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Scaling the Potential of MHPPs in Pakistan: Opportunities and Instruments

Scaling the Potential of MHPPs in Pakistan:

The Way Forward through Electricity Market Reforms

Pakistan faces a multi-faceted energy sector challenge: a growing circular debt and financial burden driven by the excess capacity, operational inefficiencies, and fuel imports, and at the same time a significant population (nearly 25%) living without access to reliable grid electricity (Khan, 2025). While electricity is generated at a comparatively lower rate, it is sold to consumers at around Rs 45 per unit (variable as per the slabs and time of use), with taxes and surcharges playing a major role in driving up the price (Rana, 2024). The financial losses due to transmission congestion have surged dramatically in recent years, increasing from Rs 3.67 billion in FY2021-22 to Rs 20.2 billion in FY2022-23, and further rising to Rs 60.38 billion in FY2023-24 (Waleed, 2025). Given the limited fiscal space of the country, the expansion and improvements in the Transmission & Distribution (T&D) sector remains challenging, making it difficult for a large population to have a sustainable energy supply, contributing to its socio-economic development.

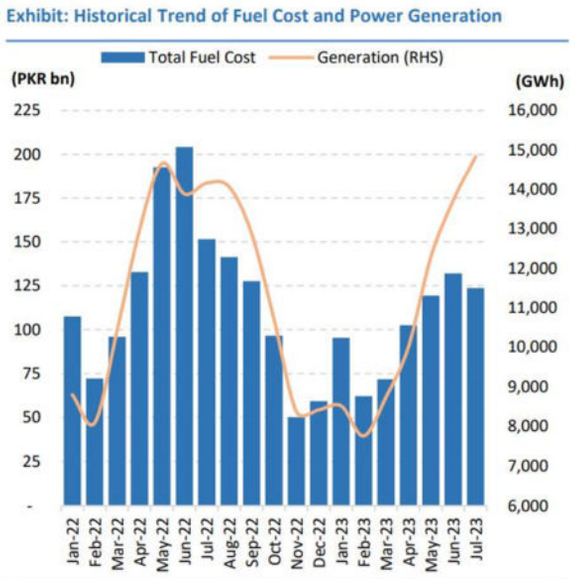

Figure 1: Historical patterns of fuel costs and power generation (Ahmad, 2023)

Driven by these challenges, Pakistan in recent years has observed a rapidly increasing trend of decentralized and small-scale systems such as Solar PV (off grid or net-metered) and Mini/Micro Hydro Power Plants (MHPPs). This brief particularly focusses on the development prospects of MHPPs in Pakistan to provide affordable, reliable, and clean energy, specifically analyzing how the existing challenges can be addressed, and the systems be further scaled up. Small hydropower plants, known for their minimal environmental impact, are categorized into mini hydropower plants (100 kW–1 MW), micro hydropower plants (5–100 kW), and pico hydropower plants (< 5 kW) (Akorede, 2022). Due to their relatively small scale, these plants require less complex construction and are often located in rural areas (both on and off-grid). Small-scale hydropower systems offer a promising solution for decentralized energy access, providing power to communities while reducing transmission losses and preserving natural ecosystems.

By tapping into this potential, these plants can further play a crucial role in addressing the country's energy crisis, all while promoting environmental sustainability. According to the Pakistan Council of Renewable Energy Technologies (PCRET), the small hydro potential of Pakistan is estimated to be more than 10,000 MW and more than 90% potential is still untapped (PCRET, n.d.). The northern areas of Pakistan, particularly Khyber Pakhtunkhwa (KPK) and Gilgit Baltistan (GB) already have a number of MHPPs installed owing to the efforts of multiple organizations particularly Pakhtunkhwa Energy Development Organization (PEDO), Agha Khan Rural Support Programme (AKRSP), Sarhad Rural Support Programme (SRSP), Pakistan Poverty and Alleviation Fund (PPAF) and support from development partners such as KfW.

However, while MHPPs serve as a promising solution, their sustainability and effectiveness has also remained under discussion. While some operational models have succeeded, others couldn't sustain, resulting in the closure of many plants. This was particularly the case of community-driven systems owing to operational, financial, and capacity challenges, coupled with inefficiencies in handling existing plants. This underscores the need for significant policy reforms along with a sustainable community approach to ensure the proper development, financing, management, and sustainability of MHPPs, enabling them to contribute meaningfully to the country's energy landscape.

In the backdrop highlighted above, this brief drives its debate and recommendations for scaling up MHPPs in Pakistan using a mixed-method approach. Along with secondary data analysis and desk review, it also drives its insights from the consultative dialogue on "Scaling the Potential of Mini/Micro Hydropower Plants in Khyber Pakhtunkhwa and Gilgit-Baltistan: Opportunities and Instruments" organized by the Pak-German Climate and Energy Partnership (PGCEP) and Sustainable Development Policy Institute (SDPI).

Objectives:

Based on the scope and approach defined above, this policy brief aims to address the following key objectives:

To explore policy and regulatory challenges, need for standardized regulations, public-private partnerships, and provincial-level support to create a conducive environment for MHPP growth.

To analyze the potential of innovative financing mechanisms (e.g., grants, concessional loans, climate funds) for ensuring financial sustainability, local involvement, and long-term management of MHPPs.

To highlight technical challenges related to design, data, and maintenance while integrating gender perspectives and climate resilience into MHPP development to ensure sustainability in the face of environmental risks.

Key Messages:

- MHPPs presents a viable business model, particularly in the regions with high distribution losses. Given that some of the DISCOs face Aggregate Technical & Commercial (AT&C) losses up to 65%, upscaling micro-grids in underserved areas can help mitigate financial losses, attract private investment, and reduce reliance on expensive grid extensions.
- The 2022 floods exposed significant vulnerabilities in existing projects. According to PEDO, during Phase 1 of the Access to Energy program funded by ADB, 72 of their units in KPK were completely destroyed by floods. Future project planning must integrate climate resilience through rigorous site assessments, robust infrastructure design, and risk mitigation strategies.
- To successfully scale MHPPs, Pakistan needs improved policy coherence, stronger institutional frameworks, and better access to financing, along with minimized and streamlined regulatory processes that encourage local-level decision making and facilitate private sector involvement.
- Successful micro-hydro initiatives rely on inclusive decision-making at the community level from the outset. Embedding cooperative models and enabling micro-utilities under municipal oversight can improve accountability, project sustainability, and equitable distribution of energy benefits. This also ensures that local governments remain key stakeholders in the long-term governance of decentralized energy systems.
- Enhancing community engagement, empowering women, and addressing security concerns are crucial for the long-term success and socio-economic impact of MHPPs.

Key Challenges:

The energy planning of Pakistan has remained largely central with a limited policy cover going towards off-grid and decentralized systems. For MHPPs, this has remained a key challenge that hindered their scalability. A clear framework for integrating them into the national grid (once it reaches those areas) remains unclear. Further uncertainty around asset transfer, pricing infrastructure, and long-term management has discouraged the investment particularly from the domestic sources. This led to a lack of blended finance models and structured incentives that restricted the private sector involvement either in upscaling or through any technology improvement programs. While the developments happened through support of donor-driven programs, their post installation sustainability was compromised owing to multiple reasons highlighted in the figure. In recent years, however, regulatory efforts such as the NEPRA Microgrid Regulations 2022 have laid the groundwork for promoting microgrid adoption, particularly in off-grid regions of Baluchistan, Khyber Pakhtunkhwa (KPK), and Sindh. These regulations aim to attract commercial investment by providing a structured framework covering tariff settlement, financing, and development while balancing long-term sustainability with affordability for consumers.

Technical Challenges

The lack of standardized designs and equipment, along with inadequate hydrological data, creates inefficiencies in MHPPs development. Additionally, maintenance and operational issues persist due to a shortage of technical expertise. Climate risks, including floods and changing precipitation patterns, further complicate the infrastructure planning of MHPPs.

Financial Challenges

High initial costs for MHPPs, limited access to financing, and a dependence on grants create financial instability. Community-based projects face challenges with revenue generation, as local tariffs are often too low to cover operational expenses, hindering long-term sustainability.

Institutional and Policy Challenges

Policy incoherence and weak institutional frameworks impede the smooth implementation of MHPPs. Regulatory barriers and an inadequate approach to integrating small-scale projects into the national grid restrict private investment and limit the scalability of MHPPs.

Socio-Economic Challenges

Limited utilization of generated electricity, gender inequality in decision-making, and security concerns in certain regions prevent MHPPs from realizing their full potential. These issues also create barriers to sustainable community ownership and the broader socio-economic benefits of MHPPs.

Key Recommendations

- **Comprehensive Policy and Framework:** Formulate a comprehensive policy (or integrate within a broader energy policy) with a clear institutional framework to address gaps in regulation, financing, and grid integration. The policy should define the roles of federal and provincial governments, streamline approvals, introduce incentives for private sector participation, and set clear targets in line with Pakistan's RE and electrification goals.
- **Enhancing Off-Grid Electrification through NEPRA's Microgrid Framework:** Utilize the regulatory framework established under NEPRA Microgrid Regulations 2022 to scale decentralized energy systems in off-grid regions through mechanisms such as bilateral tariff settlements, concessional financing instruments, and structured public-private partnerships. Emphasize investment-driven deployment models that ensure long-term financial viability while maintaining affordability for end-users.
- **Standardization of Equipment and Designs:** Enable collaboration between local manufacturers and research institutions to standardize hydropower equipment, reducing reliance on foreign technology, and improving financial viability. Such collaboration may also leverage digitalization and smart technologies to improve MHPPs efficiency and sustainability.

- **Grid Integration and Net-metering Framework:** For maximizing energy utilization from MHPPs – particularly their integration within grid – clear technical standards, wheeling regulations must be developed along with upgradation of local distribution networks in hydro-rich areas.
- **Integrating Climate Resilience into MHPP Planning through Coordinated Institutional Mandates:** The Ministry of Climate Change and Environmental Coordination, in collaboration with the Ministry of Water Resources and relevant provincial departments, should mandate the integration of climate risk assessments and watershed management into the planning and design of MHPPs. This coordinated approach will ensure that project designs account for changing hydrological regimes, sedimentation risks, and extreme weather events — enhancing long-term reliability, environmental sustainability, and climate resilience at both national and subnational levels.
- **Blended Finance Models:** Develop and institutionalize blended finance models that combine grants, concessional loans, and private sector investment to mobilize capital for MHPP projects. Instruments such as viability gap funding, green bonds, and climate finance can help secure long-term financing, while donor-backed credit guarantees can mitigate perceived risks and enable local financial institutions to engage more confidently. For instance, Acumen's provision of a concessional loan to ARKSP for the development of 2–3 MHPPs in the Chitral region demonstrates the potential of such models in catalyzing investment in decentralized renewable energy.
- **Promoting Mature Models of Community-Led Financing:** Creating awareness and discourse around adopting cooperative ownership models where local communities collectively invest, manage, and reinvest revenue. This may further encourage community-led tariff collection and surplus reinvestment to ensure long-term sustainability and local economic benefits.
- **Performance-Based Incentives:** Introduce performance-based incentives for MHPP operators, such as feed-in tariffs or subsidies for meeting certain performance benchmarks. This will encourage efficient operation and maintenance of MHPPs and attract private sector investment.
- **Integrating Public, Private, and Community Partnerships (PPCPs):** To foster sustainable energy development, the government should focus on creating conducive business models by integrating public, private, and community partnerships (PPCPs). This includes supporting entities like AKRSP and SRSP, enabling access to climate financing, promoting market-driven solutions, and leveraging carbon market opportunities, while ensuring the active participation of local communities to drive innovation and long-term success.
- **Gender-Responsive Policies:** Integrate gender equality and social inclusion (GESI) into energy policies and MHPP projects. This includes ensuring women's participation in decision-making processes and providing them with access to clean energy for income-generating activities.
- **Streamlining Approvals:** Develop a single-window facilitation system to make the licensing and regulatory processes more efficient. This would also fast track approvals from environmental agencies, water rights authorities, and energy regulators.
- **Local Economic Development:** Link MHPP projects with local economic development initiatives, such as small-scale industries and ecotourism. This would increase the demand for electricity and create economic opportunities for local communities.
- **Facilitation and Risk-Responsive Business Models for Investment in High-Risk Areas:** To enable investment in remote and security-sensitive regions such as KPK, federal and provincial governments must strengthen coordination to streamline NOC procedures and provide administrative facilitation for development partners. In parallel, explore risk-responsive business models that reduce upfront capital barriers.

CASE STUDY: KfW's Renewable Energy Projects in Pakistan

KfW is supporting Pakistan's renewable energy transition more than €200 million To date, HRE-I and HRE-II are being implemented, totaling an investment of €24 million in ongoing initiatives, including six completed hydropower projects and 68 solar mini-grids across six districts in KPK in Phase I (2023). The partners include PPAF, AKRSP, SRSP, NRSP, and CMDO. Phase II focuses on the development of three small-scale hydropower projects in off-grid regions in GB, with commissioning anticipated by 2025/2026. Additionally, HRE-III amounting to €18 million—is also planned for implementation in GB.

Key barriers include the high upfront costs of hydropower, which deter private investment, and the lack of reliable hydrological data, leading to adaptive implementation strategies. Furthermore, the slow pace of manufacturing standard hydropower turbines forces reliance on foreign equipment, hindering local growth. Once funding organizations step away, the sustainability of projects depends on a small team of operators, with no formal systems in place to ensure continued operation. Additionally, the region faces increasing climate risks, including floods, which raise infrastructure costs and demand more resilient designs.

To address the critical operation and maintenance (O&M) challenges, it has been proposed to develop a comprehensive policy framework that promotes sustainable management of mini-hydropower plants (MHPs). Among the various approaches, outsourcing O&M activities to private sector companies through performance-based contracts could be one potential solution. The case study highlights how innovative financing mechanisms — such as concessional loans, PPPs, and performance bond-based initiatives — have been instrumental in supporting off-grid renewable energy development in Pakistan. Alongside financial innovation, Pakistan must direct its efforts towards adopting climate-resilient infrastructure and exploring models for feed-in tariffs and grid integration to enhance both the scalability and sustainability of decentralized energy solutions. As the MHPP sector evolves, there is an increasing need for adaptive implementation strategies, greater private sector engagement, and the establishment of enabling policy environments to ensure long-term viability and impact.

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