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# Econometric Model of Electric Power Sector's Development in Uzbekistan

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**Abstract.** The article is aimed at building an econometric model of sustainable development in the energy system of Uzbekistan. The peculiarities of the organizational and economic mechanism are analyzed. The paper locates the place of the sustainable development mechanism in the system of functioning of an industrial enterprise in today's digital economy. We analyze the Concept Note on the Provision of Electricity in the Republic of Uzbekistan in 2020-2030 and adopted legislative acts of the country. Factors influencing the implementation of major programs for the development of thermal power plants are identified and recommendations are given for their use for the further progress of the energy industry. The article gives directions for sustainable development of energy system in Uzbekistan in the period of 2022-2026.

**Key Words:** Sustainability; Econometric model; Energy system.

## 1 Introduction

Current challenges facing the energy sector are caused by the need to ensure sustainable development in the context of global climate change and the transition to a digital economy. In this regard, the study of organizational and economic mechanisms that promote sustainable development of energy systems and their adaptation to the specific conditions of different regions is of particular importance. In Uzbekistan, with its unique economic and environmental characteristics, sustainable development of the energy system requires special attention to the integration of economic, social and environmental factors.

An analysis of the problem of sustainability of thermal power plants has shown that research in this area is being carried out to the maximum extent possible, but researchers are mainly focused on their economic aspects. In recent years, economists from many countries have been studying the problems of sustainable development. However, many issues remain unresolved in science, and Western experience requires careful revision and analysis and, in most cases, does not correspond to the conditions of the transitional digital economy for the countries of Central Asia.

The purpose of this article is to develop and test an econometric model that allows for a quantitative assessment of the impact of various factors on the development of the electric

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power sector in Uzbekistan. The paper examines the features of the functioning of thermal power plants and analyzes legislative initiatives and strategic documents that determine the directions of energy development in the country for the period up to 2026. Particular attention is paid to identifying key factors influencing the implementation of major programs for the modernization of thermal power plants and developing recommendations for their use for further progress in the energy sector.

This study is aimed at deepening the theoretical and methodological approaches to the sustainable development of economic systems in the context of the digital economy and the search for new factors that contribute to the development of the energy sector. The developed model is intended to become a tool for forecasting and planning the sustainable development of energy enterprises in Uzbekistan in the long term.

## 2 Literature Review

Many problems remained beyond the scope of the study: there is no consensus on such categories as “sustainability”, “sustainable development” of industrial and energy enterprises; in the issue of using the term “stability”, the dynamic aspects of systems, conditions and models that make it possible to predict sustainable development were not considered and especially the functioning of thermal power plants.

The term “sustainability” is interdisciplinary and used in different branches of science, and based on the transition of the economy to other development stages, it changes its meaning. “Sustainability” comes from the word “abutment” which means “a firmly rooted tradition, the fundamental principle or foundation of something” [1]. The economic term “sustainable development” became widespread after the report “Our Common Future”, prepared in 1987 by the International Commission on Environment and Development, created by the UN [2]. The direction under review was introduced to study the mutual relations between human, society and nature. As a rule, in modern scientific literature the definition of the concept of sustainable development is used, which refers to the generation that needs to meet its needs in which it lives [4]. The new strategy for the development of civilization does not proceed from priorities aimed at ensuring today, but makes an attempt to put two different generations on the same level, to equalize them in terms of their ability to satisfy vital needs in the future.

Works on sustainable development use different types of approaches, which consider the structure, including social, environmental and economic systems and their interactions. Taking into account the target orientation, the considered indicators are divided into three categories, namely impact, status and management.

Sustainable development of industrial enterprises, according to the authors, is a state of operation of an enterprise that, under the influence of various factors, retains the ability to increase or stably maintain the state during the period of time under consideration. The key factor is the stable financial and economic condition of enterprises in the long term. Ensuring the sustainable development of thermal power plants involves solving a scientific and practical problem: substantiating the theoretical foundations, searching for opportunities, developing and testing sustainability tools. The transition from a scientific formulation of a problem to its practical solution presupposes a clear understanding of the specifics of the research object and the environment of its functional activity.

According to Gutman, Miroedov and Fedin [4], “Sustainable development is a state of the socio-ecological-economic system in which there is progressive progress, maintenance of internal and external balance, a gradual transition of the economy from simple phenomena to complex phenomena are necessary conditions for its transition to a new level”.

Koptyug, Matrosov and Levashov [5] note “Sustainable development of society or the world community as a whole means stable or predictable development without sudden shocks and cataclysms”.

The article by Alferova and Tretyakova [6] outlines that “Sustainable development is a complex of processes consisting of positive changes aimed at harmonizing relations between the economic, environmental and social spheres and the introduction of their technologies to meet the needs for the long-term functioning of social economic system”.

Dreyer and Los [7] stated that sustainable development is economic growth that ensures the satisfaction of the material and spiritual needs of present and future generations while maintaining the balance of historically established ecosystems, and is the basis of a “sustainable civilization”.

Tietenberg [8] mentions that the main criterion for sustainability should be considered that the average life expectancy of future generations is not less than the average life of the current generation.

The transition to sustainable development of the entire energy system of Uzbekistan and each of its subsystems is an urgent task of the current period. Modern scientific research is aimed at deepening theoretical and methodological approaches to the sustainable development of economic systems, in particular, subsystems of the fuel and energy complex, as well as searching for new factors influencing the development of the industry. To do this, it is necessary to study and systematize theoretical and methodological approaches to sustainable development in the digital economy. The category of sustainability is an interdisciplinary concept, it is used differently in different disciplines and studies and changes its meaning over time.

In our opinion, Sustainable development is maintaining a balance and proportions between environmental, economic, social, technical, technological and political aspects that have an equal impact on the development of energy system enterprises.

## 3 Model and Analysis

The study used statistical and mathematical analysis, methods for constructing trend models, a method of collecting data and taking logarithms of various data. Fisher's criterion was applied to determine the adequacy of the constructed model. Correlation coefficients were identified to determine the relationship between the factors used.

Of key importance is the analysis of financial, economic and production processes at the level of energy enterprises, which is the main link of the digital economy. It is at this level that it is necessary to deeply study what opportunities each entity has to achieve and maintain sustainable development.

Ensuring sustainable development of energy enterprises is expressed in achieving social, economic, technical and environmental goals based on consistent implementation and responsibility to the economy. In this case, profit is no longer the ultimate goal that should guide the organization. It is one of the economic goals and performs an important function - it acts as a means of achieving all goals. As a criterion for assessing the sustainable development of energy enterprises, it is proposed to consider the following indicators: achieving sustainable rates of economic growth, that is, achieving the core activity of an energy enterprise sufficient for self-investment in the economic process and ensuring its sustainable development.

The quality of the national economy and society necessary to enter the phase of economic growth is only beginning to take shape, especially at thermal power plants. Currently, there are efficient energy enterprises in which the interests of all participants are balanced. To increase the number of such energy enterprises, the process of their transition from the current state to the desired sustainable development should be supported by the state by organizing the development of enterprise reform programs, especially in industry.

Ensuring the sustainable development of energy enterprises in Uzbekistan consists of econometric modeling, analysis of findings and future development directions. Econometric modeling allows one not only to quantitatively analyze the expansion coefficient of coronas in the heat energy supply, but also to determine the share of the contributing factor and the contributing factor. In Uzbekistan, the econometric modeling of the expansion multiplier of the energy plant allows to quantitatively determine the factor affecting the electricity produced in the plant and to develop an optimal plan for the development of the plant.

The following factor can be used to establish the development of Uzbekistan energy puzzle:

1. As a result factor:

- Electricity production volume (mln kWh), ($Y$);

2. As a precipitating factor:

- The volume of coal production is thousand t ($X_1$);
- The volume of consumed coal is thousand t ($X_2$);
- The volume of extracted gas is mln m $^3$ ($X_3$);
- The volume of consumed gas is mln m $^3$ ($X_4$);
- The amount of investments in fixed capital is billion soums ($X_5$);
- The volume of industrial products is billion soums ($X_6$);
- The volume of electricity consumption by the population is 1,000 kWh ($X_7$).

First of all, before creating a multi-factor econometric model for the volume of electricity production in the Republic of Uzbekistan, it is necessary to determine the density of dependence on the factors that are included in this model.

For this purpose, the coupling coefficient is calculated in the factor cell. Now we will create a multi-factor econometric model for the volume of electricity production in the Republic of Uzbekistan based on the factors mentioned above. In this case, if the potentiation method is not used in the first model type, the values in the natural logarithm are not obtained. It has the following distribution:

$$\hat{Y} = 80304{,}337 + 1{,}656\,\mathrm{x}_1 - 1{,}241\,\mathrm{x}_2 + 0{,}063\,\mathrm{x}_3 - 0{,}239\,\mathrm{x}_4 - 0{,}352\,\mathrm{x}_5 + 0{,}280\,\mathrm{x}_6 - 15546{,}551\,\mathrm{x}_7$$
$$\mathrm{R} = 0.985$$
$$R^2 = 0{,}9703 \qquad F_{calculation} = 18{,}664 \qquad (1)$$

The coefficient of 77506.248 in the model increases the influence of the factor that is not taken into account, that is, the amount of electricity production in the Republic of Uzbekistan was 80304.337 million kWh.

As seen from the complex model, when the volume of coal production ($X_1$) exceeds 1,000 tons, the volume of electricity production in the Republic of Uzbekistan ($Y$) can lead to a total increase of 1.656 million kWh. The amount of consumed coal ($X_2$) may increase to 1,000 tons, and the amount of electricity production in the Republic of Uzbekistan (Y*)* may decrease by 1,241 million kWh. The volume of extracted gas ($X_3$), about 1 mln. It can be added that the increase of m$^3$ can lead to the increase of the volume of electricity production in the Republic of Uzbekistan (Y) by 0.063 million kWh. The volume of consumed gas ($X_4$) may decrease by approximately 1 mln m$^3$, and the volume of electricity production ($Y$) in the Republic of Uzbekistan may decrease by approximately 0.239 mln kWh. The amount of investments in fixed capital ($X_5$) 1 bln per soum, the volume of electricity production ($Y$) in the Republic of Uzbekistan may decrease by 0.352 million kWh.

The volume of industrial production ($X_6$) 1 bln per soum, the volume of electricity production ($Y$) in the Republic of Uzbekistan may increase by 0.280 million kWh. The volume of electricity consumption by the population ($X_7$) may decrease by 1,000 kWh, the volume of electricity production ($Y$) in the Republic of Uzbekistan may decrease by 15546.551 million kWh.

$R^2 = 0{,}9703$ the coefficient of determination shows that 97.03% of the volume of electricity production in the Republic of Uzbekistan depends on the factor included in the multifactor econometric model. About 3% of the rest are caused by other factors that have not been taken into account.

Fisher's $F$-criterion is used to test the effectiveness or statistical significance of the constructed multifactor econometric model.

$F$-criterion is calculated by formula:

$$F = \frac{R^2(n-m-1)}{(1-R^2)m}, \tag{2}$$

where $n$ is observation cone; $m$ is the influencing factor in the model; $R$ is the multifactor coupling coefficient.

The calculated Fisher criterion is compared with the value in the table. To find the Fisher coefficient, $k_1$ and $k_2$ are determined: $k_1 = n - m - 1$ and $k_2 = m$. Therefore, the constructed econometric model is called adequate $F_{calculation} > F_{table}$.

Therefore, the constructed econometric model is called statistically significant $F_{calculation} < F_{table}$ In this case, a non-linear econometric model is chosen instead of a linear econometric model.

$$Fcalculation > Ftable$$
$$F_{\text{calculation}} = 18{,}664 > F_{table} = 0{,}0066. \tag{3}$$

So, the created econometric model is statistically significant, it is able to directly determine the state of electricity production volume in the Republic of Uzbekistan.

Calculated and actual value of electricity production volume in the Republic of Uzbekistan in model ACOC is presented in Fig. 1.

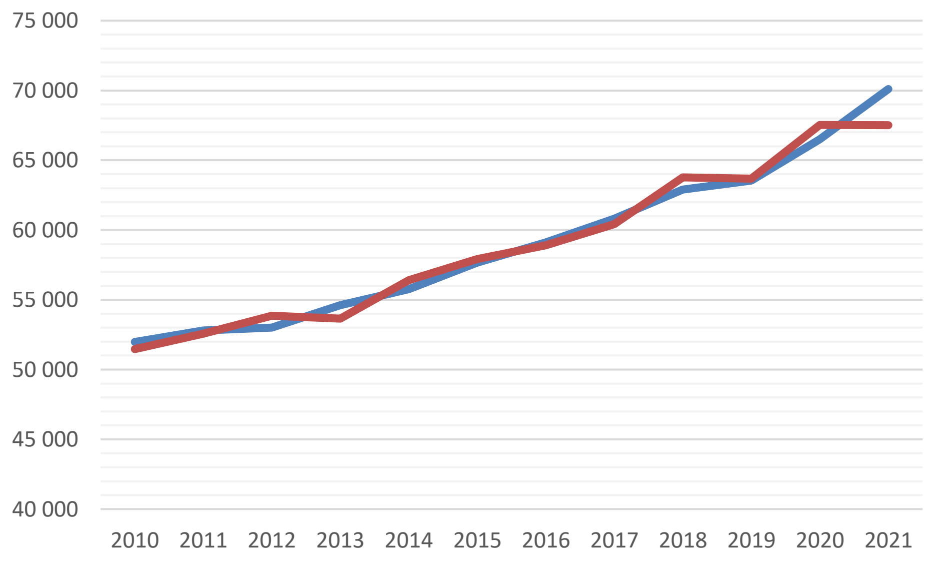


**Fig. 1.** Calculated and actual value of electricity production volume in the Republic of Uzbekistan.

From Fig. 1, it can be concluded that the calculated and real value of electricity production in the Republic of Uzbekistan during 2010-2021 had different values. In other words, it is not very big.

It is possible to predict the volume of electricity production in the Republic of Uzbekistan (Table 1).

**Table 1**. Electricity network in the Republic of Uzbekistan in 2010-2021 and forecast multiplier in 2022-2026.

| Years | Electricity production capacity (million kWh) | Coal production volume (thousand tons) | Amount of coal consumed (thousand tons) | Volume of extracted gas (mln $m^3$) | Volume of consumed gas (mln $m^3$) | Main to capital investment s amount (billion) | Industry product lot volume (billion soums) | Population by electricity consumption volume (thousands kWh) |
|---|---|---|---|---|---|---|---|---|
| 2010 | 51 976.3 | 3 629.4 | 2 644.5 | 65 958.5 | 52 794.3 | 16 463.7 | 38 119.0 | 1.8 |
| 2011 | 52 806.2 | 3 844.8 | 2 831.1 | 63 040.9 | 54 571.9 | 19 500.0 | 47 587.1 | 1.8 |
| 2012 | 52 999.6 | 3 752.9 | 3 831.0 | 61 531.0 | 47 343.1 | 24 455.3 | 57 552.5 | 1.8 |
| 2013 | 54 618.6 | 4 090.0 | 5 720.9 | 58 305.4 | 46 318.4 | 30 490.1 | 70 634.8 | 1.8 |
| 2014 | 55 766.0 | 4 396.8 | 5 264.5 | 54 161.2 | 43 273.8 | 37 646.2 | 84 011.6 | 1.8 |
| 2015 | 57 658.1 | 3 488.0 | 4 235.6 | 54 600.5 | 41 524.5 | 44 810.4 | 97 598.2 | 1.8 |
| 2016 | 59 100.5 | 3 867.3 | 5 003.3 | 56 132.1 | 43 690.3 | 51 232.0 | 111 869.4 | 1.8 |
| 2017 | 60 820.1 | 4 038.6 | 4 724.6 | 56 642.2 | 46 065.3 | 72 155.2 | 148 816.0 | 1.9 |
| 2018 | 62 896.6 | 4 174.4 | 6 768.0 | 61 585.5 | 48 343.1 | 124 231.3 | 235 340.7 | 1.9 |
| 2019 | 63 531.6 | 4 047.9 | 5 698.6 | 60 711.9 | 49 711.0 | 195 927.3 | 322 535.8 | 1.9 |
| 2020 | 66 500.7 | 4 133.1 | 7 988.2 | 49 768.2 | 46 057.5 | 210 195.1 | 368 740.2 | 2.0 |
| 2021 | 70 100.0 | 4 167.4 | 7 414.3 | 53 414.7 | 44 505.7 | 188 133.9 | 333 190.6 | 1.95 |
| 2022 | 69 052.3 | 4 203.4 | 7 821.1 | 52 583.2 | 44 049.2 | 206 957.6 | 364 740.5 | 1.97 |
| 2023 | 70 603.3 | 4 239.4 | 8 227.9 | 51 751.8 | 43 592.7 | 225 781.4 | 396 290.3 | 1.98 |
| 2024 | 72 154.4 | 4 275.4 | 8 634.6 | 50 920.3 | 43 136.1 | 244 605.1 | 427 840.2 | 2.0 |
| 2025 | 73 705.4 | 4 311.5 | 9 041.4 | 50 088.9 | 42 679.6 | 263 428.8 | 459 390.1 | 2.02 |
| 2026 | 75 256.5 | 4 347.5 | 9 448.2 | 49 257.4 | 42 223.1 | 282 252.5 | 490 939.9 | 2.04 |

Using the information in Table 1, we will form the graph of changes in the forecast period based on the factors influencing the volume of electricity production in the Republic of Uzbekistan. In order to emphasize the dynamics in it, a graphic is given in Fig. 2.

As we can see, based on the considered factors, the volume of electricity will reach 75.3 billion kWh in 2026 and will increase by 107.4% compared to 2021.

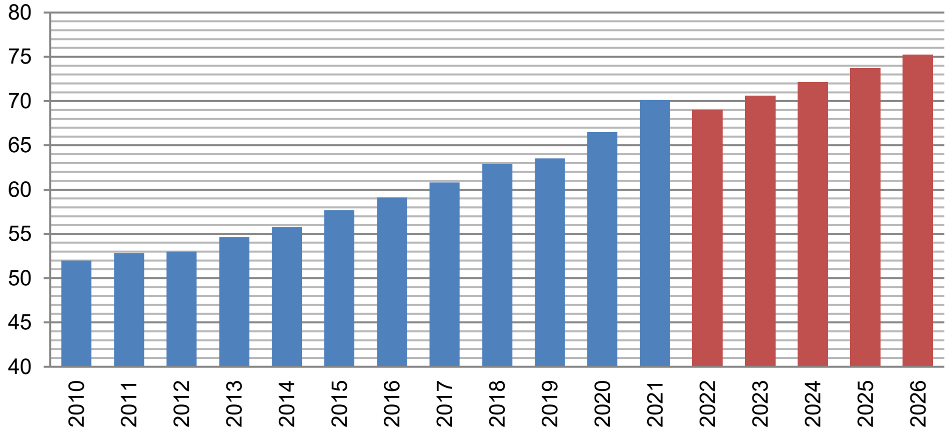


**Fig. 2.** Actual and estimated values of electricity production in the Republic of Uzbekistan in 2010-2021 (billion kWh).

There is another way to create a multi-factor econometric model of the volume of electricity production in the Republic of Uzbekistan and the factors influencing it. In contrast to the first type of model, in the case where the potentiation method is used, the natural logarithm indicators of the values are taken and used. The regression equation has the following product:

$$\hat{Y} = 10{,}805 + 0{,}013\, x_1 - 0{,}046\, x_2 + 0{,}063\, x_3 - 0{,}207\, x_4 - 0{,}137\, x_5 + 0{,}262\, x_6 + 0{,}694\, x_7$$
$$R = 0.9796$$
$$R^2 = 0{,}9597 \quad F_{\text{calculation}} = 13{,}603 \qquad (4)$$

$R^2 = 0{,}9597$ the coefficient of determination shows that 95.97% of the volume of electricity production in the Republic of Uzbekistan depends on the factor included in the multifactor econometric model. More than 4% of the rest are caused by other factors that have not been taken into consideration.

It can be seen from the complex model that when the volume of coal production (ln $X_1$) exceeds 1,000 tons, the volume of electricity production in the Republic of Uzbekistan (ln $Y$) can lead to a total increase of 0.013 million kWh. The amount of consumed coal (ln $X_2$) may reach 1,000 tons, and the amount of electricity production in the Republic of Uzbekistan (ln) may decrease by 0.046 million kWh. The volume of extracted gas (ln $X_3$), approximately 1 million m$^3$, it can increase the volume of electricity production (ln $Y$) in the Republic of Uzbekistan by 0.063 million kWh. The volume of consumed gas (ln $X_4$) can decrease by 1 mln m$^3$, the volume of electricity production in the Republic of Uzbekistan (ln $Y$) can decrease by 0.207 mln kWh. The amount of investments in fixed capital (ln $X_5$) is 1 bln per soum, the volume of electricity production in the Republic of Uzbekistan (ln $Y$) may decrease by 0.137 million kWh. The volume of industrial output (ln $X_6$) is 1 bln per soum, the volume of electricity production in the Republic of Uzbekistan (ln $Y$) may increase by 0.262 million kWh. The volume of electricity consumption by the population (ln $X_7$) may increase by 1,000 kWh, and the volume of electricity production in the Republic of Uzbekistan (ln $Y$) may increase by 0.694 million kWh.

The calculated Fisher criterion is compared with the value in the table. From this it turned out that $F_{\text{calculation}} > F_{\text{table}}$, i.e. $F_{\text{calculation}} = 13{,}602 > F_{table} = 0{,}012$.

So, the created econometric model is statistically significant, it is able to directly determine the state of electricity production volume in the Republic of Uzbekistan. In the model, it is possible to predict the volume of electricity production in the Republic of Uzbekistan (Table 2).

**Table 2.** Electricity network in the Republic of Uzbekistan in 2010-2021 and forecast multiplier in 2022-2026.

| **Years** | **Electricity work release capacity (million kWh)** | **Coal digging release volume (thousand tons)** | **Consumption done coal volume (thousand tons)** | **Dig up volume of released gas (mln m$^3$)** | **Consumption volume of gas produced (mln m$^3$)** | **Main to capital investments amount (billion sum)** | **Industry product volume (billion soum)** | **Popula-tion by electricity consumption volume (thousand kWh)** |
|---|---|---|---|---|---|---|---|---|
| 2010 | 51 976.3 | 3 629.4 | 2 644.5 | 65 958.5 | 52 794.3 | 16 463.7 | 38 119.0 | 1.8 |
| 2011 | 52 806.2 | 3 844.8 | 2 831.1 | 63 040.9 | 54 571.9 | 19 500.0 | 47 587.1 | 1.8 |
| 2012 | 52,999.6 | 3 752.9 | 3 831.0 | 61 531.0 | 47 343.1 | 24 455.3 | 57 552.5 | 1.8 |
| 2013 | 54 618.6 | 4 090.0 | 5 720.9 | 58 305.4 | 46 318.4 | 30 490.1 | 70 634.8 | 1.8 |
| 2014 | 55,766.0 | 4 396.8 | 5 264.5 | 54 161.2 | 43 273.8 | 37 646.2 | 84 011.6 | 1.8 |
| 2015 | 57 658.1 | 3 488.0 | 4 235.6 | 54 600.5 | 41 524.5 | 44 810.4 | 97 598.2 | 1.8 |
| 2016 | 59 100.5 | 3 867.3 | 5 003.3 | 56 132.1 | 43 690.3 | 51 232.0 | 111 869.4 | 1.8 |
| 2017 | 60,820.1 | 4 038.6 | 4 724.6 | 56 642.2 | 46 065.3 | 72 155.2 | 148 816.0 | 1.9 |
| 2018 | 62,896.6 | 4 174.4 | 6 768.0 | 61 585.5 | 48 343.1 | 124 231.3 | 235 340.7 | 1.9 |
| 2019 | 63 531.6 | 4 047.9 | 5 698.6 | 60 711.9 | 49 711.0 | 195 927.3 | 322 535.8 | 1.9 |
| 2020 | 66 500.7 | 4 133.1 | 7 988.2 | 49 768.2 | 46 057.5 | 210 195.1 | 368 740.2 | 2.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2021 | 70 100.0 | 4 167.4 | 7 414.3 | 53 414.7 | 44 505.7 | 188 133.9 | 333 190.6 | 1.95 |
| 2022 | 69 360.2 | 4 207.4 | 8 502.7 | 52 661.8 | 44 174.5 | 296 825.4 | 495 536.4 | 1.97 |
| 2023 | 71 199.9 | 4 246.6 | 9 251.5 | 51 911.1 | 43 773.0 | 381 625.0 | 615 944.8 | 1.99 |
| 2024 | 73 088.5 | 4 286.1 | 10 066.2 | 51 171.2 | 43 375.1 | 490 651.0 | 765 610.7 | 2.0 |
| 2025 | 75 027.1 | 4 326.0 | 10 952.6 | 50 441.8 | 42 980.9 | 630 824.4 | 951 643.3 | 2.02 |
| 2026 | 77 017.2 | 4 366.3 | 11 917.1 | 49 722.7 | 42 590.2 | 811 043.8 | 1 182 879 | 2.04 |

Using the information in the table, we will form the graph of changes in the forecast period based on the factors influencing the volume of electricity production in the Republic of Uzbekistan. In order to emphasize the dynamics in it, a graphic is given in Fig. 3.

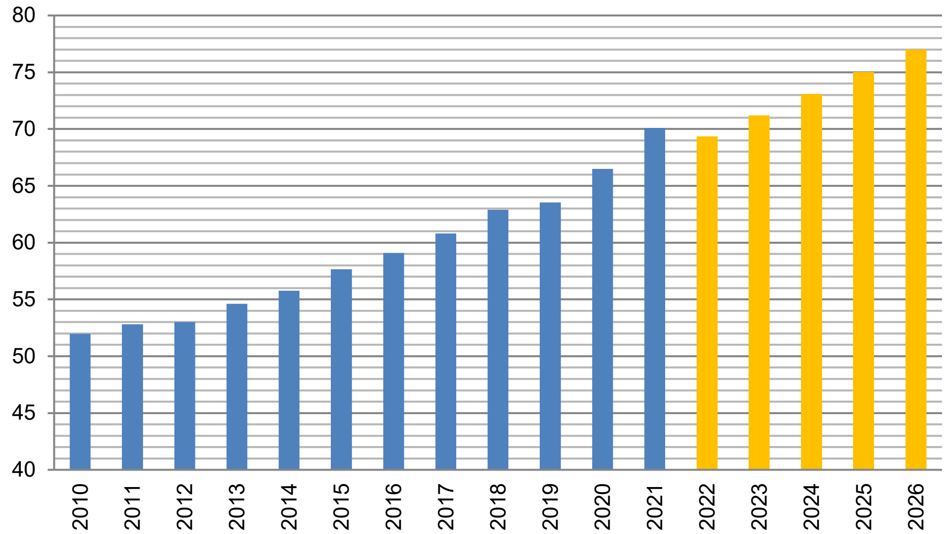


**Fig. 3.** Actual and estimated values of electricity production in the Republic of Uzbekistan in 2010-2021 (billion kWh).

As seen from Fig. 3, the amount of electricity in 2026 will be 77 billion kWh and 70.1 billion kW in 2021 (an increase of 109.8%). But for this, it is necessary to start new energy production facilities and increase energy efficiency.

## 4 Conclusion

The results of the study confirm the need for an integrated approach to the sustainable development of the energy sector of Uzbekistan, taking into account the interaction of economic, environmental and social factors. The developed econometric model allowed not only to quantitatively assess the impact of key factors on electricity production volumes, but also identify the most significant of them to ensure sustainable growth of the industry.

Data analysis showed that the stable development of the energy system requires not only modernization and expansion of production capacity, but also the introduction of new management solutions that promote the optimum use of resources and increased energy efficiency. The most important factor in sustainable development is investment in fixed assets, which is directly related to the need for state support and the development of long-term programs for reforming the energy sector.

Forecast calculations based on the proposed model indicate the positive dynamics of growth in electricity production in Uzbekistan in the coming years, subject to the implementation of the proposed measures to improve management and technological processes. The commissioning of new production capacities, as well as increasing the efficiency of existing facilities, will ensure the sustainable development of the country's energy sector, which is the key to economic growth and social well-being. In conclusion, it should be noted that the proposed model and the results obtained can be used as a tool for planning and forecasting the development of the energy sector of Uzbekistan, and can also serve as a basis for further research in the field of sustainable development of economic systems in the context of digital transformation.

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