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KAZAKHSTAN'S ENERGY TRANSFORMATION: HOW GREEN TECHNOLOGIES CAN CHANGE THE FUTURE

The article is devoted to the energy transformation in Kazakhstan, focusing on the need to switch to sustainable energy sources in the face of growing electricity consumption and environmental problems associated with dependence on coal-fired power. The text examines global trends such as reducing carbon emissions and the transition to renewable energy sources, as well as the role of Kazakhstan in these processes. The article analyzes the current problems of the country's energy infrastructure, including the high level of deterioration of heating networks and the need for modernization, as well as discusses the prospects and challenges of developing green technologies such as solar, wind and biomass energy. Special attention is paid to financial support for renewable energy projects, as well as opportunities for the country to improve the environmental situation and economic growth through the introduction of innovative technologies. In conclusion, the importance of further efforts to develop infrastructure, train specialists and attract investments to achieve a sustainable energy future for Kazakhstan is emphasized.

Keywords: Renewable energy sources, energy transformation, green technologies, solar energy, wind power plants.

Introduction

Energy transformation in Kazakhstan is becoming an important topic in the context of global changes facing the global energy sector. Every year, the country's population increases, which leads to an increase in electricity consumption and increases pressure on the existing energy infrastructure. Traditionally, Kazakhstan depends on coal and other fossil energy sources, which contributes to high levels of environmental pollution and environmental degradation. It is important to note that Kazakhstan is one of the ecologically polluted countries, and its energy sector requires serious transformations to ensure sustainable development [1, P.1].

In the context of global trends such as the reduction of carbon dioxide emissions, the transition to renewable energy sources and the fight against climate change, Kazakhstan cannot remain on the sidelines. Striving to improve the environmental situation and transition to green technologies is not only an internal necessity, but also an important part of global efforts to reduce global warming. The world's leading countries are already actively implementing projects to introduce green technologies into the energy sector, and Kazakhstan, with its rich natural resources and strategic location, has every opportunity to take its rightful place among the leaders in clean energy production in Central Asia [2, P.8–9].

The Mazhilis of the Parliament of the Republic of Kazakhstan has repeatedly considered this issue, as the country's heating networks are under significant pressure due to high wear and tear (53 %) and insufficient funding. Many heating companies face problems such as debt obligations and low profitability, which limits their ability to modernize infrastructure. In response to these challenges, a new law «On Thermal Energy» was adopted, which provides for the transfer of authority to manage heating networks to the Ministry of Energy, the development of heat supply schemes and increased state control. In 2024, 119.77 billion tenge is planned to be allocated from the national and local budgets for the modernization of heating networks [3, P.1].

In the context of these efforts, an important question arises about priorities in the development of energy infrastructure. The choice between repairing thermal power plants and building renewable energy sources depends on long-term goals. If the priority is sustainable development, reducing carbon emissions and switching to clean energy, then the construction of wind and solar power plants will be more profitable in the future. Green technologies not only contribute to environmental protection, but also ensure economic efficiency in the long term, reducing dependence on fossil energy sources [4, P.110].

This article will examine how energy transformation based on green technologies can become a decisive factor for Kazakhstan's sustainable development, as well as how the country can contribute to solving global environmental problems.

Materials and methods

According to a report by the Energy Institute, global carbon emissions from energy production in 2023 reached a record 40.4 billion tons of CO₂ equivalent, up 2.1 % from the previous year. After the reduction of emissions in 2020 caused by the pandemic, carbon emissions from energy have started to rise again, indicating the inevitability of a global problem related to the consumption of fossil energy sources.

In this regard, the energy sector remains the main source of greenhouse gas emissions, mainly due to the burning of fossil fuels such as oil and coal. In 2023, China accounted for almost a third of global carbon emissions, which produced 12.6 billion tons of CO₂ equivalent. This is significantly more than the combined emissions of all countries in the Western Hemisphere and Europe. China's high emissions are due not only to its large population, but also to the country's significant dependence on coal and oil, despite active investments in renewable energy. China's carbon emissions increased by 6 % over the year.

Further, the United States took the second place in terms of carbon emissions in 2023 with 5.1 billion tons, and India took the third place with 3.1 billion tons. In India, coal accounts for 56 % of primary energy consumption, and the country is actively planning to double its coal production by 2030, which will lead to an increase in its share of global carbon emissions to 10 % by 2030, according to forecasts by the International Energy Agency.

As for Kazakhstan, like many other countries, it does not stay away from this global trend. In 2023, carbon emissions from energy production in Kazakhstan increased by 11.2 %, from 277.5 million to 308.7 million tons of CO₂ equivalent, which is a record high. This situation is alarming, since the increase in carbon emissions is directly related to the high level of dependence on coal-fired power and insufficient diversification of the country's energy sector [5, P. 1].

Despite efforts to introduce green technologies such as solar and wind farms, Kazakhstan still faces serious environmental challenges related to the energy sector. In this context, urgent measures must be taken to reduce carbon emissions and transition to more sustainable energy sources, which will help the country not only improve its environmental situation, but also integrate into the global environmental agenda.

Experts of the Power Tech 2025 conference in Almaty mentioned that one of the sections of the forum will be devoted to discussing the development vectors of «green» financing. Green finance is an important component of investments aimed at implementing environmentally friendly, energy efficient and low-carbon projects. Such projects include renewable energy, improving the energy efficiency of existing enterprises, environmentally friendly transport, and developing a low-carbon economy. According to the Astana International Financial Center (AIFC), in 2024, the volume of the sustainable finance market in the country amounted

to 277.8 billion tenge, including «green» bonds and loans. The main part of the «green» money is directed to energy efficiency and renewable energy projects [6, P. 2].

As the population grows and the number of companies increases, there is a steady increase in electricity consumption in Kazakhstan. According to estimates by power engineers, they were the reason for the shortage of capacity of more than 1 GW. In response to this situation, Kazakhstan was forced to step up its electricity imports from Russia. To ensure a sustainable energy supply to the country, further development of energy infrastructure and the introduction of alternative energy sources are necessary [7, P.1].

According to the analysis, the population of Kazakhstan by 2030 may range up to 21.5 million under a positive scenario. By 2050, the population is expected to increase to 27.7 million people (Fig. 1). In this regard, an increase in electricity consumption is predicted, due to an increase in the number of consumers and an increase in energy demand against the background of demographic changes [8, P.1].

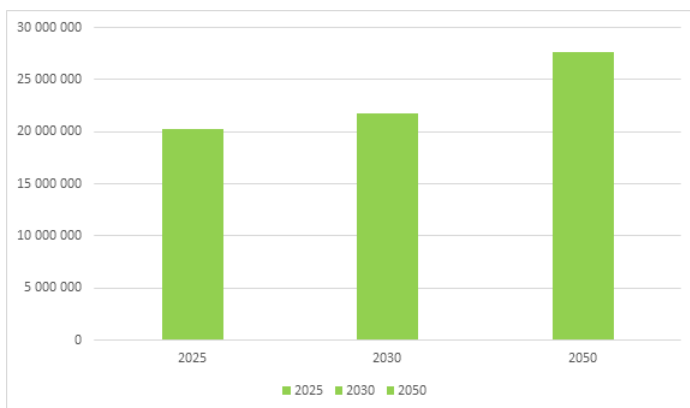


Figure 1 – Forecast of population growth dynamics in Kazakhstan based on data from the Center for Human Resources Development JSC

The government is taking steps to stimulate the growth of the sector. As part of the energy sector modernization program, it is planned to launch 40 new renewable energy projects by 2025. These projects should create more than 3,000 jobs and contribute to the economic development of the regions. However, the implementation of these initiatives requires clear planning and coordination between various government agencies and the private sector [9, P.1].

The Government of Kazakhstan plans to increase the share of renewable energy in total electricity production to 15 % by 2030 and 50 % by 2050 [10, P.1].

Kazakhstan has great potential for using solar energy. The country is located in regions with high solar insolation, especially in the southern and central regions, which makes solar stations very promising. In recent years, there has been an increase in the number of solar power plants.

Economically, solar panels have low operating costs, and their efficiency increases significantly with lower technology costs. The emergence of new, more efficient panels makes solar installations economically attractive.

Kazakhstan is actively developing solar energy, and this industry has a high potential for further growth. It is also important that solar installations can be located in various regions, including remote areas where there is no access to centralized electricity supply.

Kazakhstan has great opportunities for the development of wind energy, especially in many steppe regions and on the coast of the Caspian Sea, where the average annual wind speed is quite high. Wind turbines can generate stable amounts of energy, especially in regions with constant wind conditions.

Wind turbines require significant initial investment, but they can provide long-term and sustainable energy generation. Also, wind energy does not depend on fuel prices, as it happens with thermal power plants [11, P. 2].

The development of biomass energy can be beneficial for Kazakhstan, especially in rural and agricultural regions where there is excess agricultural waste. Using biomass for energy production helps to reduce carbon dioxide emissions and reduce waste. This aspect of biomass is so relevant, with a skillful organization, it could well realize the self-sufficiency of rural areas, in particular, every yard in rural areas with gas, moreover, natural fertilizer gardening, as part of an ecosystem solution - reducing CO₂ emissions. It should be emphasized that today more than 35 % of the population is still rural, then with the successful implementation of the above-mentioned issue regarding biomass, a number of problems would naturally find a solution in rural areas. Moreover, the optimal solution to biomass problems would to a certain extent become attractive to the population as part of the development of small and medium-sized businesses in rural areas [12, P.1].

Energy production from biomass can be cost-effective, especially in rural areas, due to the availability of raw materials such as animal manure on small farms. In rural areas, it is often a problem to transport manure to remote disposal sites, which requires additional transportation costs. The use of these raw materials for energy production can not only reduce export costs, but also become a source of income, as well as help solve environmental problems related to the disposal of organic waste.

Biomass energy in Kazakhstan has potential for development, but at the moment it is less developed than solar and wind energy. However, with increasing interest in sustainable energy sources, this sector may become more in demand.

Moreover, green technologies can bring significant advantages to Kazakhstan. First, they will help reduce dependence on fossil energy sources such as coal and oil, making the country more energy independent and resilient to fluctuations in global hydrocarbon prices. Secondly, the transition to renewable energy sources such as solar and wind energy will improve the environmental situation by reducing emissions of carbon dioxide and other pollutants. Thirdly, the development of green technologies will open up new opportunities for job creation in various industries, from the construction and operation of energy facilities to scientific research and innovation development. Thus, Kazakhstan, by actively developing environmentally friendly energy, can attract foreign investment, which will stimulate economic growth and the country's integration into global environmental and economic processes.

To date, 148 renewable energy facilities (over 100 kW) with an installed capacity of 2903.7 MW have been commissioned and are in operation:

- 59 wind power plants with a capacity of 1409.55 MW;
- 46 solar power plants with a capacity of 1222.61 MW;
- 40 hydroelectric power plants with a capacity of 269.785 MW;
- 3 facilities of biogas power plants with a capacity of 1.77 MW.

Based on the results of the auctions and contracts concluded with RFC LLP for Renewable Energy, 66 renewable energy projects with a total capacity of 1,682.4 MW are planned to be commissioned. The amount of attracted investments will amount to about 720 billion tenge:

- 34 hydroelectric power plants with a capacity of 311.11 MW;
- 20 wind power plants with a capacity of 1110 MW;
- 9 250 MW solar power plants;
- 3 biogas power plants with a capacity of 11.35 MW.

By the end of this year, it is planned to implement eight new renewable energy projects with a total capacity of 163.35 MW. Two wind power plants for 4.95 and 10 MW have been built in Akmola region by Jasil jel LLP; a solar power plant for 20 MW by HEVEL KAZAKHSTAN LLP has been built in Zhambyl region; a 3 MW hydroelectric power plant by «ВЭС Толкын» LLP is under implementation in Almaty region; a 14.9 MW hydroelectric power plant by Baskan Power LLP is under construction in Zhetysu region; A 12.5 MW wind power plant of ERG Capital Project LLP is under implementation in Aktobe region; In the Mangystau region, a 50 MW wind power plant is under construction by Sarkylmas Kuat LLP; in the Atyrau region, a 48 MW wind power plant by «Divitel» LLP is under implementation.

By 2027, the Ministry of Energy plans to hold auctions for the implementation of renewable energy projects for a total installed capacity of more than 4,500 MW of various types of renewable energy generation.

Within the framework of intergovernmental agreements, the Ministry of Energy, together with NWF Samruk-Kazyna JSC, have started implementing renewable energy projects: with Total Energies, 1 GW wind farm in Zhambyl region, Masdar 1 GW wind farm in Zhambyl region, Unigrin Energy 1 GW, 1 GW wind farm project in Zhetysay region. Within the framework of the above projects, it is expected that at least 30 % of domestic-made equipment will be used. Large-scale projects will begin construction and installation work in 2025 [13, P.12].

In 2024, three new renewable energy facilities with a total capacity of 34.75 MW were commissioned. This was made possible by attracting investments in the amount of 13.7 billion tenge. Five more facilities with a total capacity of 128.4 MW are expected to be completed by the end of the year, which will further strengthen the country's energy potential.

Currently, there are 148 renewable energy facilities in Kazakhstan with a total installed capacity of 2903.7 MW. These facilities play a key role in reducing the carbon footprint and provide the country's energy system with clean and sustainable energy [14, P.1].

In 2024, the share of renewable energy sources in total electricity generation in Kazakhstan amounted to 6.4 % (7.58 billion kWh). 8 new projects with a total capacity of 163 MW were commissioned [15, P.1].

An intergovernmental agreement has been signed with the People's Republic of China on the implementation of renewable energy projects, under which it is planned to build renewable energy facilities with a total capacity of 1.8 GW. In accordance with this agreement, it is possible to include additional renewable energy projects in the outline of the intergovernmental agreement [16, P.2].

Results and discussion

During Kazakhstan's transition to green technologies, several infrastructural problems arise. One of the main reasons is the lack of modern equipment and high initial costs for the construction of new facilities, which can become a serious obstacle to the rapid introduction of renewable energy sources. In addition, remote and rural areas of the country may lack the necessary logistics for efficient energy distribution, which limits access to renewable sources and reduces their economic efficiency. It is also important to note that the lack of experience and qualified specialists in the field of green technologies can slow down the process of transition to sustainable energy.

Addressing these challenges in the future will require significant investments in energy infrastructure modernization, including the construction and renovation of power grids to integrate renewable energy sources. It is also necessary to encourage private and public investment in the development and implementation of new technologies by providing support through subsidies and tax incentives for the first stages of construction. It is important to develop logistics for efficient energy

distribution, especially in remote regions, and ensure access to green energy for all citizens. Finally, significant efforts should be directed towards training qualified specialists in the field of green technologies, which will help accelerate innovation and increase the efficiency of the transition to sustainable energy [17, p.2].

According to a report by the International Energy Agency, renewable energy sources will become the largest source of electricity in the world in 2022–2027. Their share in the global energy mix will reach 38 %, thereby reducing the share of coal, natural gas, nuclear energy and oil. The transition to renewable energy sources opens up new prospects for digital innovations designed to solve global energy problems.

The intensive development of the alternative energy sector in Kazakhstan has become possible thanks to the support and long-term financing from international financial institutions. One of the key partners in this process is the Asian Infrastructure Investment Bank (AIIB), which actively cooperates with Kazakhstan to use the potential of the country's natural resources in the development of renewable energy sources. A striking example of the AIIB's participation in a green energy project is the Zhanatas wind power plant in Southern Kazakhstan.

This is the first AIIB project in the country, with a total capacity of 100 MW and an annual output of about 320 million kWh. The plant annually reduces about 250,000 tons of carbon dioxide emissions, which is a significant contribution to reducing the country's carbon footprint [18, P.2].

There are several unique and interesting features of financing renewable energy projects in Kazakhstan, in particular, Kazakhstan offers state support to renewable energy projects in the form of tax incentives, customs preferences and simplified licensing procedures. Depending on the type of investment, the Business Code provides, in particular, the following investment preferences:

- 1 Exemption from customs duties and value added tax on import;
- 2 Government subsidies.

According to the Concept of the Investment Policy of the Republic of Kazakhstan until 2026, despite the global crisis, Kazakhstan remains attractive to foreign investors and is the undisputed leader in the inflow of foreign investment in the Central Asian region. However, in order to maintain and strengthen this position in the current geo-economic and geopolitical conditions, Kazakhstan needs to actively take the initiative in the fight for foreign investment and create the most optimal conditions for investors.

List of legislative acts adopted in the implementation of the law on renewable energy support:

– «On the definition of a settlement and financial center for the support of renewable energy» (Crane work project (CWP) №1281 dated 11/29/2013);

- «On approval of the Rules for monitoring the use of renewable energy sources» (CWP №1529 dated 05.10.2009);
- «On approval of the Rules for determining the nearest point of connection to electric or thermal networks and connection of renewable energy facilities» (CWP №119 dated 19.01.2012);
- «On approval of the Rules for determining fixed tariffs» (CWP № 271 dated 03/27/2014);
- «On approval of the Rules for determining the tariff for renewable energy support» (CWP №290 dated 04/01/2014);
- «On approval of fixed tariffs» (CWP №645 dated 12.06.2014);
- «On approval of a fixed tariff for projects of solar power plants using photovoltaic modules based on Kazakh silicon (Kaz PV) for the conversion of solar radiation energy» (CWP №644 dated 06/12/2014);
- «On approval of tariffs not exceeding the selling price level set out in the feasibility study of the construction project for the use of renewable energy, approved and agreed with the authorized or local executive body, and its validity period in accordance with the feasibility study for energy-producing organizations using renewable energy» (CWP №419 dated 30.04.2014); [19, P.4–5].

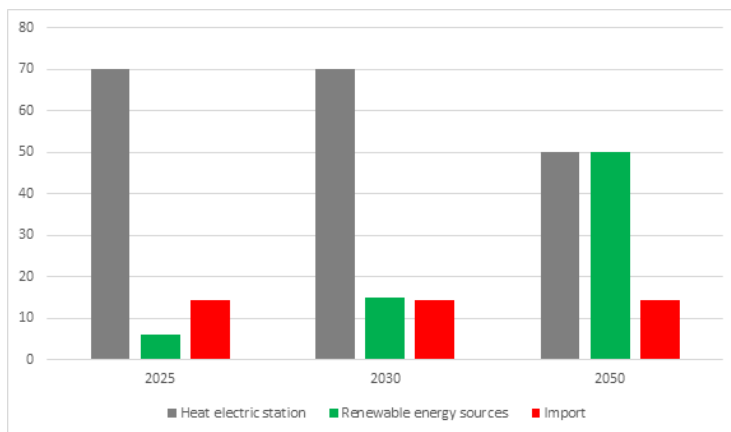


Figure 2 – Forecast of the energy consumption ratio

According to the report of KEGOC JSC dated 08/13/2024, electricity consumption in Kazakhstan has increased by 2.3 billion kWh over the past year, which corresponds to an increase of 3.9 % [20, P.2]. This growth reflects a natural increase in electricity needs against the background of the country's population growth. It should be noted that in the future, with the development of renewable energy sources (RES), electricity production at thermal power plants (CHP) may

decrease, especially by 2050 (Fig. 2), which will lead to a change in the country's energy balance and the need for new approaches to ensuring sustainable energy supply. The growth of renewable energy sources, respectively, leads to a reduction in fuel use, therefore, all this together will be reflected in ensuring the eco-system as a whole.

Conclusion

Thus, emphasizing the importance of energy transformation for the sustainable development of the country, it is necessary to assess how green technologies can change the future of Kazakhstan if existing barriers are overcome and strategic initiatives are implemented.

Kazakhstan's energy transformation is an important and urgent process that will determine the country's sustainable development in the face of global challenges such as climate change and the depletion of fossil resources. The transition to green technologies and the introduction of renewable energy sources is not only an environmental necessity, but also an important step towards diversifying Kazakhstan's energy sector, reducing carbon emissions and improving economic sustainability.

Green technologies such as solar, wind and biomass energy have significant potential for Kazakhstan due to its geographical location and growing investments in this sector. In the future, Kazakhstan may well take a leading position in Central Asia as a producer of clean energy, attracting foreign investment and stimulating the creation of new jobs.

However, there are serious challenges on the way to the successful implementation of energy transformation, such as the need to modernize infrastructure, develop logistics and train specialists. These challenges require an integrated approach, cooperation between public and private entities, as well as significant investments in technology and infrastructure.

The advantages of switching to sustainable energy are obvious, reducing dependence on hydrocarbon sources, improving the environmental situation, creating new economic opportunities and attracting foreign investment. Kazakhstan will have to implement an energy transformation that may well provide the country with a sustainable future and an important contribution to global efforts to combat climate change.

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ҚАЗАҚСТАННЫҢ ЭНЕРГЕТИКАЛЫҚ ТРАНСФОРМАЦИЯСЫ: ЖАСЫЛ ТЕХНОЛОГИЯЛАР БОЛАШАҚТЫ ҚАЛАЙ ӨЗГЕРТЕ АЛАДЫ

*Мақала Қазақстандағы энергетикалық трансформацияға
арналған, электр энергиясын тұтынудың өсуі жағдайында тұрақты
энергия көздеріне көшу қажеттілігіне және көмір энергетикасына
тәуелділікпен байланысты экологиялық проблемаларға назар*

аударарды. Мәтінде көміртегі шығарындыларын азайту және жаңартылатын энергия көздеріне көшу сияқты жаһандық үрдістер, сондай-ақ Қазақстанның осы үдерістердегі ролі қарастырылған. Мақалада елдің энергетикалық инфрақұрылымының ағымдағы мәселелері, соның ішінде жылу желілерінің тозуының жоғары деңгейі және жаңғырту қажеттілігі талданады, сондай-ақ күн, жел және биомасса энергетикасы сияқты жасыл технологиялардың даму перспективалары қарастырылады. Жаңартылатын энергетика саласындағы жобаларды қаржылық қолдауға, сондай-ақ инновациялық технологияларды енгізу арқылы елдің экологиялық ахуалды жақсарту және экономикалық өсу мүмкіндіктеріне ерекше назар аударылды. Қорытындылай келе, Қазақстанның Тұрақты энергетикалық болашағына қол жеткізу үшін инфрақұрылымды дамыту, мамандарды оқыту және инвестициялар тарту маңыздылығы атап өтіледі.

Кілтті сөздер: Жаңартылатын энергия көздері (ЖЭК), энергетикалық трансформация, жасыл технологиялар, күн және жел станциялары.

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ЭНЕРГЕТИЧЕСКАЯ ТРАНСФОРМАЦИЯ КАЗАХСТАНА: КАК ЗЕЛЕННЫЕ ТЕХНОЛОГИИ МОГУТ ИЗМЕНИТЬ БУДУЩЕЕ

Статья посвящена энергетической трансформации в Казахстане, акцентируя внимание на необходимости перехода к устойчивым источникам энергии в условиях растущего потребления электроэнергии и экологических проблем, связанных с зависимостью от угольной энергетики. В тексте рассмотрены глобальные тенденции, такие как снижение углеродных выбросов и переход к возобновляемым источникам энергии, а также роль Казахстана в этих процессах. В статье анализируются текущие проблемы энергетической инфраструктуры страны, включая высокий уровень износа тепловых сетей и необходимость модернизации, а также рассматриваются перспективы и вызовы развития зеленых

технологий, таких как солнечная, ветровая и биомассовая энергетика. Особое внимание уделено финансовой поддержке проектов в области возобновляемой энергетики, а также возможностям для страны в улучшении экологической ситуации и экономическом росте через внедрение инновационных технологий. В заключение подчеркивается важность дальнейших усилий по развитию инфраструктуры, обучению специалистов и привлечению инвестиций для достижения устойчивого энергетического будущего Казахстана.

Ключевые слова: Возобновляемые источники энергии (ВИЭ), энергетическая трансформация, зеленые технологии, солнечные станции, ветровые станции.

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