

Sustainable Mini-grid Solutions for Off-grid Electrification in Pakistan

Policy Brief

This policy brief highlights the importance of sustainable mini-grid solutions for off-grid electrification in Pakistan. It discusses the need for renewable energy (RE) mini-grids, emphasizing their cost-effectiveness, reliability, and ability to meet the specific energy needs of the communities. It also addresses the challenges faced in implementing mini-grid projects and explores the economic attractiveness and potential benefits of mini-grids. By focusing on these aspects, Pakistan can unlock the potential of mini-grid solutions and improve energy accessibility in remote areas, thus stimulating economic growth and enhancing the quality of life for local communities.

Executive Summary

Pakistan, with a population of approximately 232 million, ranks as the fifth most populous country globally. Electricity access rate in the country is 87.87,¹ however, the figures are debatable and a significant portion of the population lacks this fundamental necessity. Access to energy, including its affordability, is integral to the United Nations' Sustainable Development Goals, aimed at eradicating poverty, fostering sustainable communities, promoting industrial innovation, and providing clean and renewable energy. The socio-economic development of communities heavily relies on dependable energy access.

Pakistan, as a developing nation, faces significant challenges in overcoming its energy crisis, which encompasses various aspects. One pressing issue is the electrification of areas that are currently without access to the power grid. The power sector in Pakistan is regulated, with distribution managed by state-owned companies known as DISCOs (distribution

companies), responsible for providing electricity through their network infrastructure. Unfortunately, the distribution system was not designed to cater and achieve electrification up to the highest level.

For areas with a population density of 26 to 50 persons per square kilometer located at a distance of 20 kilometers outside the grid, the DISCOs find it economically unviable to provide energy access through their wirelines network. Expanding grid infrastructure to the off-grid areas has remained a complex issue without resolution for decades.

A recent study estimates that more than one thousand villages and communities, with a population of around 50 million, reside in off-grid areas scattered across Pakistan's four provinces.² The challenge of expanding grid infrastructure to reach these off-grid areas has persisted for decades. RE-based mini-grids offer a promising solution for electrifying these regions. Mini and micro-grids provide a viable option for last mile electrification, considering the essential need for energy access. Without reliable access to

¹ "Pakistan National Census Report 2017," Pakistan Bureau of Statistics, https://www.pbs.gov.pk/sites/default/files/population/census_reports/ncr_pakistan.pdf

² Hussain Samad and Fan Zhang, "Electrification and Household Welfare – Evidence from Pakistan," Policy Research Working Paper 8582 (September 2018), World Bank Group, <https://documents1.worldbank.org/curated/en/585231536778611429/pdf/WPS8582.pdf>

energy, these communities face significant obstacles in maintaining sustainable and prosperous livelihoods. Implementing mini-grids as a cost-effective solution enables communities lacking economic viability for grid connection to access electricity and pave a path towards a sustainable future.

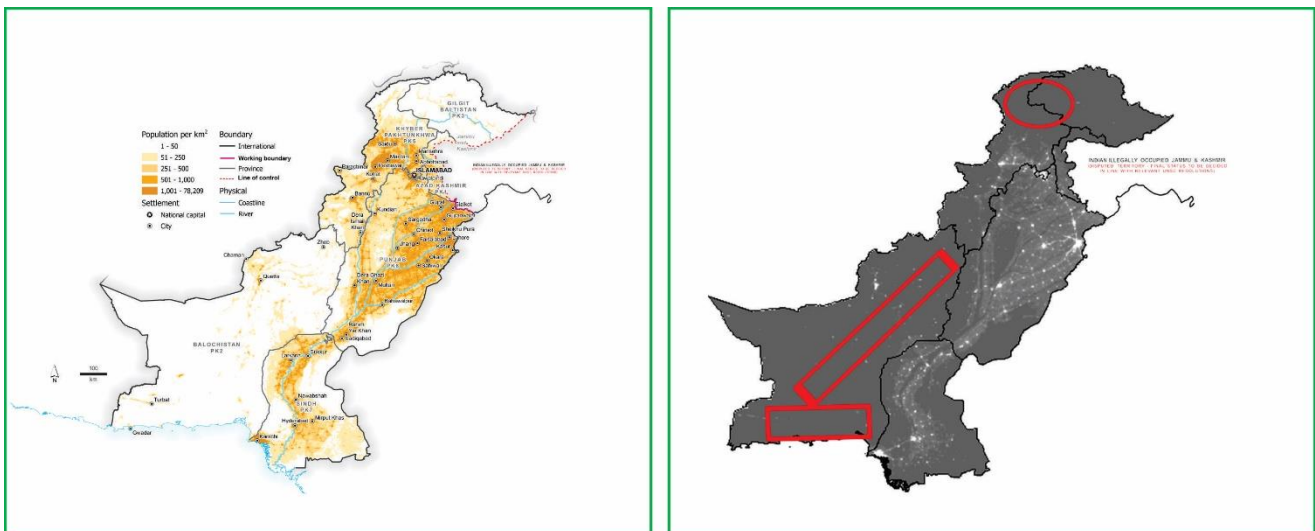
Need for RE Mini-grids in Pakistan

Mini-grids can be designed to meet the specific needs of a community, providing a more efficient and cost-effective way of generating, transmitting, and distributing electricity compared to extending the national grid to remote areas.³ Moreover, mini-grids offer improved reliability compared to centralized grids, which are vulnerable to disruptions and blackouts. With RE sources such as solar and wind, mini-grids can help to achieve targets aligned with the Alternative and Renewable Energy Policy of Pakistan. By providing reliable and affordable electricity to remote areas, RE mini-grids can stimulate economic growth, create new job opportunities, and improve the quality of life for local communities.

Energy Accessibility in Pakistan

To conduct an analysis of off-grid areas, a comparative assessment of off-grid electrification has been performed utilizing maps of satellite imagery. This analysis reveals that certain regions within the provinces of Balochistan and Khyber Pakhtunkhwa lack access to reliable energy sources due to their geographically isolated nature, rendering them beyond the coverage range of existing power grids. These areas exhibit a population density ranging from 50 to 100 individuals per square kilometer and are characterized by remote locations housing distinct communities that are deprived of electricity. The provinces of Khyber Pakhtunkhwa and Balochistan encompass dispersed populations that are primarily concentrated in mountainous regions and vast desert landscapes. Consequently, this geographical context presents a challenging scenario for policymakers, necessitating the consideration of alternative interventions beyond the mere enhancement of grid infrastructure.

Figure 1: Comparison of Population Density and Off-grid Areas Through Night Imagery⁴



* The maps have been modified to show the existing status of the disputed region of Jammu and Kashmir illegally occupied by India.

³ “Clean Energy Mini-Grid Policy Development Guide,” United Nations Industrial Development Organization (UNIDO), 2020, https://www.unido.org/sites/default/files/files/2021-03/CEMG_Development_Guide_EN.pdf

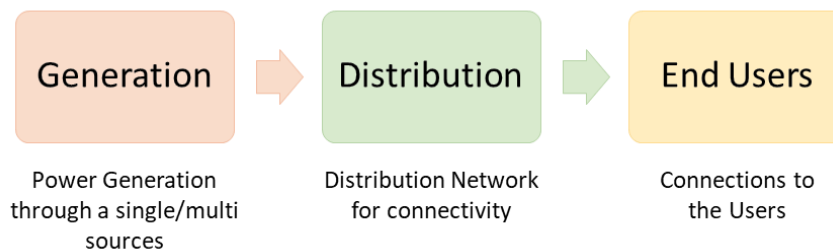
⁴ “Baseline population estimates,” MapAction, May 30, 2023, <https://maps.mapaction.org/dataset/pak-ma010-v1> “Pakistan; and GADM maps and data, nightlight imagery, GADM, <https://gadm.org/maps/PAK.html>.

Mini-grids – Midway of Standalone and Grid Systems

Mini-grids are independent, decentralized electricity networks that can function separately from a national grid. These provide an enabling environment for the project developers to better track and understand a community's energy needs, with higher reliability of supply and better power quality in the remote and rural areas, thus lessening the transmission and distribution (T&D) losses. Majorly, the T&D losses of the DISCOs are due to the lengthy transmission lines meant for

supplying electricity to the far-flung rural areas. As such, mini-grids are very useful in mitigating these losses as decentralized remote solutions of energy access would lessen the T&D losses of the DISCOs. Mini-grids based on RE sources have many success stories around the world. They are perceived to achieve economic sustainability of the community in their operational areas by improving rural livelihood, enhancing business activities, adding value to the local products and boosting the living standards of the society collectively.

Figure 2: Operational Components of Mini-grids



Development of Mini-grids in Pakistan

In Pakistan, a prominent feature concerning mini and micro-grids is the development of the NEPRA Licensing (Microgrid) Regulations, 2021. In this regard the National Electric Power Regulatory Authority (NEPRA) has developed a policy framework which ensures that the tariffs are reasonable for the consumers and are settled through bilateral cooperation/settlement between the mini-grid developer and consumers. The other features of the policy include facilitation of localized energy systems, business-to-business (B2B) entities and social welfare organizations to maintain the energy affordability.

The development of mini-grids in Pakistan can be facilitated by several factors. One key factor is the cost-effectiveness of mini-grids for off-grid electrification, which has improved due to advancements in deployment techniques for RE sources. Additionally, the participation of private sector entities in the development of RE projects has contributed to the growth of mini-grids.

However, the evolution process towards the development of mini and micro-grids has remained uneven. One significant factor for this situation is the disparity in infrastructure development across various regions in Pakistan. Remote and underserved regions lack the necessary infrastructure to have a more favorable environment for the development of mini and micro-grids, making it more challenging to implement such projects.

Experience of Development of Micro-grids in Pakistan

Regarding development of micro-grids in Pakistan, insignificant progress has been made to eradicate energy inaccessibility in some of the rural regions. Currently, there are 13 micro-grid-based installations in the construction phase, based on hydropower and solar energy. Moreover, Pakistan Poverty Alleviation Fund is implementing 68 state-of-the-art solar energy micro-grid projects in remote and off-grid locations of Lakki Marwat, Swabi and Karak districts of Khyber Pakhtunkhwa.⁵

⁵ Danial Saleem, "Techno-Economic Analysis of Widespread Microgrid/Minigrid (MG) Deployment in Pakistan's Electrical Power Sector," Research for Social Transformation & Advancement, Pakistan Institute of Development Economics, Islamabad, March 2022, <https://rasta.pide.org.pk/wp-content/uploads/Danial-Saleem-Conference-Paper.pdf>

To support steady development and adoption of micro-grids, feasibility and economic analysis are vital for the facilitating and regulatory bodies to explore the financing options and business models.

Economic Attractiveness and Challenges in Development of Mini and Micro-grids

RE sources have emerged as a highly financially viable option for micro-grids compared to traditional fossil fuel-based power generation. With advancements in both the technical and commercial aspects of RE sources, RE sources have proven to be the most cost-effective means of generating power.

The potential applicability of RE sources, such as solar, wind, biomass, and mini-scale hydropower, supports localized solutions through micro-grids, resulting in cost savings. However, some critical barriers and challenges exist in adoption of mini-grids, as described below:

- a. Policy formulation at the national level has remained largely focused on large-scale procurement of power (independent power producers' mode).
- b. Difficulties with accessing finance by mini-grid developers.
- c. Lack of experience in mini-grid development.
- d. Perceived consideration of mini-grid businesses as risky ventures.
- e. Lack of technical and financial capacity by local developers to meet the equity requirements.

Tariff Settlement for Micro-grids

Settlement of tariff is the base factor on which the sustainability of the mini-grids is highly dependent and NEPRA allows tariff to be settled bilaterally by the micro-grid developer and the consumers. On the other hand, the consumers' ability to pay is an important factor to determine how the business models can work. Some of the objectives to consider are:

- a. Attracting commercial entities to invest in micro-grids
- b. Ensuring financial viability and sustainability
- c. Supporting economic development and improvement in living standards
- d. Balancing sustainability and affordability

Financial Sustainability of Micro-grids

To ensure that mini-grids are financially sustainable, it is important that consumer tariff remains low in order

to maintain energy affordability. Support from the government, financial institutions and international bodies for funding needs to cover the operation and maintenance costs. Moreover, donors' support is also instrumental for the financial sustainability of micro-grids.

Some of the highlighted areas for financial sustainability of micro-grids are:

- a. **Public-Private Partnerships:** Development framework for micro-grids requires close working cooperation between government agencies, commercial entities, research institutions, international organizations and financing institutes.
- b. **Corporate Social Responsibility:** Commercial entities can be driven to contribute in RE-based micro-grid development through the obligations of corporate social responsibility (CSR).
- c. **Regulations of Subsidized Tariff for Off-grid Electrification:** The government is required to enforce tariff equitable with the energy affordability of the consumers.
- d. **Streamlining Financing Schemes:** For steady development, concessional financing schemes are necessary.

Conclusion

Development of sustainable mini-grids hold great potential for off-grid electrification in Pakistan. These can be tailored to meet the specific needs of communities, offering a more efficient and cost-effective alternative to extending the national grid to remote areas. By providing reliable and affordable electricity to far-flung areas, RE mini-grids can stimulate economic growth, create job opportunities, and enhance the quality of life for residents.

The analysis of off-grid areas reveals that certain regions, particularly in Balochistan and Khyber Pakhtunkhwa, lack access to reliable energy sources due to their isolated nature. Mini-grids can bridge this gap and provide a decentralized electricity network, offering higher reliability and better power quality to remote and rural areas. Additionally, mini-grids can help reduce transmission and distribution losses, which are common in centralized grid systems.

The development of mini-grids in Pakistan has been facilitated by factors such as improved cost-effectiveness due to advancements in renewable

energy deployment techniques and the participation of private sector entities. However, challenges remain, including disparity in infrastructure development across regions, difficulties in accessing finance for mini-grid developers, and a lack of experience and technical capacity in mini-grid development.

To address these challenges and promote the development of mini-grids, several recommendations are proposed. These include the establishment of financing schemes involving public-private partnerships, international funding organizations, development banks, and government incentives. Encouraging indigenous development, fostering market-based participation, and promoting technological breakthroughs, innovative business models, and enabling regulations and policies are also essential for the accelerated growth of micro-grids in Pakistan.

Recommendations

• Necessity of Financing Schemes for Development of Micro-grids

It can involve public-private partnerships, international funding organizations, development banks, and government incentives to attract investments and support the financial sustainability of micro-grid projects.

• Persuasive Focus on Framework for Development of RE-based Micro-grids Aligned with ARE Policy 2019

The development of RE-based micro-grids should be aligned with the policy framework set forth by the

Alternative and Renewable Energy (ARE) Policy of 2019. By focusing on this framework, stakeholders can ensure that the development of RE-based micro-grids adheres to the policy goals to increase energy access, and promotes sustainable development.

• Indigenous Development

To foster indigenous development and innovation in the micro-grid sector, it is important to establish strong linkages between industry and academia. Collaborative efforts can facilitate knowledge sharing, research, and development of technologies and solutions specific to the local context.

• Market-based Participation

Market-based approaches mainly include business models, which are pursued with the support of public-private partnerships. Other main supporting mechanisms include corporate social responsibility of the commercial entities, and incentives provided by the government. Investments, funding, technology transfers, and capacity building are the major considerable factors to maintain market-based adoption.

• Encourage Technological Breakthroughs, Innovative Business Models, and Enabling Regulations and Policies

To accelerate the development of micro-grids, it is essential to encourage technological improvements, innovative business models, and establish enabling regulations and policies.

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