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Article

Improving Financial Mechanisms for Attracting Private Investment in The Hydropower Sector

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Abstract: This article examines financial mechanisms for attracting private investment into hydropower using recent global and Uzbek evidence. The analysis draws on IHA, IRENA, World Bank, IFC and official Uzbek sources. The findings show that project finance, long-term PPAs, blended finance, partial guarantees, enabling-infrastructure support and green capital-market instruments should operate as a coordinated financing package. Based on the experience of Nepal, Türkiye and India, the paper proposes for Uzbekistan a portfolio-based model combining sponsor equity, long-term local bank debt supported by development-finance resources, risk-sharing instruments and post-commissioning green-bond refinancing.

Keywords: Hydropower, Private Investment, Project Finance, PPP, Blended Finance, PPA, Green Bonds, Risk-Sharing

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1. Introduction

In the global energy system, hydropower is increasingly being reassessed as a strategic infrastructure asset capable of simultaneously providing electricity generation, power-system balancing, and long-term energy-storage services. According to the International Hydropower Association (IHA), global installed hydropower capacity reached 1,469 GW by the end of 2025, with 28 GW of new capacity commissioned during the year; global pumped-storage hydropower capacity also exceeded 200 GW for the first time [1].

The investment attractiveness of hydropower projects is primarily determined by their long operational lifespan and relatively low operating costs. However, these advantages are offset by substantial upfront capital requirements and prolonged construction periods. The International Renewable Energy Agency (IRENA) reports that the global weighted-average total installed cost of newly commissioned hydropower projects was USD 2,267/kW in 2024, while the levelized cost of electricity (LCOE) was USD 0.057/kWh [2]. Consequently, financing cost, loan maturity, and the allocation of risks among the government, investors, lenders, and electricity off-takers are decisive factors in project bankability.

The academic literature emphasizes that multilateral financial institutions can play a catalytic role in mobilizing private capital and connecting diverse investor groups within hydropower projects [3]. Research on small hydropower also shows that investment costs and project efficiency are highly sensitive to technical configuration and site-specific conditions [4]. From a financing perspective, blended-finance structures can improve

bankability when concessional resources and risk-sharing mechanisms are designed to mobilize, rather than displace, private capital [5]. These findings indicate that hydropower financing should be considered as an integrated architecture rather than as a set of isolated instruments.

The utilization of Uzbekistan's hydropower potential has accelerated considerably in recent years. In 2017, the country operated 36 hydropower plants with a combined installed capacity of 1.6 GW; by 2025, the number of facilities had increased to 100 and total installed capacity reached 2.4 GW, while hydropower generation amounted to 6.5 billion kWh [6]. In addition, 73 prospective projects with an estimated total investment value of USD 5.8 billion are planned for 2026–2032, with the objective of adding approximately 3.6 GW of generating capacity [7]. The scale of these planned investments shows that public and corporate resources alone are insufficient and that bankable mechanisms for private and institutional capital are required.

Against this background, the research gap lies in the need to combine revenue-security instruments, long-term credit, blended finance, guarantees, infrastructure support, and capital-market refinancing within a coherent model adapted to Uzbekistan. The present study therefore treats Power Purchase Agreements (PPAs), development-finance resources, risk-sharing instruments, viability-gap support, and green financing as mutually reinforcing components of a single financing framework.

The objective of this study is to systematically examine and classify internationally established financial instruments for attracting private investment into the hydropower sector, assess recent institutional developments in Uzbekistan, and develop a multi-layered financing mechanism tailored to small- and medium-scale hydropower investment projects.

2. Materials and Method

This study employs the principle of data triangulation to ensure the reliability and comprehensiveness of the analysis. Global hydropower development and cost statistics were obtained from the International Hydropower Association and IRENA. Project-level and development-finance evidence was drawn from World Bank documentation on Uzbekistan and IFC/ADB documentation on Nepal [8]. Regulatory and policy evidence was obtained from official sources in Türkiye and India [9], together with relevant Uzbek government sources. The methodological framework incorporates comparative benchmarking, institutional analysis, financial-architecture assessment, and the calculation of relative performance indicators.

To assess the current pace of private sector participation in hydropower development, three quantitative indicators are employed. The first is the capacity commissioning ratio, calculated as:

$$\mathbf{Kq = (Qcommissioned / Qplanned) \times 100}$$

The second indicator is the project initiator participation ratio, expressed as:

$$\mathbf{Kt = (Ninitiators / Nplanned) \times 100}$$

The third indicator is the commercial capital mobilization ratio, determined as:

$$\mathbf{Km = Ccommercial / Cconcessional}$$

These indicators are used to evaluate the current implementation performance of the government development program and to determine the extent to which concessional financial resources facilitate the crowding-in of private capital.

The proposed financing model is based on the fundamental principles of project finance. Under this approach, each investment project is implemented through a separate special purpose vehicle (SPV), with debt repayment primarily secured by the cash flows generated by the project itself. To assess financial sustainability, the Weighted Average

Cost of Capital (WACC) and the Debt Service Coverage Ratio (DSCR) are adopted as conceptual evaluation criteria, as expressed by the following equations:

$$WACC = [E / (D + E)] \times Re + [D / (D + E)] \times Rd \times (1 - T)$$

$$DSCR = CFADS / Debt\ Service$$

Within the scope of this study, a detailed discounted cash flow (DCF) model is not developed. Instead, the analysis primarily focuses on the institutional arrangements and financial instruments required to establish bankable conditions for attracting private investment into hydropower projects.

3. Results and Discussion

Although the global hydropower market continued to expand in terms of installed capacity in 2025, access to adequate financing remains one of the sector's major constraints. According to IHA estimates, achieving an approximately twofold increase in global hydropower capacity by 2050 under net-zero emissions scenarios would require nearly USD 3.7 trillion in cumulative investment, equivalent to average annual investment of about USD 130 billion [10]. The scale of this requirement indicates that such targets cannot be achieved without active participation by private investors, pension and insurance funds, commercial banks, and capital-market instruments.

Table 1. Latest Global and Uzbekistan-Specific Hydropower Market Indicators

Indicator	Value	Period	Remarks
Global installed hydropower capacity	1,469 GW	2025	IHA; combined conventional hydropower and pumped-storage capacity
New hydropower capacity added globally	28 GW	2025	Including 11.7 GW of pumped-storage hydropower
Global hydropower project pipeline	1,127 GW	2026 Report	Including 621 GW of pumped-storage hydropower
Levelized cost of electricity (LCOE) for new hydropower projects	USD 0.057/kWh	2024	IRENA global weighted average
Total installed cost of new hydropower projects	USD 2,267/kW	2024	IRENA global weighted average
Installed hydropower capacity in Uzbekistan	2.4 GW	2025	50% higher than in 2017
Number of hydropower plants in Uzbekistan	100	2025	Compared with 36 plants in 2017
Hydropower electricity generation in Uzbekistan	6.5 billion kWh	2025	Ministry of Energy of the Republic of Uzbekistan
Commissioned private small- and micro-hydropower projects	64 projects; 41.6 MW	August 2026	Equivalent to 25.4% of the previously planned 164 MW capacity
Revised target for small- and micro-hydropower development	Over 204 MW; 620 million kWh/year	2030	Presidential Resolution No. PQ-298 (2026)

The data presented in Table 1 indicate that Uzbekistan's hydropower assets are expanding rapidly; however, the actual pace of private sector participation in the small- and micro-hydropower market remains below the planned development targets. As of August 2026, 64 projects with a combined installed capacity of 41.6 MW had been

commissioned, representing 25.4% of the previously established 164 MW private-sector development target; project initiators had been identified for 932 out of approximately 3,000 prospective projects [11].

These findings suggest that the primary challenge extends beyond the mere existence of investment demand and lies in the insufficient effectiveness of mechanisms designed to bring projects to financial close. Limited bankable project documentation, long-term debt financing, and risk-mitigation instruments continue to constrain private-capital mobilization for small- and micro-hydropower projects in Uzbekistan [12].

The World Bank's Uzbekistan Small Hydropower Development Project for 2025–2030 aims to address these financing gaps. The project has been allocated USD 150 million in concessional financing and is expected to mobilize approximately USD 38 million in commercial financing; by 2030, supported small hydropower capacity is projected to reach up to 150 MW with annual electricity generation of 520 GWh.

Based on the announced financing amounts, the commercial capital mobilization ratio is calculated as Km = 38/150 = 0.253, indicating that approximately USD 0.25 in commercial financing is expected to be mobilized for every USD 1 of concessional financing. This ratio could be further increased as the project portfolio develops through financial guarantees, refinancing facilities, and green capital-market instruments.

Presidential Resolution No. PR-298, adopted in 2026, established a new investment framework for small- and micro-hydropower projects in Uzbekistan [13]. For projects with an installed capacity of up to 5 MW, electricity purchase tariffs are determined through a descending-price auction mechanism conducted on the E-auksion electronic platform. The initial and minimum permissible bid prices are established as percentages of the electricity tariff applicable to Group II consumers, depending on the installed capacity of the project.

For micro-hydropower plants with a capacity of up to 500 kW, the initial auction price is set at 150% of the Group II consumer tariff, while the minimum permissible price is 50%. For projects with capacities ranging from 500 kW to 2 MW, the corresponding thresholds are 120% and 40%, respectively, whereas projects with capacities between 2 MW and 5 MW are subject to initial and minimum price thresholds of 100% and 30%, respectively.

According to the Ministry of Energy of the Republic of Uzbekistan, electricity generated by these facilities is purchased under long-term guaranteed Power Purchase Agreements (PPAs), with purchase tariffs indexed in accordance with changes in consumer electricity tariffs [14]. This regulatory approach enhances revenue predictability and creates more favorable conditions for attracting private investment. Nevertheless, bankability screening is required so that excessively low auction bids do not undermine debt-servicing capacity and long-term project viability.

International Experience and Mechanisms Applicable to Uzbekistan:

Nepal's Upper Trishuli-1 Hydropower Project represents a significant example of how a large-scale hydropower facility can be structured as a bankable private-sector investment in an emerging market. The 216 MW project has an estimated total investment cost of approximately USD 650 million, with a lender consortium led by IFC arranging a debt package of approximately USD 453 million.

The project is being implemented under a 35-year Build–Own–Operate–Transfer (BOOT) concession model, supported by a long-term Power Purchase Agreement (PPA) with the national electricity utility. In addition to financing provided by the IFC and the Asian Development Bank (ADB), the project has attracted concessional climate finance resources.

This experience demonstrates that private capital alone is insufficient to ensure the financial viability and bankability of large-scale hydropower investments in emerging

markets. An integrated framework combining long-term PPAs, concession agreements, political and foreign-exchange risk mitigation, and blended finance is therefore required.

In Türkiye, a key component of the framework for attracting private investment into the hydropower sector is the integrated operation of electricity generation licenses, water-use rights, and the Renewable Energy Resources Support Mechanism (YEKDEM) .

Hydropower purchase tariffs are subject to indexation mechanisms incorporating inflation and foreign exchange components. In addition, projects utilizing domestically manufactured electromechanical equipment are eligible for a separate local content premium, designed to stimulate domestic industrial production and strengthen national supply chains.

For Uzbekistan, the most significant implication of the Turkish experience lies in the potential integration of domestic equipment manufacturing under the UzHydroPower initiative with targeted tariff incentives or capital subsidies. Such an approach could encourage the use of locally manufactured hydropower equipment, reduce foreign-currency demand associated with imported technologies, and strengthen project sustainability.

India's experience demonstrates that government intervention can improve the financial viability of hydropower projects without directly assuming the role of a private investor. Under India's hydropower support framework, public resources are used for enabling infrastructure and small-hydropower development, including support mechanisms applicable to private projects.

Furthermore, under a separate small hydropower development program for 2026–2031, the Indian government has allocated INR 2,584.6 crore to incentivize the development of approximately 1,500 MW of additional installed capacity. Depending on the geographical location of the projects, central financial assistance may cover up to 20–30% of total project costs.

The Indian experience suggests that introducing viability gap funding (VGF) and enabling-infrastructure grants would be particularly appropriate for Uzbekistan. Such instruments can reduce initial investment burdens for projects facing substantial grid-connection, access-road, or hydraulic-infrastructure costs and thereby improve bankability without replacing private investment.

Table 2. Mechanisms for Attracting Private Investment in International Practice and Approaches to Their Adaptation in Uzbekistan

Country	Existing Mechanism / Key Indicators	Main Financial Impact	Proposed Adaptation for Uzbekistan
Nepal	Upper Trishuli-1: 216 MW; approximately USD 650 million in total investment; USD 453 million debt financing package; 35-year BOOT concession and long-term PPA.	Blended finance involving IFC/ADB, standardized bankable PPAs, and concession agreements.	SPV-based financing for 5–50 MW and large hydropower projects, standardized PPAs, partial credit guarantees, and international lending consortia.
Türkiye	YEKDEM: 10-year purchase support; tariff indexation based on inflation and USD/EUR exchange rates; local content incentives.	Improved revenue predictability and mitigation of foreign exchange risks.	Introduce inflation and exchange rate adjustment mechanisms into the PR-298 tariff framework, alongside incentives for domestically manufactured UzHydroPower equipment.

India	INR 12,461 crore enabling infrastructure support program covering private projects; financial assistance of up to 20–30% for small hydropower projects.	Public financing of socially beneficial infrastructure components reduces private investors' capital expenditure requirements.	Introduce VGF and infrastructure grants for grid connections, access roads, and hydraulic infrastructure to improve bankability and facilitate competitive auction tariffs.
Uzbekistan	USD 150 million in World Bank concessional financing and USD 38 million in expected commercial financing; E-auksion; guaranteed electricity purchases; target exceeding 204 MW of small- and micro-hydropower capacity.	Development of an institutional and financial framework for attracting private hydropower investment.	Mobilize private capital through portfolio aggregation, partial credit guarantees, green bond refinancing, and standardized Environmental and Social Management Systems (ESMS).

The findings of the analysis indicate that attracting private investment into small- and medium-scale hydropower projects in Uzbekistan requires an integrated, multi-layered financing structure (financial stack) rather than reliance on a single financial instrument.

The **first layer** comprises equity contributions from project sponsors and strategic investors. The **second layer** consists of long-term senior debt financing provided by domestic commercial banks, with loan maturities extended through credit facilities supported by the World Bank and other development finance institutions (DFIs).

The **third layer** incorporates risk mitigation instruments, including partial credit guarantees, first-loss reserves, and insurance coverage against construction-related and political risks. The **fourth layer** involves viability gap funding (VGF) or enabling infrastructure grants for economically viable projects that face substantial upfront infrastructure costs.

The **fifth layer** provides for refinancing through green bonds or sukuk once hydropower facilities become operational and generate stable and predictable cash flows.

This multi-layered financing architecture is designed to facilitate effective risk allocation, enhance project bankability, reduce financing constraints, and mobilize long-term private and institutional capital for the sustainable development of Uzbekistan's hydropower sector.

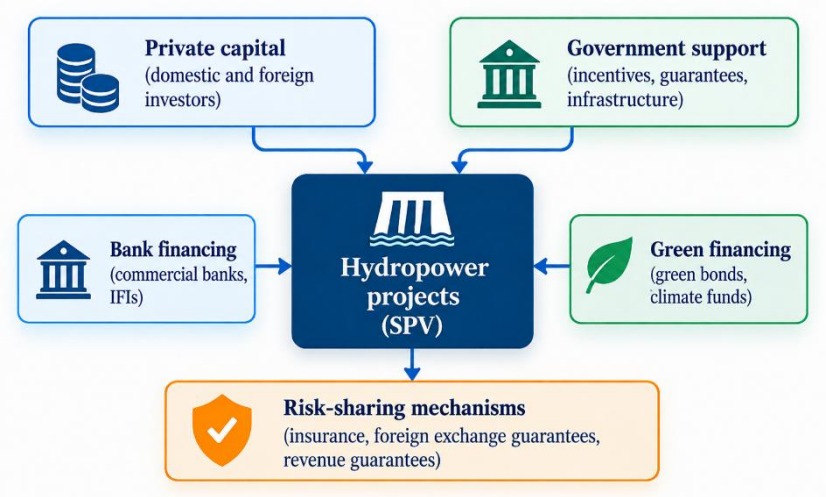


Figure 1. Proposed Financial Mechanism for Attracting Private Investment into the Hydropower Sector in Uzbekistan

The key distinguishing feature of the model proposed in Figure 1 is its emphasis on portfolio-based financing rather than individual lending to small hydropower projects. For instance, consolidating dozens of hydropower facilities with installed capacities ranging from 100 kW to 1 MW within a single financing platform or master special purpose vehicle (master SPV), supported by standardized technical designs, uniform Power Purchase Agreements (PPAs), a common Environmental and Social Management System (ESMS), and standardized loan documentation, can significantly reduce transaction costs. This approach enables banks to diversify their credit risks while providing investors with opportunities to issue green bonds or sell equity interests in the project portfolio to institutional investors.

The indicative financing structure may vary depending on the characteristics of individual projects and could comprise 20–30% sponsor equity, 50–60% long-term senior debt, with the remaining financing requirements covered through concessional financing, guarantees, or viability gap funding (VGF). These proportions should not be interpreted as regulatory requirements; rather, they represent flexible financing ranges proposed by the author to enhance project bankability. In small-scale hydropower projects, construction-related risks generally decline following project completion and commissioning. Subsequently, refinancing the operational project portfolio through green bonds could release lending capacity on commercial banks' balance sheets, thereby enabling them to provide additional financing for new hydropower investment projects.

The introduction of guaranteed electricity purchase arrangements and competitive auction mechanisms in Uzbekistan in 2026 represents a significant turning point in creating favorable conditions for private investment. However, electricity pricing alone does not guarantee project bankability. In the hydropower sector, construction periods, seasonal variations in water flows, irrigation regimes, equipment delivery schedules, foreign exchange fluctuations, and grid connection costs directly affect project cash flows. Therefore, project sites offered through competitive auctions should be supported by several years of hydrological data, clearly identified grid connection points, legally established land and water-use rights, preliminary environmental screening, and a standardized PPA documentation package prepared in advance.

The second major issue concerns currency mismatches. Although the localization of hydropower equipment manufacturing is progressing, certain electromechanical components and international debt obligations may still be denominated in foreign currencies, whereas project revenues are predominantly generated in Uzbek soums. Drawing on Türkiye's experience, establishing clearly defined adjustment corridors for inflation and exchange rate indices, rather than fully dollarizing electricity purchase tariffs, could improve cash flow predictability for lenders. In this context, a cap-and-floor mechanism could be introduced to limit excessive pressure on consumer electricity tariffs while providing an appropriate level of protection against inflationary and foreign exchange risks.

The third critical issue relates to hydrological risk. Since a substantial proportion of small hydropower plants in Uzbekistan are planned along existing irrigation canals, project risks depend not only on natural water flows but also on irrigation schedules and water-allocation arrangements. The World Bank's environmental and social documentation for the small-hydropower program provides relevant project-context evidence for this risk-management requirement [15].

The fourth critical issue concerns the availability of long-term financing resources within domestic commercial banks. Although the World Bank's USD 150 million credit facility represents a significant source of initial funding, the development of a sufficiently bankable project pipeline remains a core implementation challenge. Establishing a dedicated Project Preparation Facility (PPF) could improve feasibility studies, hydrological

assessments, ESMS documentation, legal due diligence, and standardized financial models.

The fifth critical issue concerns the linkages between domestic manufacturing and project financing. Uzbekistan has commissioned the UzHydroPower manufacturing facility, specializing in hydropower generating units with capacities ranging from 1 kW to 40 MW . Targeted incentives for domestically manufactured equipment could reduce foreign-currency expenditures, spare-parts costs, and logistics costs.

The principal limitation of this study is the lack of project-level microdata on comprehensive financial models, internal rates of return (IRR), net present values (NPV), and debt repayment schedules for individual hydropower projects in Uzbekistan. Consequently, the proposed capital structure ranges are conceptual in nature. Future research should focus on developing Monte Carlo simulation models or scenario-based discounted cash flow (DCF) models for three distinct hydropower capacity categories: 0.1–0.5 MW, 0.5–2 MW, and 2–5 MW. These models should incorporate project-specific capital expenditures (CAPEX), capacity factors, electricity purchase tariffs, and lending terms to provide a more comprehensive assessment of investment risks and financial viability.

4. Conclusion

The findings of this study demonstrate that the primary role of the government in promoting large-scale private investment in the hydropower sector is not to provide full project financing, but rather to establish an institutional and financial framework capable of improving the risk–return profile of investment projects to a level that meets bankability requirements. In Uzbekistan, the increasing number and installed capacity of hydropower plants, the World Bank's USD 150 million credit facility, the introduction of the E-auksion platform, guaranteed electricity purchase arrangements, and the national target of expanding small- and micro-hydropower capacity to more than 204 MW by 2030 have established an essential foundation for attracting private capital into the sector.The study substantiates the following practical recommendations: developing standardized bankable Power Purchase Agreements (PPAs) and comprehensive project documentation packages for small-scale hydropower projects; expanding long-term project finance credit facilities for domestic commercial banks using resources provided by the World Bank and other development finance institutions (DFIs); introducing partial credit guarantee schemes and first-loss risk-sharing mechanisms; implementing viability gap funding (VGF) and enabling infrastructure grants for projects characterized by substantial expenditures on access roads, grid connections, and irrigation infrastructure; aggregating small-scale hydropower facilities into diversified investment portfolios; refinancing operational project portfolios through green bonds or sukuk; establishing cap-and-floor adjustment corridors to address inflation and foreign exchange risks in electricity tariff indexation; and linking the utilization of domestically manufactured UzHydroPower equipment to targeted financial incentives.The coordinated implementation of these mechanisms would ensure that concessional public and international financial resources do not crowd out private investment but instead generate a **crowding-in effect**, facilitating the mobilization of additional private and institutional capital. Consequently, the proposed financial architecture could shorten the time required for hydropower projects to reach financial close, strengthen the project financing capabilities of domestic commercial banks, improve the predictability of revenue streams for foreign investors, and accelerate the commissioning of decentralized renewable energy generation capacities across Uzbekistan's regions.

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