Off-Grid Renewable Energy Guidebook

RENEWABLES FIRST

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About Renewables First

Renewables First (RF) is a think tank for energy and environment. Our work addresses critical energy and natural resource issues with the aim to make energy and climate transitions just and inclusive. Toiled in a plethora of challenges, decarbonization and energy transition remains a low priority for the World's fifth largest population in Pakistan. RF is leading energy transition coalitions, incubating organizations & networks and cooperating with existing local think tanks and civil society organizations to drive the energy transition, through collaboration and complementarity across all geographic levels.

As Pakistan's only dedicated energy transition think- and do- tank, Renewables First's uniqueness lies in our approach towards driving the energy transition. By emphasizing inclusivity and immediate action, we are positioned to drive change that is both sustainable and equitable. By leveraging partnerships and data-driven research, we identify, promote, advocate and communicate evidence-based, viable solutions that are tailored to the needs of the country. Our young and passionate team is brimming with enthusiasm and ideas on ensuring the energy transition for them and their future generations.

Disclaimer

Most of the data used in this study has been gathered from publicly available resources and direct consultations with stakeholders including, but not limited to developers, contractors, and development agencies involved in distributed energy project development in Pakistan. While our team has been extremely cautious in carrying out this process as well as in making any assumptions with regards to the process, the respective organizations do not assume any liability or responsibility for any financial or other loss resulting from the use of this data and results.

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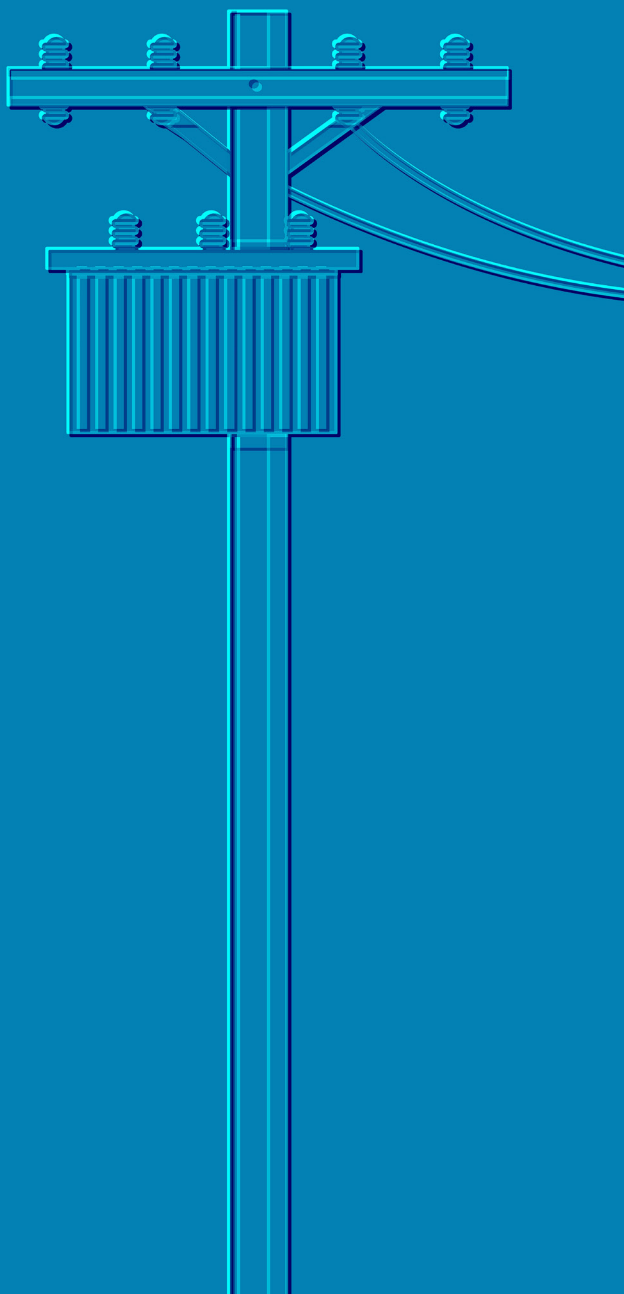
Purpose of the Guidebook

Pakistan's power sector faces considerable challenges related to its grid system. This has rendered the national power infrastructure both unsustainable and non-viable. While comprehensive solutions to these grid and power sector issues may take decades, there's an immediate and growing emphasis on off-grid renewable energy. This is especially crucial for fostering human development, as off-grid solutions are typically well-suited for areas without existing electrification.

Currently in Pakistan, the market for off-grid renewable energy projects remains in its early stages, with the exception of Micro Hydel Power Projects (MHPP). However, even the market for these MHPPs is fragmented. Most often, they operate either informally or on an individual project basis, backed by various development agencies. Engagement from the private sector is either minimal or non-existent.

One significant barrier is the absence of comprehensive information about the potential and the process of developing off-grid and distributed energy systems. Recognizing this gap, "Renewables First" has embarked on an initiative to provide a document detailing the development process and the available opportunities in this sector. This guidebook is intended to serve as a central repository of knowledge for newcomers to the off-grid market. It will guide them through the developmental process, underline potential opportunities, and introduce key stakeholders and their respective roles.

This first edition of the guidebook delves into the development of Solar Micro Grids (MG), referencing the Micro Grids regulations set by NEPRA in 2021. It also covers MHPP in the Northern regions, placing special emphasis on community-based models. While the present document primarily discusses Distributed Generation in non-electrified zones, future editions will expand to include commercial and industrial distributed generation. This will encompass captive power systems, maintaining a primary focus on clean energy technologies.



National Overview

Access to reliable and affordable electricity, for example, can have an immediate and transformative impact on quality of life, access to basic services (e.g., health, education) and livelihoods. With 24 percent of population lacking access to reliable grid electricity, Off-grid renewable energy solutions have emerged as a mainstream solution to expand access to modern energy services in a timely and environmentally sustainable manner in Pakistan. Moreover, the country grapples with substantial issues concerning grid reliability, particularly in rural areas. Distribution companies (DISCOs) like Quetta Electric Supply Company (QESCO), Peshawar Electric Supply Company (PESCO), and Hyderabad Electric Supply Company (HESCO), spanning across vast regions, offer a mere few hours of grid availability daily.[1] This limited service comes with a host of issues, including persistent low voltage and frequent system tripping. The inadequate grid reliability presents significant challenges for the rural populace, compromising their daily routines and productivity. Not only does it affect domestic life—interrupting tasks like cooking, studying, and household chores—it also adversely impacts agricultural and small-scale industrial activities that are the backbone of rural economies. These chronic grid reliability issues strengthen the case for incorporating off-grid solutions, particularly in the most affected rural areas. Off-grid solutions such as solar home systems (SHS), mini-grids, and stand-alone systems could provide reliable, uninterrupted power, alleviating the daily struggles faced by these communities. Not only do these solutions offer a potentially more reliable service, they also contribute towards a greener, more sustainable future, aligning with global efforts to combat climate change.

These renewable energy sources have several advantages compared to conventional electricity generation systems due to their lower generation costs, independence from fossil fuels, and short installation times. Over the past five years, the deployment of stand-alone MG, particularly MHPP, has witnessed tremendous progress as technology costs have plummeted, innovation in deployment and financing models has picked up.

Resource Potential

Solar

Pakistan has tremendous potential for solar power generation. According to the ESMAP Solar Resource report of March 2017 the western region of Pakistan tops the Global Horizontal Irradiance Chart (GHI) with average annual values exceeding 2330 kWh/m^2 (average daily total of 6.4 kWh/m^2). Higher up in the Northern areas, the GHI score tends to fluctuate from 1750 to 1300 kWh/m^2 with daily averages of 4.8 kWh/m2 to 3.6 kWh/m^2. In Pakistan, the annual averages of PV output lie between 1240 kWh/kWp (with the daily averages amounting to approximately 3.4 kWh/kWp) and 2100 kWh/kWp (around 5.8 kWh/kWp per 24 hrs.) with greater values recorded in the Balochistan province. However, terrain shading in the mountainous regions up North reduce PV output significantly by 20% or more.[2] Higher altitude and lower air temperature of sites in Baluchistan Province make them the best sites for PV based generation and exhibit serious GHI potential due to lesser volume of aerosols present in the atmosphere. These factors not only improve the efficiency of a Solar PV system, but also reduce the number of PV modules required to produce the same power.

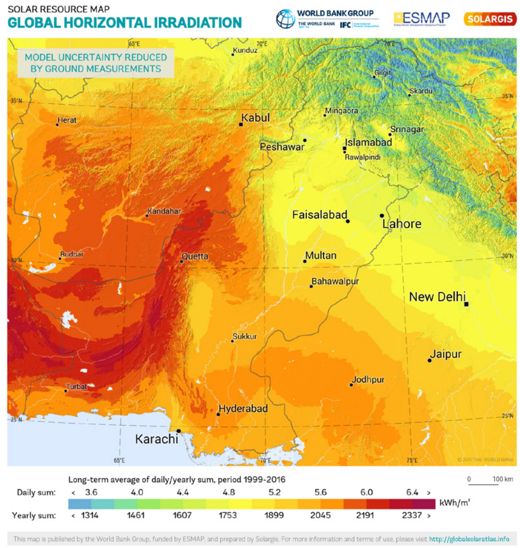


Figure 1 Solar GHI level- Source Solargis ESMAP Report

Wind

The National Renewable Energy Laboratory (NREL) of the US in its survey report estimated Pakistan's wind power potential to be 346 GW. The research – "A Research on Electricity Generation from Wind Corridors of Pakistan (Two Provinces): A Technical Proposal for Remote Zones" finds the total wind potential of 88.460 GW and 146.145 GW in Sindh and Balochistan respectively. The Gharo-Jhimpir wind corridor in Sindh carries a potential of 40 GW alone.[3]

As of June 2022, the country's total installed wind power capacity is stated at 1838 MW.[4] Various prominent local and foreign developers like FFCEL, General Electric, China Three Gorges, Zorlu and more have set up wind power plants in the Gharo-Jhimpir wind corridor. The latest IGCEP 2022-2031 plans a total of 4,928 MW of installed wind capacity by 2031 through the upcoming auction scheme in Pakistan.[5]

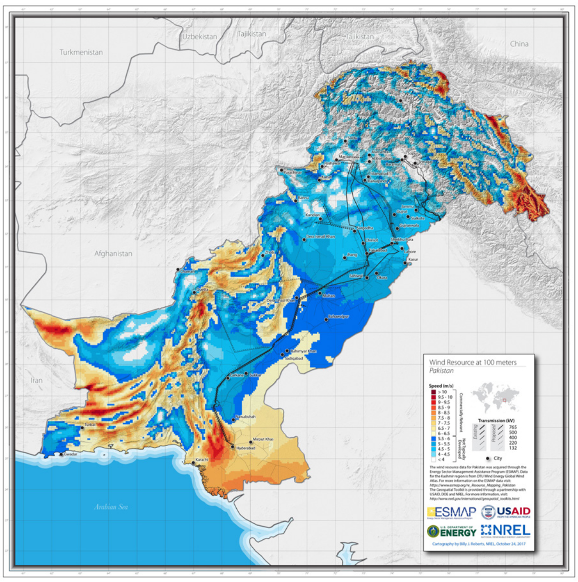


Figure 2 - Wind resource in Pakistan

Situational Analysis of Electrification and Off-grid population

The average population density in Pakistan currently stands at approximately 295 people per square kilometer. A significant portion of this population, corresponding to around 4 million households or 24 million people, does not have access to reliable electricity. Considering the per capita annual electricity consumption in the country is 399 kWh, this amounts to a staggering 9,576 GWh of unfulfilled energy demand. This gap presents an immense potential for off-grid electricity solutions.[6]

Population Density: 295 per km2

Un electrified population: 24 million

Annual Electricity consumption per Capita: 399 kWh

Un-met Energy Demand: 9576 GWh

Electrified Households: 88 %

Figure 3 – Dashboard on Access to Electricity in Pakistan

On a provincial level, electrification rates vary. Punjab boasts the highest rate with 94% of its 17,103,982 households having access to electricity. Sindh follows with an 80% electrification rate among its 8,566,286 households. Khyber Pakhtunkhwa and Balochistan have rates of 85% and 71% respectively, among their 4,299,883 and 1,769,674 households. The Federal Capital, Azad Jammu and Kashmir, and Gilgit Baltistan show high rates as well, with 97%, 97%, and 93% respectively. In total, out of 32,906,578 households across Pakistan, 88% are electrified, leaving 3,893,249 households without access to electricity.

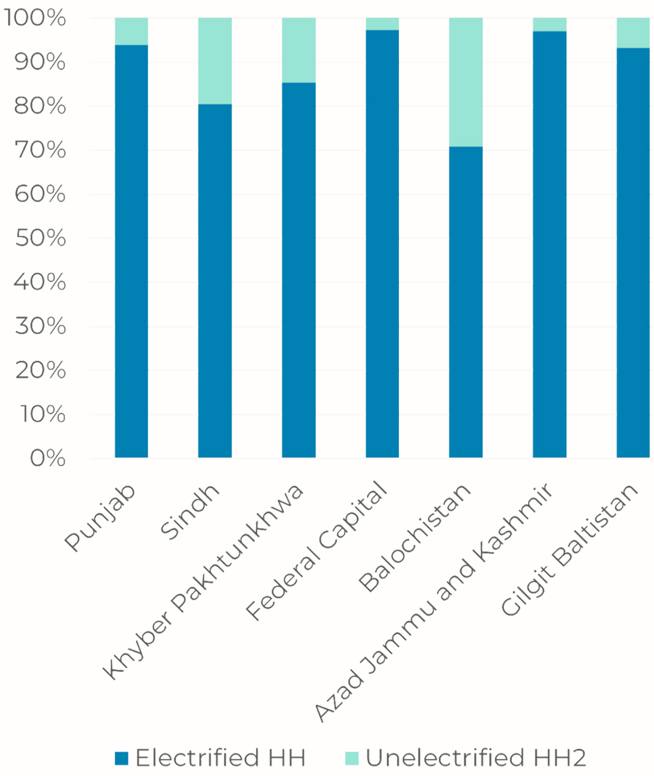


Figure 4 - Household electrification in provinces, census 2017

If the country is to achieve universal access by 2030, it is estimated that Pakistan will need nearly 40 million electricity service connections across its four major provinces. As of 2020, the existing customer count for all utilities serving these provinces is 20.1 million. This figure, however, does not include informal connections and those through small off-grid systems, as their geospatial location information is not available. A household survey conducted by ESMAP in August 2022 indicated these types of connections constituted nearly 20% nationwide.[7]

The Unusual Dichotomy of Energy Access in Pakistan

Pakistan presents a unique contrast in its energy access landscape. Despite facing numerous challenges regarding electricity access, there is a stark geographical mismatch in electrification levels, with an apparent concentration of electrified regions on the eastern side of the country, extending from north to south.

The vast southwestern region of Balochistan, in contrast, remains largely unelectrified. This uneven distribution of electricity access underscores the immense potential for the implementation of MG in areas such as Balochistan, where traditional grid connectivity is lacking or unreliable.

This uneven distribution of electricity access is starkly evident when visualized on a night light map of Pakistan, clearly delineating the electrified and non-electrified areas of the country. The marked disparity in illumination levels across the country's geography signals the urgent need for intervention and the opportunity to address this challenge through innovative energy solutions such as MG. [8]

Figure 5 - Street lights Map of Pakistan (Google Earth Streetlight map)[8]

Building on ESMAP data, the World Bank has developed a more nuanced understanding of electrification. They delineate electricity access into distinct Tiers, ranging from Tier 0, signifying no electricity access, to Tier 5, which represents high-quality, uninterrupted service accommodating full loads. For communities initially establishing electricity access, employing a MG can be an effective approach. This may commence at Tier 1 or Tier 2 to keep initial investment costs at bay. As renewable resources become more available and as the demand escalates, these communities can progressively ascend to higher Tiers of electricity access.

MINIMUM REQUIREMENTS BY TIER OF ELECTRICITY ACCESS

Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least 4 hours of electricity per day is available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio. Sources that can be used to meet these requirements include a SLS, a solar home system (SHS), a minigrid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and the national grid.	At least 4 hours of electricity per day is available (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances—such as multiple lights, a television, or a fan (see table 1)—as needed during that time. Sources that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, and the national grid.

Tier 3	Tier 4	Tier 5
At least 8 hours of electricity per day is available (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances—such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1)—as needed during that time. In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1)—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high- load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source

Figure 6 - Electricity Access Levels by ESMAP[9]

Regulatory and Institutional Landscape

Distributed generation requires policy support from the government at several levels to build up its financial case. Pakistan have been substantially late and setting up provisions for distributed generation and providing policy support. Nevertheless, several policies and regulations have been adopted at provincial and national level making case for distributed generation in the country.

ARE Policy 2019

The policy envisions incorporation of solar and wind of up to 30 percent by 2020, which includes distributed generation (DG) and MG. Keeping in view that the current deployment of on-grid renewables is being hampered due to multiple macro-economic and financial challenges, Pakistan must leverage developments in DG, to reach the targets. Key incentives under the policy for off-grid solar developers include:

- Exemption from corporate income tax
- Exemption from import duties
- Repatriation of dividends and disinvestment proceeds
- 100% foreign equity permitted
- Foreign currency accounts permitted
- Protection against change in law
- Robust market-tested contractual framework[10]

National Electricity Policy

The overarching goal of this policy is access to affordable, secure and sustainable energy. According to clause 5.1.7 "Distributed generation, including net-metering additions, shall conform to the integrated planning for the sector. Steps will be taken to integrate distributed generation in sector-level planning to ensure its sustainability."[11] It also stresses off-grid and micro-grid solutions to promote electricity access to areas where grid expansion is financially unviable.

SDG 2030 targets

Pakistan affirmed its commitment to the 2030 Agenda for Sustainable Development by adopting the Sustainable Development Goals (SDGs) as its National Development Agenda through a unanimous National Assembly Resolution in 2016. In line with this Agenda, the Ministry of Planning, Development, and Special Initiatives and the United Nations Development Programme (UNDP) signed an agreement and designed the National Initiative for SDGs to develop mechanisms for achieving the SDGs per national and provincial priorities.

According to SDG 7, the country plans to achieve 100 percent access to electricity by 2030. Distributed generation and off grid solution will be vital to achieve these targets as a lot of UN electrified regions are in the areas with much archaic or limited or no distribution systems.

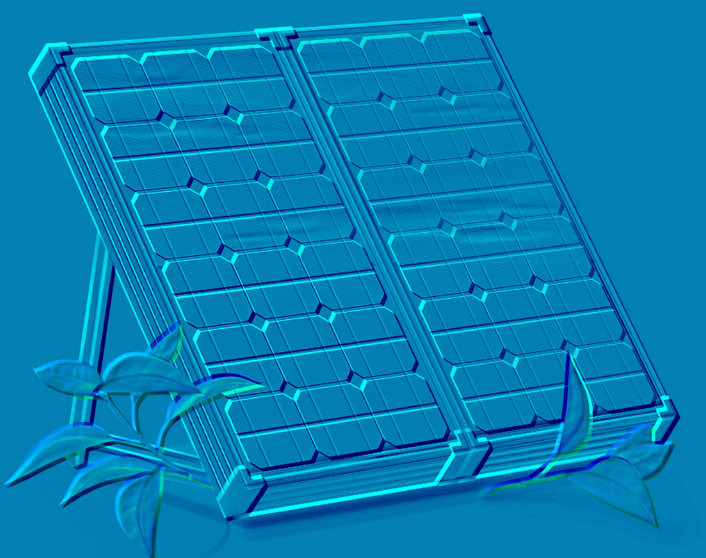
NEPRA MG Regulations 2022

NEPRA also approved MG regulations in 2022 to provide a framework for the development of MG in the country. The regulations provide key requirements and standards that needed to be adopted for 2022. The details process and features of regulations are covered in subsequent chapter.

State Bank of Pakistan Renewable Energy Financing Scheme

In a bid to accelerate renewable energy uptake in the country, the State Bank of Pakistan (SBP) introduced Renewable Energy Financing Scheme". As part of their Green Banking initiative of 2016. The scheme was set for renewable energy investment entities looking to develop both small- and large-scale renewable energy projects in Pakistan including solar, wind, hydro, biogas, bio-fuels, bagasse cogeneration, and geothermal power projects. The SBP financing scheme for renewable energy projects is a valuable concessionary finance scheme for the investors to benefit from. Through this scheme, funds are channeled through private sector local banks and Development Finance Institutions (DFIs) and have till date disbursed a total of Rs. 53 billion for 717 RE projects of 1082 MW.[12] However, the scheme is currently inactive with little clarity on its future.

Solar Micro Grids Development Guide

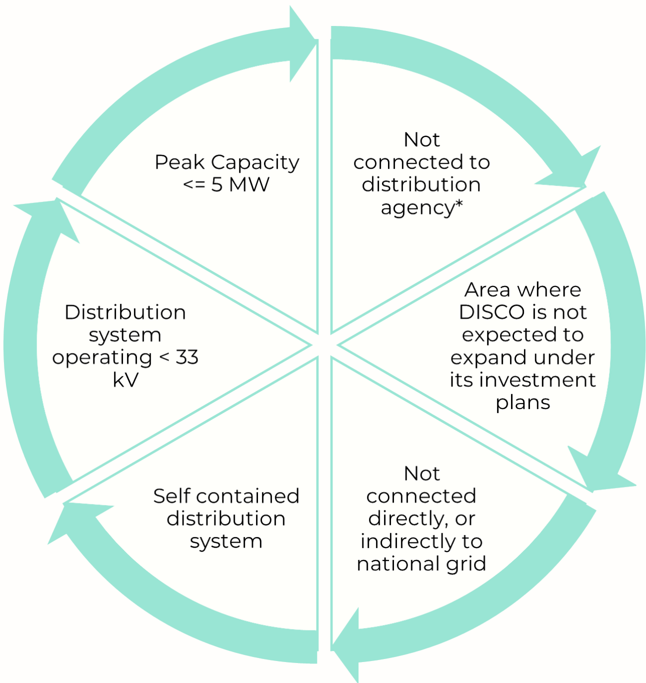


Pakistan holds significant potential for the implementation of solar MGs due to high irradiance available in sparsely populated areas. As highlighted in a least-cost electrification study by the World Bank, in order **for Pakistan to achieve its 2030 target of universal electricity access in the most cost-effective manner, it's imperative to connect approximately 4 million consumers to MGs.** This represents about 14% of the currently un-electrified population. The estimated investment required to achieve this goal is approximately USD 1.8 billion.[13]

Definition

There are multiple definitions for a MG worldwide, but this guidebook shall adhere to the definition prescribed by NEPRA. Adhering to NEPRA's regulations, MG systems discussed in this guide are often termed as "off-grid" or "stand-alone". They uphold stringent reliability standards as defined in the MG regulations. As these systems operate independently, they often necessitate more substantial generation and storage resources.

NEPRA Regulations 2022 established the following criteria for MGs:



**The MG site is outside five kilometers on either side or tail end points of existing distribution facilities of the host distribution licensee at time of application*

Conceptual Design

The development of MGs require closely curated conceptual design involving a careful balance of five elements i.e., safety, security, reliability, sustainability, and cost-effectiveness (Figure 4). These critical elements often interplay in complex ways, and require tailored solutions that cater to distinct community needs. The guidebook entails a methodical, step-by-step framework to evaluate the viability of MGs at specific sites in Pakistan along with process of project development. The conceptual design of MGs serves as an initial blueprint, outlining a preliminary configuration and cost estimate that encompasses facets like generation, storage, distribution, operation, and the overall life-cycle management. It is pertinent to note that the conceptual design is not an exhaustive design but offers enough granularity to pave the way for implementation of the projects. It is an invaluable tool for communities, simplifying the intricacies of assessing potential MG solutions, and offering comparisons for informed decision-making.

Figure 7 - Elements of Conceptual Design for Micro Grids

Site Identification and Selection

The table 1 gives us an in-depth comparison of the development of MGs across the four major provinces of Pakistan. **In total, there are 1,015 potential MG sites with an overall capacity of approximately 158 kWp per site.** This would lead to an average of 304 connections per site, costing an average of USD 1,310 per connection. The entire endeavor would require a capital expenditure (CAPEX) of USD 360.5 million and aims to cover nearly 1.85 million people, fulfilling a demand of about 448,000 kWh per day.

Parameter	Balochistan	KP	Punjab	Sindh	Total
No. of mini-grids sites	185	331	340	159	1,015
Avg. PV capacity (kWp)	75	214	153	148	158
Avg. Number of connections	191	445	220	323	304
Avg. Cost per connection (USD/connection)	1,343	1,165	1,531	1,097	1,310
Avg. CAPEX Cost per mini-grid (USD/cluster)	233,213	467,972	317,404	343,365	355,227
Total Estimated CAPEX Cost (millions of USD)	43.1	154.9	108	55	360.5
Total population covered	219,108	880,515	429,470	318,157	1,847,250
Total demand (kWh/day)	45,265	191,187	140,586	70,955	447,993

Table 1 - Potential of Micro/Mini Grids across different provinces

World Bank's Mini Grid Portfolio Assessment study presents a detailed district-wise potential of MGs in different provinces across Pakistan, as shown in Figure 8. It becomes readily apparent that districts exhibit significant variations in their potential for mini-grid sites. Certain districts prominently stand out as prime candidates for MGs development, boasting a larger number of potential locations including Bhakkar, Tharparker, Chitral, Khairpur and Bahawalnagar. These distinctions are influenced by a confluence of factors, such as population concentrations, the state of existing electricity infrastructure, and distinct geographical attributes. On the other hand, some districts present a limited number of potential sites. This might be a reflection of already well-established electricity frameworks or regions with sparser population densities. Importantly, a limited number of sites in a district does not diminish its significance in the broader grid development plan.

District Wise potential for Micro grids (Number)

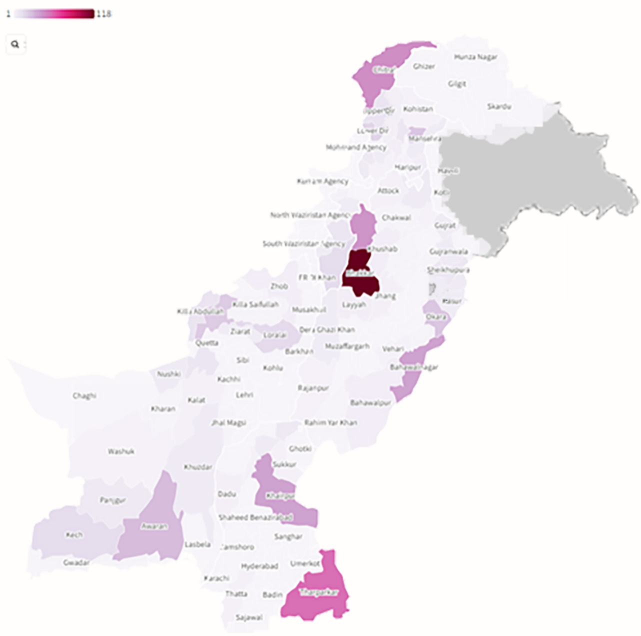


Figure 8 – District wise potential of Micro Grids in Pakistan

https://public.flourish.studio/visualisation/15187713/

The Figure 9 offers insights into the average capacity of potential MG sites across each district. Interestingly, some districts display a heightened average MG's capacity, even if the number of potential sites isn't particularly large. This suggests the intention for more expansive grid setups, possibly aimed at serving denser populations or pivotal commercial and industrial hubs. In contrast, other districts present a moderate or even low average capacity. This may hint at a strategy where numerous MG are developed, each catering to more intimate communities or specialized regions.

District Wise potential for Micro grids (kWp)

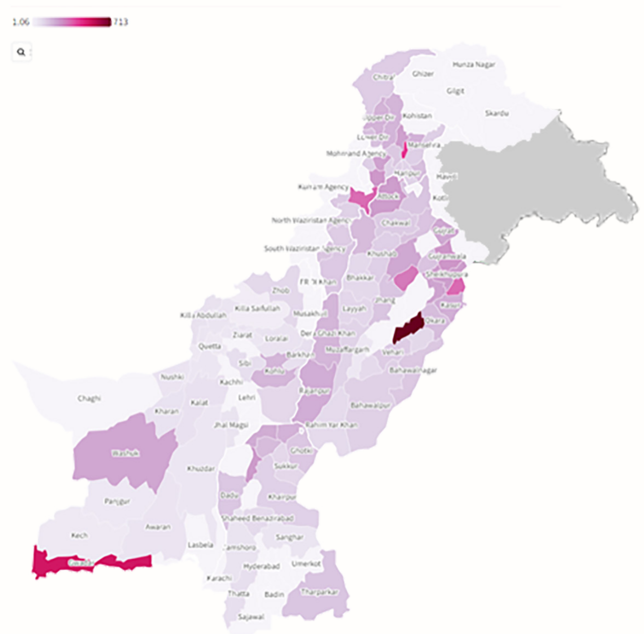


Figure 9 - District wise average capacity of potential Micro grid sites

https://public.flourish.studio/visualisation/14833882/

Using the above data, the developers may select a perspective site for development of MGs. **Ideally, the project should focus on un-electrified rural communities, distanced by at least 5 kilometers from the national grid and unlikely to be integrated in the upcoming 5-10 years.** Consider demographic factors, including the demand for electricity and a cluster of households, to determine mini-grid viability. A preference for larger villages can ensure more sustainable revenue streams, bolstering the MG longevity. A community may be as small as a few neighbors creating a small MG or as large as an entire city looking to build a large MG or a system of MGs to serve its residents.

System Characterization

Once the potential sites are identified, next step is to establish the initial energy system boundaries and map key stakeholders impacted from the project. To design system boundary, following information needs to be evaluated:

- Defining the geographical limits, whether it's a campus, military base, or an entire village.
- Gauging the proximity to existing distribution systems and DISCO expansion plans.
- Documenting demographic data, assessing villagers' willingness to pay, and identifying current lighting sources and expenses.
- Evaluating energy needs of various potential customers including households, commercial entities, community centers, and productive loads. The demand assessment should consider all types of potential customers and their energy needs, including:
    a. households: lighting, mobile phone charging, TVs, and possibly larger appliances such as fans and refrigerators;
    b. commercial loads: lighting and appliances for eateries, entertainment venues, and small shops;
    c. community centers: lighting, computers, and other appliances for schools, temples,
    d. Productive loads: processing of agricultural products, manufacturing, etc.; and streetlights.
- Mapping pivotal stakeholders, ranging from distribution companies and local governance to community entities and consumers.
- Considering funding constraints, potential land acquisitions, and bank lending attitudes toward such projects.
- Highlighting critical loads within the system's purview, such as hospitals, government establishments, banks, and transport hubs.
- For community driven projects, assess community cohesiveness and identify any critical social conflicts that exists in the area.
- Accounting for the logistics of transporting equipment to the village.

Once the system boundary is established, key aspects of system may be defined and characterized:

1. **Distributed Energy Resource (DER) Options**: Explore a mix of DERs, including solar, wind, and micro-Hydel.
2. **Duration:** Define the time frame (days, weeks, or longer) during which these services and assets should be consistently supported.
3. **Funding:** Identify available funding avenues, such as public sector development programs, non-profit grants, international development agencies support, private sector, and familiarize with any associated stipulations.
4. **Demand Analysis:** Ascertain both average and peak load demand, emphasizing the critical loads' demand.

Crucial Considerations

Existing Solar Systems

In villages where many households already possess solar home systems—often through government or non-profit initiatives—establishing a mini-grid might not be feasible. This is because these households might resist contributing to a new mini-grid scheme.

Community Organization

The pre-existing level of community organization greatly influences MG development potential. For instance, community working groups established by different non-profit organizations could pave the way for community focused MG projects. Collaboration with provincial rural support programs like BRSP, NRSP, SRSP and other non-profit community organization could be crucial in this regard.

Villager Engagement

Retaining villager interest can be challenging. A significant number of villages may withdrew interest later on. Therefore, having a comprehensive list of potential villages and a swift project execution timeline is crucial to retain engagement.

Income Seasonality

Given the seasonal nature of rural incomes in Pakistan, predominantly dependent on farming production, the collection of contributions and fees can be erratic. Hence, offering flexibility in payment timelines—perhaps post-harvest—can be beneficial.

Navigating Policy and Regulatory Constraints

The system's design must be aligned with NEPRA's Micro Grid regulations, particularly regarding grid and system standards. Ensuring a developer's adherence to widely accepted technical standards outlined in MG Regulations and other NEPRA regulations is crucial. This guarantees unhindered integration with DISCO network, in the event the host distribution licensee expands their network. In such scenarios, the developer can request technical standards from the concerned DISCO, which is obligated to respond within a week.

The MG must follow following standards for construction and operation of the system:

IEEE 1547.4-2011: IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE Std 2030.10™ 2021: IEEE Standard for DC MGs for Rural and Remote Electricity Access Applications

IEEE Std 1013-2019: IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems

IEEE Std 1526™ 2020 IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems

IEC TS 62898: AC Microgrids

LEC TS 62257: Recommendations for small renewable energy and hybrid systems for rural electrification

Formulate Initial Technical Design

Based on the key regulations, standards and initial site data, initial technical design of the MG shall be formed.

To conceptualize an initial design:

- **Generation Source Mapping:** Identify and earmark potential generation sources and establish capacity objectives.
- **Facility Clustering:** Identify facility or service groupings that might amplify resilience opportunities. The primary goal is to influence the maximum user base with individual MG.
- **Design Sketching:** Draft preliminary designs of proposed feeders and switch placements.

Several design considerations are paramount:

- **AC or DC Current:** The choice between alternating and direct current hinges on both the technology employed and the intended electricity application. While PVs and batteries yield DC power, hydro and biomass typically generate AC power.
- **Grid Phasing:** Decide between a single-phase grid, which is more cost-effective but limited in appliance support, or a three-phase grid, which can support larger equipment and potential national grid integration.
- **Battery Considerations:** For systems incorporating batteries, deep-cycle varieties are essential. Battery capacity largely hinges on system longevity without recharging and without exhaustive battery drainage, especially during seasons with minimal sunshine.
- **Infrastructure Protections:** Wires and conduits should be designed to minimize voltage drops and must be robustly protected from physical harm, weather, and UV rays. Ensure that circuits have adequate protection via fuses and breakers, with battery-linked wires being imperative.
- **Flooding Contingencies:** Given the susceptibility of certain regions to flooding, install systems at elevated or flood-resistant locations to ensure continued operation or minimize damage during floods.

Financial Analysis

Financial analysis evaluates the viability of a project from a monetary standpoint. For privately driven projects, it's essential for investors to determine the profitability timeline. Even for projects primarily funded by grants, financial stability remains paramount, ensuring that the revenue from connections and electricity services can sustain ongoing operations and maintenance (O&M) activities. The purpose of a financial analysis, therefore, extends beyond profitability; it's also about establishing the minimal fees essential for sustainable operations.

Basic financial model should include:

- **Project Costs:** Encompasses all equipment, labor, and transport essential for system installation. A holistic cost estimate should address:
  1. **Design and Engineering:** Surveying the electrical system, supporting analysis, plan formulation, compliance documentation, permit applications, and overseeing construction.
  2. **Construction:** Encompasses equipment, installation, and necessary permits.
  3. **O&M Costs:** Factoring in expenses like fuel, calibration, preventive maintenance, spare parts, and labor distributed throughout the installation's lifespan.
  4. **Retirement and Disposal:** Planning for the system's end-of-life phase.
- **Financial Contributions:** A sum of grants, community contributions, and private investments
- **Service Fees:** The amount users pay for electricity consumption, structured as a fixed fee or based on kilowatt-hour usage.
- **Connection Fees:** Charges that customers incur for initiating a connection and availing services.
- **Operation and Maintenance (O&M):** Covers expenses like staff salaries, operational costs, spare parts, and periodic replacements (e.g., batteries).

For a practical estimation approach, engineering, permitting, and construction costs can be framed as a percentage of the MG setup and its affiliated equipment. After computing base equipment costs, one can incorporate consulting and labor fees to deduce the comprehensive foundational costs. Construction and management oversight costs are typically approximated at 20% of the total equipment expenditure. Engineering and design are gauged to be around 12.5% of the construction equipment expenses. These percentages are grounded in data from international projects.[14]

Note: It's pivotal to recognize that cost estimations often anchor decision-making. In a conceptual design framework, where the intricacies of final design and construction remain to be detailed, these estimations provide a ballpark figure, outlining the potential costs associated with proposed energy system upgrade.

License Application and approval

Developers aspiring to construct, own, or operate a power plant and subsequently distribute the generated electricity must apply for a unified license from NEPRA. Entities, ranging from individuals, companies, and cooperative societies to partnerships and social welfare organizations, are eligible to apply. This non-exclusive license empowers the applicant to undertake all micro grid-related activities, including but not limited to connection, metering, billing, collection, and disconnection in case of payment defaults by consumers.

Following is the process to apply for license:

Figure 10 - NEPRA MG License Approval Process

Post-license acquisition, the licensee can adjust tariffs as per agreements with consumers. Such tariff modification agreements must be submitted to NEPRA within 30 days. If NEPRA finds the tariff adjustment unwarranted, it may initiate a tariff reassessment.

Current Licencees

As of September 2023, The National Electric Power Regulatory Authority (NEPRA) has awarded licenses for micro-grid projects to Quaid-e-Azam Solar (Private) Limited (QASPPL). A total of eleven licenses have been granted, split between six and five locations, each possessing a cumulative capacity of 700 kilowatts and 600 kilowatts respectively.

Site Location	Installed Capacity (kW)	No. of Consumers
Basti Chaapu, Bahawalpur	280	40-45
Gatta Raikh, Dera Ghazi Khan	71	40-45
Basti Mud Sainad, Rajanpur	84	50-60
Basti Kheersar, Bahawalpur	91	35-40
Pughla Shumali/ Janubi, DG Khan	195	40-45

These micro-grid projects are dispersed across seven districts in Pakistan: Bahawalpur, Dera Ghazi Khan, Bahawalnagar, Rajanpur, Rahim Yar Khan, Multan, and Muzaffargarh. The aim is to enhance access to reliable and renewable electricity, especially in regions with lower grid reliability. The implementation of these projects will contribute to the ongoing efforts to improve the country's energy landscape, bringing us one step closer to universal electricity access.

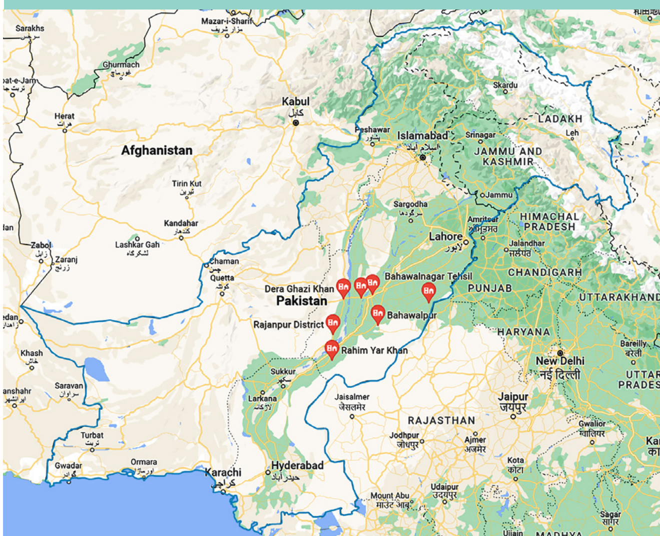


Figure 11 - Map of MG under NEPRA regulations

Arrival of Grid

The expansion of DISCO distribution networks into territories served by MG might spawn conflicts. In such events, NEPRA will facilitate a public hearing, exploring two avenues:

1. **Option 1:** DISCO may opt to acquire the operations and assets of the Micro grid, ensuring appropriate compensation is settled upon. Alternatively, DISCO can exclusively handle the power supply, letting the Micro grid owner retain distribution and generation functions.
2. **Option 2:** NEPRA could postpone or delay the acquisition for a stipulated period.

Capacity Building

For a mini-grid's success, fostering local skills is crucial. This includes training villagers, management committees, and local technicians in system usage and O&M. Especially for community-centric projects, extensive capacity-building measures ensure smooth operations. Without it, projects risk technical and financial failure. From the pilot projects, several considerations emerge:

- Involving villagers for O&M is cost-effective but mandates proper training, tools, and guidance.
- Despite training, local technicians might struggle with non-routine challenges, emphasizing the need for external expert intervention.
- Budgets should account for basic maintenance essentials to reduce system downtimes.
- Plans must accommodate periodic replacements like batteries, ensuring user fees cover such costs and establishing reserve funds.
- Clarity in roles and responsibilities across multiple stakeholders prevents conflicts.

Four level of trainings need to be considered for successful delivery of Micro Grid projects:

1. **End Users:** Train on safety, efficient electricity use, and basic technological introductions.
2. **Village Committee:** Cover renewable energy mini-grids, electricity services, project management, fee collection, and financial aspects.
3. **Local Technicians:** Equip with skills for routine maintenance, basic repairs, and ensure long-term system operability.
4. **Local Government Staff:** Offer a broad spectrum of training from basic technical knowledge to electrification planning.

Tool kit

Several tools, albeit not exhaustive, are available to communities for power system modeling and micro grid solutions:

1. **Micro Grid Design Toolkit (MDT):** A foundational toolkit for micro grid design.
2. **GIZ Mini-Grid Builder:** A free online tool that minimizes initial project costs via site survey data utilization. Users can calculate energy demand and requisite generation capacity. It also offers a financial analysis component (minigridbuilder.com).
3. **HOMER:** A dedicated software for micro grid and distributed generation system design and optimization (homerenergy.com).
4. **RET Screen:** A comprehensive software system for renewable energy, energy efficiency, and cogeneration project feasibility (nrcan.gc.ca).

MG business models

A micro grid's success is intricately tied to its supporting business model. It's pivotal to tailor delivery models to local socio-economic conditions, adopted technologies, and current and future electricity service demands. A community-engaged approach spanning design to maintenance phases not only heightens community endorsement but also bolsters sustainability and rural employment opportunities. Taking Nepal's micro-hydropower policy as a case in point, intertwining community ownership within delivery models often maximizes socio-economic dividends.

Ownership Structure

For mini-grids, several ownership models prevail:

- **Community Ownership and Management:** Here, the community wears the owner-operator hats, overseeing maintenance, tariff collection, and other managerial tasks. Commonly necessitating grant funding and potential community contributions, this model demands substantial development time and rigorous capacity building. However, the model is more sustainable in long term due to community buy-in and support. An external party may often assist in facilitating this. Once established, operational authority usually rests with a village committee.
- **Private Ownership and Management:** A private entity—be it a community member, utility company, or an external investor—orchestrates the MG. A clear emphasis on larger communities is observed in this model, ensuring rapid ROI.
- **Mixed Ownership:** Marrying elements from both above models, a private entity may handle generation and storage, while the community oversees distribution infrastructure and payment collection. Clearly defined roles are imperative to ensure smooth collaboration.

Fees and Payment Collection

A non-negotiable facet of mini-grid sustainability is a clear mechanism for setting and collecting user fees. Not only must fees adequately cover O&M, including component replacements like batteries, but they also should be palatable for consumers. Moreover, striking a balance between affordability and stimulating electricity use for commercial purposes is key to ensuring consistent revenues post-operation.

The fee structure can encompass:

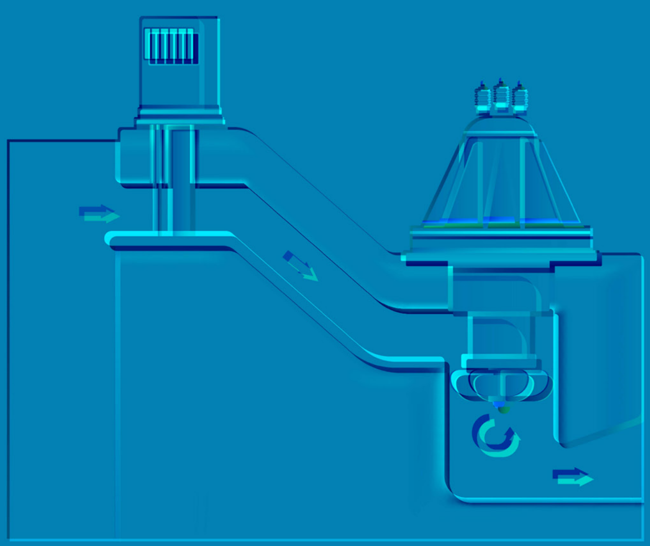
1. **Fixed Monthly Fee:** A preset fee accommodating basic electricity usage or appliance count.
2. **Tariff:** Usage-based periodic billing, facilitated

by metering. Advanced prepayment meters (PAYG) are advantageous, albeit pricier.

Diverse payment structures might coexist, tailored as per consumer groups. Whichever method is adopted, it's crucial that it's collectively agreed upon and transparently communicated.

Access to bespoke, affordable, long-term financing can exponentially elevate off-grid solution accessibility. Blending technology and finance delivery models, as seen in Bangladesh's micro-finance infrastructure and East Africa's mobile payments, offers a promising avenue. Contemporary financial tools, like crowd funding, have surfaced as potent alternatives when mainstream financing becomes elusive. For instance, in 2016, crowd funding platforms amassed USD 8.7 million for energy projects in Africa and Asia—a whopping 156% increase from 2015. While such instruments herald promise, a conducive regulatory environment is essential to channel their potential efficiently.

Mini/ Micro Hydel Development Guide



Definition

"Small hydro" is a term that is fluid in its definition, with its interpretation often shaped by geographical location and context. There isn't a universally accepted benchmark that universally differentiates 'small hydro' from other hydro classifications.

On the international platform, the categorization of hydro power plants is often based on their capacities:

- **Small Hydro Power Plants:** Typically, these have capacities ranging from 1 MW to 50 MW.
- **Mini Hydro Power Plants:** These usually have capacities between 100 kW and 1 MW.
- **Micro Hydro Power Plants:** The smallest of the category, these plants boast capacities under 100 kW.[15]

Opportunity

MHPPs stand out as the most promising decentralized renewable energy solution for delivering consistent and cost-effective electricity to Pakistan's remote and isolated regions. This is highlighted by the fact that 30% of the population in the northern regions of KP remains without grid electricity access. MHPPs come with several advantages:

- **Cost-effective:** They offer a low initial investment.
- **Consistency:** Continuous power generation without the intermittency concerns of some other renewable sources.
- **Suitability:** Ideal for community-based energy solutions.
- **Ease of Operation and Maintenance**: Minimal training required for community-based operations.
- **Quick Installation:** Less time to set up compared to larger-scale projects.
- **Minimal Land Issues:** Rarely requires land acquisition or compensation.
- **Smaller Transmission Infrastructure:** Due to its decentralized nature.

The northern mountainous areas of Khyber Pakhtunkhwa and Gilgit-Baltistan are teeming with MHPP potential. The unique topography and water flow characteristics in these regions provide opportunities for high-head, medium-head, and low-head run-of-river and storage dam power stations. This potential is all the more significant considering the low grid penetration in these regions, leaving them largely unelectrified and grappling with poverty. Notably, most of the MHPPs in these areas have been funded by MDBs and non-profit organizations.[16]

Several programs centered on MHPPs have been rolled out in KP and Gilgit-Baltistan:

- **356 Mini – Micro Hydel Projects (HDF assisted):** Totaling Rs. 5501.66 million, these projects have seen the completion of 251 units over 4 years, generating about 12 MW. Mansehra and Chitral recorded the highest numbers with 90 and 81 projects, respectively.
- **Peace Program (EU Assisted) in Malakand Division:** Operationalizing all 165 units, this program has been producing 21.1MW for the region's domestic and economic needs at a cost of Euro 40 million (2012-2018).
- **Water and Energy Security through Micro Hydels in Hundukush (SDC assisted):** Costing 3.492 million CHF, this project's second phase is underway in Laspur and Yarkhun valleys in Chitral. From 2011-15, power was supplied to over 2200 households through MHPPs, and under the second phase, another 2,278 households have been connected across 21 villages. The project is set to conclude in October 2018.
- **ADB Clean Energy Investment Program:** This initiative is divided into three components:
  1. Construction of 512 MHPs on rivers and tributaries.
  2. Construction of 160 MHPs on canals.
  3. Solarization of schools and BHUs.[17]

History of Small and Micro-Hydels

The inception of micro-hydro power (often referred to as "micro-hydels") in Pakistan can be traced back to the early 1950s. By April 1959, the Pakistan Water and Power Development Authority (WAPDA) took the reins of the power sector. Upon its establishment, WAPDA amalgamated the power generation, transmission, and distribution capabilities from various regions within the country.

- Rasul Hydro Power Station (July 1938):
  - Location: Malakand, NWFP
  - Capacity: 9.6 MW, composed of three units each with a capacity of 3.2 MW.
- Rasul MHP (December 1952):
  - Location: Punjab
  - Capacity: 22 MW, split between two units of 11 MW each.
- Dargai MHP (1952):
  - Location: N-W.F.P (erstwhile)
  - Capacity: 20 MW, with four units each delivering 5 MW.
- Kurram Garhi Hydel Power Station (February 1958):
  - Location: N-W.F.P (erstwhile)
  - Capacity: Total 4.256 MW, with a primary capacity of 4 MW and an auxiliary unit of 256 kW.
- Chichoki Malian MHP (May-June 1959):
  - Location: Near Sheikhupura
  - Capacity: 13 MW.
- Shadiwal MHP (June 1961):
  - Location: Near Gujrat
  - Capacity: 14 MW, divided into two units of 6.75 MW each.
- Nandipur MHP (March 1963):
  - Location: Near Gujranwala
  - Capacity: 14 MW, consisting of three units each of 4.6 MW.

Key Stakeholders

Most MHPPs are constructed in collaboration with the Aga Khan Rural Support Programme (AKRSP), Khyber Pakhtunkhwa Energy Development Organization (PEDO), Pakistan Poverty Alleviation Fund (PPAF), and Sarhad Rural Support Program (SRSP).

Pakistan Poverty Alleviation Fund

PPAF long experience span over 40 years in energy project execution, they've built a reputation for enabling remote communities to access electricity. Their flagship project is HRE project. This project has established five mini/micro hydropower plants in Chitral, Upper Dir, and Buner Districts of Khyber Pakhtunkhwa. These plants, with a total installed capacity of over 800 kW, do more than just providing basic electricity. They're catalysts for economic development, supporting energy needs of local enterprises, enhancing household income, and uplifting local communities.

It is also currently exploring Nanga Parbat Hydro Power Project aimed at electrifying major tourist spots like Karimabad and Aliabad. The ambition is broad, targeting 21 telecom towers and around 1,000 establishments including hotels, guest houses, and shops.

Key MHPPs based program taken up by PPAF includes:

- Provided electricity access to a whopping 65,000 underserved households through off-grid solutions.
- Specifically in Gilgit Baltistan, they've served 6,000 households, establishing themselves as leaders in the region.
- Executed micro and mini hydropower generation projects in Gilgit Baltistan with a capacity of 13.7 MW.
- Successfully set up the Ahmedabad Utility Company, which manages 520kWA and services over 1,300 consumers.[18]

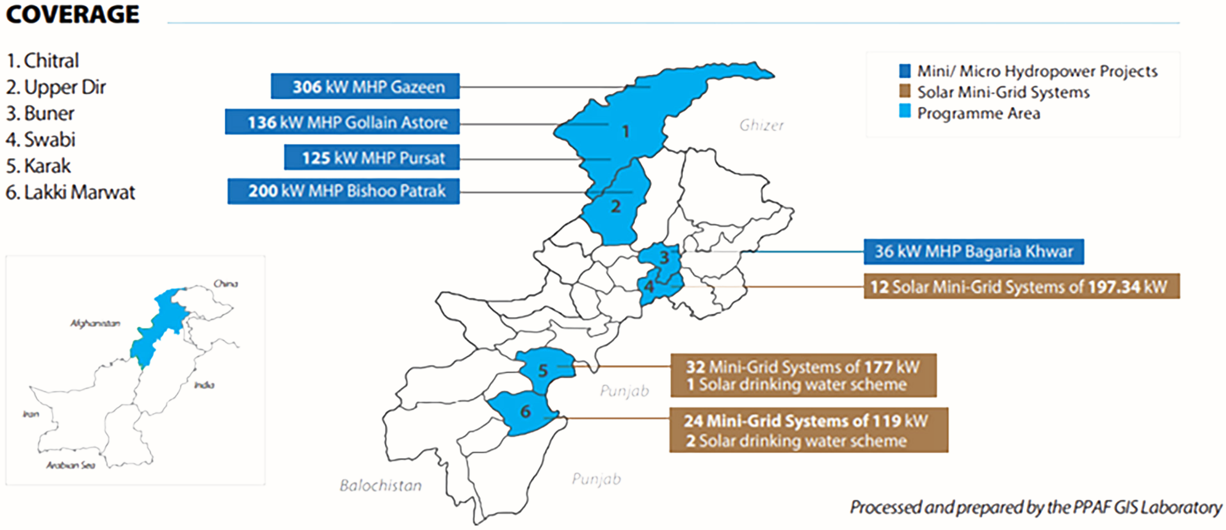


Figure 12 - MHPPs installed under PPAF portfolio in Pakistan

Aga Khan Rural Support Programme

AKRSP is one of the pioneers of MHPs in Pakistan which started in 1990s with the objective to provide decentralized, cost-effective and manageable means of energy supply to the remote hamlets of Northern Areas and Chitral.

Key MHPPs based program taken up by AKRSP includes:

1. Supported the construction of over 270 MHPPs with a total capacity of 21 MW.
2. Collaborated with PEDO for 55 projects in Chitral.
3. Introduced the "Community Based Power Utility Company" model.
4. Launched a project in Yarkhun and Laspoor valleys funded by the Swiss Agency of Development Cooperation, which also introduced institutional reform.[19]

AKRSP Success Story - Journey to Self-reliance

Nestled in the remote Hunza valley of northern Pakistan, Ahmedabad village is an energy beacon. Unlike many in this power-starved region, Ahmedabad produces more electricity than it consumes. It's home to Pakistan's first community-run private power company, fueled by micro-hydropower plants and financed by the UN's Clean Development Mechanism (CDM).

In a vision championed by AKRSP, the plan was to generate up to 15 MW from various small hydropower plants, establishing private utilities to sell excess power. Meeting the CDM's funding criteria, the community mobilized resources from livestock and timber sales, covering 20% of the costs. With AKRSP's initiative, the remaining funds were procured from the Acumen fund and a national poverty alleviation grant. Registered in 2009 with the UNFCC, the venture also received technical assistance from the German government.

Today, Ahmedabad's 200 KW hydropower plant powers its own village, neighboring areas, commercial ventures, hotels in the tourist hub of Karimabad, and even a Chinese road construction company. Local enterprises, including a women's carpentry business and restaurant, thrive on this sustainable energy.

Pakhtunkhwa Energy Development Organization

PEDO's roots date back to 1986 when it began as the "Small Hydel Development Organization". Over the years, it underwent various rebranding, with the most recent in 2014, becoming PEDO.

Key MHPPs based program taken up by PEDO includes:

1. Launched Ujalon Ka Safar Initiative to harness the mini-micro hydropower potential of the region, targeting a massive 619 mini micro hydropower projects.
2. Completed Small Hydro projects including Malakand-III, Dargai (81.0 MW), Pehur, Swabi (18.0 MW), Reshun, Chitral (4.2 MW), and several others with a total capacity of 161.2 MW. Seven Projects with combined capacity of 233 MW are under construction.[21]

Following are the roles of different organization based on PEDO model:

PEDO

- Bidding and TORs for agreements
- Award and termination of contracts
- Preodic audits of the projects
- Guidelines for tariff
- Material and Spare parts for MHPPs
- Approval of community developmen proposals

Operator/Contractors

- O&M for the project for 5 years
- Developing and implementingManagement Information system
- Tariff implementation
- Financial Managment
- Community mobilization

Communities

- Connections and disconnections
- Tariff determination
- Audit and verification of expenses and collections
- development activites
- Grievance redressal mechanisms.

Figure 13 - Mapping of Stakeholders Roles under PEDO projects

Sarhad Rural Support Programme

Since its inception in 1995, SRSP has emerged as an independent entity addressing a myriad of sectors from rural development to power. Venturing into the realm of MHPPs in 1999, starting with Battagram, SRSP broadened its horizon to Malakand by the EU-funded PREECD's aid, erecting 165 units, summing up to a capacity of 21.75 MW.

Key MHPPs based program taken up by SRSP includes:

1. Across nine districts in Khyber Pakhtunkhwa, they have set up 353 MMHPPs, ranging from 15 kW to a robust 2 MW, aggregating to an output surpassing 29 MW. This PKR 4 billion initiative illuminates the lives of 143,122 households, or 1,073,428 individuals, made possible through diverse contributors including EU, PEDO, PPAF, UNHCR, IKF, CIDA, AUSAID, ICCEO, KPAP, RAHA, and more.
2. Launched the Social Enterprise Model *(Covered in subsequent sections)*

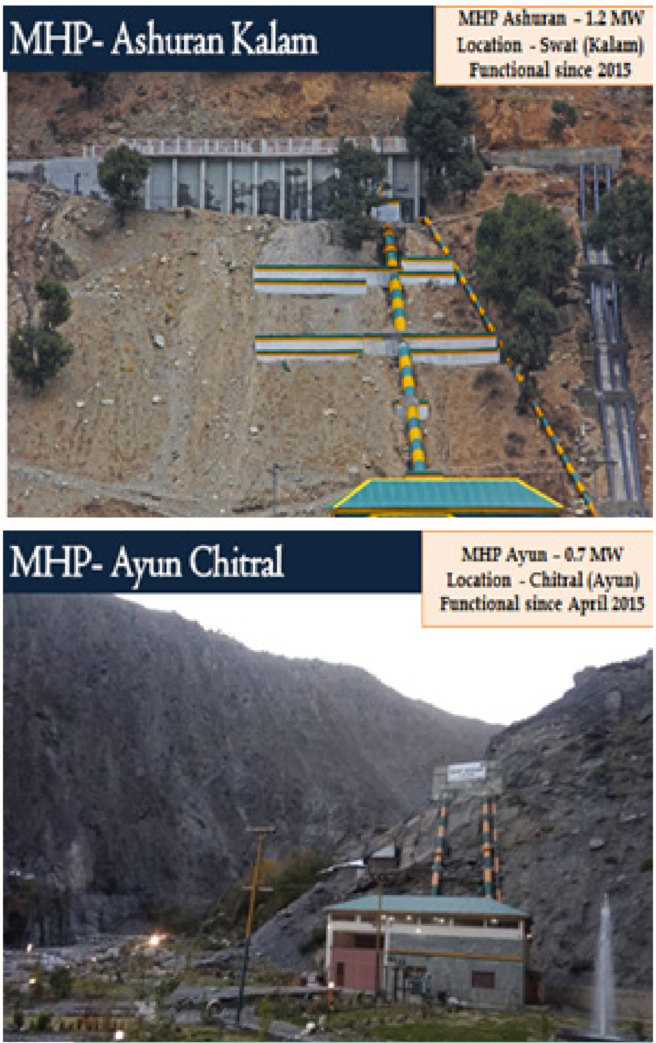


Figure 14 - MHPP in Kalam and Chitral

Federal Working Committee

In January 2018, at the federal echelon, a pivotal steering committee was birthed to oversee all Mini/ Micro Hydel undertakings in Khyber Pakhtunkhwa. With responsibilities spanning from endorsing annual work plans, scrutinizing project evolution quarterly, to eradicating development hurdles, the committee boasts eminent members:

- Additional Chief Secretary (Chair)
- Secretaries of Finance, Energy & Power, and LGE&RD Departments
- Senior Chief of Power Section, P&D Department
- Director General M&E, P&D Department
- Chief of Foreign Aid, P&D Department
- CEO of PEDO
- Delegates from EU, ADB, Swiss Development Corporation, AFD France, SRSP, and AKRSP.

Provincial Task Force

A dedicated Micro Hydel taskforce at the provincial front exists, pooling expertise from PEDO, GIKI, SRSP, FAO, and Green Hydro Company under the banner of ADP 2021-2022.

Pakistan Environment Trust

With an eco-centric vision, PET is orchestrating carbon financing avenues for MHPPs, collaborating with developers to secure i-RECs and carbon offsets against these green projects.

GIZ

Standardization in the MMHPs sector, both nationally and provincially, remains elusive. This void often culminates in sub-par, inefficient MHP units fraught with issues. Identifying and instituting minimum quality benchmarks, design guidelines, and fabrication standards is paramount. GIZ champions this cause, striving to instate standardized protocols for Micro-Hydel projects.

MHPP Business Models

1. **Basic Model for Small Size MHPP – AKRSP / SRSP**

Financing: Typically, developer and community jointly finance, with potential for grants or donor funding.

Development: Developer assists in technical planning while the community provides land and labor.

Community Engagement: Community members play a crucial role in decision-making processes, fostering a sense of ownership.

Operation & Maintenance (O&M): Managed by local community members with periodic oversight and training from developer and its partners.

2. **Community-Based Power Utility Company – AKRSP / SRSP**

Financing: A tripartite system where developer, community contributions, and formal loans or grants share by development partners of non-profit organizations share the financial burden.

Development: AKRSP provides technical expertise, while the community aids in the physical setup.

Community Engagement: Through equity shares, locals have a vested interest in project success. They are also involved in tariff setting and O&M decisions.

O&M: Community members operate and maintain, with a formalized system in place for transparency and efficiency.

3. **Social Enterprise Model**

Financing: A model by SRSP where developer takes the lead, sometimes seeking external grants or loans.

Development: Development is done by SRSP.

Community Engagement: Profits are shared with the community, ensuring their continued interest and involvement.

O&M: SRSP handles operations, but community feedback shapes the maintenance approach.

4. **Institutional Self-Sustained Model – Sheringal University Kumrat**

Financing: Institutions source funds, sometimes assisted by external donors or grants.

Development: Managed by the institution, with technical assistance from development partners.

Community Engagement: The academic community, students, or staff might be involved in initial phases.

O&M: The institution, potentially with external technical support.

5. Public-Private Partnership (PPP) Model

Financing: Shared between the government and private entities. Government can provide land and water rights, while the private sector can bridge the remaining financing gap

Development: Jointly managed by both parties. Typically, the development is spearheaded by private party based on pre-defined terms set forth in concession agreement.

Community Engagement: Often facilitated through consultations, ensuring the project aligns with local needs.

O&M: Typically the private entity, but under the guidelines set by the government.

6. Private Sector Model

Financing: Fully funded by private investors or enterprises.

Development: Private enterprises or contractors lead the development.

Community Engagement: Typically limited, though some projects may involve community consultations.

O&M: Managed by the investing private entity.

Current private Sector MHPPs in KPK constructed over canals are following:

S.#	Project name	Location	Capacity (Kw)	Load connected	Construction year
1	MHP Perano	Dargai,Malakand	800	Furnace	2018
2	MHP Brigadier	Katlang,Mardan	1000	Furnace	2019
3	MHP Katlang	Katlang,Mardan	2000	Furnace	2018
4	MHP Hatyan	Shergharh,Mardan	100	Ice Factory	2015
5	MHP Takkar	Tahtbhai,Mardan	200	Ball Mill	2019
6	MHP Qazi Surf	Tahtbhai,Mardan	40	Surf Factory	2020
7	MHP Markaz	Tahtbhai,Mardan	30	Tablighy Markaz	2010
8	MHP Chargali	Rustam,Mardan	so	Ice Factory	2020
9	MHP Warsak	Warsak Road,Peshawar	100	Ice Factory	2021
10	MHP Khanpur	Khanpur	250	Ice Factory	2014
11	MHP Ayun	Ayun,Chitral	700	Ice Factory	2001
	TOTAL		**5270**		

Table 2 -Prvate Sector MHPPs in KPK for Industries

To address energy poverty, improve energy security and decrease the rate of climate change by harnessing and distributing affordable hydroelectric power, a hypothetical business model is proposed by MMHP Taskforce report. The key features of the model are:

- Investment size: $20M (50% donor-funded, * 25% loan, 25% equity)
- Return on Investment: 16% > (32% with half the capital costs donor funded)
- Payback period / exit: 5 – 7 years
- Tariff pricing: Three quarters of revenue from commercial customers at an average of PKR 15 to PKR 18; 25% of revenue from householders at an average of PKR 10 (50%-75% discount to national grid).

The financials of the business model template is annexed (Annex II).

Project Development MHPPs – Island Mode

Identifying Site

The site area should ideally be a location not already connected to the national grid, as grid connectivity introduces additional challenges. Communities may be less inclined to support the project if they already have access or potential access to a grid connection.

The power house should ideally be located close to the village. A distant power house might deter community members from operating and maintaining the project due to the inconvenience of long travel.

Social Viability Assessment

Understanding the social dynamics and ensuring community buy-in is paramount. This is not only to ensure the successful implementation of the project but also its long-term sustainability. Organizing workshops and interactive sessions can provide insights into the community's aspirations, apprehensions, and suggestions regarding the MHPPs.

Given the economic disparities in different regions of Pakistan, assessing what the community can afford versus what they are willing to pay becomes crucial. It also aids in designing a tariff structure that's both affordable and ensures project sustainability. Exploring different tariff structures or payment models, like pay-as-you-go or community pooling, can be beneficial.

Ensuring that the distribution of energy and its benefits reach all segments of the community, irrespective of their social or economic standing, is vital. Given the communal nature of water resources and the shared benefits of power, establishing mechanisms to resolve disputes becomes essential. This is especially relevant in regions with intricate tribal or community dynamics.

Technical Viability Assessment

Although licensing might not be required due to the absence of existing water usage rights, it's essential to investigate if any irrigation channels are linked to the primary water source. The presence of such channels could mean water scarcity during crop seasons. If irrigation channels exist, a more in-depth study on water availability for hydro projects becomes necessary.

When conducting technical feasibility studies, always consider the potential need for grid connectivity in the future. The technical designs should be forward-looking, accounting for possible interconnections.

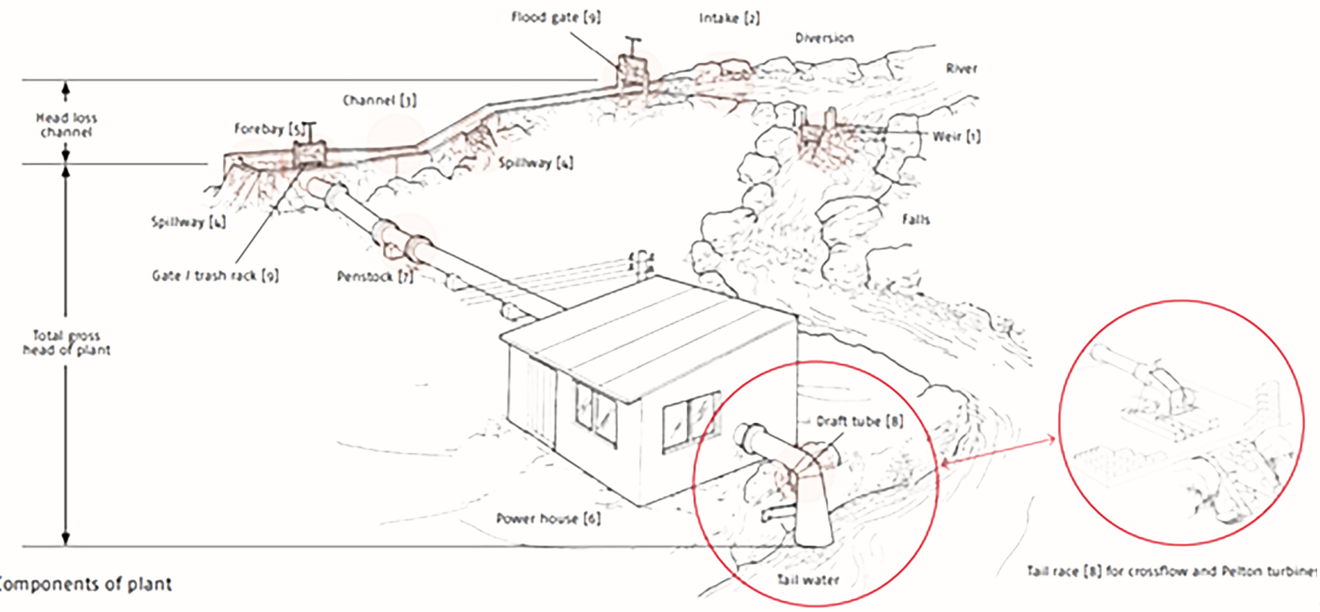
Keeping in view the extreme weather events driven by climate change including the floods, some additional factors of safety in hydrological designs of civil structures may be consider at the design stage like:

- **Protection against Natural Hazards:** Ensure all civil works components are adequately protected against unexpected and frequent natural calamities, ensuring project longevity.
- **Safety Measures Against Floods:** Incorporate an added safety factor to mitigate risks associated with high flood levels.
- **Control Gates:** Install regulated control gates at both intake and discharge points, allowing better control over water flow, especially during high rainfall and flooding events.
- **Free Board Enhancement:** Given the unpredictability of rainfall patterns, increase the freeboard in the power channel to accommodate sudden and heavy inflows.
- **Protection Works:** Make sure to introduce protective measures such as embankments, retaining walls, or other structures to guard against erosion, landslides, and other potential threats.

Components of Micro Hydro Power (MHP) Plants

Micro Hydro Power (MHP) plants capitalize on the kinetic and potential energy of flowing water to generate electricity. Here's a detailed breakdown of the components based on the provided information:

- **Weir [1]:** To raise the water level of the river.
- **Intake [2]:** To divert water from the river into the channel.
- **Channel [3]:** To transport water from the intake to the forebay.
- **Spillways [4]:** To safeguard the system from excessive water flow and prevent damage.
- **Forebay [5]:** To settle out sediment and regulate water before it enters the penstock.
- **Penstock [7]:** To channel water to the powerhouse under pressure.
- **Power House [6]:** To house the equipment that converts the energy of flowing water into mechanical and then electrical energy.
- **Draft Tube [8]:** To allow water to exit the turbine.



Components of plant

Tariff Design

The provision of 24/7 electricity through MHPPs, at rates of 4-5/unit for domestic use and 7-10/unit for commercial use, alleviates economic strain for communities. Community engagement is crucial to collaboratively decide on a tariff structure that ensures financial viability and maintains the trust and cooperation of the community. MHPPs predominantly operate without meters at consumer households, leading to a fixed rate calculated and charged per household.

Tariff of Community MHPPs is 1/6th of National Uniform Tariff after the recent electricity hike in July 2023.

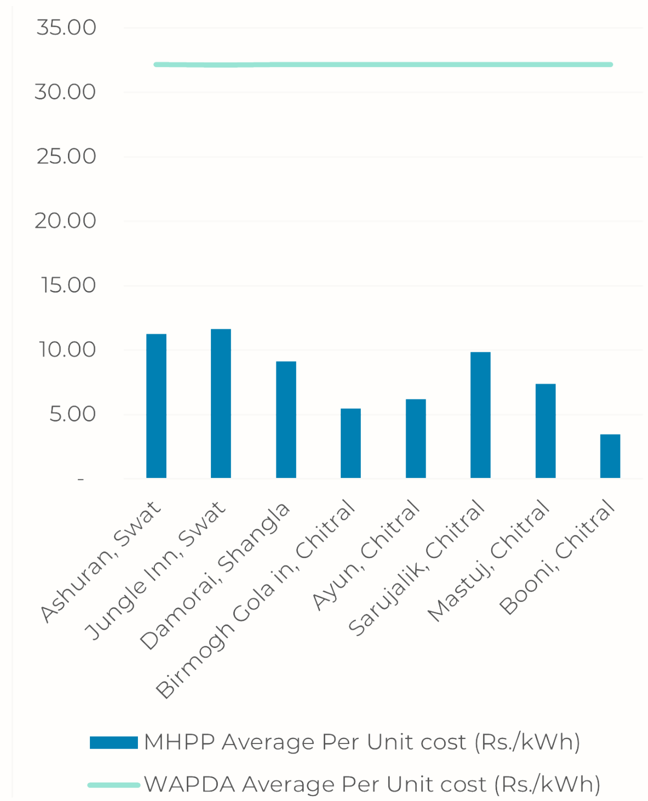


Figure 15 - Tariff of MHPPs Vs National Uniform Tariff

Procurement

Historically, Pakistan relied heavily on imported machinery for large hydro power projects. However, local manufacturing for micro hydel equipment and turbines has been growing.

While previously, turbines of less than 100 kW were produced locally, the industry has now evolved to manufacture turbines of up to 500 kW.

A shift towards the localization of the manufacturing industry is evident, leading to hybrid models. In these models, the dynamic components of the turbine machinery are imported, while static components are produced domestically. This results in significant cost savings, as importation, custom duties, and transportation costs are reduced. Furthermore, the quality and specifications of the locally-produced turbines match that of the imported ones.

Key Manufacturers of MHPP in Pakistan

1. Chitral Engineering Works: Recognized for its high-quality manufacturing, this firm has made significant contributions to the MHPP industry.
2. Mukhtar Engineering Works: A stalwart in the industry, they specialize in various hydro products and have a rich history of installations across the country.
3. Hydrolink Engineering: With expertise in hydro turbines and associated equipment, they offer end-to-end solutions for MHPPs.
4. Green Hydro Engineering: A newer player, they emphasize sustainable and green solutions in hydro power projects.
5. Lahore Engineering: Known for their wide range of products and services, they cater to both small and large hydro power projects.

The products offered by these facilities include manufacturing of hydro turbines (Cross-flow, Pelton, Kaplan), mechanical equipment (penstock pipes, mechanical control gates, trash racks) and electrical equipment (Control Panels, ELC Panels & Systems, Transformers and Electric Poles) whereas various services are provided by these manufacturers which includes supplies (Imported E&M & T&D, Local E&M & T&D and Spare Parts), Installation & Commissioning and testing of E&M & T&D and Commissioning of Plants and after sale services (trouble shooting, operation & maintenance, repairs & overhauling).

Construction

For smaller-scale projects, hiring construction workers from the local community can be beneficial. This not only supports the local economy but also fosters a sense of community ownership and satisfaction. While local workers carry out the construction, developers should deploy site-engineers to supervise the work, ensuring that the project aligns with technical and safety standards.

Operation and Maintenance

An ongoing O&M team, usually comprising one lineman and one operator, should be on-site to handle tariff collection and manage routine maintenance tasks.

Although scheduled maintenance costs are often factored into the tariff design, unforeseen issues may necessitate additional funds. In such cases, the community can explore several avenues:

- Mobilize its own resources to raise the needed funds.
- Seek assistance from regional political actors.
- Appeal to overseas relatives of community members for donations to repair or rehabilitate the project.

Annexures

Annex I - Stakeholder List

S.no	Organization	Contact
1	Ministry of Water & Power (MoWP)	
2	Alternative Energy Development Board (AEDB)	http://www.aedb.org
3	National Electric Power Regulatory Authority (NEPRA)	http://www.nepra.org.pk
4	Central Power Purchasing Authority (CPPA)	http://www.cppa.pk
5	National Transmission and Despatch Company (NT DC)	http://www.ntdc.com.pk
6	Lahore Electric Supply Company (LESCO)	http://lesco.gov.pk
7	Karachi Electric Supply Company (KESC)	http://www.kesc.com.pk
8	Faisalabad Electric Supply Company (FESCO)	http://www.fesco.com.pk
9	Multan Electric Power Company (MEPCO)	http://www.mepco.com.pk
10	Islamabad Electric Supply Company (IESCO)	http://www.iesco.com.pk
11	Gujranwala Electric Power Company (GEPCO)	http://www.gepco.com.pk
12	Hyderabad Electric Supply Company (HESCO)	http://www.hesco.gov.pk
13	Quetta Electric Supply Company (QESCO)	http://www.qesco.com.pk
14	Peshawar Electric Supply Company (PESCO)	http://pesco.gov.pk
15	Tribal Electric Supply Company (TESCO) Sukkur Electric Power Company (SEPCO)	http://tesco.gov.pk
16	Sukkur Electric Power Company (SEPCO)	http://www.sepco.com.pk
17	Pakistan Council for Renewable Energy Technologies (PCRET) Federal Board of Revenue (FBR)	http://www.pcret.gov.pk
18	Federal Board of Revenue (FBR)	http://www.fbr.gov.pk
19	Pakistan National Accreditation Council (PNAC)	http://www.pnac.org.pk
20	Pakistan Standards & Quality Control Authority (PSQCA)	http://www.psqca.com.pk
21	Punjab Energy Department	http://www.energy.punjab.gov.pk
22	Sindh Energy Department	http://www.sindhenergy.gov.pk
23	Pakhtunkhwa Energy Department	http://www.kpkep.gov.pk
24	Gilgit Baltistan Energy Department	http://www.gilgitbaltistan.gov.pk
25	PSA	http://www.pakistansolarassociation.org
26	REAP	http://www.reap.org.pk
27	USAID	http://www.usaid.gov/pakistan
28	JICA	http://www.jica.go.jp
29	ADB	http://www.adb.org/countries/pakistan
30	KfW	http://www.kfw-entwicklungsbank.de
31	EU	http://www.ec/europa/eu
32	GIZ	http://www.giz.de
33	UNDP	http://www.pk.undp.org/
34	NUST (USPCAS-E)	http://www.nust.edu.pk/CES

Annex II – Private Sector MHPP Business model

	MHP: Business Plan Model		
1	MHP Name		MHP - 1
2	District		Chitral
3	Installed Capacity	KW.	10,000
4	No of MHP	Rs.	3
5	Standard Avg Cost per KW	Rs.	340,000
6	Useful Life	Yrs.	15
7	Land Required *(per MHP 10 Kanal)*	KN	30
8	Per Kanal Land Cost (If purchased)	Rs.	3,000,000
9	Units Generated *(Power House per Hrs.)*	No.	24
10	Units Generated *(Power House No of Months)*	No.	12
11	Units Loss *(against Units Generated)*	%	16%
12	Domestic Connection *(Plan 1)*	%	80%
13	Commercial Connection - Plan 1	%	20%
14	Domestic Connection - Plan 2	%	25%
15	Commercial Connection - Plan 2	%	75%
16	Per HHs Units Consumed	No.	100
17	Per Commercial Units Consumed	No.	300
18	Monthly Expense *(Per KW)*	Rs.	800
19	Monthly Depreciation(Per KW)[1]	%	1,200
20	*Depreciation Fund Investment Rate*	%	10%
21	Return to Investor (Per KW)[2]	%	8,000
22	Connection Charges- Domestic	Rs.	3,000
23	Connection Charges- Commercial	Rs.	7,000
24	Institutional Cost against total Investment	%	10%
25	Exchange Rate Dollar	Rs.	200

Summary Of Business Plan		
Heads	**Rs.**	**$**
System Cost	3,400,000,000	17,000,000
Land Cost	90,000,000	450,000
Implementation Cost	558,760,000	2,793,800
Total Investment	**4,048,760,000**	**20,243,800**
Total - Return	14,400,000,000	72,000,000
Direct Return %		**23.7%**
After Dep Amount		**30.5%**
Tariff - Plan 1(Domestic 80% & Commercial 20% Connection)		**27.56**
Tariff - Plan 2(Commercial 100% Connection)		**28.94**

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