

ENVIRONMENTAL

IMPACT OF THE USE OF HYDROPOWER POTENTIAL AND ITS ROLE FOR SUSTAINABLE DEVELOPMENT IN AZERBAIJAN

IMPACTO AMBIENTAL DEL APROVECHAMIENTO DEL POTENCIAL HIDROELÉCTRICO Y SU PAPEL PARA EL DESARROLLO SOSTENIBLE EN AZERBAIYÁN

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ABSTRACT

This study evaluates the hydropower potential of the Karabakh and East Zangezur regions of Azerbaijan and assesses the environmental and economic trade-offs associated with rapid deployment of small- and medium-scale hydropower in territories. Although these basins contain roughly one quarter of the country's water resources, there is limited integrated analysis that couples empirical commissioning data, hydrometric records and advanced monitoring/optimization tools to guide sustainable expansion. Results show a rapid build-out of small hydropower: initial commissions produced approximately 270 MW and on the order of 492–550 million kWh annually, with aggregate active capacity reaching ~307 MW by mid-2025. These deployments correspond to substantial fuel-saving and emissions reductions (estimated natural-gas savings in the order of 120–200 million m³ and CO₂ avoidance between ~225,000 and 400,000 tonnes, alongside a reported 55.3% surge in generation in January–February 2025). While small hydropower delivers measurable energy security and climate benefits, the analysis documents ecological risks—flow regulation, habitat fragmentation, sediment and erosion impacts—and prescribes safeguards: rigorous Environmental Impact Assessments, enforcement of ecological flows, run-of-river prioritization, fish-pass and habitat restoration measures, deployment of sensor networks and adaptive operational regimes, and stakeholder consultations. By combining empirical deployment evidence with an operational monitoring framework, the study provides actionable guidance to maximize feasible hydropower potential while minimizing ecological costs, thereby informing policy choices aligned with Azerbaijan's 2030 green-energy objectives.

Keywords:

Karabakh, Eastern Zangezur, Hydropower, River flow, Sustainable development.

RESUMEN

Este estudio evalúa el potencial hidroeléctrico de las regiones de Karabaj y Zangezur Oriental de Azerbaiyán y evalúa las compensaciones ambientales y económicas asociadas con el rápido despliegue de la energía hidroeléctrica de pequeña y mediana escala en territorios. Si bien estas cuencas contienen aproximadamente una cuarta parte de los recursos hídricos del país, existe un análisis integrado limitado que combine datos empíricos de puesta en servicio, registros hidrométricos y herramientas avanzadas de monitoreo/optimización para guiar la expansión sostenible. Los resultados muestran un rápido desarrollo de la energía hidroeléctrica de pequeña escala: las puestas en servicio iniciales produjeron aproximadamente 270 MW y entre 492 y 550 millones de kWh anuales, con una capacidad activa total que alcanzará los ~307 MW para mediados de 2025. Estos despliegues corresponden a ahorros sustanciales de combustible y reducciones de emisiones (ahorros estimados de gas natural del orden de 120 a 200 millones de m³ y una reducción de emisiones de CO₂ de entre ~225.000 y 400.000 toneladas, junto con un aumento reportado del

55,3 % en la generación entre enero y febrero de 2025). Si bien la minicentral hidroeléctrica ofrece seguridad energética y beneficios climáticos mensurables, el análisis documenta los riesgos ecológicos (regulación del caudal, fragmentación del hábitat, impactos en sedimentos y erosión) y prescribe salvaguardias: rigurosas Evaluaciones de Impacto Ambiental (EIA), cumplimiento de los caudales ecológicos, priorización de los ríos de pasada, medidas de restauración de hábitats y pasos para peces, despliegue de redes de sensores y regímenes operativos adaptativos, y consultas con las partes interesadas. Al combinar la evidencia empírica del despliegue con un marco de monitoreo operativo, el estudio proporciona una guía práctica para maximizar el potencial hidroeléctrico factible y minimizar los costos ecológicos, fundamentando así las decisiones políticas alineadas con los objetivos de energía verde de Azerbaiyán para 2030.

Palabras clave:

Karabaj, Zangezur Oriental, Energía hidroeléctrica, Caudal fluvial, Desarrollo sostenible.

INTRODUCTION

Hydropower refers to the use of the kinetic and potential energy of water for human purposes; therefore, a hydroelectric plant is a facility that converts that energy into electricity using turbines and generators (Yang, 2024). Harnessing hydroelectric potential is presented as one of the most visible and powerful levers in national energy transition and sustainable development strategies, especially in countries whose river basins provide significant water resources (Faundes-Peñafiel, & Campos-Mello, 2024; Wang et al., 2023). However, contemporary discussion demands simultaneously a recognition of the enormous energy potential of water resources and a rigorous critique of their environmental, social, and economic externalities (Othman et al., 2025; Soomro et al., 2024). This dichotomy—renewable energy with non-trivial impacts—defines the research framework proposed here: understanding the environmental impact of hydroelectric development and its role in the path toward sustainable development in the Republic of Azerbaijan.

It is important to emphasize that hydropower potential is a concept that requires a multidisciplinary approach for its comprehensive understanding. From a technical perspective, hydroelectric potential is defined as the maximum theoretical electricity generation capacity that can be obtained from the exploitation of a given region's water resources, considering factors such as flow rate, height of fall, and energy conversion efficiency (Ismail, 2025). However, this purely technical definition is insufficient to

fully address the complexity of the phenomenon. From an environmental perspective, the concept becomes more complex when incorporating the ecological limitations and ecosystem services that water bodies provide beyond their energy potential (Hatamkhani et al., 2023). As Rosenberg et al. (2000) pointed out in his pioneering analysis of the global environmental effects of hydrological alterations, “the global-scale environmental effects of hydrological alterations” require systematic consideration that transcends immediate energy benefits.

This holistic perspective recognizes that aquatic ecosystems function as complex systems where human intervention generates cascades of effects that can extend far beyond the area of direct impact. As an additional layer of complexity, the socioeconomic dimension of hydroelectric potential introduces further considerations related to economic viability, social acceptance, and impacts on local communities. The concept of “feasible potential” emerges as a more realistic categorization that considers not only technical and environmental limitations, but also the economic, political, and social constraints that determine which projects can actually be implemented (Beaumelle et al., 2023).

From a technical point of view, the volume of water entering the 13 largest rivers in the world is 9 trillion cubic meters. If we take an average height of 100 meters, then approximately 100 trillion kWh of electricity can be produced annually. This is 6 times more than the energy consumed by the planet in a year. Currently, hydropower plants (HPPs) can be classified according to energy categories as follows:

- 1. Power of small hydropower plants:** In many European countries, small hydropower plants are considered to be plants with a capacity of up to 10 MW. For example, the European Union has adopted this indicator as a standard. USA: Small hydropower plants are usually classified in the power range of 5-30 MW. China: In China, the power of small hydropower plants can reach up to 50 MW.
- 2. Large hydroelectric power plants:** The capacity constraints for large hydroelectric power plants are largely determined by natural conditions. For example, China's Three Gorges Dam is the world's largest hydroelectric power plant with a capacity of 22,500 MW. In other countries, such power plants typically have a capacity of 1,000 MW or more.
- 3. Medium-sized HPPs:** There are also different approaches to the power range of medium-sized HPPs, which fall between small and large HPPs. For example, in some countries this interval is accepted as between 10-100 MW.

4. Micro and mini HPPs: Micro hydroelectric power plants (usually up to 100 kW) and mini hydroelectric power plants (from 100 kW to 1 MW) are widely used to provide energy for agriculture and residential areas.

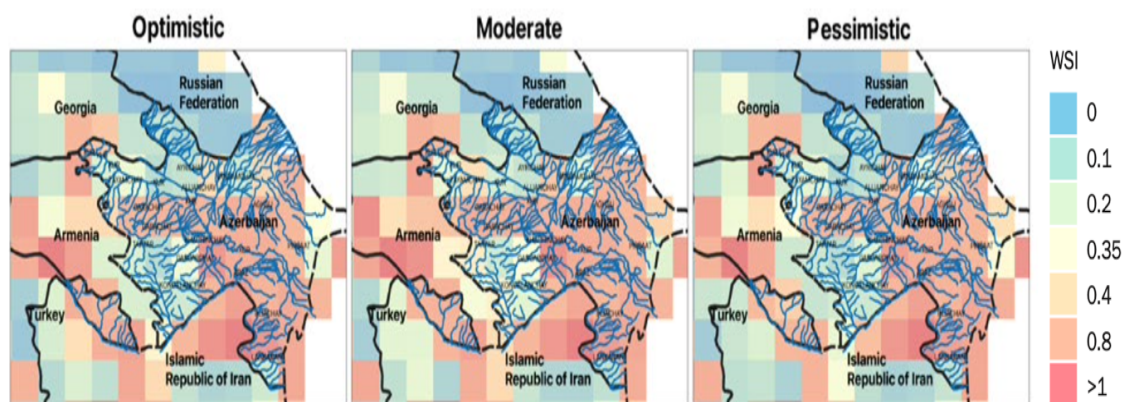
Given that the concept of a small hydroelectric power station includes, in addition to the installed capacity, its construction volumes and total capital investments, which depend not only on the capacity but also on the size of the turbines, specific parameters determine the classification. Small hydroelectric power stations equipped with turbines with a unit capacity of up to 10 MW or a wheel diameter of not more than 2.8 m are classified as small hydroelectric power stations and are decisive in low-pressure circuits. These installation parameters determine not only the technical characteristics of the hydroelectric power station but also enable significant simplification of the hydroelectric power station building design, elimination of numerous devices and structures, and integration of flow path elements with the building structure (Tomczyk et al., 2025).

Understanding the specificities explained above is of great importance because it allows for greater utilization of hydroelectric resources, as it influences decision-making regarding management and modernization in the context of strategic planning. Azerbaijan has basins and reservoirs with hydroelectric potential (e.g., Mingachevir, Shamkir, Yenikend) that have played a central role in its electricity grid and in water regulation in the Kura-Araz Basin. Hydropower plants contribute to energy diversification, which is especially necessary for seasonal demands (Sakal, 2022). But Azerbaijani reservoirs not only generate electricity; they also regulate floods, store flows for irrigation, and shape the ecological landscape and sedimentary dynamics in the Kura Basin. The creation of reservoirs and the inefficient operation of HPPs can cause changes in lagoon and riparian habitats, affecting local ecosystem services and, in some cases, fishermen and rural communities that depend on seasonal water regimes. The above underpins the relevance of this research.

DEVELOPMENT

The reconstruction and construction of hydroelectric power plants (HPPs) on small rivers in the Republic of Azerbaijan is considered one of the most promising areas for the development of renewable energy sources. Small rivers are vital components of the river system. Therefore, harnessing the hydropower potential of small rivers requires a more strategic approach. In other words, it is important to study both their positive and possible negative impacts during the construction of small HPPs. As a renewable energy source, the development of the hydropower sector and the construction and rehabilitation of small and micro hydroelectric power plants are priority areas. As can be seen in Figure 1, the hydrographic network in the republic is quite uneven. The average density of the river network is 0.33 km/km². There are sufficient rivers in the republic, and utilizing the hydropower potential of these rivers is of great importance.

Fig 1. Forecasting water shortages in neighboring countries.



Source. Results from an Integrated Assessment Model, World Bank.

Note. Regional Water Scarcity Index (WSI > 0.4 denotes conditions of scarcity) by 2050 under three climate scenarios. The three climate scenarios used here are Optimistic (SSP 1–1.9), Moderate (SSP 2–4.5), Pessimistic (SSP 3–7.0)

But also, Azerbaijan's environmental policy is based on protecting ecological systems, realizing the country's economic potential, and efficiently using natural resources to meet the energy needs of current and future generations. Ensuring environmentally sustainable development means preventing or minimizing serious environmental impacts resulting from economic activities (Khan et al., 2019). The three main goals of Azerbaijan's environmental policy may be sum up as follows:

1. To implement the principles of sustainable development by accepting ecological safety as a fundamental requirement, minimizing human impacts on the environment, and applying the best available practices to regulate its protection.
2. To use natural resources efficiently, to obtain energy from renewable energy sources to meet the needs of current and future generations, and to use alternative, non-traditional methods to achieve energy efficiency.
3. To assess national requirements, taking into account global environmental issues, find solutions, and ensure their implementation by expanding relations with international organizations.

One of the 5 targets in the "Azerbaijan 2030: National Priorities for Socio-Economic Development" approved by the President Aliyev in February 2021 is the transition to 'green energy'. According to the document, the share of alternative and renewable energy sources in primary consumption should be increased in all sectors of the economy to reduce the negative impacts of climate change. At the same time, the use of environmentally friendly vehicles will be stimulated to achieve this goal. Eight months after this document – in December 2021 – the government adopted another document. The Presidential Decree on "Accelerating Economic Development in the Liberated Territories" states that investors will be supported in the liberated territories for the purpose of implementing environmentally friendly technologies, creating 'green growth', and using renewable energy sources.

In addition, according to another decree signed in May 2021, projects have been developed to create a 'green energy' zone in the liberated territories. The solar energy potential of these territories has been determined as 7,200 MW and the wind energy potential as 2,000 MW. At the same time, it is noted that there are suitable water sources for electricity generation. The Ministry of Energy states that the goal of the transition to 'green energy' in the period until 2030 is to increase the share of alternative energy from the current 17% to 30%.

Hydropower projects in the liberated territories of Azerbaijan

The hydropower potential of Karabakh and East Zangezur is noteworthy due to the regions' abundant water resources, which account for approximately 25% of Azerbaijan's total water resources. Major rivers such as the Tartar and Bazarchay play a crucial role in this potential. Ongoing assessments have shown that a large part of this hydropower potential remains untapped and offers great opportunities for future expansion. Harnessing these resources would not only meet current energy needs but would also position Azerbaijan as a leader in sustainable energy development in the region (Majidli et al., 2023).

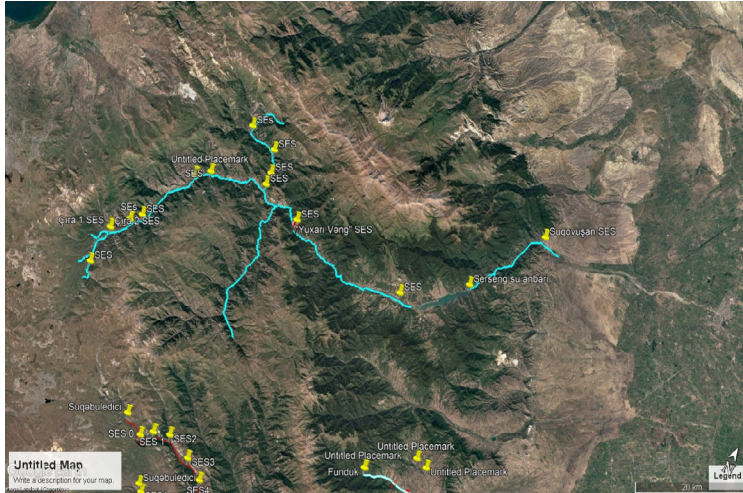
To increase energy production and promote environmentally friendly energy sources in the Karabakh and East Zangezur regions, several small hydroelectric power plants were commissioned at the end of 2023 (Chirag-1 with a capacity of 8.33 MW, Chirag-2 with a capacity of 3.6 MW, Qamishli with a capacity of 6.33 MW, Soyuqbulag with a capacity of 5.3 MW, Meydan with a capacity of 3.4 MW, Mishni with a capacity of 8.25 MW, and Alkhasli with a capacity of 6 MW). These facilities, either newly built or reconstructed after damage during past conflicts, have a combined capacity of approximately 270 MW. Their annual electricity production is approximately 492 million kilowatt-hours (kWh), a figure that significantly meets regional energy needs while reducing dependence on fossil fuels and creating a more sustainable energy grid.

In addition, Azerbaijan has announced plans to commission 12 hydroelectric power plants by 2024. Among these projects, six new hydroelectric power plants with a total capacity of 37.5 MW are currently under construction. These plants are expected to produce more than 110 million kWh of electricity annually, further strengthening the region's energy infrastructure. The strategic importance of these small hydropower plants is multifaceted. They play a crucial role in increasing Azerbaijan's energy independence by reducing the country's dependence on natural gas imports. This change is expected to save 350-400 million cubic meters of gas annually, thereby strengthening the country's energy security and providing additional reserves for export or alternative domestic use. From an environmental perspective, these power plants are designed to produce zero-emission electricity, making them a key contributor to Azerbaijan's goals of carbon neutrality and environmental sustainability. By reducing greenhouse gas emissions, these initiatives align with global efforts to combat climate change and promote a greener future.

In 2024, a total of 32 hydroelectric power stations between Karabakh and Eastern Zangazur achieved a combined capacity of 270 MW, producing 550 million kWh of green energy. This output not only supplied liberated areas but also fed into the national grid, saving 120 million cubic

meters of natural gas and cutting 225,000 tons of CO₂ emissions. New facilities (see Figure 2) commissioned include the Yukhari Vang (22.5 MW), Zar (4.3 MW), Zabukh (2.8 MW), Gyrygishlag (4.6 MW), and three 10.5 MW plants in Zangilan. Small plants such as Zabux (4×0.7 MW) and Garikishlaq (4 MW) in Lachin collectively generated 21 million kWh by May 2025. In January–February 2025, hydroelectric generation surged by 55.3%, underscoring hydropower's growing share in the national energy output.

Fig 2. HPPs built on the Tartar River



Source: satellite images available on the internet

Expansion and Integration in Karabakh and Eastern Zangazur

By mid-2025, Azerbaijan has ramped up to 38 hydropower plants (32 active + 6 soon operational) in Karabakh and Eastern Zangazur, reaching a total capacity of 307 MW. This generated green energy that translates into a projected annual saving of 200 million m³ of natural gas and avoidance of 400,000 tons of CO₂ emissions. The Ashagi Malibeyli (3.1 MW) and Mirik (3.5 MW) plants were inaugurated in Lachin in May 2025 and integrated into the national SCADA grid via fiber optics. The Giz Galasi Dam, a bilateral hydroelectric project on the Aras River with Iran, came online in May 2024, boasting 2×40 MW capacity and serving both electricity and irrigation needs. Additionally, the Khoda Afarin complex, with a 102 MW capacity, was inaugurated the same day, marking two strategic cross-border hydro projects. In Table 1 is shown the current HPPs in the liberated territories.

Table 1. Plants commissioned so far in Karabakh and East Zangezur regions.

Plant	Location	Power (MW)
Chirag-1	Zangezur	8.33
Chirag-2	Zangezur	3.6
Qamishli	Zangezur	6.33
Soyuzbulag	Zangezur	5.3
Square	Zangezur	3.4
Mishni	Lachin	3
Alkhasli	Lachin	6
Zabukh	Zangezur	2.8
Gariqishlag	East Zangezur	4
Yellow-haired	Zangilan	5

Upper Wang	Kalbajar	15
Kalbajar-1	Kalbajar	4.4
Wandering	Kalbajar	50
Sugovushan-1	East Zangezur	7.8
Sugovushan-2	East Zangezur	3
Rosebird	East Zangezur	8
God bless you	Gabriel	100
Maiden Tower	Zangilan	40
Dice SES	Kalbajar	4.8
Jahangirbeyli	Zangilan	10.5
Shayifli	Zangilan	10.5
Zangilan	Zangilan	10.5

Source: own elaboration.

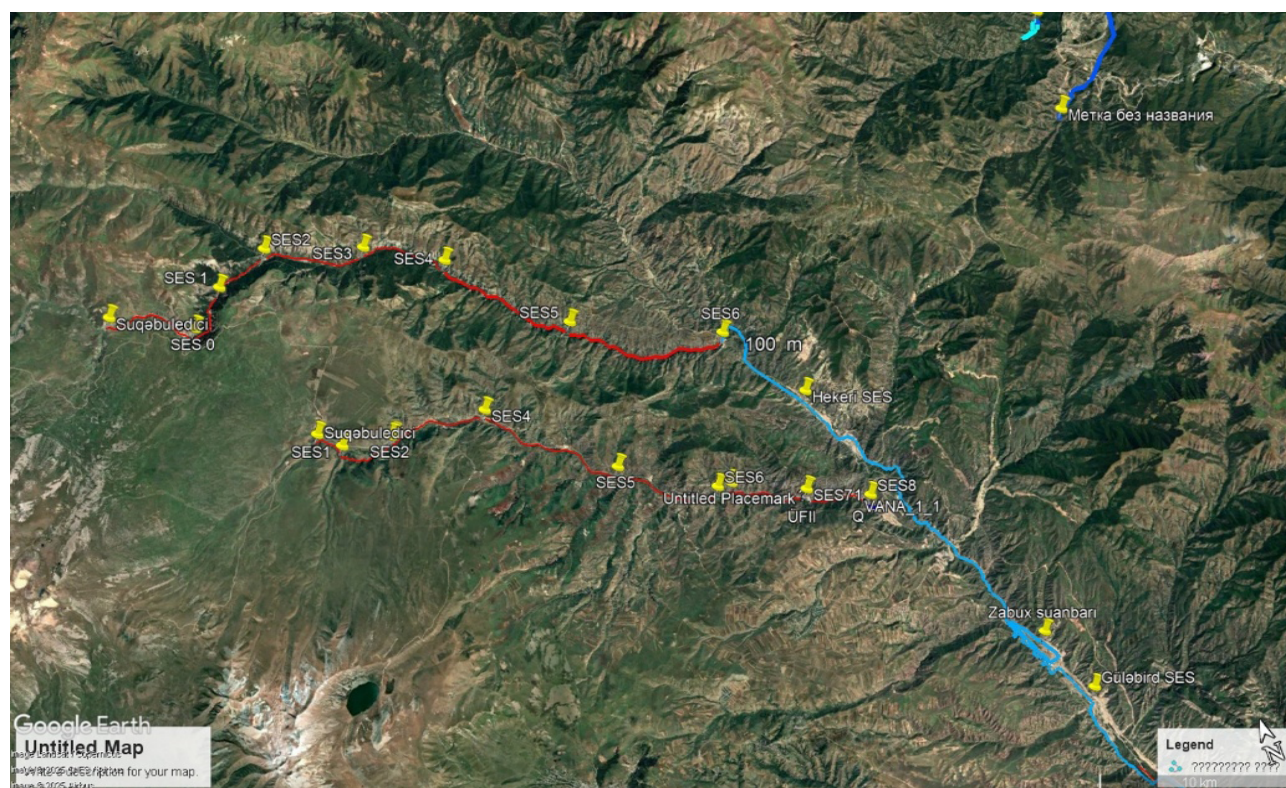
The government has announced plans to build 28 new small hydropower plants in Karabakh and East Zangezur (Figure 3 and 4). These facilities are expected to strengthen regional energy security, create jobs and support local communities. One of the most ambitious projects involves the construction of a large hydropower plant with a capacity of more than 20 MW. This initiative aims to set new standards for sustainable infrastructure in the South Caucasus.

Fig 3. Location plan of HPPs on the Ohchu River.



Source: satellite images available on the internet.

Fig 4. Plan for the use of the hydropower potential of the Zabukh branch of the Hakkari River.



Source: satellite images available on the internet.

Prospects of Small Hydroelectric Power Plants

In general, it is envisaged to design small hydropower plants on small mountain rivers, but the exact sources are not specified. Based on the basic analysis of the project, a general assessment has been made, taking into account the main environmental threats to mountain rivers. Since small hydroelectric power plants are expected to use the diversion method to generate power, the electricity produced by this method does not cause any environmental pollution or adverse environmental effects (Guliyev, 2025). Small hydroelectric power plants are easy and cost-effective, and are also less likely to have accidents. Small hydroelectric power plants are long-lived and the power generation process is largely automated, so less manpower is required to operate and monitor the power plant. Small hydroelectric power plants are usually not designed with dams and have minimal impact on the grid. However, this method may require the construction of dams in technological project proposals or may plan to build several small hydroelectric power plants on a small river, and may also require the storage of large amounts of water in reservoirs without interfering with the flow of water regardless of the water regime.

The advantages of small hydroelectric power plants, including general hydroelectric power plants, can be summarized as follows:

- Fuel saved compared to thermal power plants: 0.4 tons of fuel per 1,000 kW; in other words, the energy produced by a 1.0 billion kW hydroelectric power plant has a fuel equivalent of 400,000 tons;
- Reducing damage from freshwater floods;
- Improving water supply for the population and production facilities located near the HPP;
- Increasing the efficiency of irrigation, land reclamation and other agrotechnical works;
- Improving the microclimate near the HPP, etc.

The development of small hydropower plants, in addition to economic and environmental benefits, also has an important social aspect and will help the country meet its commitments to reduce CO₂ emissions under the Kyoto Protocol. Small HPPs create conditions for decentralized, independent use of electricity, accelerate the development of regions, improve electricity supply quality indicators, and improve the ecological state of rivers. The costs of small hydroelectric power stations, in terms of the repetition of the technological process, are significantly lower than those of smaller analogues of larger stations. At the same time, although small hydroelectric power stations need to be protected from environmental damage, these stations have a much smaller negative impact on the environment (Couto & Olden, 2018; Moran et al., 2018). Because Azerbaijan's small hydropower potential is mainly located in mountainous areas, the stations to be built will have high pressure and will require less water for the same amount of energy. The lifetime management costs of small hydroelectric power stations are particularly significant, and project efficiency is crucial to minimizing them.

However, as mention before, the construction of these plants in mountainous areas can lead to the destruction of coastal areas and the destruction of the natural environment, especially biodiversity, due to the engineering and geological conditions that cannot be utilized compared to plain areas (Mammadov, 2024; Othman et al., 2025; Soomro et al., 2024). The use of hydroelectric energy in rivers and mountain streams leads to changes in the natural environment, flow regulation, chemical composition, temperature and oxygen, which can have a significant impact on the aquatic ecosystem in the lower reaches of the river (Majidli, 2023; Majidli et al., 2023). Debris in rivers has a significant negative impact on the ecosystem, creating barriers on the migration routes of spawning fish and causing uneven reproduction. In general, the development of hydroelectric energy can lead to changes in the physical and chemical parameters of water in streams (temperature, flow regimes, dissolved gases). This can lead to pressure on aquatic biodiversity.

Although small HPPs are constructed using the diversion method, the construction of several small hydroelectric power stations on mountain rivers can negatively impact the river ecosystem by drying up the rivers during drought periods, reducing flows and, as a result, affecting the habitats of water-related plants and animals (e.g., changing fish species, depriving fish of their food sources). Riverbed basins created for the operation of small HPPs can cause and increase soil erosion. In this regard, it is advisable to consider areas exposed to severe erosion before planning and to conduct research in this direction. In Table 2 is shown the potential risks of these projects, that have to be consider for a proper management.

Table 2. Expected significant, negative, short-term impacts of HPPs effects.

Expected Effects	Suggestions, Mitigation Measures
Hydropower development may have a negative impact on canals, but it can also harm the river ecosystem by reducing river flows. The construction of diversion channels may cause changes in the riverbed. The method of water abstraction (although it is a diversion method) and the lack of an equal water balance in the upper and lower reaches of the river can create a risk of drying out in one part of the river.	Designing small hydroelectric power plants, taking into account water consumption, seasonal flow assessment, and the ecological sensitivity of the river (e.g., based on the past 5–10 years). Limiting the construction of small hydroelectric power plants on rivers with a risk of statistical water use, or avoiding the construction of several small water supply stations on one river. Ensuring the protection of ecological flows in rivers to reduce the impact on the ecosystem. In addition to population water needs, addressing technical and irrigation water needs through public consultations with local populations.

Source: taken from AREA (2015).

However, depending on the relief form of the small HPP, the technological option may require more or less land. In small HPP projects, large areas with forest areas or riverbed cover may be required for the construction site. In this case, it is important to anticipate the construction camp and the Small HPP facilities and buildings for the temporary placement of technical equipment, as well as the requirements for productive layers and plant protection. In particular, erosion can lead to an increase in soil load and soil erosion or desertification processes with anthropogenic influences. In all other cases, no significant changes in the ecology of the soil are observed when receiving energy through hydroelectric power plants. At the same time, when a hydropower plant is created, along with alternative electricity, additional water sources for irrigation and additional irrigated land areas can lead to positive changes. The following proposals and mitigation measures are appropriate:

- An environmental assessment of the current state of the upper or lower reaches of the riverbed for KSES should be carried out at the stage of designing and justifying suitable options.
- Projects should be developed that reduce the placement of HPPs in areas that require extensive land use and excavation.
- To preserve soil fertility and prevent leaching, measures should be taken to study the physical and hydrogeological properties of the soil, manage drainage, rainfall, and waste during the design phase, as well as protect the soil from chemical contamination.
- Restriction of movement of vehicles and equipment on certain routes, restoration of vegetation cover, isolation measures, taking into account particularly sensitive summer and winter pastures or natural areas, and monitoring activities should be implemented to prevent the release of pollutants into the environment.
- Creation of facilities for cleaning and discharging slag deposits generated during the construction of dams.
- Hydropower plants should not be located in natural reserves (natural and biosphere reserves, national parks, important ornithological areas, etc.).
- Planning for small hydropower plants should consider impacts on drinking water sources, water demands from various sectors, and local fisheries.
- It is necessary to prevent or significantly limit the discharge of stormwater runoff laden with pollutants from cleaning and construction activities into water bodies.

When considering the location of geothermal power plants, which is limited to regions where geothermal water sources are available, factors affecting water resources - steam pipes, buildings and other infrastructure, groundwater levels, land subsidence, waterlogging, seismic activity, and the release of methane, hydrogen, nitrogen and hydrogen sulfide from deep layers of the earth to the surface - must be taken into account when choosing a location (Milenić et al., 2010). Where hydropower plants are to be located, a detailed study should be conducted that analyzes the likely cumulative impacts of the entire river basin. This study should consider the following issues (but not limited to):

- Minimum ecological flows (i.e., the quantity, timing, and quality of water flows required to maintain freshwater and marine ecosystems)
- River fragmentation for fish and other aquatic life
- River water consumption, seasonal flow regime and ecological sensitivity of watersheds (e.g., limiting the construction of hydroelectric power plants on rivers at risk of drying up within 5-10 years or preventing the

construction of several hydroelectric power plants on one river)

- Water demand of the population living in the river basin (including technical and irrigation water)
- Run-of-river types of hydropower plants should prevail on the river.
- Technical measures to prevent the fragmentation of migratory fish corridors should be incorporated into the project design and the effectiveness of these measures should be assessed during the Environmental Impact Assessment process.
- For geothermal power plants, closed systems should be used in which water is injected back into the original ground layers.

Rehabilitation and modernization of irrigation schemes is key to increasing water productivity. Over the past decade, authorities have invested heavily in the rehabilitation and modernization of on-farm and off-farm irrigation schemes, with more than 118,000 hectares of land rehabilitated between 2011 and 2017. Despite high cropping intensity, many farmers lack access to quality irrigation services due to infrastructure degradation and salinization — more than 600,000 hectares were affected by salinization in 2017. Only half of the irrigated areas are equipped with drainage, and most on-farm infrastructure consists of earthen canals. Finally, water user associations, as the entities legally responsible for providing irrigation services, must have sufficient capacity to manage and maintain hydraulically complex systems. For this reason, the creation of small-scale reservoirs and the construction of hydroelectric power stations on them is very important. At the same time, the following measures should be in the spotlight:

- Flow regimes should be adapted to seasonal fish spawning periods.
- Migration routes should be restored by installing fish ladders, fish elevators and bypass channels.
- Sensor networks should be installed for real-time monitoring of water temperature, dissolved oxygen, and other parameters.
- Automatic alerts and activation of action plans should be implemented in case of abnormal changes.
- During periods of drought, energy production should be switched to a minimum environmental impact mode.
- Adaptive management models that reduce the impact of climate change should be implemented.
- Real impacts should be assessed in collaboration with local fishermen and ecologists.

- Public consultations should be conducted from the project stage.

CONCLUSIONS

Azerbaijan's hydropower strategy has implications beyond its borders. As a major player in the global energy market, the country's commitment to renewable energy serves as an example for neighboring states. By prioritizing green energy in post-conflict regions, Azerbaijan is demonstrating how sustainable development can contribute to peacebuilding and regional stability. In addition, Azerbaijan's efforts are aligned with global climate goals, including the Paris Agreement. Expanding hydropower supports the country's commitment to reducing greenhouse gas emissions and transitioning to a low-carbon economy. These achievements have positioned Azerbaijan as a leader in renewable energy development in the South Caucasus.

By harnessing the power of its rivers and streams, the country is securing its energy future and making a significant contribution to global efforts to combat climate change. Through strategic investments, innovative technologies, and a commitment to sustainability, Azerbaijan is creating a lasting legacy of green energy for future generations. The Azerbaijani hydropower market is expected to show steady growth during the forecast period 2023-2027. This growth is explained by the country's favorable geographical conditions for hydropower production and the government's efforts to diversify its energy mix. Azerbaijan has implemented supportive policies and regulations to encourage the development of hydropower projects. These initiatives include providing incentives for private sector participation in the sector and foreign direct investment.

The outlook for Azerbaijan's hydropower market is positive, driven by growing renewable energy demand and the country's commitment to reducing its dependence on fossil fuels. As priority is given to the development of hydropower infrastructure, the market is expected to witness significant investments and project installations. Consequently, Azerbaijan's hydropower segment appears poised for growth over the forecast period. The country's favorable geographical conditions, supportive government policies, and commitment to renewable energy make it an attractive location for hydropower development.

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