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Econometric Models for Assessing the Relationship Between Regional Energy Security and Economic Growth (The Case of Kashkadarya Region)

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Abstract: This article examines the relationship between regional energy security and economic growth using the Kashkadarya region of Uzbekistan as a case study. Based on official statistical indicators on electricity generation, industrial energy consumption, and gross regional product, together with a review of the relevant econometric literature, the article substantiates a multifactor regression model linking regional economic growth with energy-security indicators such as generation capacity, supply reliability, and the share of renewable sources. The analysis shows that Kashkadarya region, as one of the country's leading electricity-generating regions, occupies a strategically important place in ensuring national energy security, while at the same time facing structural risks associated with an aging generation base and uneven diversification.

Keywords: Energy Security, Econometric Model, Economic Growth, Regional Economy, Electricity Generation, Renewable Energy Sources, Energy Efficiency, Regression Analysis, Forecasting, Kashkadarya Region

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1. Introduction

Ensuring a reliable and stable supply of energy resources is one of the fundamental conditions for the sustainable economic development of any region. Energy security understood as the uninterrupted physical availability of energy resources at an affordable price is directly linked to industrial output, investment attractiveness, and the living standards of the population [1]. Although a range of definitions and measurement frameworks for energy security has been proposed in the literature, most converge on the core dimensions of availability, affordability, reliability and sustainability of energy supply [2], [3]. In Uzbekistan, the strategic importance of the energy sector is reflected in a number of state programs, including the presidential resolution on improving the efficiency of reforms aimed at transitioning to a “green” economy by 2030 and the “Solar Household” program supporting the installation of household solar panels.

Kashkadarya region occupies a special place in the country's energy system: according to the National Statistics Committee, the region accounts for approximately 19.0 percent of the electricity generated nationwide, ranking among the leading regions together with Tashkent, Syrdarya, and Navoi regions [4]. The region hosts several large energy-intensive industrial complexes including the Shurtan Gas-Chemical Complex, the Mubarek Gas Processing Plant, and Uzbekistan GTL whose stable operation depends directly on the reliability of the regional energy supply. At the same time, statistics show

that during periods of peak summer demand, temporary supply restrictions have been introduced in several districts of the region, including Kokdala and Chirakchi, in order to prevent major accidents on overloaded networks [5]. This illustrates that, despite its leading position in generation, the region's energy system remains exposed to structural risks associated with rising consumption and an aging technical base.

At the same time, the region is gradually diversifying its energy mix: in the third quarter of 2025, households in Kashkadarya region received one of the largest volumes of subsidy payments nationwide for electricity supplied to the grid from rooftop solar installations, reflecting growing household-level investment in renewable generation [6]. The relevance of this study lies in the fact that, given this combination of leading generation capacity, rising demand, and gradual renewable diversification, an econometric assessment of the relationship between energy-security indicators and regional economic growth can provide a scientifically grounded basis for regional energy and investment policy.

The issues of energy security and energy efficiency in Uzbekistan have been addressed by a number of researchers. H. A. Ismoilov and D. S. Tojimirzayev examined the prospects for the use of alternative energy sources in Uzbekistan, showing that the broad application of renewable energy corresponds to the country's priority objectives and energy-security tasks, and that substantial work has been undertaken on developing hydropower potential [7]. S. Mamasoliyev applied an econometric ARIMA model to forecast long-term energy consumption in Uzbekistan based on data for 1985–2023, employing the Box–Jenkins methodology to identify the optimal model specification; the study found that an ARIMA(0,1,3) model provided the most accurate forecast, with an average forecasting error of 7.2 percent, and concluded that ARIMA-based forecasting is an effective tool for long-term tactical decision-making in the energy sector [8]. The Box–Jenkins approach on which such models rest remains the standard methodology for univariate time-series forecasting [9].

A. Tokhtashev and co-authors conducted an econometric analysis of the relationship between household income and demand for consumer goods, including the evaluation of per-capita energy consumption; using correlation analysis and elasticity coefficients, they assessed how a one-percent change in household income is associated with a corresponding change in electricity consumption, providing a methodological basis for linking household-welfare indicators with energy-sector variables [10]. These local contributions are embedded in a large international literature on the energy–growth nexus. The empirical study of the relationship between energy use and output originates with the work of Kraft and Kraft [11], and subsequent surveys have systematized the diverse and sometimes conflicting findings on the direction of causality between energy consumption and economic growth [12], [13]. At a more fundamental level, Stern emphasizes that energy is a critical factor of production whose availability and quality shape long-run growth [14]. Taken together, these studies confirm that econometric and time-series methods are increasingly applied to Uzbekistan's energy sector; however, the specific relationship between regional energy-security indicators and regional economic growth — particularly for major energy-producing regions such as Kashkadarya — remains an insufficiently developed area of research, which defines the scholarly niche addressed in this study.

2. Materials and Method

This study employs comparative analysis and correlation-regression (econometric) modeling approaches to examine the relationship between energy security and economic growth in Kashkadarya region. The empirical basis of the study consists of indicators on electricity generation, industrial energy consumption, gross regional product, and renewable-energy capacity published by the National Statistics Committee of the Republic

of Uzbekistan, the Ministry of Energy, and the Kashkadarya regional statistics department for the period 2015–2025. The energy-security indicators used as explanatory variables follow the availability, reliability and sustainability dimensions established in the energy-security measurement literature [15], [16].

Within this methodology, a multifactor econometric model is formulated in which the growth rate of gross regional product is treated as the dependent variable, while a set of energy-security indicators is treated as explanatory variables. The general form of the proposed regression model is as follows:

$$GRPt = \beta_0 + \beta_1 \bullet GENT + \beta_2 \bullet RELt + \beta_3 \bullet RENT + \beta_4 \bullet INVt + \beta_5 \bullet LOSSt + \varepsilon t$$

where GRPt denotes the growth rate of the region's gross regional product in year t ; GENT is the volume of electricity generation in the region; RELt is an indicator of energy-supply reliability (share of uninterrupted supply time, or inverse of outage frequency); RENT is the share of renewable sources in total regional electricity generation; INVt is the volume of investment directed toward the energy sector, including generation and grid modernization; LOSSt is the level of technical losses in transmission and distribution networks; β_0 is the constant term; β_1 – β_5 are the regression coefficients to be estimated; and εt is the random error term. This specification allows, once a sufficient regional time series has been compiled, for the empirical estimation of the contribution of each energy-security dimension to regional economic growth and for identifying which policy levers offer the greatest expected effect.

3. Results and Discussion

The analysis of statistical indicators shows that Kashkadarya region plays a structurally important role in the country's energy balance, generating close to one-fifth of national electricity output and hosting several of the largest industrial energy consumers in Uzbekistan. This concentration of generation and heavy industry creates a mutually reinforcing relationship: reliable energy supply sustains industrial growth, while industrial and demographic growth in turn increases the region's own electricity demand, occasionally straining network capacity during peak periods, as illustrated by the temporary supply restrictions recorded in several districts of the region during the record summer demand of July 2026 [5].

Applying the proposed econometric model to the regional context makes it possible to identify a set of factors that either strengthen or constrain regional energy security and, through it, economic growth. These factors are summarized in Table 1.

Table 1. Factors influencing energy security in Kashkadarya region

Strengthening factors	Constraining factors
The region generates a large share of the country's electricity (about 19 percent), giving it a strong industrial energy base	A high share of generation still depends on large gas-fired thermal power plants sensitive to gas-supply fluctuations
Major industrial energy consumers (Shurtan Gas-Chemical Complex, Mubarek Gas Processing Plant, Uzbekistan GTL) provide a stable base load and investment interest	Peak-season demand growth has led to temporary supply restrictions in several districts during periods of extreme heat
Growing installed capacity of solar photovoltaic systems and rising household subsidy uptake diversify the regional energy mix	The share of renewable sources in total regional generation remains modest relative to national averages
State programs such as the "Solar Household" initiative and the green-economy strategy support investment in renewables	Limited use of econometric forecasting and monitoring tools in regional energy planning and load management

Digitalization of energy accounting (smart metering, digital energy-control systems) is expanding	Ageing generation and transmission infrastructure raises technical losses and vulnerability to supply disruptions
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The analysis shows that the region's strengthening factors are primarily linked to its large-scale generation capacity, its major industrial energy consumers, and growing investment in renewable and digital solutions, while the constraining factors are concentrated around infrastructure ageing, peak-load vulnerability, and the still-limited application of quantitative forecasting tools in regional energy planning. These constraints correspond closely to the reliability and sustainability dimensions emphasized in the energy-security literature [3][15].

From the standpoint of the proposed regression model, the expected direction of relationships can be substantiated theoretically: an increase in generation volume (GEN) and supply reliability (REL) is expected to have a positive effect on regional economic growth (GRP), since both directly support uninterrupted industrial operation, consistent with the view that energy availability is a critical input to output [14]; growth in the share of renewable sources (REN) is expected to strengthen long-term energy security by reducing dependence on gas-fired generation; increased investment (INV) is expected to expand and modernize generation and grid capacity; while a higher level of technical losses (LOSS) is expected to have a negative effect on regional growth, reflecting inefficiencies in the energy-supply chain. The mixed international evidence on the energy-growth nexus [12], [13] underscores that the sign and strength of these relationships are ultimately empirical questions; once the corresponding regional time-series data are compiled in full, this specification provides a basis for empirically estimating the elasticity of regional economic growth with respect to each of these energy-security factors.

5. Conclusion

The results of the study show that energy security is closely and structurally linked to economic growth in Kashkadarya region, given the region's leading position in national electricity generation and its concentration of large energy-intensive industrial enterprises. Although the region's generation base is substantial and renewable-energy investment is growing, the reliability of supply during peak-demand periods and the pace of infrastructure modernization remain the main factors constraining the region's full economic potential. The multifactor regression specification proposed in this study, complemented by ARIMA-type forecasting of generation and consumption, provides a scientifically grounded, quantitative framework through which the relationship between regional energy-security indicators and economic growth can be monitored, estimated, and integrated into regional economic-development planning.

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