

The Impact of Institutional Factors on the Development of Renewable Energy in Kazakhstan: An Econometric Analysis

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Abstract: Kazakhstan's energy system faces a serious challenge due to its high dependence on hydrocarbons. It's worth noting that the country's energy system was built during the former Soviet Union. The country still generates over 70% of its electricity from coal and gas. New energy facilities and capacities are being commissioned very slowly. Consequently, the country's energy infrastructure is extremely deteriorated. This, in turn, translates into significant transmission losses and a high accident rate. The growing electricity deficit is the main obstacle to ensuring high rates of economic growth and sustainable demand. Over the past 10 years, the country has placed a strong emphasis on the construction and commissioning of renewable energy facilities, which will account for 7% of total electricity generation by 2025. Furthermore, the rapid rise in gas prices over the past four years has prioritized an active transition to renewable energy sources to achieve national energy security. Therefore, the aim of this article is to conduct an econometric assessment of the contribution of institutional factors and provide recommendations for stimulating the promotion of renewable energy sources in Kazakhstan.

1 INTRODUCTION

In the post-pandemic period, as economic activity gradually recovered, oil and gas prices rose. However, it should be noted that energy uncertainty and reduced gas supplies from Russia due to trade sanctions related to the special operation in Ukraine contributed to this increase (URL 1).

Globally, there is a growing public and private sector push to achieve net-zero emissions. Investments in renewable energy sources (RES) are particularly important for the oil, gas, and power sectors, both to ensure compliance with greenhouse gas (GHG) emissions regulations and avoid fines, and to ensure the stability of company market value due to the more flexible nature of RES compared to coal-fired generation.


According to Igliński et al. (2024), a clear shift from traditional energy sources to RES has been observed over the past few years.


We believe that the use of RES contributes to a reduction in energy dependence on energy suppliers.


RES are identified as important approaches (Jaiswal et al., 2024) for strengthening socioeconomic resilience. They include solar and wind energy, hydrogen, and geothermal systems.


It should be noted that over the past 5-6 years, the cost of generating energy from solar panels has fallen by approximately 50% globally. This is clearly due to the implementation of scientific and technological progress and digital technologies. According to the IEA, over 95% of renewable energy projects in 2023 were cheaper than those using traditional fuels (URL 2).

The energy sector plays a key role in the socioeconomic development of a country or region.

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This is especially true for energy-exporting countries, including the Republic of Kazakhstan.

Kazakhstan's GDP for 2023 and 2024 was 5.1% and 5%, respectively. And for the first six months of 2025, it was 6.3% (URL 3). Electricity generation in the country in 2023 was 112,823.1 million kWh, and in 2024, 117.9 billion kWh (URL 4). The 2025 target is for electricity production to reach 117.1 billion kWh, including 7.2 billion kWh from renewable energy sources.

Kazakhstan's gross domestic product (GDP) is significantly dependent on raw material export volumes and global oil prices. Therefore, the country has a highly energy-intensive economy. The main industries are the oil and gas sector, the coal industry, and extractive industries.

Economic growth drives increasing energy demand, as emphasized by Lu et al. (2024). Therefore, there is a direct link between electricity consumption and GDP.

Statistics show that the growth rate of electricity generation is lagging behind Kazakhstan's economic growth. This suggests a clearly growing energy deficit in the country. Therefore, in the near future, this sector will not be able to sustainably and reliably support the national economy.

One of the most significant steps toward achieving a sustainable national energy system is the development of the renewable energy sector. For example, in accordance with international trends for reducing carbon emissions, 50% of Kazakhstan's electricity should be generated from renewable energy sources by 2050 (URL 5).

By 2025, the share of renewable energy generation in the overall energy sector will be approximately 7%.

Attracting public investment in alternative energy sources directly impacts the greening of the global economy and Kazakhstan. At the same time, as Nurgaliuly & Smagulova (2025) emphasize, directing investments toward depreciation of fixed assets of energy facilities strengthens the preconditions for increased economic development in Kazakhstan.

The distribution of renewable energy facilities in Kazakhstan directly depends on the region's natural potential. Renewable energy development trends in Kazakhstan indicate that solar power plant construction predominates over other energy sources, driven by significantly lower logistics costs compared to wind turbines, lower maintenance and repair costs for solar power plants compared to wind power plants, favorable climatic conditions, and high demand in the south of the country. For example, the Kyzylorda region averages 280 sunny days.

The energy industry faces challenges such as the unpreparedness of Kazakhstan's power grid infrastructure for the full integration of renewable energy sources.

A significant obstacle to stimulating the construction of renewable energy facilities is the presence of a significant share (approximately 70%) of non-maneuverable coal-fired power plants in the country. For example, coal-fired power plants account for approximately 27% of all power plants in the United States, approximately 20% in the EU, and approximately 17% in Russia.

This reflects a significant shortage of flexible generating capacity, such as gas turbines and hydroelectric power plants. Therefore, this clearly demonstrates the need to attract investment in decarbonization and the construction of innovative renewable energy facilities.

A significant problem (Zhou, 2024) today globally is the insufficient use of tools and innovative methods for storing energy using renewable energy sources.

In this regard, it is worth emphasizing the significantly outdated structure of the power grid and energy storage system in Kazakhstan. Thus, our national energy sector was not designed for the variable generation mode of renewable energy sources.

In addition to the shortage of reserve capacity and microgeneration, there is the deterioration, low transmission capacity, and geographical limitations of the power grid, the impossibility of integrating renewable energy sources with thermal energy, and the isolation of the western region of Kazakhstan. In particular, despite the region's high natural potential, the development of renewable energy sources will lead to a significant increase in energy costs for end users.

Moreover, although Kazakhstan's grid operator, KEGOC, provides significant support for the development of renewable energy sources, global experience points to problems arising from an energy surplus from traditional and other alternative energy sources.

According to Campana et al. (2025), increasing the share of renewable energy should be accompanied by the use of innovative and digital IoT technologies. It is worth noting that Kazakhstan faces significant challenges in implementing new information technologies in the renewable energy sector.

Like any infrastructure project, renewable energy projects require significant capital expenditures at the initial stage. Since most Kazakhstani renewable energy projects are financed through loans from

international institutions, there is a currency risk for investors, which can significantly increase the project cost in tenge. This risk significantly limits the development of the sector.

Overall, despite certain obstacles and threats, Kazakhstan possesses high natural and economic potential for improving the development of advanced innovative infrastructure and the security of the energy system. All this provides the necessary preconditions for the further development of the renewable energy sector.

Based on this, we decided to conduct an econometric assessment to determine the contribution of institutional factors to the development of renewable energy sources in Kazakhstan.

2 MATERIALS AND METHODS

Identifying the relationship between renewable energy development indicators and economic and institutional factors is a pressing issue in the modern scientific community. A number of studies employ econometric methods, such as correlation and regression analysis. For example, a scientific article by Uddin & Shahbaz (2026) examines the impact of investment and digitalization on renewable energy development in African countries from 2003 to 2021 using LASSO and linear regression with cross-fitting. The results show that foreign investment increases renewable energy production and consumption, while digitalization has a negative impact.

Zhang et al. (2026) study the impact of renewable energy technology innovation (RETI) on energy security (ES) using data from 45 countries over the period from 2000 to 2022. The authors use quantile regression. The results demonstrate that RETI has a positive impact on ES, while the institutional environment plays a moderating role in ES growth.

In Wang et al. (2026), the authors construct regression models to identify the relationship between AI, financial development, and the energy transition. Their findings suggest that RETI stimulates the transition to RES. However, given the dominance of fossil fuels in the energy sector, financial development may have a negative effect on the transition to a green economy.

In Dinh et al. (2026), econometric models combined with AI were used to address imbalances in the energy system and improve the efficiency and reliability of RES. Wehbi & Kemper (2025) assess the impact of different levels of government on renewable energy integration in small and medium-sized communities in the United States. The findings

indicate that local governments include renewable energy targets in their local plans less frequently than county and state governments. A regression analysis identified factors influencing the percentage of renewable energy consumption.

In Ostadzad & Ghafoorian Yavarpanah (2025), the authors examine the nonlinear relationship between financial development, economic complexity, and R&D investment as a control variable for the transition to renewable energy in OECD countries. The results indicate that increasing economic complexity hinders the energy transition, which could be accelerated through investment in renewable energy.

Asabie & Tadesse (2025) use regression analysis to examine the impact of socioeconomic factors on access to renewable energy in Ethiopia. The results showed that education and income levels significantly influence access to electricity. Using regression analysis, Schischke & Rathgeber (2025) demonstrated that increasing the share of renewable energy in EU countries reduces volatility in electricity markets.

Using moment quantile regression methods, it was possible to identify the negative impact of renewable energy sources on greenhouse gas emissions in the BRICS countries (Alsulami & Raza (2025)). In the article by Teixeira et al. (2025), the authors used regression analysis to study the interaction between environmental sustainability and economic growth in 20 countries. It is noted that economic growth stimulates the development of renewable energy sources.

In the studies by Moskalenko et al. (2022), Kassi et al. (2022), Kwakwa (2023), the authors created regression models to study the impact of the quality of institutions, renewable energy sources, and financial development on investment attractiveness and carbon dioxide emissions. The countries considered were the EU and African countries. Indicators of institutional quality include the rule of law, political stability, regulatory quality, control of corruption, and government effectiveness, which are provided annually by the World Bank. However, we note a lack of scientific papers devoted to the influence of the quality of institutions on the development of renewable energy sources in Kazakhstan.

Karatayev & Hall (2017) examine the availability, potential, and use scenarios of RES in Kazakhstan, discussing institutional factors such as government policy, economic aspects, and barriers hindering renewable energy development in the country. The authors suggest that significant investment in wind

and solar energy systems will cover 30% of electricity demand by 2030. To reduce greenhouse gas emissions and increase the share of renewable energy sources in total electricity generation, direct use of government mechanisms in the form of laws is necessary.

Our study uses correlation-regression analysis to predict and analyze relationships between indicators. Regression analysis utilizes the ordinary least squares (OLS) method (Sarstedt & Mooi, 2014), one of the most commonly used tools in scientific practice.

The following formula is used to calculate the coefficient of variation:

$$C_v = \sigma / \mu \quad (1)$$

where, C_v – coefficient of variation, σ – normative deviation, μ – mean deviation.

The multiple linear regression model is expressed as follows:

$$Y = f(X_1) + f(X_2) + f(X_n) + \varepsilon \quad (2)$$

where, Y – dependent variable, X_n – independent variables, n – number of factors, ε – random error.

To conduct a multiple regression analysis, we collected the necessary statistical data from open sources. We selected the time period from 2018 to 2023 because statistics on renewable energy auctions in Kazakhstan began to be compiled in 2018. The data was collected from World Bank reports, The Global Economy online resource, and reports on renewable energy project auctions in Kazakhstan prepared by the Financial Settlement Center for Renewable Energy Sources LLP (RFC). The list of selected indicators is presented in Table 1.

Table 1: List of indicators.

| Name of variables | Unit of measurement |
|--|---------------------|
| The share of RES in the total volume of electricity production in the Republic of Kazakhstan (Y) | % |
| Renewable energy generating capacity in developing countries (X_1) | In watts per capita |
| Innovation Index for Kazakhstan (X_2) | Point |
| Renewable energy projects at auctions (X_3) | MWh |
| Rule of law in Kazakhstan (X_4) | Point |

| | |
|---|-------|
| Political stability in Kazakhstan (X_5) | Point |
|---|-------|

Calculations were conducted using the Gretl econometric modeling program.

Based on the above information, the following research hypotheses were formulated, requiring proof:

1. Hypothesis 1: The innovation index has a negative impact on the share of renewable energy sources.

2. Hypothesis 2: The rule of law index has a positive impact on the share of renewable energy sources.

3 RESULTS AND DISCUSSION

The study's authors compiled a set of indicators reflecting the development of renewable energy sources in Kazakhstan, the quality of institutions, and the effectiveness of public administration. Six indicators were selected, the resulting indicator measuring the share of renewable energy sources in total electricity generation.

The Government of the Republic of Kazakhstan has set a target of increasing this indicator by 2030 as part of one of the UN Sustainable Development Goals. Specifically, this is Goal 7 – Ensure access to affordable, reliable, sustainable, and modern energy for all (URL 6). Therefore, it is crucial to identify patterns between this key indicator, the quality of institutions, and the results of auctions for renewable energy projects.

The authors decided to determine the linear relationship between the share of renewable energy in total electricity generation and the factor variables using correlation analysis. A correlation matrix was constructed using the Gretl program based on the data in Table 2. Correlation analysis allows us to determine the presence and degree of correlation between the indicators.

Table 2: Key indicators for building a model.

| Year | Y | X_1 | X_2 | X_3 | X_4 | X_5 |
|------|------|--------|-------|--------|-------|-------|
| 2018 | 1,38 | 531,7 | 31,4 | 857,93 | -0,5 | -0,05 |
| 2019 | 1,87 | 1085,5 | 31 | 212,89 | -0,51 | -0,17 |
| 2020 | 2,78 | 1554,1 | 28,6 | 147,95 | -0,47 | -0,26 |
| 2021 | 3,46 | 1987,7 | 28,6 | 86,95 | -0,51 | -0,23 |
| 2022 | 4,44 | 2373,2 | 24,7 | 440,00 | -0,47 | -0,47 |
| 2023 | 5,90 | 2868,8 | 26,68 | 767,81 | -0,45 | -0,27 |

Note - compiled by the authors based on (URL 7, 8, 9).

Below are the correlation coefficients (R), which indicate the degree of relationship between the resulting indicator and the variables. R values range from -1 to 1. The closer the coefficient value is to 0, the weaker the correlation between the indicators. A positive correlation ($R > 0$) means that one variable is directly related to another. According to econometric science, when deciding on the level of strong significance for an indicator, an R of 0,5 or higher is accepted. With a negative correlation ($R < 0$), an increase in one variable leads to a decrease in the other.

The results of our analysis are shown in Table 3.

Table 3: Correlation matrix.

| | Y | X_1 | X_2 | X_3 | X_4 | X_5 |
|-------|---------------|--------|--------|-------|--------|-------|
| Y | 1,0 | | | | | |
| X_1 | 0,982 | 1,0 | | | | |
| X_2 | -0,853 | -0,880 | 1,0 | | | |
| X_3 | 0,169 | -0,014 | -0,004 | 1,0 | | |
| X_4 | 0,763 | 0,694 | -0,712 | 0,371 | 1,0 | |
| X_5 | -0,684 | -0,760 | 0,941 | 0,245 | -0,557 | 1,0 |

We then selected the indicators with the strongest impact on the dependent variable Y , based on the R coefficient.

R_{yx1} is 0,982. This means that the relationship between the share of renewable energy sources in total electricity production and the installed renewable energy generating capacity is very close and positive.

R_{yx2} is -0,853. This means that the relationship between the resulting indicator and the innovation index is close and negative. In our opinion, this can be explained by the fact that the innovation index covers various elements of the national economy: institutions, human capital, infrastructure, business and market development. Consequently, other sectors of the economy may divert attention and resources from renewable energy production.

It should also be noted that the innovative development of Kazakhstan's energy infrastructure is very low.

R_{yx4} is 0,763. The relationship between the resulting indicator and the rule of law index is moderate and positive. To strengthen the energy system and promptly counteract negative factors, government agencies, together with private organizations, are developing, approving, and implementing measures to improve the country's energy security.

The next step was to conduct a regression analysis of the data using Gretl to determine which variables satisfy the t-statistic and p-value requirements, i.e.,

whether they are statistically significant. The ordinary least squares (OLS) method was used for this purpose. Considering the correlation coefficient R , significant factors were selected. Of the five independent variables, X_1 , X_2 , and X_4 are strongly correlated. In this study, we are interested in the relationship between the share of renewable energy in total electricity generation and two indices: rule of law and innovation index, which demonstrate a strong relationship with the dependent variable.

Table 4 presents the results of the regression analysis for constructing the $Y(X_2)$ model.

Table 4: Model 1: OLS, using observations 2018-2023 (T = 6) Dependent variable: Y .

| | Coefficient | Std. Error | t-ratio | p-value | |
|----------------------|-------------|--------------------|----------|---------|-----|
| X_2 | 0.111488 | 0.0275779 | 4.043 | 0.0099 | *** |
| Mean dependent var | 3.304833 | S.D. dependent var | 1.678340 | | |
| Sum squared resid | 18.65152 | S.E. of regression | 1.931399 | | |
| Uncentered R-squared | 0.765731 | Centered R-squared | 0.324294 | | |
| F(1, 5) | 16.34295 | P-value(F) | 0.009897 | | |
| Log-likelihood | -11.91614 | Akaike criterion | 25.83227 | | |
| Schwarz criterion | 25.62403 | Hannan-Quinn | 24.99867 | | |
| rho | 0.919571 | Durbin-Watson | 0.304102 | | |

The coefficient of determination (R^2) is 0,76, indicating the proportion of variation in the Y indicator based on the factors examined. The regression model is presented below:

$$Y = 19,32825 - 0,56229 * X_2 \quad (3)$$

This model shows that the Y indicator will decrease by 0,56229 as the innovation index increases.

The model was tested for autocorrelation and a heteroscedasticity analysis was performed.

White's test for heteroskedasticity - Null hypothesis: heteroskedasticity not present. Test statistic: $LM = 3,66378$, with p-value = $P(\text{Chi-square}(2) > 3,66378) = 0,160111$.

LM test for autocorrelation up to order 1 - Null hypothesis: no autocorrelation. Test statistic: $LMF = 3,7563$, with p-value = $P(F(1, 4) > 3,7563) = 0,124647$.

Table 5 shows a retrospective forecast and confidence intervals.

Table 5: Retro-forecast results/

| Obs | Y | prediction | std. error | 95% interval |
|------|---------|------------|------------|---------------------|
| 2018 | 1.37700 | 3.50071 | 2.11664 | (-1.94028, 8.94171) |
| 2019 | 1.87300 | 3.45612 | 2.11215 | (-1.97334, 8.88558) |
| 2020 | 2.78100 | 3.18855 | 2.08624 | (-2.17430, 8.55140) |
| 2021 | 3.46000 | 3.18855 | 2.08624 | (-2.17430, 8.55140) |
| 2022 | 4.43800 | 2.75375 | 2.04800 | (-2.51080, 8.01830) |
| 2023 | 5.90000 | 2.97449 | 2.06680 | (-2.33839, 8.28738) |

Based on the data obtained, a forecast for 2026–2030 was constructed (Table 6). We assume that variable X_2 increases by 10% each year.

Table 6: Confidence analysis of the forecast, 2026-2030.

| Obs | Y | prediction | std. error | 95% interval |
|------|-----------|------------|------------|----------------------|
| 2026 | undefined | 3.66126 | 2.13320 | (-1.82230, 9.14481) |
| 2027 | undefined | 4.05704 | 2.17657 | (-1.53800, 9.65208) |
| 2028 | undefined | 4.49295 | 2.22834 | (-1.23517, 10.2211) |
| 2029 | undefined | 4.97235 | 2.28979 | (-0.913745, 10.8584) |
| 2030 | undefined | 5.49857 | 2.36226 | (-0.573821, 11.5710) |

We also created a graph with a forecast for 2026-2030 (Figure 1).

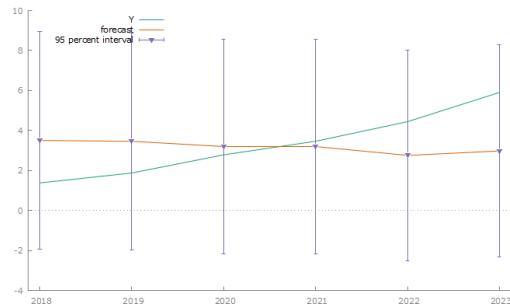


Figure 1: Forecast graph, 2026-2030.

According to forecast Table 6 and Figure 1, the Y indicator will initially decline between 2026 and 2030 relative to the period under review, but subsequently begin to grow. However, it will not reach 2023 levels. Therefore, it can be concluded that the share of renewable energy in total electricity production is negatively impacted by the growth of the innovation index. Therefore, Hypothesis 1 is confirmed.

Subsequently, the $Y(X_4)$ model was constructed (Table 7).

Table 7: Model 2: OLS, using observations 2018-2023 (T = 6) Dependent variable: Y .

| | Coefficient | Std. Error | t-ratio | p-value | |
|----------------------|-------------|------------|--------------------|---------|----------|
| X_4 | -6.68523 | 1.52270 | -4.390 | 0.0071 | *** |
| Mean dependent var | 3.304833 | | S.D. dependent var | | 1.678340 |
| Sum squared resid | 16.39838 | | S.E. of regression | | 1.810987 |
| Uncentered R-squared | 0.794031 | | Centered R-squared | | 0.164316 |
| F(1, 5) | 19.27547 | | P-value(F) | | 0.007085 |
| Log-likelihood | -11.52990 | | Akaike criterion | | 25.05980 |
| Schwarz criterion | 24.85156 | | Hannan-Quinn | | 24.22620 |
| rho | 0.916975 | | Durbin-Watson | | 0.355674 |

The coefficient of determination R^2 is 0,79. The regression model is presented below:

$$Y=28,0637+51,04921 * X_4 \quad (4)$$

This equation shows that the Y indicator will increase by 51,04921 with an increase in the rule of law index.

The model was tested for heteroscedasticity and autocorrelation.

White's test for heteroskedasticity - Null hypothesis: heteroskedasticity not present. Test statistic: $LM = 3.66378$, with p-value = $P(\text{Chi-square}(2) > 3.66378) = 0.160111$.

LM test for autocorrelation up to order 1 - Null hypothesis: no autocorrelation. Test statistic: $LMF = 3.7563$, with p-value = $P(F(1, 4) > 3.7563) = 0.124647$.

Table 8 shows a retrospective forecast and confidence intervals.

Table 8: Retro-forecast results.

| Obs | Y | prediction | std. error | 95% interval |
|------|---------|------------|------------|---------------------|
| 2018 | 1.37700 | 3.34262 | 1.96452 | (-1.70734, 8.39257) |
| 2019 | 1.87300 | 3.40947 | 1.97047 | (-1.65578, 8.47472) |
| 2020 | 2.78100 | 3.14206 | 1.94727 | (-1.86356, 8.14767) |
| 2021 | 3.46000 | 3.40947 | 1.97047 | (-1.65578, 8.47472) |
| 2022 | 4.43800 | 3.14206 | 1.94727 | (-1.86356, 8.14767) |
| 2023 | 5.90000 | 3.00835 | 1.93628 | (-1.96902, 7.98573) |

Based on the data obtained, a forecast for 2026–2030 was constructed (Table 9). We assume that variable X_4 increases by 10% each year.

Table 9: Confidence analysis of the forecast, 2026-2030

| Obs | Y | prediction | std. error | 95% interval |
|------|-----------|------------|------------|----------------------|
| 2026 | undefined | 3.91086 | 2.01821 | (-1.27711, 9.09883) |
| 2027 | undefined | 4.21170 | 2.04937 | (-1.05639, 9.47978) |
| 2028 | undefined | 4.51253 | 2.08233 | (-0.840265, 9.86533) |
| 2029 | undefined | 4.81337 | 2.11699 | (-0.628527, 10.2553) |
| 2030 | undefined | 5.11420 | 2.15327 | (-0.420962, 10.6494) |

A graph with a forecast for 2026-2030 was also constructed (Figure 2).

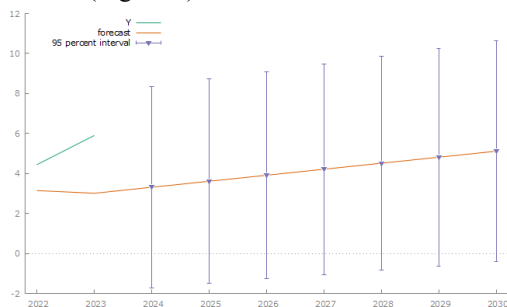


Figure 2: Forecast graph, 2026-2030.

According to forecast Table 9 and Figure 2, an increase in the Y indicator will be observed between 2026 and 2030. However, it will not reach 2023 levels. Therefore, it can be concluded that the share of renewable energy sources in total electricity generation is positively impacted by an increase in the rule of law index. Therefore, Hypothesis 2 is confirmed.

A research gap in this article is the lack of scientific studies devoted to quantifying the impact of legislation, innovation, and political stability on the energy sector in Kazakhstan, particularly on the development of renewable energy sources. The entire process, from the approval of renewable energy projects to their operation, is based on regulatory legal acts (RLA). Since the adoption of the Law “On Support for the Use of Renewable Energy Sources” in 2009 (URL 10), the Government of the Republic of Kazakhstan has regularly amended and supplemented it to improve the institutional and legal framework for the development of renewable energy sources. For example, amendments were introduced in December 2020 to incentivize the construction of generating units with flexible generation modes and to extend the term of renewable energy purchase contracts from 15 to 20 years. Furthermore, in 2017, an auction mechanism was introduced to replace

fixed tariffs for renewable energy. It's worth noting that one of the key indicators of the sector's development – the share of renewable energy in total electricity generation – has been gradually increasing.

The regulatory framework for renewable energy sources in Kazakhstan consists of current legislation and other regulatory legal acts in the electric power and renewable energy sectors, the activities of JSC Kazakhstan Electricity Grid Operating Company (KEGOC), and the activities of the Financial Settlement Center for Renewable Energy Sources LLP (RFC) under the Ministry of Energy of the Republic of Kazakhstan. The RFC centralizes the purchase and sale of electricity generated by renewable energy facilities and supplied to the power grid.

At the same time, the weak diversification of the energy sector increases the vulnerability of the national economy to external and internal threats to energy security. One of the main problems facing the industry in Kazakhstan is the high level of infrastructure depreciation, exceeding 70% (Figure 3).

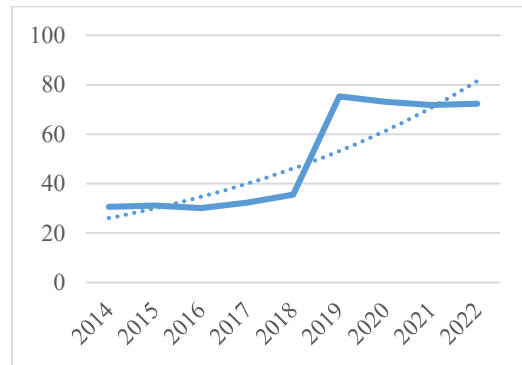


Figure 3: The level of depreciation of fixed assets of the electric power industry in Kazakhstan, with an exponential trend line, %, 2014-2022.

As was shown in Figure 3, the authors added an exponential trend line to reflect the nature of changing trends over time and show the dynamics of changes in values subject to very sharp changes. In this case, the trend line shows an increase over the past nine years.

Significant investment risks include: tenge devaluation; project construction financing in foreign currency, given that it is not always possible to defer payments linked to the launch of electricity production; a long payback period; delays in tariff indexation (the tariff is fixed at the time of the auction and indexed one year after the project launch), etc.

The role of the state in mitigating investment risks is particularly important. Providing state guarantees

to ensure the solvency of renewable energy producers and aligning offtake agreements with international standards could significantly increase Kazakhstan's attractiveness to large international investors, both private and from funds and development banks.

The Law on Supporting Renewable Energy Sources in the Republic of Kazakhstan was passed in 2009, but only subsequent revisions to the legislation between 2013 and 2017 had a significant impact on the development of renewable energy sources in the country. Since 2020, renewable energy projects have been included in the list of priority investment projects and are exempt from property tax, land tax, and corporate income tax (CIT).

In Kazakhstan, the main sponsors of renewable energy projects (in terms of capacity) are currently development banks and foreign investors. The implementation of renewable energy projects directly impacts Kazakhstan's economic growth through increased electricity generation (Smagulova et al., 2024).

The study utilized econometric modeling and forecasting to identify factors influencing the growth of renewable energy generation using Kazakhstan's energy sector as an example.

Through the economic and mathematical modeling, two hypotheses were posed and confirmed. Specifically, Hypothesis 1: The "innovation index" has a negative impact on renewable energy generation. We believe the relationship between the contribution of renewable energy to electricity generation in Kazakhstan (Y) and the "innovation index" can be interpreted as follows: R_{yx2} is equal to -0,853.

Since 2014, our country has been implementing reforms to reduce state participation in the economy in a more active and intensive manner. This has led to approximately 80 percent of energy facilities now being owned by private investors. The lack of investment from private companies limits the potential for implementing new technologies and modernizing energy facilities. It should be noted that the payback period for projects is quite long.

According to Hossain et al. (2023), expensive investment projects and regular underfunding significantly worsen the depreciation of fixed assets in the energy system. Another significant challenge is the ineffective monitoring of energy transmission and storage. Therefore, it is not profitable for private investors to wait and invest heavily in energy infrastructure.

As noted above, Kazakhstan has been experiencing a growing energy deficit in recent years.

This is due to the fact that energy generation rates are lagging behind economic growth.

In this regard, significant emphasis must be placed on the introduction of new technologies and innovations in the energy sector, including renewable energy facilities. For example, the issues of introducing new energy facilities to expand infrastructure, decarbonization, and modernization of old power lines are acute.

The south of the republic boasts significant solar radiation potential, making it a strong candidate for solar generation. At the same time, Kazakhstan has its own resources for wind energy development. For example, several large wind farms are already operational in the Zhambyl and Aktobe regions. Construction of new wind projects has begun as planned in the North and East Kazakhstan regions.

The study noted that power plants and energy facilities are experiencing high levels of depreciation of electrical equipment. The industry-wide average depreciation of fixed assets ranges from 45 to 85 percent. The solution to the energy sector's problems is linked to a lack of investment.

In our opinion, this lack of investment is precisely what led to the "innovation index" (R_{yx2}) having a negative value of -0,853.

Regarding Hypothesis 2, which assumes that the "rule of law index" has a direct positive impact on the share of renewable energy sources. Based on the modeling results, the Rule of Law index (R_{yx4}) is 0,763. This indicator has a significant impact on the rate of electricity generation by renewable energy facilities. We believe the Rule of Law Index has a positive impact for the following reasons:

Kazakhstan Electricity Grid Operating Company (KEGOC) is a major operator of the Kazakhstan Electricity Grid Operating Company and is considered a key operator of the main power grid and general electricity trading within and outside Kazakhstan. KEGOC annually modernizes and repairs its power grids in accordance with approved investment projects. This obviously reduces depreciation. However, these measures are insufficient due to the significant depreciation of equipment throughout the power system.

According to forecasts in the Concept for the Development of the Fuel and Energy Complex of Kazakhstan for 2023–2029, the share of renewable energy generation in total electricity generation will increase to 12,5% in 2029. (By 2025, the share of renewable energy sources is approximately 7%) (URL 11). It is assumed that public investment will be directed toward the construction and

implementation of storage, accumulation, and large-scale maneuverable capacities.

At the same time, it's important to consider that regional energy needs are heterogeneous. For example, transmission capacity needs to be increased in the Southern zone. In the Western zone, integration with the national power grid is essential. Furthermore, transit potential must be expanded through digitalization and the North-South corridor must be expanded to 2,000 MW, taking into account the construction and future production of a new nuclear power plant.

Therefore, in our view, the implementation of investment projects based on state support can justify the high correlation between the Rule of Law index (R_{yx} : 0,763) and renewable energy generation.

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5 CONCLUSIONS

Further development of the industry requires increasing government investment for the following compelling reasons: the urgent need to replace outdated structures, machinery, and equipment; the development of large-scale projects, such as the construction and operation of a nuclear power plant (NPP); increasing the share of renewable energy sources in overall electricity production; and the implementation of digital technologies to maintain the industry's competitiveness.

To achieve these goals, the Government of the Republic of Kazakhstan is improving the institutional and legal framework for renewable energy development. Kazakhstan was one of the first countries in the Central Asian region to introduce an auction mechanism for project selection, which also determines tariffs for renewable energy electricity.

Government support measures for renewable energy are used in various countries (Kılıç and

Kekezoğlu, 2022), where a broad methodology is implemented to stimulate the construction and implementation of renewable energy facilities.

In this study, we conducted an econometric analysis to identify the most significant indicators influencing the increase in the generation of alternative energy sources. Based on the economic research, we propose the following recommendations for stimulating the development of renewable energy in Kazakhstan: organizing the construction of new power generation capacity, as well as energy storage systems; modernizing power grids to reduce transmission losses and improve the country's energy security; Improve the operation of the Centralized Automatic Frequency Control System (WACS) by increasing throughput capacity using synchrophasor technologies and power to minimize emergency situations; enhance the quality of power demand forecasting; implement digital Smart Grid technologies and artificial intelligence through the use of energy drones, energy storage, and the expansion of automated monitoring and control.

Thus, implementing the proposed recommendations will ensure increased electricity production through the commissioning of new renewable energy facilities, sustainable demand, improved personnel skills and the creation of new jobs, a reduction in accidents at power facilities, a reduction in energy dependence on imports, and the reliability of the entire energy system through the use of new digital technologies. As a result, these proposals are fully consistent with the UN's adopted guidelines for achieving the Sustainable Development Goals (SDGs).

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