

# **V International Scientific and Technical Conference Actual Issues of Power Supply Systems**

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## **History of electrification of the cities of Karakalpakstan**

AIPCP25-CF-ICAIPSS2025-00550 | Article

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# History of electrification of the cities of Karakalpakstan

Jalgas Toreniyazov <sup>a)</sup>, Gulmira Yembergenova, Raxat Ilauatdinov, Azamat Kungratbaev, Manzura Rzaeva

*Karakalpak State University named after Berdakh, Nukus, Uzbekistan*

<sup>a)</sup> Corresponding author: [jalgastoreniyazov6@gmail.com](mailto:jalgastoreniyazov6@gmail.com)

**Abstract.** This article provides a comprehensive analysis of the electrification process of cities and large settlements of the Republic of Karakalpakstan from historical, socio-economic, and technical points of view. The work highlights the current state and prospects based on archival materials, regional statistical data, and energy projects implemented in recent decades.

## INTRODUCTION

Electricity is one of the most important infrastructural factors in the development of modern society, ensuring the uninterrupted functioning of industry, agriculture, transport, information and communication technologies, and the social sphere. The level of economic development of each region, the pace of urbanization, and the quality of life of the population are directly related to the level of development of the power supply system. From this point of view, the study of the historical stages of the electrification process in the Republic of Karakalpakstan, located in the northwestern part of Uzbekistan, has important scientific and practical significance.

The territory of Karakalpakstan has unique natural and geographical conditions, characterized by desert and semi-desert zones, the Amu Darya basin, irrigated farming systems, and settlements stretching over long distances. These factors directly influenced the formation of electricity generation, transmission, and distribution systems.

Until the beginning of the 20th century, the use of electricity in the region was limited, mainly mechanical energy sources, petroleum products, and gas lighting were used.

The large-scale electrification of Karakalpakstan began during the period of the former Soviet Union, in particular, within the framework of the GOELRO plan. This plan aimed to provide electricity not only to industrial centers but also to remote areas, laying the foundation for the construction of the first small power plants and later large thermal power plants in the region. In particular, the commissioning of the Takhiatash Thermal Power Plant played a decisive role in the formation of the energy system of Karakalpakstan and gave a powerful impetus to the socio-economic development of such cities as Nukus, Kungrad, Khojayli, Chimbay, Muynak, Beruni, Turtkul.

During the years of independence, the republic's electric power industry has reached a new level. The transition from a centralized Soviet system to market mechanisms, the modernization of outdated infrastructure, increasing energy efficiency, and the introduction of alternative and renewable energy sources have become urgent tasks. Projects implemented in Karakalpakstan in recent years in the field of solar and wind energy, along with strengthening the energy security of the region, also contribute to ensuring environmental stability.

The main goal of this article is a phased analysis of the history of electrification of cities and large settlements of the Republic of Karakalpakstan, identifying the features of the formation and development of the electric power infrastructure, and highlighting the socio-economic significance of modern reforms and promising projects on a scientific basis.

## HISTORICAL STAGES

1) Early stage: until the beginning of the 20th century

The widespread use of electricity in the territory of Karakalpakstan was limited until the middle of the 20th century. In cities and settlements, mainly gas, boilers, and mechanical energy sources were used, and oil products and oil lamps were used for lighting.

2) Soviet-era electrification policy (1920-1945)

The programs of electrification of the national economy (electric power industry), implemented within the framework of Soviet economic policy, also affected Karakalpakstan: practical projects and regional transmission networks were created. In the 1920s and 1930s, small hydroelectric power stations based on water resources and local generators began supplying electricity to a number of settlements.

3) Post-war expansion and industrialization (1945-1970). During this period, stable power supply was ensured through main power transmission lines and large thermal power plants. Nukus and other major centers were formed as regional energy nodes.

5) Independence and Transformation (1991-2010)

After independence, the energy sector entered the stage of liberalization, modernization, and turnover adaptation. Networks have been modernized, increasing energy efficiency and interest in renewable sources, but investment restrictions and outdated facilities have affected the stability of the system.

6) New era: modernization and green energy (2010-present)

## RESEARCH RESULTS

In recent decades, solar and wind energy projects have been implemented in Karakalpakstan as part of Uzbekistan's overall energy reforms. Projects with local and international financing are aimed at providing cities and districts with additional capacity. In order to implement the tasks of reforming the electric power industry and increasing its investment attractiveness, a number of decrees and resolutions have been adopted, and great attention is being paid to deepening economic reforms in the republic's energy sector (PF-2812.22.02.2021). The Resolution of the President of the Republic of Uzbekistan dated March 27, 2019 No. PP-4249 "On the Strategy for the Further Development of the Electric Power Industry of the Republic of Uzbekistan and Optimization of Production Processes" defines some tasks for the further development of this industry [1,2].

The development of the Karakalpak electric power industry began with the implementation of the GOELRO plan, which was the first promising plan for the development of the national economy after the 1917 revolution.

The Amu Darya and its tributaries (canals) were seen as potential locations for the construction of small hydropower plants, but these projects were mainly implemented in the late 1930s and 1940s. Although the construction of small hydroelectric power plants in Karakalpakstan was planned in the 1920s-1930s, in practice these projects developed mainly after the mid-1930s and significantly expanded in the 1940s-1950s. The stations built during this period were mainly small, designed for local needs[3].

In the mid-1930s, a certain change occurred in the industry of Karakalpakstan. At the end of 1934, the Turtkul power plant was put into operation[4].

After the Second World War, one of the underdeveloped industries in Karakalpakstan was energy. As of January 1, 1956, 117 power plants with a total capacity of 12,773 kW generated 32,159 thousand kWh of electricity. In March 1956, the construction of the Takhiatash Thermal Power Plant began, and on September 10, 1961, the first turbogenerator with a capacity of 12 thousand kW was commissioned[4.5].

Until recently, the electric power industry consisted only of separate small and scattered power plants due to the lack of a fuel base. For example, in 1961, there were 411 power plants, totaling only 1,477 million kWh of electricity. Of these, 16 have a capacity of 500 kW, totaling 125.9 million soums per year kWh. Or 85.2% of the annual electricity generated in the Republic of Karakalpakstan. Since 1960, in connection with the commissioning of the I-II power lines of the Takhiatash GRES in the Republic of Karakalpakstan, the annual volume of electricity production in 1975 amounted to 1.8 million kWh and the Takhiatash Thermal Power Plant has become a powerful thermal power plant and a technical base. As a result, the electricity produced in the 1940s is now produced in a matter of hours. The volume of electricity production per capita reached 2,679 kWh, and in this indicator, the Republic of Karakalpakstan caught up with many countries of the world.

Today, the Takhiatash Thermal Power Plant provides electricity not only to the Republic of Karakalpakstan, but also to the neighboring Khorezm region. In 1964, the capacity of the Takhiatash Thermal Power Plant reached 48 thousand kWh. In 1965-70, three additional turbogenerators with a capacity of 100 thousand kW/h were installed. Thus, by 1990, the total capacity of the Takhiatash Thermal Power Plant was 348 thousand kW. kW/h, and since the beginning of 1990, its capacity has increased by another 420 kW/h, in addition, the Bukhara-Aral-Central Asia-Central

and further to Europe gas pipeline passes through the territory of the Republic of Karakalpakstan, as well as the discovery of oil and gas fields, all this led to the provision of gas fuel to the Takhiatash Thermal Power Plant. If in 1961 the cost of each kilowatt-hour of electricity exceeded 6 kopecks, then by the end of the 80s it fell to 1.2 kopecks. Currently, the GRES has a new technical base. In such a short period, the cost of electricity has decreased fivefold [6].

Starting in 1970, the construction of high-voltage power transmission lines reached a number of cities, such as Nukus, Kungrad, Mangit, Beruni, Turtkul, Urgench, and thus the developed energy system of Karakalpakstan was created. Due to the increase in electricity production, the demand for it also increased. Currently, there is not a single industrial enterprise, not a single agricultural enterprise, and not a single village in the republic that does not use the electricity of the Takhiatash Thermal Power Plant. Electricity production increased by 73.5% in 2010 compared to 1990. This is due to the collapse of the former Soviet Union, the complexity of the transitional economy, the disruption of production ties, and the obsolete equipment of power plants.

As a result of the implemented reforms and the strategy for the further development of the republic's heavy industry, including electric power, electricity production increased by 112.6 percent compared to 2020. However, these figures do not meet the electricity needs of industrial sectors, agriculture, as well as the rapidly growing population of the country [7]. Therefore currently, 32 "green" projects with a total value of \$19 billion are being implemented in Uzbekistan, which will allow adding 18.6 gigawatts of capacity to the country's energy system. Karakalpakstan, which has the capacity to generate 680 gigawatts of solar and 120 gigawatts of wind energy, plays an important role in this area. Today, the construction of the first wind power plant with a capacity of 1 gigawatts, worth \$1.2 billion, has begun in Kungrad, implemented by the Chinese company "Sany Renewable." The second project - a wind power plant with a capacity of 200 megawatts with a storage system of 100 megawatts worth 250 million dollars - will be implemented in the Beruniy and Karauzyak regions in cooperation with the Saudi company ACWA Power.

In the future, these projects will provide 4.2 billion kilowatt-hours of green energy, equivalent to the annual consumption of 1.75 million households. This will save about 1.3 billion cubic meters of natural gas and reduce emissions into the atmosphere by almost 2 million tons. Construction of enterprises for the production of spare parts and wings for wind turbines in the Kungrad region [8].

**Territorial statistical analysis.** For the analysis, open data from the Statistics Committee of the Republic of Uzbekistan and territorial administrations were used. Regional energy production and consumption indicators in recent years show the following trends:

- Annual electricity production volumes in the Republic of Karakalpakstan (according to the latest online statistics) are measured at the level of thousands of megawatts-hours, and there are significant changes between 2010 and 2023. Precise numerical indicators of regional production are obtained from monographs and official statistical data.
- Overall national electricity coverage indicators reached almost full coverage between 2000 and 2020 (national-level electricity access indicators were recorded in the range of 99-100%). There are regional differences, and in previous years, disruptions and technical restrictions were observed in rural areas.

**Nukus and wind/solar projects.** In recent years, several wind and solar energy projects have been implemented in Karakalpakstan. "Nukus-1,2" and related projects are aimed at strengthening the energy balance of the region, which are important both from an investment and from a social point of view. Project documentation and EIA materials indicate that such projects will create new jobs in the region and contribute to reducing carbon emissions.

**Socio-economic impacts.** Electrification has led to the following socio-economic changes in the cities of Karakalpakstan:

- Transition of industrial and agricultural enterprises to electrical technologies;
- Increasing the level of service provided by educational and healthcare institutions;
- Expanding living conditions and access to household services for the population;
- Expansion of information and communication infrastructure and digitalization opportunities.

## CONCLUSIONS

The conducted research showed that the electrification of the cities of the Republic of Karakalpakstan is a long and complex historical process. The power supply system, which was practically non-existent at the beginning of the 20th century, became the main industrial and social infrastructure of the region as a result of large-scale state programs implemented during the Soviet era, in particular, the GOELRO plan and the construction of the Takhiatash Thermal Power Plant. The sharp increase in electricity production volumes contributed to the rapid development of industry, agriculture, and urban infrastructure.

Problems that have arisen in the energy sector during the years of independence - obsolete equipment, lack of investment, and interruptions in energy supply - have begun to be addressed through phased reforms. Based on state programs and presidential decrees, important measures have been taken to modernize electrical networks, increase production capacities, and improve the management system. As a result, electricity production has increased significantly in recent years, but the rapid growth of industrial and household needs indicates the need to search for additional opportunities.

The research results show that the implementation of wind and solar energy projects is of strategic importance for Karakalpakstan. These projects will not only strengthen the energy independence of the region, but will also create new jobs, reduce carbon emissions, and achieve environmentally sustainable development. At the same time, the digitalization of existing power grids, the introduction of energy storage technologies, and the accurate accounting of the regional energy balance are among the important tasks for the future.

In general, the process of electrification of the cities of the Republic of Karakalpakstan played a decisive role in the economic and social development of the region and remains relevant today. The results of this article can serve as a theoretical and practical basis for improving regional energy policy, developing sustainable development strategies, and conducting future scientific research.

**Recommended practical measures:**

- Attracting current and international investments for the modernization of industries;
- Digitalization of local energy monitoring and high-quality accounting of regional energy balances;
- Effective integration of renewable energy sources through the introduction of energy storage and network integration technologies.

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