimed at combating climate change.

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