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The Dilemma of Long-Term Development of the Electric Power Industry in Kazakhstan

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Abstract: This article discusses the current state and trends in the development of the electric power industry in Kazakhstan. An analysis of the energy supply and energy intensity of Kazakhstan's GDP is provided in this paper. The results of the foresight of the risks and opportunities of the energy industry are described. This study identifies the relationship between the traditional development of the energy industry and the development of alternative energy sources. In addition, the work examines the risks and consequences of various trends in the development of national and global energy. Previous studies have shown that government efforts are insufficient in developing an alternative energy sector in Kazakhstan. The research results show that there is a need to transform energy production from traditional sources towards greater efficiency and environmental friendliness, as well as the active involvement of the business community in the development of an alternative energy market. This is expected to attract more investments and transfer technologies to maintain the country's position in the energy market of the future.

Keywords: energy industry; energy supply; energy intensity; energy efficiency; energy industry risks; dilemma; development; Kazakhstan



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1. Introduction

In 1996, Kazakhstan became one of the first states of the former Soviet Union to begin reforming the existing energy sector and transition to a market economy. Using the British and Norwegian electricity markets as models, the government dissolved the existing vertically integrated state monopoly, splitting it into separate electricity management and business management companies. Since then, more than 85% of the electricity sector has been privatized [1]. Although the privatization of Kazakhstan's energy sector is almost complete, the sale of regional distribution companies has been slower. Kazakhstan's energy sector continues to be under tight government regulation and price controls, and relations between the Eurasian Natural Resources Corporation and international investors are unsatisfactory.

Despite the incoming investments and the development of the power grid infrastructure, there are still no direct electric connections at a voltage of 500 kV in the three regions of the Southern Zone and the Western zone with the unified power system of Kazakhstan. There is also a high degree of wear and tear of the main equipment of power transmission organizations and regional power grid companies, as well as a significant number of unattended power grid facilities.

According to the estimates provided by the Ministry of Energy of Kazakhstan, the average annual growth rate of electricity production in 2020–2025 will be 3% [2]. At the

same time, consumption is expected to grow by 1.9% per year and increase from 110.1 billion kWh in 2020 to 120.9 billion kWh in 2025. By 2025, 28% of all electricity production is expected to come from stations commissioned between 2020 and 2025, which indicates the need for additional capital investments in this industry. At the same time, 19% of the stations planned for commissioning will relate to renewable energy sources (RES) [3].

Today, the cost of electricity in Kazakhstan is one of the cheapest in the world [1]. This situation is related to the fact that energy is produced in coal-fired power plants. A feature of the use of coal is its cheapness, availability, and storage capability. However, given the high deterioration of coal-fired power facilities, in the conditions of maintaining a high energy supply, Kazakhstan faces a difficult choice—to direct its efforts to the modernization of the coal-fired power industry or to develop renewable energy sources.

The dilemma in determining the directions of the country's long-term energy development lies, not only in the choice between traditional and alternative sources, but also includes a whole range of problems of an economic, political, and social nature. We can talk about the complexity of the dilemma, since choosing one of the two opposites is equally difficult, generates risks, but also opens up certain opportunities.

The purpose of this study is to identify alternatives for the development of the national energy sector, based on forecasting the main development trends and assessing development directions in the long term.

The dilemma of the long-term development of the electric power industry in Kazakhstan is also part of ensuring the country's energy security and part of the broader concept of national security, which gives rise to additional important aspects in addressing the problem.

In this regard, representatives of the scientific community note the importance of the concept of energy security for the development of the country's energy system [4–6]. Energy security is seen not only as an uninterrupted supply of electricity to enterprises and end-users [7,8], but also an indicator of environmental safety [9], energy efficiency [10] and sustainable development [11]. Building an energy system and the features of energy security of various countries were considered in Kuik et al. [12], Johnson and Boersma [13], Lei and Xuejun [14], Shiroyama et al. [15]. The prospects for the implementation of projects of renewable energy sources were also studied in detail [16–18].

Within Kazakhstan, these issues are devoted to works [19,20] that consider the potential for the development of the bioenergy sector and the main political, economic, and technological problems that impede the large-scale use of renewable energy sources.

The author's hypothesis assumes that the country cannot abandon the use of traditional raw materials soon, but should instead focus on improving the efficiency and environmental friendliness of its use. In the long term, it is necessary to join the transition to alternative energy, so as not to be technologically behind. In the short term, it is necessary to ensure the maintenance of the level of energy supply based on traditional fuels. The scientific novelty largely lies in the fact that the combination of the development of a pragmatic approach to a more efficient and environmentally friendly use of traditional raw materials, and the promotion of alternative energy production models. These factors will enable Kazakhstan to accumulate resources for a timely transition to innovative energy markets and ensure the position of an energy-secure and economically developed country. The formation of alternative energy in the country should be based on the development and support of modern technologies and the creation of conditions for the development of a free energy market, while ensuring adequate guarantees for the population through appropriate social institutions and mechanisms.

The presented work is based on the study of world experience in researching the problems of the development of the energy industry and is a continuation of the original author's developments in the field of energy in Kazakhstan. We have previously conducted research on certain issues of energy efficiency of Kazakhstani enterprises [21], in particular, analysis of losses and inefficient distribution of electricity in Kazakhstan [22,23]. In this study, we aimed to study the directions of development of the electric power industry in

Kazakhstan to understand possible alternatives for the development of the industry in the coming decades. In Section 2, we consider the views of the modern scientific community on the problems of the development of modern energy, which characterizes the multi-faceted manifestations of the electric power industry in the socio-economic life of any region and country. Section 3 is devoted to the research methodology and the description of the initial data. Section 4 contains an analysis of the results that are discussed in Section 5. Section 6 draws general conclusions and identifies prospects for further research.

2. Literature Review

Studying regional and national energy systems are highly relevant for countries of all levels of development. The efficiency of the country's production activities and the quality of life of households directly depend on the reliability and efficiency of the energy system. At the geopolitical level, the global energy system is seen as the basis for ensuring national security, the most important part of which is energy security. Initially, if energy security was considered because of the functioning of the energy supply chain [4], then later, the concept of energy security acquired different meanings with a few internal contradictions. Researchers from various countries come to the conclusion that the concept of energy security is traditionally used to justify state control over energy and unwillingness to deal with energy problems at the global level [12,13]. Emphasizing the multidimensionality of the key concept of energy security, Soysal and Soysai [24] state that energy security is an "umbrella term" that encompasses many of the issues linking energy, economic growth, and political power.

Under the auspices of the state, energy security has often meant excessive, inefficient, and sometimes dangerous production and consumption of energy. Researchers have found a way to mitigate the various multilevel contradictions in energy security in their need to develop reliable, continuous, affordable, and environmentally efficient energy services. Directly studying the impact of energy efficiency on the need to invest in new technologies, the so-called "avoided power costs" were carried out by York et al. [25], Bilton et al. [26], York et al. [27], Nguyen and Tran [28], Igaliyeva et al. [29]. Improving energy efficiency depends on the ultimate equilibrium impact on energy security through demand, price, investment, and spare capacity in the short- and long-term [4,10,25,30–32].

A few authors focus attention on economic attributes (for example, the amount of energy required at a reasonable price) [31–36], Yergin [37], Luft et al. [38], Hughes [39], Mansson et al. [40], consider the cultural, political and economic aspects of energy security.

Comparative analysis shows that the dilemma of energy development in different regions contains serious contradictions. Considering the evolution of energy policy in East Asia, Shiroyama et al. [15] suggest that the golden principle of "increasing your energy self-sufficiency ratio and not depending on external suppliers" cannot be the most suitable for this region. East Asia, as the region with the highest energy consumption, must strive to design and build a reliable energy supply in the context of changing production and consumption patterns reflecting the global power shift. In a study assessing the level of energy security of 30 countries Du et al. [41] conclude that the level of energy security in these countries varied significantly during 2001–2012. This is closely related to each country's resources, energy technologies and national policies. Therefore, each country needs a differentiated system of energy policy in accordance with the economic, social, political and resource situation. In fact, each country faces its own energy dilemma and solves it based on its own criteria for choosing well-being and independence. The multifaceted nature of this problem is also revealed in Böhringer and Keller [42], Checchi et al. [43], Kruyt et al. [44], Mitchell [45], Chester [46], Cherp and Jewell [47], Joskow [48], Chehabedine and Tvaronavičienė [49], Alkhateeb et al. [50], Shumilo et al. [51].

Focusing on the developing countries of the Asian region, one can also see that Cronshaw et al. [52]. In the study of energy systems of the countries of the Asia-Pacific region over 30 years draw conclusions about the growing demand for improving environmental performance and at the same time improving energy services [52]. Therefore, the long-term

development of the electric power industry in the regions requires approaches that support reliable and sustainable energy networks and promote the flexibility and resilience of energy systems and markets. The focus is on reliability, efficiency, environmental safety and social acceptability of energy services for end users [7,9].

Consideration of various aspects of the reliability of the energy system leads researchers to the idea of avoiding risks affecting the continuity of energy supplies relative to demand. Ecofys [4], Jansen and Seebregts [5], Winzer [6], Levèvre [53], Plèta et al. [54] identify sources of risks associated with energy security. At the same time, the problems of stability of power systems are considered through the prism of the impact of the experience of destruction and the perception of risks. Many researchers have focused on identifying the key threats to a particular energy system. Ecofys [4] defined such categories as extreme events, inadequate market structures and supply shortages associated with resource concentration. Winzer [55] identified the types of risks and their sources, associated risks (threats) with their impact on the energy supply chain, as well as threats, and also identified those risks that can be predictable, probabilistic, heuristic and unknown. Mansson et al. [40] and Gracceva and Zeniewski [8] propose a classification of threats to energy security according to the following criteria: Place in the energy supply chain; time frame; origin.

Modern research is expanding the focus of attention from the sources of destruction to the ability to respond to them (that is, the resilience of energy systems). In later concepts, the emphasis has shifted from the issue of measuring energy security to the characteristics of the energy system, allowing control and immediate response to risks [56]. Blum and Legey [56] see energy system vulnerability as a combination of risk exposure and resilience. At the same time, the differentiation of energy systems makes it possible to better measure their vulnerability and purposefully orient the policy of long-term development [57–60].

The study of various aspects of the energy system of Kazakhstan has been especially active over the past five years. In a study by Xiong et al. [61] analyzes the factors affecting carbon emissions in Kazakhstan in 1992–2014. The results of the analysis showed the largest amount of carbon emissions associated with the production of energy. This is due to the high power consumption of energy resources, high energy consumption and low economic effect of productivity. Kerimra et al. [62] address the problem of unsustainable household energy use and lack of access to energy infrastructure.

In the study of Kazakh scientists, the complexity of the problems of the development of domestic energy is noted, so the authors conclude that the energy system of Kazakhstan requires a significant amount of water resources to cool the power plant, and in the future these needs will increase [63]. A comprehensive overview of the current energy situation in Kazakhstan, including fossil energy sources and renewable resources is presented in the book by Kalyuzhnova et al., showing the possibilities and implications of a global transition to cleaner energy for Kazakhstan [64] and articles [65–67].

The reviewed publications helped the authors of this article in the development of original research, assessing the dilemma of the long-term development of the electric power industry in Kazakhstan.

3. Materials and Methods

The priority, system-forming role of modern energy for the economy and all life activities have determined the basic theoretical approach to the study of the problems of its development. We considered the electric power industry not only as a specific industry, but rather as a unique institution in which development is determined not only and not so much by technological factors, but primarily by accepted norms and rules. In analyzing the patterns of choosing the paths for the long-term development of the energy industry, the authors, based on the institutional approach, since they did not limit themselves to analyzing economic categories but considered non-economic factors. In particular, the most important factors are international norms and obligations, to which Kazakhstan joins and which force it to make a certain choice.

An important methodological approach is Path Dependency, which assumes that we cannot consider the choice of an industry development model based only on current conditions and future opportunities. It is necessary to consider further decisions, depending on the sequence of past actions, each of which led to a certain result.

The assessment of the state of the energy industry in Kazakhstan is considered based on systematization of comparative analysis, which allows obtaining a description and explanation of the similarities and differences in the development of energy industries.

The study used the foresight method, which allows improving decision-making and managing the choice of technologies, creating alternative directions for future development, increasing preparedness for unforeseen circumstances and motivating participants to make and implement decisions to achieve the desired future. Foresight is a system of methods for expert assessment of strategic directions of socio-economic and innovative development, identification of technological breakthroughs that can have an impact on the economy and society in the medium and long term.

In 2020, a “Study of the image of the future and demanded professions in the energy sector of the Republic of Kazakhstan” was carried out in Kazakhstan [68]. The authors were part of the development team of the industry foresight methodology and were directly involved in conducting foresight sessions, interviewing experts, and processing the results. A total of 136 Industry forecasts expert advice from several leading industry experts, academics and educators were involved. The interviewed experts are highly qualified specialists—more than half of them have been working in the industry for more than 15 years, and another 13% have experience from 10 to 15 years. The average work experience in the energy industry of the interviewed experts was 13 years, which is optimal for understanding the current problems and prospects for the development of the industry. Forecasts made by experts combined knowledge of technological innovations with an understanding of the specifics of the real situation in the country and in the industry.

Obtaining expert assessments was carried out by the Delphi method—a technology used to predict and assess development trends. The method consists in structuring the group communication process aimed at creating the conditions for effective team work on a complex problem.

The survey of experts by the Delphi method was supplemented by the method of in-depth interviews with CEOs of KEGOC JSC, Kazakhstan Solar Energy Association, Burnoye Solar-1 LLP, Kazatomprom National Atomic Company JSC, Kentau Transformer Plant JSC, professors of Almaty University of Energy and Communications.

In August 2020, foresight sessions of the energy industry stakeholders were also held in which 56 participant of industry foresight sessions formed forecasts and alternative scenarios for the development of the energy industry in Kazakhstan. Within the framework of these sessions, issues of risks and opportunities for the development of the energy industry in Kazakhstan were also considered.

For a quantitative assessment of risks and opportunities, a map was modeled as an integrated information-graphic method of nature, which allows the risks to be monitored based on their classification and ranking, assessment of the likelihood of occurrence and possible damage, in order to analyze the development of the situation in the industry and further impact on it. The method of mapping the risks and opportunities for the development of the industry applied for its construction makes it possible to comprehensively consider the totality of the opinions expressed and evaluate them on the basis of quantitative data. The mapping method was applied in stages: Factors (risks or opportunities) are classified, the strength of their influence and the likelihood of occurrence are determined, and then the degree of managerial impact is assessed. At the final stage, a map is modeled, which makes it possible to determine the patterns and priorities of the development of factors. The resulting map contributes to the adoption of adequate decisions aimed at compensating risks or realizing opportunities and allows you to display these decisions as a general management system.

4. Results

4.1. Analysis of the Current Situation in the Industry

Despite the active progress of Kazakhstan on the path of diversification, energy resources will remain of primary importance for its economy. At the moment, the oil and gas sector provide 1/5 of GDP (21.3% in 2018), about 2/3 of total export revenue (70% in 2018) and almost half of the country's state budget revenues (44% in 2018). The fuel and energy complex also occupies a leading position in attracting foreign direct investment to Kazakhstan [69].

Energy has always been the “fuel” for the economy and its importance grows with the intensification of industrialization. Most of the territory of Kazakhstan is located in unfavorable climatic conditions, therefore, both enterprises and ordinary people also need fuel in the literal sense. For the country, the provision of energy directly means ensuring the living conditions of the population. Also, the task of power engineering is to meet the needs of the national economy for heat and electric energy and provide an opportunity to export electricity to the countries of near and far abroad. The energy industry is a set of systems that convert primary energy: minerals, natural energy, artificial raw materials into secondary energy: electrical and thermal. The share of the energy sector in the country's GDP is 1.6%.

Energy production involves successive stages:

- transportation of resources and energy carriers to generating power plants,
- processing of the energy carrier into secondary energy,
- distribution of energy and its transportation to the end user.

At each stage of production, specific problems accumulate that require a balanced solution.

In 2019, 138 power plants with an installed capacity of 22,936 MW were operating in Kazakhstan (in 2018—21,902 MW). About 82.7% of all electricity generated in Kazakhstan is produced at thermal power plants. The country has large reserves of energy resources (oil, gas, coal, uranium) and is an energy power. The balance of generated energy in Kazakhstan is as follows: about 70% of electricity is generated from coal, a little more than 10%—from hydro resources, a little more than 10%—from gas and 5%—from oil. The current structure reflects the first dilemma of the energy sector—should coal prevail as the main raw material resource, or is it possible to replace it? Let's consider in more detail the state of each energy resource.

Coal-fired power generation is the most widespread in Kazakhstan. The coal industry and coal generation have historically been and remain an important source of economic development in many countries around the world. A feature of the use of coal is its cheapness, availability, and storage capability. According to some data, today the 13 largest countries in the world, including China, the United States, India, South Africa and others, account for up to 90% of the world's electricity generation from coal. In Kazakhstan, the coal industry is one of the most important resource industries, its contribution to GDP today is about 1.5%. In 2018, the country produced 113.7 million tons of coal, which is 6.5% more than in 2017. The main volume of electricity in Kazakhstan is generated by about six dozen power plants operating on coal (Ekibastuz, Maikubensky, Turgay and Karaganda basins), gas, and fuel oil.

The high share of coal in energy production is due to the orientation of end consumers in Kazakhstan precisely to inexpensive coal-fired generation, while gas in the country is more expensive than coal, although its cost is still low relative to world prices. This makes it difficult for power plants to switch to gas while maintaining price competitiveness. For example, the transfer of the thermal power plants in Nur-Sultan from coal to gas increase the cost of electricity generation by about 50%.

In second place in terms of electricity generation is the hydropower industry in Kazakhstan. Economically efficient hydro resources are concentrated mainly in the east (Gorny Altai) and in the south of the country in the Irtysh, Ili and Syrdarya rivers. The largest hydroelectric power stations in the country are: Bukhtarma, Shulba, Ust-Kamenogorsk (on the

Irtysh River) and Kapchagai (on the Ili River). They provide 10% of the country's electricity needs. Kazakhstan plans to increase the use of water resources in the medium term.

Earlier decisions have influenced the current situation in the energy sector of Kazakhstan. Despite the presence of significant hydrological resources, preference was given to raw coal. The use of oil and gas is limited for energy production in the republic due to the high demand for these resources in the external market. Therefore, when choosing the path of long-term development, the national energy sector fell into the so-called path dependence, when the choice of further development depends on previous decisions and past experience of operating the industry.

The global energy sector is shifting towards renewable energy sources (RES), but the pace of this process is not fast enough to compensate for the growth of the global economy and population. The problems of energy saving, and alternative energy sources are relevant for the Republic of Kazakhstan, the issues of "green" energy have become one of the strategic directions of the national economy, as a component of energy resources supplied to the domestic market and as an additional source of income. They form a second strategic dilemma—can Kazakhstan, when replacing coal energy with an alternative one, ensure the need for energy and security?

Priority sources are solar power plants, wind farms, small hydro power plants with a capacity of less than 25 kW, biomass power plants. The country has launched 100-megawatt solar stations in the Kapchagai region near Almaty, in the city of Saran, Karaganda region, in the village of Burnoye, Zhambyl region. Today there is a 50-megawatt wind station in the Zhambyl region, a 45-megawatt station in the city of Ereimentau, and a 42-megawatt station in the Mangistau region. The first phase of a 100-megawatt wind station has been commissioned near the capital. Alternative energy power plants are less powerful than conventional power plants. Renewable energy also brings imbalances to the country's energy systems. In Kazakhstan, there is no flexibility in capacities that can quickly provide or reduce unplanned electricity.

The development of nuclear energy is promising for Kazakhstan, but social acceptance is an important condition for its development. For nuclear power to arise in any country, society must accept it. The only nuclear power plant in Kazakhstan was in the city of Aktau with a fast neutron reactor with a capacity of 350 MW. Nuclear power plants (NPP) operated in 1973–1999. Currently, nuclear energy is not used in Kazakhstan, even though the country's uranium reserves (according to the IAEA) are estimated at 900 thousand tons. The main deposits are in the south of Kazakhstan (South Kazakhstan region and Kyzylorda region), in the west of Mangystau, in the north of Kazakhstan (Semizbay field). The prospect of nuclear power in Kazakhstan raises many doubts, primarily related to the culture of maintenance, operation, and reliability of equipment. The public has no confidence that it will be safe and secure. Since the south of Kazakhstan is quite in a high seismic zone, the construction of nuclear power plants there is unsafe, and in the northern regions this project is quite feasible. NPP will generate a significant amount of electricity at an affordable price. Although the construction of a nuclear power plant is not a cheap option, but later getting electricity from there will be much cheaper than from the traditional one.

Nuclear, solar, wind, hydropower and even energy from biofuels pose not one dilemma for the republic, but a whole "bunch of dilemmas" when it is necessary to make a choice from difficult options and none of them is definitely advantageous.

Infrastructure issues are added to the choice of energy sources. Electric networks in Kazakhstan consist of substations, switchgears, and power transmission lines with a voltage from 0.4 kV to 1150 kV. The national electric grid of Kazakhstan provides a connection between the regions within the country and the energy systems of neighboring states (Russia, Kyrgyzstan, Uzbekistan). In addition, the national electricity grid transfers electricity from producers to wholesale consumers. The largest organization that carries out the transmission of electricity in Kazakhstan is KEGOS JSC. It serves interstate power lines and transmission lines that provide electricity from power plants with a voltage of

220 kV or more. The distribution of electricity at the regional level is handled by 21 regional energy companies and almost 300 small energy transmission organizations. Regional energy companies transfer energy to retail consumers and provide connections within the region. Energy transmission organizations also transmit electrical energy through electrical networks to wholesale and retail consumers or supply organizations. Energy supply organizations buy electricity from energy-producing companies and resell it to the final retail consumers.

Previous studies by the authors show that it is in the electric grids that the price of energy increases, including the administrative burden of a significant corruption component [21]. The increase in energy prices from the source of production to the source of consumption is a serious problem for economic development. As our previous calculations show [22,23], the costs of heat and electric energy form “cost nodes” of production costs and generate their growth both in production and in the service sector. Thus, the following dilemma arises: An increase in energy tariffs ensures the modernization of the industry but increases the total costs of the economy and worsens the situation of the population. In Kazakhstan, there are 2.5 thousand heat supply sources providing the production of about 90 million Gcal. The received heat energy is distributed to end users through networks with a length of 11,357.9 km in two-pipe calculation. From these networks, 27.5% are in a dilapidated state, 27.9% are in need of replacement. This leads to the fact that the losses amounted to 16.9% of the total volume of energy supplied to the consumer.

In 2025, it is planned to create a common electricity market of the Eurasian Economic Union. Kazakhstan’s electric power industry will also have to seriously prepare for this. In the country’s strategic development plan until 2020, one of the main goals in the energy sector is the creation of a vertically integrated company with a nuclear fuel cycle. This means that dozens of specialists will be required in nuclear reactors and power plants, protection and non-proliferation of nuclear materials, electronics, and automation of physical installations.

4.2. Energy Supply and Energy Intensity of Kazakhstan

Kazakhstan is one of the top ten energy-rich countries in the world. Energy supply indicator (the ratio of primary energy production/extraction to the volume of gross consumption of fuel and energy resources) of Kazakhstan is 228%. The ratio of gross consumption and production of fuel and energy resources is shown in Figure 1.

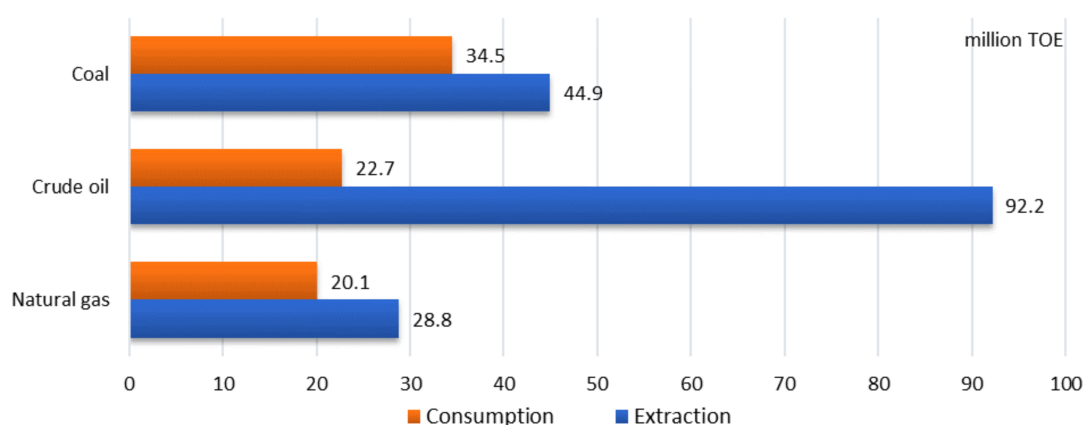


Figure 1. Dynamics of gross consumption and production of fuel and energy resources in Kazakhstan in 2019, million tons of oil equivalent (TOE). Source: compiled by the authors based on data from [69,70].

The gross consumption of fuel and energy resources in 2019 in Kazakhstan was 73 million TOE, and the final energy consumption was 41.6 million TOE. The largest energy consumption was shown by the industrial sector, the housing sector, and the transport sector (Figure 2).

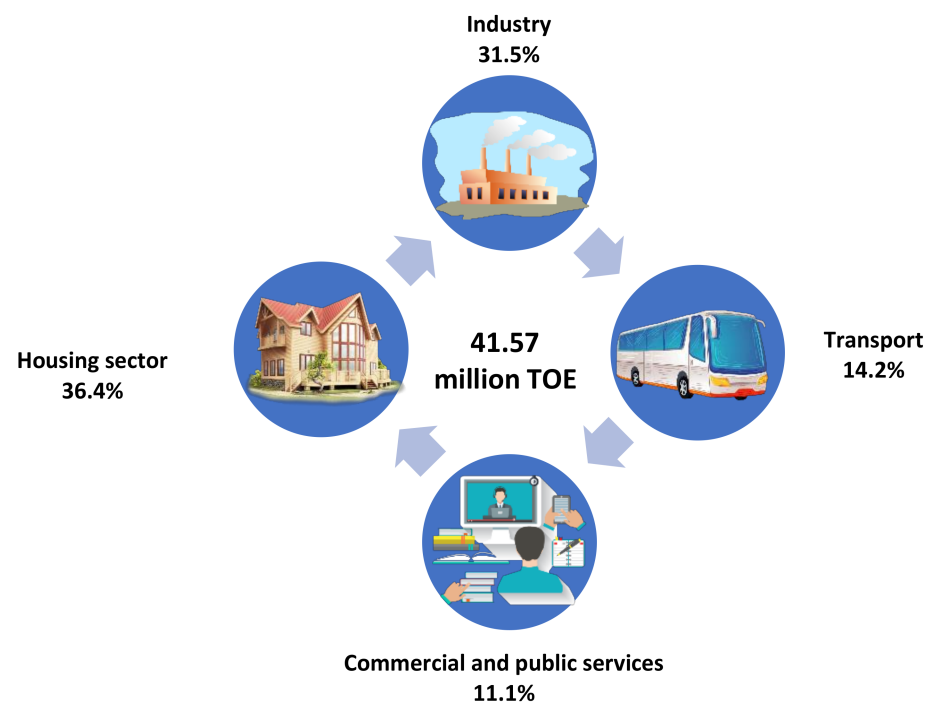


Figure 2. Structure of the main items of final consumption of fuel and energy resources in Kazakhstan in 2019, million TOE. Source: Compiled by the authors based on data from [69,70].

An indicator of the economic efficiency of consumption of fuel and energy resources is the indicator of the energy intensity of GDP. It is defined as the ratio of the volume of gross consumption of fuel and energy resources for all production and non-production needs in tons of oil equivalent to the value of GDP. The energy intensity of the economy is a particularly strong indicator of the nature intensity. This is a key indicator that characterizes the sustainability of the development of both the country as a whole and the energy sector. This indicator is one of the basic indicators in most systems of sustainability indicators.

According to statistics, with a high energy supply of the economy, the indicator of energy intensity of GDP in Kazakhstan is one of the highest (Figure 3). This situation demonstrates a very low efficiency of the economy of Kazakhstan.

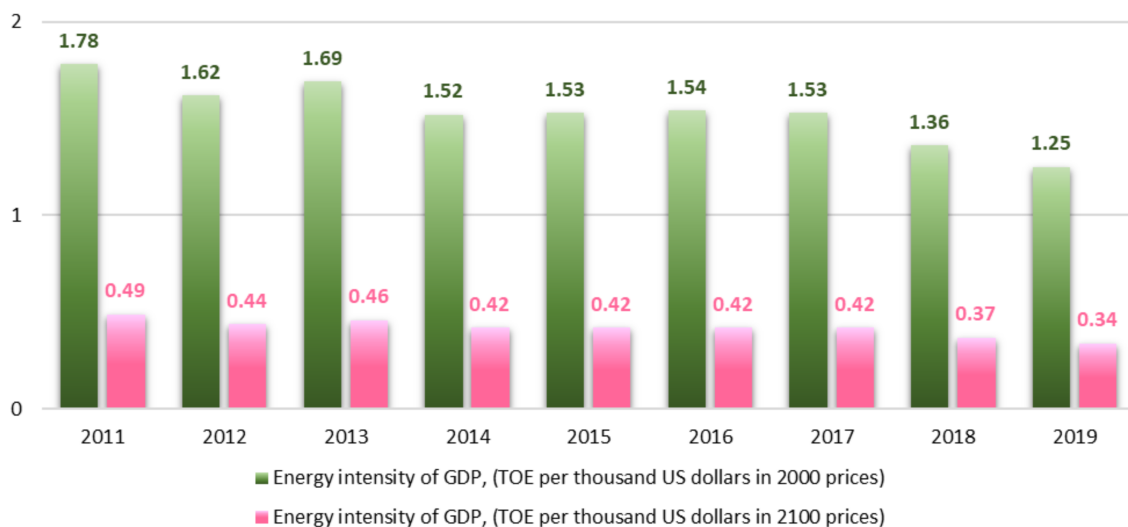


Figure 3. Dynamics of energy intensity of Kazakhstan’s GDP in 2011–2019. Source: compiled by the authors based on data from [70].

The energy intensity of Kazakhstan's GDP in comparison with the world average exceeds 2 times, with the OECD countries—4 times, among the CIS countries is on the 4th place. The strategic plan for the development of the Republic of Kazakhstan until 2025 and the Concept for the transition to a "green economy" set goals to reduce the energy intensity of the country's GDP by 25% by 2025 and by 50% by 2050. Another indicator of the modernization that has begun in recent years is the boom in street lighting at night. Today, about one third of street lamps in Kazakhstan have been converted to LED lamps. Annual savings in this segment alone amounted to more than 500 million tenge (about 1 million euros) [69].

The development of energy efficiency in Kazakhstan is regulated by the law "On Energy Saving and Energy Efficiency Improvement" (adopted in 2012). At the same time, in 2015, the Ministry of Investment and Development of the Republic of Kazakhstan developed an energy efficiency map. As part of the implementation of the energy efficiency map in September 2019, the Institute for the Development of Electric Power and Energy Saving JSC published the results of an energy audit of the country's main industrial enterprises. It turned out that, on average, enterprises can reduce energy consumption by 10%, and budget organizations—up to 40%. However, the heads of institutions are not interested in the introduction of energy-efficient technologies due to the long payback period of such energy projects [71].

One of the tools that stimulate the introduction of energy-efficient technologies in Kazakhstan is the State Energy Register. State institutions (kindergartens, schools, medical organizations, theaters) that consume more than 100 tons of conventional fuel per year and industrial enterprises that consume more than 1500 tons of conventional fuel per year are added to the register. Organizations that are included in the register are required to conduct an annual energy audit and follow the auditor's recommendations for five years, otherwise they will be fined. But the fines system is designed in such a way that in some cases it is much cheaper to pay a fine than to invest in energy efficiency. Nevertheless, according to the Ministry of Industry and Infrastructure Development of Kazakhstan, over 5 years the share of enterprises implementing the energy efficiency system increased from 9.7% to 41.7%, and the effect of the introduction of energy-saving technologies in Kazakhstan in 2018 amounted to 27 billion tenge (about 54 million euros), and in 2019—28.2 billion tenge (about 54 million euros) [72].

The main reasons for the high energy intensity of Kazakhstan's GDP:

- the current structure of the economy with a predominance of energy-intensive types of industries—extractive industries, mining and metallurgical complex, oil and gas sector, coal energy.
- climatic conditions when the heating season lasts 9 months in the northern parts of Kazakhstan. This leads to an energy-spending and energy-consuming heat supply sector.
- the general technological backwardness of many sectors of the economy, which leads to a high energy intensity of products (in some industries, it exceeds the similar European indicator by several times).
- relatively low cost of energy prices, which does not encourage many consumers to be energy-efficient.
- the deterioration of networks and equipment in the housing and communal services, the associated significant losses, fuel, and energy consumption.

Summarizing the review of energy availability and energy intensity, it should be noted that increasing the level of energy management remains an important task. Because whichever of the development alternatives the industry chooses, the indicators of efficiency of production and energy consumption should be significantly improved.

4.3. Alternative Energy Sources

Despite the still significant role of coal in the energy sector, global challenges are leading to a reduction in the share of coal generation in the global energy mix. To ensure sustainable energy development, one of the priorities is the environmental friendliness of

energy sources. Immediate and complete rejection of the use of coal is not possible. The latest technological solutions make it possible to ensure coal mining and the operation of coal stations more environmentally friendly and maneuverable. On this basis, the development of coal seams becomes “green”, and the operation of modern coal plants is almost as clean as gas plants: carbon dioxide emissions at such facilities can be reduced or captured and used effectively.

A large-scale transition from coal to gas in the economy, as well as improving energy efficiency and further increasing the use of renewable energy sources are the most important factors that allow Kazakhstan to fully reach the unconditional emission reduction target (15% of 1990 levels by 2030) under the Paris Agreement.

Another direction in the development of the coal industry is the production of liquid fuel and various chemical products by hydrogenation, liquefaction, and coal extraction methods. This is one of the important directions in the coal chemical industry of the future. In several countries, public and private companies are conducting intensive research into the production of synthetic liquid fuels from coal. In addition, today it is relevant to study the issues of obtaining synthetic liquid fuel and humic preparations from Kazakhstani coals, which will make it possible in the future to bring the processing of local solid hydrocarbon raw materials closer to a comprehensive one.

According to international experts [73], by 2100 the share of oil and coal in the world fuel and energy balance will be 2.1%, and 0.9%, respectively, thermonuclear energy will reach 10% of the market, and more than 25% of all world electricity will be generated by the sun. There will be a gradual decrease in the use of hydrocarbons and a reorientation to the production of cleaner energy industries.

In 2009, Kazakhstan passed a law “On the support of renewable energy sources”. The share of renewable energy sources is still small—just over 10% (including hydropower) (Figure 4, Table 1) [2,74–76]. But the existing difficulties in its implementation call into question that by 2050 the share of the use of renewable energy sources in Kazakhstan will reach 50%.

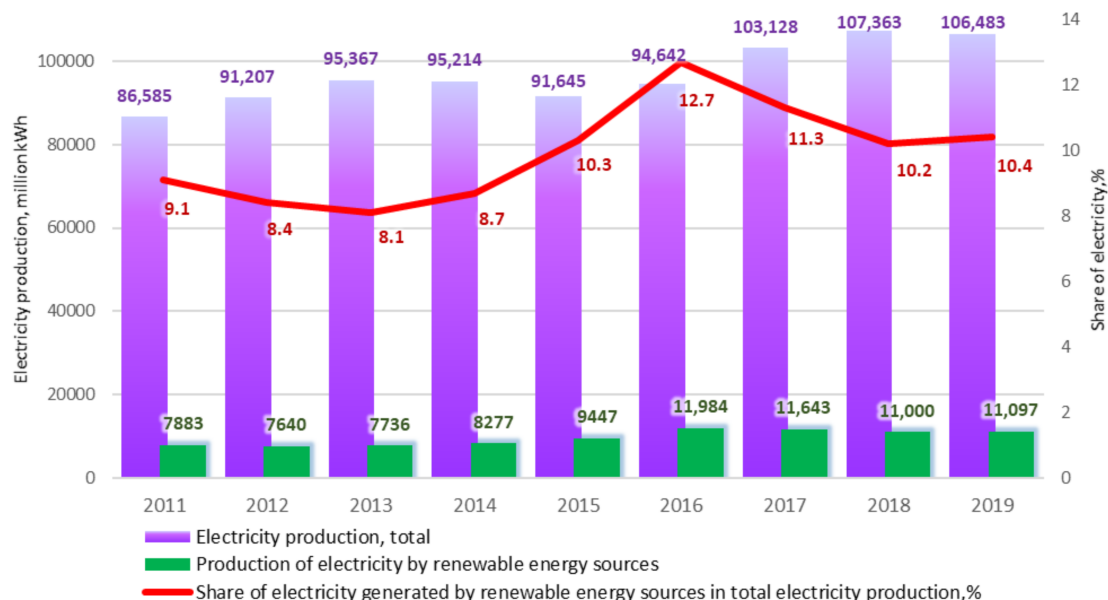


Figure 4. Dynamics of electricity production in Kazakhstan in 2011–2019, million kWh. Source: compiled by the authors based on data from [2,74–76].

Table 1. Structure of production of renewable energy sources in Kazakhstan, thousand kWh.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
produced by hydroelectric	7,883,323.0	7,637,265.9	7,730,762.5	8,262,830.9	9,269,190.4	11,620,763.9	11,210,191.7	10,395,354.1	9,993,658.8
produced by wind farms	147.0	2665.0	4546.9	13,300.8	131,722.3	274,982.8	339,840.3	460,583.1	707,135.1
produced by solar power plants		21	775.8	1268.3	46,171.0	88,403.1	93,038.8	141,311.1	391,229.6
produced using biogas							200.0	2832.1	4967.1

Source: compiled by the authors based on data from [2,74–76].

The use of biological fuel has a certain reserve. Due to the processing of agricultural waste, up to 35 billion kWh of electricity and 44 million Gcal. of thermal energy can be obtained annually. However, apart from a part of hydropower, these resources have not been widely used until now (Table 1).

The potential of renewable energy resources (hydropower, wind, and solar energy) in Kazakhstan is quite significant. The Ministry of Energy of Kazakhstan has estimated the potential of the republic at more than 2.7 trillion. kW, of which:

- wind energy potential—920 billion kWh,
- potential of solar energy—15 billion kWh (1300–1800 kW per 1 sq. m of area per year),
- potential of hydropower—170 billion kWh.

The calculated indicators demonstrate significant potential to enable Kazakhstan to make the transition from traditional to alternative energy sources. However, the choice of an alternative path of development is not carried out only based on calculations, it is accepted and carried out by people. The authors proceed from the assumption that the decision in the dilemma of long-term development of the electric power industry in Kazakhstan will be made under the influence of the industry stakeholders and will be implemented in the overall result. Therefore, it will reflect the common vision of the most interested and influential participants.

4.4. Industry Risks and Trends

The considered tendencies of the electric power industry in Kazakhstan pose a difficult choice for the country to modernize the existing production base and improve coal processing methods or direct its efforts to a more expensive but promising direction for the development of renewable energy sources.

The authors of the article were directly involved in a series of events to determine the forecast for the development of the energy industry in Kazakhstan in August 2020. In particular, the authors were the moderators of the foresight sessions, which allowed further analysis to be carried out using the original author's methodology. The Foresight was attended by 136 experts representing the manufacturing sector of the energy sector of Kazakhstan, industry science and education. The assessment of the future development of the industry was an important point in studying the opinion of experts, enabling us to determine, in a first approximation, the difference and coincidence in the vision of stakeholders. (Figure 5).

The weighted average assessment of the industry's prospects on a 10-point scale was 8.03 points—stable development of the industry. Moreover, the weighted average assessment of the possibility of an expert's personal influence on the development of the industry on a 10-point scale was 5.89 points, i.e., experts assess their influence as average, and the influence of companies in which experts work—6.75 points, which is slightly higher than the assessment of personal influence.

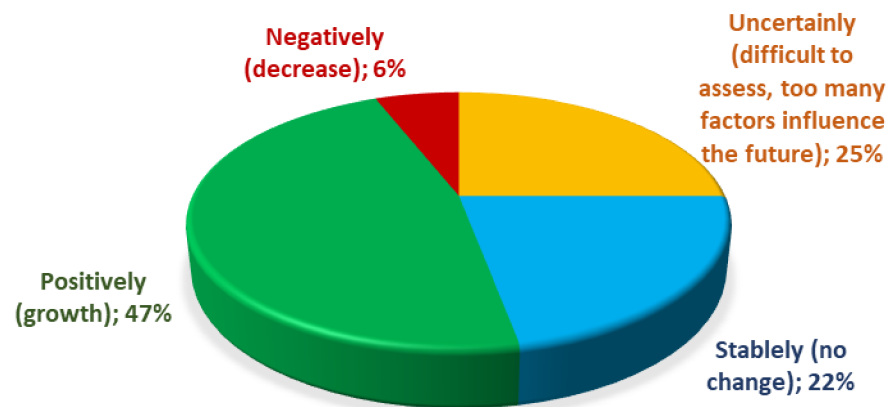


Figure 5. Expert assessment of the future development of the energy industry in Kazakhstan. Source: compiled by the authors based on the results of the Foresight.

According to experts, the following subjects have the greatest influence on the development of the industry (in descending order of the power of influence):

- Government of Kazakhstan,
- line ministry,
- owners and shareholders of energy companies,
- multinational companies,
- resident top managers,
- production personnel of energy companies,
- banks and credit institutions,
- functional management of energy companies,
- local executive authorities,
- universities and colleges.

It is obvious that it these participants not only form the future development agenda of the industry, but also have the greatest influence on the choice of the development model. The influence of the state and big business is still decisive, the role of the population and the public on such an important issue as the future of energy is, unfortunately, small.

All experts showed restrained caution in assessing the prospects for the development of the industry. Experts consider the development of monitoring and data processing technologies and new technologies for transmission and distribution of energy as growth zones for the domestic energy industry. This is where the main investment and management efforts of the next period should be directed.

Like any production system, the energy sector of Kazakhstan is subject to risks, not only of a technical and technological nature, but also of an environmental, social and labor nature. The authors of the article also took part in the development of the foresight methodology and in the analysis of its results. The experts were asked to assess 12 types of risks in the energy sector of Kazakhstan (Figure 6).

To further use the views of stakeholders as a basis for making management decisions, the weighted average probability of each risk and the severity of their consequences was determined, which made it possible to map the risks of the energy industry in Kazakhstan (Figure 7). Figure 7 uses the same risk numbering as in Figure 6.

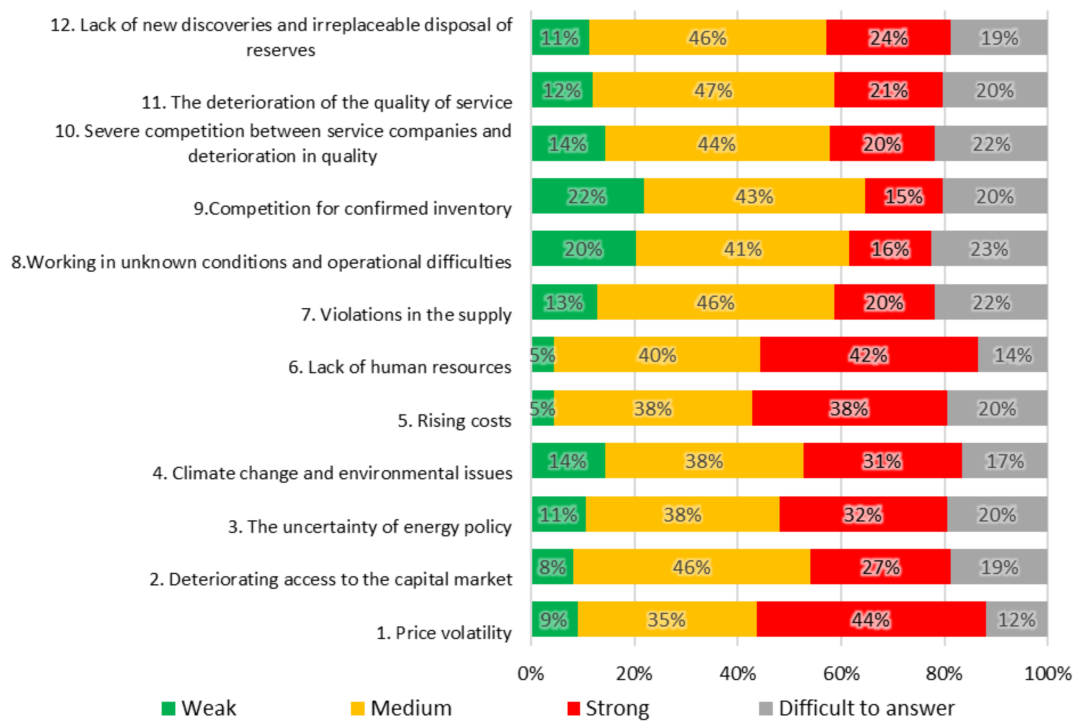


Figure 6. Expert assessment of the risks of negative development of the electric power industry in Kazakhstan. Source: compiled by the authors based on the results of the Foresight.

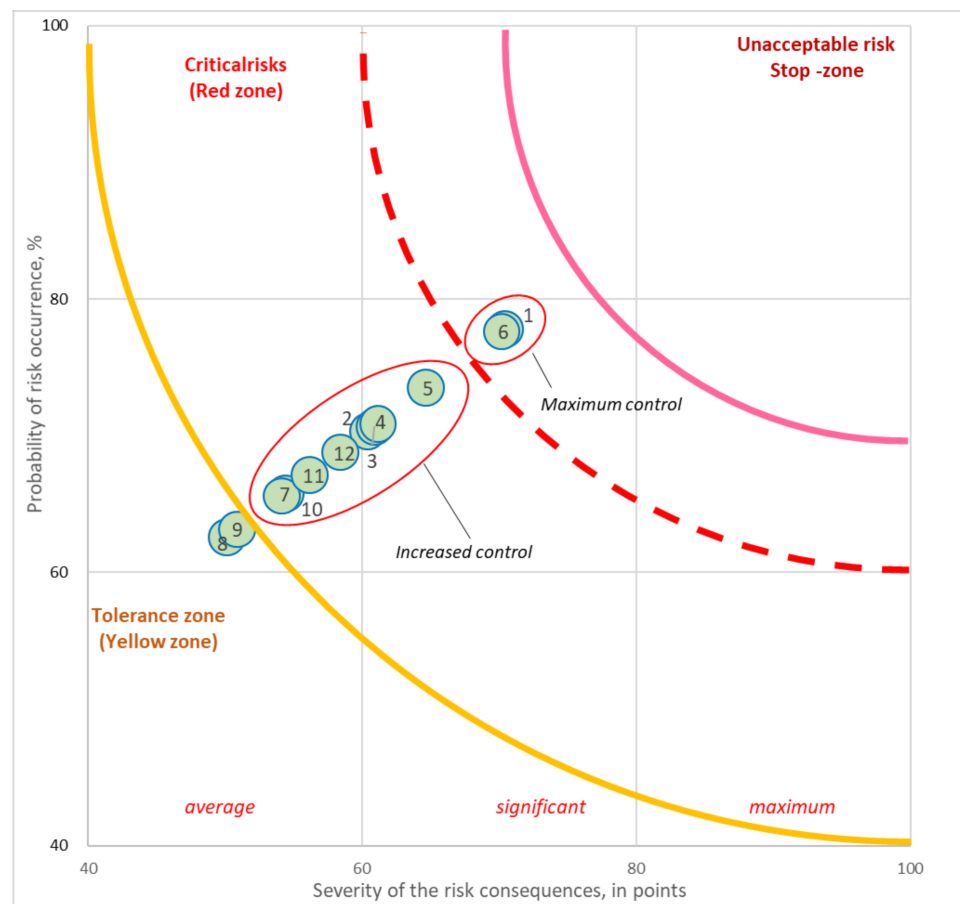


Figure 7. Risk mapping of the energy sector in Kazakhstan. Source: compiled by the authors based on the results of the Foresight.

When mapping risks, four zones are distinguished: Unacceptable risk, critical risk, tolerant risks, acceptable risks. Given that, based on the calculations, the risks were concentrated mainly in one zone, the scale of the map was increased by the authors and the zone of acceptable risks was not shown (it did not include the risks of the energy industry).

As can be seen from the figure, according to experts, there are currently no unacceptable risks in the industry. However, there are two risks that require maximum control: 1. Price volatility and 6. Lack of human resources. Eight more risks fall into the critical control zone. And two risks—8. Working in unknown conditions and operational difficulties and 9. Competition for confirmed inventory—the experts recognized as tolerant.

The risks selected by the foresight participants reflect not only their expert assessment, but also the conviction of specialists working in the industry. In every day practice, it is necessary to confront the noted threats that arise from the risks of the implementation of a particular development scenario. Therefore, the authors consider it possible to use the collective opinion of experts to assess the development dilemma. We have built a comparative matrix (Table 2), which allows us to evaluate the alternatives for new construction and operation of various power generation facilities according to four characteristics. The points in the table were distributed as follows: 4—the maximum negative assessment for this characteristic, 1—the minimum negative assessment. The matrix makes it possible to formalize the foresight experts' assessments, taking into account the strength of the influence of each characteristic when choosing the use of energy sources.

Table 2. Matrix for assessing the choice of using energy sources.

Assessment Characteristics	Nuclear Power Plants	RES	Coal Power Plants
Construction cost including equipment manufacturing	4	2	2
Lack of human resources, including the availability of educational infrastructure on the relevant technologies of the electric power industry	4	2	1
Electricity price	2	3	1
Environmental impact	4	1	4
Total	14	8	8

Source: compiled by the authors based on the results of the Foresight.

The cost of building a nuclear power plant is the highest compared to renewable energy sources and coal-fired power plants. In addition, a project for Kazakhstan, requiring significant investment and the involvement of experienced contractors.

The lack of personnel is also the most typical for the nuclear power industry due to its absence in the mill. Colleges and universities in Kazakhstan do not train specialists in nuclear energy. Traditionally, personnel are trained in the specialties of coal energy, and in the last 5 years, renewable energy sources.

Due to the low price of coal, the stability and availability of technological processes, the price of coal energy is minimal. The price of nuclear power is slightly higher since it is necessary to take into account the return-on-investment costs. However, since nuclear power plants are designed for a long service life and a large volume of electricity production, the cost of 1 unit of electricity is relatively low. The highest price for renewable energy sources is associated with high investment costs with unstable electricity production, as well as the need to maintain shunting capacities.

The assessment of the environmental impact is the highest in the nuclear power industry due to the catastrophic consequences in case of possible accidents and the need to dispose of nuclear waste. The maximum assessment in coal power engineering is associated with both emissions into the atmosphere and disturbance of the landscape and microclimate during coal mining.

Thus, having calculated the scores for each type of power plant, we see the maximum negative (risk) potential for nuclear energy and the same values for the assessment of RES

and coal energy. This result once again confirms the presence of a dilemma in choosing a further path for the development of Kazakhstan's energy sector.

The choice of management methods for identified risks directly depends on industry development trends that are expected soon and on actors and stakeholders, whose influence is most significant in this sector of the economy of Kazakhstan.

Among the strong and dominant (in total), experts identified the following trends:

- introduction of new technologies for generation, transmission, and distribution of energy (65% of respondents),
- digitalization, data collection and big data analytics (60% of respondents),
- growth of environmental requirements (51% of respondents).

The rest of the trends have a low dominant influence (less than 50% of respondents), or rather an indirect influence (Figure 8).

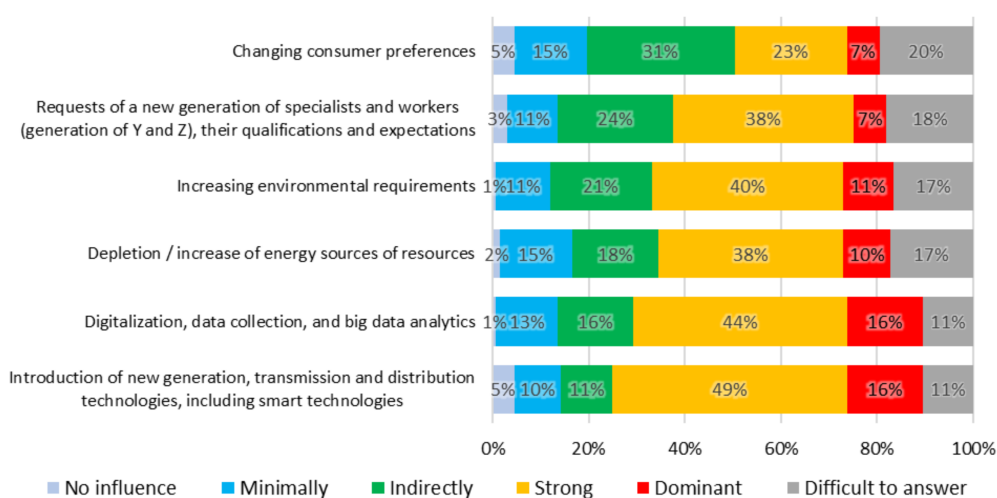


Figure 8. Expert assessment of the impact of major trends on the future of the energy industry in Kazakhstan. Source: compiled by the authors based on the results of the Foresight.

Experts predict different activity of implementation of the identified trends and the likelihood of risks. The participation of experts in building the desired future of the industry depends on how much they themselves position their influence on the development of the industry, as well as new opportunities for the development of the industry experts see.

As shown by the answers of experts, the main opportunities in the industry in the future open up primarily in the construction of generating stations in alternative energy (2 in Figure 9) and coal, gas, oil (1 Figure 9).

Further, in the group of dominant influence, there are opportunities (in order of decreasing probability of occurrence and strength of influence):

6—Significant reduction in energy losses,

7—Significant reduction in personnel due to the introduction of telemetry.

The following opportunities fell into the zone of strong influence with a 50% probability of attack (in order of decreasing strength and possibility of influence):

5—Consolidation of companies, optimization of processes and costs.

3—Stabilization of the price market and their stability in the next 5 years,

4—Reduced energy transportation costs.

Considering the almost equal dominant prospects that the experts identified—the construction of classical power plants (fueled by coal, gas, and oil) and renewable energy sources, we can state that the dilemma of choosing a development path for experts.

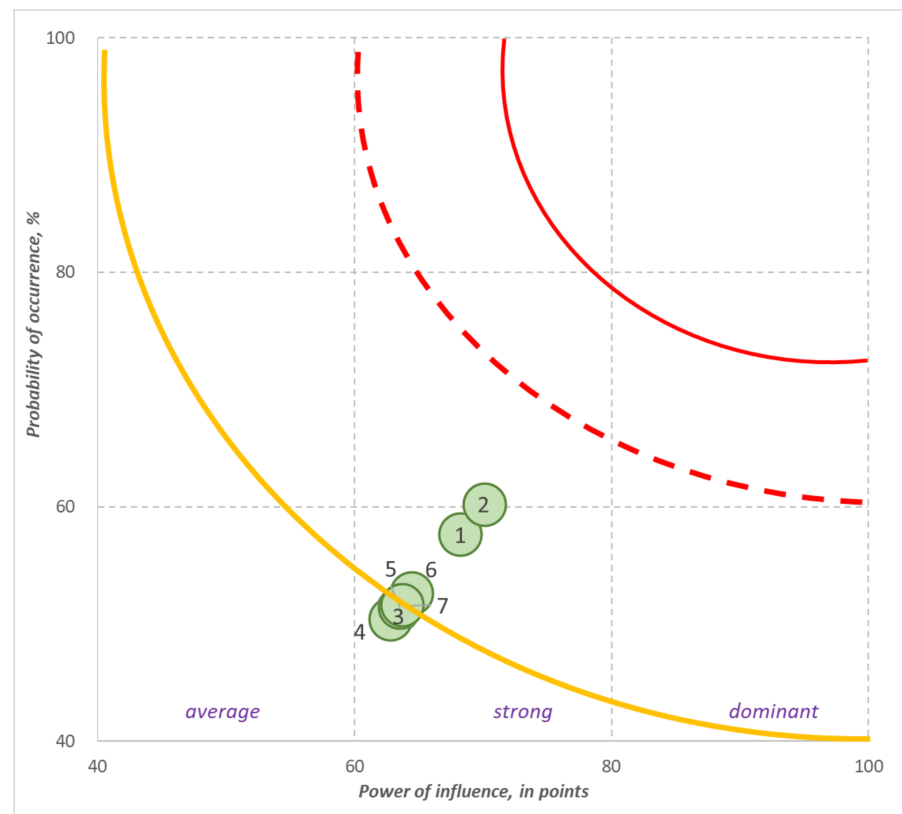


Figure 9. Expert assessment of opportunities for the development of the electric power industry in Kazakhstan. Source: compiled by the authors based on the results of the Foresight.

5. Discussion

The existing electric power facilities in Kazakhstan were built in Soviet times and are quite worn out. They require serious modernization or complete replacement of equipment that is not produced in Kazakhstan. In this regard, we are witnessing a dilemma facing the country—where to direct financial resources: Modernize existing predominantly coal-fired thermal power plants or build renewable energy facilities?

On the one hand, the country has vast coal resources, and thus, low prices for traditional coal energy. According to the Internet portal GlobalPetrolPrices [77], the cost of electricity in Kazakhstan for one kWh is \$0.04, while the average price in the world is \$0.14. In Belarus, one kWh of electricity costs \$0.07, in Georgia \$0.06, and in Ukraine \$0.05. Modernization projects for existing coal-fired power generation facilities are an order of magnitude lower than projects for new construction of renewable energy sources. Traditional heat producers will resist the invasion of alternative green energy competitors.

On the other hand, the global environmental situation dictates the need for a transition to green electricity based on renewable energy sources. The Government of Kazakhstan has set a strategic goal that by 2050, half of the country's total energy consumption should be generated by renewable energy sources (RES), using water, wind, sun. Large investments are required for the construction of renewable energy sources. The unstable position of the state currency in the world market and an opaque operating environment are a deterrent for foreign investment in Kazakhstan. Therefore, the main obstacles to the development of renewable energy sources in Kazakhstan are the lack of access to long-term money and taxes on imported equipment. It is also necessary to understand that an increase in the share of renewable energy sources in the energy sector requires a proportional volume of modern shunting capacities, which is absent in Kazakhstan. In addition, green energy will increase the tariff burden on end users by 2.5–3 times.

Since the issues of long-term development of the electric power industry are closely related to the energy security policy, we consider it expedient to consider the choice of a

development model with the provision of an appropriate level of energy security for the country (Table 3). The authors rely on the international classification of energy security, depending on the period of the forecast assessment [24].

Table 3. Methodological approaches to solving the dilemma.

Period	Energy Security	Choice Dilemma
short	associated with the risks of power outages	<i>Social approach</i> —ensuring the preservation of moderate costs of energy costs for the population and enterprises, especially during the period of coming out of the pandemic lockdown and overcoming the crisis generated by them
mid-term	uninterrupted, reliable, sufficient power supply ranging from years to decades	<i>A pragmatic approach</i> —a transition to effective energy management, reduction of harmful effects on the environment, accumulation of funds and their investment in alternative sources, gradual integration into the global energy system
long term	ensures the availability of energy sources in the future	<i>An innovative approach</i> is to ensure such a share of innovative (alternative) energy, which will allow the country to fully participate in global economic and energy cooperation and ensure high efficiency in the production and use of energy

Source: compiled by the authors based on the source [24] and their own developments.

It should also be noted that the problem of choosing an energy model affects the interests of various territories and groups of society in the republic, which are contradictory in nature and content. The authors previously considered regional features in the study of energy management problems and noted the difference in its effectiveness both by region and by industry [21–23]. The works of Kazakh authors also note the need to differentiate approaches to energy management, models of energy systems are proposed with a breakdown by subnational regions, types of buildings and urban/rural areas, which in their opinion, will increase the energy security of households [59]. The various choices in the way electricity is developed in the republic, combined with significant social obligations, reduce the importance of rational factors, especially in the short term.

The authors consider that a controversial position about the need to introduce a ban on the use of coal and move to cleaner alternatives for generating energy in the shortest possible time. The dilemma of choosing the long-term development of the electric power industry in Kazakhstan should be solved using different approaches for solutions of different implementation periods.

6. Conclusions (Prospects for the Development of the Industry)

It is necessary to consider the directions of development of the energy industry in Kazakhstan from different time perspectives. Soon, the development of environmentally friendly and efficient technologies for the processing of fossil fuels (oil, coal, gas) based on steam-gas plants and methods of deep processing of coal, is of greatest relevance. At the same time, fossil fuel will remain a priority energy source. It should provide an exit for the economy from the crisis generated by the need for a lockdown and ensure the accumulation of investments for the transition to alternative energy sources.

In the future, there will be an active introduction of renewable energy sources and the development of effective methods for converting and storing energy, including fuel cells. These technologies have already begun to be implemented, but a radical change in the structure of the world energy because of the displacement of coal and its replacement by carbon-free sources will come after 2050. Nuclear energy plays a key role, in combination with solar energy, hydropower, and environmentally friendly biofuels. Although it is nuclear energy, which has indisputable economic advantages for Kazakhstan, may be not chosen for political and social factors.

In conclusion, it should be noted that modern energy is already in the process of digital transformation. Digital technologies are actively penetrating the energy sector, making it possible to analyze and manage the production, transportation, and consumption of energy

more efficiently. As a result, technological innovations shape the future of the energy sector and form the basis for economic and social choice.

The staffing dilemma remained outside the scope of this study. The issues of staffing the electric power industry in Kazakhstan are important, but require separate consideration, which will be presented in subsequent publications of the authors.

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