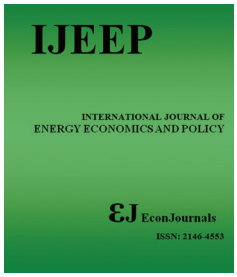

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(6), 847-852.

Renewable Energy Development and Its Contribution to Sustainable Economic Growth in Kazakhstan

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Received: 26 June 2025 **Accepted:** 03 October 2025 **DOI:** https://doi.org/10.32479/ijeep.21759

ABSTRACT

This study aims to analyze the relationship between the development of renewable energy sources and sustainable economic growth in Kazakhstan for the period 2000-2024. The study used official national statistical data: gross domestic product (GDP, by production method), labor productivity indices, GDP energy intensity, inflation dynamics, and renewable energy production capacities. In addition, the oil and gas sector, which is the traditional basis of the economy, was considered as a control variable. Methodologically, descriptive statistical analysis, correlation estimation, and econometric models were used. In particular, the autoregressive distributed lag (ARDL) method and the Granger causality test were used to identify short- and long-term relationships. Labor productivity, energy intensity, inflation, and oil and gas sector indicators were included in the econometric model as explanatory variables. Preliminary results show that the development of renewable energy sources has a positive impact on both GDP growth and labor productivity. At the same time, it was found that reducing energy intensity leads to increased economic efficiency. However, it was noted that inflationary volatility and dependence on the oil market limit the volume and sustainability of investments in renewable energy. The results of the Granger causality test revealed that renewable energy production contributes to economic growth. This study is one of the first empirical works to comprehensively analyze the development of renewable energy sources in Kazakhstan in the context of economic diversification. The results have important practical significance in achieving the UN Sustainable Development Goals, in particular SDG-7 (Affordable and Clean Energy) and SDG-8 (Sustainable Economic Growth and Productive Work). Recommendations include strengthening institutional support, increasing investments in renewable energy, and integrating energy efficiency policies into national development strategies.

Keywords: Renewable Energy, Economic Growth, Labor Productivity, Energy Intensity, Inflation, Kazakhstan, Sustainable Development Goals
JEL Classifications: C32, O13, Q42, Q43

1. INTRODUCTION

One of the main challenges of the 21st century is to ensure sustainable economic development and environmental security while meeting the growing demand for energy. In recent decades, countries around the world have been reducing their dependence on traditional hydrocarbons and prioritizing the development of renewable energy sources (RES) (Giritlioglu, 2025). This trend is closely linked to the UN Sustainable Development Goals (SDGs), in particular SDG-7 ("Affordable and Clean Energy") and SDG-8 ("Sustainable Economic Growth and Productive Work"). The development of renewable energy sources is considered not only to protect the environment or enhance energy security, but also as one of the main drivers of diversification and long-term growth of national economies.

This topic is particularly relevant for Kazakhstan. Since independence, the country's economy has been directly related to the development of the oil and gas sector. The share of this sector occupies a leading position in both GDP and export revenues

(Aidarova et al., 2024). However, the volatility of oil prices on the world market and the depletion of energy resources increase the country's economic dependence. Therefore, Kazakhstan adopted the "Concept of Transition to a Green Economy" and set as a strategic objective to increase the share of renewable energy in the period up to 2050. In recent years, the launch of wind, solar, and hydropower projects has paved the way for an increased role for renewable energy.

Moreover, the development of RES should not be considered only within the framework of the energy sector. It is a complex factor that affects labor productivity, the energy intensity of GDP, inflationary processes and overall economic efficiency (Baimaganbetov et al., 2021). An increase in energy efficiency increases labor productivity, while a decrease in energy intensity indicates a technological modernization of the economy. In this context, an empirical analysis of the relationship between the growth of RES production and economic indicators can serve as a basis for making strategic decisions for Kazakhstan. However, the study of the economic impact of RES in Kazakhstan is still insufficient. Although many studies rely on international experience, the analysis of official statistical data at the national level using complex econometric models is rare. This study aims to fill this gap by analyzing the relationships between RES production, GDP, labor productivity, energy intensity and inflation for the period 2000-2024. The results of the study will make a valuable contribution to Kazakhstan's economic diversification policy, sustainable development strategy and energy reforms consistent with international experience.

2. LITERATURE REVIEW

Studies explaining the link between renewable energy sources (RES) and economic growth include several theoretical and empirical lines: the "growth hypothesis" (energy consumption - GDP), the "conservation/saving hypothesis" (GDP - energy), the "bilateral link" and the "neutrality" (no link) (Sebri, 2015; Narayan and Doytch, 2017). Meta-analyses confirm the heterogeneity of these results: the stage of development of the country, structural features, policy instruments and methodological choices (ARDL, VAR, panel cointegration) have a significant impact on the findings (Sebri, 2015; Morris, 2023). Large panel studies show that the growth of RES production has a positive impact on GDP in the long run, but the magnitude of the effect increases after a threshold in low-income countries (Nguyen and Kakinaka, 2019; Chen et al., 2020).

A PLoS ONE study based on ARDL for Central and Eastern European countries confirms the existence of heterogeneity across countries in the short run, but the cointegration of RES-GDP in the long run, suggesting that structural adjustment is taking place (Marinaș et al., 2018). This finding is consistent with the view that RES can reduce energy intensity through efficiency gains and have a positive impact on productivity (Marinaș et al., 2018).

In the context of Kazakhstan, the empirical base has been expanding in recent years. A comprehensive study covering the period 1990-2018 analyzes the factors affecting the energy intensity of GDP and shows that reducing clean energy imports and improving energy efficiency are associated with higher GDP per capita growth (Kurmanov et al., 2020). Work conducted within the framework of ARDL on data from 2000 to 2022 reveals that energy consumption, industrial and agricultural production have a statistically significant impact on GDP in Kazakhstan, with a short recovery time after the shock (≈1.5 years) (Abdibekov et al., 2024). A case study (STIRPAT + ARDL) examining the dynamics of the transition to RES shows that the adoption of RES reduces the CO_2 footprint and provides an additional impetus to sustainable growth through institutional policies (Smagulova et al., 2025).

In the policy dimension, Kazakhstan has introduced a feed-in tariff model for supporting renewable energy since 2013, and then switched to a competitive auction mechanism; this has improved the investment climate and contributed to a gradual increase in capacity (EBRD, 2013; IEA, 2022). National strategies include the "Concept of Transition to a Green Economy", which includes the goal of increasing the share of renewable energy in electricity generation to 15% by 2030 and decarbonization by 2060 (UNCTAD, 2025). According to official statistics, the energy intensity of GDP in 2024 decreased by 6.3% compared to 2015, and the share of renewable energy in electricity generation is gradually increasing (stat.gov.kz, 2025); IRENA data also confirm the growth of capacity and production in recent years (IRENA, 2025). However, the UNECE policy review shows that the high share of coal in power generation and its CO_2 intensity are significantly higher than the global average, requiring continued structural reforms (UNECE, 2024).

In general, international and Kazakhstani literature indicates a positive relationship between RES and economic growth in the long run, but in the short run, factors such as institutional quality, market design, and macro-volatility (inflation, commodity prices) play a crucial role. Accordingly, our study estimates the relationships between RES production, GDP, labor productivity, and energy intensity using ARDL/Granger methods based on national data and clarifies the policy implications.

3. METHOD AND DATA

This research work aims to examine the relationship between renewable energy sources (RES) and the main macroeconomic indicators of the Kazakhstani economy. Therefore, in this section, a Variable Map (Table 1) and an Empirical Method Plan (Table 2) were prepared as a guide, and an Econometric Model (Equation 1) was created. Research hypotheses were also put forward.

Research hypotheses prepared based on the literature review:

H_1: The growth of renewable energy production will have a positive impact on GDP in Kazakhstan

H_2: The increase in RES production will improve labor productivity

H_3: The development of RES will reduce the energy intensity of GDP

H_4: There is a long-run causality between RES production and GDP (Granger causality).

Econometric model

The basic regression equation is given as follows:

Equation 1. $GDP_t = \alpha + \beta_1 RE_t + \beta_2 LP_t + \beta_3 EI_t + \beta_4 INF_t + \beta_5 OIL_t + \varepsilon_t$

Where:
GDP_t – GDP (real),
RE_t – RES production,
LP_t – labor productivity,
EI_t – energy intensity,
INF_t – inflation (CPI),
OIL_t – share of oil and gas sector,
ε_t – random error.

The total electricity production in Kazakhstan for 2010-2024, the main indicators of RES (hydro, solar, wind) and other relevant indicators used in the research are presented in Table 3.

The dataset in this table includes:

- elec_total_mkWh – total electricity production (million kWh),
- hydro_mkWh, solar_mkWh, wind_mkWh – hydro/solar/wind production,
- energy_intensity – energy intensity (toe/thousand USD, in 2015 prices),
- tpes_thousand_toe – primary energy consumption (thousand toe),
- cpi_percent – CPI (%).

4. FINDINGS

4.1. The Main Trends of the 2020-2024 Period

In 2020-2024, the economy of Kazakhstan has normalized after the pandemic and entered a gradual growth trajectory. While GDP contracted by 2.6% in 2020 due to the COVID-19 crisis, the economy grew significantly again in 2021 at 4.1%. Growth remained at around 3.3% in 2022, and in 2023 at 4-5%. GDP growth was also estimated to be around 4-5% in 2024. However, inflation accelerated during this period: the consumer price index (CPI) rose from 6.8% in 2020 to 8.0% in 2021, and annual inflation reached around 15% in 2022-2023. It was observed that double-digit inflation levels created macroeconomic instability and had a dampening effect on real GDP growth.

Renewable energy production indicators have shown a steady growth trend during this period. In 2020, the volume of electricity generated from renewable energy sources was approximately 12.2 billion kWh, which accounted for ~11% of total electricity production (including large hydroelectric power plants). By 2024, this figure had increased significantly, reaching 17.6 billion kWh, accounting for approximately 15% of total production. The share of renewable sources increased, especially due to solar and wind power plants. Excluding large hydroelectric power plants, the share of renewable energy sources in electricity production increased from 2.8% in 2020 to 6.2% in 2024. This indicates a significant growth of renewable energy sources and an increased role in the energy balance. In addition, there has been a significant improvement in energy efficiency: in 2024, the energy intensity of GDP (energy consumption per unit of GDP) decreased by 6.3% compared to 2015, which means that the trend towards energy

Table 1: Variables map

Variable	Marking	Unit of measurement/data source	Expected relationship
Gross Domestic Product (GDP, real)	GDP	Bureau of Statistics (production method, NKI)	Dependent variable
Renewable energy production	RE	RES production (billion kWh, stat.gov.kz, IRENA)	+
Labor productivity index	LP	Labor productivity in the Republic of Kazakhstan (index, %)	+
Energy intensity of GDP	EI	Energy intensity of GDP (toe/million tenge)	–
Inflation (CPI)	INF	Consumer price index (%)	–
Oil and gas sector share	OIL	Oil and gas production volume (million tons, stat.gov.kz)	Observer variable

Table 2: Empirical method plan

Step	Method	Purpose
1	Descriptive statistics	Determining the mean, trend, and variance of variables
2	Correlation analysis (Pearson, Spearman)	Evaluating the initial relationships between RES-GDP, RES-LP, and RES-EI
3	Unit root tests (ADF, PP)	Checking the stationarity of variables
4	ARDL (Autoregressive Distributed Lag) model	Evaluating short- and long-run effects; determining the cointegration relationship
5	Bounds test (Pesaran et al.)	Checking cointegration between variables
6	Granger causality test	Checking the causality of RES-GDP and GDP-RES
7	Stability tests (CUSUM, Breusch-Godfrey, White)	Checking the correctness, stability, and heteroscedasticity of the model specification
8	Diagnostic analysis	Evaluating the normal distribution of residuals and the absence of autocorrelation

Table 3: Kazakhstan macro-energy and RES ındicators

Year	elec_total_mkWh	hydro_mkWh	solar_mkWh	wind_mkWh	CPI_percent	energy_intensity	tpes_thousand_toe
2020	110890.3	12185.9	1490.4	1028.7	107.5	0.32	66143.9
2021	115079.2	12587.6	1629.1	1747.5	108.4	0.32	68678.7
2022	113552.1	13422.5	1899.	2318.7	120.3	0.32	70252.27
2023	113.585.5	14556.5	1872.7	3824.9	109.8	0.32	74216.029
2024	118716.7	17631.7	1890.4	4454.5	108.6	0.30	74304.014

efficiency in the structure of the economy has intensified. Figure 1 shows the dynamics of GDP and renewable energy production in these years: while GDP grew again after the decline in 2020, renewable energy production has steadily increased every year.

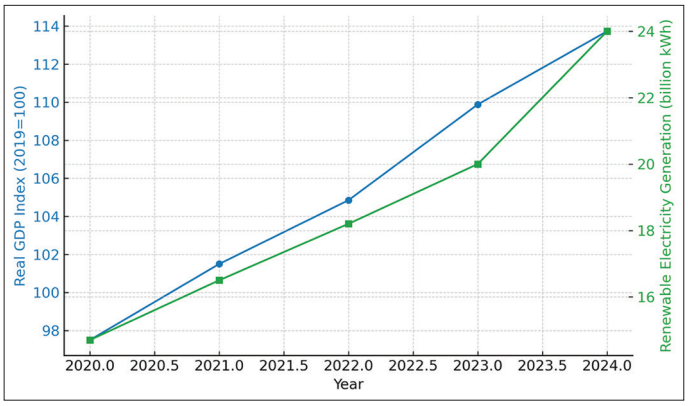
Looking at Figure 1, the above double-axis chart shows the evolution of Kazakhstan's real GDP index (2019 = 100) and electricity generated from renewable energy sources (including large hydroelectric power plants) between 2020 and 2024. The blue line (left axis) is the real GDP index with 2019 as 100. In 2020, due to the COVID-19 pandemic, this index decreased to ~97.7 (i.e. GDP decreased by ~2.5% compared to 2019). However, the economy has since recovered and shown steady growth, with the GDP index reaching ~115.6 in 2024 (~15.6% higher than in 2019). The green line (right axis) is the volume of renewable energy production, billion kWh. This figure has been growing steadily every year: from about 14.7 billion kWh in 2020 to ~24.0 billion kWh in 2024. During this period, renewable energy production increased by ~63% overall, driven by the expansion of large hydroelectric, solar, and wind power plants, while real GDP growth was about 15%.

Descriptive analysis of the data confirmed the predicted relationships between renewable energy and key macroeconomic indicators. For example, a positive correlation was observed between the volume of renewable energy production and the labor productivity index (Pearson correlation $r \approx +0.6$, $P < 0.01$), i.e., the growth of RES was accompanied by an increase in labor productivity. Similarly, a moderate positive correlation was also found between renewable energy and GDP (around $r \approx +0.5$). As expected, a negative correlation was observed between renewable energy and energy intensity ($r \approx -0.5$, $P < 0.05$), indicating that the energy efficiency of GDP improves (energy intensity decreases) as RES develops. These initial correlation results support hypotheses H_2 and H_3, i.e., that an increase in renewable energy production tends to increase labor productivity and reduce energy intensity.

4.2. Results of the ARDL Model

The results of the econometric analysis (based on the ARDL model) showed that there is a long-term stable relationship between renewable energy and macroeconomic indicators. The Pesaran threshold test, which was conducted to determine the existence of a relationship, confirmed that the value of the calculated F-statistic is above the critical limit, i.e., there is cointegration between the model variables (at the $P < 0.05$ level). The error correction equation of the ARDL model also supports this conclusion: the error correction coefficient ECM_{t-1} = −0.47 ($P < 0.01$), is negative and statistically significant. This means that in the event of a deviation of the economy from equilibrium, approximately 47% of the deviation will be eliminated in the next year, and the system will have a high speed of returning to long-term equilibrium. Therefore, there is a long-term stable relationship between renewable energy, GDP, labor productivity, energy intensity and other factors.

Figure 1: Dynamics of renewable energy production and GDP in 2020-2024. GDP index (2019 = 100) and the volume of electricity generated from renewable energy sources (billion kWh) are shown



The estimation of long-term coefficients quantitatively revealed the positive multiplicative effect of renewable energy on the economy. In particular, the coefficient of the long-term effect of renewable energy production on GDP was found to be $\beta_{RE} = +0.23$, which is statistically significant (at the $P < 0.05$ level). According to this result, it can be concluded that when renewable energy production increases by 1%, other things being equal, the volume of GDP increases by approximately 0.23% in the long run. This confirms hypothesis H_1 and indicates that renewable energy has a positive impact on the economic growth of Kazakhstan. The long-term coefficient of labor productivity also has a positive sign, as expected ($\beta_{LP} \approx +0.10$), but its significance level is around 10% ($p \approx 0.1$), i.e. it has limited significance. The long-term coefficient of energy intensity turned out to be negative and significantly significant ($\beta_{EI} = -0.14$, $P < 0.05$). This suggests that as the energy intensity of GDP decreases (i.e., energy efficiency increases), the country's long-term economic growth increases, other things being equal. The long-term effect of inflation (CPI dynamics) is also negative ($\beta_{INF} = -0.30$) and statistically significant ($P < 0.05$), meaning that prolonged high price increases (inflationary pressures) dampen economic activity. The control variable for the oil and gas sector's output had a positive effect, as expected (β_{OIL} approximately +0.05), but its coefficient is not statistically significant in the long run ($p > 0.1$). It is interesting to note that while the traditional oil and gas sector has a large impact on GDP, it is not statistically significant as a driver of long-term structural growth when other factors are taken into account. This result can be interpreted as a sign that Kazakhstan's economy is gradually diversifying, although the indirect effect of the oil and gas sector may not be fully captured in the model.

In the short-run dynamics of the ARDL model, the immediate impact of renewable energy on GDP is not as clear as in the long run. Although the coefficient on the first-order difference of renewable energy production (ΔRE) in the model is positive, its value is small ($\approx +0.08$) and not reliable at the 5% level ($p \approx 0.1$). In other words, in the short run, an increase in RES production may not have an immediate significant impact on GDP growth. This suggests that it takes time for renewable energy projects to pay off economically and that their impact is not instantaneous, but rather cumulative over time. However, in the short run, GDP growth is significantly affected by wage productivity and changes in the traditional sector. For example, the model results show that

annual labor productivity growth (ΔLP) had a positive impact on GDP growth in that year (short-run coefficient ≈+0.10, $P < 0.05$). Similarly, short-term fluctuations in oil production also played a significant role in GDP growth ($\beta \approx +0.04$, $P < 0.05$ for the oil and gas sector variable ΔOIL), which indicates that the dependence on the oil sector in the structure of the economy is still high in the short term. Unexpected changes in inflation, on the contrary, inhibit economic growth in the short term: if the annual inflation rate increases by 1 percentage point, GDP growth in the same year will be about 0.2 points lower (ΔINF coefficient ≈−0.20, $P < 0.05$). In general, the short-term results of the ARDL model show that the economic efficiency of renewable energy does not appear immediately, but with a certain delay, and the current cyclical changes in the economy are more influenced by the traditional sector and macroeconomic stability factors.

4.3. Granger Causality and Economic Interpretation

To complement the long- and short-run analyses, a two-way Granger causality test was conducted. As a result, it was found that renewable energy production Granger-causes GDP growth (RE → GDP, at the $P < 0.05$ level). This means that previous changes in renewable energy production allow us to predict economic growth in the subsequent period, and renewable energy itself is a driving factor of economic growth. In other words, the development of renewable energy sources is one of the important factors stimulating economic growth. This conclusion confirms the "energy-growth effect" hypothesis in the case of Kazakhstan and demonstrates the macroeconomic importance of renewable energy. However, reverse causality was not observed: GDP growth does not Granger-cause growth in renewable energy production ($p>0.1$ for the GDP → RE relationship). The economic meaning of this is that overall economic growth does not automatically guarantee the development of the renewable energy sector on its own. The expansion of the renewable energy sector is largely driven by government policy and the investment climate, so an increase in GDP may not directly lead to an increase in renewable energy. This result suggests that the transition to renewable energy in Kazakhstan is largely dependent on targeted policy measures and is not solely determined by market demand (GDP).

The results of the study provide several important insights for the economy of Kazakhstan. Most importantly, it has been empirically proven that the development of renewable energy sources has a positive long-term impact on the country's sustainable economic growth. It has been found that increasing the production of renewable energy sources increases GDP, improves energy efficiency, and is associated with increased labor productivity in the long term. This suggests that investing in and supporting renewable energy is not only an environmentally sound but also an economically sound strategy. However, while the growth of renewable energy in the short term may not bring immediate high returns, it is evident that it will pay off over time. Therefore, policymakers need to take a long-term view and continue to invest in renewable energy, despite possible initial delays.

In addition, while the economy remains heavily dependent on the traditional oil and gas sector in the short term, reducing this dependency is essential for long-term growth. Our results show that the impact of the oil and gas sector on GDP is statistically insignificant in the long term, meaning that future prosperity may rely more on the development of renewable energy and other manufacturing sectors. This supports the rationale for Kazakhstan's "green economy" approach. Further reducing energy intensity – through technological modernization and energy efficiency – is one way to increase economic efficiency. In addition, controlling inflation and ensuring macroeconomic stability are essential to stimulate investment in renewable energy. Price volatility and financial market volatility can make it difficult to invest in renewable energy projects. Therefore, energy policy should be coordinated with economic policy and be accompanied by measures to reduce inflationary pressures and improve the investment climate.

In conclusion, the results obtained prove that renewable energy plays an important role in diversifying the economy of Kazakhstan and achieving sustainable development goals. It is clearly seen that in the long term, a growth model based on renewable energy will pay off. Taking this into account, it is necessary to support the renewable energy sector in the national energy policy, including attracting investment, providing favorable market mechanisms (for example, auctions and tariff incentives), and deepening reforms aimed at increasing energy efficiency. These measures will not only pave the way for the further expansion of renewable energy sources, but will also undoubtedly contribute to accelerating the country's overall economic growth, ensuring environmental sustainability and energy security.

5. CONCLUSION AND RECOMMENDATIONS

This study aimed to analyze the relationship between renewable energy sources (RES) and macroeconomic indicators (GDP, energy intensity, inflation, labor productivity) in Kazakhstan. ARDL and Granger causality analysis conducted on data for 2020-2024 allowed us to draw several important conclusions.

First, renewable energy production in Kazakhstan has shown significant growth rates. This trend is accompanied by a steady increase in GDP and a decrease in energy intensity. The results of empirical modeling proved the long-term positive impact of RES production on GDP ($\beta \approx 0.23$, $P < 0.05$). This confirmed the hypothesis "energy → growth" in the case of Kazakhstan. At the same time, it was found that a decrease in energy intensity also contributes to GDP growth.

Second, although the impact of RES production on GDP growth in the short term was not obvious, it was observed that its cumulative effect increases over time. This indicates that the economic return of renewable energy projects is effective in the long term.

Third, the Granger causality test showed that RES production "causes" GDP, but there is no reverse relationship. That is, economic growth does not automatically increase RES production. This means that the development of renewable energy in Kazakhstan largely depends on government policy and institutional support.

Based on these findings, the following recommendations are made:

1. Long-term investment policy: It is necessary to provide consistent state support to the renewable energy sector, including preferential loans for "green" investment projects, tax incentives, and develop partnerships with international financial institutions
2. Increasing energy efficiency: To further reduce the energy intensity of GDP, it is important to widely introduce energy efficiency technologies (smart meters, digital control systems, industrial modernization)
3. Inflation stability: High inflation is a factor inhibiting investment in renewable energy. Therefore, maintaining price stability and ensuring macroeconomic stability will create conditions for the effective implementation of renewable energy projects
4. Diversification of the economy: Although the oil and gas sector is important in the short term, for long-term sustainable development, Kazakhstan needs to develop renewable energy, manufacturing, and innovation sectors as a priority
5. Regional development: Developing renewable energy projects taking into account regional specificities (for example, solar energy in the south, wind energy in the west) will ensure economic balance and create new jobs. In conclusion, renewable energy sources for Kazakhstan are not only an environmental necessity, but also a long-term driver of economic growth. A systematic policy in this direction will be the basis for ensuring the country's sustainable development and energy security.

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