TFE Consulting

Bridging the Energy Gap: Demand Scenarios for Mini-Grids in Myanmar

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Foreword: Bridging the energy gap

This study represents a unique collaboration between donors, investors, energy developers, non-profit agencies and research consultants who are all seeking to play a pivotal role in helping support Myanmar bridge the energy gap in a country where enormous social and economic potential will only truly be realised once the two-thirds of the country that still does not have access to constant electricity are able to access power that is affordable, high quality, reliable and, where possible, renewable.

This study aims to bridge a gap in knowledge. While many research studies and assessments have been conducted on supply-side opportunities and needs in Myanmar, very little is actually known about current patterns of demand. Almost no investment has been made into demand-side interventions to support community access to mini-grid power. Much less is known about future possible patterns of demand – a notoriously difficult area of study. But by attempting to analyse trends and typologies in 50 rural communities, the findings in this study will help to shed light on many aspects of consumer demand, and will help improve the accuracy of demand predictions and to enable all those playing a role in energy access in Myanmar to make informed decisions around site selection, investment potential, demand-side implementation strategies and policy and regulation.

» This study will help all those playing a role in energy access in Myanmar. «

Smart Power Myanmar was established in May 2018 by The Rockefeller Foundation through its implementing partner, Pact Myanmar, with the express goal of working to facilitate and support the growth of off-grid electrification in Myanmar. Supported by Smart Power's Founding Members – The Rockefeller Foundation, The World Bank, USAID and Yoma Strategic Holdings – Smart Power Myanmar will seek to play an appropriate and meaningful role in scaling up energy access to millions of underserved communities in rural, peri-urban areas and in areas of special economic potential. It is our hope that this study provides some much-needed additional data to help the energy sector as a whole maximize the opportunity of repeatable, scalable off-grid business models that can serve Myanmar for many years to come.

Richard Harrison
CEO
Smart Power Myanmar

Preface

The Rockefeller Foundation's commitment to the goal of ending energy poverty is grounded in the knowledge that the lack of reliable electricity denies people the ability to work, weakening health and safety, education, and limiting the opportunity to rise out of poverty. Electricity is not only critical to human wellbeing, it is the undercurrent of a thriving economy.

Through The Rockefeller Foundation's Smart Power initiative, which has now been extended to Myanmar through the Smart Power Myanmar Facility, our aim is to end energy poverty and transform the livelihoods of hundreds of millions of people by extending productive use power to those without sufficient access. Worldwide, we work with governments, donors, investors, the private sector, technologists, and other advocates to catalyze an energy transformation by accelerating electrification in environmentally and economically sustainable ways. One solution that could fill an important gap in the energy landscape in Myanmar is mini-grids—decentralized distribution networks increasingly powered by renewable energy. But as we have learned from our work in India and Africa, it is not enough to build technology solutions and expect low income rural communities to be able to seamlessly connect and utilize electricity; there are many demand-side challenges that need to be overcome.

Very little is currently known about energy usage in households and businesses in rural Myanmar. This report is one of the first attempts to provide insights into electricity consumption, demand behaviors of families and businesses in the central Dry Zone, and current and potential demand scenarios that will inform decision makers in the energy and rural development sectors. It is our hope that this report will contribute to accelerating the adoption and scaling up of mini-grids and other rural energy solutions, with the context of more integrated electrification planning that adopts the quickest, least-cost methods to connect millions of households and enterprises.

> » This report is one of the first attempts to provide insights into electricity consumption, demand behaviors and current and potential demand scenarios. «

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The research and analysis was conducted by Mohit Anand, Nabin Raj Ghaire, Andre Perez, Francesca Marasca, Sam Duby and Tobias Engelmeier from TFE Consulting. Shafiquer Rahman and Kyaw Naing of Development Resources International led the village survey teams.

Technical feedback and continuous support were provided by Sabine Joukes (Pact Myanmar), Michael Florian (Pact Myanmar), Richard Harrison (Smart Power Myanmar), Adriana Karpinska (Smart Power Myanmar) and Matthew Cullinen (Energy for Prosperity).

In addition, Pact Myanmar is grateful for valuable external reviews on the research design and inputs at various stages of this study, provided by Sunil Khosla, Anil Cabraal (The World Bank), Mark Hayton, Patrick Pawletko (GIZ RELEC), Bill Gallery (International Finance Corporation), Tarek Ketelsen (Australia Mekong Partnership for Environmental Resources and Energy Systems) and Dipti Vaghela (Hydropower for Community Empowerment in Myanmar) and the team at InfraCapital Myanmar.

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Executive summary

Myanmar's future growth and prosperity depends on reliable, affordable and high-quality access to electricity throughout the country. More than two-thirds of the country's 55 million people lack access to reliable electricity, many of them live in rural villages. Currently, more than 30,000 rural villages across Myanmar are not connected to the national grid. Even if the expansion of the grid through Myanmar's National Electrification Plan goes according to plan, many would still remain under-electrified for many years to come. However, such plans across the developing world have, all too often, underperformed.

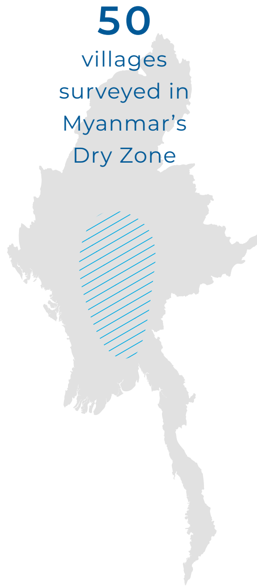
Decentralized solutions such as mini-grids can play a major role in creating a modern, reliable, decentralized energy system. If powered by renewable sources, they can also ensure that new electrification at the village level is environmentally sustainable. Most importantly, by providing readily deployable, high-quality electricity access, mini-grids can greatly accelerate economic productivity and related development gains.

The government as well as the private sector are now beginning to invest in the decentralized energy sector – the former mostly via subsidies, the latter through investment. In order for that financial commitment to grow and be deployed efficiently, developers, investors, policy-makers and communities need good quality information on energy demand. This allows them to make appropriate, evidence-based decisions. Beyond anecdotal evidence from various early projects, very little is currently known about the trends in energy use from mini-grids in rural Myanmar. That makes it hard for business modelers to plan for potential future demand. This gap is especially severe for productive uses tied to commercial and agricultural machines in villages.

In an attempt to bridge this gap and to provide insights into current and potential future energy uses and related demand and supply side challenges, Pact Myanmar commissioned TFE Consulting in October 2017 to conduct a survey of 50 villages in Myanmar's Dry Zone (44 of them non-grid connected, NGC). The work encompassed an assessment of current energy demand, and the outlining of scenarios of future energy use.

» Mini-grids can greatly accelerate economic productivity and related development gains. «

These findings are summarized in this report, designed to provide data and insights to energy services companies (ESCOs), financing institutions, development institutions and policy-makers. Some key points from this research include:



1 There is a significant need for demand-side interventions and investment. General findings of this study point to a significant need and opportunity to support the demand-side of rural energy. Most financing currently goes towards the construction of mini-grids, but only very little goes to consumer support and demand-side interventions such as the building up of energy-dependent commercial activities. Without increased investment, load levels may lag, potentially leading to underutilization of current and future mini-grids and a reduced business viability for mini-grids operators.

2 Village geography shapes energy demand and use types. Geographic characteristics such as access to water and road connectivity are important factors that can drive larger and more diverse energy loads. Wetland villages with access to water tend to have higher demand and more productive loads compared to dry villages. Road connectivity is an even stronger driver, pushing dry villages to the same level of demand and productive use as wetland villages that are not well connected.

3 There is diverse use of electricity in non-grid connected villages. 87% of the population in non-grid connected villages surveyed already has some form of electricity access. Crucially though, 62% of the population has access through solar home systems (SHS) and solar lighting products, suitable only for basic lighting and mobile charging. Only 25% of the surveyed population has electricity access from diesel or petrol generators that can support larger loads like appliances and machinery.

4 Productive loads, such as agricultural machinery, drive village electricity demand. Average per capita load across all the NGC villages surveyed is 4.6 kWh per month. 75% of this or 3.43 kWh per capita is productive load. 35 out of 44 villages have productive load tied to the use of machinery for welding, carpentry, rice milling, water pumping, grinding of pulses or beans, and oil milling. Only a quarter of the load is consumptive, tied to the use of LED bulbs and appliances like TVs, refrigerators, radios, and rice cookers amongst others.

5 Welding and carpentry are two productive uses found to be suitable for mini-grids. Welding and carpentry are the two non-agricultural productive uses most commonly found. Together, they make up close to 27% of productive load. Machines used for these activities have a high power rating of 15-40 kW, making them a good source of demand for mini-grids. Moreover, because such use is decoupled from agricultural seasonality, it can provide reliable annual loads with base-load like characteristics and potentially attractive commercial terms.

6 Villages with high total demand are not always the most attractive. It is important to consider the per capita consumption or ‘density’ of load in a village when evaluating investment attractiveness. High load density – meaning high concentration of load within a given population – is preferable to a more dispersed scenario, as a denser village will require less distribution infrastructure, reducing mini-grid costs. This can make some smaller villages more attractive than larger ones.

7 Telecom towers are an anchor load opportunity, but not always: While telecom towers are useful in supporting the village electrification business case, this is the case only if they are relatively close to the community. For telecom towers that are too far away, the cost of transmitting electricity outweighs the benefits. Of the 44 NGC villages, only three have a telecom tower within a 1 km radius, close enough to be a viable anchor load for a mini-grid.

8 Non-grid connected villages spend more on less electricity: Surveyed NGC villages on average spend more than MMK 7,500 (USD 6) per household per month or 5% of total monthly income on energy (excluding for cooking). Although this is twice as much as electricity spend in grid-connected villages, it buys NGC villages only 5% of the amount of energy that is consumed in grid-connected villages.

9 Diesel or petrol generators supply the bulk of enterprise energy demand. Enterprises rely heavily on generators for productive loads. They spend 96% of their energy expenditure on such generators. Since productive loads are the bulk of energy use, spend on generators is nearly equal to the total energy spend for villages as a whole. That relationship is consistent across village types and sizes.

10 Demand for consumptive load could increase around 1.6x in NGC villages. We project a 1.6x increase in consumptive load over three to five years, if NGC villages are electrified by mini-grids at the current estimated cost of electricity, which is over 14x higher than current subsidized grid rates. This is "Scenario 1" in the report. With a 37% subsidy, demand could rise 3.6x ("Scenario 2") and at a mini-grid tariff subsidized to match current grid rates, we can expect a 24x growth in demand matching that in current grid connected villages ("Scenario 3").

11 Productive load could also increase 1.6x in NGC villages. At current mini-grid electricity rates, NGC villages could see a productive load demand increase of 1.6x, mirroring current demand in grid connected villages. Even though businesses in grid-connected villages have access to subsidized electricity, they are currently forced to use generators due to the low quality of grid power supply, putting them in a similar position as NGC villages. If mini-grids can compete in NGC villages, they will see a demand trajectory similar to demand trends in grid-connected villages.

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The authors acknowledge that there are limitations to this study. It provides only a partial view of demand trends through the lens of just 50 villages in a region that is demographically fairly homogenous within rural Myanmar and is wealthier than many more remote areas. This study does not provide decision-makers with a complete national picture due to limitations in scale, geography, access to up-to-date ESCO data, and time. For example, more and better data over time will help fine-tune cost of electricity estimates included in this study. One way of further improving the data could be through earth observation, for instance from satellites[1]. The hope is that the data and analysis in this report will provide insights into typologies and trends that can inform both initial investments into mini-grids and demand-side measures and help instigate additional research in the future.

Source:

[1] For example, TFE Consulting is currently piloting satellite-based earth observation methods for improving the business case for mini-grid developers in India.

1 Introduction

1.1 Project background and objectives

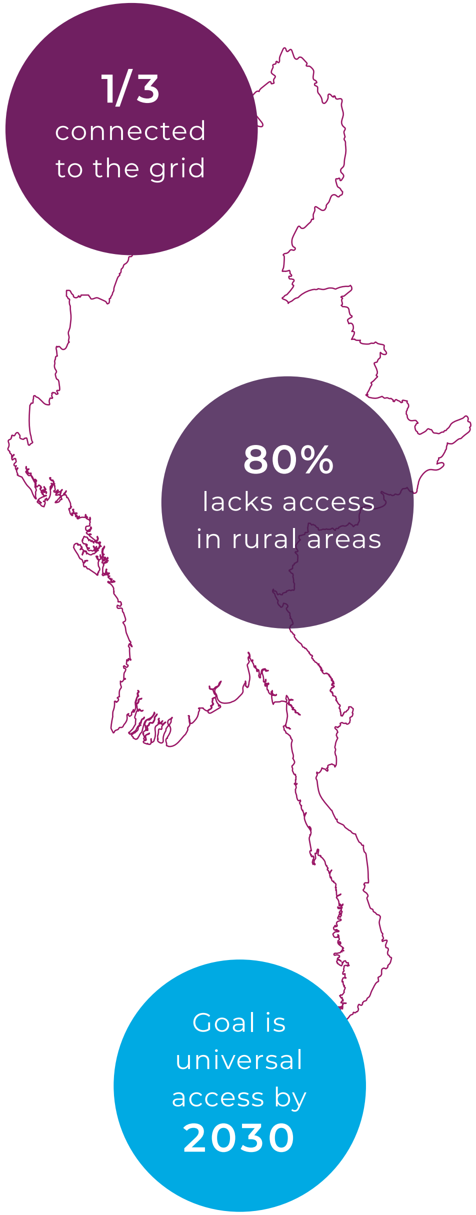
Only around one-third of Myanmar's population of 55 million is connected to the grid, with most of this access concentrated in urban areas. Over 80% of the rural population lacks access to grid electricity[2]. Myanmar's National Electrification Plan (NEP), in place since 2014, is the primary driver of improving electricity access. Its goal is to achieve universal access by 2030. However, the plan prioritizes grid-connected supply for 98% of all new electrification[3]. This is not surprising – many developing countries build their electrification strategies on expanding the grid. It is an understandable approach from an institutional perspective as the grid is under the direct control of government bodies; and is also understandable from a political perspective as grid prices can be controlled and are often subsidized. However, grid-based electrification plans often fall short of targets. Many have been around for decades across the developing world and have in most cases underperformed due to high investment costs, weak demand from sparsely populated regions, challenging terrain, a lack of grid power generation capacity and institutional implementation deficits. As a result, a significant portion of rural un-electrified populations have not and will likely not gain reliable grid access as planned. There is little reason to think that Myanmar is different.

» Grid-based electrification plans often fall short of targets «

At the same time, decentralized solutions like mini-grids can help address the rural electrification challenge. If powered by renewable sources like solar energy, they can also ensure that a significant portion of new electrification is locally produced and environmentally sustainable. Importantly, by accelerating electricity access, mini-grids can ensure that the productivity gains and development that can follow from electrification are available to rural communities faster.

The Government of Myanmar recognizes this and has launched an off-grid initiative managed by Myanmar's Department of Rural Development (DRD), funded by a USD 90 million (MMK 119.7 billion) loan by the Work Bank, of which USD 7 million is dedicated to mini-grid development. In response to this and partly driven by the potential for electrification, there is also considerable interest by private sector actors to enter the market with mini-grid solutions. Many have indicated an interest in exploring the feasibility of individual sites, mainly in the country's central Dry Zone.

While interest in mini-grids is meaningful, there is a significant lack of data and understanding regarding energy demand, the types of uses for energy and potential future demand in the rural context in Myanmar. This gap is especially severe when it comes to productive uses that are typically tied to the commercial and agricultural use of machinery in villages. Such uses have the potential to strengthen the local economy and drive

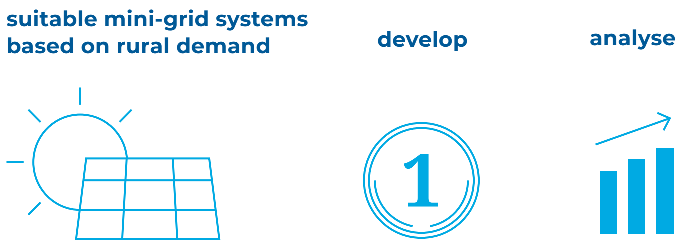


socio-economic development and could also be ideal sources of demand for mini-grids.

» There is a significant lack of data and understanding regarding energy demand «

To fill this knowledge gap, Pact Myanmar and its partners initiated this project. The research and analysis has been led by TFE Consulting with in-country support from Development Resources International (DRI). This report is the result of our work and has the following key objectives:

1. Generate a deeper understanding of rural demand to inform community engagement approaches and community pricing models.
2. Inform energy service companies (ESCOs) and other donors who are planning to invest in rural development and/or rural electrification programs in Myanmar in the design of suitable mini-grid systems based on rural demand with a trajectory of increasing productive use.
3. Help attract ESCOs and other players such as micro-finance institutions to participate in and support the mini-grid market.
4. Generate analysis that can be used for government engagement and advance policy dialogue and government decision-making.
5. Develop insights that can contribute to decision-making on demand-side and supply-side business models, interventions and investment.



Sources:

[2] The World Bank, Policies for Shared Prosperity in Myanmar. See also the website on Myanmar Off-Grid Analytics by the Asian Development Bank: http://adb-myanmar.integration.org

[3] Castalia Strategic Advisors, Myanmar National Electrification Program (NEP) Roadmap and Investment Prospectus

[4] Department of Rural Development of Myanmar, Rural Power Planning and Implementation of a Model Village

1.2 Project approach

With a focus on the Dry Zone, this study involved a quantitative community survey of 50 villages across the four townships[5] of Thazi (Mandalay Region), Mindon and Pauk (Magway Division) and Salingyi (Sagaing Region). These villages included 44 non-grid-connected villages (NGC) to understand current electrification needs and six grid-connected villages to understand how energy use evolves as villages electrify, and to assess the potential for future energy use. As part of the survey, respondents across 1,263 households were asked questions on human development indicators, local economic drivers, household, enterprise and community energy use, and other village-level impact factors.

Figure 1:
Survey and research scope

4 townships	50 villages	1263 households
1 Thazi	16 villages	325 hh
2 Mindon	12 villages	299 hh
3 Pauk	12 villages	324 hh
4 Salingyi	10 villages	315 hh

For this report, we analyzed survey data to provide an assessment of the current quantity and type of demand and energy spend in non-grid-connected villages in the Dry Zone. Thereafter, we analyzed scenarios of future energy use developed using a demand projection model. The study also involved Human Centered Design (HCD) workshops, in which community members were engaged in an open but deliberate manner to gain additional insights to complement the survey data and our analysis. Finally, a mini-grid assessment engine[6] was used to provide a ranking of villages for mini-grid developers as well as for development institutions.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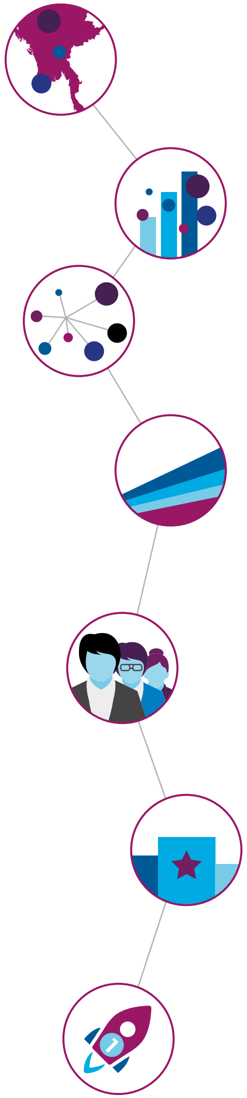
Sources:

[5] A township is the lowest civil administration unit in Myanmar, immediately above the village level. It is similar to a district or a county in some other countries

[6] The mini-grid assessment engine consists of an algorithm that pulls in data on village characteristics from a survey like the one conducted for this study, sorts and normalizes the data, attributes programmable and adjustable weights and provides village prioritization or ranking to enable easy and quick site selection.

1.3 Analytical framework of this report



1 Village categorization First, villages are categorized based on geographic features, namely proximity to water and road accessibility. These factors have been chosen as the data shows they have the strongest impact on energy use characteristics in the surveyed villages. Based on this, villages are identified as belonging to one of four unique categories (A1, A2, B1, B2).

2 Energy use analysis Here we analyze current energy use and demand in non-grid connected villages. The analysis focuses on the quantity and types of energy use on a per capita basis and total load basis, subdivided into village categories. Per capita load assessment helps compare relative differences across villages and total load helps understand if villages are attractive from a mini-grid sizing perspective.

3 Energy spend analysis Next, data on current energy spend in non-grid connected villages is analyzed to understand communities' ability to pay. This data is then compared with our analysis of mini-grid electricity prices to provide an assessment of the competitiveness of mini-grids.

4 Demand scenario projections Here a projection of future energy demand in non-grid connected villages is developed. For this, demand in recently grid connected villages is used as a benchmark for projecting demand in the non-grid connected villages and developing scenarios of future energy use. This provides an understanding of the potential for demand and the combination of uses that can be expected in the non-grid connected villages in the future.

5 HCD insights Insights from the four Human-Centered Design (HCD) workshops conducted as part of this project are brought into the overall analysis. HCD workshops helped bring together a diverse range of individuals that represent as many socio-economic and energy use conditions as possible to get the richest pool of insights. These insights are used to validate the survey data, fill gaps in the analysis and complement the key insights developed earlier in the report.

6 Prioritization for mini-grids Finally, all the analysis is consolidated to prioritize villages based on their suitability for mini-grids. A mini-grid assessment engine allows the prioritization of villages on factors beyond electricity demand including multiple socio-economic factors that impact rural communities and, therefore, electricity demand. This analysis allows decision makers at ESCOs to assess the relative strengths of villages and develop their mini-grid rollout plans.

7 Prioritization for development Additionally, villages are also prioritized for development institutions from the perspective of their needs for development interventions. Again, TFE Consulting's proprietary mini-grid assessment engine allows the prioritization of villages on factors like current economic and inclusive growth potential in addition to electricity demand. This analysis allows decision makers at development institutions to assess the relative strengths of villages and develop their intervention plans.

1.4 A note on data gathering

The project – the first systematic rural energy demand assessment in Myanmar – faced several challenges in data collection. Often, it was found that household heads were away in the field and family members were unable to confidently recall all the appliances used in the household. To compensate for this, surveyors made an effort to directly observe the presence of appliances, but this was not always possible. Moreover, in some cases, even in instances where appliance-use recall

» Surveyors relied on observation where possible. «

was strong, respondents were unsure about the exact hours of use. Again, surveyors relied on observation where possible. We have also worked with market-standard benchmarks of wattage of different appliances observed. Gathering data on energy and household expenditure was particularly challenging. Here, recall by the respondents was very weak and this has left considerable gaps in the project's energy spend data – for example, data on spend on energy sources other than generators is missing or unreliable. Such gaps have also been observed in similar surveys conducted in other parts of the world[7]. They make it difficult for the mini-grid sector to assess demand viability in rural communities and present significant challenges for rural electrification planning. Engaging with enterprises some challenges, too, though less often than in the case of households. Gathering data from village community institutions such as religious centers, schools and health centers was particularly difficult, as respondents were rarely able to recall the energy use of an entire building. This has resulted in a gap in understanding community institutions' energy use.

» Keeping the challenges in mind, we have made every effort to paint a well-reasoned and data-driven picture of rural energy use. «

We have tried to compensate for these challenges by working with assumptions where possible, organizing data in a more meaningful way, drawing on HCD insights and leveraging our experience of working on similar projects under similar conditions in other developing countries in South Asia and Africa.

Source:

[7] See, for example, the TFE Consulting report "Kenya: The World's Mini-grid Lab"

2 Village characteristics with respect to energy demand

This study focuses on 44 villages without access and six villages with access to grid electricity in four townships located in the Dry Zone in central Myanmar. The Dry Zone covers only around 15% of the country, yet it is home to nearly a third of its total population of 55 million. The region has limited water resources. It receives less than 700 millimeters of rainfall annually compared to 2,000-5,000 millimeters in other parts of the country[8]. Furthermore, rainfall is erratic and drought-like conditions are common.

This shapes the nature of energy demand in the region. Our data shows that the majority of the population in the surveyed villages is involved in farming. As a result, most energy use is for water pumping to compensate for the low and erratic rains, and for crop milling to process the harvest.

However, geographic conditions across surveyed villages differ in significant ways. Most importantly, they are not all equally dry. Typically, villages with some access to water have relatively higher and more stable agricultural productivity, higher incomes and a broader occupational mix. Such characteristics significantly impact the nature and potential of energy use. For this reason, we use geography as a key impact-characteristic to categorize villages.

Type A villages
have a mix of cultivable wetland in addition to dry land. The wetland comes from accessible natural irrigation sources such as rivers, streams or stationary water bodies like lakes and ponds. From the data collected in the survey for this study, we find that such villages tend to have higher agricultural productivity and higher incomes (including rice paddy cultivation, which sells at higher prices compared to other crops). A stronger agricultural economy in turn drives a greater variety of occupations beyond farming.

Type B villages
only have cultivatable dry land as they lack access to natural irrigation sources. In these villages, paddy cultivation is rare and overall agricultural productivity tends to be lower. According to the survey data, incomes are 10-20% below those in Type A villages. A weaker agricultural economy means that there are few occupations beyond farming.

44 villages without electricity

15% of Myanmar is covered by the Dry Zone

1/3 of population living in Dry Zone

Less than **700ml** of rainfall per year

Source:

[8] Myanmar Environment Institute

A sensitivity analysis of the data collected on indicators such as access to transportation, village road connectivity to the township center, share of women's participation in village activities, and access to markets shows that out of these, road connectivity to the township center has the greatest impact on energy use in the surveyed villages. This factor is therefore taken as the second key impact-characteristic:

Type 1 villages
are well connected to the township center (usually the largest urban area in a township), typically through a well-conditioned road, which is useable throughout the year. Many also have good access to markets, although the data did not show any conclusive correlation on this. In such villages we see a larger number and greater variety of commercial enterprises.

Type 2 villages
lack good road connectivity to the township center. In cases where connectivity exists, they are connected only through a poor road, which in most cases is available for use only in the dry season. As a result, such villages tend to have few to no commercial enterprises.

These village types overlap to provide four categories of villages – A1, A2, B1, and B2 – based on which we analyze the quantity and types of uses of electricity in the surveyed villages. They are not township specific, but rather spread across the four townships surveyed (see Figures 2 and 3).

Figure 2: Map of the Dry Zone and the townships surveyed in Myanmar

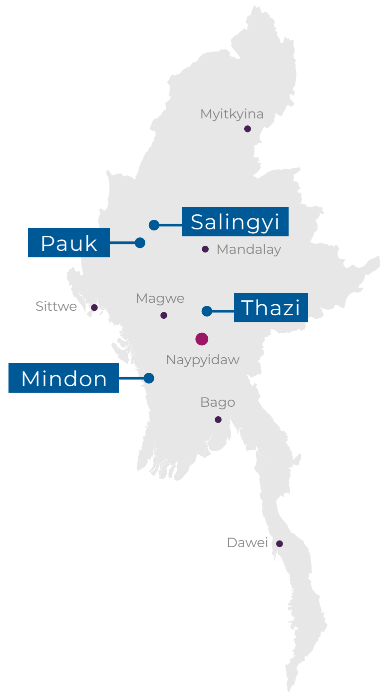
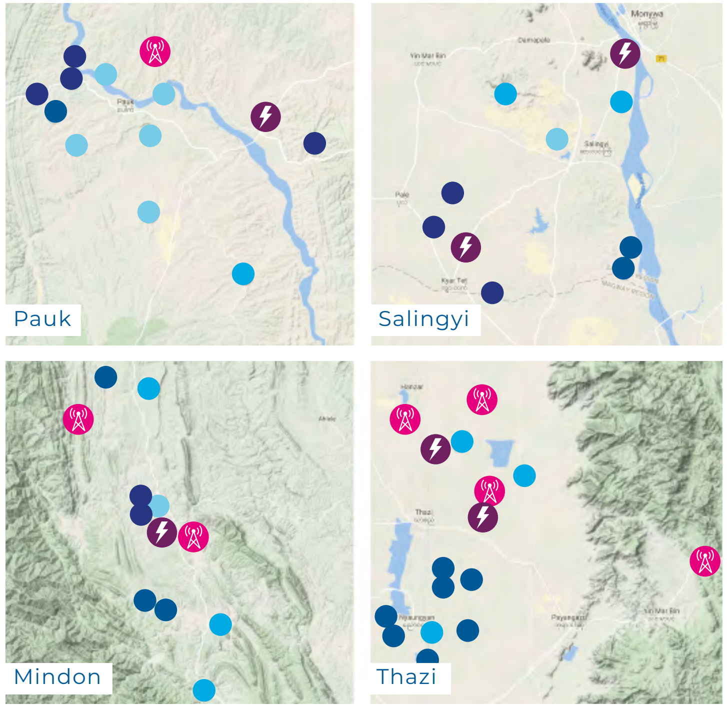


Figure 3: Maps of each township and villages surveyed



	Type A (Irrigation access)	Type B (No irrigation access)	Grid connected	Telco tower nearby
Type 1 (Good road connectivity)	A1 Access to irrigation ; Good road connectivity	B1 No access to irrigation ; Good road connectivity		
Type 2 (Poor road connectivity)	A2 Access to irrigation ; Poor road connectivity	B2 No access to irrigation ; Poor road connectivity		

3 Understanding current energy demand

3.1 Per capita demand and use types

Per capita energy demand is an important metric to understand current energy use. It gives mini-grid developers a sense of the density of electricity demand independent of population size, thus making villages more comparable. Furthermore, it conveys the types of uses of electricity at an aggregate level, again comparable across villages. For development institutions as well, this metric is key as it allows them to assess the relative disparities in energy use between villages and identify different electricity use cases around which they can plan future interventions.

Data from the 44 non-grid-connected (NGC) villages shows that despite them lacking grid connectivity, electricity use is widespread: 70% of the population has some form of electricity access there[9]. This is higher than expected since according to the World Bank, in 2016, only 40% of rural Myanmar had access to electricity[10]. A key reason for greater access is that the Dry Zone, which is the focus of this study, is wealthier and better connected than other parts of Myanmar. However, a deeper look at the survey data reveals that the quality of electricity access is weak: 62% of the population has access to 'light load' electricity suitable only for basic lighting and mobile charging. This electricity is available primarily through solar home systems (SHS) and solar lighting products. On the other hand, a mere 25% of the surveyed population has access to 'high load' electricity of the type that can support appliances and machinery tied to productive uses that can drive economic development. This electricity is currently available from diesel or petrol generators. Finally, 13% of the population has no access to any kind of generated electricity and instead relies on candles, kerosene lamps or batteries for basic lighting[11].

Productive uses, mini-grids and rural prosperity

Electrification by itself does not automatically lead to development. Electricity is a crucial, but not a sufficient condition. A recent study of small mini-grids in India showed that lifestyles changed little in many locations where solar mini-grids were installed. Users just replaced one source of energy (burning fuels) with another (electricity). To facilitate development, local economic capacity building (including finance) and growth needs to go hand in hand with electrification[12].

The starting point for electrification in the past has often been the provision of individual electrical products or solar home systems (SHS). However, for economic growth, communities also require increasingly sophisticated and heavy loads that can drive productive uses such as food processing, irrigation or welding and thereby offer new income opportunities. Mini-grids are key to that.

One way to exemplify this is through the concept of the "energy ladder". It lays out the range of increasing uses and matching electrification sources as defined by the World Bank's Multi-Tier Framework For Measuring Energy Access[13]. For example, a kerosene lamp is at Tier-0 as it provides non-electric, basic lighting. SHS are at Tiers 1 and 2 depending on their capacity as they provide electricity for basic lighting and usually allow a user to charge a mobile phone. Most mini-grids are at Tiers 3 and 4 as they typically provide much more power than a SHS, allowing users to power heavy machinery in their businesses and household appliances such as a fridge, a TV or a rice cooker. Importantly, these different rungs of the ladder can, and typically do, coexist. For example, a user might have a SHS at home and be connected to a mini-grid at work.

In surveyed villages,
25%
have access to higher load electricity (e.g. for machines)

62%
have access to light load electriciy (e.g. for lighting)

13%
have no electricity

Sources: [9] In comparison, of the six grid-connected villages surveyed, on average 95% of the population has access to electricity. [10] World Bank, Sustainable Energy for All (SE4all) database from the SE4all Global Tracking Framework [11] For context on the sample size and associated population size tied to this analysis, please refer to the Survey Methodology section in the Appendix.

With this in mind, there are two types of demand that mini-grid developers can find across the surveyed NGC villages[14].

Household demand

is typically from appliances and lighting exclusively within households (covered in detail in the next section). Such demand has no direct impact on the production of goods or services and provides no source of income for the user[15]. It typically adds to the revenue of a mini-grid business model but is insufficient to make it viable. Such demand can vary drastically or altogether drop off as families change consumption patterns with shifts in the weather, shifts in income or travel and migration. There is also usually a disproportionately high investment required[16] to connect these users to the mini-grid and given their relatively modest consumption, returns are often unviable.

Productive demand

is based on activities that generate income for the user through the production of goods or services or support community development needs and thereby add to the village economy. Such demand typically comes from machinery, lighting and other appliances used by commercial enterprises, from machinery used for farming and agricultural processing or from village community institutions like religious centers, schools and health centers. Such demand constitutes the bulk in a village and is critical to the viability of mini-grid business models. Since such demand is often tied to income generating activities, it can make related electricity payments more reliable.

The ideal demand for mini-grids

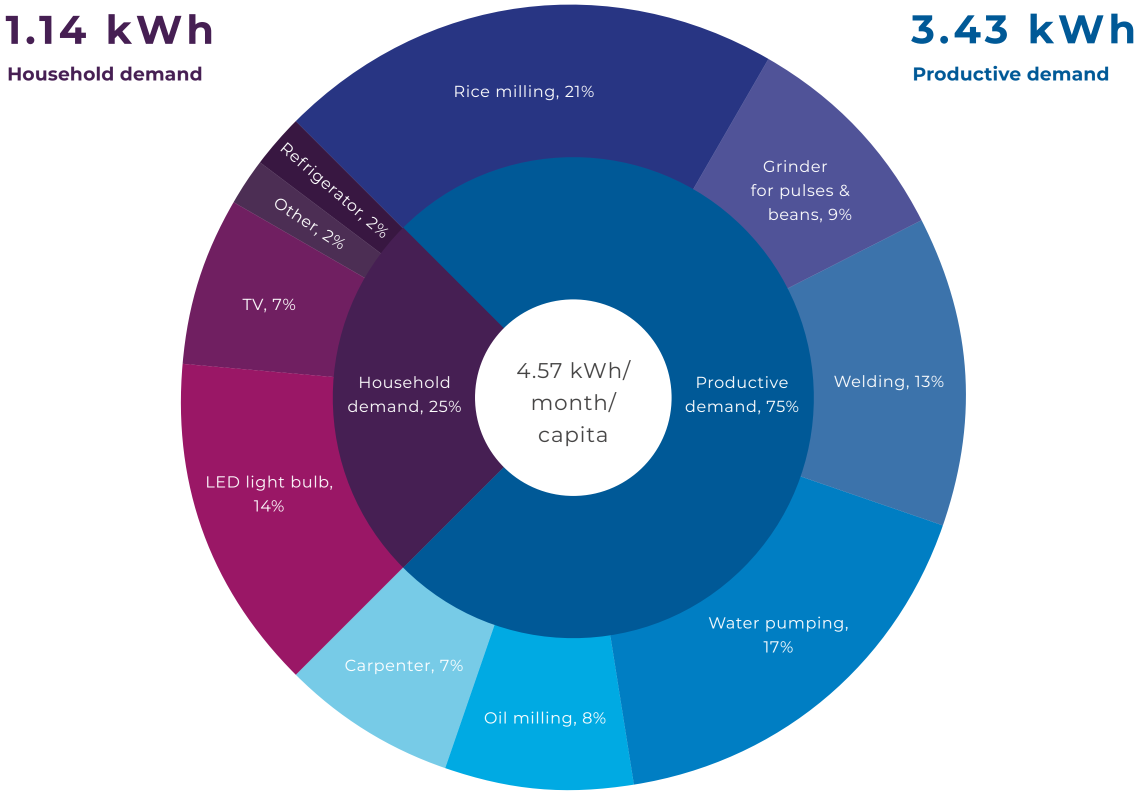
The most important viability factor for a solar or solar hybrid mini-grid is that its electricity should be mainly consumed during the daytime. Demand outside daytime hours drives up the use of the batteries, which are very expensive components. They also have a comparatively shorter lifespan with a limited number of charge cycles before which capacity reduces significantly. As a result, productive demand tied to daytime commercial enterprises is a strong driver for mini-grid viability. Households, on the other hand, use most electricity at night for their relatively smaller loads (i.e. light bulbs, phone charging, TV).

Seasonality also plays a role. The mini-grid business case benefits from predictable, consistent demand so that equipment can be sized correctly, and the system's use can be maximized. Some productive demand, however, such as agricultural demand for the processing of a particular crop, is seasonal and therefore less supportive of a mini-grid business case. Other activities, such as welding, carpentry or more service-oriented demand such as beauty salons and local shops provide much more predictable power demand. Telecom towers are ideal as they have a fixed capacity (2-4 kW) and run round-the-clock.

Another criterion for ideal demand is tied to the idea of extracting maximum value for each watt-hour of energy. An example of a high value use of power is hair clipping. A set of hair clippers (which has a relatively modest power draw) might be used for a maximum of ten minutes on each client who pays a relatively large sum of money for that ten-minute service. Therefore, the perception of the barber of the value of each watt-hour used should be relatively high. Another example of high utility might be the provision of a basic service like welding which, if not available locally would require the customer to travel considerable distances to access. By contrast, pumping water requires a relatively high-power load with an indirect value (growing crops that in turn bring income) and hence the perceived 'utility' of each watt-hour used to pump water is lower. In other words, highly productive demand is preferable[17].

Sources: [12] Aklin, Bayer, et. al., Science Advances: "Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India", May 2017 https://goo.gl/ROrmUu [13] Accessible at https://www.esmap.org/node/55526 [14] For this report, we have excluded an analysis of demand from community organizations like religious centers, schools and health centers because data on this could not be gathered at a meaningful level during the survey. [15] However, household use can contribute significantly but perhaps indirectly to productive use and income generation via education, better health and communications. [16] This depends on the distance of the user from the mini-grid hub. As a reference, in standardized DRD-led mini-grid projects the connection fee is MMK 200,000 (USD 150) [17] This might not be true, if the cost of metering certain electrical equipment is particularly high.

Figure 4:
Cumulative productive and consumptive load share and major use types across all NGC villages



Source: Survey data and TFE Consulting analysis

The average per capita demand across all NGC villages surveyed is 4.6 kWh per month[18]. All the villages have some degree of household demand and 35 out of 44 villages have productive demand. Household demand per capita is on average only 1.14 kWh a month, or a quarter of total demand[19]. 56% of it is used for high efficiency basic LED lights that have very low power consumption[20]. This use is for average household sizes (in our sample consisting of 4.2 members), where light bulbs are used for an average of 3.2 hours a day. Next, are higher load household appliances like TVs (28%), refrigerators (8%) and other appliances like radios, video or CD players, mobile phone chargers, lanterns and rice cookers (combined 8%). These 44% of all non-lighting loads currently rely on diesel or petrol generators that are typically owned directly by the household and only in some cases are shared between two or three adjacent households.

» Average per capita demand across all NGC villages surveyed is 4.6 kWh per month. «

The share of household uses is also reflected in the data on incidence of use. In Figure 5 below, we see that while close to 90% of all households on average use LED light bulbs, less than 30% use TVs, mobile phone chargers and radios.

Sources:

[18] This includes the entire population of the village and not just those with current electricity use. For grid-connected villages surveyed, the average demand is 32.8 kWh/capita/month

[19] For grid-connected villages surveyed, average household demand is 27.5 kWh/capita/month

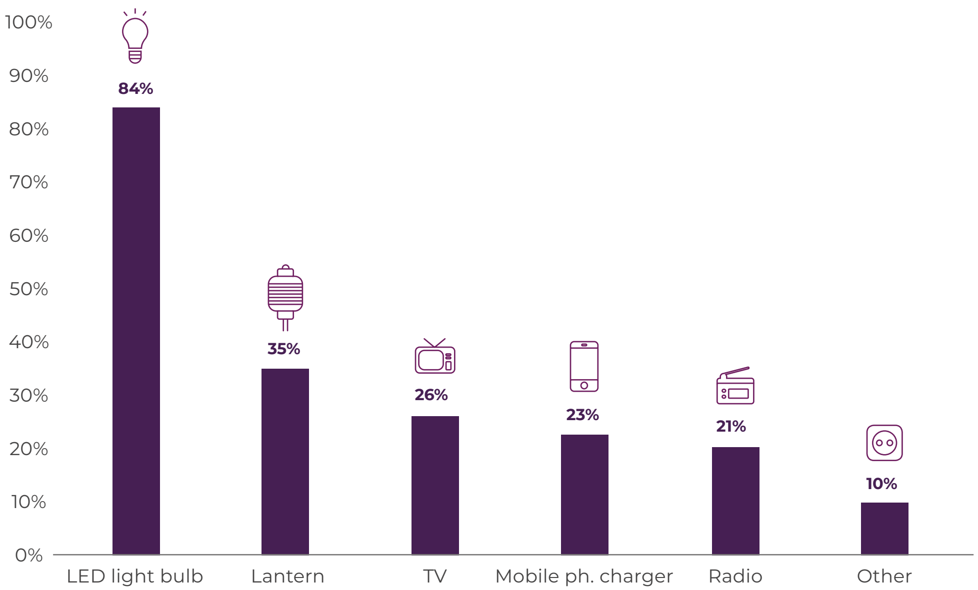
[20] In the surveyed data, LED lights were found to be around 5-7 W per bulb.

Although home appliances are widely used in rural Myanmar, their share of household demand as compared to lighting is relatively low. This could be a function of the weak economic status of households. Across all villages surveyed, 57% of households were identified as "poor" while the remaining were identified as "non-poor"[21]. The fact that households struggle to afford appliances is important for mini-grid developers as it means that within household demand, the share of daytime electricity demand is small. Average per capita productive demand across the surveyed NGC villages is 3.43 kWh or 75% of average total demand[22]. As can be expected, especially the "non-poor", who have some disposable income, are able to invest into machinery that can support productive uses.

Given the high prevalence of farming among the surveyed villages, a large portion of productive demand is for machinery for rice milling (28%), water pumping (23%), grinding of pulses and beans (12%) or oil milling (11%). Diesel or petrol generators currently supply such demand. Mini-grids could replace this, if competitively priced. However, such demand is not ideal for a mini-grid's business model, because of its seasonality. Moreover, given the vulnerability of farming to poor rainfall, the use of machinery tied to it is also erratic, making demand prediction more difficult.

Welding and carpentry constitute the largest share of non-agricultural productive uses. Together, machinery tied to these two activities makes up close to 27% of productive demand. They also have a high power rating: machines surveyed ranged from 8-15 kW. This makes them a strong source of demand and ideal for high capacity mini-grids. Moreover, because such use is largely decoupled from agricultural seasonality, it can provide reliable demand for mini-grid electricity, with base-load like characteristics and potentially attractive commercial terms.

Figure 5:
Percentage of households with appliance use in NGC villages (average for all villages)



Source: Survey data and TFE Consulting analysis

Sources:

[21] From the data, "poor" consists of very low and low-income households that earn MMK 2,000-5,000 (USD 1.5-3.75) per day or less. These households typically have assets such as cattle, some small livestock for breeding, and a bamboo home with thatch roofing. Non-poor households are those that earn above MMK 5000 (USD 3.75) per day and may have assets such as a car, motor bike, store or workshop, tools, and a home with brick or timber walls and metal sheet roof.

[22]For grid-connected villages surveyed, average productive demand is 5.3 kWh/capita/month

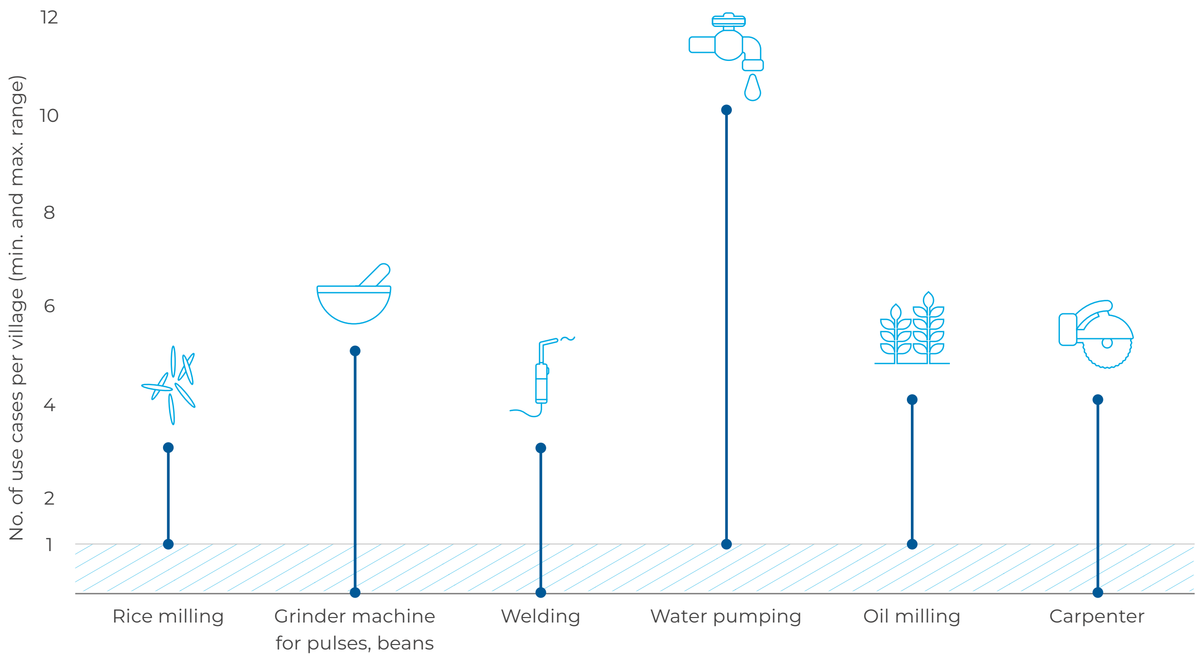
Per capita consumption in Type A villages **31%** higher than in Type B

Figure 6 below, shows the prevalence of certain machines across villages. We see that all villages have water pumps – in some cases as many as 10. Similarly, rice and oil milling is found in all villages, although the maximum number is far lower than water pumps. Non-agricultural uses like welding and carpentry are absent in some villages, but others have as many as 3-4 such machines.

The amount of productive and household demand varies drastically across villages. The two main factors driving this variation are geography and road connectivity, as captured by the village categories A1, A2, B1 and B2.

» Non-agricultural uses like welding and carpentry are absent in some villages, but others have as many as 3-4 such machines. «

Figure 6:
Incidence of productive uses in NGC villages (average for all villages)



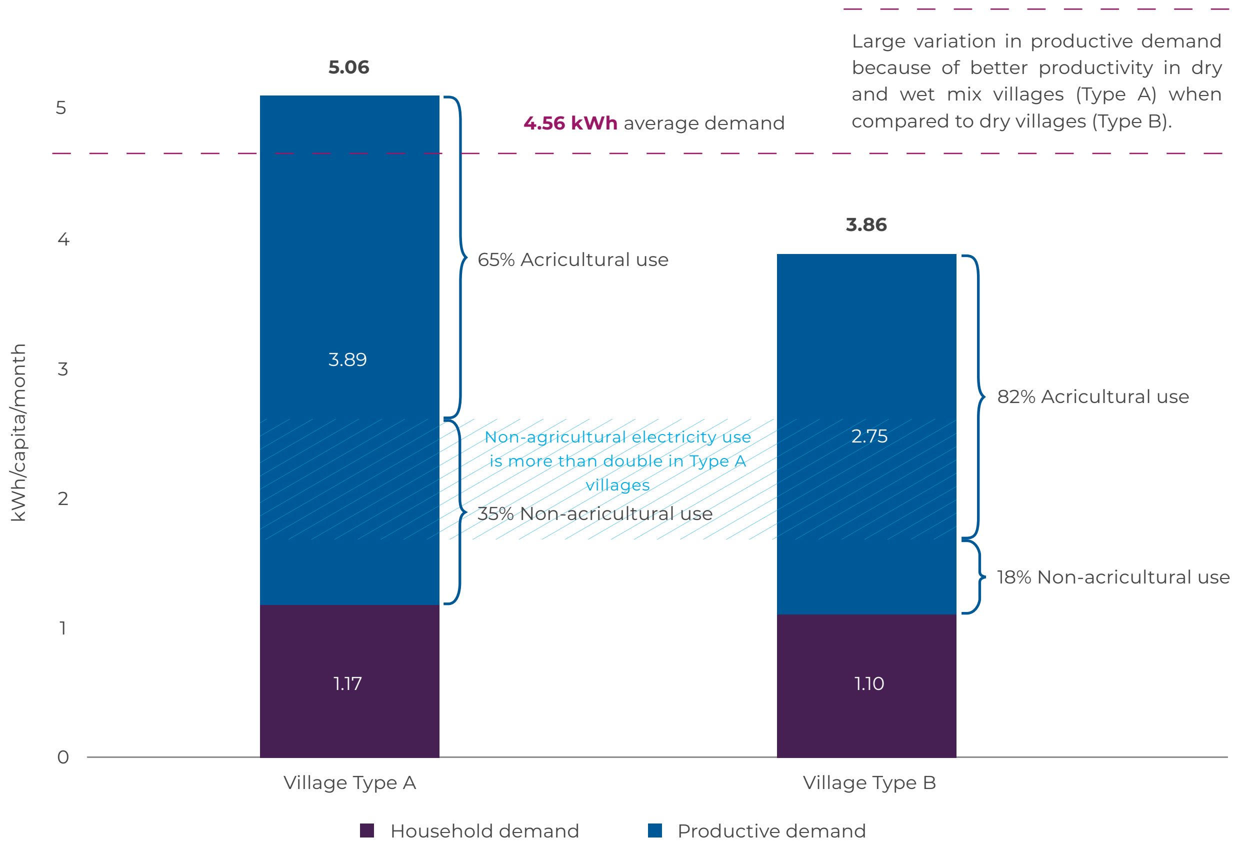
Source: Survey data and TFE Consulting analysis

When considering the impact of geography on electricity use, the data shows that Type A villages have on average 5.06 kWh per capita electricity use, which is 31% higher than Type B villages with an average of 3.86 kWh.

The difference in per capita demand is far more evident for productive demand than for household demand. For productive demand, average monthly per capita use in Type A villages is 3.89 kWh whereas in Type B villages it is 2.75 kWh. This is possibly driven by the relatively higher economic capacity. A third of productive electricity use of Type A villages is based on high-skill activities like welding and carpentry (see Figure 8). On the other hand, Type B villages are dominated by seasonal agricultural uses. 82% of the productive demand is based on water pumping, rice milling, oil milling and grinders for pulses and beans. Given the seasonality of such demand, developing a mini-grid in Type B villages poses a higher risk.

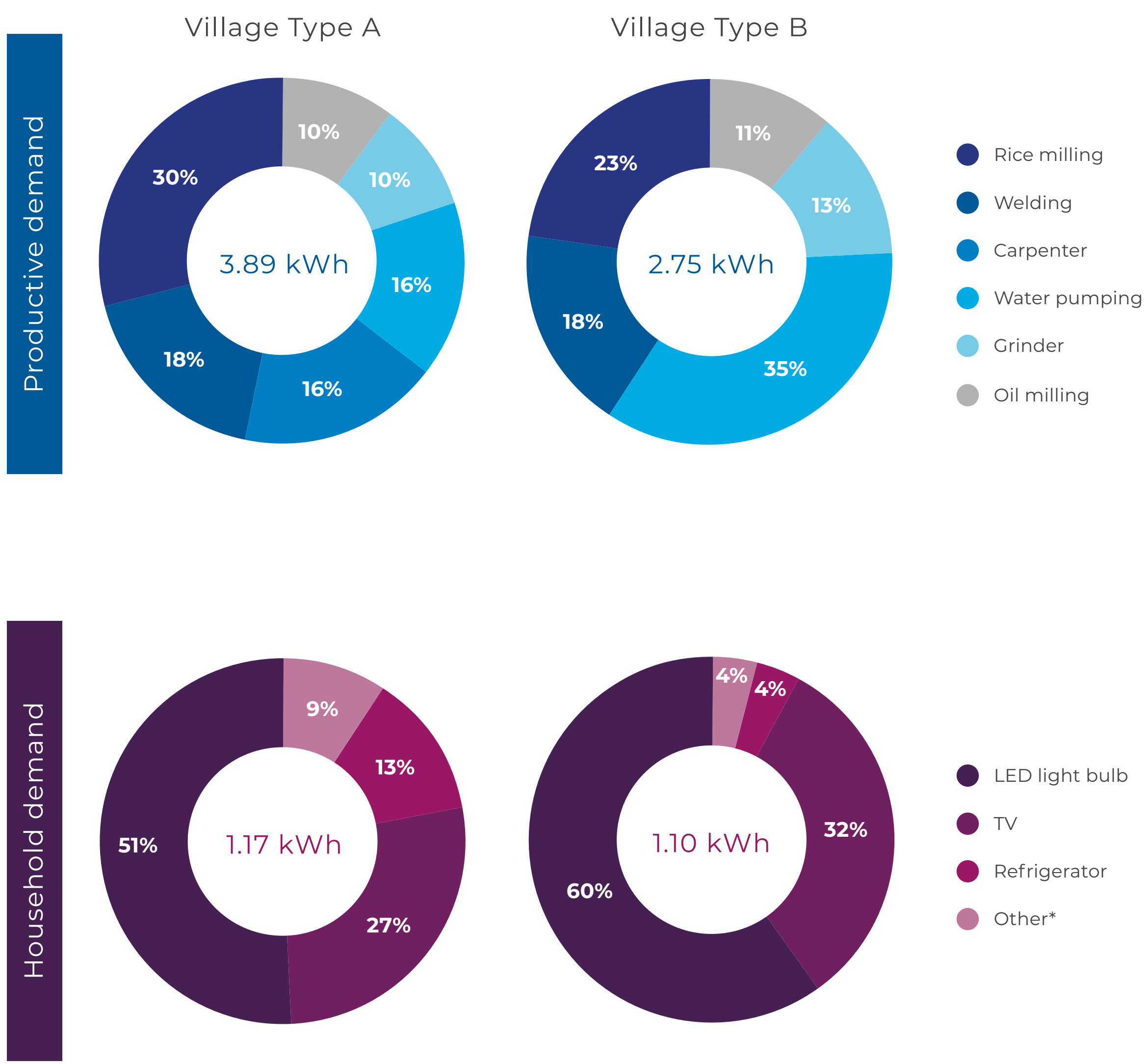
In the case of household demand, there is little difference in average monthly per capita use between Type A and Type B villages – both are around 1 kWh. The variation is significant, however, between the different types of uses of electricity. Household demand in a Type B village household is mostly for LED bulbs and TVs, while Type A village households also have access to higher load appliances such as refrigerators and rice cookers. These are also loads that are typically seen in more well-off households.

Figure 7:
Average household and productive demand comparison between Type A and Type B villages



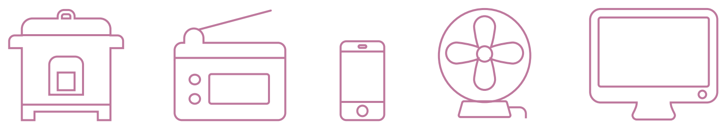
Source: Survey data and TFE Consulting analysis

Figure 8:
Share of household and productive uses in Type A and Type B villages (kWh/capita/month)



The variation in electricity use types and per capita use is more striking as we add the layer of road connectivity to village types. A1 villages have on average a 75% higher per capita demand as compared to B2 villages.

*Other includes rice cooker, radio, mobile phone charger, fan, computer and video / CD player



Source: Survey data and TFE Consulting analysis

Figure 9:
Average household and productive demand comparison between village types

Source: Survey data and TFE Consulting analysis

We see large variations in productive loads across village types A1, A2, B1 and B2. A1 villages on average have 62% more productive load per capita than A2 villages. Both village types have non-agricultural productive loads like welding and carpentry, but A1 villages have 52% more such loads than A2 villages. Productive wetlands coupled with good connectivity to their township center mean that these villages can generate income through an even mix of agricultural loads and small-scale industrial loads like welding and carpentry. In contrast, highly seasonal agricultural loads drive 100% of productive load in the surveyed B2 villages.

» A1 villages on average have 62% more productive demand per capita than A2 villages. «

B1 villages that are dry but have good road connectivity on average have similar productive demand per capita as A2 villages that have access to water bodies but without good road connectivity. In both village types, agricultural loads drive 65-67% of the productive demand, but a combination of welding and carpentry drives the remaining productive demand in A2 villages and welding alone makes up the rest in B1 villages. This suggests that road connectivity is a strong driver of productive demand, especially welding, and can pull Type B villages up to the levels of Type A villages in terms of attractiveness for a mini-grid developer.

In terms of household demand, there is little difference in per capita demand between the different village types (all are around 1.1-1.2 kWh). However, there are significant differences in the types of uses. Economically stronger A1 villages have on average more than 57% of their demand per capita based on the use of TVs, refrigerators and other modern appliances like rice cookers and computers. Only A1 and A2 villages appear to have any significant refrigerator use. However, B1 and B2 villages also have sizable TV use.

Figure 10:
Productive uses in village types (kWh/capita/month)

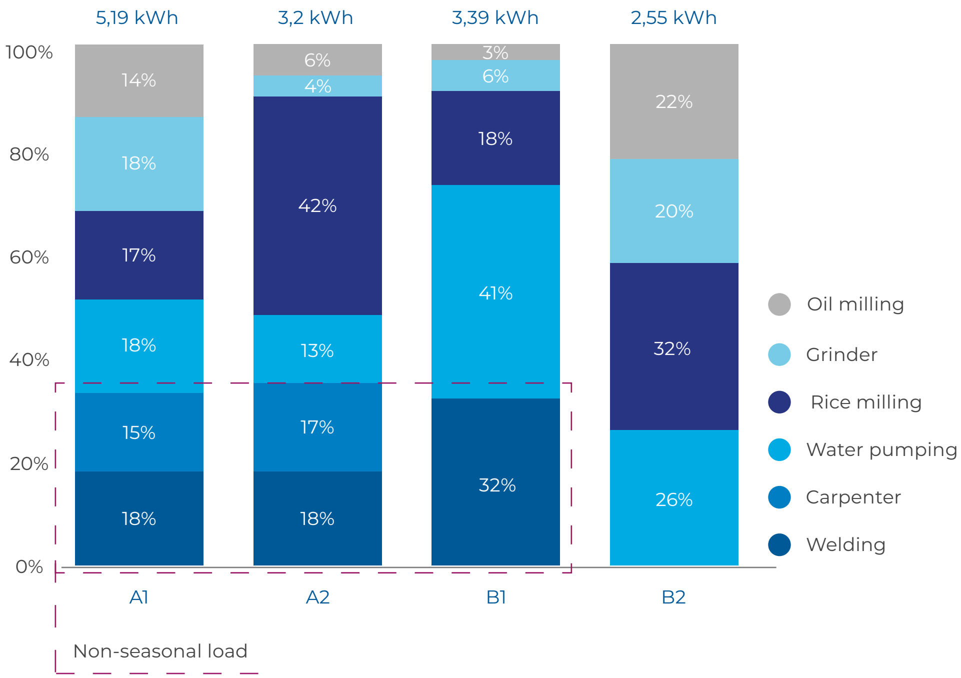
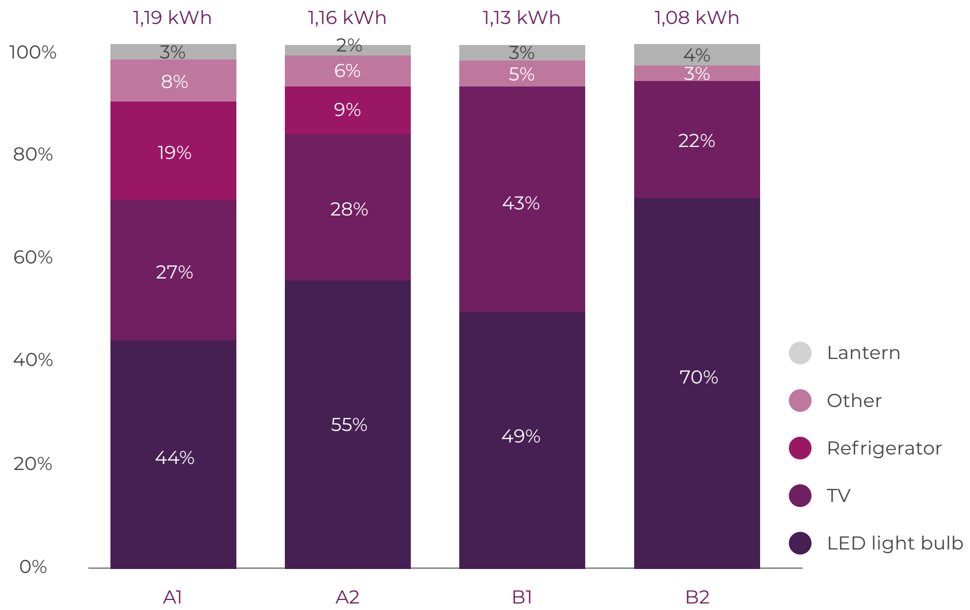


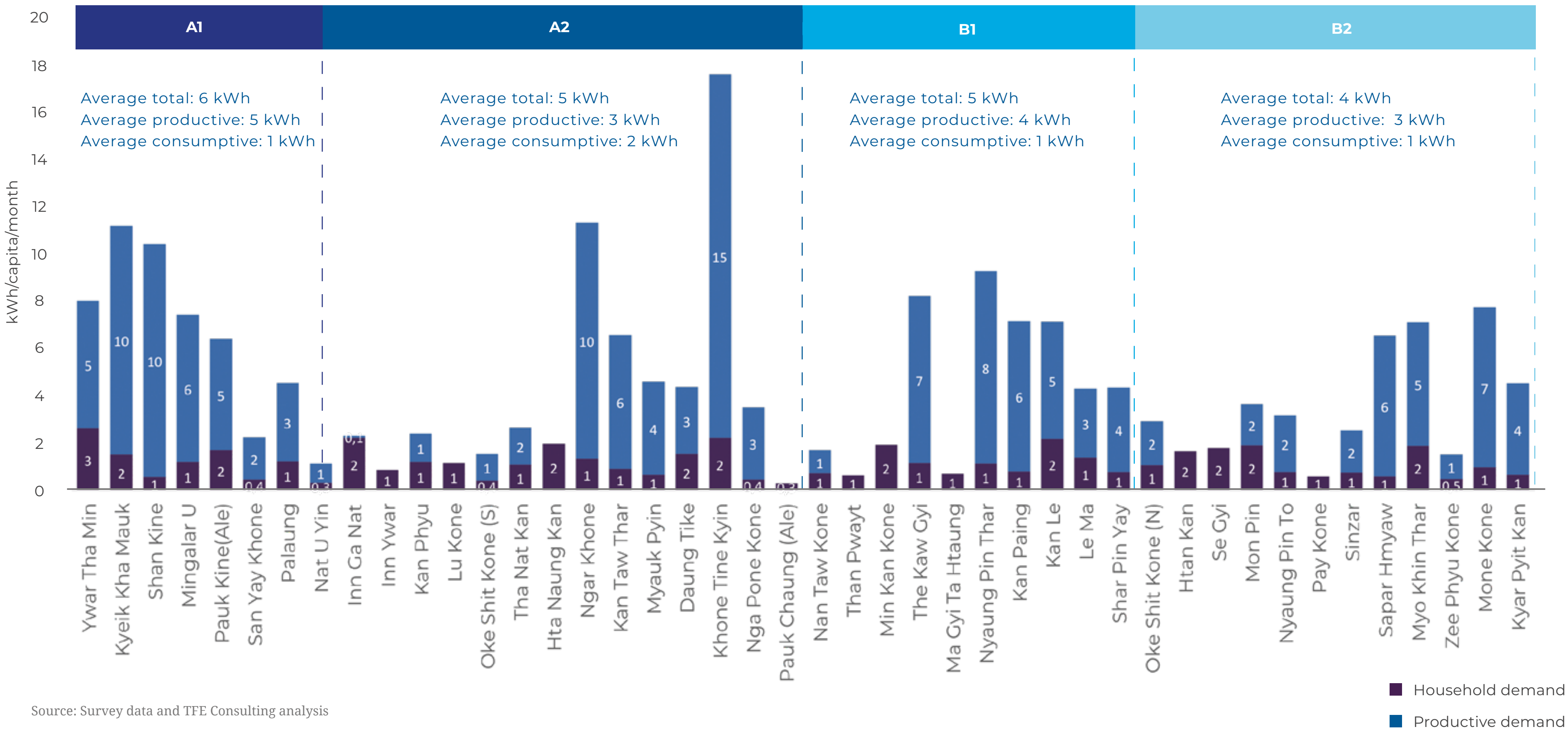
Figure 11:
Consumptive uses in village types (kWh/capita/month)



Source: Survey data and TFE Consulting analysis

Reviewing per capita demand shows that there are significant variations in the share of productive and household demand within specific village types. For example, we see in Figure 12 that within the A2 category, a village like Inn Ga Nat has almost no productive demand, but a village like Khone Tine Kyin has 15 kWh per capita per month productive demand. A wide range of social factors like education, health, women's participation, diversity of livelihoods and access to finance and economic factors like household expenditure, spend on communication and access to markets drive these variations within village types.

Figure 12:
Average household and productive demand comparison across NGC villages (kWh/capita/month)



Source: Survey data and TFE Consulting analysis

It is challenging to draw detailed conclusions on the patterns of use cases within household and productive demand across different village types because there are few clear trends. Nonetheless, what does emerge from the data is that, on average, Type A villages currently offer greater productive demand as compared to Type B villages. Therefore, villages with wetland are potentially a better fit for mini-grids compared to dry land villages. Additionally, it is also evident that road connectivity is an important driver of overall productive demand, especially for the use of machinery for welding. This effect is strong enough to bring demand in Type B dry land villages up to that seen in Type A villages with poor road connectivity. Therefore, when thinking about demand, mini-grid developers can prioritize villages on the basis of whether they have wetland and good road connectivity or not (these factors are also included in the Village Prioritization Tool shared with this report).

Key takeaways of this section

1 Village geography shapes energy demand and use types

Geographic characteristics like access to water and road connectivity are important factors that can drive larger and more diverse energy demand. Wetland villages with access to water tend to have higher and more productive demand compared to dry land villages. Road connectivity is an even stronger driver, pushing dry villages to the same level of demand and productive use as wetland villages that are not well connected.

2 Electricity use is already sizable in non-grid-connected villages

70% of the population in non-grid-connected villages already has some form of electricity access. Crucially though, 62% of the population has access through SHS and solar lighting products, suitable only for basic lighting and mobile charging. Merely 25% of the surveyed population has electricity access from diesel or petrol generators that can support larger loads like appliances and machinery.

3 Productive loads like machinery drive village electricity demand

Average per capita demand across all the NGC villages surveyed is 4.6 kWh per month. 75% of this or 3.43 kWh is productive demand. 35 out of 44 villages have productive load tied to the use of machinery for welding, carpentry, rice milling, water pumping, grinding of pulses and beans and oil milling. Only a quarter of the load is household, tied to the use of LED bulbs and appliances like TVs, refrigerators, radios or rice cookers.

4 Welding and carpentry are two productive uses found most suitable for mini-grids

Welding and carpentry are the two non-agricultural productive uses most commonly found. Together, these two activities make up close to 27% of productive demand. Machines used for these activities have a high power rating of 8-15 kW, making them a strong source of demand for high capacity mini-grids. Moreover, because such use is decoupled from agricultural seasonality, it can provide reliable demand with base-load like characteristics and potentially attractive commercial terms.

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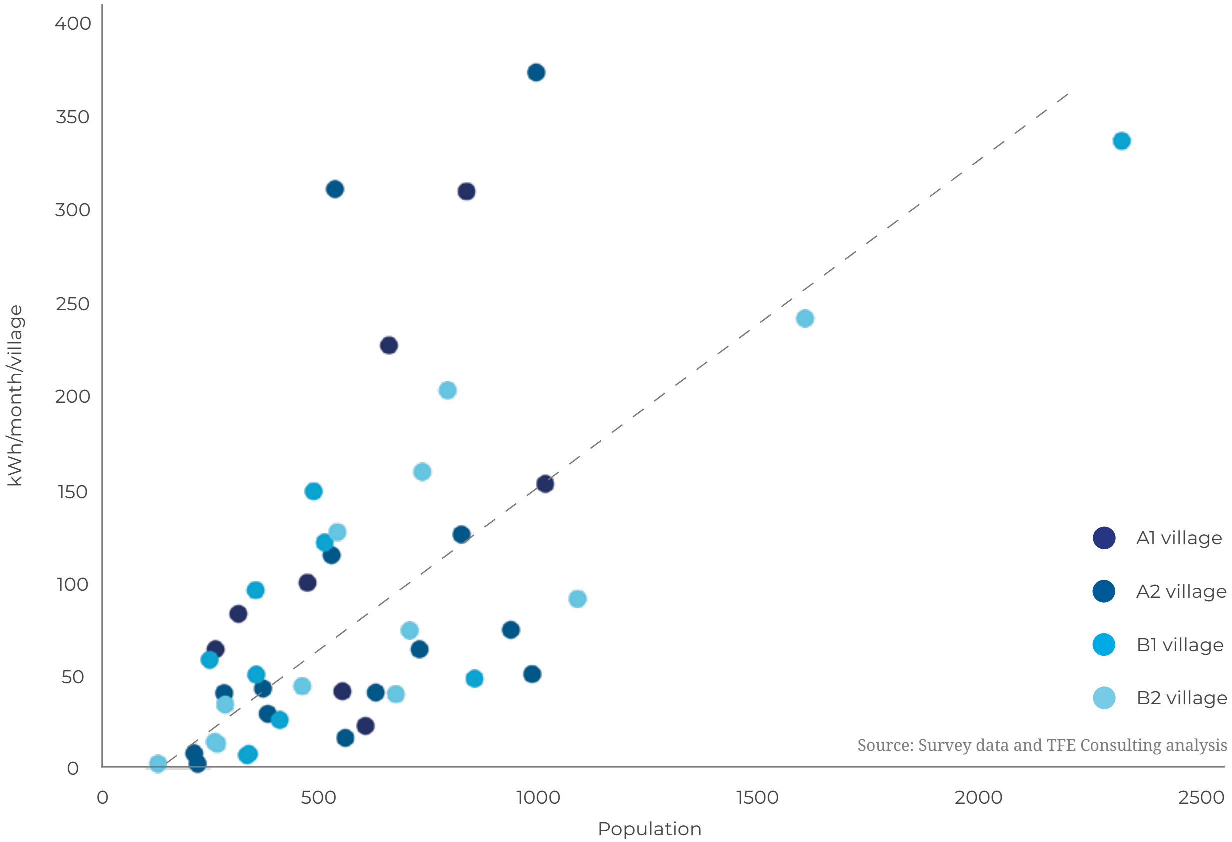
3.2 Total electricity demand and mini-grid size

Total demand in a village is a key factor in determining the size of a potential mini-grid, which impacts its viability. For a mini-grid developer, villages with large populations and high total demand require larger systems, which can reduce the cost per kWh and make for a more attractive investment case. This is because larger systems allow for greater economies of scale – as mini-grid sizes increase to match high total demand, the increase in revenue far outpaces the marginal increase in cost. In addition, size reduces the relative transaction cost per system for developing and financing it. From a development planning perspective, this raises the concern that villages with smaller total demand are less likely to be electrified by a mini-grid developer.

» Distribution infrastructure like cables, poles and transformers make up over 50% of the cost of a mini-grid «

As seen in Figure 13, smaller villages often have higher total demand and often villages of the same size can have large differences. This is because, in addition to population, per capita consumption or 'density of demand' in a village plays a key role, too. From a mini-grid developer's perspective, high density of demand is preferable to a more dispersed scenario. This is because distribution infrastructure like cables, poles and transformers make up over 50% of the cost of a mini-grid[23]. A higher density village will require less distribution infrastructure, which will reduce costs[24].

Figure 13:
Total demand vs. population size across NGC villages



Source: Survey data and TFE Consulting analysis

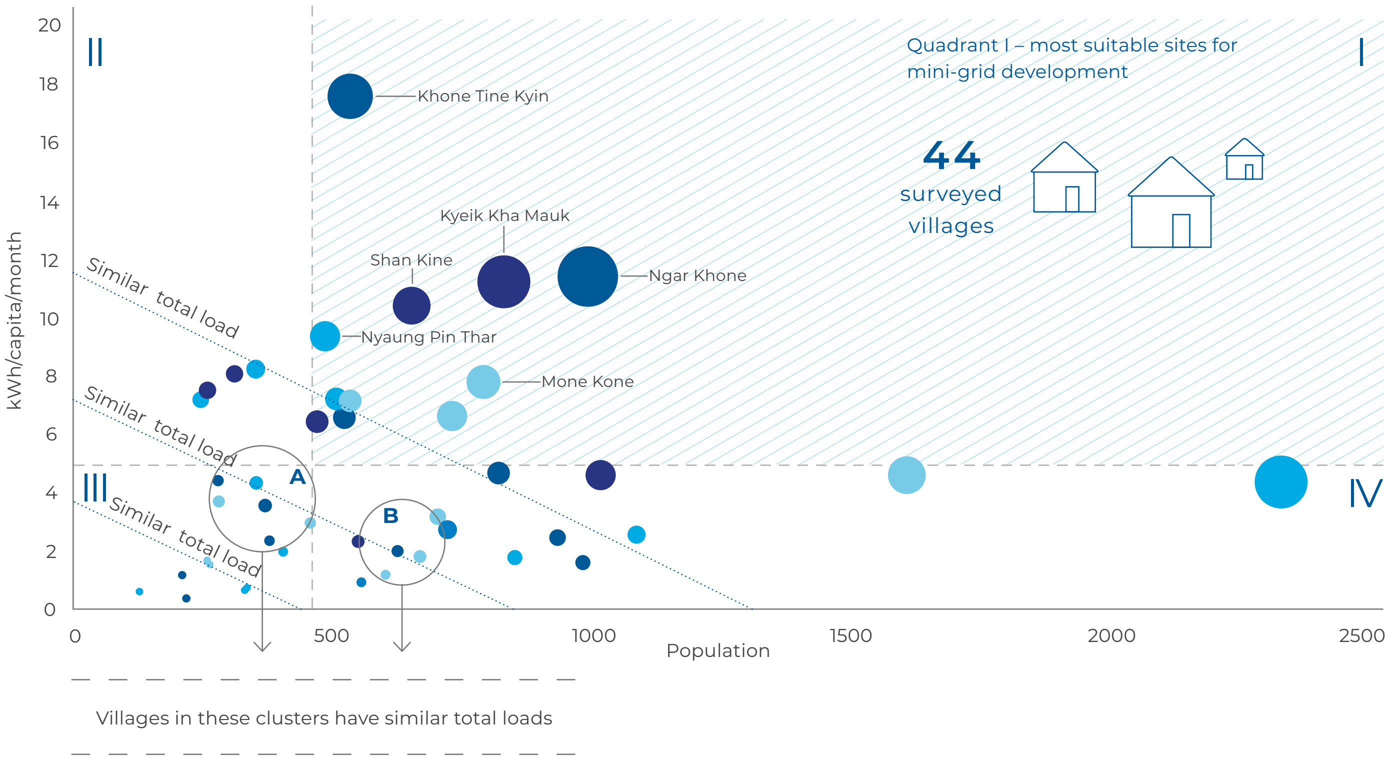
Sources:

[23]TFE Consulting "Kenya: The World's Mini-grid Lab" report

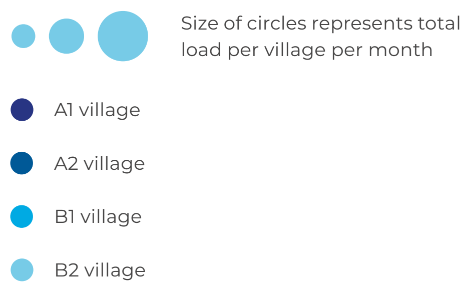
[24]Earth observation based on geo-spatial satellite technology is a valuable tool in determining the projected costs of the distribution infrastructure of a potential mini-grid site as it can, for example, rapidly provide a measure of village household density. This approach can also provide useful information such as proximity to relevant infrastructure such as roads, electricity lines and towns at scale. It can also largely be automated, providing an affordable extra data layer in determining the suitability of a large number of potential sites for a mini-grid.

Figure 14 shows that although a number of villages have relatively high total demand, they are not necessarily the most attractive for mini-grid development. For example, villages in the two clusters 'A' and 'B' highlighted with blue circles have the same total demand but villages in cluster 'A' have half the total population yet higher per capita demand compared to villages in cluster 'B'. This implies that to sell the same amount of electricity, mini-grids in cluster 'A' will likely require a shorter and more cost-effective distribution network as compared to cluster 'B'. Therefore, mini-grids in cluster 'A' might be more profitable.

Figure 14:
Per capita demand and population size relative to total demand



In this figure, total demand is a function of per capita demand and village population. We can see all 44 NGC surveyed villages represented by per capita demand and population, where the y-axis represents per capita demand in kWh per capita per month and the x-axis represents population. The total demand of each village is represented by the size of the circle. The color of the circle represents the village type. The four quadrants highlight the relative attractiveness of the villages.

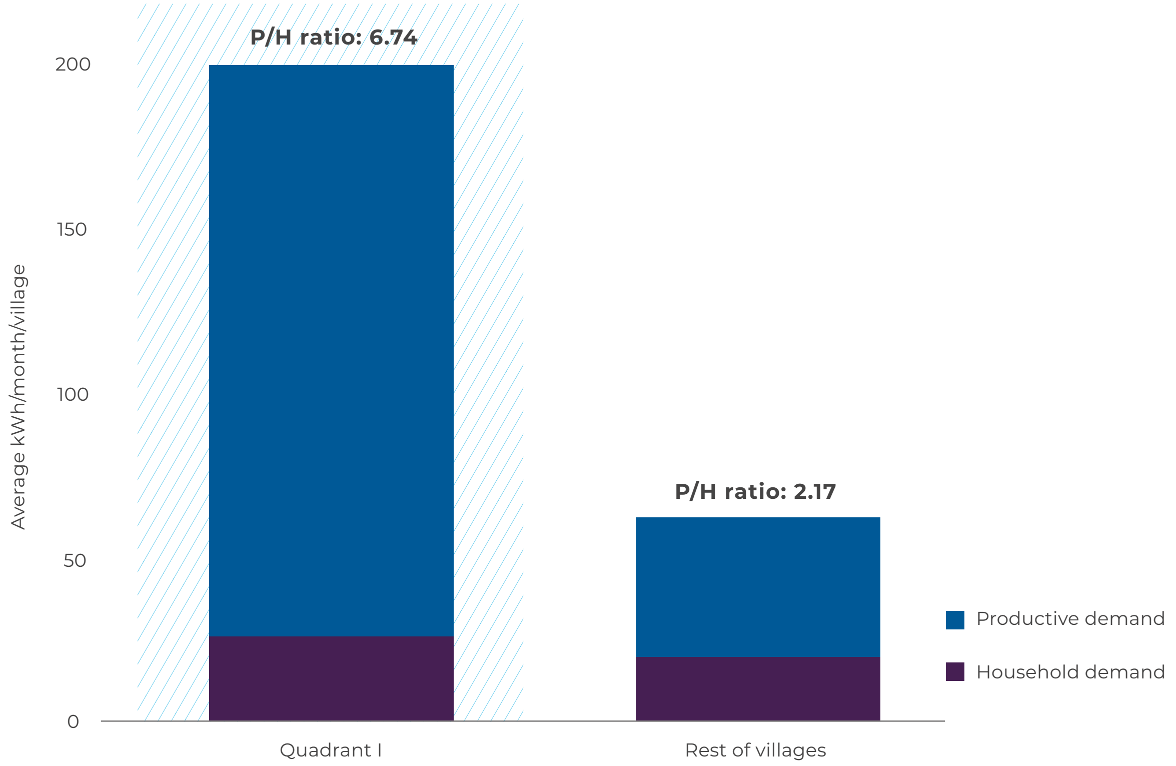


Source: Survey data and TFE Consulting analysis

Extending this analysis to all 44 NGC villages shows those in quadrant I of Figure 14 are most interesting for mini-grid developers. These 11 villages have a sizable demand (population size) at an attractive density of customers (kWh per capita per month).

The largest difference in total demand, between quadrant I villages and the rest, is the productive demand (Figure 15). The ratio of average productive demand and household demand (P/C) for villages in quadrant I is more than three times higher at 6.74 as in the rest of the villages, where the P/C ratio is 2.17. This suggests that mini-grids in quadrant I villages could derive most of their revenue and demand from a very small number of high power productive use cases.

Figure 15:
Household and productive demand comparison between Quadrant I villages and the rest



Higher productive load to household load (P/H) ratio suggests that most of the load is driven by a smaller number of large productive use cases. This means a smaller distribution network and more reliable revenue stream for mini-grid operations.

Source: Survey data and TFE Consulting analysis

Based on this analysis, below is the list of quadrant I villages with most suitable total demand for the development of mini-grids.

economic attractiveness ●●●●○

Table 1:
List of villages from **quadrant I** - most suitable for mini-grids

Sl. No.	Township	Village name	Total demand KWh/month	Population	No. of house-holds
A1 villages					
1	Salingyi	Kyeik Kha Mauk	309	831	248
2	Salingyi	Shan Kine	227	655	169
3	Mindon	Pauk Kine(Ale)	100	468	139
A2 villages					
4	Salingyi	Ngar Khone	373	991	260
5	Mindon	Khone Tine Kyin	311	531	173
6	Salingyi	Kan Taw Thar	114	523	134
B1 villages					
7	Mindon	Nyaung Pin Thar	149	482	125
8	Mindon	Kan Paing	121	508	135
B2 villages					
9	Pauk	Mone Kone	203	788	150
10	Pauk	Sapar Hmyaw	159	730	139
11	Pauk	Myo Khin Thar	127	536	110

Villages in quadrant II have relatively higher per capita demand, but relatively small populations. These villages are suitable only for small-scale mini-grid systems. However, given the relatively higher per capita demand are more attractive than quadrant II villages and quadrant IV villages with similar total demand. The attractiveness of these villages is further strengthened by the fact that they are either A1 or B1 villages that have the highest non-seasonal productive demand (as analyzed in Chapter 3.1 earlier) driven by good road connectivity.

economic attractiveness ●●●○○

Table 2:
List of villages from **quadrant II** - small, but relatively high per capita demand

Sl. No.	Township	Village name	Total demand KWh/month	Population	No. of households
A1 villages					
1	Salingyi	Ywar Tha Min	83	311	80
2	Mindon	Mingalar U	64	258	68
B1 villages					
3	Salingyi	The Kaw Gyi	95	350	87
4	Mindon	Kan Le	58	245	77

Villages in quadrant IV have large populations, but relatively low per capita demand. Given their size, the cost of the distribution network in these villages will be high, reducing their profitability. Therefore, although many of these villages have high total demand, mini-grid viability remains in question.

economic attractiveness ●●○○○

Table 3:
List of villages from **quadrant IV** – large total demand but viability risk for mini-grid development

Sl. No.	Township	Village name	Total demand KWh/month	Population	No. of house-holds
A1 villages					
1	Pauk	Palaung	153	1,011	213
2	Pauk	San Yay Khone	41	548	123
3	Pauk	Nat U Yin	23	601	121
A2 villages					
4	Mindon	Myauk Pyin	125	820	248
5	Thazi	Kan Phyu	74	933	200
6	Thazi	Tha Nat Kan	64	724	160
7	Thazi	Oke Shit Kone (S)	50	981	224
8	Thazi	Hta Naung Kan	41	624	126
9	Thazi	Inn Ywar	16	555	128
B1 villages					
10	Pauk	Shar Pin Yay	336	2,328	476
11	Thazi	Nan Taw Kone	48	850	165
B2 villages					
12	Pauk	Kyar Pyit Kan	241	1,604	319
13	Pauk	Sinzar	91	1,085	186
14	Salingyi	Nyaung Pin To	74	702	182
15	Thazi	Se Gyi	40	670	145

Villages in quadrant III are the least viable for mini-grids as they have both small population sizes and low per capita demand. With these two factors combined, these villages are least attractive for mini-grid developers from the perspective of total demand.

economic attractiveness ●○○○○

Table 4:
List of villages from **quadrant III** – least viable for mini-grids

Sl. No.	Township	Village name	Total demand KWh/month	Population	No. of house-holds
A1 villages					
none					
A2 villages					
1	Mindon	Nga Pone Kone	43	367	94
2	Mindon	Daung Tike	40	278	79
3	Thazi	Inn Ga Nat	29	378	80
4	Thazi	Lu Kone	8	210	59
5	Pauk	Pauk Chaung (Ale)	2	218	46
B1 villages					
6	Mindon	Le Ma	50	352	95
7	Salingyi	Ma Gyi Ta Htaung	8	334	88
8	Thazi	Than Pwayt	7	330	76
B2 villages					
9	Thazi	Oke Shit Kone (N)	44	456	117
10	Thazi	Mon Pin	34	281	66
11	Thazi	Min Kan Kone	26	405	98
12	Thazi	Htan Kan	14	257	66
13	Pauk	Zee Phyu Kone	13	262	64
14	Mindon	Pay Kone	3	127	34

For mini-grid developers, factoring in per capita demand in relation to total demand can make the difference in the cost and therefore viability of setting up mini-grids. Prioritizing villages that have high total demand, but also high per capita demand, like those that come up in quadrant I in Figure 14, is likely more profitable.

For development institutions looking to accelerate mini-grid deployment, focusing potential interventions on quadrant I type villages can ensure that the most cost-effective systems can be rolled out first. On the other hand, a development institution might look at the other end of the spectrum and focus on those villages least likely to be reached by commercial developers.

Key takeaway of this section

Villages with high total demand are not always the most attractive: It is important to consider the per capita consumption or 'density' of demand in a village when evaluating total demand. High demand density – meaning high concentration of demand within a given population – is preferable to a more dispersed scenario as it will require less distribution infrastructure and reduce mini-grid costs. This can make some smaller villages more attractive than some larger ones.

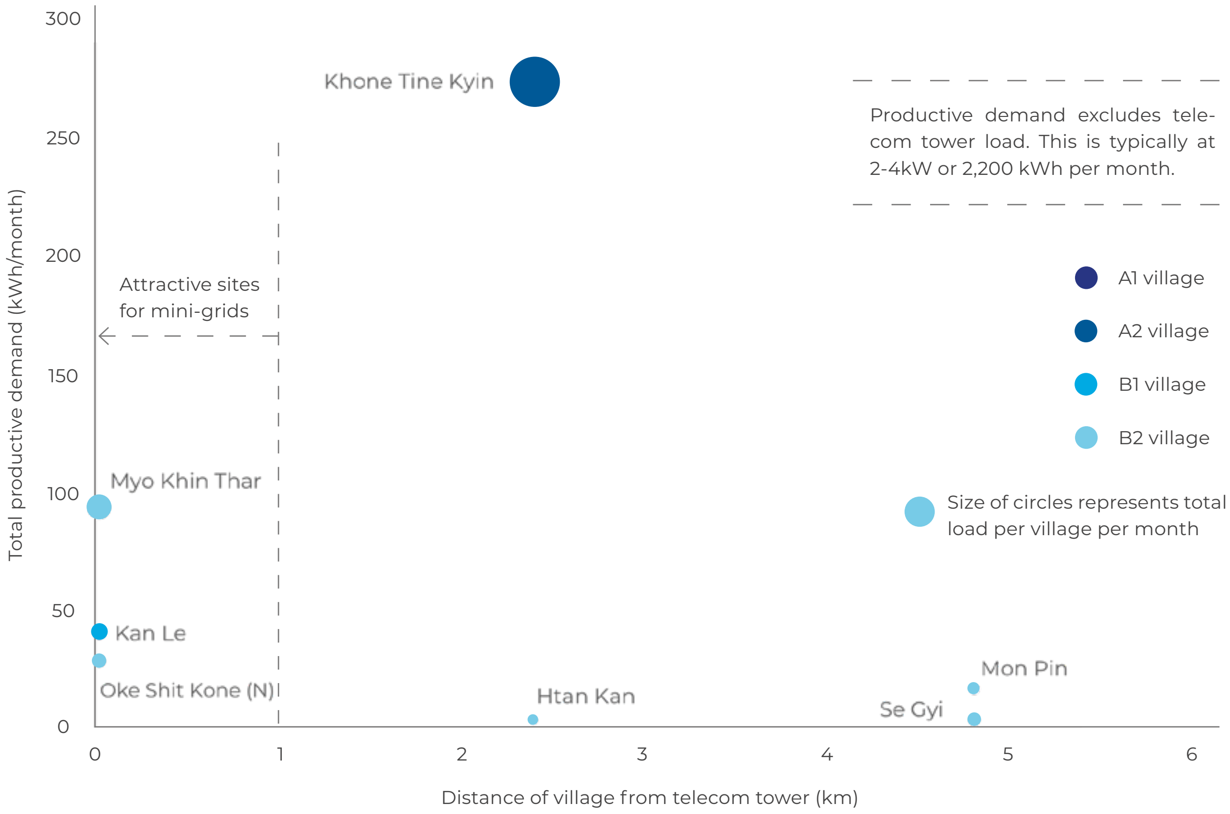
3.3 Proximity of telecom towers for anchor load

Another key factor for assessing village demand is the presence of telecom towers. Telecom towers provide consistently high demand that acts as an excellent anchor load for mini-grids. In many cases, telecom tower demand can cover the bottom line of a mini-grid operation, eliminating the risk of cost recovery. It also reduces off-taker risk as telecom operators usually are strong businesses. With the bottom line covered, supplying electricity to others in a village provides an upside and is less critical to financial viability. Additionally, the existence of a telecom tower greatly facilitates a number of key enabling technologies that underpin the operations of a commercial mini-grid. These include the ability of users to pay for energy using a mobile money platform and the ability for smart meters to communicate with the grid operator with low latency.

Despite their promise, telecom towers are useful in supporting the village electrification business case only if they are located close enough to the community. For telecom towers that are too far away, the cost of transmitting electricity to the telecom tower from the mini-grid in the village or the other way around would outweigh the benefits.

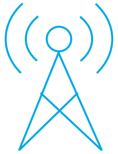
Of the 44 NGC villages, only seven have a telecom tower nearby. Figure 16 illustrates that of these seven, only three villages – Myo Khin Thar, Kan Le and Oke Shit Kone (N) – are attractive sites as they have a telecom tower within 1 km of the village, which is typically the distance beyond which telecom tower loads are no longer viable for a mini-grid.

Figure 16:
Telecom tower presence and feasibility across the NGC villages



Source: Survey data and TFE Consulting analysis

For these sites, data on the exact load of the telecom towers is unavailable as assessing this was not possible within the scope of this study. Nonetheless, depending on the location, telecom tower loads are typically 2-4 kW. This provides a benchmark monthly demand of around 2,200 kWh or close to 7x the highest productive demand of a NGC village in our sample. For the sample assessed in this study, only three villages offer a viable telecom tower site.



Of 44 NGC villages 7 have a telecom tower nearby

It is important to keep in mind that despite the anchor load advantages that a telecom tower offers, a number of additional mini-grid viability and economic or inclusive growth factors (covered in greater detail in Section 6: Village prioritization for intervention planning) plays a significant role in impacting the attractiveness of villages. These factors combined give a more holistic picture of village attractiveness, recognizing the long-term potential of villages.

Key takeaway of this section

Telecom towers are an anchor load opportunity, but only in a few cases: Despite their promise, telecom towers are useful in supporting the village electrification business case only if they are located close enough to the community. For telecom towers that are too far away, the cost of transmitting electricity outweighs the benefits. Out of the 44 NGC villages, only three villages have a telecom tower within 1 km of the village, or close enough to be a viable load for a mini-grid.

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3.4 Electricity expenditure and mini-grid competitiveness

For electricity expenditure, data collection was particularly challenging, as respondents found it difficult to recollect exact amounts and in many cases had no recollection at all. As a result, a detailed breakdown of energy expenditure is not available. This is in contrast to the more robust data gathered on energy demand.

One of the insights that the data has provided, however, is that households in the surveyed NGC villages on average spend more than MMK 7,500 (USD 6)[25] per month or 5% of their total monthly income to purchase energy (excluding for cooking). This is nearly equal to the amount they spend on healthcare and communication. Energy spend as a share of income is twice as high as compared to the grid-connected villages surveyed in the Dry Zone. One reason for this is that NGC villages spend far more on electricity than the grid-connected villages that profit from highly subsidized grid tariffs. Despite spending more on energy, however, NGC villages are able to afford only 5% of the amount of energy that is consumed in grid-connected villages, creating a sizable disparity.

» Commercial enterprises spend 96% of their electricity expenditure on generators. «

NGC villages spend money on a range of energy sources like candles, batteries, kerosene, solar home systems and diesel generators. Candles, batteries and kerosene are easy to access and affordable on a pay-as-you-go basis. However, they are used only for basic lighting. Solar home systems (SHS) are affordable for some, at a stated price of MMK 70-100 (USD 0.05-0.08) per kWh or MMK 700-1,500 (USD 0.52-1.12) per month for a 4-person household on a pay-as-you-go basis. Yet, SHS too are primarily used for basic needs, such as lighting and phone charging and, in the case of larger systems, for small appliances like fans. Electricity from generators is significantly more expensive on a per kWh basis compared to a SHS. However, the upfront cost for a generator is much lower, and they are mobile. At present, they are the only readily available source for reliable power to operate heavier loads for productive uses and larger appliances such as refrigerators.

» Electricity from generators is significantly more expensive on a per kWh basis as compared to a SHS. However, the upfront cost for a generator is much lower. «

As seen in Chapter 3.1, most energy use in surveyed villages comes from commercial, productive demand. Commercial enterprises rely heavily on petrol or diesel generators for their electricity supply. Our survey data shows that they spend 96% of their electricity expenditure on such generators. The relationship is very similar for energy spend and is consistent across village types and sizes.

Source:

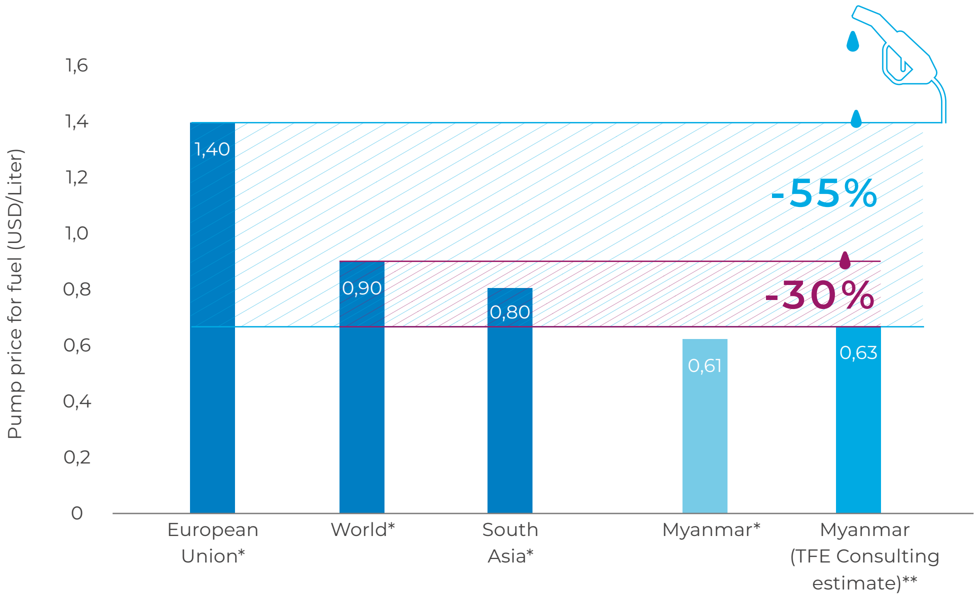
[25] At the exchange rate of USD 1 = MMK 1,334

14 of the villages spend more than MMK 1,000,000 (USD 740) each on energy per month, combined across households and enterprises. Almost all this electricity is from generators. The top village spends more than MMK 5,000,000 (USD 3,750) per month. A1 and A2 villages that have relatively higher productive demand, dominate the mix of the 14 villages spending more than MMK 1,000,000 (USD 750). Furthermore, except for two villages, all B2 villages are at the bottom in overall energy as well as generator expenditure. This is in line with the relatively lower per capita electricity consumption of B2 villages.

» Myanmar has some of the lowest diesel prices in the world at only MKK 850 - 950 (USD 0.64 - 0.71) per liter. «

Mini-grids can replace generators for productive demand only if they can compete on price per kWh, in addition to convenience and availability. Current generators are based on relatively low-cost fuel as Myanmar has some of the lowest fuel prices in the world at only MKK 850 - 950 (USD 0.64 - 0.71) per liter. This is almost 40% below the global average of MKK 1,400 (USD 1.04). In Myanmar, diesel and petrol costs are nearly the same[26]. This is partially due to the relatively low taxes on petroleum products[27]. Furthermore, villagers surveyed for this study can procure fuel from petrol stations in township centers or other urban areas almost at par with market prices.

Figure 17:
Myanmar fuel prices compared to global prices (May 2018)



Sources:

*The World Bank's world development indicators database

** TFE Consulting estimate based on market interviews; included to provide on-ground, consumer-level sense of price

[26] As of May 5, 2018. Source: www.globalpetrolprices.com and conversations with local market participants in Myanmar

[27] For example, Myanmar has a 5% tax on petroleum products compared to other Southeast Asian countries like Singapore and Thailand that tax at 20%. Source: Myanmar Times article www.mmtimes.com/news/higher-fuel-import-taxes-be-tabled.html

Figure 18:
Average quoted price for electricity from generators in NGC villages

Source: Survey data and TFE Consulting analysis

At these fuel prices, our calculations show that the operating cost of a highly efficient generator running at a maximum capacity factor is around MMK 280-320 (USD 0.21-0.24) per kWh[28]. However, in the rural setting, generators seldom are of the most efficient types. Furthermore, most of the time a generator is used under capacity: in an extreme example, someone might be running 15 W hair clippers on a 1,500 W rated generator. This means that a large amount of fuel is used for a relatively small amount of 'usefully delivered' watts. Factoring this in and accounting for fuel distribution costs, operating costs and any margins, TFE Consulting estimates the effective price of electricity from generators in a Myanmar village to be around 50% higher, at MMK 450-500 (USD 0.34 – 0.37) per kWh.

Data collected from the survey on actual spend on generator electricity broadly matches these numbers. The average price at

Sources:

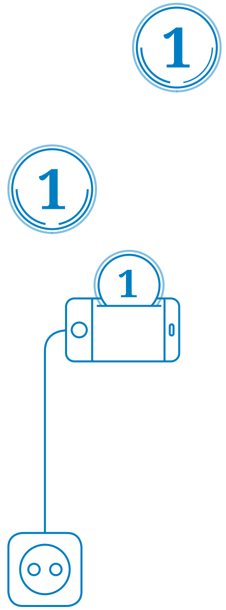
[28] Assuming standard energy content of diesel (10 kWh/liter), diesel generator conversion efficiency of 30%, and running the generator at optimal capacity.

which generator-based electricity is purchased is around MMK 510 (USD 0.38) per kWh[29]. While this rate is low for fuel-based generators by international comparison (because of the low cost of fuel), it is very high as compared to residential grid-connected electricity rates, which are as low as MMK 35 (USD 0.03) per kWh as a result of government subsidies for electricity tariffs. While looking at the survey results for generator-based electricity costs in Myanmar, it is important to note that there is a significant margin for error. As mentioned before, the level of recall of survey participants on energy expenditure was low. In addition to that, many would not consider electricity costs on a "per kWh" basis, but rather simply think of how much it costs to run a welding machine for a month or how much it costs to recharge a phone at a charging spot. Having said that, the amount of data points in the same vicinity should statistically reduce the margin of error. For comparison: research conducted by Pact and Mandalay Yoma in 2016 in 10 villages in Pakkoku and Minbu provinces found prices for generator-based electricity in rural villages to be in the range of MMK 500 to 1,200 (USD 0.37 - 0.89) per kWh. The MMK 1,200 value corresponds to the upper outliers in our data as seen in Figure 19. A further consideration is that it is likely that the cost of generator-based electricity will be higher in more remote, less accessible parts of the country, where transportation costs are higher.

The average cost of delivered power of a PV-diesel hybrid mini-grid system, including a battery, will vary widely. Today, the market for mini-grids in Myanmar is still in its early stages, with few (if any) scalable, viable, somewhat standardized projects in existence. Variations in the cost of mini-grid power will depend on, among other things, specific site characteristics (including remoteness, terrain, size, per capita demand and type of loads), technology choices (including battery capacity), project development costs (and scale of overall operations) and financing costs. With respect to the financing costs, there are several, almost invisible factors that may effectively constitute a subsidy, as both equity and debt at present is mostly "soft", i.e. not priced at real transaction and risk costs. It comes from agenda-driven financiers. Time also plays a role. The cost of equipment, such as solar panels and batteries, fluctuates from year to year with an overall long-term, downward trend.

> » Many would not consider electricity costs on a "per kWh" basis, but rather think of how much it costs to run a welding machine or to charge a phone. «

For the purpose of this study, we have looked at an estimated cost range of providing mini-grid power in Myanmar. The German development agency GiZ estimates a cost "upward of MMK 1,000" (USD 0.74) per kWh for pilot projects in Myanmar[30].

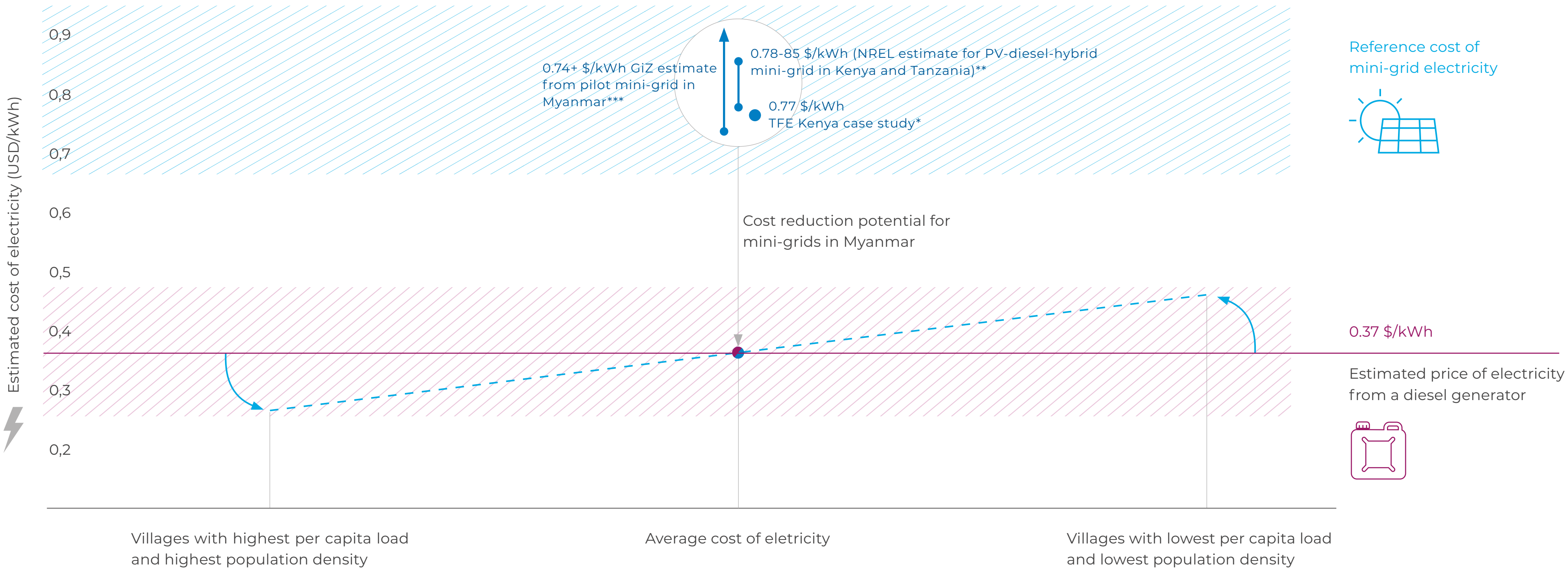


Sources:

[29] It must be noted that data collected during the survey on household and commercial enterprise monthly spend on electricity, including diesel generators is with high variation and, in some instances, of low reliability. Many respondents were unable to provide precise data on the amount of money spent specifically on electricity. To arrive at an average diesel electricity cost, a range of MKK 200-1,100 has been considered while eliminating a substantial number of data outliers.

[30] Email communication

Figure 19:
Estimated cost of electricity of a PV-and-diesel-hybrid mini-grid and diesel generators in NGC villages



* TFE Consulting report "Kenya: the world's microgrid lab"

** NREL mini-grid tool

*** GiZ email communication

Source: Survey data and TFE Consulting analysis

NREL's cost calculator tool (for Kenya and Zambia) suggests a cost of electricity of 0.78 – 0.85/kWh for a PV-diesel-hybrid mini-grid. This is at a much higher cost of diesel than in Myanmar and for a system size of 7 kW diesel generator and 5.5 kW PV system.

From this benchmark cost, we suggest a more ambitious target cost, based on the assumption that mini-grid costs can be significantly reduced. For this, we see three main drivers.

- A "China" factor: Supply lines from China into Myanmar are very strong. Chinese products have already dramatically brought down the costs of many household appliances, tools, or electronic gadgets in Myanmar. We argue that in the future, mini-grid components from China (such as solar panels, batteries, meters, etc.) will have a significant impact on mini-grid costs.
- Moving from pilots to scale: One of the reasons for assessing a large number of sites (44 non-grid connected villages) in this study is, that scale is a key driver to reduce cost. It reduces business development costs, operational costs, financing costs and the costs of components. A degree of standardization in processes can further reduce costs significantly.
- Use of (digital) technology: a number of new technology options from smart metering to earth-observation-based project development, and from remote control and maintenance to mobile payment systems, has the potential to further reduce the cost of building and running mini-grids.

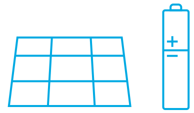
As a result, we estimate that the cost of mini-grid electricity in Myanmar can reach a level where it can compete with electricity from a generator. At the same time, we note that there is a trend towards rising prices for diesel and petrol in Myanmar[31].

The position of generators is strong, because they are considered to be well-known, reliable and flexible sources of electricity for rural commercial enterprises and well-off households – exactly the target customer groups of potential mini-grids.

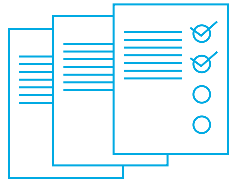
» Mini-grids could become competitive in the medium term without subsidies. «

Reducing costs

Cheaper components from China



Scale effects



Digital technologies

Source:

[31] See: Myanmar Times: https://www.mmtimes.com/news/fuel-prices-rise.html

Subsidies or other interventions from development institutions or the government could accelerate the spread of mini-grids, if this is a priority. An argument for that could be that mini-grids allow for a more inclusive and local economy to develop. A larger subsidy could help bring higher capacity mini-grid electricity to a larger number of households and potential new enterprises, thereby accelerating inclusive growth across communities.

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Key takeaways of this section

1 Non-grid-connected villages spend more but get less:

NGC villages on average spend more than MMK 7,500 (USD 6) per month or 5% of their total monthly income on energy (excluding for cooking). Although this is twice as high compared to grid-connected villages, this affords NGC villages only 5% of the amount of energy that is consumed in grid-connected villages.

2 Diesel or petrol generators are the bulk of enterprise energy use:

Enterprises rely heavily on generators for productive demand. Enterprises spend 96% of their replaceable energy expenditure on such generators. Since productive demand is a majority of energy use, spend on generators is nearly equal to the total energy spend for villages as a whole. That relationship is consistent across all village types as well as all village sizes.

3 Mini-grids will struggle to compete with generators at current prices:

Mini-grids can reduce their costs to compete with generator-based electricity.

Mini-grid costs and electricity prices vary widely. At current estimates, they are higher than those of power generators. Factors such as Chinese supply lines, scaling of solutions and adding new technology can bring down costs to levels where mini-grids can compete with generators.

4 Scenarios of future electricity demand

Out of the 50 villages surveyed for the study, six are grid-connected. They were connected in the past three to five years and give a good sense of how electricity-use evolves with access over time in the Dry Zone and possibly in other villages in Myanmar. We have used current demand in these villages as a direct reference for a projection of future demand and built scenarios of possible electricity use over the next three to five years in the 44 NGC villages. These findings, while statistically representative only for the surveyed villages, provide a strong indication of the possible scale of growth in villages more broadly in Myanmar.

» In the case of household demand, grid-connected villages today have 24 times more demand per capita than NGC villages. «

The data shows that, in the case of household demand, grid-connected villages today have 24 times more demand per capita than NGC villages. However, one cannot assume that all NGC villages, if electrified with a mini-grid, would see a 24-fold increase in demand. This is because grid electricity prices are highly subsidized and therefore not representative of a mini-grid electrification scenario. Households tend to rapidly expand their use of loads like appliances when electricity is very cheap as in the case of the grid-electrified villages. Moreover, the data also shows that there is a big shift from LED bulbs to incandescent light bulbs, possibly because they are cheaper. We call this massive rise in household demand driven by lower electricity prices the 'price effect.' Apart from price, we can expect some increase in household demand driven by rising incomes tied in part to greater productive use in the village[32]. We call this the 'income effect.'

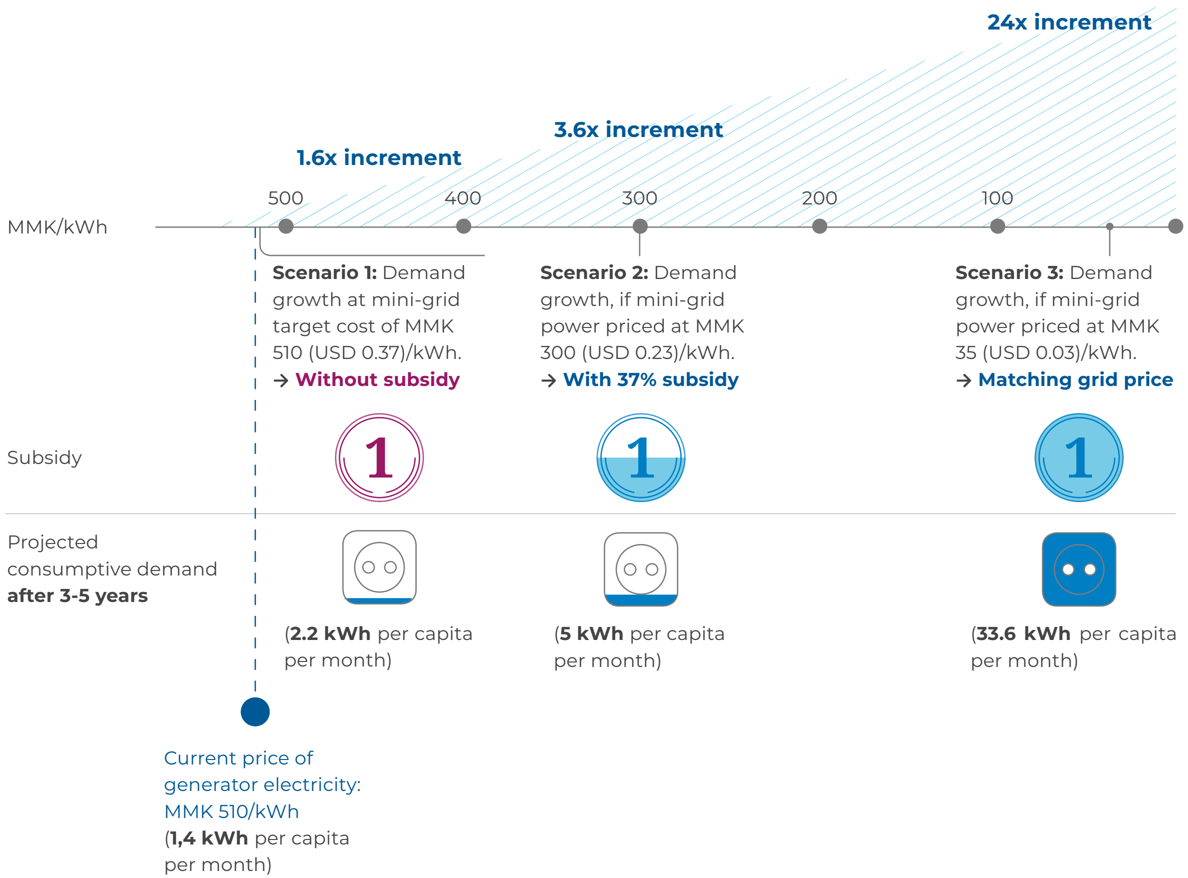
» In comparison to grid electricity, mini-grid electricity is estimated to be significantly more expensive. «

In comparison to grid electricity, mini-grid electricity is estimated to be significantly more expensive and even above the cost of diesel-generator electricity (covered earlier in Chapter 3.3). As a result, if NGC villages adopt mini-grids, they will likely not experience the price effect seen in grid-connected villages.

Source:

[32] Evidence of this effect is found in the surveyed data.

Figure 20:
Demand projection scenarios for **household demand in NGC villages with mini-grid**



Source: Survey data and TFE Consulting analysis

On the other hand, continued electricity use is likely to strengthen the local economy in mini-grid villages, which could in turn increase households' incomes and their ability to spend on electricity along the same lines as grid-connected villages[33].

» With a 37% subsidy on the current mini-grid cost of electricity, household demand could rise 3.6x «

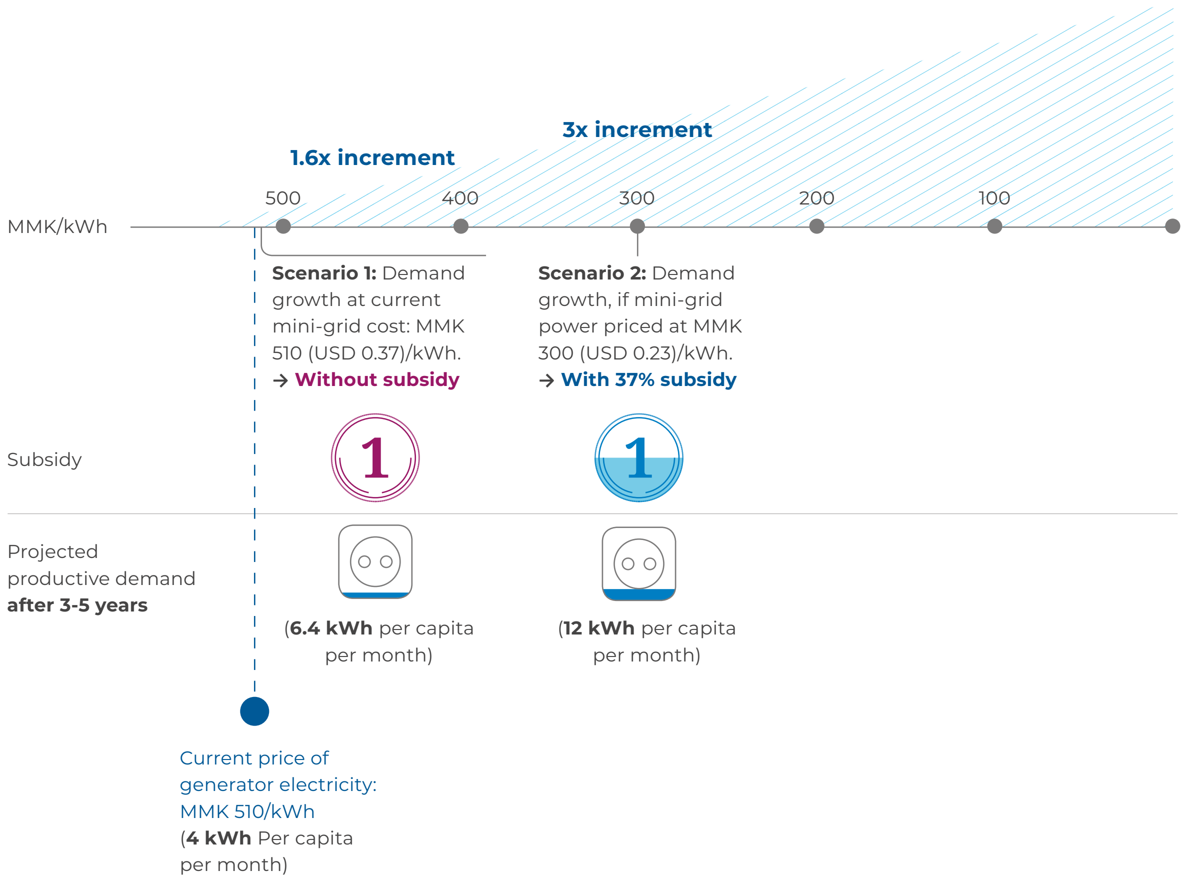
As a result, NGC villages could experience the same income effect and increase demand to the current level of grid-connected villages, excluding the price effect. Accounting for this, we project a 1.6x increase in household demand over three to five years of electrification at the current cost of electricity of mini-grids[34]. This is Scenario 1. As an alternative scenario, we have also projected that with a 37% subsidy on the current mini-grid cost of electricity, household demand could rise 3.6x (Scenario 2). If the mini-grid price were to match current subsidized grid rates, we can expect a full 24x growth in demand matching that in current grid-connected villages (Scenario 3).

Source:

[33] Evidence of this effect is found in the surveyed data.

[34] The 1.6x increase relates to where electricity demand would currently stand in grid-connected villages, after excluding the price effect.

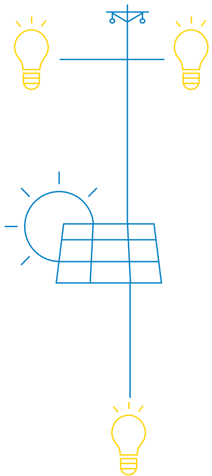
Figure 21:
Demand projection scenarios for **productive demand in NGC villages with mini-grid**



Source: Survey data and TFE Consulting analysis

On the productive side, grid-connected villages today have only 1.6x more demand than NGC villages, a stark contrast to the 24x jump seen in household demand above. A key reason, we assume, is that although businesses with productive demand have access to subsidized grid electricity, they are unable to effectively use it. Instead they continue to rely on more expensive generators. This is because the cost of a grid connection for a commercial enterprise can be as high as MMK 120,000-270,000 (USD 90-200), which is prohibitive. Also, enterprises are typically required to have a formal business license to get a grid connection. This excludes those that do not have formal documentation. For those that manage to overcome these barriers, the quality and reliability of the grid power they receive is usually poor, forcing them to continue using generators.

» The cost of a grid connection for a commercial enterprise can be as high as MMK 120,000-270,000 (USD 90-200), which is prohibitive. «



> At grid-connected villages the use of incandescent bulbs, something almost missing in NGC villages, expands the most.

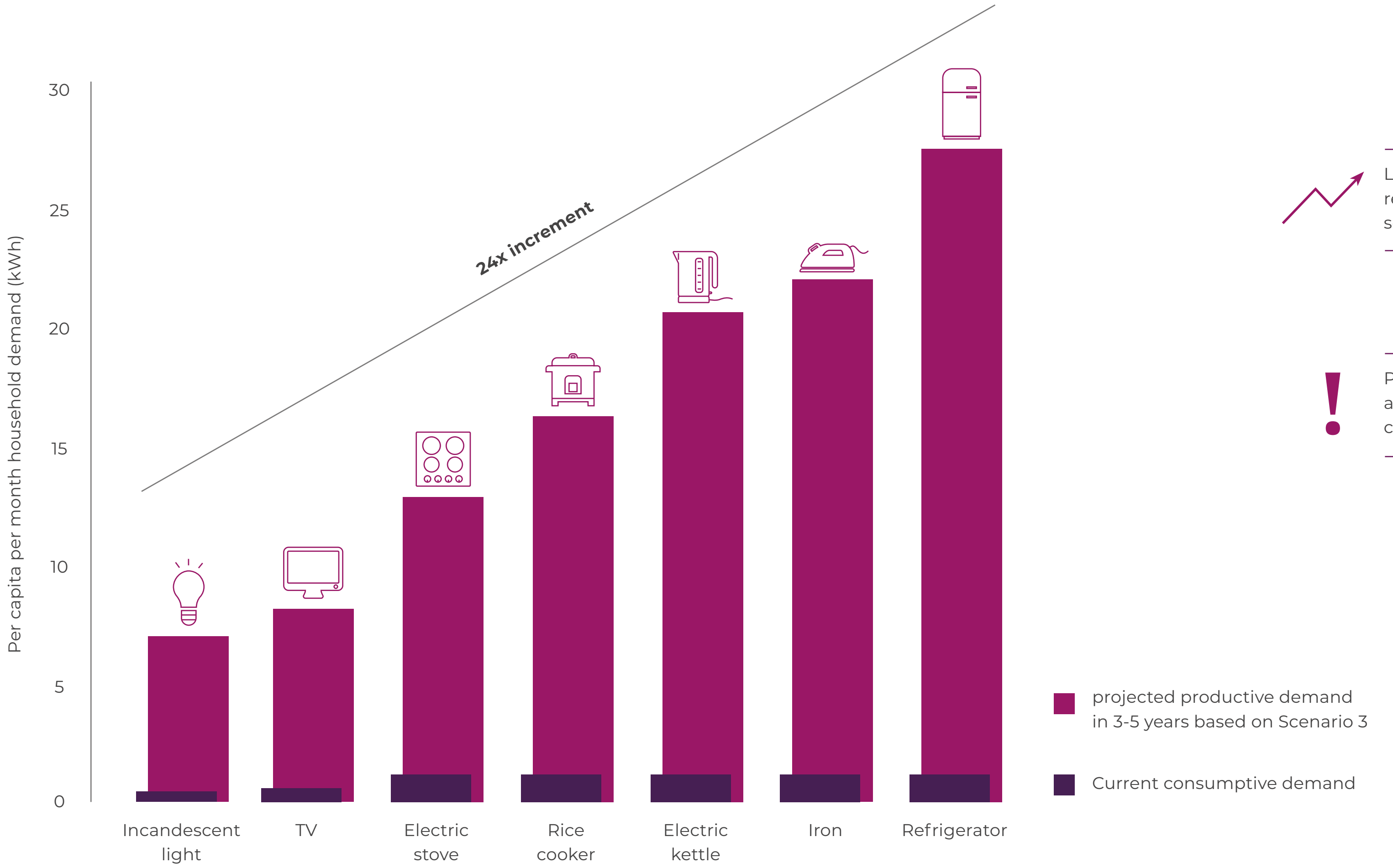
These factors mean that enterprises in grid-connected villages see no meaningful reduction in electricity prices compared to their counterparts in NGC villages and, therefore, experience no meaningful price effect that can drive growth. The only growth they experience is from the income effect tied to a stronger local economy. Since their energy mix stays the same as in NGC villages, we conclude that the productive demand in NGC villages will also increase 1.6x (Scenario 1), mirroring the growth in grid-connected villages. Here again, if we factor in a 37% subsidy on the mini-grid price, we can expect a 3x increase in productive demand (Scenario 2), as they will indeed experience a price effect. For productive demand, we cannot model a Scenario 3 where the mini-grid estimated cost of electricity matches the subsidized grid price, as we do not have a benchmark for this in the grid-connected villages.

To assess how the share of different uses of electricity could change in NGC village households over time, we can again look at grid-connected villages. In Figure 23 below, we see that the use of incandescent bulbs, something almost missing in NGC villages, expands the most. Furthermore, we see significant expansion in the use of high power rated household appliances like electric stoves, rice cookers, hot water kettles and clothes irons. These are barely or not at all a part of current household demand in NGC villages. Lastly, refrigerator use, which makes up a small but meaningful share of use in NGC villages, also grows.

When thinking about the share of household uses, again we need to exercise caution when projecting based on grid-connected villages. Here too, since the respective uses have expanded due to access to subsidized grid electricity, it is unlikely that the share will evolve similarly for mini-grid powered NGC villages, where power prices will remain high (unless highly subsidized). Furthermore, several uses seen in Figure 23 below might altogether not come up in NGC villages. For example, one can expect that uses like electric stoves, hot water kettles and clothes irons that are currently negligible in NGC villages will increase less than in grid-connected villages.

In the case of productive demand, since the electricity mix and price in NGC and grid-connected villages is similar, a projection of how uses change is more representative. In Figure 24 below we see that productive use in grid-connected villages tends to focus on activities that are non-seasonal and use high-powered machinery, while moving away from more seasonal and low powered agricultural uses. Welding stands out the most, expanding four times compared to NGC villages and displacing the dominance of agricultural uses in some villages. Some agricultural loads like water pumping and oil milling also expand.

Figure 22:
Projected share of household uses in NGC villages with mini-grid

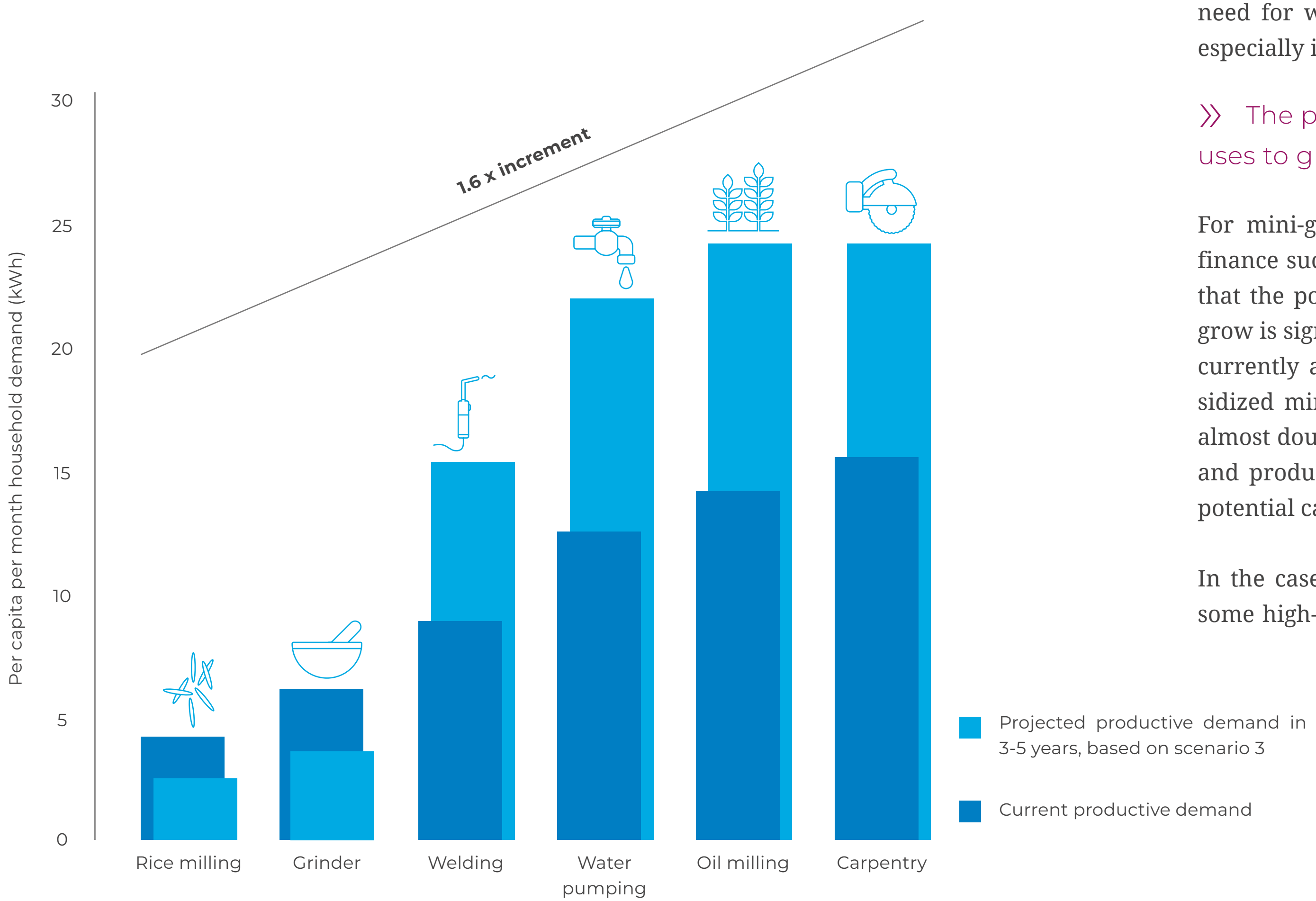


Large increases in high power appliances like refrigerators, irons, rice cookers and incandescent light.

Projected share should be assessed with caution as it is based on access to subsidized grid electricity (Scenario 3).

Source: Survey data and TFE Consulting analysis

Figure 23:
Projected share of productive uses in NGC villages



The expansion in water pumping is probably tied to the greater need for water as agricultural productive capacity expands, especially in dry land villages.

» The potential for both household and productive uses to grow is significant. «

For mini-grid developers and investors that are looking to finance such systems, the scenarios of future demand suggest that the potential for both household and productive uses to grow is significant. Even without the kind of subsidies that are currently available for grid electricity, at the current unsubsidized mini-grid cost of electricity, both types of uses could almost double in some villages where other drivers are strong and productive capacity is already high. With subsidies, the potential can be much higher.

In the case of household demand, it is likely that the use of some high-powered appliances like refrigerators and TVs will

i

Welding could grow by 4x, whereas agricultural loads either drop or have a low growth rate.

Electricity access appears to drive a shift to higher value-added activities like welding.

Source: Survey data and TFE Consulting analysis

pick up at the current unsubsidized mini-grid cost of electricity. Subsidies of the kind currently offered for grid tariffs could drastically scale demand and expand the use of high-powered appliances like refrigerators, electric stoves, electric kettles, clothes irons and TVs (it is another question if subsidies should be used to expand non-productive, household consumption).

In the case of productive demand, although only around a 1.6x increase is likely at the current mini-grid cost of electricity,

» High-powered uses like welding, which are an excellent match for mini-grids, will expand. «

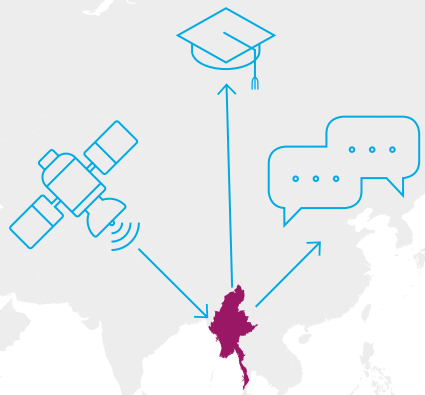
high-powered uses like welding, that are an excellent match for mini-grids, will in any case expand. If enterprises can access and effectively use cheaper electricity, demand growth will accelerate and could more than double in five years.

Providing a subsidy could no doubt be the most direct and immediate solution. This would allow mini-grids to become immediately competitive against generators and, depending on the scale of the subsidy, could make mini-grid electricity more affordable for a larger percentage of the population. For development institutions looking to accelerate productive capacity, however, this raises an important question on how and for what purpose subsidies should be offered, if at all. The current supply of subsidized power disproportionately increases non-productive household use, although this is more so because of the barriers that enterprises face in effectively using subsidized electricity. On the other hand, the data shows that although subsidies will increase productive demand, they will likely only further accelerate uses like welding. Few other productive uses take off, while agricultural uses across the board fall (as seen in Figure 24 above). As a result, subsidies would be a very blunt tool, if development institutions aim to expand productive capacity more holistically, especially with the aim of accelerating inclusive growth.

In that context, perhaps greater attention needs to be paid to interventions that can unlock productive activities, perhaps even beyond those that use welding. Improved access to finance could help communities launch more enterprises. This, combined with skills training for agricultural processing of rice, beans, oil seeds and other farm produce found in the Dry

» Satellite based remote Internet access helps improve connectivity to markets and access to information. «

Zone, could unlock a wider range of productive uses. Interventions could also be planned to offer satellite based remote Internet access leveraging existing electricity access in the villages. This would help improve connectivity to markets and access to information, factors that have the potential to improve and expand productive capacity. For example, Internet connectivity could unlock village-level remote health and remote education enterprise models that would in one go provide new demand for mini-grids and improve the inclusive growth potential of villages.



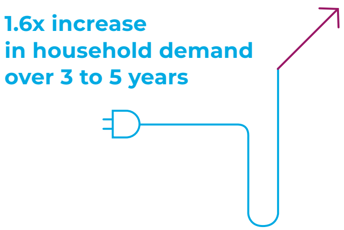
Key takeaways of this section

1 Household demand could increase around 1.6x in NGC villages

We project a 1.6x increase in household demand over three to five years, if NGC villages are electrified by mini-grids at their current cost of electricity, which is over 14x higher than current, subsidized grid rates. This is Scenario 1. With a 37% subsidy, demand could rise 3.6x and at a mini-grid price, subsidized to match current grid rates, we can expect a 24x growth in demand matching that in current grid-connected villages.

2 Productive demand could also increase 1.6x in NGC villages

At current unsubsidized mini-grid electricity rates, NGC villages could see a demand increase of 1.6x, mirroring current demand in grid-connected villages. This is because, even though businesses in grid-connected villages have access to subsidized electricity, they are unable to effectively use it. Instead they use generators, which is the same as in NGC villages. If mini-grids can compete in NGC villages, they will see a demand trajectory similar to what has taken place in grid-connected villages.



5 Human Centered Design findings

In order to complement, expand, and cross-reference our analysis, we conducted four Human-Centered Design (HCD) workshops in the townships of Mindon, Pauk, Salingyi and Thazi with participants from rural communities around the township center. Each workshop was conducted in a village since this is a familiar setting where participants feel at ease. For each workshop, a village typically a few miles outside the township center was strategically chosen to make it most convenient for participants to join, given that they were taking considerable time out of their day. The goal was to engage with a diverse range of individuals that represent as many socio-economic and energy use conditions as possible in order to get the richest pool of insights. A special focus was on drawing in an equal number of men and women and a healthy mix of age groups into the workshops.

The workshops were included in the study because they provide useful qualitative insights from focused groups of individuals in addition to the quantitative data obtained through the survey. Typically, such HCD insights are used to gain inputs for product or program design. Importantly, the ultimate goal of HCD is to test prototypes with end users and to improve them based on the insights received.

For this study, initially the goal was to test the scenarios developed from the quantitative data, playing those back to communities in order to understand if our projections fit their expectations. During the course of the project, however, we realized that using HCD in this manner was particularly challenging, as individuals will likely find it difficult to relate to abstract conceptions of future electricity use that they may not be able to relate to or even imagine. With this in mind, we decided that we would limit the use of HCD to gain insights that can validate the data we have obtained through the survey, fill any gaps, contextualize our understanding of key quantitative outcomes and bring new insights, everything that can help us develop more realistic and grounded scenarios from the quantitative data.

» The goal was to test the scenarios developed from the quantitative data, playing those back to communities in order to understand if our projections fit their expectations. «

Figure 24:
HCD workshop in theory (left) and being applied during the HCD workshop in Salingyi (right)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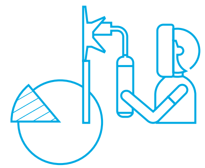
© Kyaw Naing/DRI

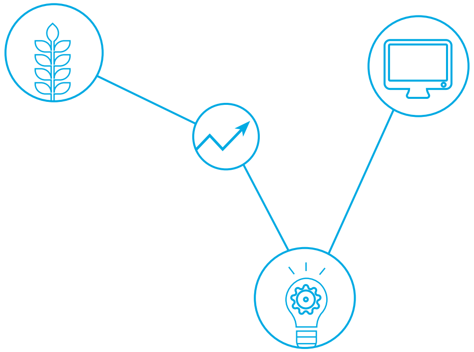
Specifically, the following three goals were set for the HCD workshops:

1. Assess whether the survey data fits what individuals express about their day-to-day activities in the HCD workshops.
2. Gain insights on demand side factors that can support the realization of demand potentials, particularly with respect to productive uses.
3. Gain insights on communities' ideas and aspirations, status symbols, purchases and use trends that can complement our understanding from the survey.

survey data = day-to-day activities?



gain insights



1 Insights on productive uses

We looked at current income sources to validate productive uses of electricity. The primary sources of income mentioned across a number of 'personas'[35] were farming and livestock rearing. Tied to these, participants mentioned several mechanical activities such as rice and oil milling, grinder machines for pulses and beans, and water pumping. These activities match the productive uses identified in the survey. An additional use case that did not come up in the survey but was mentioned frequently in the HCD workshop was weaving (mat production), while this presumably requires little electric machinery, it can be kept in mind by mini-grid developers and development institutions when planning their engagement with villages. Additional enterprise activities mentioned were bamboo basket making, hairdressing and snack making.

» An additional occupation that did not come up in the survey but was mentioned frequently in the HCD workshop was weaving (mat production). «

A major productive use reflected in the survey data is welding, but this was not mentioned in any of the HCD workshops. This might be coincidental. Equally, nothing mentioned in the workshops suggested that the survey findings on welding are wrong or inaccurate. On the other hand, an insight that indirectly points to the importance of welding is the increasing use of motorcycles in and around villages. In the past few years, participants have been investing in transportation and spending considerable amounts of money on fuel for motorcycle use. This suggests a corresponding rise in mechanical repair shops, transport service shops and fuel pumps that would all use welding.

A key insight shared was that many participants live off the money sent by younger family members working abroad or on the salaries from family members who have a stable job in government or at a larger company in the township centre. This suggests that rural communities of the kind surveyed have the required skills and education but find it difficult to access

Source:

[35] A key aspect of HCD, 'personas' refers to groups of individuals with distinctive archetypes that 'personify' the insights gained in the workshops. Grouping individuals in this way can help to understand e.g. potential electricity users, their goals and ambitions for work, and preferences in terms of expenditure.

jobs or start enterprises that can support their livelihood in the village. For mini-grid developers, this means that potential demand could be larger than expected, if the right conditions allow for the development of the local village economy. For development institutions this means that there is significant room for interventions to unlock productive potential within rural communities.

Another useful insight tied to the migration trend is that due to a large number of young individuals migrating away from rural areas in search of better-paid jobs, labour costs for farmers have increased drastically in the past years. Labour that is staying behind in villages is becoming more skilled and, therefore, more expensive. As a result, many farmers are looking to purchase machinery for work in the fields. This again expands the use of high capacity welding and other transport oriented services that could provide viable loads for mini-grid developers. Furthermore, as individuals become more skilled, it could push them to set up additional enterprises around mat making businesses, steel work, furniture work and other type of small-scale industry that were also mentioned by the participants.

2 Insights on expenditure

Over the past years, expenditure on entertainment (TV and video) and communication (telephone charging and bills) has increased for the workshop participants. Other than this, participants mentioned high expenditure on lighting, cooking and pumping ground water for household consumption. However, when asked about their actual expenditure amounts, participants were almost always unable to recollect specific expenditure amounts and insights on this were few. This fits with the challenges of data collection during the survey with respect to expenditure details.

3 Additional insights

The socio-economically disadvantaged tend to think primarily about investing in land and livestock, which do not involve energy use. To own a piece of land is considered the first step towards a better life and necessary before thinking about expanding work opportunities or household consumption. This suggests that villages with high rates of casual workers and low socio-economic status will likely invest less in productive uses.

> » Another factor which influences adoption of electricity in productive ways is the proximity to a village already connected to electricity. «

Another factor that influences adoption of electricity in productive ways is the proximity to a village already connected to electricity. This is an important factor to consider since it gives individuals a clearer picture on what they could use electricity for and aspire to own appliances or even start new enterprises that rely on electricity. Also, villagers who already have some electricity for lighting for example tend to want to have more of it for cooking or watching TV, for example, and have ideas on opening shops to sell electrical appliances.

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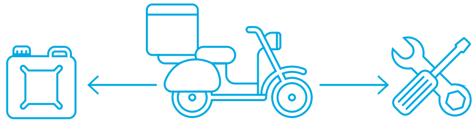

The HCD insights broadly substantiate our most important survey takeaways: a wide range of productive uses are prevalent, and welding is highly relevant and expected to expand as services supporting transportation increase. As a result, our assessment of current energy use and scenarios of future demand remains unchanged.

» Migration is an important dynamic in the villages in the Dry Zone. «

The HCD insights also show that migration is an important dynamic in the villages in the Dry Zone. For mini-grid developers, the potential shift to machinery supports expectations of future demand. For development institutions, this raises important questions on what kinds of interventions can support individuals in realizing their potential at the village level and contributing to the local economy. This is particularly important as large sections of the village population are still low on the socio-economic ladder, unable to improve their livelihood beyond basic farming.


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6 Village prioritization for intervention planning

Data from the survey was analyzed to prioritize villages for mini-grid developers as well as for development institutions. Villages were ranked and clustered into three buckets – Priority 1, 2 and 3 – to fit the decision-making needs of both mini-grid developers and development institutions. To effectively rank and cluster the villages, a mini-grid assessment engine was used. This engine allows us to rank villages on factors including but not limited to electricity demand – it can be programmed to obtain a ranking that includes multiple socio-economic factors that impact rural communities and, therefore, electricity demand.

To analyze and rank villages, three major types of drivers were used: mini-grid viability drivers, economic drivers and inclusive growth drivers. Key questions on individual household's (HH) overall energy use, productive uses of energy, projections of future demand, and socio-economic characterizes such as wealth distribution within the village, level of education attained, number of women in leadership roles, were asked during the survey. This data was consolidated, normalized and entered into the three major drivers to rank the villages.

The three major drivers were given different weights to prioritize villages. While ranking villages for mini-grid developers, the highest weight was given to mini-grid viability drivers (60%), followed by economic drivers (30%) and inclusive growth drivers (10%). For development institutions, this weightage was reversed for the same set of drivers.

» While ranking villages for mini-grid developers, the highest weight was given to mini-grid viability drivers (60%), followed by economic drivers (30%) and inclusive growth drivers (10%). For development institutions, this weightage was reversed for the same set of drivers. «

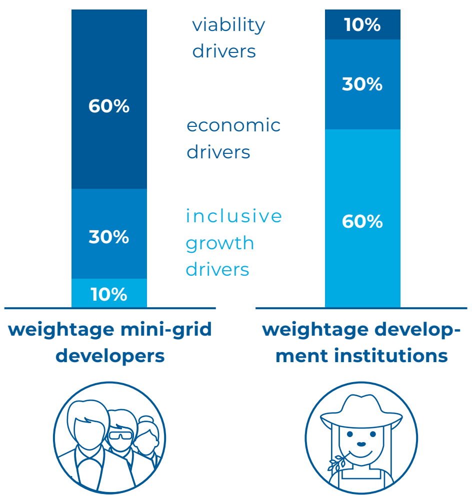
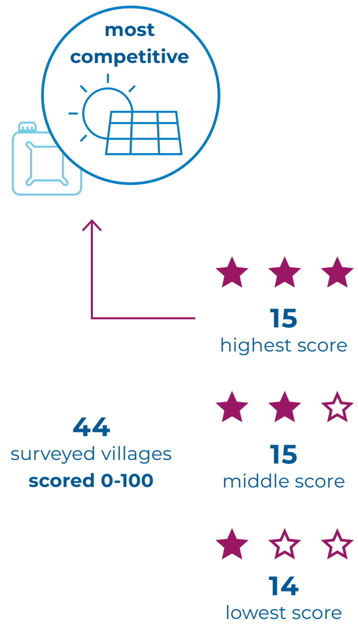


Table 5:
Key indicators and their weights for village prioritization

	Mini-grid viability drivers	Economic drivers	Inclusive growth drivers
	Per capita demand	Household spend	Portion of educated population
	Total demand	Spend on communication	Prevalence of common disease
	Spend on generators	Access to market	Female participation
	Projected demand (in 5 years)	Access to roads	Diversity of livelihood
	Productivity of uses (P/C Ratio)		Access to finance
	Non-seasonal, high-load machinery use		
	Presence of telecom tower within 1 km from village		
Weights used for mini-grid developers →	60%	30%	10%
Weights used for development institutions →	10%	30%	60%

From the 44 NGC villages surveyed, the top 15, middle 15, and lowest 14 were compared and grouped based on the key indicators mentioned above. Each village was scored between 0-100, the village with the highest score being the strongest village on each indicator.



6.1 Village prioritization for mini-grid developers

Priority 1: Villages with strong mini-grid viability drivers

Figure 25:
Villages with strong mini-grid viability drivers

Strong energy use

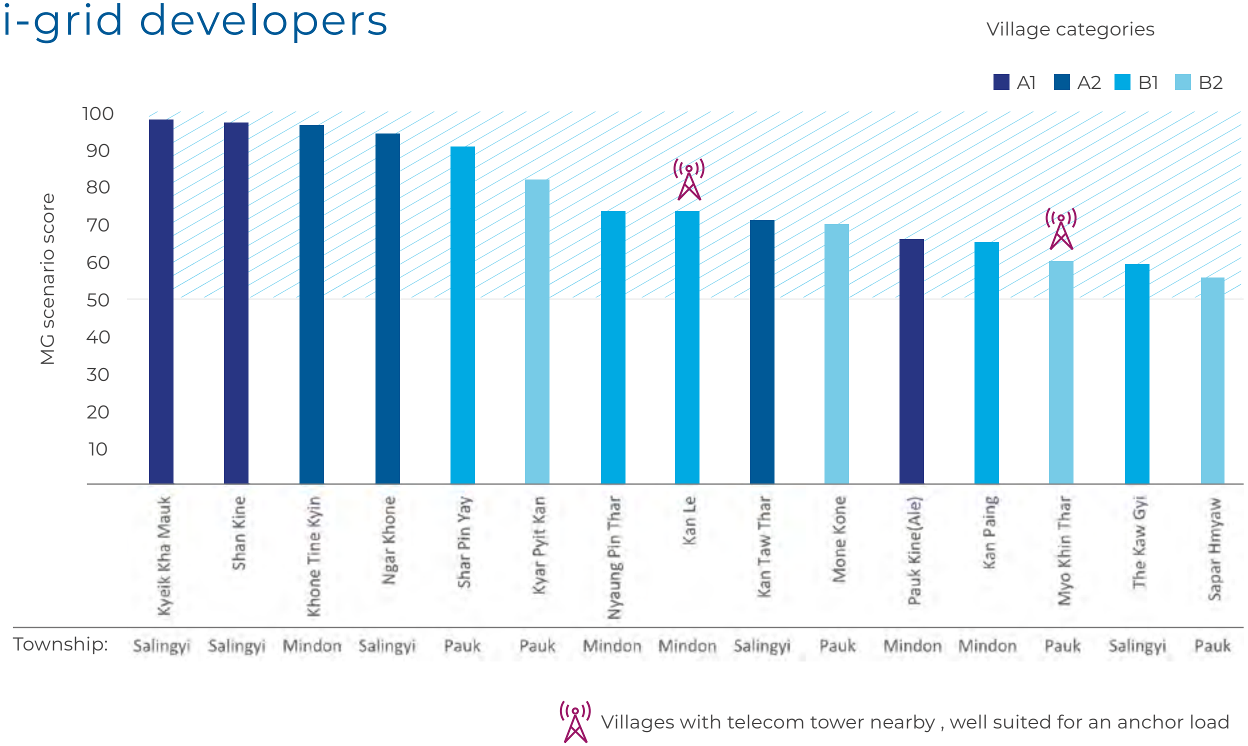
- High use of electricity for productive use cases
- Large variety of non-seasonal and industrial productive use cases.
- Large demand growth potential
- Availability of telecom towers in two villages for anchor load

Strong economic drivers

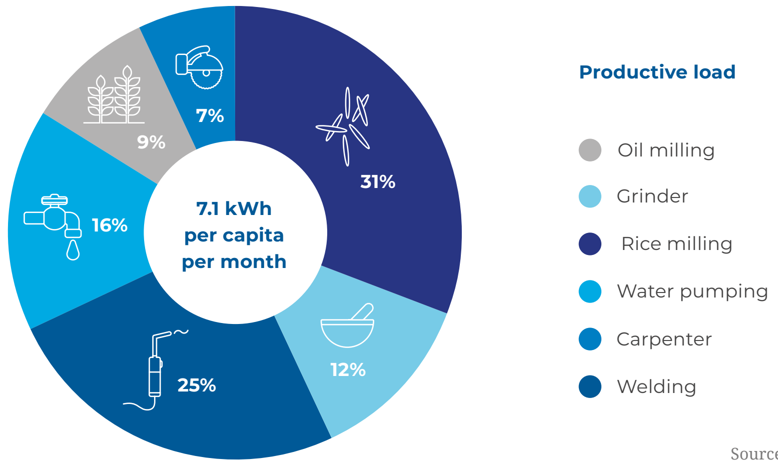
- High household income and spend
- High spend on communication
- Better access to market
- Low exposure to financial shocks

Strong inclusive growth driver

- Favourable demography including village education
- Relatively large participation of female
- Better diversity of livelihood
- Better access to finance



Mini-grid indicators (average of 15 villages)	
Per capita load	8.3 kWh/month
Total energy	195 kWh/day
P/C ratio	6.8
Spend on generator	2,030,715 MMK/month
Potential growth in demand	High
Powerable occupation	High



Source: Survey data and TFE Consulting analysis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These top 15 villages are the most suitable for mini-grids within the sample of NGC villages: they have 80% higher per capita demand when compared to the average demand in the 44 NGC villages and more than twice the productive demand of the other villages. These villages should be prioritized for mini-grid development.

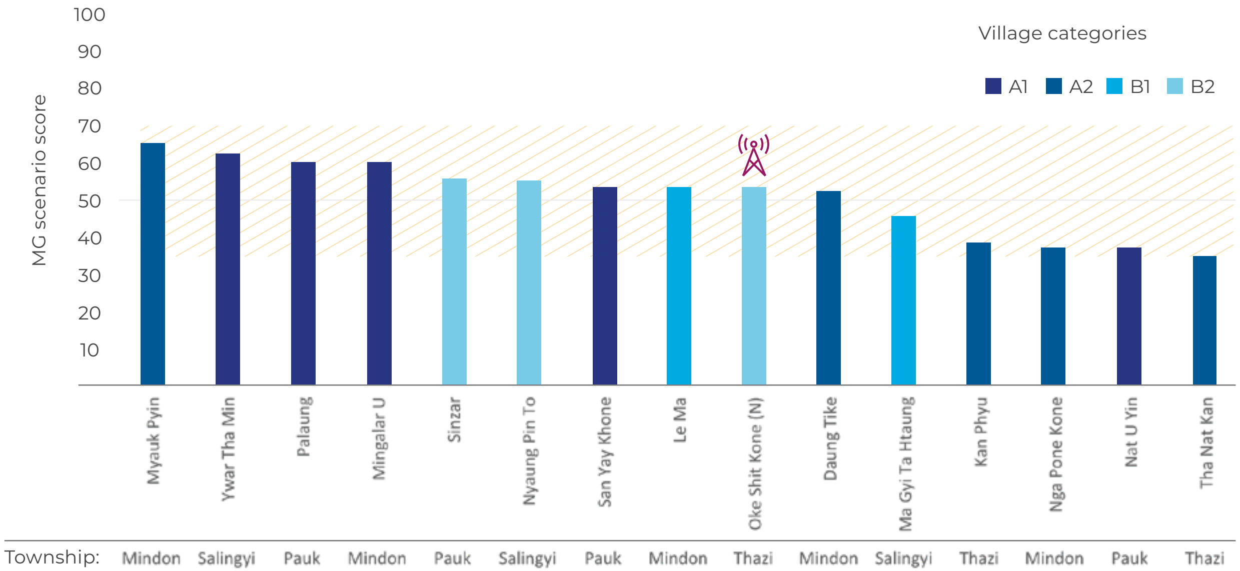
The combination of available productive demand is ideal: high-powered, non-seasonal industrial demands like welding and carpentry. This mix is quite similar to the mix we see in prosperous grid-connected villages. A very high P/C ratio in these villages implies that a few large customers will likely generate most of the revenue for a mini-grid. Also, distribution cost will likely be low if mini-grid design could be optimized to sell a large part of energy production to a handful of large enterprises that tend to be clustered in the village. 'Dense demand' in these village means that it is quite likely for mini-grids to achieve a cost of electricity that is nearly competitive with diesel generators.

» A very high P/C ratio in these villages implies that a few large customers will likely generate most of the revenue for a mini-grid. «

These are also villages with the strongest economic and inclusive growth drivers relative to the rest. As a result, the local economy has the strongest potential for growth, an aspect that makes it most likely that the projected future demand scenario will fully play out here. Given that a number of energy-dependent occupations are already prevalent, it is likely that electricity demand will rise fast with economic growth.

Priority 2: Villages on the edge

Figure 26:
Villages on the edge in mini-grid viability drivers



Average energy use

- Good use of electricity for agricultural productive use cases
- No high value generating loads like welding
- Average P/C ratio
- Risky for mini-grid operation

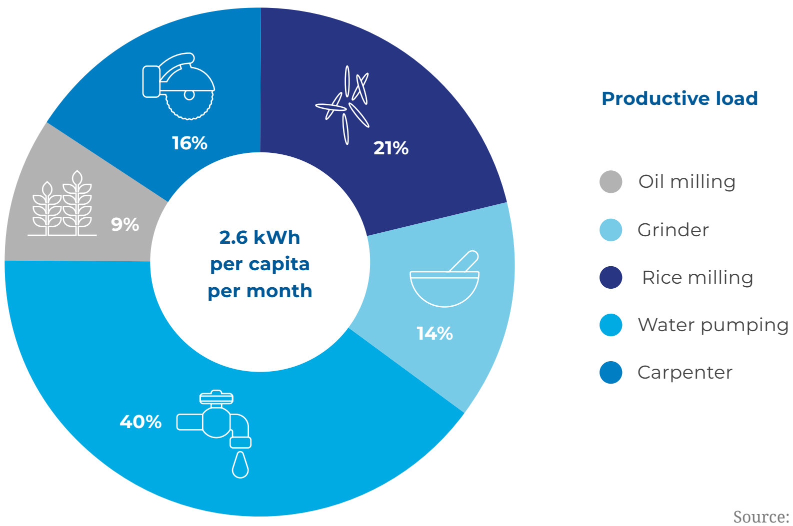
Average economic drivers

- Average household income but relatively higher spend
- Good access to market and road
- Low exposure to financial shocks

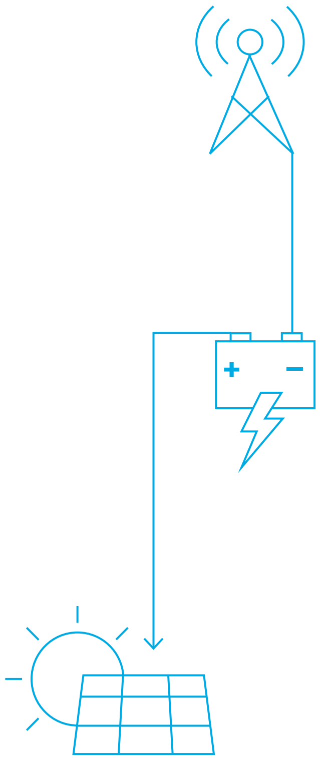
Average inclusive growth driver

- Average demography and village education
- Low participation of female.
- Good diversity of livelihood
- Better access to finance

Mini-grid indicators (Average of 15 villages)	
Per capita load	3.6 kWh/month
Total energy	65 kWh/day
P/C ratio	2.6
Spend on generator	712,350 MMK/month
Potential growth in demand	Average
Powerable occupation	Average



Source: Survey data and TFE Consulting analysis



Two villages – Kan Le and Myo Khin Thar - have a telecom tower near enough to be effectively used as anchor load. This could allow mini-grid developers to cover their bottom line and rely on other productive demand in the village to improve the system's viability.

Given the strength of these villages on mini-grid viability factors as well as economic and inclusive growth factors, further development interventions are not critical. However, the business case for mini-grids could improve drastically if development institutions offer developers low cost, patient capital that reduces costs for systems overall. Improved viability could strengthen the case for developers to enter these villages faster. Furthermore, support from development institutions to unlock technology solutions, especially satellite-based earth observation and remote operations technologies, could improve strategic planning, data capture and operations of mini-grids, further strengthening their business model.

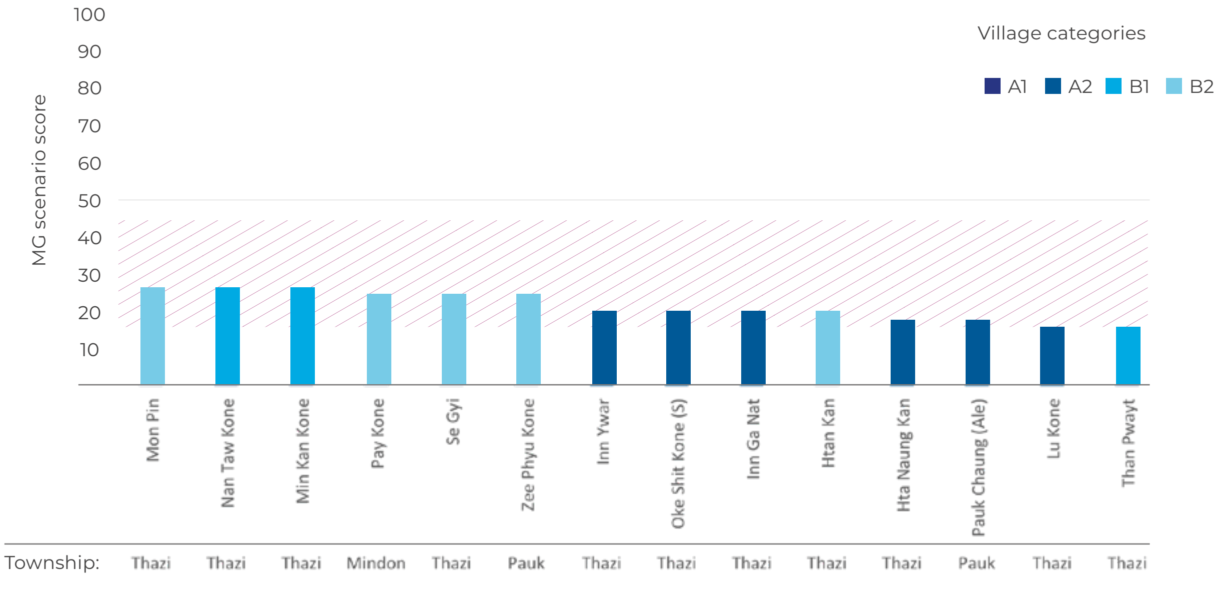
These villages have the potential but are not yet suitable for mini-grids. This is because although these villages have productive demand, they are almost entirely agricultural. The seasonality of such demand presents a significant challenge to the stability of mini-grid cash flows. Apart from one village that has a telecom tower with the potential for anchor load, lower than average per capita productive demand in these villages makes them less attractive.

Moreover, a low P/C ratio means that household customers will make up a large share of demand. With fewer enterprise customers that are likely to use high priced generators, mini-grids in these villages will struggle to find paying customers. Furthermore, even if enough high paying household customers are available, mini-grid cash flows will face significant uncertainty from potentially fickle household demand. Lastly, low productive demand relative to household demand also means that mini-grids in these villages will likely have high distribution costs. As a result, they are likely to be more expensive when compared to generators. Over time, development interventions like access to finance, skills training and improved connectivity with markets could improve productive capacity in these villages and unlock productive demand, making them more suitable for mini-grids. More immediately, if a subsidy was offered, mini-grids in these villages could find a viable business case faster.

» Over time, development interventions like access to finance, skills training and improved connectivity with markets could improve productive capacity in these villages and unlock productive demand, making them more suitable for mini-grids. «

Priority 3: Villages with weak mini-grid viability drivers

Figure 27:
Villages with weak mini-grid viability drivers



Poor energy use

- Low per capita load
- P/C ratio of less than 1 implies very low productivity in these villages
- No industrial productive load
- Low spend on electric generators
- Very low powerable occupations

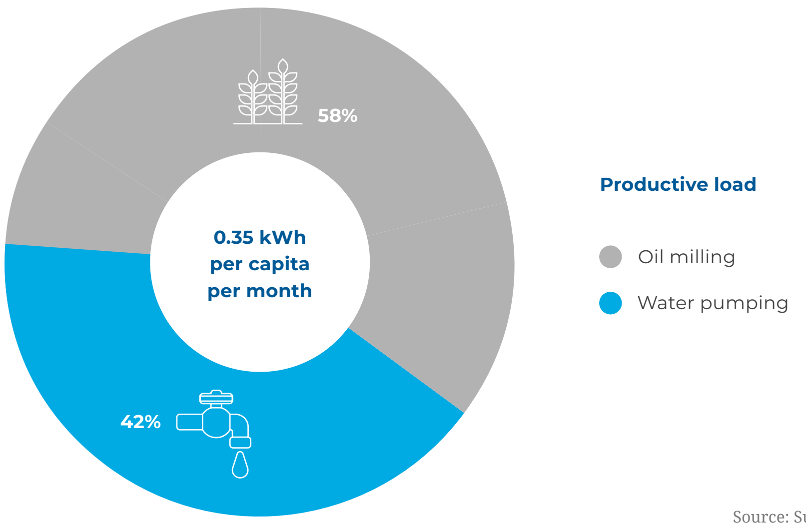
Poor economic drivers

- Low household income
- Poor access to market and road
- Large spend on communications when compared to income generated

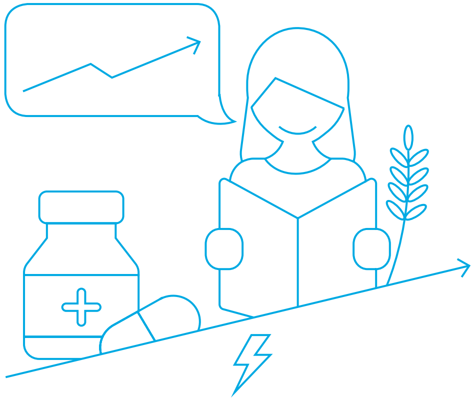
Poor inclusive growth driver

- Poor female participation
- Low access to finance
- Poor diversity of livelihood

Mini-grid indicators (Average of 15 villages)	
Per capita load	1.5 kWh/month
Total energy	24 kWh/day
P/C ratio	0.53
Spend on generator	177,760 MMK/month
Potential growth in demand	Low
Powerable occupation	Very low



Source: Survey data and TFE Consulting analysis



These villages have low demand and a markedly weak business case for mini-grids. This is because these villages are at the lowest end of the sample distribution in per capita productive demand amongst the 44 NGC villages. In most of these villages, productive demand is altogether lower than household demand, exacerbating the risks present in Priority 2 villages. Although three of these 14 villages are in proximity to a telecom tower, their distance from the village is too far to be considered as viable anchor loads. Only one village (Oke Shit Kone, N) has a telecom tower within 1 km of the village, close enough to be a viable anchor load. However, due to weaknesses in other mini-grid viability factors and particularly low economic and inclusive growth indicators (mentioned below), the telecom tower is not enough to make this village attractive for mini-grid development.

These villages are also markedly weak on inclusive growth drivers. This means that they are least likely to match the projected demand potential for NGC villages and will likely have very slow growth in electricity demand. In their current state, these villages will struggle to become relevant for mini-grids without strong intervention by development institutions.

Subsidies could be a quick answer to make these villages more attractive. However, a combination of weak mini-grid viability, economic and inclusive growth drivers means that subsidies alone, even if they were offered, would be unable to shift the attractiveness of these villages. Instead, these villages need critical interventions from development institutions to strengthen fundamental indicators like health, education and women's participation in the workforce that over time could improve productive capacity and make the energy profile of these villages more suitable for mini-grids.

» In their current state, these villages will struggle to become relevant for mini-grids without strong intervention by development institutions. «

6.2 Village prioritization for development institutions

Priority 1: Villages with strong inclusive growth drivers

Figure 28:
Villages with strong inclusive growth drivers

Strong energy use

- High use of electricity for productive use cases
- Large variety of non-seasonal and industrial productive use cases
- Large demand growth potential
- Large spend on electrical generators

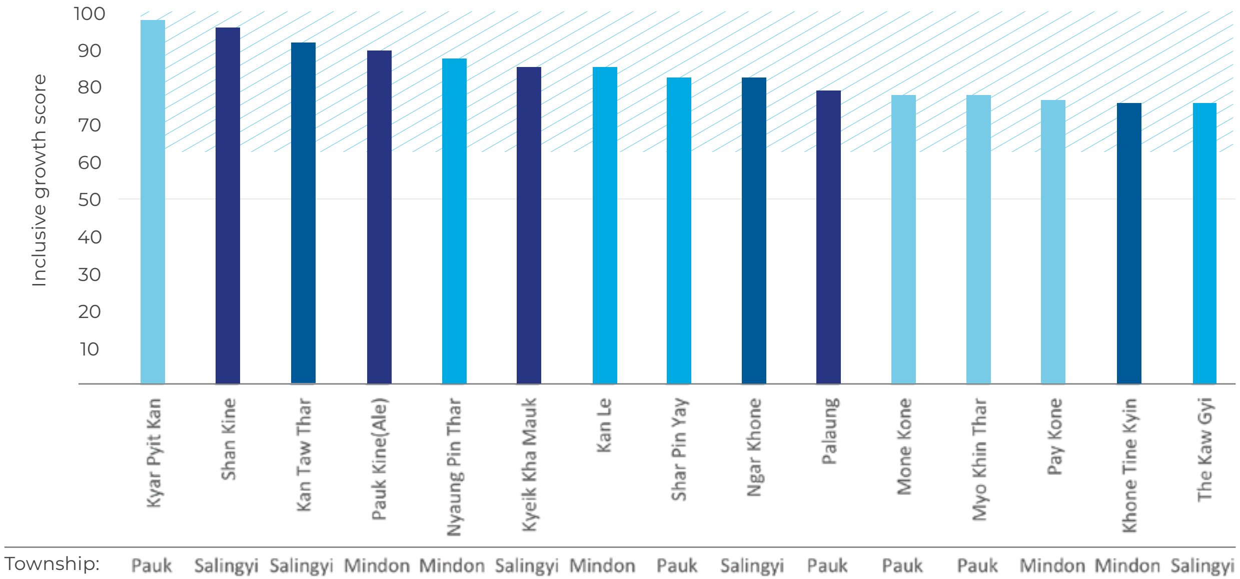
Strong economic drivers

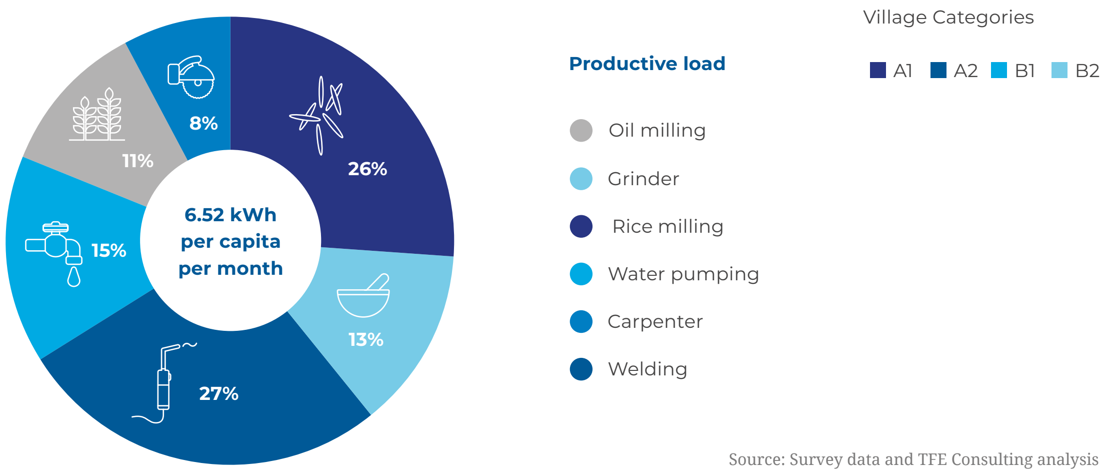
- High household income and spend
- High spend on communication
- Better access to market
- Low exposure to financial shocks

Strong inclusive growth driver

- Favourable demography including village education
- Relatively large participation of female
- Better diversity of livelihood
- Better access to finance

Development indicators (score out of 10)	
Village education	5.3
Health of village	5.9
Female participation	4.5
Diversity of livelihood	4.5
Ease of getting loan	9

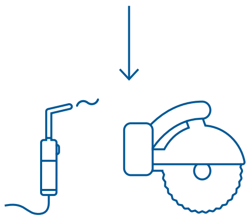




Source: Survey data and TFE Consulting analysis

>35%

of total productive demand from high-skill activities like welding and carpentry



These top 15 villages have the strongest potential for inclusive growth in the entire sample. These are also villages where, in combination with inclusive growth potential, the energy use situation is most viable for mini-grid developers.

The per capita productive demand of 6.52 kWh in these villages is close to double the average per capita productive demand across all 44 NGC villages. Furthermore, more than 35% of the total productive demand is from high-skill activities like welding and carpentry. The presence of these activities and an economic environment that is relatively stronger compared to other villages has enabled a relatively large number of commercial enterprises that use electricity as one of their key inputs. Due to these conditions, these villages could support viable business models for mini-grid development and are likely to develop rapidly from improved productive capacity.

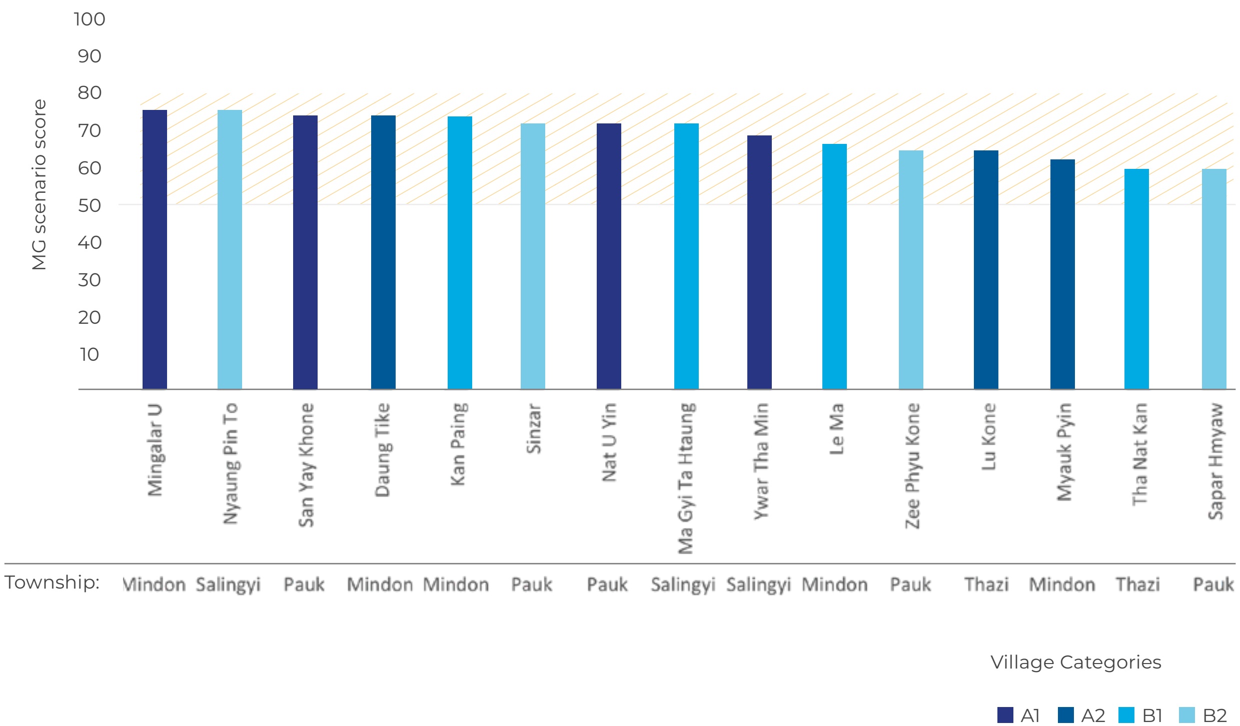
» Education levels in these villages are the highest when compared to other villages. The same applies to the participation of women in village economic life, the ease of getting a loan and the diversity of occupations followed. «

The economic status of these villages complements the energy use situation. The data shows that household expenditure in these villages is higher than other villages. Villagers also have a higher spend on communications (mobile phones, telephones or internet). These villages also have good connectivity to markets and tend to have better road access. This most likely has played a role in boosting their inclusive growth indicators and driving existing energy use that can be replaced by mini-grids. High current energy use and strong economic status of the Priority 1 villages appear to have had a positive effect on their social indicators. Education levels in these villages are the highest when compared to other villages. The same applies to the participation of women in village economic life, the ease of getting a loan and the diversity of occupations followed.

High indicators in these villages provide an opportunity to push them to the socio-economic dynamic of prosperous villages that are near town centres. Strategic and focused interventions from social organizations like PACT can help these villages accelerate enterprise productivity and reach their electricity demand potential (as projected in the scenarios) much faster, in some cases even surpassing expectations. Capacity building and vocational training to further develop industrial skills like welding, carpentry, painting, embroidery, some of which are already found in these village, might help them increase productivity faster than their current trajectory. Access to finance and improved connectivity to markets could help more enterprises launch in these villages and strengthen the economic potential of existing enterprises. Further, focused training programs to move villagers from agricultural work to small-scale industrial occupations are likely to help.

Priority 2: Villages on the edge

Figure 29:
Villages on the edge in inclusive growth drivers



Average energy use

- Good use of electricity for agricultural productive use cases
- Low availability of industrial productive load.
- Risk for mini-grid development because of seasonality of productive load
- Good spend on electrical generators

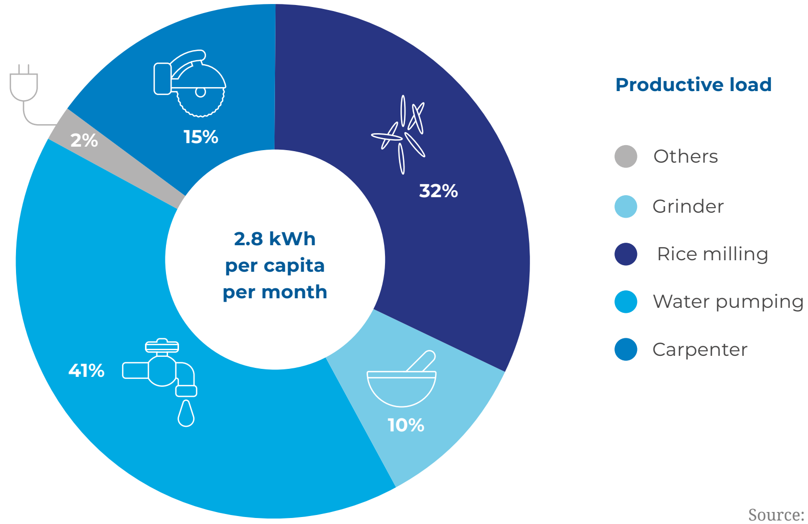
Average economic drivers

- Average household income but relatively higher spend
- Good access to market and road
- Low exposure to financial shocks

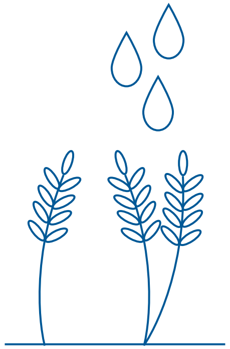
Average inclusive growth driver

- Average demography and village education
- Low participation of female.
- Good diversity of livelihood
- Better access to finance

Development indicators (score out of 10)	
Village education	4.8
Health of village	5.6
Female participation	3.7
Diversity of livelihood	3.43
Ease of getting loan	8.89



Source: Survey data and TFE Consulting analysis



>40%
of productive demand for agricultural use

less capital to invest in income generating activities

These middle 15 villages are on the verge of providing strong demand for viable mini-grid business models and achieving the top end in social indicators relative to the sample.

In terms of current productive demand, they match the average of the 44 NGC villages. Most of this is from agricultural use, with more than 40% of the productive demand tied to the heavy use of water pumps. Except for 15% of the electricity consumption used for carpentry, the remaining productive demand tied to agricultural activities is highly seasonal and not the best fit for viable mini-grid business models.

These villages are average in economic status relative to the sample. Given relatively lower productive work, households there earn less relative to those in Priority 1 villages. However, our study shows that they have similar average monthly spend as compared to the Priority 1 villages. This implies that households in these villages likely have less capital to invest in income generating activities. These villages also have good access to nearby markets, opening the potential to easily trade goods produced, provided there is know-how on how to engage in such activities and affordable access to electricity for enterprises. Our survey also suggests that it is relatively easy to get loans, which would likely help businesses in these villages get off the ground easily and engage with markets.

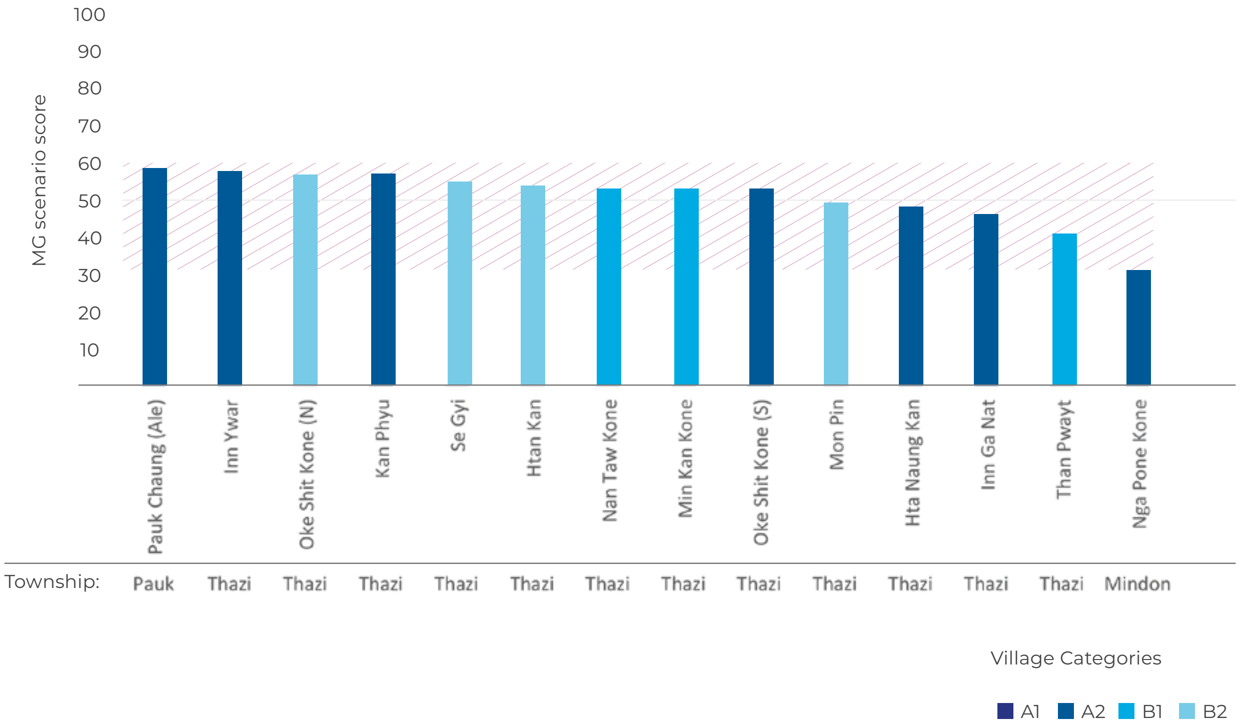
The social indicators of Priority 2 villages are lower compared to Priority 1 villages, which is in line with their average productivity and economic status. For example, women's participation with a score of 3.7 out of 10 is very low. More needs to be understood to explain exactly why women's participation is low, but data from Priority 1 village suggests that the focus of activities around agriculture and lower incomes could be potential drivers for this gap.

» These villages could benefit from gaining skills training and greater awareness of the options. «

These villages have already started using electricity, are active in agriculture, but are yet to take on highly productive use cases that can drive electricity demand. Development institutions have the opportunity to intervene to build productive capacity that is less seasonal and utilizes machinery with higher loads. These villages could benefit from gaining skills training and greater awareness of the options for highly productive small-scale industrial work of the kind seen in Priority 1 villages. Such work appears to be fitting and quite possible in the current economic setting found in Myanmar's Dry Zone. Capacity building, awareness on high productivity work, and training to trade more effectively could unlock enterprise productivity and make these villages a viable space for mini-grid operations. Within a few years of intervention, these villages could join the top 15.

Priority 3: Villages with weak inclusive growth drivers

Figure 30:
Villages with weak inclusive growth drivers



Poor energy use

- Low per capita load
- No industrial productive load
- Low spend on electric generators
- Very low powerable occupations

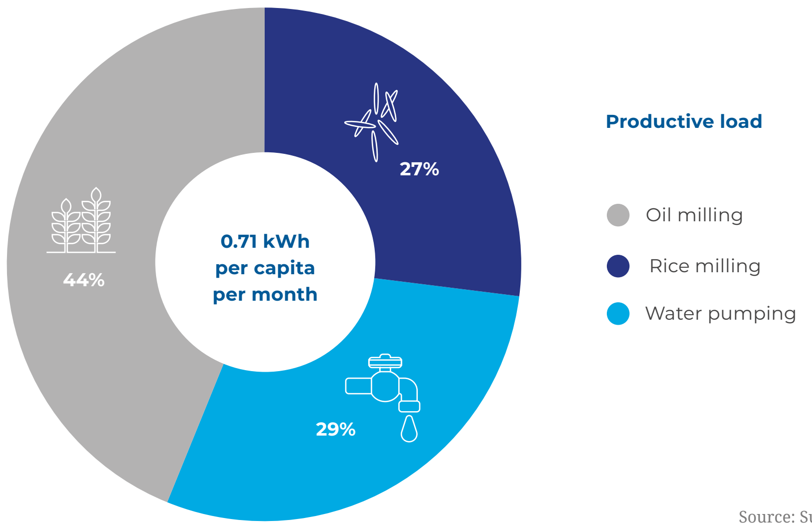
Poor economic drivers

- Low household income
- Poor access to market and road
- Large spend on communications when compared to income generated

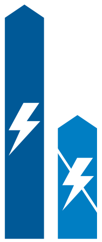
Poor inclusive growth driver

- Extremely poor female participation
- Low access to finance
- Poor diversity of livelihood

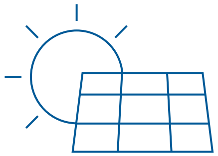
Development indicators (score out of 10)	
Village education	4.5
Health of village	6.5
Female participation	1.9
Diversity of livelihood	2.85
Ease of getting loan	5.16



Source: Survey data and TFE Consulting analysis



14 villages
7 no productive demand



3-5 Years
until business case

These 14 villages are the weakest of the 44 NGC villages surveyed. At an average inclusive growth driver score of 50 out of 100, these villages need strong attention from development institutions to holistically raise their socio-economic and, therefore, energy use status.

> These villages need strong attention from development institutions to holistically raise their socio-economic and, therefore, energy use status.

Out of these 14 villages, seven do not have any productive demand. The remaining seven villages have very little - almost 9 times less than the average productive demand in the top 15 villages. Furthermore, all current productive demand is generated by a handful of agricultural activities. As a result, these villages are likely not attractive sites for viable mini-grid business models.

Households in these villages have monthly expenditure that is similar to Priority 2 villages. Moreover, their spend on communication is almost the same when compared to the rest of the sample. Given they have similar expenses as other villages but relatively lower income, households are likely further constrained with capital that could otherwise help initiate income generating activities or set up a commercial enterprise. Additionally, the fact that these villages do not have proper access to nearby markets makes it hard to conduct trade and run businesses. This potentially explains the overall lack of productive use cases in these villages.

A weak economy and poor access to electricity have left a significant negative impact on some social indicators in these villages - they have poor to almost nonexistent women's participation and low diversity of livelihoods. This is further exacerbated by difficulties in accessing loans or any other form of finance.

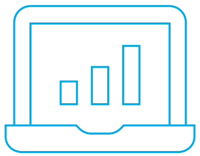
Given such low productivity and the lack of business opportunities, these villages, at their current inclusive growth levels, could be three to five years away from being relevant for mini-grid business models (around the level of Priority 2 villages). Development organizations need to focus on strategic interventions that can help shorten this wait. Interventions should be focused around building greater socio-economic capacity in health, education and women's participation that can create a basis for productive capacity that is currently missing in these villages.

> A weak economy and poor access to electricity have left a significant negative impact on some social indicators.

6.3 Village prioritization tool for investors

Village in Question				Minigrid Viability Factors								Economic Viability Factors				Inclusive Growth Drivers					Summary	
#	Example Villages	Population	# of HH	Category[5]	Per capita Demand[6]	Total Energy Demand[7]	Productive Demand[8]	Spend on Generators[9]	Projection of Future Demand[10]	Non-seasonal Machinery[11]	Telecom Tower Presence[12]	HH Spend[13]	Communication Spend[14]	Access to Market[15]	Access to Road[16]	Portion of Educated[17]	Less Disease[18]	Female Participation[19]	Diversity of Livelihood[20]	Ease of Getting Loan[21]	Total Score	Recommendation
1	Inn Ga Nat	378	80	2	2	1	1	1	1	1	1	2	3	1	3	3	4	1	1	1	41	Low Priority
2	Ywar Tha Min	311	80	4	4	3	2	3	3	1	1	4	2	1	4	4	2	1	1	3	66	Medium Priority
3	Kan Le	245	77	3	4	3	3	3	4	2	4	2	4	4	4	3	2	2	2	4	82	High Priority
4	Sinzar	1,085	186	1	2	3	3	3	1	3	1	2	1	2	2	2	1	3	3	4	52	Low Priority
5	....																				0	NA
6																					0	NA

Based on the village prioritization framework used in section 6.1 and 6.2, the following general tool has been developed. Developers and investors can use this tool to assess and prioritize other villages in Myanmar beyond those evaluated for this study. A useable, Microsoft Excel version of this tool is shared with this report.



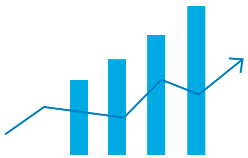
Note on scoring

1. Each factor is scored from 1 to 4, in an increasing order of importance or availability.
2. Every village is evaluated based on a total weighted score. Viability factors are weighted at 60%, economic viability factors at 30%, and inclusive growth drivers at 10%.
3. Villages with scores >80 have a green arrow and are ranked high priority. Villages with scores >60 but <80 have a yellow arrow and are ranked medium priority. Villages with scores s60 have a red arrow and are ranked low priority.
4. Scores for viability factors should be based on discussions, verbally shared data, and impressions from site visits. Precise data should be used when available. Factors like 'ease of getting loan' are not assessed through a detailed financial analysis but rather are based on impressions gained from community discussions.

5. Category draws on the village categorization established by TFE Consulting in the PACT Myanmar report under section 2. For Al input a score of 4, B1= 3, A2= 2, B2= 1
6. Per capita demand is the current energy usage per person in the village. Input a score of 1 when demand is less than 1.75 kWh/capita/month, 2 for > 1.75 kWh/ca./mo., 3 for > 3.5 kWh/ca./mo., 4 for > 7 kWh/ca./mo
7. Total energy demand for the entire village, input 1 for less than 33 kWh/month, 2 for > 33 kWh/mo., 3 for > 60 kWh/mo., 4 for > 125 kWh/mo.
8. Productive demand is the amount of energy used for work or useful activities on a per capita basis. Input 1 for less than 0.7 kWh/capita/month, 2 for > 0.7 kWh/ca./mo., 3 for > 2.4 kWh/ca./mo., 4 for > 6.1 kWh/ca./mo.
9. Spend on generators refers to the amount an entire village spends on generator use per month. Input 1 for less than 160,000 MMK/month, 2 for > 160,000 MMK/mo., 3 for > 500,000 MMK/mo., 4 for > 1,120,000 MMK/mo.
10. Projection of future demand can be derived from estimates provided in section 4 of the report (scenarios of future electricity demand), which are only aggregates and unavailable for specific villages. lt is encouranged to run independent demand projections for villages as an input when using this tool.
11. Non-seasonal machinery refers to the operation of welding or carpentry tools in the village. Input a score of 1 for none of these machines, 2 for at least 1 machine, 3 for 2 machines, 4 for 3 machines or more.
12. Telecom tower presence refers to the distance of a telecom tower from the village. 1 for more than 1 km away, 2 for < 700 m, 3 for < 500 m, 4 for < 200 m.
13. HH Spend refers to total monthly expenditures per household. Input a score of 1 for < 150,000 MMK/month, 2 for > 150,000 MMK/month, 3 for > 165,000 MMK/month, 4 for > 185,000 MMK/month.
14. Communication spend refers to the amount each household spends on communication (mobile phones) per month. Input a score of 1 for less than 7000 MMK/month, 2 for > 7000 MMK/month, 3 for > 8000 MMK/month, 4 for > 11,500
15. Access to market refers to distance to nearest market. Input score of 1 for > 15 km, 2 for 10-15 km, 3 for 5-10 km, 4 for 0-5 km.
16. Access to road is a qualitative overview of the road type (paved, unpaved, dirt, etc.), condition of the road, seasonal avalability and length. 1 availability, 4 = paved road with full availability.
17. Portion of educated refers to total percentage of village with primary education or higher. Input score of 1= if 50% or more of villagers have only primary school education, 2= more than 50% has primary education or higher, 3= 70% primary education or higher, 4= 90% primary education or higher.
18. Less disease is a qualitative overview of the prevalence of certain diseases within the village including: mosquito borne diseases (dengue, malaria), HIV, tuberculosis, hepatitis, nutritional deficiencies and other infectious diseases. 1= high presence, 2= medium, 3= low, 4= nil.
19. Female participation is a qualitative view at certain issues including: women in leadership roles, participation in village development activities, ownership of business or land, and participation in financial borrowing. 1= no women participation, 2= low, 3= medium, 4= high
20. Diversity of livelihood is a qualitative view of village non-farming economy and potential expansion, focusing on labour supply, availability of raw materials, and job skills. 1= farming only economy, 2= poor potential, 3= moderate potential, 4= high potential.
21. Ease of getting loan refers to availability of banking centers and number of HH taking accessing loans in the village. 1= difficult/not possible to obtain loan, 2= difficult to obtain loan, 3= loans are available and used by many HH, 4= has full access to loans.

We suggest the following areas for future research

1. A deeper analysis of the composition of local electricity costs both for generator electricity and for mini-grid electricity
2. A deeper analysis of actual/potential load patterns in villages
3. Assessments of the impact of new technologies, such as earth observation or remote meters and controls, on the mini-grid business case
4. A detailed assessment of the cost benefits of building mini-grids at scale in Myanmar
5. A more detailed assessment of the development impact of specific electricity-based activities (such as the use of industrial/agricultural machinery or consumptive loads) in Myanmar

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7 Appendix

7.1 Survey methodology

The survey covered 50 villages in four of the 58 townships in the Dry Zone of Myanmar. The selection was done by PACT Myanmar.

PACT Myanmar also determined that the study and its accompanying field survey would be conducted in 50 villages, of which 45 villages are in off grid areas, where there is no possibility of extension of the national grid in the next 5 to 7 years[36]. Out of these 45 villages, 15 villages have telecom towers (herein referred to as telco villages) that have been targeted by a mini-grid investor who is planning to develop an anchor-based mini-grid model in the Magway region. Five villages are grid-connected, with one electrified village in each of the three out of the four townships and two grid-connected villages are in the fourth township.

Three of the four pre-selected townships include villages with telco towers. The three townships with telco villages are Mindon, Thazi and Pauk. The fourth township - Salingyi - has no telco village. Salingyi was chosen based on logistical convenience for DRI, which has its 20 data collectors located in several villages there. Furthermore, Salingyi has a good distribution of Type A and Type B villages as described in this report.

There are two types of topography characteristics (Type A and Type B) that allow for identification of villages with these two categories of agriculture potential. However, the number of villages selected for the study is program-determined: the 15 Telco villages were included on purpose, while the remaining 35 villages were selected randomly from the four target townships.An equal distribution between the two types of topography characteristics (Type A and Type B) was maintained for all the sample villages (including telco villages).

Based on this methodology, the sample size of households distributed across the four townships is as follows:

Township	Total No. of villages (actual)	Village sample size* total	Total HH in the sample villages (based on an average of 260)	Household sample size**	
				Per village	Total
Mindon	179	12	3,120	25	299
Pauk	232	12	3,120	27	324
Salingyi	157	10	2,600	32	315
Thazi	260	16	4,160	20	325
Total	**828**	**50**	**13,000**	**25**	**1,263**

* Village sample size for each township is not statistically representative and instead has been determined by the number of telco villages and a selection of additional villages in approximate proportion of the total size of a township.

** Optimal size of households for each Township at 95% confidence level, 5% error at 50:50 probability

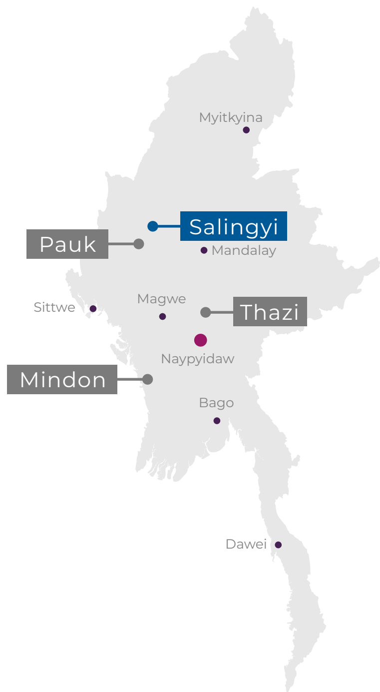
Source:

[36]This was checked with the Department of Rural Development, the Myanmar government agency responsible for the rural non-renewable energy program in off-grid areas.

Final list of 50 sample villages for the study

Table 1:
Final list of villages and households at **Salingyi Township**

No.	Village tract	Village	Type A1-B2	Total population	Total HH	Sample HH
Villages located in the northern part						
1	Palaung	Palaung (Grid-connected)	B1	852	223	41
2	Nyaung Pin To	Nyaung Pin To (prev. Thar Yar Kone)	B2	702	182	35
3	Nyaung Pin To	Ma Gyi Ta Htaung (prev. Hta Naung Kone)	B1	334	88	17
4		The Kaw Gyi (prev. The Gyi Inn)	B1	350	88	16
Villages located in the southern part						
5	Ngar Khone	Ngar Khone	A2	991	260	48
6	Hsong Tar	Hsong Tar (Grid-connected)	A1	903	218	41
7		Kan Taw Thar	A2	523	134	25
8	Ta yar	Shan Kine	A1	655	169	31
9	Ywar Tha Min	Ywar Tha Min	A1	311	80	15
10	Kyaukkamauk	Kyeik Kha Mauk	A1	831	248	46
	Total			**6452**	**1690**	**315**



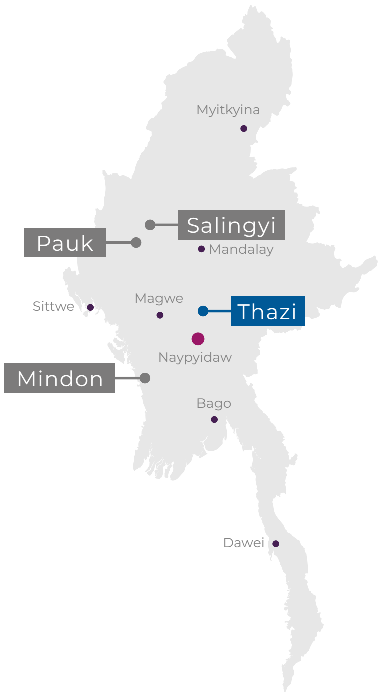
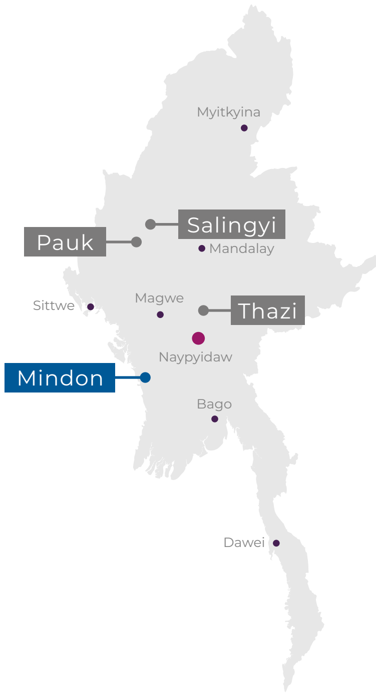


Table 2:
Final list of villages and households at **Thazi Township**

No.	Village tract	Village	Type A1-B2	Total population	Total HH	Sample HH
		Villages located at southern part of Thazi township				
1	Thu Kaung Kone	Min Kan Kone	B1	405	98	15
2	Inn	Inn Ywar	A2	555	128	19
3	Thu Kaung Kone	Hta Naung Kan (prev. Thone Pat Le)	A2	624	126	19
4	Lu Kone	Lu Kone (prev. Ma Gyi Yoe)	A2	210	59	9
5	Oke Shit Kone (S)	Oak Shit Kone (S)	A2	981	224	34
6	Tha Nat Kan	Tha Nat Kan	A2	724	160	24
7	Kan Phyu	Kan Phyu	A2	933	200	30
8	Magyi Gwa	Inn Ga Nat (prev. Bone Ta Lote)	A2	378	80	12
		Villages at the northern part of Thazi township				
9	Kan Shay	Oke Shit Kone (N) (Telco village)	B2	456	117	18
10	Oat twin	Nan Taw Kone	B1	850	165	25
11	Kan Shay	Mon Taw (Grid-connected)	B1	935	196	30
12	Thar Gra	Se Gyi (TELCO village)	B2	670	145	22
13	Nget Gyi Theik	Than Pwayt	B1	330	76	11
14	Bweit Char	Bweit Char (TELCO village) (Grid-connected)	B1	1097	247	37
15	Nyaung Pin Thar	Htan Kan (TELCO village)	B2	257	66	10
16	Pyi Nyaung	Mon Pin (TELCO village)	B2	281	66	10
	Total			**9686**	**2153**	**325**

Table 3:
Final list of villages and households at **Mindon Township**

No.	Village tract	Village	Type A1-B2	Total population	Total HH	Sample HH
Villages located at the western part						
1	Nga Pone Kone	Nga Pone Kone	A2	367	94	21
2	Tantar	Tantar (Ywar Ma) (Grid-connected)	A1	247	65	15
3	Pauk Kine	Pauk Kine (Ale) (TELCO village)	A1	468	139	31
4	Mingalar U	Mingalar U	A1	258	68	15
5	Myauk Pyin	Myauk Pyin (TELCO village)	A2	820	248	56
6	Daung Tike	Daung Tike	A2	278	79	18
7	Khone Tine Kyin	Khone Tine Kyin (TELCO village)	A2	531	173	39
Villages at the eastern part						
8	Sabatan	Nyaung Pin Thar (TELCO village)	B1	482	125	28
9	Kan Paing	Kan Paing	B1	508	135	30
10	Kan Le	Kan Le	B1	245	77	17
11	Ku Phyu	Pay Kone (Prev. Taung Pat)	B2	127	34	8
12	Le Ma	Le Ma	B1	352	95	21
	Total			**4683**	**1332**	**299**



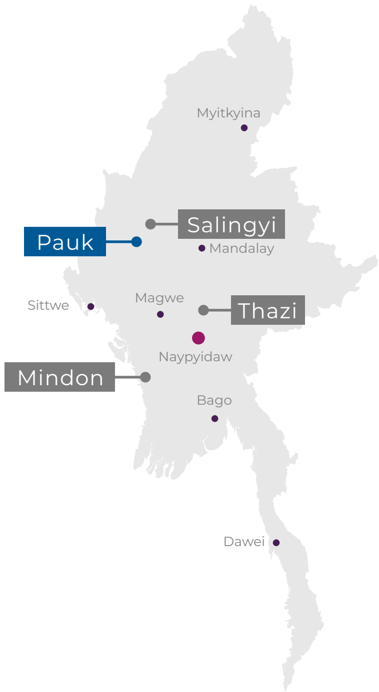


Table 4:
Final list of villages and households at **Pauk Township**

No.	Village tract	Village	Type A1-B2	Total population	Total HH	Sample HH
Villages located in the northern part						
1	Nat U Yin	Nat U Yin	A1	601	121	19
2	Myauk Bat	Sapar Hmyaw	B2	730	139	22
3	Htan Ta Pin	San Yay Khone	A1	548	123	18
4	Palaung	Palaung	A1	1011	213	33
5	Kukar	Pauk Chaung (Ale) (TELCO village)	A2	218	46	8
6	Thamar Taw	Ma Gyi Sin (Grid connected)	A1	732	132	20
located in the southern part						
7	Nanthar	Shar Pin Yay (TELCO village)	B1	2328	476	75
8	Kukar	Sinzar (TELCO village)	B2	1085	186	29
9	Taung Myint	Kyar Pyit Kan (TELCO village)	B2	1604	319	50
10	Ai Kai	Mone Kone (Solar Mini Grid)	B2	788	150	23
11	Myo Khin Thar	Myo Khin Thar	B2	536	110	17
12	Zee Phyu Kone	Zee Phyu Kone (TELCO village)	B2	262	64	10
	Total			**10443**	**2079**	**324**

7.2 Demand assessment methodology

Survey data on the amount of electricity used by households, enterprises and community institutions was the foundation of this assessment. However, the data on community institutions was dropped for the analysis due to significant information gaps.

Often, respondents shared data on the amount of electricity in kWh (with on-the-spot support on calculations by the survey personnel). Where this was not possible, wattage data on appliances and machinery was noted and market standard power ratings were used to provide an estimate of kWh.

Data on the quantity of electricity used gave a measure of total demand at the household and enterprise level. Using the definitions of household and productive demand provided in the report, total demand was categorized into those two demand types.

Survey data on quantity of use of lights, appliances and machinery was used to calculate their relative share in total use in households and enterprises.

The total demand data was calculated from the population size of each village, which was also collected during the survey. This provided an assessment of per capita electricity demand, which was then used to compare data across villages.

7.3 Energy expenditure assessment methodology

Survey data covered actual amounts of money spent per month in Kyat by respondents on accessing individual energy sources like firewood, candles, kerosene, batteries, individual fuel generators, shared access to generators and Solar Home Systems (SHS). Survey data also collected information on money spent by enterprises on the same energy sources. This data, however, had many gaps and drastic variations. To be used effectively for the analysis, statistical tools were used to identify outliers and derive averages based on the most robust set of data points. As a result, data on energy spend is highly aggregative and detailed data has not been provided.

7.4 Generator-based electricity cost calculation

As mentioned before, data collected from the survey helped us calculate the total monthly household and productive demand per village. Furthermore, data from the survey also allowed us to calculate money spent on fuel generators to access electricity by households and commercial entities. Based on these two data points, the cost of electricity by fuel generators per kWh was calculated.

Cost of fuel generator electricity per kWh paid by households = (Money spent on generators per month per kWh by household/ monthly household demand in kWh). Cost of fuel generator electricity per kWh paid by enterprises = (Money spent on generators in a month per kWh by enterprises/monthly household demand in kWh).

These two data points for each village were plotted in a scatter graph. Given that the data had significant variation, the scatter graph showed high deviation around the mean value, with some data points as low as MMK 50 (USD 0.04) per kWh and some higher than MMK 2,000 (USD 1.5) per kWh. These outliers were filtered out – assuming that recall by respondends was not always perfect and assuming that there were errors in the data gathering process – to calculate the average quoted price of electricity from fuel generators.

The average cost of generator electricity was calculated, considering data points that had values ranging from MMK 200-1,000 (USD 0.15-0.75) per kWh. Any values below or above were considered to be outliers and were not considered in the calculation of the average electricity cost from a fuel generator at MMK 510 (USD 0.37) per kWh.

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7.5 Electricity cost calculation methodology

Per capita household demand in GC villages is calculated as 24x higher when compared to NGC villages. This is a result of a very low grid price at 35 Kyat per kWh in GC villages, which is 14.5 times lower than the price in NGC villages. Because of the vast cost difference, demand in NGC villages is not likely to scale to the amount consumed in GC villages. As the estimated cost of electricity of mini-grids can only be at par with the current fuel cost, TFE's projection predicts a growth of 1.7x factoring the 14.5 times higher cost of electricity when compared to grid prices. 24/14.5 = 1.7.

We found that productive demand in GC villages is 1.6x higher than in NGC villages. The TFE prediction model estimates that NGC villages will grow by the same factor in 3-5 years. This estimation does not take into account the cost difference as it was known that commercial entities in GC villages still run on fuel generators and hence do not benefit from 14.5 times lower grid price.

7.6 Human-Centered Design workshops methodology

TFE Consulting, together with its local partner DRI, organized and carried out four Human-Centered Design (HCD) workshops in four rural villages around the townships of Mindon (Tantar), Pauk (Mon Kone), Salingyi (Kan Taw Thar) and Thazi (Mon Taw) in Myanmar. The workshops hosted individuals from villages around the township.

The HCD workshop has been included in this project because of the capacity of HCD methods to gather useful qualitative insights from focus groups of individuals directly related to the outcomes of the study. HCD is a useful tool to use in this project because it differs from survey methods in three key aspects: HCD is non-statistically representative and it looks at qualitative rather than quantitative data.

The standard steps of HCD are the following:

1. Brainstorm with target customers
2. Develop a prototype from the feedback gathered in step 1
3. Bring the prototype back to customers for further feedback
4. Build final version on feedback gathered in step 3

In this particular analysis, these steps would translate into:

1. Survey to gather necessary data
2. Scenario building, based on data gathered through survey
3. HCD workshop to test the scenarios for further improvement
4. Finalizing report, comprising of scenarios

For this particular project, given the resources available and the complexity of the outcome to test through HCD, we identified a design challenge aiming at investigating the following:

Goals

- Assess whether the survey data fits with what individuals express about their day-to-day life
- Find out key demand side factors that will support the realization of demand potentials, particularly with respect to productive uses
- Identify most likely productive uses and anchor loads for supporting viable business models and inclusive community growth
- Include possible productive uses based on ideas and aspirations, status symbols, expenses and trends

Keeping in mind that all the information gathered through HCD is useful and that it is about understanding the humans we are interacting with, we facilitated collaborative activities and encouraged free-flowing conversations to understand as much as possible about the participants.

Based on our design challenge aims, our HCD workshop activities gathered information on:

Metrics

- Current business scene; their understanding on electricity usage and expenditure; people's day to day expenses and lucrative activities
- Key energy demand factors (preferences) and barriers (financing) to help support the future demand predictions for decentralized solutions
- Main pains, needs and expectations towards their energy usage; Villagers' preferences, wishes and dreams;

The overall agenda of a workshop was the following

Opening

Introduction and warm up

The workshop would start at around 9am, when the participants arrive they receive an introduction to the purpose of the workshop. They fill "feedback cards" with some basic information and introduce each other to the group in a fun way.

HCD Activities

HCD Flow Chart and Storytelling

The HCD Flow Chart activity would then take place for the most part of the workshop, while allowing for storytelling in-between conversations. The activity could be carried out individually, in small groups or all together.

Closing

Discussion and feedback

After filling out the second part of the feedback card, containing feedback questions on the workshop, participants were offered lunch by the facilitators. This was a useful moment to listen to the informal conversations amongst participants and engage in discussions.

We found the HCD Flow Chart to be the most meaningful and insightful HCD activity carried out. This activity has participants list and explain their real-life resource flows entering and leaving the household (what brings money in and what that money is spent on).

From this activity we have also identified personas, which are groups of individuals with distinctive archetypes that personify our learning. Grouping individuals is useful to understand who the best potential users are, what kind of businesses they would support, and what their preferences are in terms of expenditures. Since our aim is to be inclusive, we tried inviting representatives of all types of personas. For us, it was important to have members who were representative of most of the village population. Here is a list and description of the most significant personas which attended the workshops.

7.7 Village prioritization methodology

The methodology for village prioritization is explained in section 6. It must be noted that our engine normalizes individual drivers like per capita demand, total load, spend on electricity, etc. into a rank from 0 to 10 (precision to +/- 0.01). This normalization allows comparison and arithmetic calculation with drivers of different units.

Shy	Extroverted	Knowledgeable	Ambitious	Disadvantaged
It was hard to have women in the workshops. Those which attended who were over 56 were shy and did not speak up often in group discussions. They contributed few new ideas. Locals explained that women are not used to taking lead roles in their society.	Most of the populations in rural villages are farmers (seen on survey). They are middle-aged men who own some land or gardens. They had many business ideas mostly related to farming, but not limited to that.	The most knowledgeable individuals were usually employed by the government (often VEC members) or those who had experience in administrative tasks. These were the most active during the workshop and brought many ideas for possible productive uses. Many came from electrified villages so were experienced with electrification. Mostly elders and some middle-aged men and women. They also engaged in storytelling. Usually this persona had younger family members studying or working abroad.	Ambitious individuals were business minded, with many ideas and plans related to their career development. They usually initiated the discussions. We were pleased to see that all young individuals were part of this persona, both male and female. The amount of business ideas that emerged was stunning, many of which were practical and applicable. These individuals had some form of education and had a very good understanding of issues dealing with electricity use.	These personas tended to prefer allocating their investment into buying a garden or farmland. They expressed their wish to acquire land and usually live off livestock or casual work in farming. These were mostly middle-aged men and some women who felt insecure about work. They did not have ideas on other possible business opportunities.

8 Imprint

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About Pact

www.pactworld.org

Pact has worked extensively in 11 States and Divisions, and remains one of the longest-serving and largest integrated development organizations in Myanmar. In our 20 year history in Myanmar, we have focused on community development through adaptive integration of microfinance, rural electrification, livelihoods; economic empowerment; health; water, sanitation & hygiene; and agriculture. With MOUs with several Government Ministries, we have worked with a variety of funders, including foundations, corporations, and governments, implementing projects ranging from $60,000 to $70 million. With financial support from Chevron, ABB, and Shell, and investing its own incubation funds, Pact has rolled out Myanmar's first community energy financing vehicle, the Ahlin Yaung Revolving Capital Fund for Energy, which enabled the purchase of quality affordable SHS solutions to 185,000 homes. In 2016, Pact's Myanmar launched its first energy-focused strategy to enable electricity access in rural communities through mini-grids, in collaboration with donors, investors, the private sector, MFIs and other stakeholders. In early 2018, Pact was awarded a grant from The Rockefeller Foundation to establish and manage the Smart Power Myanmar, which aims to connect 10 million rural people to reliable electricity in the next several years.

About TFE Consulting

www.tfeconsulting.com

TFE Consulting is an international, values-led advisory company and business incubator. Our partners are companies, investors, international organizations and governments. We focus on the creation of scalable business models and on the role of emergent digital technologies to combat climate change and accelerate development.

About DRI

www.drimyanmar.com

DRI is a socioeconomic development consulting firm based in Nay Pyi Taw, Myanmar. DRI is engaged in consulting, research, training and development solutions through project implementation in three areas: (i) village and township development planning and building capacity for community driven implementation of development schemes; (ii) rural micro and small enterprises development; and (c) facilitating rural producers gain access to energy, markets for goods and services, financial services, and technology and technical services.

Bridging the Energy Gap:
Demand Scenarios for Mini-Grids in Myanmar