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Mathematical Modeling and Forecasting of the Supply of Electricity to the National Economy of the Country

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Abstract: The national economy of the country is inextricably linked to the supply of electricity. The use of mathematical modeling and forecasting in the power supply system of the national economy allows for more effective planning of energy development, reduction of losses and optimization of energy consumption. The introduction of modern methods of data analysis helps to increase the accuracy of forecasts and the stability of the country's energy system. This article, based on the indicators of the dynamics of the volume of electricity supply in the Republic of Uzbekistan for 2010-2023, mathematical models for these periods and for the periods from 2010 to 2017 and beyond are developed. Forecast indicators for the period from 2024 to 2030 are determined. The dynamics of growth in the volume of electricity supply during the period under study are also analyzed.

1 INTRODUCTION

The stable and balanced development of the country's economy is closely related to the supply of electricity, which plays a decisive role in ensuring the reliable operation of the power grid system, increasing industrial potential in various sectors and regions of the economy, stimulating entrepreneurship, raising the standard of living of the population, and improving the quality of life of citizens.

Within the framework of the development strategy adopted in Uzbekistan to accelerate the development of the national economy and achieve high economic growth rates, systematic measures are being taken to increase energy efficiency by 20 percent and reduce harmful gases emitted into the atmosphere by 20 percent by 2026 through the widespread introduction of "green economy" technologies in all sectors.

Solving these problems requires structural reforms, modernization and diversification of key sectors, introduction of energy-efficient technologies, expansion of the use of renewable energy sources, and increase in labor productivity.

To ensure the implementation of the above-mentioned tasks, large-scale reforms have been implemented in the country since 2017. From this point of view, it is advisable to separately analyze the economic transformations carried out in the Republic of Uzbekistan for the periods before and after 2017.

The article Babkin, A., Alekseeva, N., Tashenova, L., Ochilov, A. defines and describes possible methods of digital transformation of an innovative-active industrial cluster, as well as possible results of digital transformation of an innovative-active industrial cluster and their relationship with methods of digital transformation.

Electricity supply in regions and countries of the world, indicators and analytical materials based on them are presented in https://www.eeseaec.org/ees-eaec--mirovaya-energetika (2025).

The article Abramov V., Abramov I., Putilov A. (2023) is devoted to the analysis of the economic growth rates of the world's leading countries in the context of sustainable development in energy units for 1990–2019 and the assessment of the impact of the energy consumption factor on GDP growth. Based on data from 16 countries, whose GDP accounts for at least 75% of the world, the indicators of total energy consumption and standardised power of electricity consumption are analyzed, and

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significant differences in the economic development of countries in terms of energy balance are shown.

The article Mutolapov R. (2023) “analyses statistical data on electricity consumption in various regions of Russia for the period from 1990 to 2020. The primary focus of the study is on the dynamics of changes in this indicator and per capita energy consumption. The analysis reveals the interrelationships between socio-economic conditions in the country, population movement by region, and energy consumption trends. The main conclusion of the study is that interregional differences in per capita electricity consumption have increased sharply in recent decades. This indicates an increase in socio-economic disparities in the regions of Russia. To achieve the project objectives, tabular and graphical methods of processing statistical data, as well as general scientific analytical and synthetic approaches, were used. The results of the study can be used to assess the socio-economic development of regions, determine strategies for the formation of electricity generation and transmission infrastructure. The data obtained is an important and relevant source for studying the problems of electricity use and serves as a basis for further research.”

The article by Arkhipov R., Katyshev P. (2016) studied the problem of cointegration of some macro-indicators of the Russian economy (gross domestic product, money supply, consolidated budget expenditures, real effective exchange rate) and electricity production. It was assumed that in the period under consideration (1999-2015) an endogenous structural shift occurred, as a result of which the cointegration relations could change. The presence of cointegration of the time series under consideration was determined and the moment of the structural shift was estimated. In the article

TheGlobalEconomy.com (2025) provides business and economic data for 200 countries worldwide, including Uzbekistan GDP per unit of energy.

TheGlobalEconomy.com provides researchers, academics, investors, and others with reliable economic data on foreign countries. The data includes over 500 indicators for over 200 countries, covering the period from 1960 to the present. It includes sources and methods from central banks, national statistical institutes, and many international organizations.

This database also provides data for Uzbekistan on GDP per unit of energy for the years 1990-2013. During this period, Uzbekistan's GDP per kilogram of oil equivalent averaged $1.95, while its GDP per kilogram of oil equivalent was at its lowest in 1994 and its GDP per kilogram of oil equivalent peaked at $4.44 in 2013. For comparison, the global average for 133 countries in 2013 was US$10.05 GDP per kilogram of oil equivalent. Global rankings for this indicator are available at: https://ru.theglobaleconomy.com/rankings/GDP_per_unit_of_energy/.

The article Fayziev R., Kurbanov F. (2021, 2022) and Fayziev R., Kurbanov F. Mirzoev A. (2024) analyse the level of electricity supply in the Republic of Uzbekistan in 2005-2020 up to 2017 and beyond, and provide recommendations for achieving the goals set out in the “Concept of Electricity Supply of the Republic of Uzbekistan in 2020-2030”. Below, the level of electricity supply in the Republic of Uzbekistan in 2010-2023 is analyzed, and forecast values for 2024-2030 are determined.

2 RESEARCH METHODOLOGY

In conducting this study, methods widely used in scientific research methodology were effectively used, including analysis and synthesis, systematic analysis, comparison, comparative and comparative analysis, time series analysis, and trend modeling and forecasting methods.

3 ANALYSIS AND RESULTS

The dynamics of electricity supply in the Republic of Uzbekistan for 2010-2023 are shown in Figure 1.

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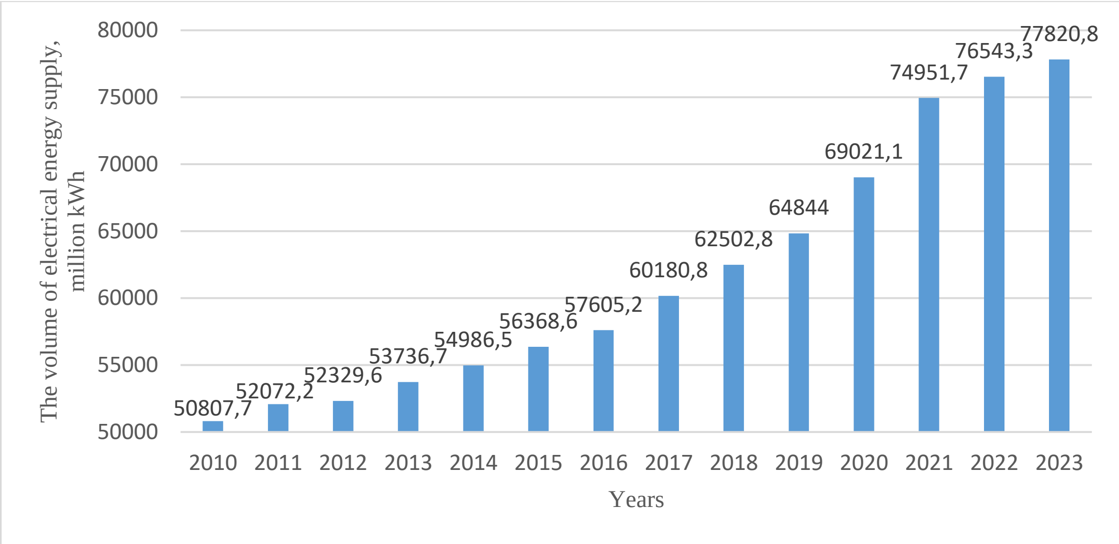

Figure 1: Indicators of the dynamics of electricity supply in the Republic of Uzbekistan in 2010-2023. Source: Author's work based on data from the Statistical Agency under the President of the Republic of Uzbekistan (https://stat.uz/en/official-statistics/industry).

In it, the volume of electricity supply has an increasing character, and the graph and function based on it look like in Figure 2. Its mathematical model is expressed as (1).

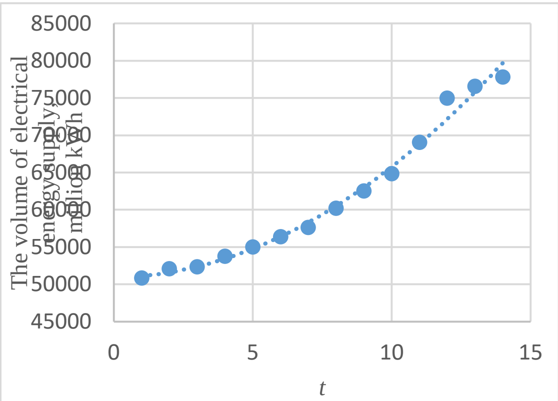

Figure 2: Mathematical modeling of the volume of electricity supply in the Republic of Uzbekistan for 2010-2023.

$.y = 142.85t\ 2 + 57.747x + 50908$, $R^2 = 0.988$. (1).

The value of this mathematical model's fit to the data is $R^2 = 0.988$, which indicates that the mathematical model has a very high level of reliability.

If we analyze these indicators separately for the periods up to and after 2017, we obtain the following graphs and models.

$$y = 1130.1t + 49466, \quad R^2 = 0.9838. \quad (2)$$

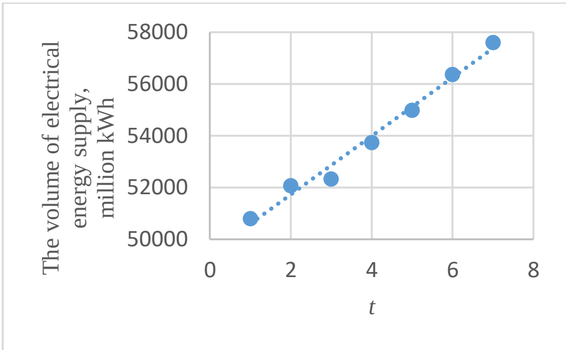

Figure 3: Mathematical modeling of the volume of electricity supply in the Republic of Uzbekistan in 2010-2016.

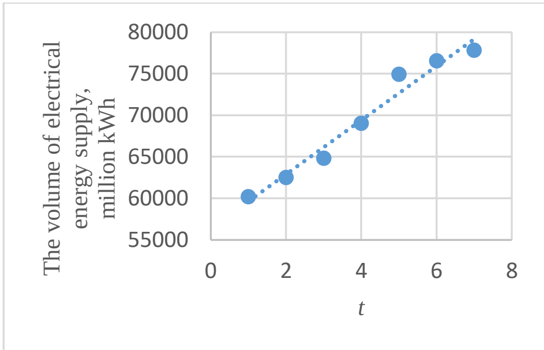

Figure 4: Mathematical modeling of the volume of electricity supply in the Republic of Uzbekistan for 2017-2023.

$$y = 3253.9t + 56394, \quad R^2 = 0.9681. \quad (3)$$

Table 1 provides an analysis of the dynamics of growth in electricity supply.

Table 1: Analysis of the dynamics of electricity supply growth in 2010-2016.

Year	Electricity generation volume (million kWh)	Absolute incremental growth		Relative additional growth		Growth rate	
		Basic	Chained	Basic	Chained	Basic	Chained
2010	50807.7						
2011	52072.2	1264.5	1264.5	102.49	102.49	2.49	2.49
2012	52329.6	1521.9	257.4	103.00	100.49	3.00	0.49
2013	53736.7	2929	1407.1	105.76	102.69	5.76	2.69
2014	54986.5	4178.8	1249.8	108.22	102.33	8.22	2.33
2015	56368.6	5560.9	1382.1	110.94	102.51	10.94	2.51
2016	57605.2	6797.5	1236.6	113.38	102.19	13.38	2.19

Based on the data in Table 1, the following can be determined:

In 2016, the absolute a

dditional growth in base case (compared to 2010) was 6797.5 million kWh, and the chain-wise absolute additional growth (compared to the previous year) was 1236.6 million kWh.

In 2016, the base (compared to 2010) relative additional growth was 113.38%, and the chain-linked (compared to the previous year) relative additional growth was 102.19%.

In 2016, the base growth rate (compared to 2010) was 13.38%, and the chain-linked growth rate (compared to the previous year) was 2.19%.

Table 2: Analysis of the dynamics of electricity supply growth in 2016-2023.

Year	Electricity generation volume (million kWh)	Absolute incremental growth		Relative additional growth		Growth rate	
		Basic	Chained	Basic	Chained	Basic	Chained
2017	60180.8						
2018	62502.8	2322	2322	103.86	103.86	3.86	3.86
2019	64844	4663.2	2341.2	107.75	103.75	7.75	3.75
2020	69021.1	8840.3	4177.1	114.69	106.44	14.69	6.44
2021	74951.7	14770.9	5930.6	124.54	108.59	24.54	8.59
2022	76543.3	16362.5	1591.6	127.19	102.12	27.19	2.12
2034	77820.8	17640	1277.5	129.31	101.67	29.31	1.67

Based on the data in Table 2, the following can be determined:

In 2023, the absolute additional growth in base case (compared to 2016) was 17,640 million kWh, and the chain-based absolute additional growth (compared to the previous year) was 1,277.5 million kWh.

In 2023, the base (compared to 2016) relative additional growth was 129.31%, and the chain-linked (compared to the previous year) relative additional growth was 101.67%.

The base growth rate (compared to 2016) in 2023 was 29.31%, and the chain-linked growth rate (compared to the previous year) was 1.67%.

Table 3: Analysis of the dynamics of electricity supply growth in 2010-2023.

Year	Electricity generation volume (million kWh)	Absolute incremental growth		Relative additional growth		Growth rate	
		Basic	Chained	Basic	Chained	Basic	Chained
2010	50807.7						
2011	52072.2	1264.5	1264.5	102.49	102.49	2.49	2.49
2012	52329.6	1521.9	257.4	103.00	100.49	3.00	0.49
2013	53736.7	2929	1407.1	105.76	102.69	5.76	2.69
2014	54986.5	4178.8	1249.8	108.22	102.33	8.22	2.33
2015	56368.6	5560.9	1382.1	110.94	102.51	10.94	2.51
2016	57605.2	6797.5	1236.6	113.38	102.19	13.38	2.19

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2017	60180.8	9373.1	2575.6	118.45	104.47	18.45	4.47
2018	62502.8	11695.1	2322	123.02	103.86	23.02	3.86
2019	64844	14036.3	2341.2	127.63	103.75	27.63	3.75
2020	69021.1	18213.4	4177.1	135.85	106.44	35.85	6.44
2021	74951.7	24144	5930.6	147.52	108.59	47.52	8.59
2022	76543.3	25735.6	1591.6	150.65	102.12	50.65	2.12
2023	77820.8	27013.1	1277.5	153.17	101.67	53.17	1.67

Based on the data in Table 3, the following can be determined:

In 2023, the absolute additional growth in the base case (compared to 2010) was 1277.5 million kWh, and the chain-based (compared to the previous year) absolute additional growth was 3736.1 million kWh.

In 2023, the base (compared to 2010) relative additional growth was 153.17%, and the chain-linked (compared to the previous year) relative additional growth was 101.67%.

In 2023, the base growth rate (compared to 2010) was 53.17%, and the chain-linked growth rate (compared to the previous year) was 1.67%.

From Tables 1-3, it can be seen that the growth rate in 2016 compared to 2010 was 13.38%, and in 2023 the growth rate compared to 2016 was 29.31%, and compared to 2010 it was 53.17%, that is, significant growth was achieved after 2017.

The forecast indicators and mathematical model of the volume of electricity supply in the Republic of Uzbekistan for 2024-2030, calculated using model (1), are presented in Figure 5, and the forecast indicators and mathematical model calculated using model (3) are presented in Figure 6, and their mathematical models are expressed as (4) and (5).

$$y = 5200.3t + 78001, \quad (4)$$

$$y = 3253.9t + 101949. \quad (5)$$

It can be seen from Figure 5 that (1) The forecast indicator calculated by the model is 115.1 billion kWh in 2030 and can be expressed by model (4).

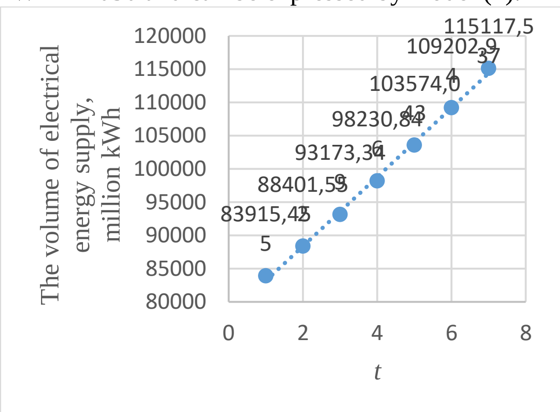

Figure 5: Forecast indicators and mathematical model of the volume of electricity supply in the Republic of Uzbekistan for 2024-2030, calculated using model (1).

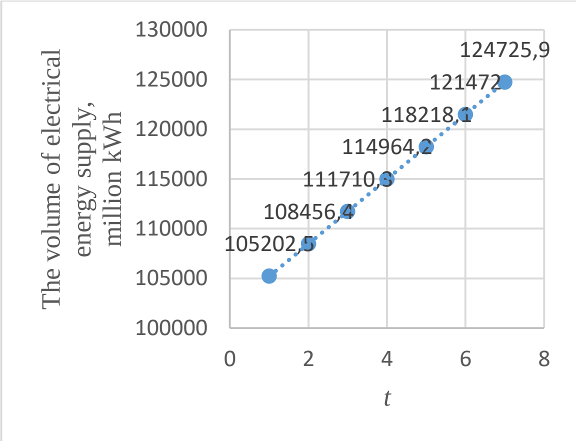

Figure 6: Forecast indicators and mathematical model of the volume of electricity supply in the Republic of Uzbekistan for 2024-2030, calculated using model (3).

It can be seen from Figure 6 that (3) The forecast indicator calculated by the model is 124.7 billion kWh in 2030 and can be expressed by model (4).

As can be seen from pictures 5-6 (1) If the forecast indicator calculated by the model is 115.1 billion kWh in 2030, (3) When calculated with the model, it amounts to 124.7 billion kWh.

It can be concluded that if electricity supply is implemented through model (5), it will be possible to increase the goal set in the “Concept of Electricity Supply of the Republic of Uzbekistan for 2020-2030”, that is, to increase the electricity supply to 120.8 billion kWh in 2030 (to 124.7 billion kWh) (https://minenergy.uz/ru/lists/view/77).

4 CONCLUSION AND SUGGESTIONS

The results of the analysis showed that, during periods of fundamental changes in the economy, it is appropriate to separately analyze the periods before and after the fundamental changes, as previously proposed by the author, and to create mathematical models and draw conclusions based on them.

In the co-authored articles Fayziev R., Kurbanov F. (2021, 2022) and Fayziev R., Kurbanov F. Mirzoev

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A. (2024), the indicators of electricity supply in the Republic of Uzbekistan for 2005-2020 were analysed separately for 2017 and 2020, and according to them, the goal set for 2030 cannot be achieved with such development indicators and recommendations are given to achieve it. From the results of the analysis, it can be seen that fundamental changes in the energy system have yielded their results. This article, based on the method of conducting a separate analysis for the period of the beginning of the reforms and subsequent periods, that is, based on the indicators of the volume of electricity supply in the Republic of Uzbekistan for 2010-2023, the forecast indicators calculated by a mathematical model for the period up to 2017 and beyond showed that the previous recommendations are appropriate. The growth rate of the volume of electricity supply in the Republic of Uzbekistan in 2016 compared to 2010 was 13.38%, in 2023 compared to 2016 - 29.31%, and compared to 2010 - 53.17%, that is, significant growth was achieved after 2017.

The article shows that if electricity supply is implemented through the model (5), the goal set in the "Concept of Electricity Supply of the Republic of Uzbekistan for 2020-2030" (2020), namely the plan to increase electricity supply to 120.8 billion kWh in 2030, can be increased (to 124.7 billion kWh).

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