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Electrifying rural India: A Case Study on Mlinda's solar mini-grids

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_VO**IS Planet** portal primarily focuses on environmental sustainability covering various aspects: **Low carbon, Renewable energy usage** and **E-waste management.**

It is aimed at aggregating and helping co-create knowledge and information on environmentally responsive behaviours and concurrently pursuing result-oriented social media campaigns to encourage people and specifically the youth, to take proactive actions in promoting sustainable lifestyle and creating a positive impact on the environmental ecosystem in their surroundings

By: _VO**IS Planet**

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Executive Summary

The page for renewable energy has turned and now there is a huge appreciation among the policy makers, industry stakeholders, as well as the common public about the potential of renewables in contributing towards accelerating the global electrification efforts in India, as well as in the entire world (5). Mini-grid sector in India has added a major part in providing reliable access to electricity for all, particularly for rural communities (5). The Central government is continuing to make progress towards achieving universal electrification and international players have been pitching in to help India achieve its target.

Mlinda, in order to enhance the access to energy, is in continuous effort of installing scalable and replicable model of decentralized village grids in rural India. Around 39 such grids covering 49 villages had been installed till March 2020. The number had increased to 49 grids in around 50 villages by March 2021, which meet both domestic as well as agriculture needs.

Nearly 7,000 households have been connected to the community mini-grids set up by Mlinda's effort. These mini-grids providing electricity benefits to around 35,000 to 40,000 people. Moreover, around 1,000 job opportunities have been created by Mlinda while installing these mini-grids across different rural areas.

Solar mini-grids provide a tremendous opportunity in terms of job creation, particularly if associated with skill development, connecting to the markets and cost-effective with a longer tenure financing (6).

1. Introduction

India has the largest rural population in the world and thus the nation confronts a major challenge of rural electrification, particularly electrifying the remote, forested and tribal habitations situated in far off places. According to IPES 2020, approximately 97% of the households in India are electrified. India, on household electrification, has made an appreciable effort. Around 96.7% of the households are now connected to grid with around 0.33% depending on off-grid electrifying sources. However, 2.4% of the Indian households still remain unelectrified. The unelectrfied regions are generally concentrated in the rural areas of Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana and Bihar (24).

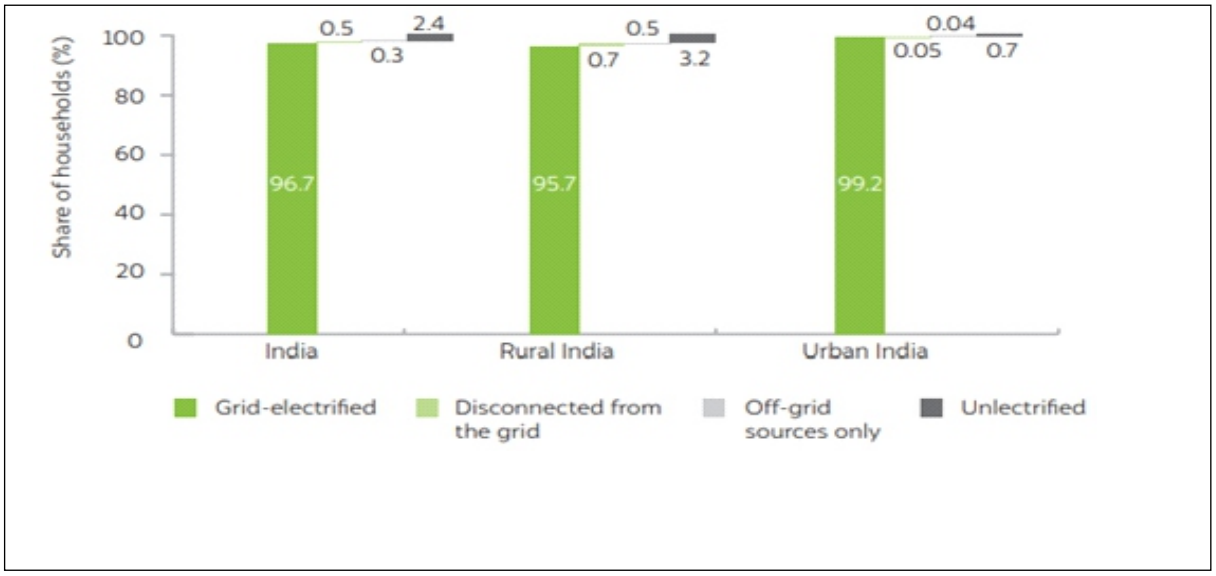


Fig: 1 Access to electricity in India (Source: CEEW)

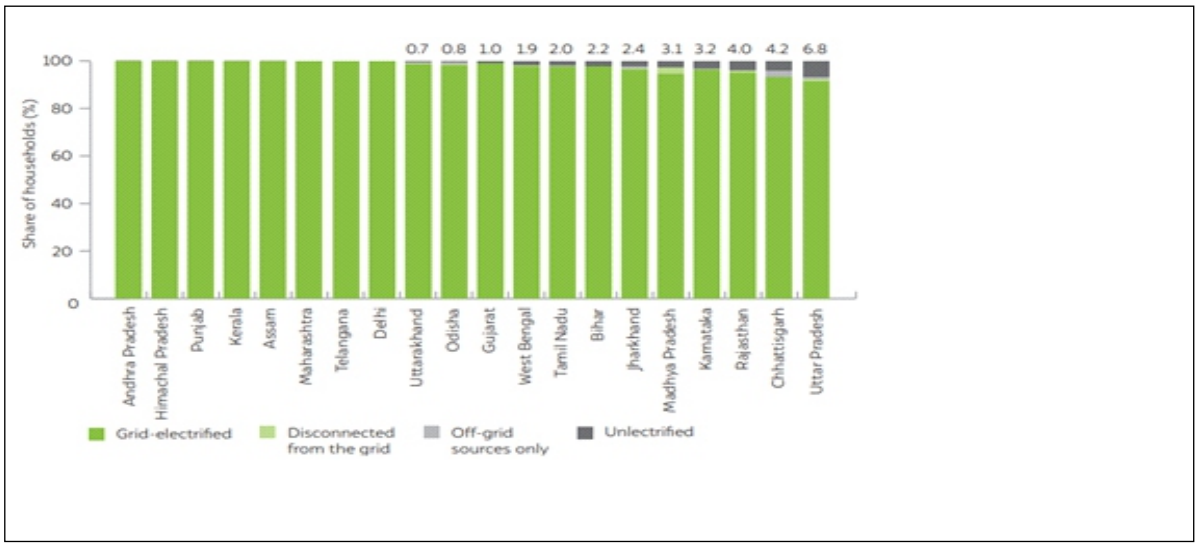


Fig: 2 States with unelectrified households (Source: CEEW)

So far, the centralized grid based electrification has been proved to be the most common approach[1], decentralized RE options, more specifically, Solar PV systems have also been utilized, and are in demand, as they are economical, particularly in areas where it is techno-economically not possible to extend the electricity grid, and also in areas where the supplied electricity from the grid is insufficient to meet the needs (3, 4). These off-grid communities are generally small, having low-income households, and are usually characterized by settlements, therefore these are economically-not-attractive for electricity distribution companies to extend grid.

Statistical reports published by Ministry of New and Renewable Energy (MNRE) show that around 12,000 villages in India have already been benefitted through RE based mini-grids and Solar Home Systems (SHSs). This has been done under Remote Village Electrification Program (RVEP). Solar PV projects (more than 1KWp) including solar mini-grids with the capacity of 1 to 500 KWP have been installed in India. These grids hold a cumulative capacity of 96.61 MWP, as reported till August 31, 2018 (1).

The solar mini-grid model has gained a lot of appreciation not only in South Asia and South East Asia but also in Africa as a source to achieve renewable energy access objectives of the Sustainable Energy for all by 2030.

Grid-based electrification is considered to be the most pre-dominant form for electrifying the rural India covering around 94.5 per cent of the inhabited area (7). Moreover, RE-based off-grid and decentralized technologies have also been utilized in areas that could be accessible for grid connectivity or are associated with hamlets that have no recognition of villages as per Indian Census (8).

[1]At present, around 94% of the inhabited areas in the nation are covered through grid electrification

2. History of Solar mini-grids in India

The idea of solar mini-grids in India was introduced long back in the 1990s. It began in the Sunderban delta region of West Bengal, and in the tribal zone of Chhattisgarh (1). West Bengal Renewable Energy Development Agency (WBREDA) in the year 1995-96, installed a solar photovoltaic plant with a capacity of 25KWP in Kamalpur village of Sagar island. This grid is continuing to provide electricity to the beneficiaries even today. The first solar plant in Chhattisgarh was set up at Lamni village in Bilaspur district. This grid is also reported to be operational till date (1). Following this, solar power plants, either in stand alone or in hybrid mode have been installed in several states and union territories such as Andaman & Nicobar Islands, Chhattisgarh, Lakshadweep, Bihar, Madhya Pradesh, Odisha, West Bengal, Uttar Pradesh and Meghalaya.

Fig: 3 A solar mini-grid in Chhattisgarh (Source: CEEW)

With time, challenges and altering priorities, solar mini-grids have evolved in India. However, the evolution was limited due to technical dimensions, new and innovative delivery models as well as financial models. Since 1990s, the solar mini-grids have undergone three phase development. The first phase of mini-grids operations took place during early nineties till around early 2000s. This phase focused on developing pilots, demonstration of the technologies developed, and testing

institutional models.

Development of these models as a potent vehicle for electrifying remote and far flung villages was the main focus of the second phase. This phase was initiated in 2001, under the government sponsored remote village electrification program. In addition, experiments on deploying larger capacity mini-grids . and hybrid mini-grids (for example solar mini-grids of Sunderban) were also a major focus area of this phase. It was during this phase when Electricity Act 2003 was introduced, where mini-grids as decentralized distributed generation was incorporated as a way for laying out rural electricity supply.

The third or current phase of mini-grids development is encountering the entrance of private sector developers since the past few years. This is thus bringing in the technical as well as the institutional innovations. The entry of private sector has led to the development of smart mini-grids that provide better supply and demand side management (1).

3. Mini-grid coverage in India

3.1 Government Initiatives

The solar mini-grids have been basically installed under the Remote Village Electrification Program (RVEP) or recently as a part of Jawaharlal Nehru National Solar Mission (JNNSM) under the Ministry of New and Renewable Energy. WBREDA has installed around more than 20 solar mini-grids with a capacity of 1 MWP, which electrifies around 10,000 households. Chhattisgarh State Renewable Energy Development Agency (CREDA), a second key component of the model has benefitted 57,698 households supplying electricity of capacity 2-6 KWP solar mini-grids (9).

3.2 Private companies' and other NGOs' contribution

In addition to government initiatives, a number of NGOs and private sector players have also contributed to the installation of solar mini-grids in various regions. A Norway – based solar manufacturer company, SCATEC solar, has electrified around thirty villages together in Uttar Pradesh, Jharkhand and Madhya Pradesh. Another start-up company, Mera Gaon Micro-grid Power, is all set to install solar direct current (DC) micro-grids in the regions of Sitapur and Barabanki districts of Uttar Pradesh. This will be providing electricity and lighting services by utilizing energy efficient LEDs. Husk Power Systems, well known for its biomass gasifier dependant electricity distribution system, had extended hands into solar DC micro-grid space. This is thus electrifying households in their respective existing operational zones. Sun Edison, Kuvam Energy, Minda NextGen technologies and Gram Power are some other private firms that are venturing into solar alternate current (AC) or DC mini-grids for providing electricity services to non or poorly electrified villages (10).

Parameter	CREDA	WBREDA	Husk Power System
Area of Operation	Chhattisgarh	Sunderban, West Bengal	Uttar Pradesh
Technology	Solar PV	Solar PV	Solar PV
Technology	Public Sector	Public Sector	Private Sector
First plant commissioned	2004	1996	2008
Achievements	1439 villages and hamlets serving about 35,000 households	22 mini-grids serving around 10,000 households	80 villages serving 25,000 households
Average size of the power plant	1-6 kWp	25-100 kWp	25-100 kWe
O&M structure	Contracted out through AMC using cluster based approach	Contracted out through AMC	Cluster-based approach with O & M done by the company
Energy provision	2x11W CFLs	2-5 light points x 11W CFL and fan point	2x 15W CFL & plug point
Energy application	Mostly for lighting, also, for running fans and TV, etc	Lighting, fan, TV and some productive activities	Lighting, fan, mobile phone charging, etc.
Supply duration (hrs/day)	5-6	5-6	6-8

Table: 1 A comparative assessment of mini-grid models in India (Source: TERI compilation, 2013)

4. Features of mini-grids

The solar mini-grids are designed in such a way that they generate electricity centrally, and the distribution of that electricity, for different uses, to households and for small businesses are spread within a certain area[2].

These solar mini-grids differ in size and capacity, usually ranging between 1-200kWP, with different places and regions adopting various size and models as per the needs of the local requirements. Mini-grids in the states of Chhattisgarh are generally smaller in capacity [<6kWP], while the ones in the Sunderbans and the Lakshadweep are installed with higher capacities [>100kWP]. Invertors as well as storage systems are incorporated into these solar mini-grids when they are installed at a particular region. This is done so as to provide a longer life, and reliable field performance to these mini-grids. Technology and community dependant innovations are being continuously incorporated into these mini-grids which would further require changes with time. Until 2000, solar mini-grids with capacity ranging between 25-26 kWP were mostly installed by WBREDA. Due to the lack of concept and technology, larger capacity were neither approved nor accepted till then. But owing to the huge demand and interest shown by the population, WBREDA also began installing and building power plants with capacities >100kWP in a number of locations and have also installed some more generation units utilizing different forms of RE, for example, small wind generators as well as biomass gasifiers to fulfill the incremental power requirements (1).

[2]As far as India is concerned, solar mini-grids generally provide 220V, 50Hz, single or 3 phase AC electricity through distribution network. It comprises of: (i) solar PV array for the production of electricity; (ii) battery bank for storing electricity; (iii) power conditioning units (which consists of charging controllers, invertors, AC or DC distribution boards and required cabling); and (iv) local low-tension power distribution network.

The solar direct current micro-grids are basically promoted by the private companies. These micro-grids generate direct current utilizing single or multiple solar panels which are distributed at short intervals from the battery banks to the cluster of homes, and small shops as well as micro markets within a village. The DC supply generally ranges between 12V to 24V that electrifies for around 5-7 hours making use of LED lamps of 2-3 watt per household. The number of households being benefitted by these micro-grids is around 20 to 100, and the facilities include lighting and mobile charging.

5. Mlinda's approach

Mlinda Sustainable Environment Private Limited (MPL) was registered in Kolkata, India, in July, 2014. MPL is a wholly owned subsidiary of the Mlinda Foundation CIO. It works in collaboration with the independent charitable trust Mlinda Charitable Trust which is responsible for community mobilization, capacity building and economic development, environmental and social impact.

Mlinda Foundation CIO and MPL work with the Mlinda Charitable Trust, which carries out activities, related to R&D, community businesses in relation to the rural electrification activities.

Mlinda is a distributed RE provider based in Jharkhand that serves residential as well as commercial energy needs with reliable power (12). The company's objective is to utilize electricity as a tool for development, and aims to end energy poverty through its work i.e. to set up community mini-grids across rural India.

Fig: 6 Local workers installing the framing for photovoltaic solar panels (Source: Mlinda, 2019)

6. Methodology for reliable energy service

Mlinda has developed a four-step methodology for deploying and ensuring reliable energy service.

6.1 Community engagement and standardized village selection criteria

The first and the foremost step is community engagement. Mlinda makes sure that its resources could meet each community's requirements. For this, the team conducts a detailed survey to assess the demand, and community's ability to pay.

6.2 Load analysis and grid designing

The second step is to conduct electricity load analysis and mini-grid designing. This analysis provides a rough estimate about the size of the community mini-grids that could provide the required capacity to electrify residential areas.

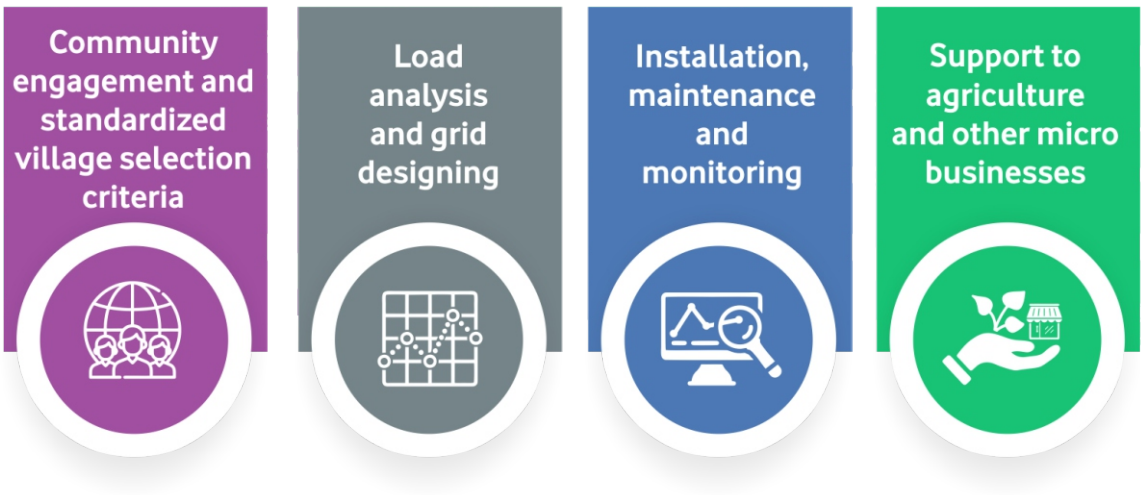
6.3 Installation, maintenance and monitoring

The next step is that Mlinda has made their operational and maintenance personnel locally-based. This creates a bond of trust between the company and community members they serve.

6.4 Support to agriculture and other micro businesses

Lastly, Mlinda has a group of members that dedicatedly work with communities to support micro-enterprises. The in-country or the local team members contribute into developing tailored strategies, for example, providing regional and specified skilled training, and productive use of appliance financing to power local economies (13).

Providing single phase energy for domestic needs such as lighting and for small water pumps, and 3-phase energy for agricultural businesses such as oil processors, wheat millers, rice hullers and larger water pumps for irrigation are also some of the support areas, where company facilitates and



7. Achievements

Fig: 7 Reliable lighting for a household in Jharkhand through solar mini-grid power has ensured unhindered home education time for school going children (Source: Mlinda, 2019)

95% of the villages in Jharkhand have been electrified under the National Grid, however, the quality and reliability of this power still remains poor. Most villages still depend on coal, firewood and kerosene to meet the energy needs. Needless to say, these sources are unhealthy and harmful to the environment.

India is the world's fourth largest consumer and producer of electricity. Rural electrification has always been a prime agenda for Indian government. In Jharkhand and West-Bengal, under the rural electrification program, Mlinda has successfully financed, installed and maintained multiple grids connecting numerous productive loads, brightening up houses of thousands of families, multiple shops and lives of children in school hostels. Mlinda has established around 310 Pico and micro-grids, 13 mini-grids that have connected 212 productive loads benefitting 2,760 families, 165 shops and electrifying three school hostels. Mlinda's project villages could also use the solar power mini-grids to power three phase productive loads used in agricultural practices.

Mlinda has helped set-up local businesses, and aided the entrepreneurs to sell their produce in urban market of neighboring states. Mlinda's energy solutions have helped their project villages in increasing their GDP and reduce the annual GHG emissions, thus ensuring a cleaner and brighter future.

In the phase III of their project in 2019, Mlinda has scaled up their solar power mini-grid to 50 villages across Jharkhand benefitting around 40,000 people, thus successfully providing tailor-made solutions to India's energy security problems.

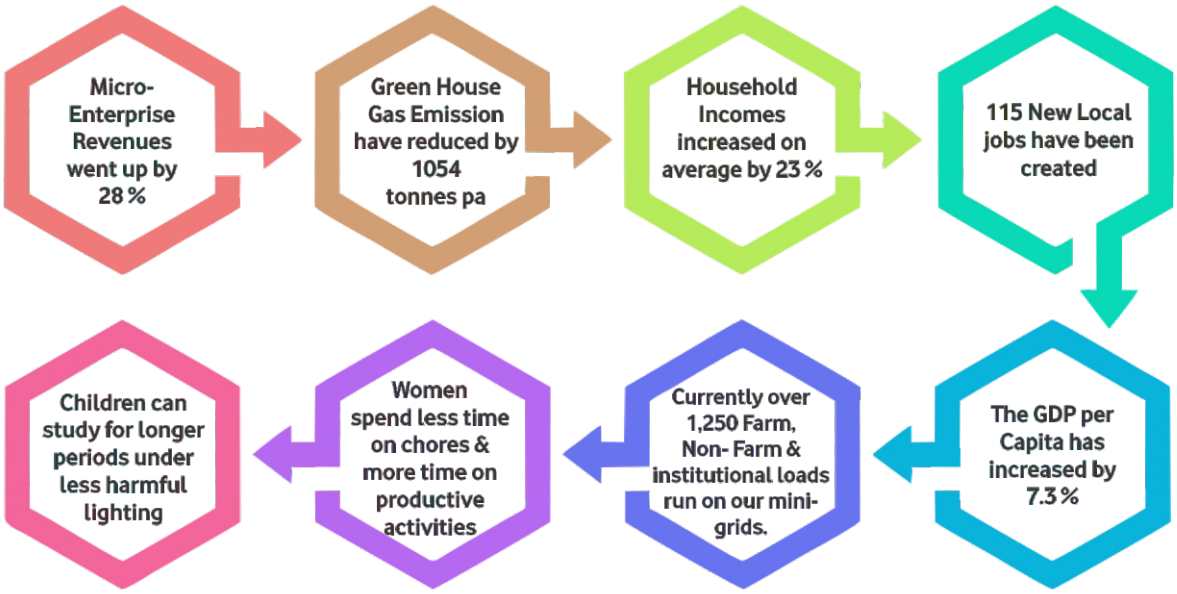


Fig: 8 Achievements of Mlinda's Project

8. Industry Hustles and Their Solutions

a. Sizing the mini-grid system and its capacity

For the distribution of RE, providers face a major challenge of business proposition in an attempt to project local requirements and capacity of the systems.

For this, Mlinda moves with a quantitative approach ensuring that its services and benefits suit perfectly according to the community's needs. Mlinda analyzes and predicts productive and residential loads in the range of specific geographical parameters, and utilizes these data to size their systems. In addition, they also provide the beneficiaries sufficient capacity to fulfill their demand growth for the next three years. Although, this raises the capital cost, but it gives a better experience to the customers, and allows for uninterrupted economic development (13).

b. Risk of grid expansion

Another common hurdle faced by the distributors of RE is the accountability of stranded assets if the national grid arrives, or if the grid reliability betters in the villages serviced by the mini-grid providers (14).

This is sorted by collaborating with the local as well the central governments' electrification efforts. By this the distributed RE suppliers can lessen their business risk, and either complement or interconnect with national grid power supply. Mlinda electrifies both the off-grid communities and grid-connected communities with intermittent power supply (15). Mlinda, a 'Rural Energy Service Provider' is certified under Ministry of New and Renewable Energy Development Agency (MNRE) (16). Mlinda in the past had collaborated with MNRE, and Jharkhand Renewable Energy Development Agency (JREDA) to expand its renewable energy sector.

c. Political support

Mini-grids could be most effective as well as successful when they are supported by the policy makers, since the off-grid space is a nascent and the technology used is often quite expensive. Without policies and amendments that foster off-grid energy development, distributed RE suppliers have been struggling to become self-sustaining. Putting-up off-grid solutions with national support for improving the quality of electricity and reliability would specifically be more necessary when or if the national government puts up efforts to privatize locally-owned DISCOMS (distribution companies of India) (17).

Fig: 9 Community mini-grid installed in Sahitoli village, Gumla district, Jharkhand (Source: Mlinda, 2019)

Giving a hand to distributed RE suppliers with a community development focus can help strengthen the central as well as the local governments' efforts to provide reliable electricity access to fulfill rural requirements, develop job opportunities, and increase the local economic development. Moreover, local operational staffs are present at each community mini-grid. This enables the distributors to look into the supply disruptions, or any other problem which could occur during the electrification process.

Since past few years, Mlinda has strongly bonded with JREDA (18). Mlinda works as a complementary solution to grid power in the state of Jharkhand. They are working in collaboration with Jharkhand State Electricity Regulatory Commission for establishing and strengthening the Draft Mini-grids Policy 2018 for Jharkhand (19). The objective of this policy is to present specific regulatory guidelines for mini-grids to strengthen the decentralized RE growth opportunities in the state of Jharkhand.

d. Tariff pricing and regulation

The dichotomy that comes between the mini-grid tariffs and the tariffs presented by the government installed grids is stark. For an instance, grid electricity tariff in Jharkhand was Rs 5.75/KWh (Kilo Watt hour) for the rural residential consumers, and around Rs 6/KWh for rural commercial consumers in 2020. As far as mini-grid tariffs are concerned, rates could be as high as 3 to 7 times of that offered by national grids (20). These high tariffs are because of the fact that the distributed RE suppliers need to keep a balance between recoupling capital and the operating expenses as well as keeping in mind the appropriate charging price that the customers could afford.

To sustain as a private supplier, Mlinda has opted for only private funding (21). Therefore, it has to keep the tariff charges higher than the Indian national grid-costs (22). Currently, the day-time tariff is approximately Rs 22/KWh and the night-time tariff is near about Rs 44/KWh. The cost difference between day and night-time tariff owes to the storage cost. The fact that mini-grids depend completely on solar generation, the cost of electricity generation during day becomes comparatively less. Storage becomes a costly process, and Mlinda during the night-time electrifies utilizing battery storage or diesel generators, which adds on to the operation costs.

9. Mlinda's Job Opportunities

Mlinda is in continuous efforts to expand its operations. In the year 2016, Mlinda was into its initial stage having just two mini-grids installed. Last year in January 2021, Mlinda managed to install 45

mini-grids. So far, the number of beneficiaries of community mini-grids is 7,000 households covering over 35,000 to 40,000 people (23). Mlinda with expansion of its mini-grids has created several direct, indirect, induced and productive use jobs.

Direct jobs include profit and output that comes from designing, installation and maintaining the mini-grid projects (23). After the completion, a community mini-grid could employ full-time jobs for around 3 to 5 individuals.

Direct short-term contractual individual are employed during the construction and installation of community mini-grids, and these job opportunities are limited for the duration of construction of these mini-grids.

Mlinda in addition, also supports, promotes and establishes local livelihoods. All these types of jobs are categorized under productive use jobs. Productive use jobs are novel, and promote entrepreneurial opportunities that stem from mini-grid electricity, and include job opportunities from mechanization and electrified micro-businesses. These types of jobs are usually variable and depend completely on the location.

Fig: 10 Mini-grid operator and engineer testing the mini-grid power supply

Job Type	Estimated jobs created
Direct Permanent Full-time Jobs	135 to 225 FTE
Direct Short-term contractual jobs	112 to 151 FTE
Productive use Jobs	450 to 900 FTE
Total Full-time Equivalent Jobs	697 to 1276 FTE

Table: 2 Jobs created from Mlinda's mini-grid deployment efforts (Source: NRDC-CEEW-SCGJ estimates based on Mlinda data, 2019).

9. 1 Mlinda's Job Opportunities

Improvement in access of energy can create livelihood improvements, especially for farmers. Most of the centers where Mlinda operates are generally villages, and the population generally depends upon agriculture for either subsistence farming or income generation. Availability of reliable electricity has enabled these farmers to switch from using diesel pumps to efficient electric pumps for irrigation. For a better experience during irrigation, Mlinda supports the farmers in three following ways. In the first step, Mlinda links the villages in which it plans to operate irrigation sources such as reservoirs or canals. In the second step, Mlinda ties up with the resellers of efficient pumps, and grants farmers credits to buy electric pumps as per their requirements. Lastly, Mlinda offers loan for pumps to farmers (with no extra charges), and the farmers just need to pay the energy cost for running those pumps.

Fig: 11 Farmers irrigating their field with electric powered pumps (Source: Mlinda, 2019)

Fig: 12 Sahitoli village irrigating fields with electric pumps powered by solar mini-grid (Source: Mlinda, 2019)

10. Creating New Entrepreneurial Jobs

Mlinda aids its community members to buy energy-efficient appliances. In this manner Mlinda acts as an intermediary body between its members, and the appliance whole sellers. In a number of cases, Mlinda also grants micro-finance to the community members in order to help them in purchasing appliances such as rice hullers and millers. Thus, these efforts increase productive use loads, and appliance access have generated new entrepreneurial opportunities, and have enhanced Mlinda's productive use loads.

Fig: 13 Mini-grids power productive use loads like grain mills (Source: Mlinda, 2019)

11. Other New opportunities

MNRE had launched Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyaan (PM KUSUM) in 2019. This is done to promote decentralized grid- connected solar mini-parks and off-grid and grid connected solar pumps in rural areas. The major aim of this program is to add 10,000 MW of grid-connected small/micro solar or other renewable source-based generation by the year 2022 with an initial target of 1,000 MW.

12. Conclusion

Across different geographies, solar mini-grids have been installed to provide access to energy to off-grids and rural communities. Mlinda's community mini-grid installation efforts have generated around 986 jobs from 2016 to 2020. This number considering each mini-grid shows around 15 to 28 jobs on each site. These jobs are generated either by direct employment or by creating entrepreneurial jobs from productive use electricity loads such as mills and electrified businesses.

Mlinda has not only helped in setting up local businesses but also assisted the entrepreneurs reach out their products to the markets. In addition Mlinda is connecting farmers of the villages where it tends to send up mini-grid communities to the organizations which can aid help to them in terms of providing various machines on loans with minimum or no extra cost.

Appendix: Job Definitions

- Direct Jobs: These include permanent and short –term contractual jobs that are associated with the designing, management, construction, installation and maintaining the projects. Mini-grids employ direct full-time jobs in the designing and maintaining and operating phases of the project.
- Direct-short-term contractual jobs: These jobs are the ones that are called only during the designing and the construction period and last for about 3-4 months
- Production use jobs: These jobs are created by the end-users of the mini-grids. These jobs include the ones from electrified hulling machines, cold storage units, oil expellers, grain milling machines, air compressors, sewing machines, shops and welding machines. Productive models differ according to geography, business model of mini-grids and also the operators.
- Indirect jobs: These jobs are related to the manufacturing of equipments and materials required in the project.

Abbreviations

AMC: Annual Maintenance Charge

DISCOMS: Distribution Companies of India

FTE: Full-time Equivalent

JREDA: Jharkhand Renewable Energy Development

KWh: Kilo Watt hour

KWP: Kilo Watt Power

MNRE: Ministry of New and Renewable Energy

MNRE: Ministry of New and Renewable Energy Development Agency

MPL: Mlinda Sustainable Environment Private Limited

MWP: Mega Watt Power

PM KUSUM: Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyaan

PV: Photovoltaic

RE: Renewable Energy

SHSs: Solar Home Systems

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and hybrid mini-grids (for example solar mini-grids of Sunderban) were also a major focus area of this phase. It was during this phase when Electricity Act 2003 was introduced, where mini-grids as decentralized distributed generation was incorporated as a way for laying out rural electricity supply.

The third or current phase of mini-grids development is encountering the entrance of private sector developers since the past few years. This is thus bringing in the technical as well as the institutional innovations. The entry of private sector has led to the development of smart mini-grids that provide better supply and demand side management (1).

3. Mini-grid coverage in India

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With time, challenges and altering priorities, solar mini-grids have evolved in India. However, the evolution was limited due to technical dimensions, new and innovative delivery models as well as financial models. Since 1990s, the solar mini-grids have undergone three phase development. The first phase of mini-grids operations took place during early nineties till around early 2000s. This phase focused on developing pilots, demonstration of the technologies developed, and testing institutional models.

Development of these models as a potent vehicle for electrifying remote and far flung villages was the main focus of the second phase. This phase was initiated in 2001, under the government sponsored remote village electrification program. In addition, experiments on deploying larger capacity mini-grids