



Stimulating rural development through energy access:
Evidence from The Rockefeller Foundation's
Smart Power India Initiative

Data from 2016–2018; published 2019

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Sambodhi Research and Communications creates high-impact knowledge and catalyzes accountability in the public domain through its research, project management, and monitoring and evaluation solutions. Sambodhi offers objective, evidence-based insights to implementers, government agencies, donors, and corporations, and has pioneered development of cutting-edge methodologies for the evaluation of large scale development interventions. Sambodhi's staff of 100 professionals works across Asia and Africa on issues concerning public health, HIV/AIDS, nutrition, water and sanitation, environment, and renewable energy, and has made valuable contributions to measurement, learning, and evaluation (MLE) programs – influencing development policies and improving implementation efficiency. Sambodhi's work has continually provided evidence to affect policy decisions and has been used in leading state policy-making documents, such as the economic survey of India.

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The Rockefeller Foundation advances new frontiers of science, data and innovation to solve global challenges related to health, food, power and economic mobility. As a science-driven philanthropy focused on building collaborative relationships with partners and grantees, the Foundation seeks to inspire and foster large-scale human impact that promotes the well-being of humanity throughout the world by identifying and accelerating breakthrough solutions, ideas and conversations.

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Acronyms

ESCO	Energy service company
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
GTF	Global Tracking Framework
Kg	Kilogram
kW	Kilowatt
M&E	Monitoring and Evaluation
MED	Micro-enterprise development
MTF	Multi-Tier Framework
OBC	Other Backward Classes
RO	Reverse osmosis
SC	Scheduled Castes
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SPI	Smart Power India
ST	Scheduled tribes
USD	United States dollar
V	Volts

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In publishing this second independent impact report, the Sambodhi monitoring and evaluation team would like to thank The Rockefeller Foundation and Smart Power India (SPI) for their leadership in the decentralized renewable energy sector and their commitment to evidence-based learning and management.

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Finally and most importantly, we are deeply grateful to our respondents from more than 2,000 households and from more than 600 enterprises – for their time and good will engaging in our impact monitoring work – without which our deep understanding of the behaviour of households and enterprises would not be possible.

Swapnil Shekhar – Chief Operating Officer, Sambodhi Research and Communications

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Preface

This is the second Smart Power Impact Report that The Rockefeller Foundation has published as part of Sambodhi's independent monitoring and evaluation (M&E) of the Foundation's investments in decentralized renewable energy in India.

With each round of impact monitoring and reporting over a period of three years, our understanding of the impact of access to reliable electricity on households and enterprises in rural villages of Bihar, Uttar Pradesh, and Jharkhand has deepened. This report provides credible evidence on the impact of mini-grids on village economies, jobs, health, and general well-being – and suggests a relationship between electricity consumption and economic growth. This evidence provides a compelling rationale for further supporting the acceleration of rural electrification in developing countries– where 840 million people today remain unconnected.

With recent advancements in the government grid, we are now learning more about the complex and nuanced relationship that households and enterprises have with both mini-grids and the government grid. This report discusses this often-symbiotic relationship and tests our assumptions about the factors of uptake in energy consumption and preferences in rural India.

We are grateful to the Sambodhi team for its ongoing diligence in developing and maintaining a robust baseline and comparison group against which to systematically measure progress in households and enterprises. We appreciate its independence in providing real data and insights that push us to challenge our assumptions and to adjust our strategies so that our investments can better help more people move up the energy ladder. We say this with humility and awareness of the importance of spending time on the ground in order to understand the realities that drive behavior.

Through learning about what is working and what is not, and understanding the barriers to change, we are hopeful that our strategy going forward can sustain and grow the positive gains of the Smart Power Initiative.

We are pleased to share this Impact Report with you and other stakeholders who are working tirelessly to bring electricity to the 840 million around the world who are living without it today.

Pariphan Uawithya – Director, Smart Power, The Rockefeller Foundation

Shawna Hoffman – Director, Program Measurement and Performance, The Rockefeller Foundation



In the village of Derni, Ankit Singh, runs a school with over 400 students:

“The mini-grid gives us the power to light our classrooms and have a digital class with learning videos. I am planning a computer center now, and that’s possible because we have 24/7 power from the min-grid that’s just behind the school. It has opened up so many opportunities for us.”

Executive Summary

What is the Smart Power Initiative?

Launched in 2015 by The Rockefeller Foundation, The Smart Power Initiative aims to accelerate sustainable development in the least electrified states of India, through the establishment of decentralized, renewable energy mini-grids.

Leveraging the global momentum to bring sustainable energy to all, The Rockefeller Foundation works with governments, the private sector and the technology sector to catalyze energy transformation by accelerating electrification in environmentally and economically sustainable ways.

In making these investments, The Rockefeller Foundation believes that providing access to reliable and affordable electricity for productive use can stimulate sustainable economic opportunities and bring a better, healthier quality of life to people living in underserved regions in India.

In the early stages of Smart Power, The Rockefeller Foundation established an independent entity, Smart Power India (SPI), to develop partnerships with a wide range of stakeholders to improve the quality of electricity access and, in doing so, promote economic opportunities for rural communities.¹

SPI deploys two models that provide rural electricity access in India.

- 1. Mini-grid model.** Mini-grids are decentralized standalone renewable energy power plants that generate and distribute electricity to homes, local enterprises, and anchor-load customers, such as cell-towers. Through its mini-grid model, SPI provides technical support to energy service companies (ESCOs) that build, own, and operate mini-grids. Some ESCOs have also received concessional loans from The Rockefeller Foundation.
- 2. Electricity as a service model.** SPI works with electricity distribution companies to improve last-mile access and services in rural areas.²

Through these two models, Smart Power works to:

- enhance local business through a reliable electricity connection and value chain support
- enhance household and rural enterprise electricity access,
- create an environment for public institutions to operate effectively with an uninterrupted supply of electricity.

¹ Smart Power India (SPI) provides project development support to ESCOs including site selection, business modelling, community marketing, micro-enterprise promotion, technology and innovation partnerships, performance analysis, and policy support.

² This impact monitoring focuses on the impact of the mini-grid model; the energy service model is outside of the scope of this data collection.

Where is Smart Power operating?

In the first phase of the Initiative's development, mini-grid plants were established in Bihar, Uttar Pradesh and Jharkhand. In 2016, there were 95 Smart Power mini-grids owned and operated by seven ESCOs, serving more than 11,000 customers. By 2018, there were 138 mini-grids directly serving more than 17,000 customers – 11,000 residential and 6,000 commercial.³

What are we learning? What difference is Smart Power making?

Prepared by Sambodhi, Smart Power's independent monitoring and evaluation partner, this impact report provides a picture of the ongoing progress and impact of the Smart Power mini-grid model, highlighting the ways in which impact is deepening in households and enterprises. The 2018 assessment sample covered more than 2,000 households and 600 enterprises from villages with and without mini-grids to enable comparison.

This report also compares the findings of the 2016 and 2018 independent impact assessments of Smart Power. The 2016 assessment sample covered 39 sites, consisting of 1,000 households and 320 micro-enterprises.

Overall impact

Since its inception in 2015, the Smart Power initiative has aimed to provide electricity access in India by supplying timely and reliable power to households and enterprises. As of 2018, it had supplied electricity to more than 11,000 households and powered nearly 6,000 enterprises across three Indian states that historically have had inadequate electricity supply – Uttar Pradesh, Bihar, and Jharkhand. This power has, in turn, affected the power consumption, health, livelihoods, and social and economic development of over 187,000 people.

The positive impacts of reliable Smart Power electricity on households are seen in numerous ways, from a light bulb helping a student study longer hours and street lighting providing greater safety for women at night, to an easily accessible rice huller and the provision of clean drinking water from a water filtration plant. Of significance is the mini-grid customers' almost complete shift away from the use of kerosene, and the associated positive health and environmental benefits of reductions in respiratory infections, improved air quality, and reductions in carbon emissions.

³ At the time of this report's publication in late 2019, the number of Smart Power India's customers increased to over 31,500 households and almost 9,000 commercial connections, benefiting approximately 310,000 people.

Smart Power has successfully created opportunities for people to participate in and benefit from a developing economy. Financial and technical support provided to commercial and high impact enterprise models benefits entrepreneurs and their employees, and also positively affects the lives of tens of thousands of people. For example, each water filtration unit that connects to a mini-grid directly benefits the entrepreneur and employees by ensuring economic returns, while also supporting direct health benefits of clean drinking water to around 30 households. Each of the 23 reverse osmosis (RO) water plants supplies an average of 20 litres of water to around 250 daily customers during summer months.

These high impact enterprises have improved the lives of villagers and modestly stimulated rural economies by catalyzing new businesses and services. The revenues of enterprises connected to mini-grids have increased by approximately 42 percent, compared with their revenue before Smart Power.

These findings point to the strong potential of Smart Power, if sustained and scaled, to ultimately transform many more lives and continue to contribute to sustainable economic growth. However, to achieve this, Smart Power will need to address the challenges raised by customers with regard to high tariffs, the lack of flexibility in timing of electricity, and the improvements needed in the engagement of women. To make an even greater impact on the economy, Smart Power will need to continue to prioritize connecting productive load enterprises and on-farm units while also ensuring adequate market linkages.

Specific highlights of initial 2015 – 2016 impact monitoring

Households and enterprises connected to mini-grids moved up the energy ladder,⁴ with low-income customers acquiring lighting for the first time, and middle and higher wealth groups moving beyond lighting to acquire electrical appliances such as fans and refrigerators to enhance the convenience and comfort of doing business.

Smart Power successfully increased the quantity, type, efficiency, and scale of micro-enterprises, and contributed to social and economic capital, with modest gains in village GDP.⁵

Mini-grids led to mechanization, expansion, and creation of new businesses, some with a larger social reach, such as training centers that expanded village human capital.

Mini-grid lighting contributed to improved health conditions, longer study time, and increased safety at night, especially for women. Lighting has also helped improve communities' access to public institutions such as health centers, educational institutions, marketplaces, and streets.

⁴ The energy ladder depicts the process of a household moving away from traditional sources of fuel and toward modern, more efficient sources (Christophe & Yan, 2016). An adapted version of this approach has been used as an analytical framework for this round of impact monitoring.

⁵ Recognizing the limitations of measuring only the monetary value of GDP to reflect the true value of Smart Power to communities, Sambodhi developed the GDP+ tool which includes measures of gross domestic product (GDP) as well as social change. The GDP+ tool captures and quantifies the key social, economic, and environmental changes generated through rural electrification.

Many Smart Power households and businesses reduced their heavy dependence on kerosene and diesel, thus reducing eye irritations and respiratory illnesses, and enabling longer and improved study conditions for children.

Challenges observed in 2016 monitoring included: the high cost of capital expenditures; the need to support an enabling business environment including access to finance to expand or create new opportunities; the need to provide technical support; the need to support greater involvement of women in decisions related to electricity acquisition as well as owning and managing enterprises; and the need to pay closer attention to post-connection customer satisfaction.

Specific highlights of 2018 impact monitoring

The profile of Smart Power enterprise and household customers has consistently reflected the demographic distribution of the communities where it is implemented. However, variations are seen from an investment lens. The larger proportion of low investment enterprises belong to the Scheduled caste communities, while high investment enterprises have a large proportion of owners belonging to the general population category.

95% of Smart Power mini-grid customers use the mini-grid connection as their primary electricity source, and 76% use it as their sole source. Most high load users – connected to Smart Power mini-grids no longer use any other electricity source to run refrigerators, chillers, computers, and printers, or for lighting. While the supply hours from the government grid have nearly tripled since 2015, the quality remains poor at ~ 50V, which cannot support commercial loads. While the perceived “value for money” associated with mini-grids has declined for households since 2016, its value in terms of reliability and quality still makes it the preferred choice for 74 percent of the mini-grid customers, particularly enterprises.

Kerosene has almost been eliminated as a lighting source for both households and enterprises, resulting in noticeable health and environmental benefits. The most remarkable shift the Smart Power initiative has seen is the almost complete elimination in use of kerosene and diesel for lighting for mini-grid customers, resulting in noticeable health and environmental benefits, such as reduced respiratory infections and cleaner air.

The enterprise development model has successfully identified entrepreneurs, and supported them with financial capital, technical training, and value chain linkages. Smart Power responded effectively to early feedback that support was needed to build an enabling enterprise ecosystem. The Smart Power strategy to incubate commercial and high impact enterprises has been successful. Each micro-enterprise developed has been able to generate employment opportunities for at least for two or three people within the village to carry out operations of the business, and some high impact enterprises have extensive reach and potential benefits.

Smart Power has successfully increased commercial high load connections in its customer portfolio and, through this, has enhanced sustainable economic development. The increase in high load enterprise mini-grid connections between 2016 and 2018 was driven by water filtration plants, grain processing mills, and bulk milk chillers. Smart Power successfully incubated and incentivized the creation and expansion of high impact enterprises, such as water filtration units. Each of these units directly benefits the entrepreneur and the employees by ensuring economic returns, while also supporting direct health benefits of clean drinking water to households that procure water from it.

Medium and high investment enterprise connections have increased, whereas low investment businesses connected to mini-grids are gradually declining. The proportion of medium and high investment enterprises connected to mini-grid is increasingly - from 63 to 73% for commercial loads and from 53 to 58% for lighting loads in 2016 and 2018, respectively.

Enterprises and households respond differently to the use of mini-grid electricity as their primary source. Preference for mini-grids is not as high for households as for enterprises. Enterprises, especially lighting loads, rely mostly on mini-grids because their needs for electricity are generally predictable, e.g. lighting. However, for households, the purpose of electricity is not as predictable given the range of household needs for power and, thus, the government grid provides more flexibility to operate multiple appliances.

The high tariffs of mini-grids have led to more household drop-outs. High tariffs have been an ongoing concern of household customers since Smart Power-supported mini-grids began operations. Household mini-grid use has declined as government connections have become available at a lower cost. Around 14 percent of connected households dropped out primarily due to the high costs required to operate a mini-grid connection. The mini-grid cost is almost four times that of government-grid electricity and, while mini-grids are appreciated for being superior in quality, the higher costs have discouraged many existing and potential users. With ongoing improvements in government grid supply and lower cost, customers are increasingly exposed to alternative options, which may affect the economics of mini-grids. This needs to be monitored closely.

While the “value for money” of mini-grids has declined for some households, their reliability, quality, and lower transaction costs still make them the preferred choice for the majority of mini-grid customers. Mini-grid customer service makes it easier for consumers to access and utilize electricity than the government grid. Customers find it easier to deal with mini-grid service for connections and complaints, and they like the fixed monthly tariffs and payment schedules. The high transaction costs of getting connected to the government grid, time-consuming paperwork to lodge complaints and to follow-up, uncertainty about the amount of the bill, and irregular payment schedules have all acted as deterrents to government grid connections for low wealth groups.

Business efficiency and revenues have improved. Almost two-thirds of connected enterprises (63 percent) perceived an increase in business efficiency after using the mini-grid connection. Statistical

tests suggest that these enterprises have an additional six customers a day and one extra hour of operation. Improved business efficiency and increased operating hours have contributed to revenue increases of 52 percent for commercial load enterprises and 36 percent for lighting load.

Entrepreneurs aspirations have increased. Sustainable performance of enterprises has encouraged entrepreneurs to diversify business through product innovation or expansion into other markets. The value of demonstrating successful high impact models to inspire others should not be underestimated in catalyzing and stimulating sustainable economic activity.

Access has increased to services and facilities within the village. Smart Power India has provided better access to services and facilities for local people. For example, because of the presence of village rice hulling units, people do not have to travel elsewhere to have their rice hulled, thus saving time and effort. Markets, health, education, and other public facilities can run for longer hours due to reliable mini-grid energy, thus serving more of the population for longer hours. In addition, new informal services are being started.

Economic welfare has shown gains, with social and environmental benefits. There has been a per capita increase of USD 81.30 in the economic welfare of Smart Power villages as measured by the GDP+ approach. The social benefits, measured through time reallocation, have contributed 73 percent of the change, while the economic and environmental benefits have contributed 23 percent and 2 percent respectively.

Implications for Smart Power

Overall, the 2018 impact assessment found that many of the 2016 impacts in households and enterprises had deepened, and significant strides had been made towards achieving Smart Power's socio-economic objectives. At the same time, we note findings that Smart Power will need to consider and monitor carefully if it hopes to sustain and scale the socio-economic gains it has made.

- 1. Households are starting to drop out,** due to high tariffs. The relatively higher cost of mini-grid power compared to the government grid has caused some customers – primarily household ones – to drop out. Capital and operating costs need to be significantly reduced through a combination of economies of scale and technology innovation so that mini-grid tariffs can become increasingly competitive – and affordable to lower-income households.
- 2. Low investment groups are starting to decline** in the investment profile of Smart Power, while medium and high investment groups are increasing. While this may help contribute to the economic viability of mini-grids, equity of access remains an important concern. Therefore this trend may be one worth continuing to monitor.
- 3. Limited supply hours and lack of flexibility of plans** are ongoing issues for customers and contribute to drop-out rates. Energy consumption patterns and customer satisfaction need to be closely monitored in order to design electricity plans that are suited to customers' demand and needs.

-
- 4. A more dynamic demand management and customer acquisition strategy** is needed to shift energy consumption patterns, mitigate fluctuation in demand due to seasonality of load profiles, and maintain and boost customer satisfaction levels. This, for example, would include encouraging and incentivizing the purchase of safe drinking water from water filtration plants year-round, not just in the hot summer months.

Findings point to a need to continue to support and create an enabling environment for enterprises to operate effectively by ensuring strong market linkages that, for example, connect productive load enterprises and on-farm units.



Introduction

The Smart Power Initiative

Launched in 2015 by the Rockefeller Foundation, The Smart Power Initiative has sought to accelerate sustainable development in the least electrified states in India – Bihar, Uttar Pradesh, and Jharkhand – through the establishment of decentralized, renewable energy mini-grids.

Leveraging the global momentum of “sustainable energy for all”, The Rockefeller Foundation works with governments, the private sector, donors, investors, research institutions, and technology companies to catalyze energy transformation by accelerating electrification in environmentally and economically sustainable ways. The Foundation believes that providing access to reliable and affordable electricity for productive use can stimulate sustainable economic opportunities and bring a better, healthier quality of life to poor and vulnerable people living in underserved regions in India, Myanmar, and Africa.

In India, the Foundation established Smart Power India (SPI) to develop partnerships with a wide range of stakeholders to improve the quality of electricity access and, in doing so, promote economic opportunities for rural communities.

SPI has two models for delivering renewable energy.

- 1. Mini-grid model.** Mini-grids are decentralized standalone renewable energy power plants that generate and distribute electricity to homes, and local enterprises, and to anchor-load customers, such as cell-towers. Through its mini-grid model, SPI provides technical support to energy service companies (ESCOs) that build, own, and operate mini-grids. Some ESCOs have also received concessional loans from The Rockefeller Foundation.
- 2. Electricity as a service model.** SPI works with electricity distribution companies to improve last-mile access and services in rural areas.

The context of global sustainable energy

Over the past decade, while a global focus on sustainable energy accelerated electrification rates across the world leading to access for 920 million people, more than 840 million people still have no access to electricity. Of these, over 100 million live in India (ESMAP, 2019). The United Nations’ Sustainable Development Goals (SDGs) recognize the need for access to clean energy and identify universal electrification as a key driver of SDG-7, which calls for affordable, reliable, sustainable, and modern energy for all.

The lack of access has been more pronounced in South Asia and sub-Saharan Africa, where nearly 700 million people remain without electricity. That said, South Asia has successfully demonstrated electrification initiatives and expanded access to electricity to 91 percent of the population. Although countries such as India, Bangladesh, and Myanmar have made the most progress since 2010, the extent of electrification varies according to the location. Access rates of rural areas, which have fragile distribution networks, remain much lower than urban areas. As a result, off-grid solutions, such as solar home systems and mini-grids, are increasingly recognized as a more favourable rural option (ESMAP, 2019).

Over the past few years, the national government in India has prioritized household electrification across the subcontinent. The government's flagship rural electrification scheme, *Pradhan Mantri Har Ghar Sahaj Bijli Yojana (Saubhagya)* (REC Limited, 2019), launched in 2017, announced it had achieved 100 percent household electrification. Despite this claim, the unreliable and low quality electricity of the government grid is not a preferred choice for many, while the reliable, timely, and high-quality electricity of mini-grids is a highly preferred choice, despite higher costs.

Measuring the impact of electricity access

The World Bank's Energy Sector Management Assistance Program (ESMAP) identifies energy access as a key driver of socioeconomic development, while noting the necessity of ensuring quality of access. ESMAP identifies attributes of energy access that are pre-requisites to socioeconomic change, such as: i) access should be at multiple locales including household, productive engagements, and commercial establishments; ii) access pertains to usability of supply rather than actual use of energy; and iii) attributes of energy supply such as adequacy, availability, reliability,

affordability, and quality affect the usability of energy (ESMAP, 2015).

Since its inception in 2015, the Smart Power initiative has aimed to ensure its electricity access has these attributes by supplying timely and reliable electricity to households and enterprises. In doing so, it has supplied electricity to more than 11,000 households and powered nearly 6,000 enterprises across three Indian states that historically have had inadequate electricity supply – Uttar Pradesh, Bihar, and Jharkhand. Smart Power's mini-grid work had reached approximately 187,000 people as of 2018.

The Smart Power initiative developed its monitoring, learning, and evaluation (MEL) by using a theory of change approach as well as by incorporating best practice from measurement efforts of global developments aimed at “universal access to modern energy by 2030.” This includes the Multi-Tier Framework (MTF) for measuring access to energy developed by Sustainable Energy for All (SE4ALL) stakeholders with ESMAP support (SE4ALL, 2019), the Global Tracking Framework (GTF) for the Global Goals, and Practical Action's Total Energy Standard (Hunt, *et al.*, 2012; Nussbaumer, *et al.*, 2013).

These and other relevant metrics in the renewable energy field emphasize the need to, *inter alia*:

- measure access along a continuum of energy access and service experience (rather than binary indicators)
- evaluate both demand and supply
- consider internal and external household and business factors
- consider the quality of electricity beyond connectivity
- consider financing and a more nuanced measure of affordability
- consider gender-disaggregated effects.

Through a multiyear grant to Sambodhi, Smart Power's independent M&E partner, M&E teams systematically

monitor short- and long-term changes in households and enterprises in villages, test key assumptions of Smart Power's theory of change, and track how the program is affected by the changing economic, political, social, and ecological environments within which it operates.

The M&E framework involves metrics across all technical indicators developed by the MTF as well as

indicators for implementation, social and economic welfare, and environmental benefits. It uses an innovative method called GDP+ that incorporates economic, social, and environmental criteria, essentially adapting GDP into a measure of economic welfare by combining estimates of income with social and environmental benefits. The section Impact on Village Economy (GDP+) of this report discusses GDP+ in detail.



Sudesh Rai operates a mini-grid connected flour mill in Parsa, Bihar.

2

Evolution of the Smart Power customer base

This chapter describes how the choices and utilization of energy by Smart Power's mini-grid customers have evolved in the context of changes in rural electrification in India.

Rural electrification in India has undergone a significant transformation in recent years. This has included the extension of the government grid, and the rural market success of solar off-grid solutions such as standalone home lighting systems, and mini-grid initiatives such as Smart Power. While enhanced access to electricity provides multiple options to Smart Power customers, it does not always translate into multiple alternatives for the rural customer. Poor quality and reliability of energy continue to be critical limiting factors with the result that multiple options play important additive roles in filling gaps in access, reliability, and quality of supply for rural customers.

The MTF developed by the World Bank categorizes households in multiple tiers based on their electricity access level. The framework assesses electricity access within households based on multiple attributes such as capacity, duration, reliability, quality, affordability, legality, and health and safety (ESMAP,2014). The Smart Power initiative ensures quality and reliable electricity supply and, as a result, positions households in the higher tiers of electricity access.

Smart Power mini-grids have two broad sets of customers: i) households and ii) local enterprises. Households generally use electricity for lighting and to run household appliances. Enterprises, on the other hand, use electricity for lighting or other productive purposes, such as running a fan or a television, or for operating machinery for commercial purposes.

Enterprise customers

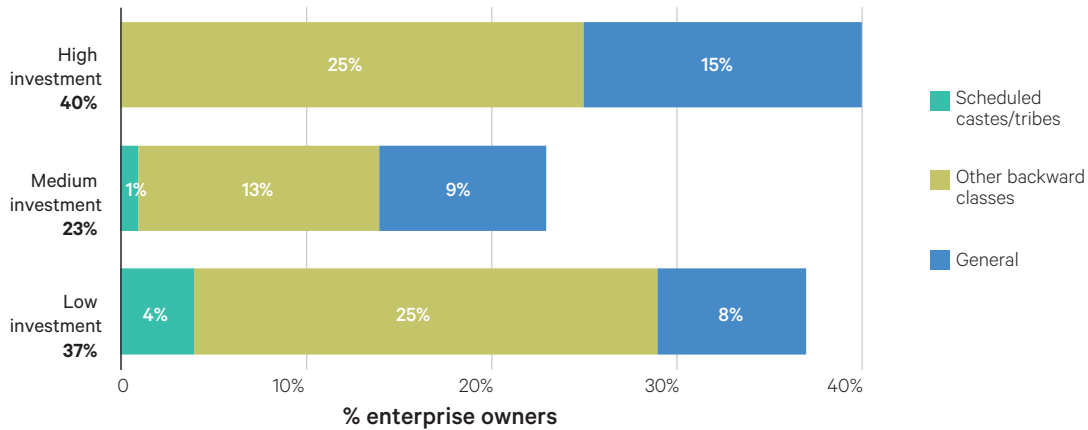
Customer profile

In the states where Smart Power India operates, there is a dominant presence of socially excluded groups such as the Scheduled Castes and Tribes⁶ and Other Backward Classes.⁷ The Smart Power customer base has consistently reflected this demographic distribution throughout its implementation. Sixty-two

⁶ Scheduled Castes (SCs) and Scheduled Tribes (STs) are official designations given to various groups of historically disadvantaged indigenous people in India. The terms are recognized in the Constitution of India and the various groups are placed in one or other of the categories.

⁷ Other Backward Class (OBC) is a collective term used by the Government of India to classify castes which are socially and educationally disadvantaged. The Backward Classes Division of the Ministry of Social Justice and Empowerment looks after the policy, planning and implementation of programs relating to social and economic empowerment of OBCs, and matters relating to two institutions set up for the welfare of OBCs, the National Backward Classes Finance and Development Corporation and the National Commission for Backward Classes

FIGURE 1: Enterprise owner profile



percent of enterprise owners belong to the Other Backward Classes which is the predominant group, and 32 percent belong to the general community, while 5 percent of customers belong to the Scheduled Castes.

However, when viewed through an investment lens,⁸ the profile varies more. For example, as illustrated in Figure 1, 40 percent of the connected enterprises are high investment units, while 37 percent are low investment units.

These proportions vary further across the investment levels of the enterprises. For example, the larger proportion of enterprise owners from the low investment categories belong to the Scheduled Caste communities, while high investment enterprises have a larger proportion of owners belonging to the general category.

Types of connection

The enterprise customer base is classified according to the load the customers draw from the mini-grids: lighting loads or commercial loads.

Lighting loads. Lighting loads are mostly for small shops, such as sweet shops or cloth shops, that utilize the mini-grid’s electricity for lighting purposes.

Commercial loads. Commercial loads include business units that utilize the mini-grid electricity to operate machinery for commercial outputs. The commercial loads can be further classified as high, medium, and low-load enterprises, according to their electricity consumption. On average, low-load enterprises, such as tailoring shops, typically consume 1.5 kWh daily while medium-load enterprises, such as photocopy centers, consume 3.9 kWh daily. High-load enterprises, such as grain mills and irrigation pumps, consume around 12 kWh of electricity daily.

With the intent of enhancing rural economic development through improved electricity access, the Smart Power initiative has aimed to increase the percentage of commercial load connections in its customer portfolio. During its three years of implementation, Smart Power saw a continuous increase in commercial load connections. However, the 2015 to 2016 increase in connections from 0 to 23 percent was greater than the 2016 to 2018 increase from 23 to 34 percent.

Since 2016, there has been a concerted effort to connect the mini-grids to high load enterprises, with

⁸ The enterprises are categorized into three categories: High investment (initial investment >\$1500); Medium investment (initial investment >\$376 & <\$1500) and Low investment (initial investment <\$376).

the successful result that, between 2016 and 2018, the increase was driven by high-load enterprises such as water filtration plants, grain processing mills, and bulk milk chillers. This has served a dual purpose of smoothing operations and increasing utilization of mini-grids, leading to improvement in the operating margin and economic viability of mini-grids as a unit level.

Smooth uninterrupted operations. High-load enterprises, such as water filtration units and grain

mills, are vulnerable to the risks of interruptions and fluctuations of poor-quality electricity supply. Mini-grids offer reliable and high-quality electricity which helps to ensure smooth, uninterrupted operations.

High utilization. High-load enterprises ensure higher utilization of the power generated by the mini-grids, which, in turn, positively impacts the economics of running mini-grids. The growth in the proportion of high-load enterprises can be attributed to this symbiotic relationship.

FIGURE 2: Shift in type of load since 2016

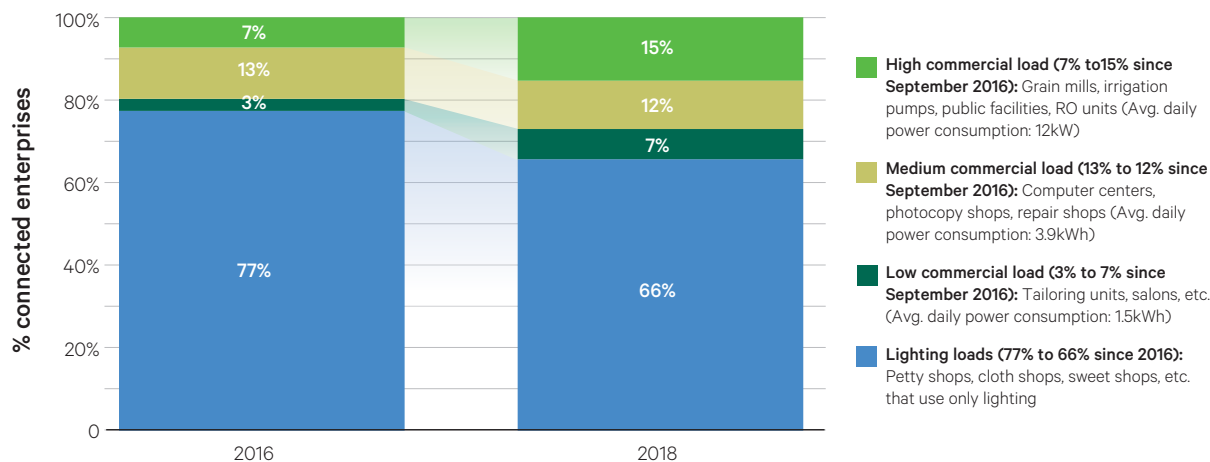
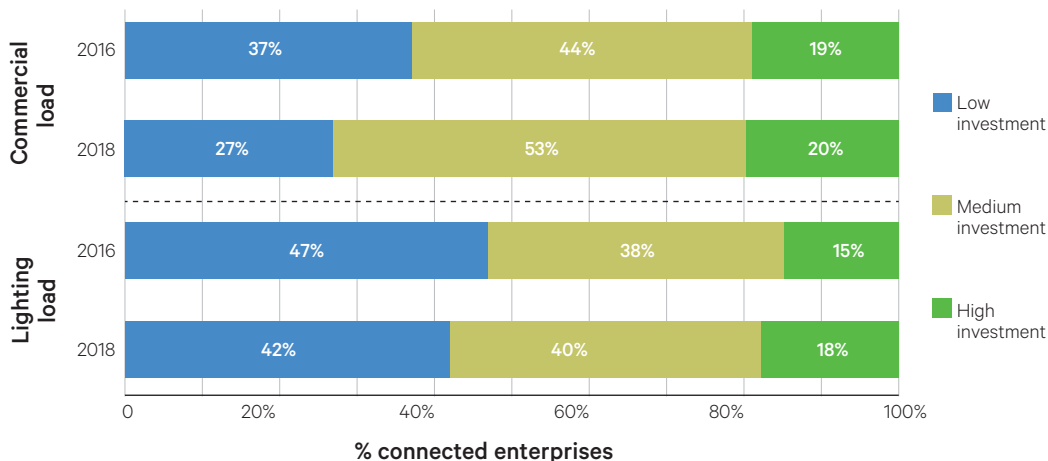


FIGURE 3: Shift in proportion of load types (based on investment level)



The fact that mini-grids have been able to attract larger enterprises is an encouraging sign since these types of enterprises are key drivers of economic growth. However, there is also concern that the proportion of low investment enterprises has gradually started to decline. Although early, it is a concern which the program might monitor in order to ensure that less well-off customers are not being left behind.

In terms of investment levels, as illustrated in Figure 3, the portfolio of enterprises between 2016 and 2018 shows that a larger proportion of medium and high investment enterprises established mini-grid connections for both lighting and commercial loads. In 2016, 47 percent of the lighting load enterprises connected to mini-grids were low investment businesses. This dropped to 42 percent in 2018 while, at the same time, medium- and high-investment enterprises increased by 5 percent, and medium and high investment enterprises connected to mini-grids for running commercial machines increased by 10 percent.

The fact that mini-grids have been able to attract larger enterprises is an encouraging sign since these types of enterprises are key drivers of economic growth within communities. However, there is also concern that the proportion of low investment enterprises has gradually started to decline. Although early, it is a concern which the program might monitor in order to ensure that less well-off customers are not being left behind. Field-level data collection suggests that the high cost of the mini-grid connections often acts as a deterrent to low investment enterprises, while enterprises which have greater access to finance can afford the connection. Affordability of the connection appears to be one of the reasons for the decline in the proportion of low investment enterprise customers in the mini-grid portfolio.

While the drop in low investment enterprise customers is of concern, the uptake of larger enterprises has produced promising socially responsible enterprise models, such as water filtration units.

Case Story 1 highlights the community economic and health benefits of water filtration units that are connected to mini-grid electricity.



CASE STORY 1

Growing businesses and scaling access to clean water through mini-grid electricity⁹

Lack of access to clean drinking water in rural areas in India makes the population vulnerable to disease

Access to basic amenities such as safe drinking water is not only an important measure of the socioeconomic status of households, it is a fundamental requirement for maintaining health standards. While the necessity of clean drinking water is widely recognized, close to 63 million people in rural India lack access (Water Aid, 2017). Despite long-term government efforts in India, the majority of rural households are vulnerable to water-borne diseases because they primarily rely on untreated water sources, such as hand-pumps, uncovered wells, or untreated tap water, for their drinking water.

Smart Power incubates reverse osmosis water-treatment units to encourage socially responsible business models

RO-based filtration systems offer a potential solution to the lack of clean drinking water. As of 2018, Smart Power had incubated 23 water-treatment units in multiple districts of Uttar Pradesh and Bihar with an investment of around USD 12,000 per unit. In a few areas, these RO-based water-treatment units have been established in collaboration with the Piramal Sarvaja initiative (Piramal Water Private Limited, 2019) that provides market support by generating awareness among potential rural customers of the benefits of clean drinking water.

Local communities have improved access to clean drinking water and livelihood opportunities

These enterprises ensure outreach of clean drinking water to households and other shops in the local as well as nearby areas. On average, the water-treatment units supply 20 litres of water to around 250 customers daily in the summer months – 20 percent to households, 40 percent to local enterprises, and 40 percent to other small and large enterprises.

These units also generate livelihood opportunities by employing village residents. The entrepreneurs employ three to five local people to carry out daily operations, such as filling water jars and delivering to customers.

⁹ Reverse osmosis (RO) is a process that forces water through a membrane to filter out and flush away contaminants, leaving clean drinking water. The data from the case story was collected within 12 months of installation, and while this case might not be representative of all RO enterprises it highlights the potential of RO units.



FIGURE 4: RO water-treatment unit in Uttar Pradesh

Positive economic returns are generated for both the entrepreneurs and Smart Power mini-grids

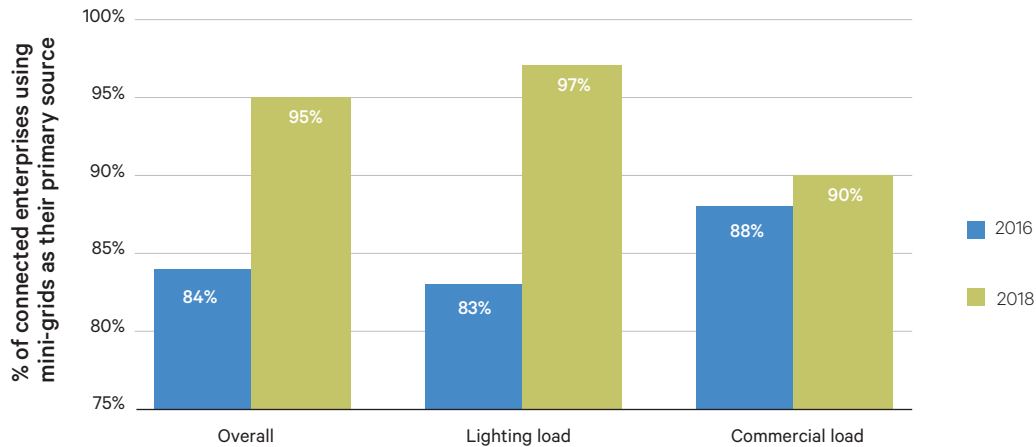
The entrepreneur of a water-treatment unit can generate monthly revenue of USD 1,679 through the enterprise. Further, RO-based water-treatment units ensure better economics for the mini-grid. On average, a water-treatment unit, incubated under Smart Power, can utilize 350 units (kWh) of electricity per month through the mini grid. This utilization accounts for approximately 16 percent of the total plant capacity and USD 150 per month of energy revenue for the mini-grid.

At the current level of operation, an RO-based water-treatment unit breaks even after 16 months of operation

One of the key challenges faced by RO-based water-treatment units is the seasonality of their operations. In most rural areas, customer demand for cold bottled water is during the hot summer months. The typical rural customer does not perceive the health benefits of clean drinking water, so there is less demand for bottled water in the off-season. As a result, the demand drops by two-thirds during the non-summer months (October to March). While the operating costs also reduce during this time, the breakeven point for the enterprise is usually reached after 16 months of operation.

Concerted efforts are needed to generate awareness of the benefits of drinking clean water year-round in order to ensure continuous operations and improve the financial security of the entrepreneur.

FIGURE 5: Shifts in primary source of electricity



Use of a mini-grid as a primary electricity source

Enhancing utilization, along with access to electricity, has been one of the primary objectives of the Smart Power initiative. The use of mini-grids as a primary electricity source is an indicator of customer uptake of the connections. As shown in Figure 5, the proportion of mini-grid customers using the mini-grid connection as their primary electricity source¹⁰ increased from 84 to 95 percent between 2016 and 2018.

Since lighting and commercial enterprises depend on reliable electricity for their day-to-day operations, most entrepreneurs use mini-grids as their primary electricity source because of its assured power supply.

Data from the 2018 round of impact monitoring suggests that there has been a near-complete electricity source shift to the mini-grid since 2016. A large proportion of connected enterprises have started relying solely on mini-grid electricity because of its higher reliability. The monitoring found that the shift is higher for lighting load connections than for commercial load connections.

The nature of reliance on electricity and its implication for businesses needs to be understood in order to fully

comprehend the differential shifts across lighting and commercial loads.

For lighting loads, electricity is a supplement to a business operation – and makes it easier to conduct business.

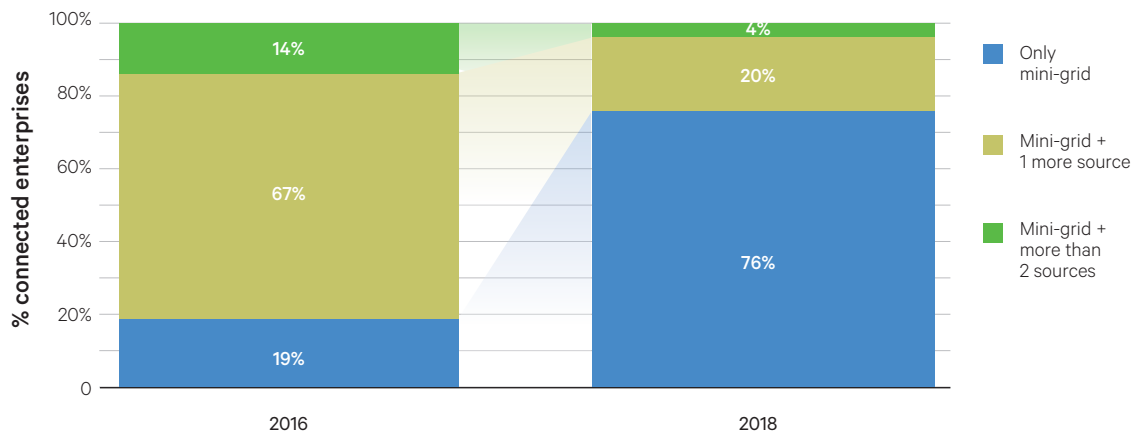
For commercial loads, reliable electricity is a key ingredient for business operation – and increases risk vulnerability to any disruption.

This means that although commercial loads rely heavily on mini-grids for their operations, they do not show as much of a shift as the lighting loads. Ninety-seven percent of lighting load customers use mini-grids as their primary electricity source, and 80 percent of them rely solely on mini-grids. In comparison, 90 percent of the commercial loads use mini-grids as their primary electricity source, but only 65 percent rely solely on mini-grids. The remaining 35 percent use other sources as backup and as alternatives to the mini-grid.

The data from 2016 found that 80 percent of the mini-grids' enterprise customers used other electricity sources as well. However, from 2016 to 2018, the number of connected enterprises completely dependent on the mini-grid electricity quadrupled, indicating a significant shift towards customers using mini-grids as their only electricity source.

¹⁰ Primary electricity source, for this study, has been defined as the most commonly used electricity source by the customer

FIGURE 6: Shifts in the % of mini-grid customers that rely on additional sources of electricity



This shift to mini-grids as a main source of electricity indicates that enterprises trust the reliability of Smart Power mini-grids, and that mini-grids are superior to the alternatives in terms of supply quality, duration, and regularity. For example, the electricity supply from mini-grids is available whenever required (mostly between 6pm and midnight) with minimal instances of low voltage and flickering. This quality of the supply, reliability of supply timings, and overall convenience associated with mini-grid electricity make it more attractive than alternatives. Other sources, such as the government grid, are often plagued with lower voltage supply, meaning the light they provide is dimmer than the light provided by the mini-grids.

While the reliability of mini-grid electricity makes it a very attractive option for enterprises, they also must be aware of issues such as tariffs (costs) and the mini-grid's vulnerability to weather conditions.

Tariffs. The cost of a mini-grid connection is USD 0.37–0.43 per kWh, while the government grid supply is available at 0.09 USD per kWh. Although customers appreciate the reliability and quality of the mini-grid supply, they tend to hedge their costs by adding cheaper sources of electricity.

Vulnerability to weather. The Smart Power program is located in the flood plains of northern India where heavy monsoons and foggy winters considerably

reduce the solar insolation for nearly four months each year. This renders the mini-grids technically incapable of supplying consistent electricity in the absence of power back-up. While some ESCOs have provisions for power back-ups, most mini-grids do not. This results in many customers acquiring multiple electricity sources to mitigate the risk of disruption of electricity.

Household customers

Customer profile – Households

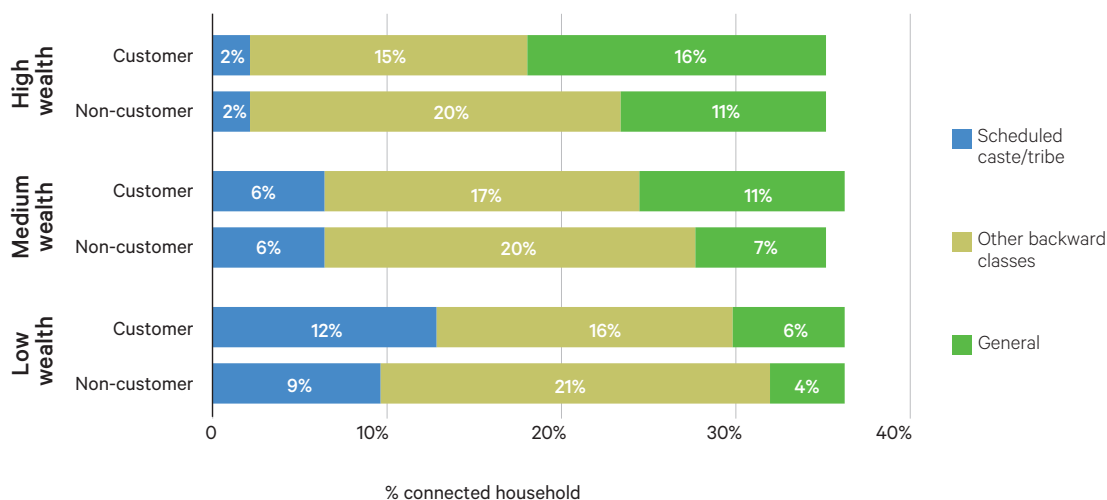
The household customer of mini-grids is mostly comprised of socially excluded groups – 27 percent belong to Scheduled Caste/Scheduled Tribes (SC/ST),¹¹ and 60 percent belong to Other Backward Classes (OBCs).¹² As with commercial customers, this mirrors the demographic distribution of the intervention states.

The economic profile of the household customers

¹¹ Scheduled Castes (SCs) and Scheduled Tribes (STs) are official designations given to various groups of historically disadvantaged indigenous people in India. The terms are recognized in the Constitution of India and the various groups are placed in one or other of the categories.

¹² Other Backward Class (OBC) is a collective term used by the Government of India to classify castes which are socially and educationally disadvantaged. The Backward Classes Division of the Ministry of Social Justice and Empowerment looks after the policy, planning and implementation of programs relating to social and economic empowerment of OBCs, and matters relating to two institutions set up for the welfare of OBCs, the National Backward Classes Finance and Development Corporation and the National Commission for Backward Classes.

FIGURE 7: Household customer profile



depicts a similar trend, showing that the program has reached out equally to all sections of the society, with each category contributing one-third of the overall household customer base. It is interesting to note that the profile of the households that have not opted for a mini-grid connection mirrors that of the customers. The non-customers are also equally spread across the three wealth groups.¹³ The mean income levels of the customers in the three wealth groups are similar to those of non-customers.

This distribution of the population across customers and non-customers implies that the customer acquisition has been proportional to socioeconomic profiles of the population. The initiative does not discriminate while targeting the mini-grid customers.

Use and uptake of mini-grid electricity – price matters but so does reliability and quality

The Smart Power initiative was launched in 2015, in India’s three least electrified states: Uttar Pradesh, Bihar, and Jharkhand. While many households were connected to the government grid, erratic supply

¹³ Low wealth group: Monthly income 164 USD; Medium wealth group: Monthly income 194 USD & High wealth group: Monthly income 283 USD

hours, low-voltage, and routine disruptions in electricity supply posed major challenges. Once launched in April 2015, households were quick to adopt mini-grid connections as a primary source of electricity – with 86 percent of the households opting for mini-grids by September 2016. At the same time, households primarily using the national grid connection dropped from 36 percent to 10 percent. Use of kerosene lamps for lighting within the households and small enterprises was greatly reduced.

The lower cost of the government grid, coupled with the flexibility to run multiple appliances has encouraged many mini-grid customers to sign up for a government grid connection.

However, from 2016 to 2018, the proportion of households using the mini-grid electricity as their primary source of electricity declined to 74 percent of the mini-grid customers, while the proportion of households using the government grid electricity as their main source increased from 10 percent to 25

percent. One of the primary drivers for this shift was the cost associated with the mini-grid.

Unlike enterprises, cost is a major driver for households that do not perceive reliable and good quality electricity as pressing a need. The lower cost of the government grid, coupled with the flexibility to run multiple appliances has encouraged many mini-grid customers to sign up for a government grid connection. With improvements in availability of government grid supply – increasing from approximately four hours before 2016 to 18 to 20 hours in 2018 – households have started making a shift towards government grid supply.

Enterprises and households respond quite differently to mini-grid electricity. Enterprises, especially lighting loads, tend to rely mostly on mini-grids, since their needs for electricity are generally predictable, e.g. lighting. However, for households, the purpose of electricity is not as predictable given the range of household needs for power. Mini-grids do not provide households with as much flexibility to operate multiple appliances as the government grid. Hence, the preference for mini-grids as the primary source is not as high for households as for enterprises.

However, due to the government grid’s poor quality and irregularity of supply, it is not necessarily a better

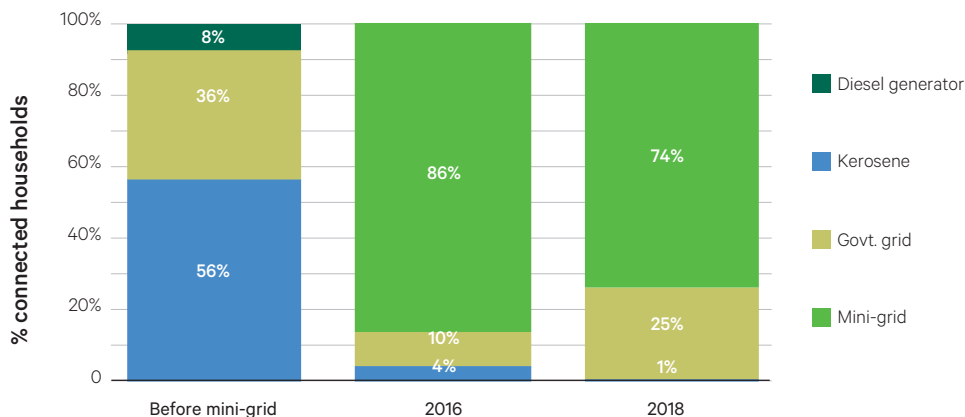
While the “value for money” associated with mini-grids has declined for households since 2016, its value in terms of reliability and quality still makes it the preferred choice for 74 percent of the mini-grid customers.

alternative. While the “value for money” associated with mini-grids has declined for households since 2016, its value in terms of reliability and quality still makes it the preferred choice for 74 percent of the mini-grid customers.

Among high-wealth households, 48 percent use mini-grids as their primary electricity source. These households prefer to run their high-power appliances, such as televisions and refrigerators, mainly on government grid electricity because of the lower cost and because these appliances are considered more of a luxury for households rather than essential, which makes considerations about reliability less critical.

Across all wealth groups, necessary appliances, such as light bulbs, are mostly run on mini-grid electricity because of its reliable and high quality electricity supply. Approximately 75 percent of low- and medium-wealth

FIGURE 8: Shift in primary source of lighting for connected households



households – households that do not own many high power consuming appliances – use mini-grids as their primary source of electricity.

Overall, it appears that Smart Power has lower barriers to entry, especially for low-wealth groups. Deterrents to government grid connections for low-wealth groups include the high transaction costs of getting connected, time-consuming paperwork to lodge complaints and to follow-up to ensure the problem is resolved, uncertainty about the amount of the bill, and irregular payment schedules. Customers find it much easier to deal with connections and complaints with mini-grids, and they like the fixed monthly tariffs and payment schedules, which are especially beneficial for lower wealth households planning their monthly expenditures.

This evolution of mini-grids and the government grid has also resulted in a major potential health benefit for connected households. The availability of mini-grids and the extension of the national grid have almost completely replaced kerosene, (Clarke, 2014; Garg, *et al.*, 2017) even though kerosene is still a subsidized commodity. Connected households that relied on kerosene lamps for lighting in the past have

now substituted kerosene with a government grid connection.

While the Smart Power initiative has increased the local appetite for electricity consumption, and enterprises have purchased additional appliances, cost remains an active concern for customers accessing and maintaining mini-grid connections.

Levels of village infrastructure affect the uptake of mini-grid electricity

Households are more likely to establish mini-grid connections in villages that lack public institutions such as schools, temples, or community buildings, and those that are farther from the main roads. For example, in low infrastructure villages, 38 percent of households opt for the mini-grid connection, and around 80 percent use it as their primary electricity source. In comparison, only 7 percent of households in villages with good public infrastructure have taken up the mini-grid connection and, of those, only around half use the mini-grid as a primary electricity source.

A similar trend is observed for lighting load micro-enterprises. With improved public infrastructure, the likelihood of shops opting for the mini-grid and then using it as their primary source declines. In villages with low infrastructure, 34 percent of shops use mini-grid electricity while, in villages with higher levels of public infrastructure, 25 percent use mini-grids.

Villages that have poor infrastructure are also likely to lack access to the government grid. This, in turn, prompts households and lighting load enterprises to opt for a mini-grid supply and use it as their primary source.

Reliable electricity supply sustains mini-grid customer base

Government grid supply, albeit cheaper, lacks regularity and quality of supply, especially in villages with poor infrastructure. Assured supply timings and adequate voltage encourages many to continue with a mini-grid connection, even if the tariff is a pressing concern.

Evolution of the Smart Power customer base: Summary of Section 2 key findings

Household customers

- **Exposure to multiple options.** Household mini-grid use declined slightly over the past year as government connections became available at a lower cost. Unlike enterprises, cost is a significant driver for households that do not perceive reliable and good quality electricity as essential. The combination of lower costs and the flexibility of government grid power to run multiple appliances has encouraged many mini-grid customers to sign up for a government grid connection.
- **Ease of access and customer service.** Mini-grid customer service makes it easier for consumers to access and utilize electricity than the government grid. Specifically, mini-grid connections and problem solving are more efficient and the monthly billing cycle is predictable.
- **Proximity to infrastructure.** Villages with low infrastructure (schools, temples, community buildings) and ones that are located farther from the main roads have greater uptake of mini-grid power than villages with higher levels of infrastructure.

Enterprise customers

- **Larger enterprise customers.** High load enterprises have driven the increase in proportion of commercial load connections since 2016. Commercial load connections increased from 23 percent to 34 percent between 2016 and 2018. This increase was primarily driven by high-load enterprises, such as water filtration plants, grain processing mills, and bulk milk chillers.
- **Customer preferences.** Preference for mini-grids as a primary electricity source has increased for lighting loads enterprises since 2016. In 2018, more than 95 percent of connected enterprises used mini-grids as their primary electricity source, mostly for lighting loads (97 percent) compared with commercial loads (90 percent).

Overall

- **Customer base.** Customer outreach and acquisition is not based on demographic profiles. This distribution of the population across customers and non-customers implies that the customer acquisition has been proportional to socioeconomic profiles of the population. However, since 2016, the uptake of the mini-grid connection is lower among the low-wealth group households than it is among other wealth groups. This should be monitored closely to ensure that low-wealth groups do not drop out of the Smart Power customer base.



Impact

The Smart Power initiative strives to develop an ecosystem that fosters economic development within a rural setting. This has meant adopting the mechanisms that enhance local economic activities by:

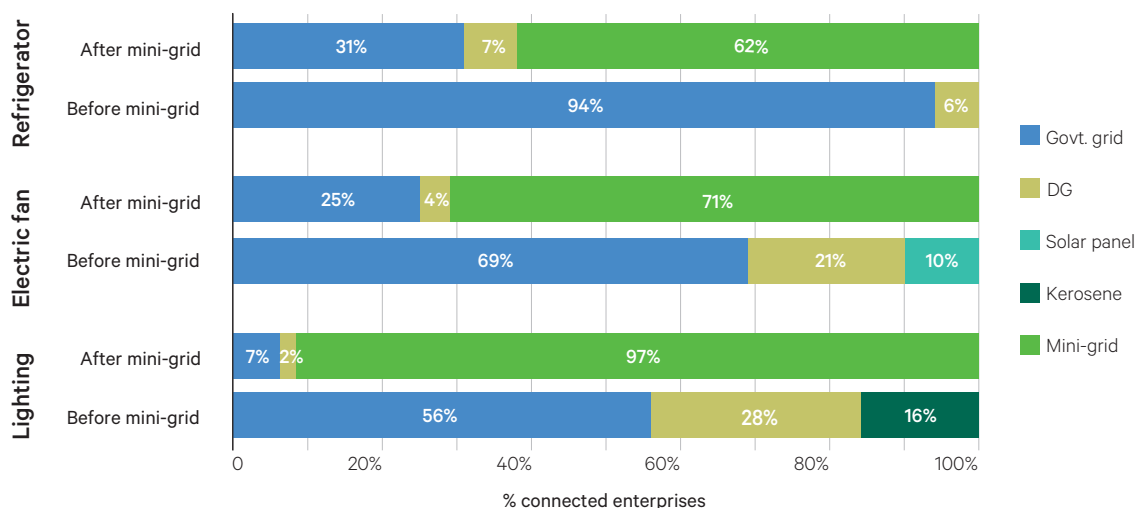
- establishing or growing local businesses through a reliable electricity connection and value chain support
- increasing household electricity access and creating an environment for public service institutions to operate effectively with an uninterrupted supply of electricity.

Enhancing local business through a reliable electricity connection

Use and purchase of new appliances

Higher reliability of the mini-grid connection, both in terms of assurance of supply times and quality of supply, has been identified as the key driver for uptake by enterprise owners. Field-level insight suggests that

FIGURE 9: Key sources used for operating appliances in enterprises



having an assured timely and good quality electricity supply has encouraged 43 percent of enterprises to invest in high-load commercial appliances – some to diversify existing business and some to start a new business activity.

An example of how customers rely on mini-grids is depicted through their increased use of mini-grid

electricity to run high-load appliances, such as refrigerators, chillers, and printers. Figure 9 compares the sources of electricity used by the different enterprises to run specific appliances.

Case Story 2 highlights a new business opportunity that the mini-grid has been able to provide and also introduces the sustainable business model that has evolved.

CASE STORY 2

Incubating rice hulling machines: A win-win for business owners, farmers, and communities

Widespread production of rice in India offers opportunities for the development of rice-based value-added business models

Paddy (rice) is one of the most commonly cultivated crops of the Indian sub-continent. India produces more than 100 million tons of paddy annually, accounting for nearly 21 percent of global paddy production (Ministry of Agriculture & Farmer Welfare, Government of India, 2019). Uttar Pradesh, Bihar, and Jharkhand together contribute around 22 million tons, which is almost one-fifth of the total national production. Given the widespread production of paddy across these states, there are opportunities for income generation through development of paddy-based value-added services, such as hulling – the process of taking the raw output from the farm and converting it into rice.

Setting up hulling businesses

Smart Power has incubated 34 micro-enterprises in the three states with energy-efficient rice-hulling equipment. Through collaboration with the ESCOs, Smart Power helps an entrepreneur purchase and learn how to run the rice-hulling machine that is powered by electricity from the Smart Power mini-grids. Setting up a rice-hulling unit requires an investment of around USD 522. The entrepreneur can repay the investment amount within 24 months if ESCOs provide financial loan support.

Adding value for rural farmers

Electric-powered rice-hulling machines require substantially less time for hulling than traditional hulling techniques. A medium-size rice-hulling machine processes up to 300 kg of rice per hour, while it would take more than five hours with traditional means.



The customers of these enterprises are mostly local households that need their paddy stock hulled into rice. Therefore, establishing rice-hulling units within the local village makes rice-hulling services more accessible for the community members. With these units incubated in Smart Power villages, households no longer need to travel sometimes significant distances to have their paddy hulled.

“I had just retired as a school-teacher and moved back to my village. While I used my land for cultivation, I wanted to run some other business as well. Encouraged by the ESCO, I invested in the rice-hulling machine. It has been doing well. People in my hamlet have also benefitted. They no longer need to go to different hamlets to get their paddy hulled”

RICE HULLER ENTREPRENEUR, JHARKHAND

(cont.)

In addition, rice huller units within the village act as a selling point for the farmers. In a couple of the Smart Power initiative's locations, rice-hulling entrepreneurs buy paddy directly from the farmers in their village at market price – paddy which would otherwise be sold to intermediaries. They hull the paddy locally in electric rice-hulling machines powered by the mini-grid and sell the de-husked rice in the market. This hulled rice fetches a higher market price than what they would

have received for paddy. The possibility to sell the rice husk along with the hulled rice provides an additional revenue stream.

In sum, developing and promoting the agri-based business model of post-harvest processing of paddy through locally available rice-hulling units makes multiple positive contributions to the local economy.

Enhancing business efficiency

Ensuring reliability of supply has driven businesses to adopt mini-grids as their key electricity source and has helped to make them more efficient.

Entrepreneurs perceive increased ease in carrying out daily operations. More than 63 percent of entrepreneurs feel that their business efficiency increased after adopting mini-grid electricity. Seventy-eight percent of connected enterprises report that their business operations improved because of better lighting conditions, which not only improved the ambiance of the enterprise but also allowed for longer operating hours.

"I used to run a printing shop in my village using the government grid electricity. Due to voltage fluctuations, I had to turn away customers many times. However, with the mini-grid electricity now available, I can run my printing business properly, and I also have purchased a lamination machine and a laptop. I have also registered as an enrolment agent for the Government of India's unique identification initiative."

ENTERPRISES OWNER, JHARKHAND.

FIGURE 10: Change in businesses' daily operating hours

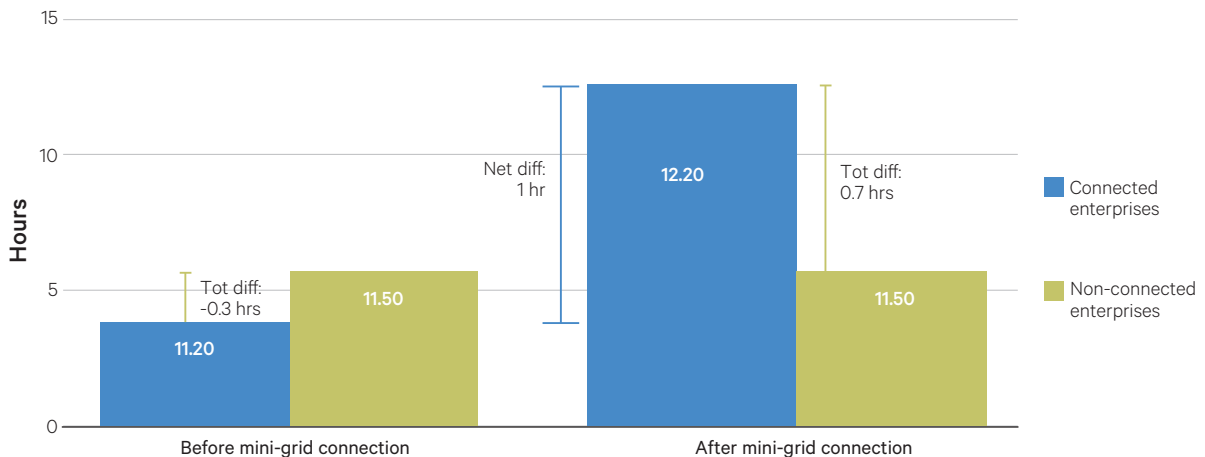
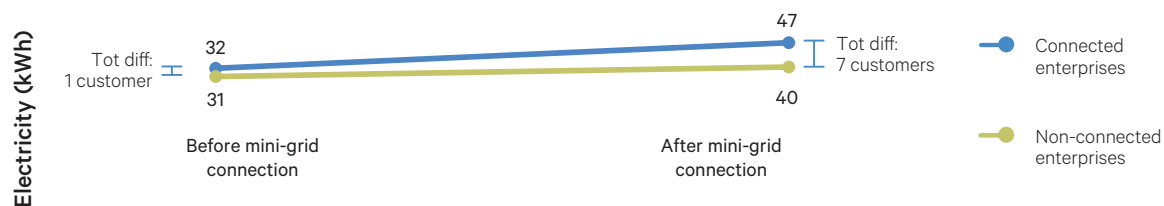


FIGURE 11: Change in customer footfall for enterprises



Analysis from 2015 to 2018 suggests that enterprises connected to Smart Power mini-grids average an hour a day more business time than the non-connected enterprises. Crucially, around 67 percent of entrepreneurs perceive an increase in the customer acquisition as well. Statistical estimates show this has led to an increase of six customers per day over non-connected enterprises.

More importantly, the supply increased, and the demand doubled during the implementation timeframe. This suggests that with improved electricity supply, the appetite for electricity consumption also goes up.

This is evidenced by enterprises increasing their operating hours, leading to increased electricity consumption.

Increasing electricity consumption

The mini-grid supply proved instrumental in significantly reducing the gap between the electricity demand and the supply. Before mini-grids, the average daily electricity demand was 1.6 kWh, but the supply was only 0.5 kWh. Increased operating hours for an enterprise translates into increased power consumption.

For the lighting load enterprises, electricity consumption has been consistent, primarily due to the change in the type of electric bulbs being used. With the advent of the Smart Power initiative, enterprises began using the more energy-efficient LED bulbs. So, while the overall electricity consumption remained consistent, the number of electric bulbs in an enterprise increased.

FIGURE 12: Daily electricity requirement-availability gap

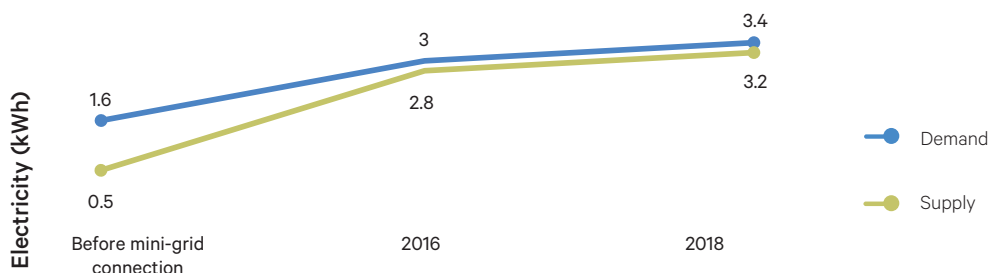
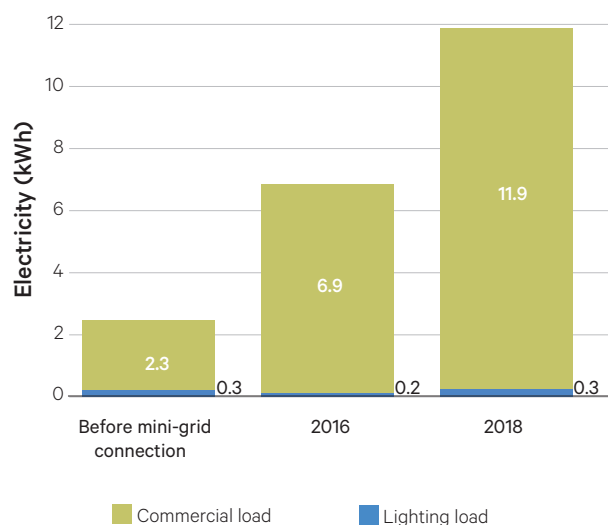


FIGURE 13: Electricity consumption across different load categories



On the other hand, as illustrated in Figure 12, the development of high load commercial enterprises, coupled with increasing operating hours, has ensured an almost six-times increase in their daily electricity consumption – from 2kW to 12kW.

Increasing enterprise economics

The Smart Power initiative aims to enhance the economic performance of the connected enterprises by creating an enabling ecosystem. Increasing hours of operation, which will lead to increased power consumption, is expected to have a positive impact on enterprise revenues.

Data from the impact monitoring rounds, conducted in June 2018, indicated that average monthly revenue of connected enterprises had increased by 42 percent¹⁴ since April 2015. As illustrated in Figure 14, enterprises with lighting loads showed a 36 percent increase, equal

¹⁴ This difference does not account for other factors such as general improvements in economic conditions that might benefit all enterprises – including those not participating in Smart Power. Hence the difference indicates contribution and not attribution.

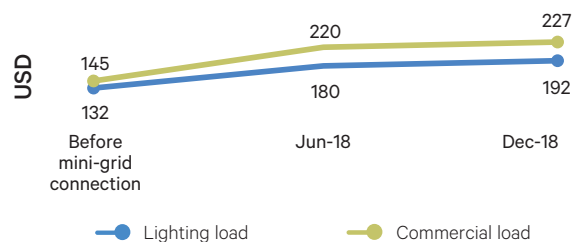
to USD 48, while commercial loads had a 52 percent increase, equal to USD 75, during the same period.

This suggests that the presence of an improved and more reliable electricity supply contributes to the economic growth of rural enterprises. Interactions with entrepreneurs suggest that increased operating hours have contributed significantly to enterprise growth. Also, the mini-grid electricity has enabled many entrepreneurs to add new appliances, expand their business line, and, thus, contribute to economic growth.

Another unique element of the initiative that has contributed to economic growth is the incubation of value chains. Smart Power helps select enterprises to expand or create new enterprises by linking them to value chains. For example, SPI sources and conducts due diligence of agricultural machineries (e.g. energy-efficient flour mills or oil expellers) and connects qualified suppliers to local enterprises. SPI also sources potential market buyers and connects them to local enterprises to facilitate market linkages and the flow of goods from villages to cities.

Case Story 3 is the case of an oil expelling unit supported by the ESCO in Jharkhand.

FIGURE 14: Growth in average monthly revenue for connected enterprises



CASE STORY 3.

Supporting the value chain of oilseed production for community economic benefit

Oilseed production plays an important role in the Indian agricultural sector, with more than 25 million hectares under cultivation and a total production of over 30 million tonnes (Ministry of Agriculture & Farmer Welfare, Government of India, 2018). This sector also deals with challenges related to lack of value-addition services, such as marketing infrastructure, transport facilities, and market options to enhance the sale of oilseed production. In addition, market intermediaries prefer grain produce to finished products, which leads to exploitation and low returns for farmers.

Improved market linkages ensure a higher selling price for produce as well as improved planning of inputs for crops. Therefore, it becomes critical to develop a linkage to larger markets for finished products to ensure greater returns for farmers.

Smart Power incubates oil expelling units to improve market access for farmers

Smart Power identifies gaps in production and sales of oilseeds, and provides catalytic support to farmers by incubating oil-expelling units within the local context, thus enabling value-chain synergies, and effective marketing and roll-out strategies.

ESCOs and the Smart Power initiative have actively provided concessional capital to capital-intensive oil-expelling production units that require an investment of around USD 4,200. Designed to operate on an aggregator model, these units employ two to three people from the village who are involved in the business

operations of the unit. The main raw material for the oil expellers is oilseed, which is procured from the nearby markets or local oilseed growers.

Priced at USD 1.5 per litre, the main customers are large buyers of oil as well as local households. The wholesalers purchase in bulk at USD 28 for a 20 kg bottle of oil.

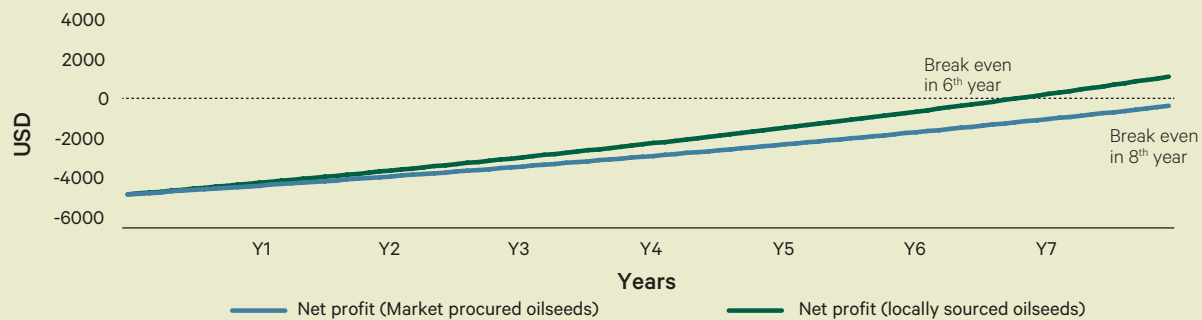
The Smart Power investment model creates a positive impact by introducing micro-level industrialization that stimulates local rural economies

To address the financial barrier of the high upfront investment of oil expelling units, the initial investment is made jointly by ESCOs and the Smart Power initiative, and not by an individual entrepreneur. Once the enterprise becomes sustainable, the ownership and operations are transferred to an eligible entrepreneur from the village community. The revenue of this micro-level industrialization accrues to the village and leads to economic advancement while also encouraging other entrepreneurial activities in the village. In this way, the community benefits from the venture without having to assume the upfront stress and risk of the initial investment.

The enterprise model ensures the procurement of oilseeds from local oilseed producers, thus improving the village economy

Since the oilseeds procured from the local oilseed growers are the major inputs of the oil expelling units,

Break even period based on point of procurement of oil-seeds



(cont.)

the stream of income stays in the village community. Sale of the final product – the refined oil – is open to the customers beyond the village, but revenue accrues to the village, thus increasing the general income level of the village.

An enterprise that procures oilseeds locally has an earlier break-even point

For any enterprise, the structuring of cost is critical to maintaining a profit. The only cost-effective strategy for oilseeds (which are expensive) is to procure them from

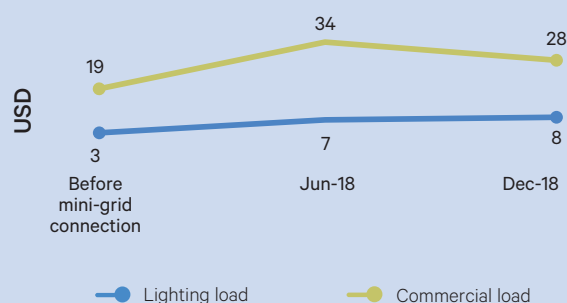
local producers. Even with this strategy, the break-even point is the sixth year of operations, whereas procuring oilseeds from external markets would add the cost of transportation and other miscellaneous costs and would push the break-even point to the eighth year.

In sum, an oil expelling unit is a flagship village enterprise model that self-sustains by procuring raw materials from the local oilseed growers, employing local workers and transferring the ownership to the community once the enterprise is fully functional and stabilized.

Increase in enterprise operating expenditure

Overall, operating expenditures have increased among businesses that connect to Smart Power electricity. This is because mini-grid power is often more costly than alternatives such as grid connections, diesel or kerosene. However, businesses demonstrate a willingness to trade off price for the increased reliability and quality offered by mini-grids.

FIGURE 15: Increase in expenditure of enterprises

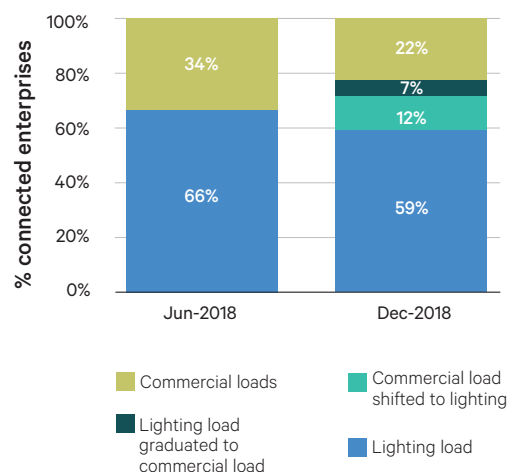


Influence of seasonality on enterprise operations

Running an enterprise in India fluctuates with each season. While grain mills are driven by harvest cycles of key cereal crops, water filtration units see a spike in operations during summer months. Other enterprises also tend to operate heavier loads, such as electric fans and refrigerators, only during summer months.

Two rounds of impact monitoring data collected in June and December 2018 highlight this seasonal variation. For instance, there is a slight drop in the overall proportion of commercial loads connected to the Smart Power mini-grids in December, because sweet shops do not use their refrigerators in the cooler months.

FIGURE 16: Seasonal shifts in type of load



Enhancing household electricity access

Enhancing household electricity consumption

While electricity “access” is understood to be a key household standard-of-living indicator, “utilization” of electricity is a more relevant measure of the progress of households. Since the initiative was launched in 2015 households have begun to rely on electricity solely for lighting needs, with some graduating to the use of heavier appliances such as refrigerators and televisions.

The data from the impact monitoring indicates that there has been a significant increase in household electricity consumption.

An assured supply of mini-grid electricity supports continuous consumption among customer households. Figure 17 shows that daily per capita electricity consumption of customer households increased from 0.41 kWh before the Smart Power initiative was implemented to 0.54 kWh in December 2018 – a 31 percent increase. This implies that the annual per capita electricity consumption among the rural households within the mini-grid areas increased from 149.6 kWh¹⁵ before mini-grid connection to 197 kWh. This served to close the gap between the national average, which was estimated at 1,010 kWh in 2014 (Ministry of Power, 2018) and the global average of 3,125 kWh (ESMAP, 2019).

¹⁵ Extrapolated values from Monitoring Rounds of 2018

FIGURE 17: Average daily electricity consumption of household customers and non-customers

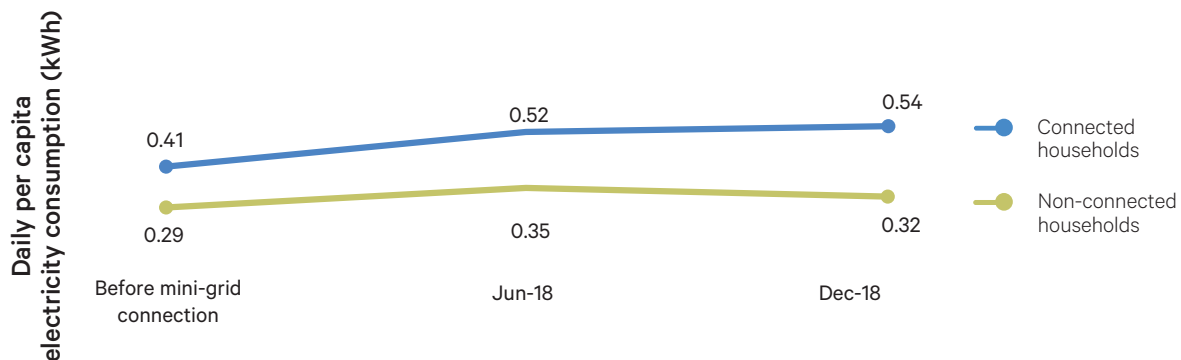
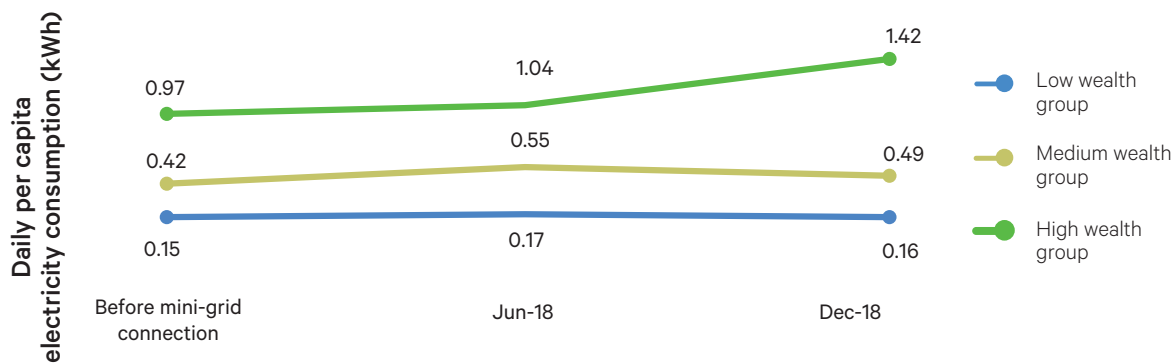


FIGURE 18: Difference in electricity consumption across wealth groups



Further, electricity consumption increases by a higher proportion when moving higher on the household wealth index. From the 2015 inception of the program until December 2018, high-wealth households registered a growth of 46 percent in daily per capita electricity consumption. There was also a 16 percent growth in electricity consumption among medium-wealth households and 6 percent growth among low-wealth households.

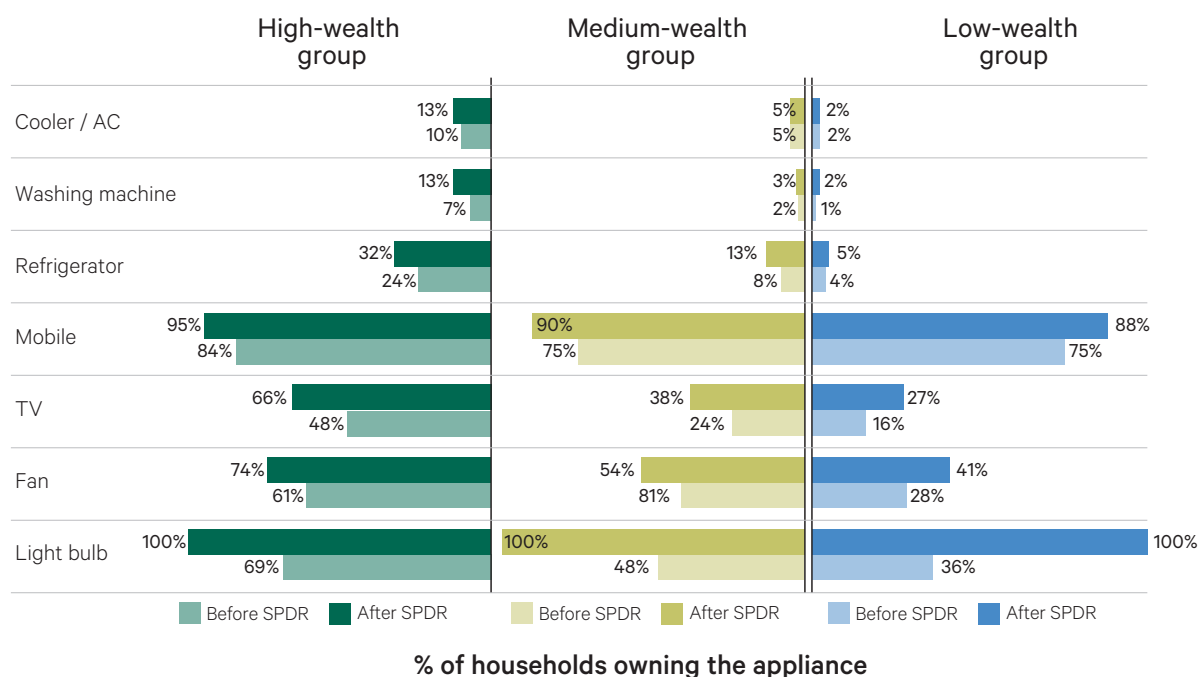
The difference in trends in electricity consumption among households in the three wealth groups is due to the difference in need and use of electricity for various types of household appliances. While low- and medium-wealth households mainly use electricity to run electric lights, mobile charging points and, to some extent, electric fans, high-wealth households require electricity for running heavier load appliances such as televisions and refrigerators.

There was also an increase in the proportion of households using various electrical appliances, and a

gradual progression of households towards higher load appliances. Since the program provides LED bulbs as a package with the mini-grid connection, low-wealth households that did not have any source of lighting have also started using electric bulbs. Moreover, 100 percent of the customers within the three wealth groups have started using LED bulbs instead of the incandescent bulbs, which are predominant in rural markets, for lighting.

Also, the proportion of low-wealth households using electric fans increased from 28 percent before the 2015 Smart Power implementation to 41 percent in 2018. Uptake of high-load appliances, such as refrigerators and washing machines, is mainly observed within medium- and high-wealth groups. There was a small increase in the proportion of households – 5 percent of the medium-wealth group and 8 percent of the high-wealth group – using refrigerators. Further, an additional 5 percent of households within the high-wealth group now use washing machines.

FIGURE 19: Movement on appliance ladder by customer households



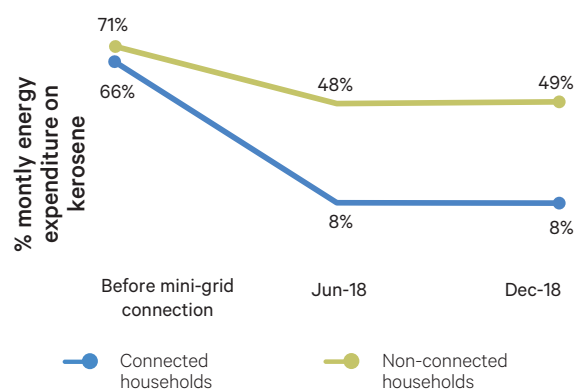
Overall improvement in electrification infrastructure – installation of mini-grids under Smart Power and extension of the national grid – has instilled confidence in rural households and encouraged them to add and use appliances. While the Smart Power initiative has encouraged the local appetite for electricity consumption, and households have purchased additional appliances, the concern for the high per-unit cost of a mini-grid connection persists.

Shifts in energy consumption and expenditure patterns

One of the most noticeable changes brought by the Smart Power initiative has been rural household customers' shifting from use of kerosene to use of electricity for lighting.

Before the Smart Power initiative, 56 percent of the households that are now mini-grid customers relied on kerosene lamps as their primary lighting source, despite kerosene being inefficient, polluting, and unhealthy. Households that had an electricity connection through the national grid also used kerosene lamps as a back-up, because of frequent disruption in electricity supply. From 2015 to 2018, these households had a nearly complete shift from kerosene usage for lighting to mini-grid electricity.

FIGURE 20: Kerosene expenditure of households



Close to 70 percent of mini-grid customers perceive an improvement in health, education, and other services within the operational areas of the Smart Power initiative.

The decrease in use of kerosene lamps by mini-grid customers reduced kerosene expenditure to 8 percent of the total energy expenditure. However, kerosene still constitutes 49 percent of the total energy expenditure for the non-customers within the mini-grid areas.

The overall energy expenditure as a proportion of income is marginally different between mini-grid-connected and non-connected households. This implies the competitive advantage of the mini-grid over kerosene usage for lighting.

Increase in services for households within the community

Access to reliable electricity through Smart Power mini-grids has instilled confidence among local people, encouraging them to set up micro-enterprises and, in turn, helping to improve their lives and their communities.

Close to 70 percent of mini-grid customers perceive an improvement in health, education, and other services within the operational areas of the Smart Power initiative. Within the health sector, many informal service providers have connected their clinics, medicine shops, and diagnostic centers to electricity through mini-grids. While historically they relied on the government grid that was often supplemented by

Thanks to the reliable electricity sourced from mini-grids, villages have been able to establish ultrasonography units. With these units operating within the village, people no longer need to travel gruelling distances for this service.

“This year I started purchasing the water jars from the reverse osmosis water treatment unit in our village. I wanted chilled drinking water at home during the summer months only. But I think I am going to continue for the entire year. My children, who normally have frequent stomach upsets, did not fall ill as much after we started using the clean water supply.”

RO WATER CUSTOMER, UTTAR PRADESH

diesel generators, electricity from mini-grids has given them a more reliable solution.

There has also been an indirect socioeconomic impact on the households due to the micro-enterprise development (MED) initiatives. For instance, more than 200 households and shops (combined) have access to clean and chilled drinking water through each of the 23 reverse osmosis water-treatment units established in mini-grid sites. Almost 30 percent of the households perceive that there have been fewer incidences of stomach infection among children since they started procuring clean water from these units.

The oil expellers and bulk-milk chillers, supported by the Smart Power initiative, provide an assured point of sale, as well as better prices for local farmers and milk-producers. As a result, their household disposable income has increased by USD 15 per month.

Impact on village economies (GDP+)

The development of mini-grid systems alongside the government grid expansion has created an ecosystem that supports rural enterprises while also increasing power consumption. Since its inception, the Smart Power initiative has continuously created opportunities for people to participate in and benefit from a developing economy. Through its supply of clean and

reliable electricity, the program fostered sustainable entrepreneurship while also working to enhance overall household living conditions.

To measure this holistic impact on the overall welfare of a village, Sambodhi used the GDP+ measurement framework, which incorporates economic, social, and environmental criteria. Designed by Sambodhi, in consultation with The Rockefeller Foundation, economists, and social development experts, GDP+ essentially adapts GDP into a measure of economic welfare by combining estimates of income with social and environmental benefits. The GDP+ method was pilot tested in 2016 and evolved through several iterations before being accepted as a tool to measure overall economic welfare created through improved electricity supply from mini-grids. The method also estimates the relative contribution of changes in economic, social, and environmental indicators to the overall GDP+ scores.

GDP+ as an indicator of economic welfare

The positive impacts of reliable electricity on a household are seen in numerous ways, from a light bulb helping a student study longer hours to an easily accessible rice huller. These benefits have the potential to stimulate rural economies, catalyse a range of new businesses and services, and, ultimately, to transform lives and trigger sustainable economic growth.

With this growth being driven by a clean, renewable source of electricity, the social, environmental, and economic returns are higher. GDP+ is a metric that combines the social, economic, and environmental returns of Smart Power, not just the monetary gains. Based on the GDP calculation approach, GDP+ charts social and environmental changes, and monetizes them to provide an overall monetary value of economic welfare.

Measuring GDP+

The GDP+ measurement includes data taken from a randomly sampled panel of 20 mini-grid villages from

Uttar Pradesh, and compares data from September 2016 and February 2019. While economic growth is measured using GDP as the metric, social change is monetized by analyzing the change in time allocation across economically productive or leisure activities using existing wage rates. Environmental change is monetized by measuring the reduced carbon footprint with the existing carbon credit prices in the global market.

ECONOMIC GROWTH

The expenditure approach¹⁶ has been adopted for calculating village-level GDP as a measure of economic growth. GDP is primarily measured by computing household-level expenditure under the following categories (Experimental Economic Centre, 2006):

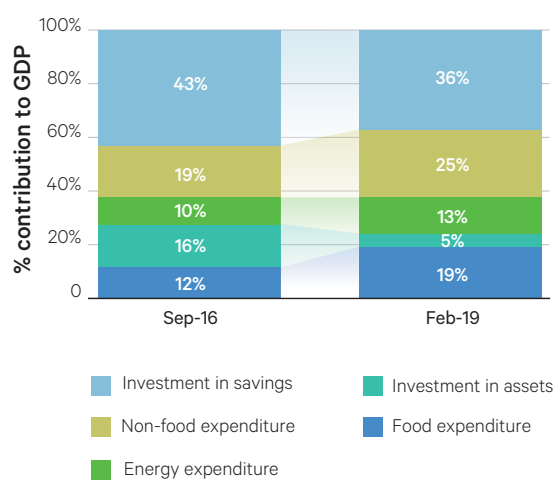
1. consumption expenditure involving the expenditure on food, such as food grains, vegetables, spices, and condiments; non-food items such as rent, healthcare, and education; and expenses on energy
2. investments in the form of the purchase of assets
3. investments in the form of savings
4. exports, such as sales of goods and services, to households or enterprises located outside of the village
5. imports involving the purchase of goods and services from households or enterprises located outside of the village.

This analysis looked at the current per capita GDP of the panel of villages, its growth during the 28 months from September 2016 to February 2019, and the factors that drove growth.

It found that the per capita annual GDP had increased by 5 percent in the panel of villages – from USD 439 to

¹⁶ This approach considers the final value of goods and services produced as the total expenditure incurred by the economy to avail them within the reference period. Components of the expenditure approach include personal consumption expenditures (C); gross private investment (I); government expenditure on services such as roads, market and health facilities; and net exports (difference between the values of goods and services produced within the economy and exported, and goods and services produced outside the economy but used within it). Thus, the GDP is calculated using the following formula: $GDP=C+I+G+(X-M)$.

FIGURE 21: Contribution of different components to GDP



USD 461 – during this period, while the per capita GDP growth of Uttar Pradesh during this period had been at 6.1 percent (CRISIL Limited, 2019). It suggests that the mini-grid villages showed a comparable growth, even though the economy is completely rural. Although we are not able to ascertain attribution, this growth rate indicates that rural economies with adequate and consistent electricity supply tend to flourish.

Specifically, it has been seen that while investments in assets have declined, consumption expenditure has increased. A deeper dive into this trend highlights that household expenditure on energy as well as non-food items has increased significantly. Improved electricity through mini-grids as well as government grid connections has contributed to the increase in energy expenditure.

SOCIAL CHANGE

An electricity connection can bring a wide array of social benefits, ranging from longer study hours for children in the evening to increased access to digital information sources and media. For women, it is helpful in domestic chores, while also enhancing safety and security, especially at night. The GDP+ measurement assigns a monetary value to these benefits, primarily by looking at the daily time reallocation across different activities.

In mini-grid households, the increased efficiency for women carrying out daily chores after sundown is notable. Time saved is used for economically productive work or personal development activities, such as knitting or sewing. Improved safety and security conditions after sundown also enable women to socialize after dark. Based on these hypotheses, the measurement includes a time reallocation scale to identify the social changes it triggers. Any increase in time spent daily on income-generating or leisure activities is considered a positive change, while an increase in the time spent on daily domestic chores is considered a negative change.

Table 1 illustrates that women in the Smart Power intervention villages have begun spending an additional half-hour daily on personal development activities, such as knitting, sewing, or reading the daily newspaper.

Thus, the Smart Power mini-grids have been able to create a change of two hours. This change is monetized using the hourly wage rate (Pradhan Mantri Yojana, 2016) for 100 productive days (Ministry of Rural Development, Government

of India, 2016) in a year. The contribution of social change to economic welfare in 28 months has been USD 60.

ENVIRONMENTAL CHANGE

The Smart Power initiative aims to trigger economic development while also reducing environmental stress by providing electricity from clean energy sources, such as solar and biomass, and reducing the usage of fossil fuels such as diesel and kerosene. The Smart Power initiative has been able to replace or reduce kerosene

Marked reduction in environmental footprint through reduction of kerosene use

While kerosene is a subsidized product available through a public distribution system in rural India, the proportion of households using it has reduced significantly from 56% before 2015 to only 1% in 2019. Improved electricity access has thus been able to encourage use of cleaner lighting sources.

TABLE 1: Daily time use for women

Daily activities	Avg. daily time invested (hrs) Sep 2016	Avg. daily time invested (hrs) Feb 2019	Change (hrs)
Agriculture on own farm	6.0	6.0	0.0
Agriculture on other farms	1.0	1.0	0.0
Non-agricultural labor	3.0	3.0	0.0
Personal development (Trainings/ knitting/sewing)	0.5	0.5	0.0
Leisure	3.0	4.0	1.0
Domestic chores	8.0	7.0	1.0

TABLE 2: Monetizing social benefits

Net positive change (hours) from September 2016 to February 2019	2.0
Hourly wage rate (USD)	0.3
Number of productive days in a year	100
Annual contribution of social benefits to change in GDP+ (USD) (per capita)	60.0

and diesel in both households and enterprises. While replacing fossil fuel sources improves the indoor ambiance, it also has a significant positive impact on environmental stress. The GDP+ measurement factors into this environmental contribution by measuring the reduction of fossil fuel used and monetizing the amount by using the carbon dioxide equivalent factor and the existing global carbon exchange rates. Table 3 highlights a 28-month change in carbon emissions at the household level.

Thus, the per capita environmental footprint for the panel of Smart Power villages was reduced by 0.060 tons of CO₂ equivalent. This change was largely brought about by the reduction in the use of diesel and kerosene as energy sources, thus, demonstrating how the initiative helps reduce emission while ensuring adequate electricity access. Monetization of this benefit points out an annual gain of USD 0.33 by each household using a mini-grid connection.

TABLE 3: Change in carbon emissions over 28 months

Energy source	September 2016			February 2019		Change (tons CO ₂ e/unit)
	Carbon dioxide equivalent ¹⁶ (tons CO ₂ equivalent)	Average annual consumption per capita	Total CO ₂ emissions (tons CO ₂ e/unit)	Average annual consumption per capita	Total CO ₂ emissions (tons CO ₂ e/unit)	
Firewood (kg)	0.10	162	0.016	49	0.005	-0.011
Kerosene (lit)	2.50	6	0.015	3	0.006	-0.009
LPG (lit)	1.70	11	0.019	17	0.029	0.010
Petrol (lit)	2.40	6	0.014	8	0.019	0.006
Diesel (lit)	2.60	33	0.085	10	0.025	-0.060
Govt. Grid Electricity (kWh)	0.53	27	0.014	35	0.019	0.004
Total	0.163	0.103		-0.060		

¹⁶ Based on Environmental Protection Agency calculations

TABLE 4: Monetizing environmental benefits

CO ₂ e reduced per capita per year (ton)	0.060
Carbon credit price ¹⁷ (USD) (Mar 2016) (Investing.com, 2019)	5.54
Contribution of environmental benefits to change in GDP+ (USD)	0.33

¹⁷ (Investing.com, n.d.)

TABLE 5: GDP+ Measurement

Aspect	Indicator	Difference observed	Difference attributable to Smart Power (monetized)	% Contribution to ΔGDP+
Economic	GDP per capita (USD)	3.0	USD 21.0	25.7%
Environmental	Carbon footprint per capita (tons CO ₂ e)	0.08	USD 0.3	0.7%
Social	Increase in time use in leisure/productive activities per capita (hrs)	0.5	USD 60.0	73.6%
	Reduction in domestic chores per capita (hrs)	0.0		
The net change in GDP+			USD 81.30	

Measuring GDP+

GDP+ aggregates the monetized contribution of the economic, social, and environmental changes. Over the 28 months from September 2016 until February 2019, the Smart Power initiative was able to bring a positive change in the economic welfare of its intervention

villages by an annual per capita amount of USD 81.30. As shown in Table 8, around 75 percent of this change was due to social benefits. This indicates that, although there has been an upward movement in the overall economic welfare, Smart Power is yet to make a significant mark on economic activities.

The impact of energy access: Summary of Section 3 key findings

Business development

- Assured timely and good quality electricity supply has encouraged 43 percent of enterprises to invest in high-load commercial appliances – some to diversify existing business and some to start a new business activity.
- The enterprise development model has successfully identified entrepreneurs and supported them with financial capital, technical training, and value chain linkages. Each micro-enterprise developed has been able to generate employment opportunities for at least for two or three people and provided an essential value-added service to community members. For example, because of the presence of village rice-hulling units, people do not have to travel elsewhere to have their paddy hulled, thus saving time and effort. However, there is further need to create an enabling environment for these enterprises to operate effectively by ensuring strong market linkages.
- Almost two-thirds of connected enterprises (63 percent) perceived an increase in business efficiency after using the mini-grid connection. Statistical tests suggest that these enterprises have an additional six customers a day and one extra hour of operation. Average monthly revenue of connected enterprises had increased by 42 percent since April 2015. Enterprises with lighting loads showed a 36 percent increase, equal to USD 48, while commercial loads had a 52 percent increase, equal to USD 75, during the same period.
- SPI villages have experienced per capita GDP growth of roughly USD 21. Monetizing the social (USD 60), environmental (USD 0.33) and economic benefits (USD 21) of mini-grid power, SPI has created USD 81.30 in value.

Enterprise electricity demand and energy use

- Data suggests a positive relationship between energy access and demand. Enterprises that have increased electricity supply from mini-grids doubled their demand and consumption.
- Most enterprises rely solely on Smart Power electricity. Seventy-six percent of the enterprises – mostly high load users – connected to Smart Power mini-grids no longer use any other electricity source to run refrigerators, chillers, computers, and printers, or for lighting. While the supply hours from the government grid have nearly tripled since 2015, the quality remains poor at ~ 50V, which cannot support commercial loads.

Household electricity consumption

- High-wealth households registered a growth of 46 percent in daily per capita electricity consumption. There was also a 16 percent growth in electricity consumption among medium-wealth households and a six percent growth among low-wealth households.
- Rural households have made a near complete shift from consumption of kerosene to electricity for lighting.
- Households connected to a mini-grid are using more appliances due to the reliable supply of electricity. A higher proportion of low-wealth households has started using the LED bulbs offered with the mini-grid connection package, and also has aspirations to own a fan and television. However, demand for high-power-consuming appliances is yet to materialize among medium- and high-wealth households.
- The higher tariff rate of the mini-grid compared with the government grid acts as a deterrent for low-wealth groups and non-customers within the mini-grid catchment. This could lead to a concentration of medium- and high-wealth customers, thus leaving low-wealth customers out.



4

Conclusion

Between 2016 and 2018, the Smart Power initiative ensured quality and reliable electricity access to more than 11,000 households and powered nearly 6,000 enterprises across three Indian states – Uttar Pradesh, Bihar, and Jharkhand – which have historically experienced inadequate electricity supply.

With its objective of simultaneously achieving a broad range of economic and social objectives, the initiative has required regular feedback on progress toward its goals, the validity of the key assumptions on which it is based, and how the program is affected by the changing economic, political, social, and ecological environments within which it operates. While evidence from the field suggests there have been significant strides towards reaching its socioeconomic objectives, it also brings to light lessons and challenges to which Smart Power will need to respond going forward.

Smart Power has facilitated a successful shift from kerosene and diesel to reliable clean energy sources. However higher costs continue to pose a challenge for scale. More competitive pricing is needed.

The most remarkable shift the Smart Power initiative has seen in its three years of operation has been the reduction in usage of kerosene and diesel for lighting. Kerosene has almost been eliminated as a lighting source for both households and enterprises. Many enterprises have made a nearly complete shift to the mini-grid as an electricity source.

However, concerns around scaling mini-grid connections remain. The tariff for mini-grid electricity is almost four times that of government-grid electricity. While mini-grid services stand out in terms of quality, the cost has discouraged many existing and potential users. Around 14 percent of connected households have dropped out primarily due to the high costs required to operate a mini-grid connection. Currently, mini-grid connections are preferred because of their reliability and quality. However, with improved government grid supply and its lower cost, there is likely to be an increase in mini-grid customers shifting their operations to the government grid.

More competitive pricing of the mini-grid connection is needed to discourage dropouts. Also, a more dynamic and engaged customer acquisition strategy is needed to enhance appreciation of the Smart Power initiative's benefits and, at the same time, respond to some of the

barriers to adoption, such as assumptions concerning pricing and value for money.

Impacting rural lives through enterprise development

The Smart Power initiative has supported excellent examples of commercial and high impact enterprise models – mainly sustainable enterprise business models with a large impact catchment.

These models have been developed so that benefits not only go to the 206 connected entrepreneurs and their direct employees, they also positively affect the lives of another 33,000 individuals. For example, each reverse osmosis water filtration unit directly benefits the entrepreneur and the employees by ensuring economic returns, as well as supporting direct health benefits to around 30 households that procure water from it. Currently, each of the 32 reverse osmosis plants impacts the lives of around 7,800 individuals.

The monthly revenues of Smart Power micro-enterprises have increased by around 42 percent, compared with their revenue before Smart Power. Going forward, to make an even greater impact on the economy, there is a need to connect productive load enterprises and on-farm units, while also ensuring an adequate market linkage.

Thus, through the three intervention approaches that Smart Power takes up – connecting existing enterprises, incubating value chains of new enterprise models, and connecting households – the impact reaches around 187,000 individuals.

While these numbers speak highly of the potential that the initiative holds, Smart Power needs to address the high tariff and flexibility concerns flagged by customers, if it is to enhance its impact coverage sustainably.

Strong focus on economic welfare with social and environmental benefits

The Smart Power initiative aims to create an ecosystem that incentivizes the expansion of economic activities through the provision of reliable and clean electricity. There has been a concerted effort to reduce use of emission-heavy energy sources such as diesel and kerosene.

Apart from these, the program has focused on impacting rural lives through the incubated business models – all part of its efforts to develop an ecosystem that enhances economic welfare.

A measurement of this welfare, through the GDP+ approach, suggests that there has been an annual per capita increase of USD 81.30 in the economic welfare of the panel of Smart Power villages. The social benefits, measured through time reallocation, contribute 74 percent of the change, while the economic and environmental benefits contribute 16 percent and 3 percent respectively. This indicates a positive impact of the Smart Power initiative on economic welfare but, at the same time, suggests that the program should renew its focus on leveraging economic impacts.

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Annex 1

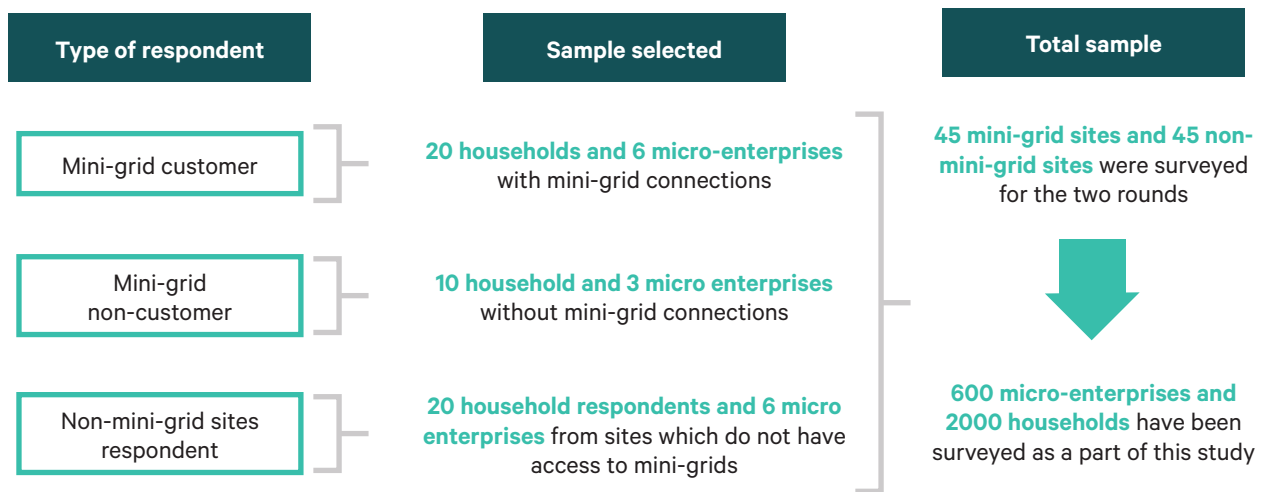
Sample selection

The rounds of monitoring conducted in 2018 involved qualitative and quantitative interactions with enterprise, and household customers of Smart Power mini-grids spread across 45 villages. Interactions were also carried out with non-customers within the mini-grid site as well as households and micro-enterprises from non-mini-grid villages. More than 600 enterprises and 2000 households are interacted with for each monitoring round. This sample was selected at two levels:

Site level: A sample frame of all sites more than six months old was created. Around 50 percent of operational sites were sampled randomly from each ESCO under the program viz: OMC, Tara Urja, Husk Power, HCL Foundation, Claro.

Respondent level: Customers and non-customers of mini-grids, along with respondents from non-mini-grid sites.

FIGURE 22: Sampling methodology adopted





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