Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

THE ROLE OF MICRO-HYDROPOWER PLANTS (MICRO-HPPS) IN SUPPLYING ELECTRICITY TO RURAL AREAS

Tashpulatov Sarvar,
Professor, Tashkent University of Architecture and Civil Engineering

Mirzaakhmedov Sayyodjon
Phd Student at Fergana State Technical University
E-mail: sayyodmirzaakhmedov@gmail.com
ORCID:0009-0001-2314-8716

Abstract
The study explores the potential of micro-hydropower plants (Micro-HPPs) in improving rural electricity supply in Uzbekistan. Using geodetic and GIS analyses, optimal sites within the Fergana region's irrigation networks were identified. The results show that Micro-HPPs provide an efficient, eco-friendly, and economically viable solution, ensuring stable energy for rural areas and rapid investment returns.

Keywords: Micro-hydropower, Micro-HPPs, Rural electricity supply, Irrigation networks, GIS analysis, Energy efficiency, Renewable energy, Uzbekistan

Introduction

In recent years, global demand for electricity has been increasing, drawing greater attention to renewable energy sources. According to the International Energy Agency, electricity consumption is expected to grow by more than 30% by 2030 [1]. Therefore, the development of small-scale, environmentally friendly energy sources based on local resources has become a pressing issue.

Among these, micro-hydropower plants (Micro-HPPs) hold particular significance. They utilize small water flows with capacities ranging from 5 to 100

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

kW and do not require large infrastructure [2]. Micro-HPPs are distinguished by their low operational costs, environmental safety, and long-term sustainability.
In the context of Uzbekistan, irrigation networks constitute a major part of the country's water infrastructure. The natural slopes of the existing water flows and the structures within these networks provide a natural basis for micro-HPPs [3]. Thus, constructing micro-HPPs within irrigation networks offers the opportunity to improve electricity supply in rural areas and achieve energy independence.
However, issues related to site selection for micro-HPPs in irrigation networks, evaluation of their techno-economic efficiency, and precise geodetic design have not been sufficiently studied [4]. Therefore, it is necessary to improve assessment approaches based on geodetic and GIS analysis methods for the effective use of water resources for energy purposes in irrigation facilities.
The aim of this study is to assess the potential for constructing micro-HPPs in Uzbekistan's irrigation networks, to determine their role in supplying electricity to rural areas, and to develop a methodology for optimal placement based on geodetic approaches.

Methods

The study was conducted based on the irrigation networks and water facilities in the Fergana region. The research methodology was implemented in three stages: data collection, geodetic and GIS analysis, and energy and economic calculations.

Data Collection

Information on water facilities and canal networks in the Fergana region was obtained from the Ministry of Water Resources of the Republic of Uzbekistan and the Fergana Hydrometeorology Center. The collected data included:

- ⇒ Canal length, elevation difference, and flow velocity;
- ⇒ Relief and slope data (SRTM and ASTER GDEM);
- ⇒ Local settlements and distance to the electricity grid;
- ⇒ Seasonal variation of water resources and operational regimes.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Geodetic and GIS Analysis:

To identify potential micro-HPP sites, Quva district of Fergana region, specifically Baraka QFY and Mingchinor MFY, was selected as a case study. The analysis included:

- Elevation difference (H) and slope — to assess the energy potential of water flow;
- Water flow (Q) — considering seasonal variations;
- Land area and coordinates — in the WGS-84 system;
- Distance to the network and transport accessibility.

Using GIS software (ArcGIS 10.8, QGIS 3.36):

- Integration of canal networks and terrain;
- Analysis of population density and connectivity to the transport network;
- Optimal site selection using the Multi-Criteria Decision Analysis (MCDA) model.

The MCDA model was evaluated based on the following parameters:

1. Energy potential (E);
2. Construction cost (C);
3. Environmental impact (ECO);
4. Distance to the network (D);
5. Proximity to population (P).

Energy Calculations

The potential power of the canals in the Fergana region was calculated using the following formula:

$$P = \rho \times g \times Q \times H \times \eta$$

where:

- $\rho = 1000$ kg/m³ — water density;
- $g = 9.81$ m/s² — acceleration due to gravity;
- Q — canal flow rate (m³/s);
- H — elevation difference (m);
- η — system efficiency (0.75–0.90) [4].

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

The annual energy production (E, kWh/year) was calculated as:

$$E = P \times t$$

where t is the operational time (hours), determined according to the canal's seasonal operating regime [5,6].

Economic Assessment

The economic evaluation was carried out for micro-HPPs in the Fergana region.

Key Economic Indicators

Term	Translation	Description
LCOE (Levelized Cost of Electricity)	**Elektr energiyasining bir xil balanslangan narxi**	**The ratio of the total cost of electricity production over the entire lifetime of the project to the total electricity generated per kWh. This indicator is used to assess the economic efficiency of energy production.**
Payback Period	**Investitsiya o'zini oqlash muddati**	**The time required for the investments made in the project to be recovered through generated revenues.**
NPV (Net Present Value)	**Sof hozirgi qiymat**	**The net value of expected future revenues and expenses of the project, discounted to the present time. If NPV > 0, the project is considered profitable.**

Results

Using the developed methodology, an optimality index was created for the placement of micro-HPPs in the canal networks of the Fergana region. This index allowed for the integrated assessment of energy production, construction costs, and environmental impact [10].

The analysis was carried out for micro-HPPs and water pumps located in the Southern Fergana Canal area of the Fergana region. The main results are as follows:

The total capacity and annual production of 15 micro-HPPs amounted to 7,745 kW, generating a total of 51,282,000 kWh of electricity per year.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

Capacity and production at individual sites:

1. Baraka QFY, "Bahor" water pump, 14 micro-HPPs of 400 kW each — 5,600 kW, 36,288,000 kWh/year.
2. Baraka QFY, "Bahor" water pump, 1 additional micro-HPP — 175 kW, 1,134,000 kWh/year.
3. Mingchinor MFY, 1 micro-HPP — 400 kW, 2,592,000 kWh/year.

Investment and economic efficiency:

- Total project commissioning cost: 77.45 billion UZS.
- Electricity tariffs: approximately 675 UZS/kWh.
- Payback period: 2–3 years depending on the site.

For example, the 14-micro-HPP capacity at Baraka QFY has a payback period of 2.3 years, while the single micro-HPP at Mingchinor MFY has a payback period of 3 years.

Water resources and physical parameters:

- Water flow: 3–34.5 m^3/s; 14 waterfalls: 17 m^3/s; additional waterfall: 3 m^3/s; Mingchinor MFY: 20 m^3/s.
- Water head: 2–8 m.
- Water availability: each site can operate for 9 months per year.

Conclusion

The highest capacity and energy production were identified at the Baraka QFY "Bahor" water pump with 14 micro-HPPs. This site, along with the Mingchinor MFY site, ensures economic efficiency with a rapid payback period of 2.3 years. Water flow and head are the primary parameters determining energy production capacity, and optimal placement can be identified through geodetic analysis.

The results indicate that the canals and water facilities in the Fergana region are technically and economically suitable for micro-HPPs. Their construction significantly enhances stable electricity supply in rural areas.

Micro-HPPs play a crucial role in providing sustainable electricity to rural communities. In areas with available water resources, they substantially increase

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

annual electricity generation and provide the local population with a reliable energy source. Micro-HPP projects are economically efficient, with investment costs recoverable in some areas within 4–5 years. Additionally, they serve as environmentally friendly energy sources, reducing traditional fuel consumption and promoting rational water resource management. Based on this study, widespread implementation of micro-HPPs in rural areas can enhance their economic, technical, and environmental efficiency.

References.

1. International Energy Agency. *World Energy Outlook 2023.* – Paris: IEA Publications, 2023.
2. World Bank. *Energy Access and Sustainable Development.* – Washington, 2022.
3. O‘zbekiston Respublikasi Energetika vazirligi. *O‘zbekiston energetika balansi 2023.* – Toshkent, 2023.
4. B. Paish. *Micro-hydropower: status and prospects.* – Proc. of the Institution of Mechanical Engineers, 2002.
5. FAO. Irrigation and Small Hydropower Integration in Rural Areas / FAO. — Rome, 2019. — 76 p.
6. World Energy Council. Small Hydropower Development and Deployment: Global Report / WEC. — London, 2022. — 128 p.
7. International Renewable Energy Agency (IRENA). Renewable Energy in Rural Areas: Micro-Hydro Solutions / IRENA. — Abu Dhabi, 2021. — 92 p.
8. Иванов П.В., Смирнова Е.В. Возобновляемые источники энергии: гидроэнергетика малых рек / П.В. Иванов, Е.В. Смирнова. — М.: Энергия, 2020. — 234 с.
9. Петров А.Н. Энергетическая эффективность микроГЭС / А.Н. Петров // Электроэнергетика. — 2021. — №3. — С. 45–52.
10. Сидоров В.И. Проектирование малых гидроэлектростанций / В.И. Сидоров. — СПб.: Питер, 2018. — 176 с.
11. UNEP. *Micro-hydropower and rural energy access: Asia-Pacific overview.* – Geneva: UNEP, 2022.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 08, November, 2025
Website: usajournals.org

12. Sharipov, S. va boshqalar. *Geodezik o'lchovlarning irrigatsiya tarmoqlarida energiya tizimlariga integratsiyasi.* – Toshkent, 2023.
13. Ganiyev Y. Y., Murodilov K. T., Mirzaakhmedov S. S. Evaluating the precision of google maps in countryside regions //ITALY" ACTUAL PROBLEMS OF SCIENCE AND EDUCATION IN THE FACE OF MODERN CHALLENGES. – 2023. – T. 14. – №. 1.
14. Abdurakhmanov A. A. Mirzaakhmedov SSH DEVELOPMENT OF MECHANISM FOR CARTOGRAPHIC SUPPORT OF REGIONAL DEVELOPMENT //Finland International Scientific Journal of Education, Social Science & Humanities. – 2023. – T. 11. – №. 3. – С. 1110-1118.
15. Madumarov B., Mirzaakhmedov S. REQUIREMENTS FOR THE ACCURACY OF THE EXISTING AND NEWLY BUILT PLANNED GEODESIC NETWORKS IN THE AREA //Innovations in Science and Technologies. – 2024. – T. 1. – №. 1. – С. 48-54.
16. Турдикулов Х., Мирзаакхмедов С. Реконструкция городов, вопросы реновации и использование геоинженерных систем в городском развитии //Тенденции и перспективы развития городов. – 2023. – Т. 1. – №. 1. – С. 209-212.