COBENEFITS STUDY

October 2019

Secure and reliable electricity access with renewable energy mini-grids in rural India

Assessing the co-benefits of decarbonising the power sector

Executive report

This study has been realised in the context of the project "Mobilising the Co-Benefits of Climate Change Mitigation through Capacity Building among Public Policy Institutions" (COBENEFITS). This print version has been shortened and does not include annexes. The full version of this report is available upon request.

This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag. The COBENEFITS project is coordinated by the Institute for Advanced Sustainability Studies (IASS, lead) in partnership with the Renewables Academy (RENAC), the Independent Institute for Environmental Issues (UfU), International Energy Transition GmbH (IET) and in India the Energy and Resources Institute (TERI).

October 2019

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Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

INTERNATIONAL CLIMATE INITIATIVE (IKI)

COBENEFITS of the new energy world of renewables for the people of India

India is in the midst of an energy transition, with important social and economic implications depending on the pathways that are chosen. India's energy pathway will define the basis for its future development, including economic prosperity, business and employment opportunities as well as health impacts. At the same time, current investment decisions in India's energy sector will have a substantial impact on combatting global warming and securing the livelihoods of people in India and elsewhere.

With its bold decision to substantially ramp up renewable energy generation capacity, from 80 gigawatts as of May 2019 to 175 GW by 2022, the Government of India has sent a strong signal on both the direction and pace of India's energy transition. Political decisions on India's energy future link the missions and mandates of many government departments and agencies beyond energy and power, such as environment, industrial development and labour. Hence, the timely debate on India's energy future boils down to assessing how renewables can improve the lives of Indian people.

Employing scientifically rigorous methodologies and the most recent technical data, the study at hand contributes to estimating such co-benefits associated with the shift to renewables. It also provides guidance to government agencies on further shaping an enabling political environment to unlock the social and economic co-benefits of the new energy world of renewables for the people of India.

The Energy and Resource Institute (TERI), as the India Focal Point, together with the Institute for Advanced Sustainability Studies (IASS) invited ministries and government agencies such as the Ministry of New and Renewable Energy, Ministry of Environment, Forests and Climate Change, Ministry of Power, Ministry of Finance and NITI Aayog to join the COBENEFITS Council India, to provide their guidance to the COBENEFITS Assessment studies along with the COBENEFITS Training Programme and Enabling Policies Roundtables. Since its constitution in November 2017, the COBENEFITS Council India has guided the programme in framing its assessment topics for India and ensuring their direct connection to the current political deliberations and policy frameworks of their respective ministries.

We are also indebted to our highly valued research and knowledge partners, for their unwavering commitment and dedicated work on the technical implementation of this study. This COBENEFITS study was facilitated through financial support from the International Climate Initiative (IKI) of Germany.

India, among 185 parties to date, has ratified the Paris Agreement to combat climate change and provide current and future generations with opportunities to flourish. With this study, we seek to contribute to the success of this international endeavour by offering a scientific basis for harnessing the social and economic co-benefits of building a low-carbon, renewable energy system while facilitating a just transition, thereby **making the Paris Agreement a success for the planet and the people of India.**

We wish the reader inspiration for the important debate on a just and sustainable energy future for India!

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Executive Summary

COBENEFITS

Secure and reliable electricity access with renewable energy mini-grids in rural India

Assessing the co-benefits of decarbonising the power sector

Energy access is essential for economic and human development and is an important driver for the progress of India. Access to modern forms of energy, especially electricity, becomes even more important for the socio-economic development of rural areas (which lag behind urban areas in terms of infrastructure). "Full electrification" to achieve social and economic development goals (and SDGs) in India requires 24/7 electricity access for every household, family and local enterprise, even in rural communities. To achieve this goal, successive Indian governments have focussed on providing access by extending the centralised grid while still trying to incentivise the use of decentralised off-grid solutions through renewable energy sources such as solar and biomass. Although a considerable number of villages and households have gained access to the grid, the reliability and quality of power supply still remain a growing challenge for rural consumers. Mini-grids have thus emerged as pivotal in providing ancillary services to the grid and improving the level of services to last-mile consumers. To this end, a number of private companies have emerged, setting up mini-grids in unconnected villages in order to bridge this electrification gap and drive economic development around rural clusters. Nonetheless, investment in renewable-powered mini-grids in India still lags behind, partly because of a lack of replicable and sustainable models in the face of subsidised grid-electricity tariffs that make alternative solutions cost uncompetitive.

This study assesses the viability of renewable-energy-powered mini-grids to both drive and support economic growth in India from the perspective of augmenting the current electrification of rural areas. This is carried out in the context of the COBENEFITS project with the aim of assessing the range of additional benefits[1] resulting from a low-carbon energy transition in India. For renewable-energy-powered mini-grids to thrive alongside the conventional grid in a sustainable manner, mini-grids will have to match the grid – in terms of cost-competitiveness, capacity and affordability – while remaining profitable and viable.

The study employs a dual approach comprising a qualitative "on the ground" assessment of the social benefits in three rural communities in India, combined with a techno-economic analysis to determine the factors that affect the economies of scale of mini-grids (specifically solar-powered mini-grids) and their suitability for supporting socio-economic development in rural areas of India. This approach is chosen to ensure transferability of the case study findings obtained for rural India. Data and test variables used in this study are India-specific and are drawn from detailed stakeholder engagements, and are in alignment with local conditions (at the time of compiling this report). This study focuses strictly on solar-powered-mini-grids in India to represent the term "mini-grids" within the Indian context.

- **Key policy message 1:** Solar-powered mini-grids of high installed power capacity can remain economically viable and cost-competitive with the centralised grid in rural areas of India. Solar mini-grid systems greater than 100 kW with interest rates as low as 8 % and a 15 % return on equity can achieve grid parity and a low cost of electricity supply to the rural consumer.
- **Key policy message 2:** Solar mini-grids are effective for improving rural education in India, as most schools in remote areas of India experience continuous power cuts which impede the quality of education that the students receive. The mini-grid can provide electricity at schools or education centres consistently during the teaching hours to help stimulate better educational outcomes for the students in rural India.
- **Key policy message 3:** To drive the growth of higher power capacity mini-grids that are essential for reliable 24/7 rural electrification, mechanisms are needed to be developed (in collaboration with the private sector) to make it suitable for the mini-grid developer to transfer the system's assets to the state-owned utility when the central grid arrives at the area served by the mini-grid. This mechanism must be developed in collaboration with the private sector.

[1] The term 'co-benefits' refers to simultaneously meeting several interests or objectives resulting from a political intervention, private-sector investment or a mix thereof (Helgenberger et al., 2019). It is thus essential that the co-benefits of climate change mitigation are mobilised strategically to accelerate the low-carbon energy transition (IASS 2017a).

KEY FIGURES:

- The average unit cost of supply from a standard[2] solar mini-grid in rural India is approximately Rs29 ($0.42/kWh)[3] while consumers pay a unit cost of Rs40 ($0.59/kWh). The reverse is the case for grid consumers, who pay a government-subsidised unit cost of approximately Rs 3 ($0.044/kWh) from a unit cost of Rs6.4 ($0.094/kWh) incurred by the grid supplier.
- By gradually increasing mini-grid capacity while reducing the levelised cost's interest rate from 12% to 8%, the unit cost supply from the mini-grid drops to as low as Rs6.26 ($0.091/kWh), which is cheaper than and also cost-competitive with the grid supply cost.
- For a typical 700 kW capacity solar mini-grid, the average unit cost of supply of Rs7.62 ($0.11/kWh) can be achieved, while for a typical 1 MW solar mini-grid, an average unit cost of supply of Rs6.88 ($0.109/kWh) can be achieved.

COBENEFITS
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available on www.cobenefits.info

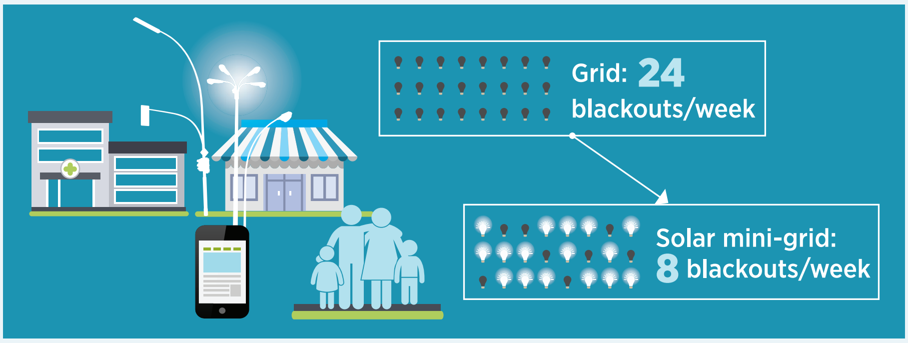
KEY FINDINGS:

- **Fewer blackouts experienced by consumers supplied by solar mini-grids.** Surveyed solar mini-grid-consumers reported an average of 8 blackouts per week, up to 2 hours per day, while the grid-consumers reported an average of 24 blackouts per week, for over 5 hours per day.
- **Establishing mini-grids as a complementary and supplementary extension of the centralised grid service.** In the Indian context with almost 100% grid coverage at the village and household levels, mini-grids may be utilised as natural extensions of the grid in areas where reliability of supply is a concern. This would require clear guidelines for grid-integration, making it an attractive business opportunity for investors.
- **Pricing of mini-grid services: cross-subsidies for mini-grid consumers.** In a scenario where medium- or MW-scale mini-grids are deployed, there should be a mechanism to extend cross-subsidy to mini-grid consumers, to ensure cost parity with grid tariffs. This would not only make reliable and quality supply through mini-grids affordable, but also serve to meet the government's objective of transitioning to clean sources of energy.
- **Skills development to service scaled-up mini-grids.** In the event of national-level expansion and scale-up of mini-grids in India, skilled technicians would be required for operation and maintenance of the plant and for business operations. To this end, skill development programmes are essential for creating local employment opportunities for the community.
- The overall experiences of mini-grid and grid consumers in terms of evening lighting in rural areas are marginally similar; however, grid consumers could use electricity for purposes beyond lighting and ventilation – major electricity consuming appliances that can be used by mini-grid-consumers.

[2] A standard solar mini-grid in rural India has a system capacity of 27 kW.

[3] 1 Dollar = 68.42 Rupee as of the time of writing this report. The dollar value is specified as an indication for non-local consumers to have a broader perspective of the Rupee value.

In rural India, mini-grids significantly improve the reliability of supply for municipal services and basic household energy needs.



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1. Understanding the context of renewable energy mini-grids and last-mile electrification in India

Access to energy is an important pre-condition for socio-economic development, contributing towards greater productivity, better access to information, and improved overall quality of life. Approximately 70 percent of India's total population lives in villages. Thus, India's economic and social development is inherently linked to growth in the rural sector; in order to contribute to India's overall development, the rural sector must therefore have access to modern forms of energy, primarily electricity (Palit & Sarangi, 2014). Between 2000 and 2016, India made striking progress in providing electricity access to its citizens, with its electrification rate growing from 67% to 89% (IEA, 2017). However, despite the government's continuous efforts to provide reliable and affordable power for all, nearly 240 million people still lacked access to electricity in 2017. Many of these were located in hamlets and satellite villages that lacked dedicated electricity supply infrastructures (IEA, 2017).

The concept of mini-grids in India was first highlighted in February 1996, when the West Bengal Renewable Development Agency (WBREDA) commissioned a 25 kWp capacity solar photovoltaic (PV) plant in Kamlapur Village, Sagar Island. Since then, fifteen more such mini-grids have been installed in the Sundarbans region for village electrification (WBREDA). Solar PV is the most commonly used technology for RE based off-grid power systems in India. The ease of installation, lower cost, and availability have made solar PV a popular choice for mini-grids across the country, although not entirely without challenges (Bhattacharyya & Palit, 2014). Over the years, mini- or micro-grids have been deployed across multiple states in India, ranging in scale from pilot or demonstration project to fully-fledged electrification systems. Gradually, technological innovation led to the emergence of hybrid mini-grids employing more than one technology. Similarly, with time, private players also entered the market and have introduced innovations in technical and business models, and also created space for smart mini-grids (Palit, Sarangi, & Krithika, 2014). Owing to the enduring electricity access gap in the country, private energy service companies (ESCOs) have entered the market over time, to provide energy access through renewable energy (RE) sources such as solar and biomass. By addressing consumers' fundamental need for reliable and timely electricity supply, ESCOs have emerged in the last decade as effective providers of basic energy access for non-electrified and poorly electrified households in rural India.

Notwithstanding these developments, the mini-grid sector has not witnessed an organic expansion pursuant to the kind of demand that existed in rural India for adequate and reliable electricity access. The absence of replicable and sustainable business models is often attributed to the market risks that mini-grid developers face from the fast-expanding grid infrastructure (which may render mini-grids irrelevant or redundant), as well government tariff subsidies for grid-based electrification, which directly compete with mini-grid tariffs and undercut profit margins for mini-grid developers. In September 2017, the Government of India announced an electrification scheme

INFOBOX

The term mini-grid used in this study is based on energypedia's definition that it represents a set of electricity generators (with a system capacity between 10kW and 10MW) and possibly energy storage systems interconnected to a distribution network that supplies electricity to a localized group of customers and can operate in isolation from national electricity transmission networks.

called Pradhan Mantri Sahaj Bijli Har Ghar Yojna (SAUBHAGYA), to electrify all remaining non-electrified households in the country by March 2019. While this scheme may be seen as a major deterrent to mini-grid businesses going forward, it is also acknowledged that even if nearly all households in rural India get connected to the centralised grid (henceforth "grid") by March 2019, ensuring a high-quality and reliable electricity supply to them will be a challenge for distribution companies – at least in the initial few years, as they also grapple with their own operational and financial hurdles to catch up with the exponential increase in the consumer base. Similarly, with the draft National Policy on RE-based Mini/Micro Grids (MNRE, 2016), the central government of India also aims to deploy at least 10,000 RE-based micro- and mini-grid projects across the country with a minimum installed RE capacity of 500 MW (at an average size of 50 kW) by the year 2021. There is, therefore, still significant growth opportunity for mini-grids (and more prominently for solar mini-grids) in India. However, to establish their relevance and thrive alongside the conventional grid in a sustainable manner, mini-grids must, at some level, match the grid – in terms of cost-competitiveness, capacity of the power system and affordability – while at the same time maintaining profitability and viability.

1.1 Scope of the study

This study examined the viability for scaling up solar mini-grids in India, looking into specific demand- and supply-side parameters that demonstrate the value delivered by mini-grids to consumers and the wider community; accordingly, the study seeks to determine the scope and feasibility of mini-grid growth within the context of India's current grid electrification status. To achieve these specific objectives, the following questions were addressed:

- What value and level of service do solar mini-grids currently deliver to end users?
- What is the cost-of-supply and tariff comparison between grid and solar mini-grid electricity; what does it really cost to provide energy services through solar mini-grids at the current scale?
- What is the economy of scale benefit for medium-scale (> 50 kW) mini-grids over smaller-scale (< 50 kW) mini-grids; at what scale can solar mini-grids provide additional co-benefits to end users and still be tariff-competitive with grid connections?
- What mechanisms need to be in place to achieve 100% last-mile electrification in India, that are supported by solar-powered mini-grids?

2. Overall methodological approach and guiding questions

2.1 Overall methodological approach and guiding questions

A case study-based approach is used to examine the business and economic profile of a practical mini-grid operating in India and to map the socio-economic co-benefits. Using this approach, comparisons were drawn between the centralised grid and the decentralised mini-grid through primary survey and secondary data sources, to understand the benefits delivered to end users (with regard to variations in service quality, reliability, affordability, safety, etc.) and the cost-of-supply and tariffs charged (to understand how economies of scale may ensure the profitability of mini-grids in the country). This study focuses solely on solar mini-grids, as their growth and proliferation in India serve as a basis for sound data-gathering, analysis, and policy appraisal and support. Figure 1 provides a stepwise overview of the analysis. The following guiding questions are adopted for the analysis and also detailed in the figure below:

- **Question 1 (RQ1):** To what extent does the electricity service differ, between the grid and solar mini-grids, with respect to adequately fulfilling household and community energy needs (reliability, quality, affordability, safety, etc.)?
- **Question 2 (RQ2):** Based on the electricity tariffs paid by consumers from both types of supply system (grid and mini-grid), what are the key cost components for mini-grids, which contribute to "cost of supply", and how do these costs reflect over a twenty-five year operational lifespan for mini-grids? Are such costs impacted by changes in the scale or size of mini-grids?
- **Question 3 (RQ3):** What socio-economic benefits might be derived from scaling up mini-grids?

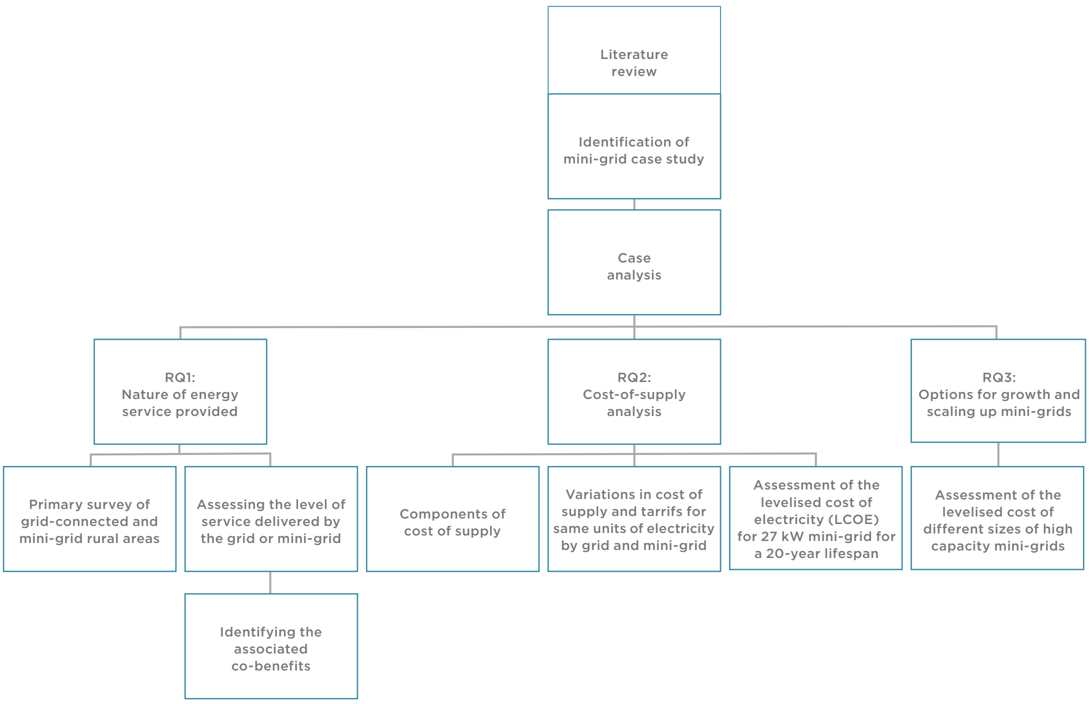


Figure 1: Schematic overview of the study methodology

Source: own

2.2 Identification of mini-grid assessment locations and case-study sites

INFOBOX: Contextualising energy access in India

- Electrification or grid access to a village does not mean all households or business enterprises in the village are electrified.
- 100 % electrification in India (through the centralised grid infrastructure) has not translated into "24/7" electricity supply for rural households or businesses, thus the emphasis and relevance of mini-grids for last-mile electrification and reliability of supply.
- The Indian Government highly subsidises consumer tariffs for grid-electricity supply; therefore, to ensure the viability and scalability of mini-grids for rural consumers, especially renewable energy-powered mini-grids, their cost-competitiveness needs to be addressed.

In India, the introduction of solar mini-grids has been driven by government grants and through private investment (financed through impact investment and corporate social responsibility (CSR) funds, and commercial banks). These solar mini-grids typically range between 10 kW and 300 kW, and are predominant in the states of Chhattisgarh, Uttar Pradesh (UP), Rajasthan, Andhra Pradesh, Odisha, Jharkhand, Assam, and Jammu & Kashmir. Each state differs in its policies and regulations for mini-grids. Until mid-2018, these states had among the lowest electrification rates in India, ranging from less than 70 % UP, Odisha, Jharkhand and Assam, to just over 85 % in Rajasthan and Chhattisgarh[4]. With an electrification rate of 66 % and the largest installed mini-grid capacity in India, as well as a state-level mini-grid policy, Uttar Pradesh was chosen as the case-study region for the present study. It is estimated that there are more than 1800 mini-grids operating in UP, with an aggregate capacity of 3 MW (P. Bhati, & M. Singh, 2018). Private mini-grids have done well in UP over the past decade as the centralised grid failed to establish the necessary infrastructure in non-electrified areas, and had a track record of poor power supply in electrified regions[5]. Within UP, mini-grids in Hardoi district were chosen to conduct survey and analysis in collaboration with the locals and mini-grid project developers (cf. Figure 2). Primary surveys of households and user groups were conducted in three neighbouring villages (grid and mini-grid) with similar socio-economic status to draw comparisons on the cost-to-supply, reliability, affordability, capacity and associated co-benefits of electricity services in the area.

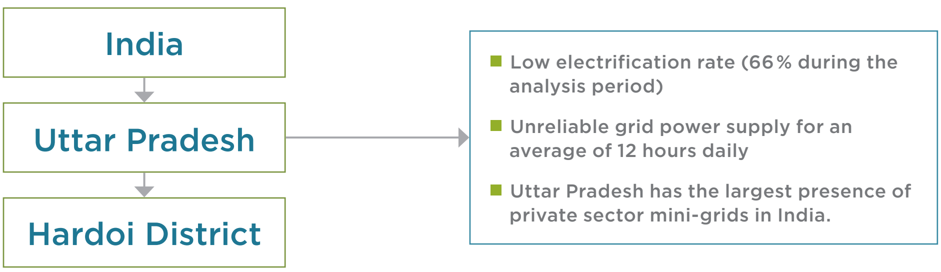


Figure 2: Flow chart representations of the case study locations

Source: own

[4] http://saubhagya.gov.in/ (accessed on 8 August 2018).
Note: Owing to the unrelenting push by the government through the SAUBHAGYA scheme, it is presumed that, at the time of publishing this study, most states had (or nearly) achieved 100 % electrification access.

[5] Under SAUBHAGYA, Uttar Pradesh had a projected target of providing nearly 12 million connections by March 2019. However, as implementation activities progressed, the actual number of households to be connected on the ground reduced significantly (by nearly 40 %). This is because the initial target was based on the census of 2011, in which many households were found to be non-existent. Furthermore, some households refused connections due to affordability issues, while others were found to be already connected to the grid through pending regularisation. As per official government statistics, Uttar Pradesh has achieved its target in January 2019 of electrifying 7.5 million.

2.3 Assessment framework

A key aspect of establishing the relevance of mini-grids in India's currently expanding grid electrification context is the nature of services that mini-grids offer to fulfil the energy needs of consumers, in relation to the service delivery cost or price paid. It is through the framework of the services offered that the co-benefits of mini-grids can be best defined and assessed. The World Bank Multi-Tier Framework (MTF) for energy access provides a multi-dimensional lens to assess the adequacy, reliability, affordability and availability of an energy service to an end user. This framework is used as the basis to study and compare the extent to which electricity services from the mini-grid and the centralised grid meet the energy needs of consumers, and the ways in which they enable and drive social and economic impacts (cf. Table 1). Other factors were also examined, such as domestic and productive uses of electricity, and demand versus supply under the current scale of the mini-grid system.

A primary household survey was conducted in three neighbouring and socio-economically similar villages in Hardoi district. Case study area 1 was connected exclusively to the grid through the government supplier, Madhyanchal Vidyut Vitran Nigam Limited (MVVNL). Case study area 2 with 225 households was jointly electrified by the centralised grid and also by a 27 kW[6] mini-grid. Case study area 3 with 135 households was exclusively electrified through one stand-alone 27 kW mini-grid supplying electricity to the households and also to anchor loads such as, a telecommunication tower and a medical shop.

Table 1: Framework for assessing co-benefits of mini-grids

Source: own

Co-benefits of mini-grids	Sub-category	Indicators
Fulfilling household (HH) energy needs adequately	Capacity	Number and type of appliances supported
	Duration	Hours of supply (day/night)
	Reliability	Number and duration of power cuts/ interruptions
	Quality	Voltage fluctuations leading to appliance spoilage
	Affordability	Expenditure on electricity as a share of monthly income
	Safety	Number of accidents
	Aspirational needs	Number and type of appliances that respondents aspire to purchase
Social benefits	Enhanced convenience	Use of appliances, increased comfort
	Increase in awareness	Use of mobile phones, television, Internet
	Improved public services	Better health services (better-equipped public health centres), school infrastructure (lights, fans, ICT), electrification of community centres
	Improved water supply	Public piped water supply/Number of HHs with piped water supply
	Safety	Street lighting
Supporting productive uses of electricity	HH-based productive use	HHs engaged in small-scale activities such as tailoring, small shops, food processing, poultry, etc.
	Commercial/SME	Small to medium enterprises (grain mill, shop, cooling unit, etc.)
Employment generation	Local operations/maintenance/ service positions for and due to mini-grid/grid	▪ Number of jobs created over the lifetime of the project. ▪ Number of local persons engaged in the operation and maintenance of the mini-grid. ▪ Training and capacity-building of local persons.

[6] The current literature shows that the average size of AC mini-grids in India ranges from 2 kW to 150 kW.

2.4 Cost of supply and levelised cost analysis

Mini-grid developers operate on the assumption that the centralised grid connection will "only" be able to provide sufficient energy access to a new location within a five- to seven-year timeframe from when the mini-grid connection is made. On this premise, returns on investment (characterised by the tariffs) are structured in such a way that they can be recovered within that period of time. This, in turn, results in very high cost per unit (tariff) for consumers. Hence, this makes mini-grids highly vulnerable to the grid's tariff competitiveness (which is often subsidised by the state and also cross-subsidised by other consumers on the grid who have higher standards of living).

To this end, the input costs for mini-grids, which contribute to the gap between the per-unit cost of supply and the effective tariff paid by the consumer, were analysed (cf. Figure 3) These costs were then compared to the cost of supply and tariff (per unit charged) for grid supply in the same area, obtained in consultation with the electricity distribution company. A levelised cost of electricity (LCOE)[7] analysis, using a model[8] built in Microsoft Excel, was then conducted for the identified mini-grid sizes (from 100 kW to 1 MW) in order to understand the economies of scale at which a mini-grids could become viable and cost-competitive with grid supply.

2.5 Study limitations

Assessments conducted in rural locations typically face challenges associated with limited data on the granular input costs of mini-grid (because private developers are often unwilling to divulge vital competitive and proprietary data). The present study employs a case study assessment (bottom-up) approach to estimate the co-benefits of RE mini-grids in India, in order to address the paucity of "publicly" available data needed to conduct a comparative analysis of mini-grid electrification in the country within the assigned timescale and scope of this study. However, common parallels applied in this study can be drawn for other locations in the country. Broad analyses of wind- or biogas-powered mini-grids in the country are not included in this study, but should be considered for future studies on this topic.

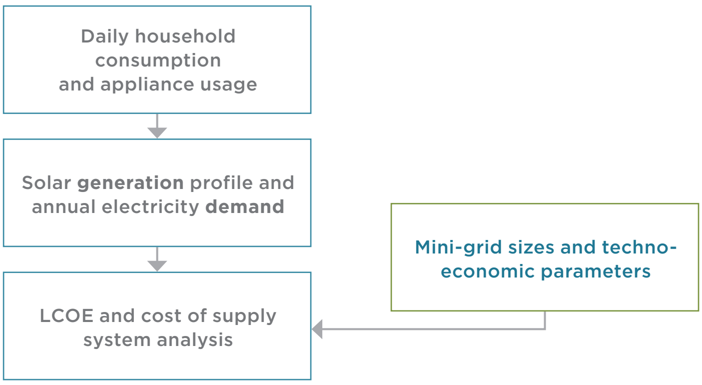


Figure 3: Flow chart representations of cost-of-supply analysis

Source: own

[7] The levelised cost of electricity (LCOE) is the net present value of the unit cost of electricity over the lifetime of a generating asset. It is often taken as a proxy for the average price that the generating asset must receive in a market in order to break even over its lifetime.

[8] Government agencies such as the Ministry of New and Renewable Energy (MNRE), the Central Electricity Regulatory Committee (CERC), the Rural Electrification Corporation (REC), Power Finance Corporation (PFC) and the Indian Renewable Energy Development Agency (IREDA) provided standardised procedures and financial input parameters for calculating the LCOE.

3. Identified co-benefits of mini-grids in rural India

3.1 Socio-economic profiles and energy needs of consumer groups in rural India

In order to establish the relevance of mini-grids in India's current electrification context, the nature of the service it offers to meet the electricity demand of the consumers is necessary. To investigate the electrification service delivered to the average consumer, an analysis was conducted for the three case study sites. The socio-economic profiles of the three case study areas are summarised in Table 2. While the three villages are similar in most aspects, an emerging difference was in the average income levels of the grid and mini-grid households. Grid-connected households (Case study area 1) had 40 % higher average monthly incomes than the non-grid connected households.

	Case study area 1 (GRID)	Case study area 2 (GRID & MINI-GRID)	Case study area 3 (MINI-GRID)
House ownership	100 %	100 %	100 %
Literacy rate	55 %	47.6 %	46.8 %
Land holding (farmland)	71 % (marginal farmers)	86 %	76 %
Water source	Public tap: 24 % Hand pump: 73 %	Public tap: 24 % Hand pump: 76 %	Public tap: 35 % Hand pump: 65 %
Average monthly reported income	Rs 8949/-	Grid: Rs 7000/- Mini-grid: Rs 4386/-	Rs 4338/-
Electricity source	Grid	Grid, Mini-grid	Mini-grid
Total respondents	79	73	46
Split between male and female respondents	63 % male, 37 % female	Grid: 60 % male, 40 % female; Mini-grid: 80 % male, 20 % female	50 % female

Table 2: Socio-economic profiles of surveyed villages

Source: own

Further, for individual households, the average monthly usage in the mini-grid case study areas were found to be as low as 2.7 units (kWh), compared to households in the grid-connected location (case study area 1), with a monthly average of 82 kWh (cf. Table 3). In this scenario, there is little scope for households supplied by the mini-grid to derive pronounced benefits beyond the convenience of having lighting for a few hours in the evening, and saving time and money to charge their mobile phones. On the other hand, grid consumers have the opportunity to use a range of appliances based on their affordability levels. However, the mini-grid proved to provide a more reliable electricity supply in rural areas, with only one-third the number of blackouts experienced by grid electrification, and in terms of supply quality showed only minimal voltage fluctuations (cf. Table 3).

	Sub-category	Mini-grid case study areas	Grid case study area
HH energy needs	Capacity	■ 27 kW systems ■ Average consumption 2.7 kWh	■ Sanctioned load 1 kW ■ Average consumption 82 kWh
	Duration	■ Fixed at 6 hours (6 pm – 12 am)	■ Average: 10.46 hours/day ■ 3.73 hours/evening
	Reliability	■ Average: 8 blackouts/week ■ Duration: 20 minutes to 2 hours per day	■ Average: 24 blackouts/week ■ Duration: over 5 hours per day
	Quality	■ Minimal voltage fluctuations	■ Some voltage fluctuations
	Affordability	■ Fixed tariff: Rs 110/month ■ Average subscription fee: Rs 209 ■ Average internal wiring fee: Rs 113 ■ 57 % of respondents found it to be expensive	■ Average monthly bill: Rs 388 ■ Average subscription and internal wiring fee: Rs 1500 ■ 51 % of respondents found it to be expensive

Table 3: Household energy needs served by mini-grid and grid connections

Source: own

Despite having some form of electricity access, most households still used backup sources to meet their energy demand in case of power failure or insufficient supply from their primary electricity source. Among these, kerosene was found to be the most important secondary fuel in both grid (53%) and mini-grid (71%) households. Rechargeable batteries were also commonly found in households of both access types, along with solar lanterns, solar home systems (SHSs), candles and flashlights (cf. Table 4). Only a fraction of consumers (9% mini-grid and 16% grid) did not use any form of backup energy source.

Is the quality of electricity service the same throughout the year?	Mini-grid service	Grid service
Yes	32%	14%
No	68 %	86 %
Main backup source of lighting during outages/blackouts	**Mini-grid service**	**Grid service**
Kerosene lamp	71%*	52.6%**
Solar lantern	5.4%	6%
Battery	8.6%	16%
Solar home system (SHS)	2.1%	6%
Candle	4.3%	3%
No backup	8.6%	16%

*Mini-grid service: 20 days/month, 4 hours/day
** Mini-grid service: 18 days/month, 3 hours/day

Figure 4: Better quality of supply obtained from the solar powered-mini-grid than from the grid

Source: own

Kerosene lamps were widely used in the grid and mini-grid villages for more than half the month (18 days in mini-grid HHs and 20 days in grid HHs), and reportedly used daily for 3–4 hours. The main reason for the huge reliance on kerosene lamps by mini-grid consumers was the limited capacity and hours provided by the system, and also due to seasonal variations in quality of supply. On the other hand, for grid consumers, this was due to the irregular and unreliable supply from the utility. Kerosene lamps were also stated as the main source of lighting for children to study during the evening or at night in both grid and mini-grid households.

Additionally, the mini-grid service providers in the case study areas supplemented power generation from the solar mini-grid with diesel generators (DG) in order to plug supply shortages and to also supply 24 hour power to the anchor loads. From the data collected, it is evident that, in the surveyed regions, neither of the two power generation systems (grid or mini-grid) was able to adequately meet the total electricity demand of users independently. While the mini-grid fell short in power capacity and length of supply duration, the grid also fell short with irregular power supply and was unsuitable for the planning purposes of consumers. Practically, the level of service for both systems ranges between Tier 2 and Tier 3 of the MTF (cf. Table4). Thus, the overall experiences of mini-grid and grid consumers in terms of lighting in the evening in assessed regions are broadly similar; however, grid consumers could use electricity for purposes beyond lighting, when supplied.

Duration	Mini-grid service (hours)	Grid service (hours)
Daytime	6	10.5
Evening	3.9	3.7

Table 4: Classification of service delivery tiers for both sources

Source: own

Furthermore, surveying the aspirations of consumer appliance use if adequate, timely and regular electricity supply was achievable showed that aspirations in a non-electrified area are principally based on affordability. However, the perceived expectations of an energy supply system, based on how consumers experience their current electricity supply, also served as a major factor for determining the consumer's affinity for productive loads[9] or appliances. The case study areas that were predominantly supplied from the mini-grid aspired to own appliances that were more fundamental to their daily requirement and comfort (such as cooling appliances such as fans). The mini-grid consumers surveyed had lower rated power and energy consuming appliances because the average energy supply received per day from the mini-grid was unable to meet their aspirations for higher power capacity appliances, such as refrigerators. On the other hand, grid-based consumers were able to use more energy -intensive appliances such as refrigerators, computers and printers (cf. Figure 5) because the quality of electricity received from the grid was sufficient to cater for the high energy demand. The contribution of each appliance to the energy demand of either consumer group was, hence, obtained to depend on the income level of the household and also the average kWh the household receives per day.

Thus, in view of India's development targets, the current power capacity of an average installed solar mini-grid in the country might be unable to drive the energy demand of high energy consuming productive loads needed in the rural areas. Consequently, there could be an argument for higher-capacity mini-grids to visibly enhance the socio-economic development of rural-India.

[9] These are appliances or devices that aid in boosting people's businesses and income-generating activities within a designated area; hence they improve local standards of living.

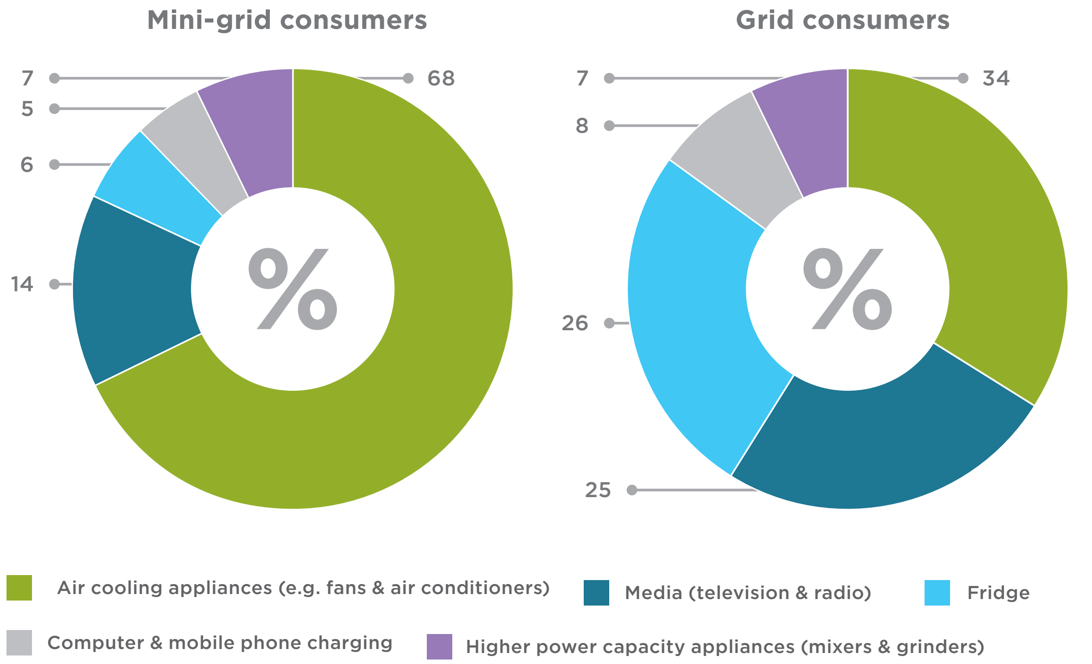


Figure 5: Contribution of different appliances to the energy consumed by mini-grid and grid consumers.

Source: own

3.2 Can RE-powered mini-grids improve the standard of living in rural India?

Access to electricity, especially in rural contexts, has significantly improved quality of life and community welfare for un-electrified communities in India. These improvements include increases in the level of health services, education access and commercial opportunities to improve living standards. Through India's electrification progress, mini-grids have emerged as a key medium in bridging the electrification access gap between energy-poor rural consumers and service delivery from the centralised grid network. However, because most installed mini-grids in India have low power capacity, they offer only limited possibilities for significantly improving local living standards (Table 5). From the surveyed case study areas, the main co-benefits realised thus far are related to:

Enhanced convenience and improved indoor environment due to more reliable, cleaner and improved indoor lighting

Prior to having access to electricity in the household, mobile phone users from non-electrified households spent time and money at the local market, or travelled to a nearby electrified village, to get their phones charged every few days. Additionally, following the installation of the mini-grid, reliance on kerosene lamps had considerably reduced, from 30 days per month to less than 18 days in those communities where electricity supply from the grid infrastructure was completely non-existent.

For women, who spend more time cleaning and cooking, having a brighter and cleaner lighting solution has positively impacted their health and allowed them to optimise their daily schedules, which were previously largely defined by the availability of daylight. Also, a key benefit attributed to mini-grids is the opportunity for children to study in the evening with good-quality lighting.

Improvement in public services

Electricity supply from mini-grids has made it possible to establish medical stores in both the two mini-grid equipped case study areas. A medical store that received approximately 24 hours of supply from the mini-grid was able to power a medical refrigerator which stored essential drugs for patients; this especially improved the service delivery of the medical store to women in the case study area.

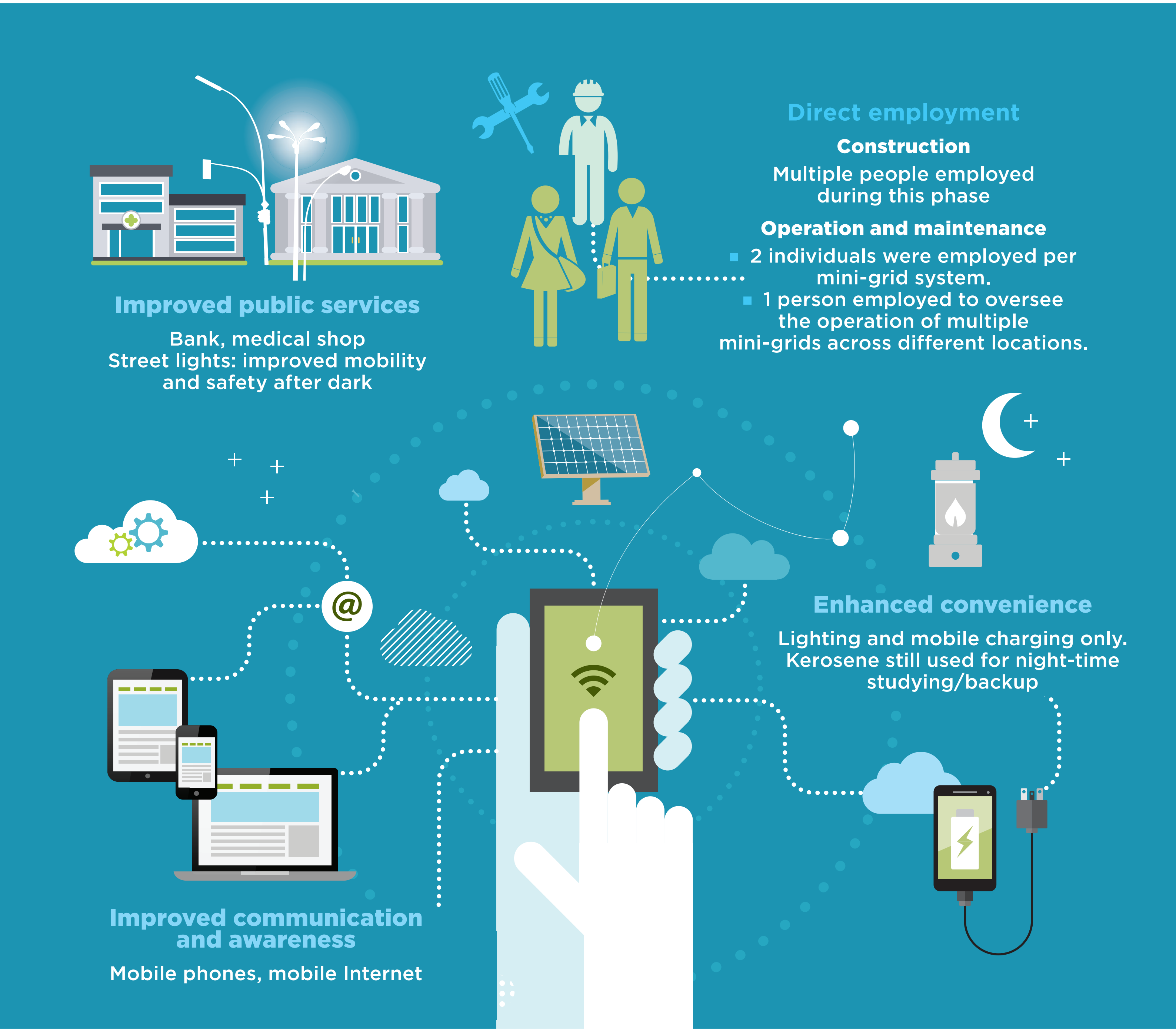
Furthermore, streetlights, powered by the mini-grid installed in one of the study areas, improved mobility and safety at night. This public facility had huge positive impact on women. This is because most households in the study locations (74% and 81% of respondents in case study areas 2 and 3 respectively) did not have a toilet in their homes, and thus women have to walk long distances at night to make use of the convenience services. The presence of proper street-lighting helped make the environment safer for them and prevented easy occurrences of rape and other negative acts perpetrated against women in the rural community.

Direct employment creation

The deployment of mini-grids within the communities opened up some employment opportunities for the local population. Residents were involved in the construction and installation of the mini-grid systems across both case study areas. Considering the small system size, two semi-skilled individuals (technicians) were directly employed for the operation and maintenance of the facility. Additionally, another skilled person was employed and trained to oversee the operation of the mini-grids across multiple locations.

Table 5: Observed social co-benefits of the assessed mini-grids

Source: own



4. Cost-competitiveness of mini-grids at higher power capacity in rural India

It is evident that in order for a mini-grid to effectively play a major or leading role in providing adequate energy supply in rural or remote communities in India, there needs to be an increase in the system size or capacity as well as growth in the scale of use. However, the current tariff of an average solar-powered mini-grid is higher than those paid by grid-consumers for the capacity and service it delivers. Since most mini-grids in India are privately operated, there is no standardisation of pricing because each developer operates a project-specific/proprietary business and financial model. As mini-grids serve communities where grid electrification is non-existent or unreliable, the developers are able to charge a premium for providing electricity services to these areas.

4.1 Case 1: Baseline analysis of the difference in tariffs and the cost of supply

Although, it may not be entirely possible to provide an 'apple-to-apple' comparison of the unit tariffs between mini-grid and grid supply options, this assessment provides a baseline comparison of what an average rural consumer pays for electricity supply from a mini-grid at different scales of need or system sizes versus the costs for grid supply. This, in turn, helps explain the appropriate cost of supply (COS), which makes a mini-grid with a high installed capacity competitive with the grid, taking into consideration the quality of service in the context of India's 100% electrification target.

	Mini-grid (27 kW)	Grid
Average cost of supply	Rs29.21/kWh	Rs6.40/kWh
Average monthly consumption per HH	2.7 kWh	82 kWh
Average unit tariff	Rs40.75/kWh	Rs3.61/kWh

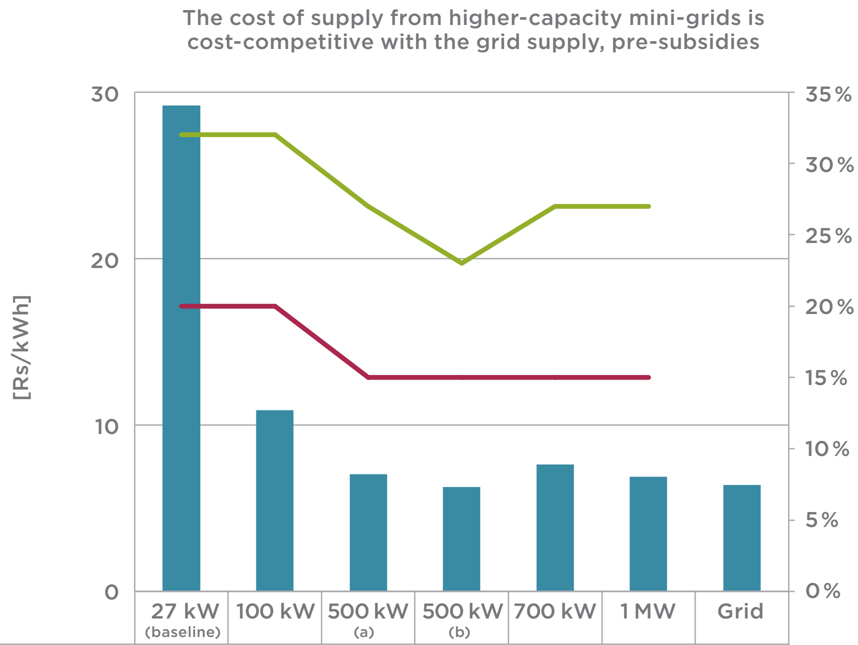
Table 6: Cost of supply and tariff (grid versus mini-grid)

Source: own

As shown in Table 6, for an average mini-grid consumer, the estimated unit cost of supply is about Rs 29.21/kWh, which is five times greater than the average grid consumer with a COS of Rs6.40/kWh. From the survey and subsequent analysis, an average grid-consumer in a rural area consumes approximately 82 kWh of electricity per month (unit tariff Rs3.61/kWh). In comparison, a consumer connected to a solar-powered mini-grid uses 2.7 kWh per month, which is limited by the low power capacity of the appliances used in such households. Their unit tariff is Rs40.75, which is about 1.4 times the system's cost of supply and is greater than the grid-consumer. Overall, grid-connected consumers receive eleven times greater subsidy.

4.2 Case 2: Inflexion point at higher (scaled-up) mini-grid sizes

The calculations show that it is possible and justifiable for mini-grids to become economically viable at higher power capacities, due to specific economic input parameters. As shown in Figure 6, a 500 kW mini-grid with an interest rate of 8% (below the 12% standard interest rate), or a 1 MW capacity solar mini-grid with a 15% return on equity (RoE) can achieve parity with the grid electricity supply in terms of the cost of supply. Mini-grids of 500 kW and 700 kW capacity and with input economics that are equivalent to the standard market condition, but with 15% RoE, have a levelised tariff of Rs7.04/kWh and can therefore also be competitive with the grid (cf. Figure 6). The annex to this report provides a breakdown of each input economic parameter.



	27 kW (baseline)	100 kW	500 kW (a)	500 kW (b)	700 kW	1 MW	Grid
Levelised Tariff (Rs/kWh)	29,21	10,90	7,04	6,26	7,62	6,88	6,40
Interest rate (%)	12 %	12 %	12 %	8 %	12 %	12 %	
RoE (%)	20 %	20 %	15 %	15 %	15 %	15 %	

Figure 6: Return on Equity (RoE), interest rate and levelised tariffs of different mini-grid sizes or capacities (the "grid" tariff includes government subsidies, which is one of the reasons why grid electricity supply is so cheap)

Source: own

For the 100 kW system, which serves one village including key public services and some commercial loads (cf. Figure 7), a change is achieved in the percentage of annual operation and maintenance (O&M) cost (from 9% to 6% at 27 kW) with respect to the system's capital cost. This results in a huge reduction of almost one-third in the electricity tariff from the mini-grid, from Rs29/kWh to Rs10.9/kWh which gradually enables the cost of electricity supplied by the mini-grid to converge with that supplied from the grid.

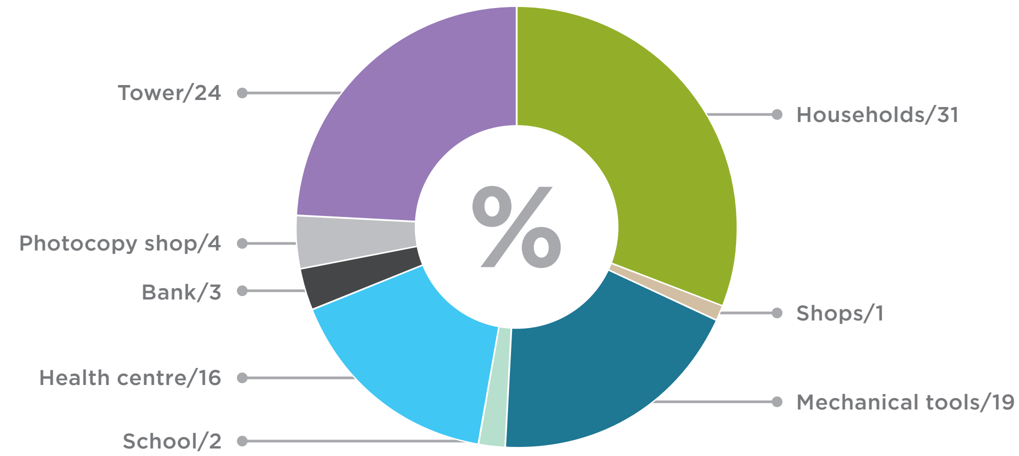


Figure 7: Consumption profile for a 100 kW mini-grid (serving one village)

Source: own

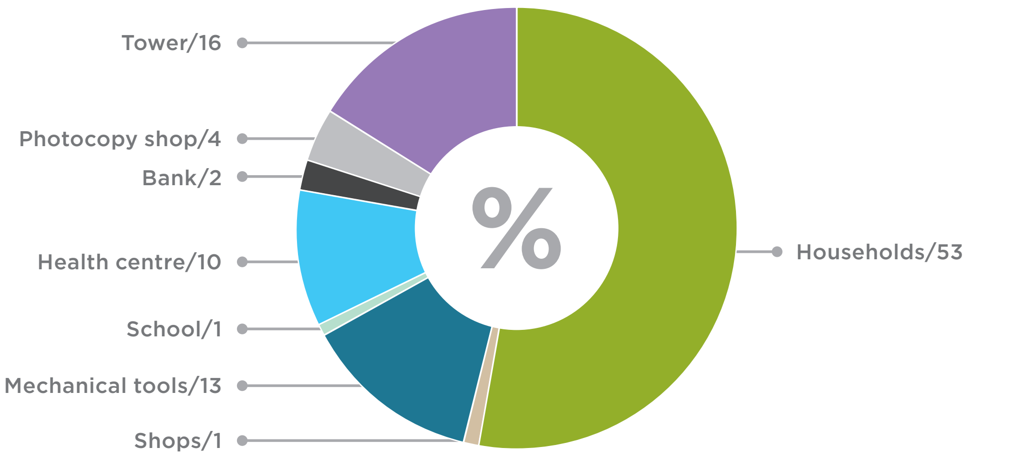


Figure 8: Consumption profile for a 500 kW mini-grid with additional daytime supply[10] (serving at least two villages)

Source: own

Two scenarios for this system were tested;

- In the first scenario (a: 500 kW), two financial parameters were adjusted: First, the O&M expense was reduced to 2% of the capital cost, to conform with changing industry norms; second, the return on equity (RoE) was brought down to 15%, aligning with the standards provided by the Central Electricity Regulatory Commission (CERC). The resultant tariff is approximately Rs7/kWh, which is more than Rs3.5/kWh lower than for a smaller 100 kW mini-grid and Rs22/kWh less than the average 27 kW mini-grid.
- In the second scenario (b: 500 kW), an additional assumption was made for the 500 kW mini-grid system: that if the government were to provide support in the form of an interest subsidy on the loan component, then it could contribute, in a market-friendly way, to reducing the overall cost of supply. Accordingly, the 'interest on loan' component was reduced from 12% to 8%, keeping all other parameters the same as in scenario (a). This sensitivity adjustment led to a further reduction in the levelised tariff to Rs6.26/kWh, which was lower than the average cost of supply from the grid (at Rs6.40 per unit; cf. Figure 6).

[10] For systems of >500 kW capacity, there was surplus generation after meeting all connected load requirements. It is proposed that this may either be supplied to households and other users for a few hours per day, to further increase utilisation without additional capital cost to the developer, or may be fed into the grid, which could provide an additional financial incentive to the mini-grid developer.

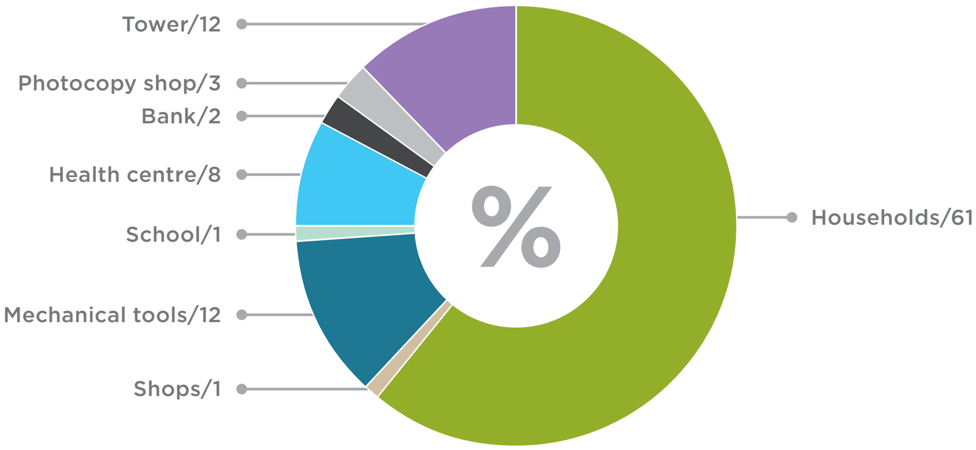


Figure 9: Consumption profile for a 700 kW mini-grid with additional daytime supply (serving three villages)[11]

Source: own

Furthermore, the analysis considered cases of 700 kW and 1 MW capacity mini-grids (cf. 9). Both systems were designed to serve the energy needs of three villages. Keeping the interest rate and RoE similar to the 500 kW case (a), the equivalent tariff for the 700 KW system increases marginally to Rs7.62/KWh; this is primarily due to the higher capital expenditure for a plant of this scale. On the other hand, the 1 MW mini-grid had a lower tariff of Rs6.88/kWh, which is almost equivalent to the 500 kW case (b) and the grid tariff of Rs6.40/KWh, despite having a higher interest rate and weighted cost of capital. This low tariff obtained for the 1 MW mini-grid case demonstrates the benefit of leveraging economies of scale to achieve lower costs for consumers served by mini-grid systems. It is important to note that tariffs obtained in the analysis do not account for other non-techno-economic costs, such as the cost of land leasing amongst others.

This analysis demonstrates that it is theoretically possible for mini-grids to scale-up and remain economically viable and cost-effective (even when clustered together to increase the power capacity and electricity supply to consumers). As detailed above, two cases (500 kW (b) and 1 MW) almost achieve parity with the grid in terms of average cost of supply (ACOS). However, there is another aspect that still poses a challenge when comparing the tariffs of electricity suppled from the mini-grid and from the distribution company (i.e., the grid). **This is because even though the ACOS for the grid electricity supply from the distribution company is Rs6.40/kWh, the effective tariff charged to the rural consumer is nearly half (approx. Rs 3.61/kWh. Owing to low income and affordability levels, rural grid consumers are significantly cross-subsidised by other, larger consumers (industrial/commercial) who pay a higher electricity tariff,** and additionally by a capital subsidy from the state government. These subsidy mechanisms do not currently exist in the mini-grid sector in India, thus placing the total cost burden on the consumer. Nonetheless, the reliability of electricity supply to rural consumers remains a pressing issue. Solving this need presents an opportunity for renewable energy mini-grids to remain relevant and feasible within the rural electrification context in India, while still enhancing other socio-economic benefits to consumers.

In conclusion, this analysis suggests that to make mini-grids highly competitive with direct grid connection in terms of tariffs and costs, the interest rate for developers needs to be reduced to as low as 8% while keeping other key economic and financial indices constant. There is immense potential for the adoption of solar-powered mini-grids to deliver additional socio-economic co-benefits to rural Indian communities. Mini-grid project developers need to consider the energy profiles of key public institutions in the host community, and design such systems to ensure that the energy supplied also meets the collective needs of the community.

[11] The maximum number of villages served by a single mini-grid (700 kW and 1 MW) was limited to three; at higher capacities, it becomes financially and operationally unfeasible to cater to additional loads, due to additional battery backup and network costs that drive the levelised tariffs up again.

5. Creating an enabling environment to foster rural electrification: Impulses for furthering the debate

This COBENEFITS study shows that solar-powered mini-grids can become cost-competitive with the grid, and can aid in improving the reliability of rural electrification in India. The cost-of-supply and equivalent tariff analyses show that scaling up mini-grids to higher power capacities (as either single, stand-alone systems or a cluster of multiple projects within a single portfolio) can make them more cost effective while maintaining their economic viability.

The study findings show that the deployment of mini-grids at scale within communities has the potential to provide both direct and indirect employment opportunities for the local population; this is also driven by higher power capacity mini-grids. Due to low income levels in rural areas, grid-electricity consumers are significantly subsidised by the state through different mechanisms. Therefore, by replicating a similar subsidy mechanism for high-capacity renewable-energy-powered mini-grids (especially solar-powered), the huge cost burden presently placed on mini-grid-consumers in rural areas can be ameliorated. Hence, the resulting socio-economic benefits can be effectively realised. In India's context of almost 100% electrification at the rural level, mini-grids can be utilised as natural extensions of the grid in areas where reliability of supply is a concern. This would require clear guidelines for grid-integration, making it an attractive business opportunity for investors.

What can government agencies and political decision makers do to unlock the combined benefits of grid/mini-grid solutions for rural India?

How can other stakeholders unlock the social and economic co-benefits of building a low-carbon, renewable energy system while facilitating a just energy transition?

Building on the study results and the surrounding discussions with political partners and knowledge partners during the Enabling Policy Round Tables, we propose to direct the debate toward the following areas, where policy and regulations could be put in place or enforced in order to maximise the benefits or rural electrification within the shift to a less carbon-intensive power sector:

- Enhance individual mini-grid capacities (500 kW and above) to make supply for community institutions possible.
- Establish mini-grids as a complementary/supplementary extension of grid services.
- Establish a dialogue for short, medium and long-term planning and the development of suitable business models for mini-grids.
- Pricing of mini-grid services: cross-subsidies for mini-grid consumers.
- Skill development to maintain the growth of mini-grids in the country.

Enhance individual mini-grid capacities (500 kW and above)

One of the key study findings is the limited capacity offered by the studied mini-grid systems. The present capacities not only fall short of the desire for lighting alone, but also limit the types of electrical appliances that consumers can use at home to improve their quality of life. This limitation also extends to the possibility of starting new enterprises or mechanising/enhancing pre-existing ones, and to support important community institutions such as schools, markets, public health and community centres with electricity. This upscaling will make mini-grids more economically viable and bring down the per-unit tariff for consumers. Therefore, for future solar mini-grid projects, we recommend that appropriate policy guidelines should mandate the inclusion of key public institutions, together with local households. As suggested by the scenarios developed in the study, medium-scale mini-grids serve the dual purposes of providing higher available load as well as longer duration of reliable supply. It is recommended to promote this novel concept for electrifying clusters of villages. However, such systems should be designed to accommodate the growing energy demand of the consumers.

Another way of increasing the load available to various types of consumers is to install multiple, small mini-grids, such as the ones surveyed, connected together to form a grid-like network. This can vastly enhance the provision of power to multiple locations, and also reduce the losses associated with extending power lines to distant households. The management of these numerous systems would require additional personnel, leading to the possibility of employment generation. However, such a system would present its own technical challenges. Limitations may also be present in integrating this network with the grid, as the study proposes. Therefore, further research and pilot models would be required to study the on-ground realities of deploying this technology.

Establish mini-grids as a complementary/supplementary extension of grid services

In the Indian context of fast-expanding and policy-driven grid extension throughout the country, the electricity distribution companies, which were already struggling with issues of reliability of supply and network maintenance, now face the added burden of numerous new connections. In such a situation, instead of viewing mini-grids as an alternative to grid supply, by scaling up mini-grids and the corresponding services they can then offer, mini-grids may be utilised as natural extensions of the grid in areas where reliability of supply is a concern. This will not only help to counteract the perceptions of mini-grid supply being sub-par and more expensive than grid supply, but will essentially refocus on the electricity service rather than its source. This will also make a much stronger business/investment case for mini-grids in India.

Surplus energy from mini-grids can be fed back into the grid, as well as provided during the daytime when grid supply is presently unreliable. Although the technicalities of such connection are beyond the scope of this study, these interconnections can also reduce the pressure on distribution companies struggling with demand management and network maintenance issues in rural areas. Thus, we recommend that clear guidelines for interconnecting mini-grids with the grid network be formulated, making it easier and more attractive for investors to consider this as a viable business opportunity.

Establish a dialogue for short-, medium- and long-term planning and the development of suitable business models for mini-grids

As pointed out, there are several opportunities to use mini-grids as a complementary extension to the grid or as a supplementary source of electricity, even when grid-supplied electricity is eventually expanded to include remote communities. However, the political discussion concerning the most appropriate options is only slowly gaining momentum, and promising approaches are often not yet apparent for decision makers, distribution companies and mini-grid developers.

The initiation of multi-stakeholder dialogue, for example in the form of round tables comprising state governments, distribution companies, mini-grid developers and civil society representatives, can serve as a joint hub for planning future approaches to mini-grid use. Besides being a platform for sharing data and experiences between business and state agencies as basis for joint planning, strategies elaborated with the participation of all important stakeholders have strong potential to serve as a blueprint for the development and political support of new and suitable business models for mini-grids in India. Mini-grid planning hubs need to be supported by further research on appropriate options and models, to examine approaches for growth and expansion, to reduce stress on distribution companies and to reimagine the consumer base for mini-grids.

Pricing of mini-grid services: Cross-subsidies for mini-grid consumers

Successive governments have sought to make electricity access affordable to even the poorest sections of society; to achieve this, a number of subsidies have been rolled out. Rural domestic consumers are cross-subsidised by industrial and commercial consumers, making tariffs very low and affordable. However, this benefit is not available to mini-grid consumers within the same economic strata, and who pay much higher per-unit tariffs for much more limited energy services.

We therefore recommend that in a scenario of medium- or MW-scale mini-grids, where the cost of supply is comparable to that of the grid (as established in this study), consumer tariffs should also become comparable and some provision should be made to cross-subsidise rural mini-grid consumers to achieve parity in electricity pricing for consumers reliant on grid and non-grid electricity sources. This would not only make reliable and quality supply through mini-grids affordable, but also serve to fulfil the government's objective of achieving a widespread transition to clean energy sources.

Develop skills to maintain growth

Direct employment created by mini-grid projects in host communities is currently limited to semi-skilled operators and technicians, which are often few in the current scenario. Opportunities for increased direct employment in the mini-grid value chain will be fostered with the development of a large number of high-capacity systems; this essentially aids "localisation of industry", which in turn drives local employment creation and skills transfer. Premised on an expansion and scale-up of mini-grids in India, skilled technicians would be required for operating and maintaining plants, and revenue staff for collecting tariffs. Thus, it is recommended to mandate skill development programmes to create employment opportunities within local communities.

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List of abbreviations

ACOS	Average cost of supply
DG	Diesel generator
ESCO	Private energy service company
HH	Household
LCOE	Levelised cost of electricity
MTF	Multi-tier tariff framework
MW	Megawatt
RoE	Return on Equity
SHS	Solar home system
MNRE	Ministry of New and Renewable Energy
CERC	Central Electricity Regulatory Committee
PFC	Power Finance Corporation
IREDA	Indian Renewable Energy Development Agency
REC	Rural Electrification Corporation
SAUBHAGYA	Electrification scheme with the aim of electrifying all households in India by March 2019
UP	Uttar Pradesh

COBENEFITS
Connecting the social and economic opportunities of renewable energies to climate change mitigation strategies

COBENEFITS cooperates with national authorities and knowledge partners in countries across the globe such as Germany, India, South Africa, Vietnam, and Turkey to help them mobilise the co-benefits of early climate action in their countries. The project supports efforts to develop enhanced NDCs with the ambition to deliver on the Paris Agreement and the 2030 Agenda on Sustainable Development (SDGs). COBENEFITS facilitates international mutual learning and capacity building among policymakers, knowledge partners, and multipliers through a range of connected measures: country-specific co-benefits assessments, online and face-to-face trainings, and policy dialogue sessions on enabling political environments and overcoming barriers to seize the co-benefits.

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