



# Decentralised Energy Market Assessment in Myanmar

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MAY 2019

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# List of Acronyms used in the Report

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ADB	Asian Development Bank
AFD	Agence Française de Développement
AICS	Agenzia Italiana Cooperazione allo Sviluppo
AIIB	Asian Infrastructure Investment Bank
CAPEX	Capital Expenses
DESCO	Distributed Energy Service Companies
DRD	Department of Rural Development
EEP	Energy and Environment Partnership
EGAT	Energy Generating Authority of Thailand
EMS	Energy Management System
ESCO	Energy Service Company
ESE	Electricity Supply Enterprises
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSMA	Global System Mobile Association
IFC	International Finance Corporation
IMF	International Monetary Fund
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
JICS	Japan International Cooperation System
KfW	Kreditanstalt für Wiederaufbau

LCOE	Levelised Cost of Electricity
MESC	Mandalay Electricity Supply Company
MG	Mini-grid
MMK	Myanmar Kyat
MOALI	Ministry of Agriculture, Livestock and Irrigation
MOEE	Ministry of Electricity and Energy
MOPF	Ministry of Planning and Finance
NEP	National Electrification Plan
OPEX	Operational Expenses
PV	Photovoltaics
REF	Rural Electrification Fund of Cambodia
SME	Small and Medium Enterprise
SPD	Small Power Distributor
SPP	Small Power Producer
UN	United Nations
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USD	United States Dollar [1USD =1378 MMK (2018)]
VSPP	Very Small Power Producer
WWF	World Wildlife Fund
YESC	Yangon Electricity Supply Company

## Preface

Over the past two years, Smart Power Myanmar has spoken to hundreds of companies, donors, investors, micro-finance agencies, non-profits, community members and government officials to understand the key challenges at a systems level that prevent and inhibit greater access to energy in Myanmar, and to develop solutions for overcoming those challenges. We have done this to try to plug one of the biggest key gaps: the need for a clear understanding of the potential size of the market for decentralised energy solutions, an analysis of where and when such solutions make the most sense, and the steps various market participants must take in order to capture that market potential.

Through the generous financial and technical support of The Rockefeller Foundation, GIZ and Agence Française de Développement, this Market Assessment therefore began with a simple premise: develop a clear and credible evidence base, and set forth a series of recommendations to expand access to energy in Myanmar. We hope that this Assessment will serve as an advocacy tool and a strengthened vision for electrification where the national grid explicitly includes decentralised power generation at scale.

One of our clearest findings is that investing in decentralised energy solutions is not only the *lowest cost* option for Myanmar, but it is also the *fastest route* towards energy access for millions of under-served people. This Assessment makes the case for various market participants to view decentralised energy solutions as part of a national infrastructure base, instead of stand-alone solar or hydro-mini-grids. We could call this vision for an interconnected future “Grid 2.0.”

The case for scaling up decentralised energy solutions in Myanmar is compelling. Based on our analysis, in the next couple of years — if the correct actions are taken — the viable, potential market could be as large as 2,300 mini-grids covering 2 million people, helping to increase GDP by more than \$230 million. Longer term, with the adoption of clear measures as outlined in this Assessment, the number of viable mini-grids could be as high as 16,000 by 2030, which would cover more than 20 million people — or almost two-thirds of all under-served people in Myanmar today.

Needless to say, turning this potential into reality will require investment, determination, cross-sectoral coordination, positive market conditions and favorable policies and our Assessment attempts to highlight these issues in detail. One thing is clear: achieving scale will require *systemic solutions* on a large scale — support structures that successfully match the *supply* of electricity with the effective and profitable use of electricity.

Connecting rural customers to reliable and affordable sources of electricity has thus far proven very challenging without philanthropic support. In addition to the financing of energy infrastructure through extensive subsidy programs, for example, financing for connections, appliances and equipment will be needed. Most developing countries that have invested in electricity infrastructure have failed to invest in demand and related productivity improvements. We estimate that in Myanmar, less than 1% of current total financing in energy access is connected to productive use; a lesson that should have been learned from experiences elsewhere. As Rocky Mountain Institute states in their 2018 publication “Closing the Circuit”:

*“..from 2000 to 2008, supply expansion represented almost half of the nearly \$4 billion the World Bank approved for investment in energy access, whereas investment in productive use represented 0.7%.” And goes on to add: “In Africa, all investment in productive use financed technical assistance; no such financing was directed to implement productive use investment projects.”*

In short, Myanmar’s future “Grid 2.0” will need to operate as a system comprised of a wide range of components, spanning community structures, rural businesses, equipment suppliers, state and non-state actors, commercial banks, global financing institutions and development institutions, all supported by conducive policies and regulations.

While Myanmar’s nascent energy market may lag behind many of its neighbors, the country has the distinct advantage of being able to learn from mistakes and to accelerate growth. Choices can be made now. We have seen such tremendous change happen before, with the transparent liberalization of the telecom sector, helping to bring cellphone ownership to the vast majority of the population in just a few years. Such radical transformation and change had been almost unthinkable several years ago. We hope that this Assessment goes some way to positively influencing those policies and the communities that depend on them.

Richard Harrison  
CEO, Smart Power Myanmar  
Yangon, May 2019



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## Executive Summary



- Access to electricity remains an issue in Myanmar with an estimated 58% of the population, approximately 30 million people, not connected to the main power grid
- In 2015, the Government of Myanmar formulated the National Electrification Plan (NEP), an ambitious program structured around 5 phases aiming to reach 100% grid electrification by 2030 — in the NEP, mini-grids played a limited role as interim electrification solutions covering 0.7 million people or 2% of the off-grid population
- Based on global benchmarks, implementation of the 2015 NEP roadmap appears very challenging — instead it is expected that grid electrification will take considerable time and investment
- In this context, mini-grids could play a pivotal role as a “grid 2.0” distributed solution bringing electricity to off-grid areas while expansion of the main grid progresses
  - » Mini-grids cost per connection is on average approximately 40% lower than main grid expansion
  - » Mini-grids have substantial development impact as they can support demand from business users (productive loads)
  - » If “grid-ready” mini-grids are developed, they can be easily integrated once the main grid arrives. Mini-grids generation and energy storage assets can be leveraged as small-scale distributed generation and energy storage systems, and distribution assets can be utilised to ensure last-mile connections to households and businesses in villages
  - » Thus mini-grids support a bottom-up “grid 2.0” solution that can accelerate electrification while expansion of the main grid is carried out



- However, grid-ready mini-grids are still expensive and require subsidy support. In addition, absence of a comprehensive regulatory framework and of a clear transition mechanism in case of grid arrival, pose risks for mini-grid projects close to the main grids

- » Currently, mini-grids serving residential and local businesses are financially viable from private developers' perspective only if investment subsidies are provided
- » Mini-grids are not regulated under a licensing system and no compensation and/or transition mechanisms exist in case of grid arrival. Hence, only remote sites under Phase 4 and 5 of the NEP with low likelihood of grid arrival are targeted by private developers for mini-grid investment

- Thus, with the current subsidy budget availability and without any regulatory changes, the size of the potential market is expected to remain limited to approximately 230 mini-grids by 2025, covering 110,000 people or 0.3% of the off-grid population, and growing to 590 mini-grids by 2030, covering 531,000 people or 2.3 % of the off-grid population

- » By 2025 only mini-grids under the investment subsidy scheme are financially viable. With the current level of budget available for investment subsidies, approximately 230 mini-grids can be developed
- » By 2030, as equipment costs decrease, mini-grids beyond the investment subsidy scheme are expected to become financially viable in favourable locations. However, in the absence of regulatory reform, investible sites are limited to villages in the phase 4 and 5 of NEP resulting in a total potential market of 590 mini-grids

- Instead, scenario analysis shows that implementation of five combined measures could trigger in the short term a potential market of up to 2,300 mini-grids covering approximately 2 million people or 6.4% of the off-grid population:

- 1 Increase power demand from businesses through demand-side support measures
- 2 Decrease private developers' hurdle return rate by facilitating access to finance and de-risking mini-grids
- 3 Enable investment in mini-grids in villages under Phase 3 of NEP in addition to those under Phase 4 and 5 by de-risking grid arrival
- 4 Increase the number of mini-grid projects by increasing available budget for investment subsidies to generate sufficient scale in the market
- 5 Enable economies of scale through larger scale developers or by pooling resources across developers

- With the five measures above and thanks to equipment cost reduction and technology improvement, the potential market is projected to increase to ~8,000 mini-grids by 2025 and then double to more than 16,000 mini-grids by 2030
- Roll-out of all 2,300 mini-grids viable in 2020 would require a USD 537 million investment. In the longer term, if the market fulfills its potential, USD 1.8 billion investment would be required to implement all viable mini-grids



Table 1. Summary view of potential market projections by scenario

Scenario	Potential market metric	Potential market projections		
		2020	2025	2030
<b>Business as usual scenario</b> <ul style="list-style-type: none"><li>• Subsidy budget unchanged at USD 18.6 million</li><li>• No regulatory reform to de-risk grid arrival</li></ul>	Number of viable mini-grids	229	229	584
	Population covered	108,000	108,000	570,000
	% of off-grid population covered	0.4%	0.4%	2.5%
	Investment required to roll-out all viable mini-grids	USD 31 m	USD 31 m	USD 202 m
<b>Scenario with 5 measures</b> <ul style="list-style-type: none"><li>• Demand-side measures</li><li>• Access to finance</li><li>• De-risking of grid arrival</li><li>• Subsidy budget at USD 100 million</li><li>• Economies of scale</li></ul>	Number of viable mini-grids	2,253	8,051	16,444
	Population covered	1,954,000	5,894,000	10,229,000
	% of off-grid population covered	6.4%	21.9%	45.2%
	Investment required to roll-out all viable mini-grids	USD 537 m	USD 1,844 m	USD 3,356 m

- Based on these findings, a comprehensive framework of initiatives structured around 3 pillars and enablers is recommended
  - » **Pillar 1:** promote de-risking and access to finance to increase investible sites and decrease hurdle return rate for private developers. Recommended actions include introduction of a comprehensive regulatory framework to de-risk grid arrival, measures to de-risk cash flows such as revenue guarantees and measures to support access to finance such as two-step loans schemes
  - » **Pillar 2:** support growth of demand, focusing on productive loads through direct subsidies of electricity prices, or through micro-finance of electrically powered machinery and technical assistance
  - » **Pillar 3:** support generation of economies of scale through pooling of key development and procurement processes, and supporting growth of sizeable private developers
  - » **Enabling initiatives** include extension and optimization of the current subsidy scheme and cost reductions, initiatives to increase community involvement, to develop and share best practices and capacity-building initiatives to train the required workforce
- In addition to triggering a large potential market covering millions of off-grid households, these measures could result in an increase of GDP by up to 233 million USD and create 48,300 jobs
  - » Mini-grids can accelerate socio-economic development in Myanmar in three ways: direct economic impact, indirect economic impact and social impact
  - » Most of the economic benefits of mini-grid projects would be derived indirectly from the impact of electrification on businesses; this reinforces the importance of productive loads not only in ensuring the viability of mini-grids, but also in supporting development impact through GDP growth and job creation

This study provides an assessment of the current market for mini-grids in Myanmar, the projected size of the market by 2030, the key market drivers, and a set of scenarios based on those drivers.

The study is articulated along three axes:

- Review of current status, issues, market participants, their business models, sources of funding, and pipeline
- Identification of key market drivers and their implications
- Formulation of scenarios for evolution of the market for mini-grids in Myanmar and assessment of potential market size for each scenario

Based on best practices and the outcome of scenario analysis, the study also identifies key recommendations for stakeholders including policymakers, investors and international donors, local and global private developers and the wider business community to help accelerating the deployment of mini-grids in Myanmar.

This study involved numerous interviews with key stakeholders, including Government officials, multilateral institutions, current and potential mini-grid developers and equipment manufacturers.

# 1.0

## Introduction

### Status of Electrification in Myanmar

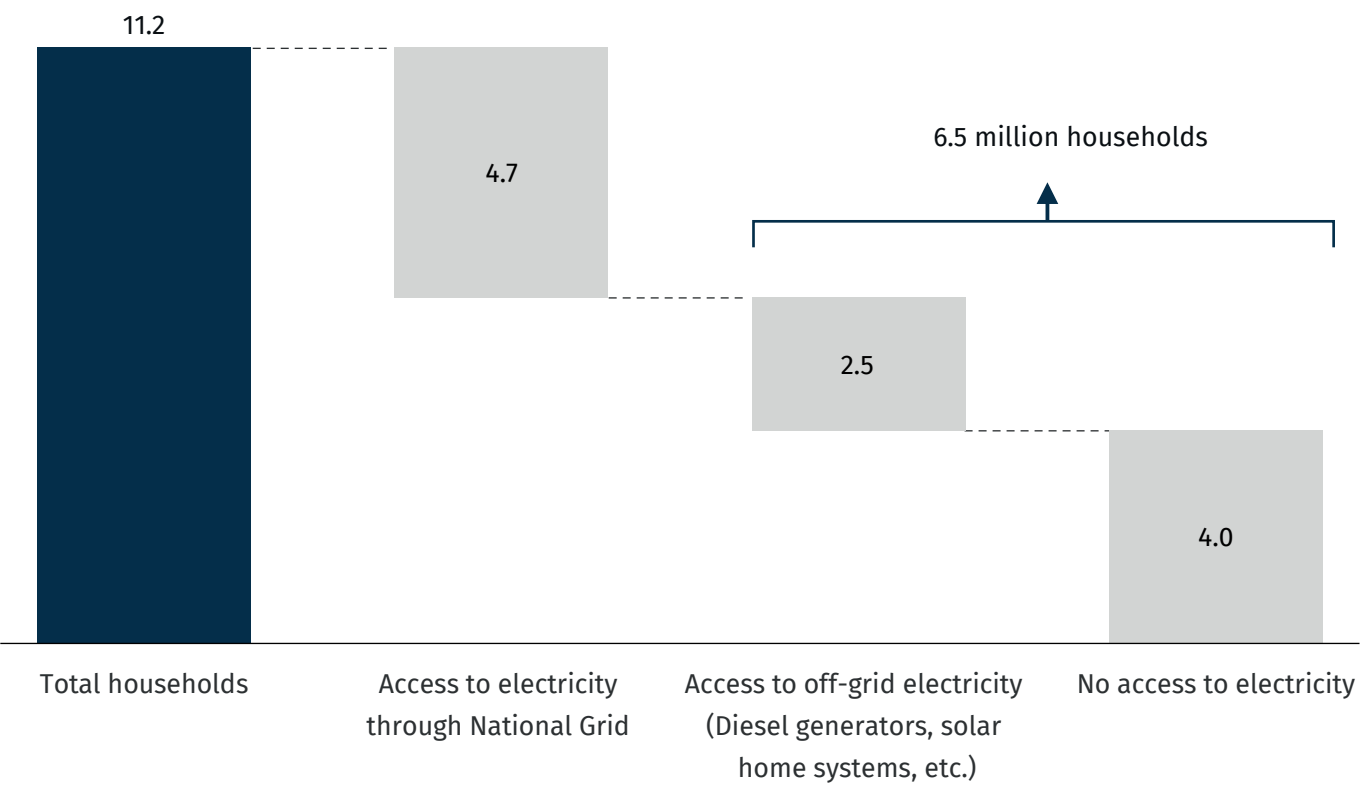
Access to reliable electricity is a long-standing problem in Myanmar. Out of 11 million households, 6.5 million or approximately 58% are not connected to the national electricity grid. Among off-grid households, 4 million have no access to electricity at all and utilise kerosene, oil and solid fuels as energy sources for lighting, cooking and other domestic uses. The remaining 2.5 million off-grid households have access to electricity through diesel generators, solar home systems or other on-site power generation devices<sup>1</sup> — however, supply from these off-grid solutions is often unreliable and expensive.

Providing reliable electricity at affordable tariffs to off-grid households and businesses is critical for Myanmar’s socio-economic development. In other developing countries, electrification of off-grid areas greatly benefited rural areas. For example, in India, rural electrification programmes have revealed significant social, health and economic benefits.

Rural electrification can be achieved through grid expansion and through off-grid solutions. The Government of Myanmar is planning for grid expansion (see Section 2.3), but this will take time and will require significant investment. In parallel, technology advances leading to significant cost reduction in distributed renewable power generation and storage open new possibilities for off-grid solutions. In certain regions, Myanmar has a

<sup>1</sup> Roland Berger estimates from Census and Department of Rural Development

Figure 1. Current status of access to electricity among Myanmar’s households (2018, million households)



Source: Roland Berger estimates from Census and Department of Rural Development

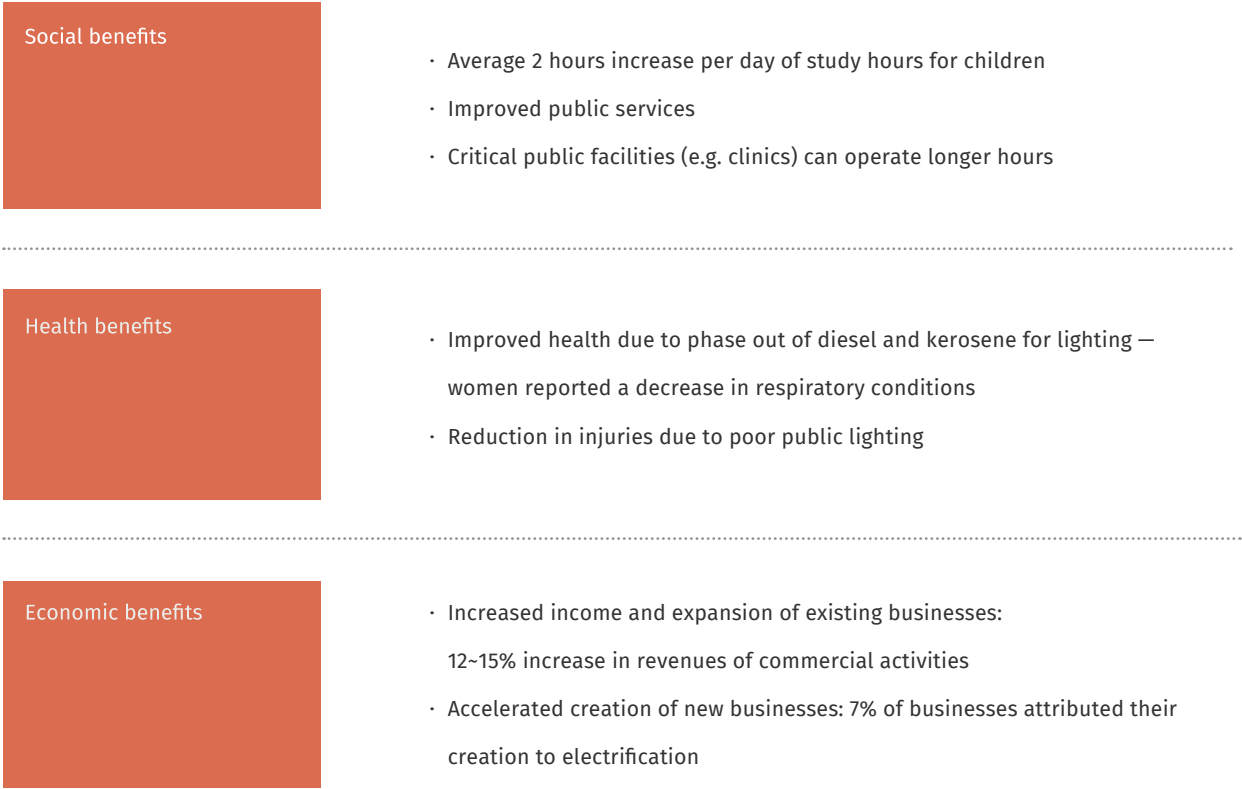
unique opportunity to leapfrog to a decentralised power system, thereby accelerating electrification cost-effectiveness. A decentralised model of electrification can have advantages in terms of efficiency and security of supply. For example, much smaller distances between power generation sources and consumption centres can decrease the amount of electricity losses through transmission and distribution networks.<sup>2</sup> In addition, decentralised systems can be more resilient to failures of the main grid and/or centralised power plants as they allow easier islanding of sub-section of the system.<sup>3</sup>

<sup>2</sup> Interview conducted by Roland Berger with bilateral institution. Data from the World Bank World Development Indicators indicate that transmission and distribution losses amounted to 20% of generated power in 2014 in Myanmar

<sup>3</sup> Interview conducted by Roland Berger with mini-grid developer



Figure 2. Benefits of rural electrification in India



Source: Sambodhi, “Understanding the Impact of Rural Electrification in Uttar Pradesh and Bihar, India”, 2017

Evolution towards a decentralised power system would parallel the successful development of the telecommunication sector in Myanmar that was achieved by leapfrogging fixed telecommunication infrastructure through the rapid roll-out of mobile networks, achieving 100% mobile penetration in only 3 years — the fastest mobile uptake ever recorded worldwide. The successful liberalisation of Myanmar’s telecommunication sector can be attributed to a clear legal and regulatory framework, transparent tendering, strong engagement between regulatory agencies and private operators, and a government commitment to bring in private investors and the latest technologies. In addition, when licensing the new telecommunication operators, the Government of Myanmar imposed stringent but reasonable obligations on the operators including rural coverage commitments. Similar to the successful telecommunication sector liberalisation, this study assesses necessary policies to leapfrog and positively transform electricity access in rural areas.

## The role of mini-grids

To increase electricity access, the Government of Myanmar has set an ambitious roadmap of 100% grid electrification by 2030. This implies an increase in electrification rate of 58% points within 12 years (from 42% in 2018). Benchmarks across developing countries (see Section 2.3) show that, on average, over a period of 12 years, grid electrification typically increases by about 20% points. In addition, the availability and source of funding for grid expansion in Myanmar remain unclear — while the electrification programme requires an estimated 5.8 billion USD, only about 700 million USD have been secured so far through government budget and international financial institutions. Moreover, implementation capacity further restraints grid electrification, even if funding were available.

Instead of relying only on grid electrification, there are solutions to provide electricity locally or regionally in off-grid areas, chiefly diesel generators, solar home systems and mini-grids (including mini-grids combining solar PV generation with storage and backup diesel generation systems). These solutions differ by (1) their ability to support not only residential loads such as lighting and small appliances, but also larger productive loads, such as machinery for welding, carpentry, water pumps, machinery for processing of agricultural crops (e.g. rice milling), etc. and (2) cost and reliability of power supply.

Diesel generators utilise a diesel-fuelled internal combustion engine to generate electricity locally. Typical generation capacity is more than 5 kW, large enough to provide electricity to multiple households and productive loads. Their main drawbacks are that the average cost of electricity is very high (average MMK 510/ kWh but can be higher than MMK 1,000/kWh). In addition, fuel prices can be highly volatile and securing reliable fuel supply and maintenance can be challenging in remote areas.

Solar home systems are standalone photovoltaics systems for individual households. They provide reliable power as they require minimal maintenance. Typically they have less than 150 W of generating capacity which is only sufficient to supply power for lighting, small appliances and cellular phone charging. The main drawback of this solution is that it cannot support larger loads for residential use and productive activities. Because of these limitations, this study does not focus on solar home systems.

Mini-grids combine generation assets with distribution grids that have sufficient scale to cover off-grid villages or townships.

They can support residential and productive loads and, in some cases, also larger commercial loads (known as “anchor loads”) such as a small manufacturing facility or a telecommunication tower in the vicinity of a village. Typically mini-grids have generation capacity between 10 kW to a few hundred kW, however case studies of larger, MW-scale mini-grids supplying power to entire townships exist in Myanmar (notable examples are found in Tanintharyi and include diesel-fuelled mini-grids in Myeik – 12 MW, Kawthaung – 8 MW, Dawei – 6MW).<sup>4</sup>

Therefore, mini-grids have the potential to play a crucial role in providing reliable power to off-grid areas serving residential, productive and anchor loads and not only small villages, but also entire townships.

## Challenges

Given the potential of mini-grids, the Department for Rural Development (DRD) has put in place a subsidy scheme, co-financed by the World Bank, to support the development of renewable-energy based mini-grids in Myanmar.

A number of private developers are involved in developing mini-grids with different configurations and business models (see Annex 8 for a list of mini-grid projects with relevant developers).

Currently, private developers face a number of key challenges in developing mini-grids in Myanmar, including:

- Lack of regulation pertaining to mini-grids, providing uncertainty for investors over the likelihood of national grid arrival and the transition after grid arrival (see Section 2.3 and Section 2.6)
- Uncertainty over existing and latent demand, especially for productive loads (see Section 2.4)
- Difficulty to streamline and scale up development (see Section 2.7)
- Limited opportunities to access financing. This is compounded by the fact that most private developers in Myanmar are small companies.<sup>5</sup>

<sup>4</sup> For a review of large scale mini-grids in Tanintharyi, see also The Asia Foundation, “The Role of States and Regions in the Myanmar Energy Sector”, 2019

<sup>5</sup> World Bank estimates suggest that the typical loan tenure does not exceed 1 year with interest rates as high as 40% (World Bank, “Upscaling mini grids for low cost and timely access to electricity”). This is further confirmed through interviews with private developers and multilateral institutions, suggesting that private developers in Myanmar typically finance mini-grid projects purely using own equity as they cannot access loans at sustainable conditions. However, some banks such as A-Bank and KBZ have started lending to the mini-grid sector.

## Opportunities

Despite these challenges, there are opportunities to improve the viability and to decrease the risk profile of mini-grid development in Myanmar:

- **Technology advances** mean that for certain configurations, mini-grid equipment costs are expected to decrease substantially (see Section 2.7):
  - » As solar PV is emerging as one of the key generation technologies worldwide, increased production volumes of solar panels and other key equipment is driving rapid cost reductions. Scenarios by the International Renewable Energy Agency (IRENA) forecast a more than 60% decrease in cost per unit of capacity by 2030<sup>6</sup>
  - » Equally, increasing production volumes of lithium-ion batteries, driven by the diffusion of hybrid and electric vehicles, are expected to decrease the cost of electricity storage by 50 to 65% by 2030<sup>6</sup>
  - » Advancement in simulation tools allows to optimize mini-grid design and reduce the risk of over-sizing equipment<sup>7</sup>
  - » Reduced costs of sensors and communication modules and advancements in mobile payment technologies are expected to drive cost reduction in remote metering, billing and payment systems, reduce payment risk and allow for new tariff structures<sup>8</sup>
- **Leveraging economies of scale** by developing mini-grid in “blocs” of standardised projects is expected to result in reduction of equipment and consumables procurement costs<sup>9</sup> (see Section 4.4)
- **New Regulations covering mini-grids** have been proposed by the DRD with support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and are currently under discussion. The goal is to introduce a comprehensive set of regulations governing mini-grid licensing, introducing site exclusivity and a compensation or transition scheme in case of national grid arrival (see Sections 2.6 and 5.1)

<sup>6</sup> IRENA, “Electricity Storage and Renewables: Costs and Markets to 2030”, 2017

<sup>7</sup> Parami Energy and Tractebel: “Mini-grid for a rural island in Myanmar — Techno-economic feasibility and preparation of tender documents”, 2018

<sup>8</sup> Interviews with equipment manufacturers conducted by Roland Berger

<sup>9</sup> Pact, “Minigrids in Rural Myanmar: Unlocking the Potential for Decentralised Energy”, presentation at the 5th Myanmar Power Summit





- Capitalising on favourable **evolutions in the market**, such as:

- » Government's increased interest to explore mini-grid models (e.g. Ministry of Electricity and Energy's (MOEE) interest in exploring the suitability of mini-grids for decentralised solutions)<sup>10</sup>
- » Market entry of international energy players such as Mitsui and Engie
- » New investment from multilateral/bilateral institutions such as International Finance Corporation (IFC), Norfund, Yoma Strategic Holdings, Italian Development Cooperation (AICS), and growing interest from key donors such as Agence Française de Développement (AFD), United States Agency for International Development (USAID), Asian Infrastructure Investment Bank (AIIB), European Union (EU) and United Nations (UN)

- » Creation of dedicated facility (Smart Power Myanmar) to support rural electrification initiatives and complementing efforts of organisations such as GIZ and United Nations Development Programme (UNDP) (currently developing a proposal for a new energy program in Myanmar)

In light of these opportunities that may accelerate mini-grid development, this study aims to assess the potential market size for mini-grids in Myanmar, the key market drivers, to formulate projections and scenarios for future market evolution, as well as recommendations for policy directions to stimulate the mini-grid market.

<sup>10</sup> Interviews with MOEE conducted by Roland Berger



# 2.0

## Review of the Current Market and Key Drivers for Off-Grid Solutions

### 2.1 Current market for off-grid solutions and mini-grids in Myanmar

As outlined in Section 1, 6.5 million households are not connected to the national electricity grid in Myanmar. Out of these, 2.5 million households have access to electricity through off-grid solutions.

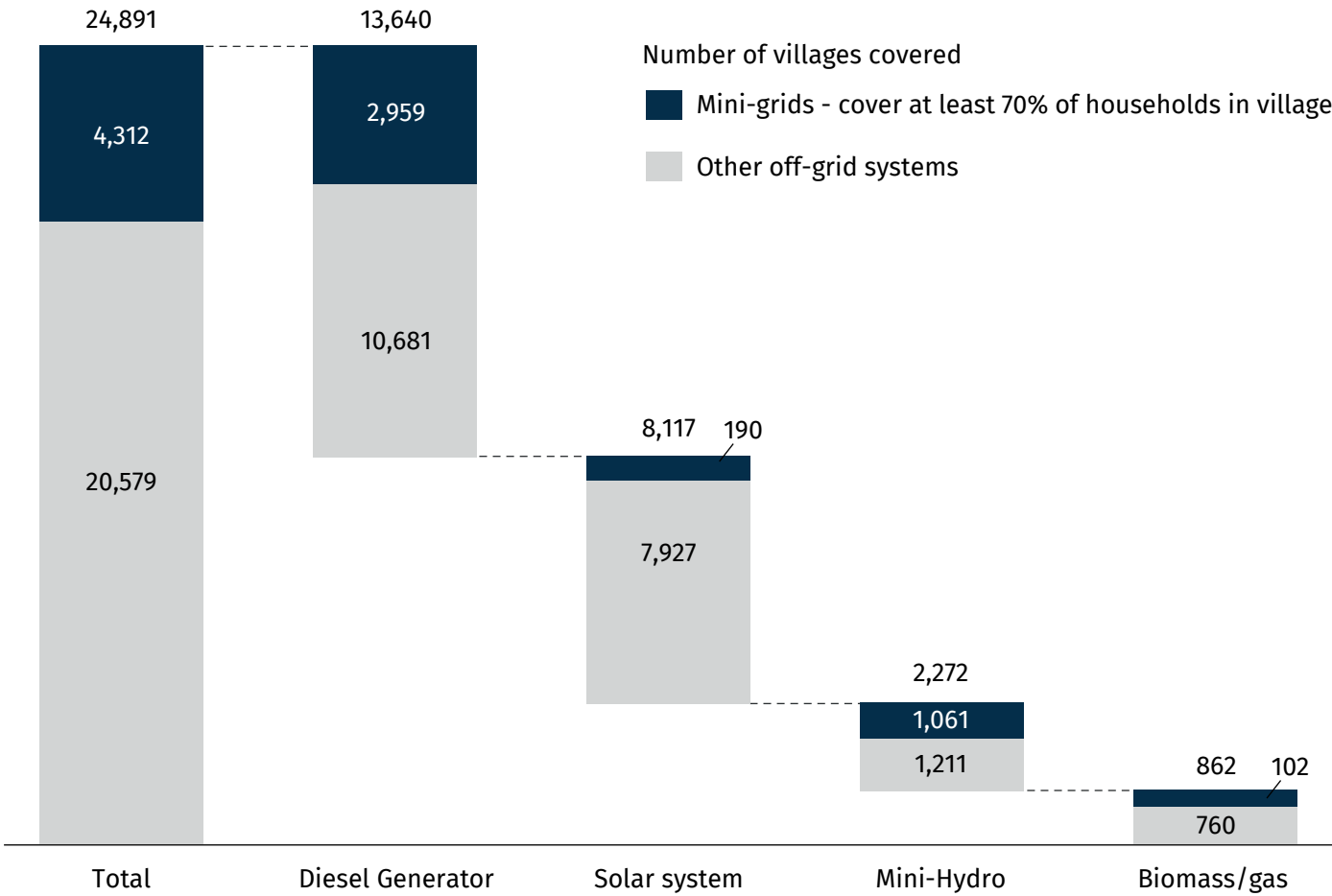
Data from the Department of Rural Development (DRD) show that almost 25,000 villages are electrified<sup>11</sup> (i.e. provided with electricity) through off-grid solutions including diesel generators, solar systems, mini-hydro systems and biomass generation systems.

DRD estimates that about 4,312 of these off-grid systems supply electricity to at least 70% of households in the village where they are located and hence can be defined as mini-grids (see Figure 3). Details on the definition of mini-grids are included in Annex 1.

According to DRD, 69% of these 4,312 mini-grid systems are powered by diesel generators, followed by small hydroelectric systems (25%) and solar mini-grids (4%). Biomass gasification or Biomass/biogas systems make up the remaining 2% of the total number of mini-grids.

<sup>11</sup> Some electrified villages may only have electricity for commercial use demand and not for residents

Figure 3. Estimated number of villages covered by off-grid solutions and number of existing mini-grids in Myanmar



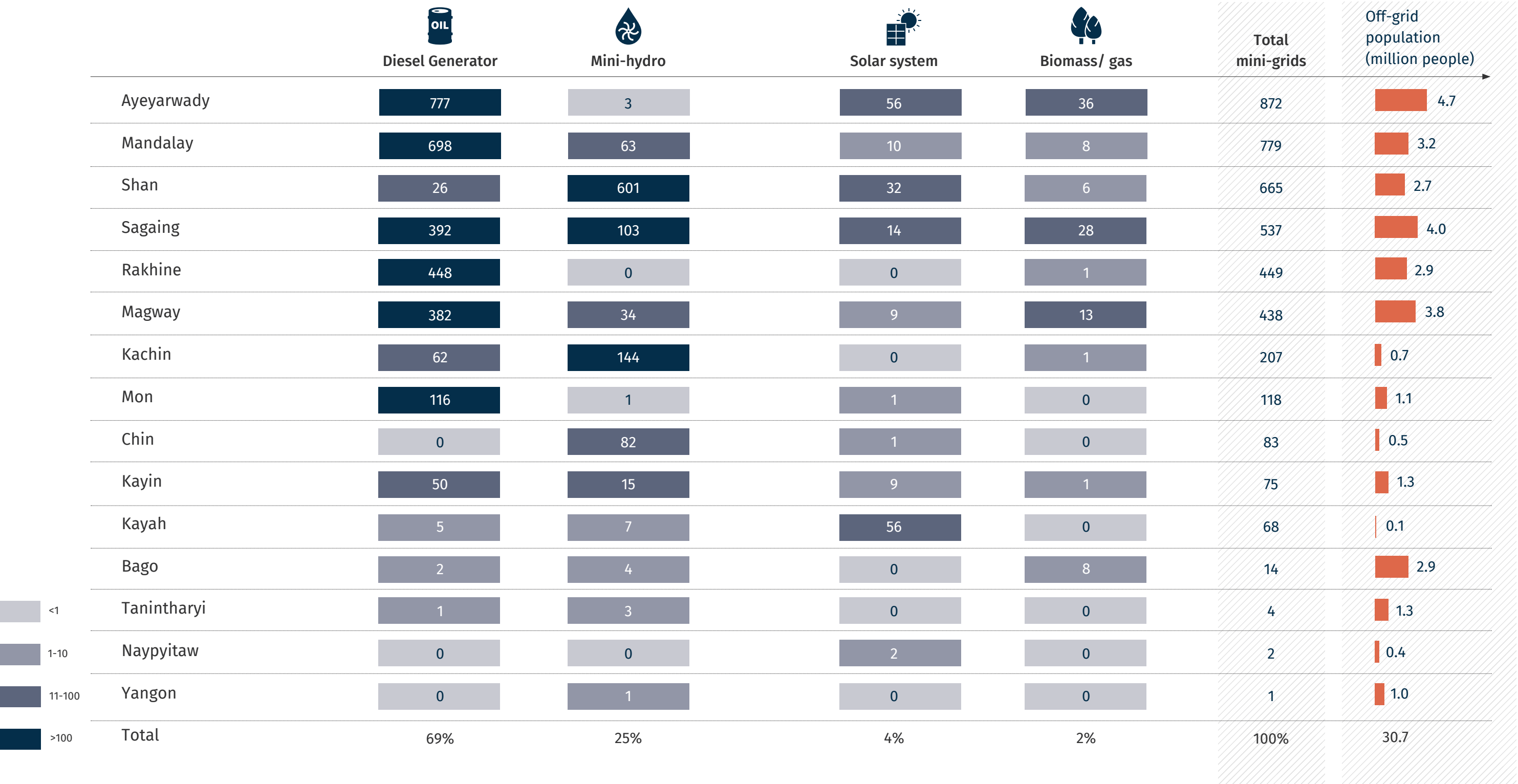
Source: DRD, World Bank “Myanmar Mini-grid Overview”, presentation at Upscaling Mini-Grid Workshop (2017)

In general, the top States/Regions by number of mini-grids have high off-grid populations (e.g. Ayeyarwady, Mandalay, Shan, Sagaing, Rakhine, Magway). Furthermore, States/Regions in mountainous areas such as Shan and Kachin have high prevalence of hydro mini-grids (see Figure 4).

Interviews with stakeholders suggest that only a small fraction of these systems were built for commercial purposes and most are not “grid-ready”, i.e. the infrastructure is not compatible with that used in the national grid.<sup>12</sup>

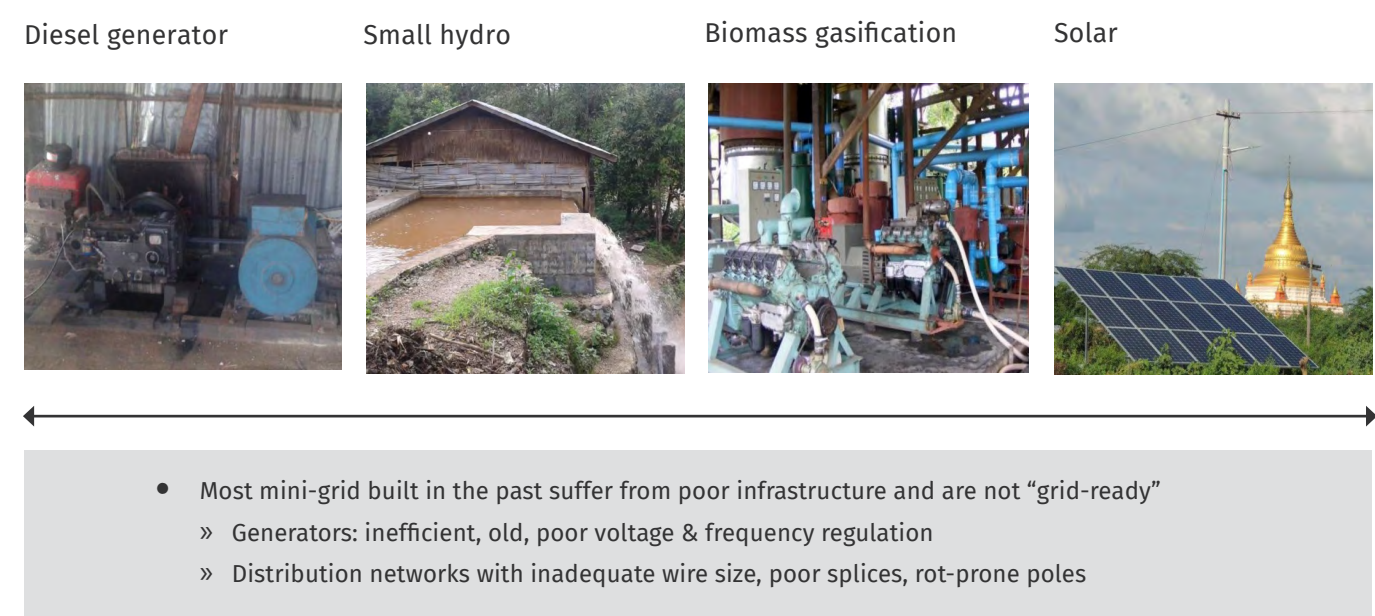
<sup>12</sup> Interviews with multilateral organisations, equipment suppliers and private developers conducted by Roland Berger. Grid readiness include infrastructure compliance with grid code (e.g. poles, cables) and possibility to connect and synchronize generation equipment to the grid.

Figure 4. Number of existing mini-grids by State/Region



Source: DRD, Roland Berger

Figure 5. Status of existing mini-grids



Source: World Bank “Myanmar Mini-grid Overview”, presentation at up scaling Mini-Grid Workshop, 2017

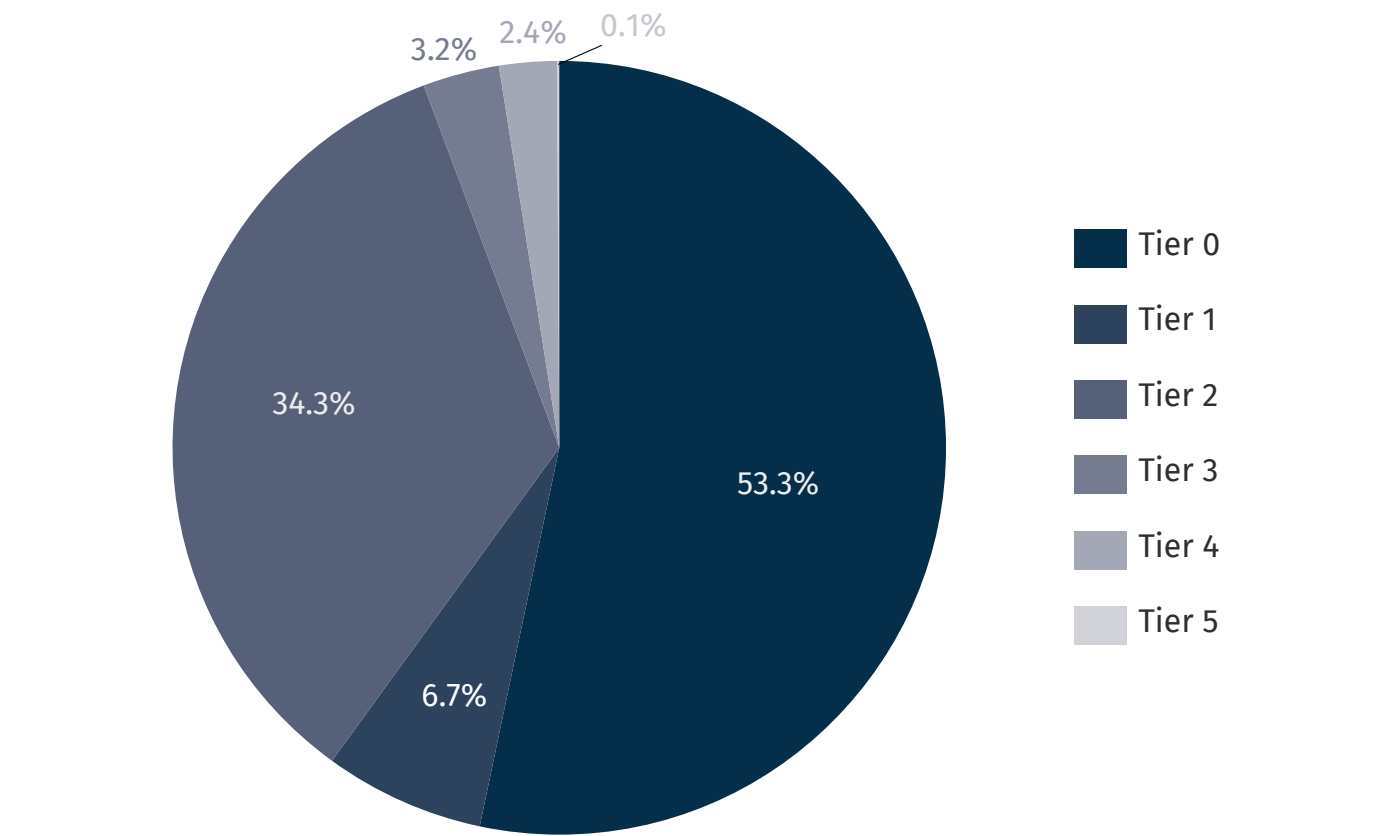
Furthermore, a survey on energy access in Myanmar conducted by the World Bank using the Multi-Tier Framework for quality of energy supply confirms that the vast majority of existing mini-grids in Myanmar can only provide lower tier electricity access. Taking into account mini-grids not developed under the DRD subsidy scheme, an estimated 94% of the population with electricity access through mini-grids can only enjoy Tier 0 to Tier 2 electricity access.<sup>13</sup>

Out of the existing mini-grids, only a small fraction is thought to be grid-ready. These grid-ready mini-grids are developed by private developers<sup>14</sup> and mostly relying on solar PV generation combined with batteries and backup diesel generators. A list of 68 grid-ready mini-grid projects (existing and planned) is included in Annex 8.

13 World Bank, “Myanmar: Energy Access Diagnostics Results Based on Multi-Tier Framework”, 2019

14 Refer to Annex 1 for an outline of private developers

Figure 6. Quality of electricity supply of existing mini-grids

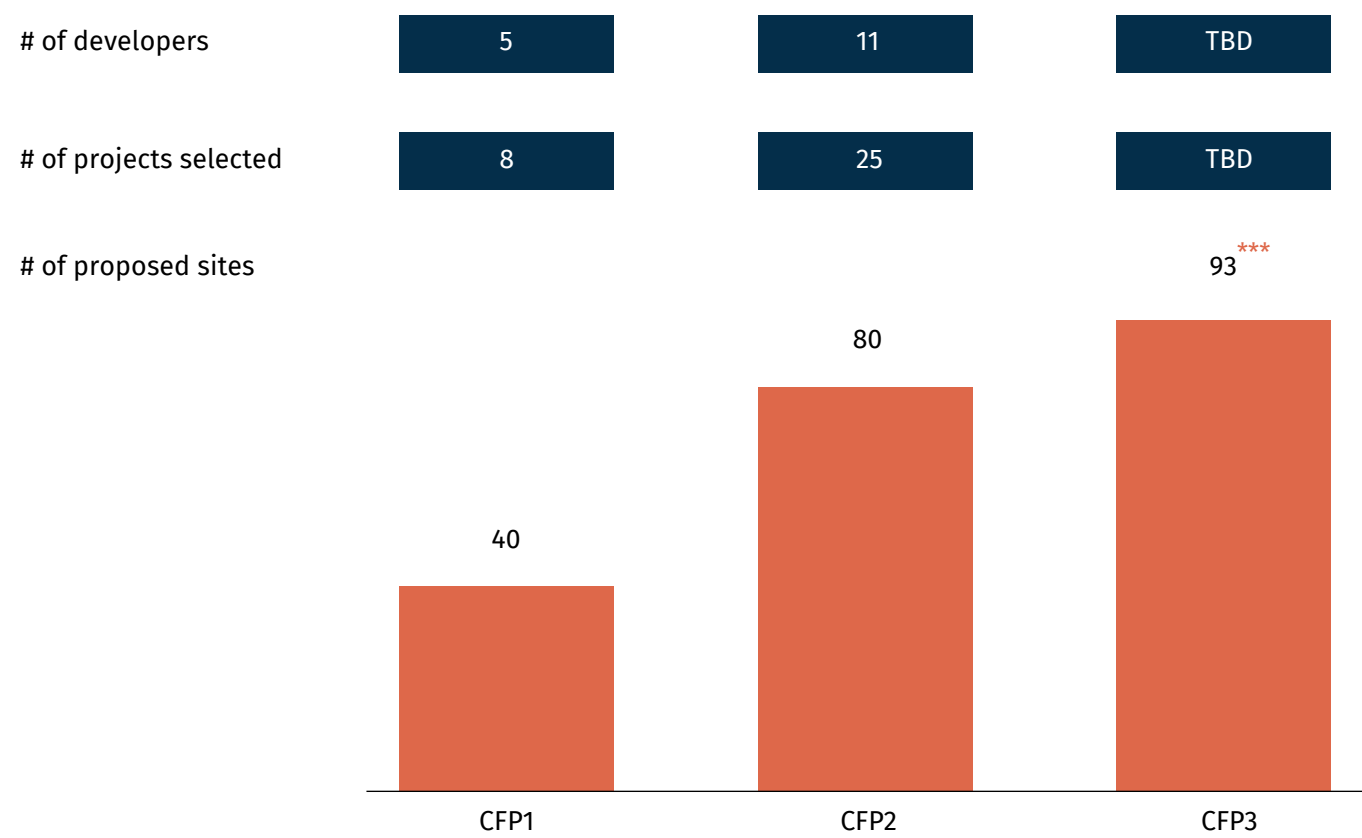


Source: World Bank, “Myanmar: Energy Access Diagnostics Results Based on Multi-Tier Framework”, 2019

The subsidy programme introduced (see Section 2.5 for details) by the DRD and backed by a World Bank loan, has been a major driver for the development of this new generation of grid-ready mini-grids and resulted sofar in the selection of 33 mini-grid projects announced and developed by private developers in the first two years of the scheme — selection of projects for year 3 is currently under way and it is expected that an even larger number of projects will be implemented.<sup>15</sup> Figure 7 shows the evolution of DRD mini-grids scheme.

15 Interview with GIZ conducted by Roland Berger

**Figure 7.** Evolution of number of proposed sites, projects selected and developers under the Call for Proposal (CFP) for investment subsidiess



\*\*\* Number of villages which have been pre-screened and released to prospective developers

Source: Interview with GIZ conducted by Roland Berger

## 2.2 Business models and market drivers

### Existing business models in Myanmar

As described in Section 2.1, there are thousands of mini-grids in Myanmar of which at least 68 are grid-ready mini-grids planned and/or developed by private developers – this section describes business models for mini-grids as well as adjacent business models for off-grid electrification that may be leveraged by mini-grid developers.

Business models can be classified according to the nature of the target load and the type of income streams.

Possible income streams include not only sales of electricity, but also subsidies from government and multilateral organisations, contributions from village households to be connected to the mini-grid and sales/rent of equipment to final customers.

In the **anchor-focused business model**, the private developer supplies electricity mainly to an anchor tenant such as an industrial site or a telecommunication tower, covering most of the generated supply. The existing case studies in Myanmar rely on off-grid telecommunication towers as anchor tenants. The contractual agreement between the private developer and the telecommunication tower company involves typically a fixed price per kWh of electricity supplied that is negotiated prior to project development and that can be reviewed periodically thereafter. This model has potential to be scaled nationwide for several reasons: (1) 80% of the approximately 15,000 telecommunication towers existing in Myanmar are owned by 6 companies<sup>16</sup> – hence private developers could potentially ink multi-site agreements covering hundreds or thousands of sites, (2) tower design and power requirements are standardized – hence private developers could potentially use standardized power systems significantly simplifying multi-site roll-out. Currently, the leading player in Myanmar relying on this business model is Yoma Micro Power. As of end 2018, Yoma Micro Power had 10 mini-grid projects in Myanmar of which 6 supply power to telecom towers only and 4 supply power to telecom towers and some nearby households. Going forward, Yoma Micro Power is targeting to scale up the number of projects to more than 2,000 by 2023.<sup>17</sup> SolaRiseSys also is targeting to scale up its mini-grid portfolio to more than 1,000 projects.<sup>18</sup> Other companies such as Voltalia are active in providing off-grid power solutions to telecommunication towers, and manage portfolios exceeding 100 projects, but do not operate mini-grids serving villages in addition to towers.

In the **residential-focused subsidised business model**, the private developer supplies electricity mainly to village households. The existing case studies include pay-as-you-go tariffs with pre-paid schemes to limit payment collection risks. In addition, this model is dependent on subsidies and contributions from the local community to ensure financial viability. This model is less scalable than the anchor-focused model as project development requires negotiations and site specific engineering on a village-by-village basis. Some players relying on this model, such as Mandalay Yoma, aim to combine residential and anchor loads to increase viability and scalability.<sup>19</sup>

<sup>16</sup> Interviews conducted by Roland Berger with mobile network operators and tower companies

<sup>17</sup> Interview conducted by Roland Berger with Yoma Micro Power

<sup>18</sup> Interview conducted by Roland Berger with SolaRiseSys

<sup>19</sup> Interview conducted by Roland Berger with Mandalay Yoma



**Figure 8.** Categories of current off-grid business models in Myanmar



### A. Anchor-focused

- Core business: sales of power to anchor loads under PPA or Service Level Agreement
- Sustainable without subsidies & highly scalable in case of telco towers
- Now expanding to residential & productive loads.

### B. Residential-focused subsidised

- Core business: sales of power to villages under pay-as-you-go or fixed fee model
- Relies on subsidies
- Expanding to productive & anchor loads

### C. Equipment-focused

- Mainly used by Solar Home System players in combination with subsidies
- Mini-grid developers considering use to enhance and stabilize power demand

**Source:** Interviews with market players, Roland Berger

Private developers developing mini-grid projects under the investment subsidy scheme are also adopting this business model – the structure of the subsidy scheme is outlined in Section 2.5. It should be noted that, as of now, there is no private developer with unsubsidised mini-grids focusing on residential supply, as these projects are not viable at this stage<sup>20</sup> – further analysis of viability of unsubsidised mini-grids is presented in Section 3.2.

The **equipment-focused model** is mainly utilised by solar home system players that rent electrically-powered equipment to end users to secure power demand. Mini-grid private developers are also considering applications of this model to support growth of demand in off-grid villages to increase mini-grids viability. A new approach that is being explored based on successful case studies in other markets such as Africa is financing of electrically powered equipment to be utilised by small businesses to increase their productivity.

## Market drivers

Five types of key drivers for the mini-grid market can be identified: (1) Grid electrification, (2) Power demand from off-grid areas, (3) Subsidies and contributions, (4) Regulatory environment, (5) Technology potential.

**Grid electrification** directly impacts the addressable market for mini-grids as grid-electrified locations become unattractive to mini-grid development due to subsidised grid electricity tariffs. In addition, in the absence of appropriate regulatory provisions, uncertainty on grid expansion plans can prevent investment in mini-grids.<sup>21</sup>

**Power demand from off-grid areas** both in terms of load size, density and types of loads (residential, productive, anchor loads and public buildings) determines the financial viability of mini-grids in terms of capacity sizing, investment, operating costs and revenues.

**Subsidies and contributions** are an important determinant to assess the size of the mini-grid market, as most mini-grid models without subsidies are not currently viable standalone.

20 Interview conducted by Roland Berger with Smart Power India

21 If appropriate regulations are in place existing mini-grids can be integrated into the national grid at the time of  
grid arrival or mini-grid developers can transfer the assets to the national grid operator upon compensation.

**Regulatory environment** defining for example, legal status, rights of developers, options for transition at the time of grid arrival, affects the risk profile of mini-grid projects influencing investment decisions.

**Technology potential** chiefly in terms of generation and storage technologies, their standardization and modularization impacts mini-grids development; for example more cost effective solar PV and batteries leading to enhanced financial viability of mini-grids.

2.3 Market driver 1: Grid electrification

The 2015 National Electrification Plan (NEP): an ambitious roadmap where mini-grids play only a marginal role

To increase electricity access, the Government of Myanmar in 2015 set an ambitious roadmap to reach 100% grid electrification by 2030.

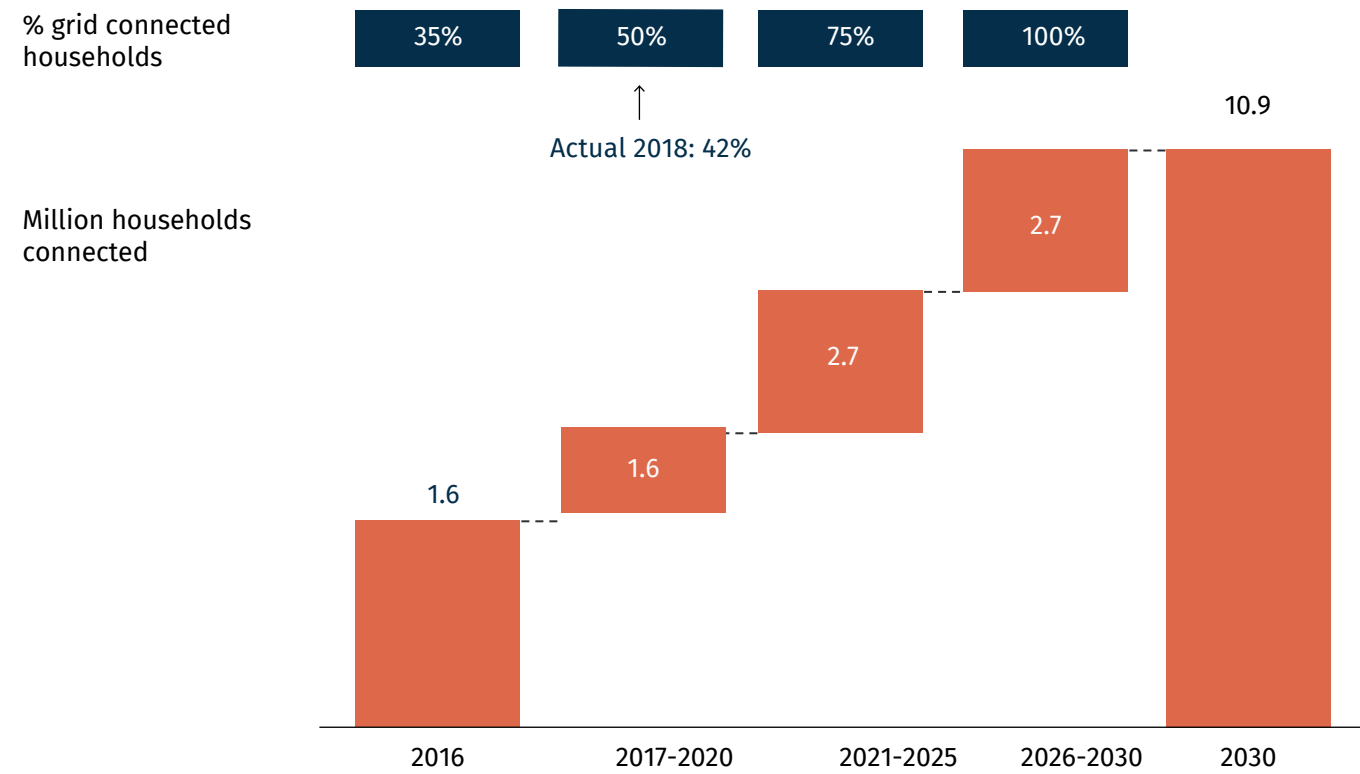
The NEP roadmap was structured around a two-pronged approach<sup>22</sup>:

- Extend medium-voltage distribution lines to connect off-grid villages according to a prioritised roadmap in 5 phases. Areas with higher population density and closer to the existing grid infrastructure would be connected first (Phase 1), while low-density areas further away from grid infrastructure and with higher cost per connection would be connected last (Phase 5, to be completed by 2030)
- For villages in Phase 4 & 5 of grid roll-out (about 3% of total off-grid population), leverage pre-electrification solutions in the short term. The optimal solution is identified depending on the size of villages: for villages with less than 50 households utilise solar home systems, for larger villages, utilise mini-grid solutions

The NEP identified 100% grid electrification as the most suitable option for Myanmar, while mini-grids and other off-grid solutions occupy only a very marginal role, only in the interim, and are confined to low-density areas concentrated in a few States/Regions such as Shan, Chin, Kayah and Kachin. In the NEP roadmap, the number of households to be electrified through mini-grids is expected to be 155,000, corresponding to a few thousands mini-grids, while the remaining phase 5 households would be electrified through solar home systems.

22 World Bank, “Myanmar: Towards Universal Access to Electricity by 2030”, 2014

Figure 9. Evolution of grid-connected households according to the National Electrification Plan



Source: World Bank; Press research; Myanmar Energy Monitor; Roland Berger

Caveats

The NEP roadmap was based on geospatial analysis of cost per grid connection in different areas, and identified the least cost option for reaching 2030 electrification targets.<sup>23</sup> However several caveats exist.

Firstly, although the overall roadmap is cost-optimized, the NEP’s targets do not take into account budget constraints and assume that unlimited budget can be secured to achieve 100% electrification.

Secondly, while the total investment for extending medium-voltage lines (distribution lines) was estimated at 5.8 billion USD, the total required investment in high-voltage transmission lines and additional power generation capacity required to power the new on-grid areas, is not specified in the roadmap. World Bank estimates suggest that, to cover additional residential demand only, approximately 2.5-3 GW additional generation capacity would be required.<sup>24</sup>

23 Columbia University Earth Institute, “ National Electrification Planning for Myanmar (NEP): National Geospatial, Least-Cost Electrification Plan”, 2014

24 World Bank, “Myanmar: Towards Universal Access to Electricity by 2030”, 2014

Figure 10. Roadmap and costs for the National Electrification Planning



Source: World Bank, “Myanmar: Towards Universal Access to Electricity by 2030”, 2014

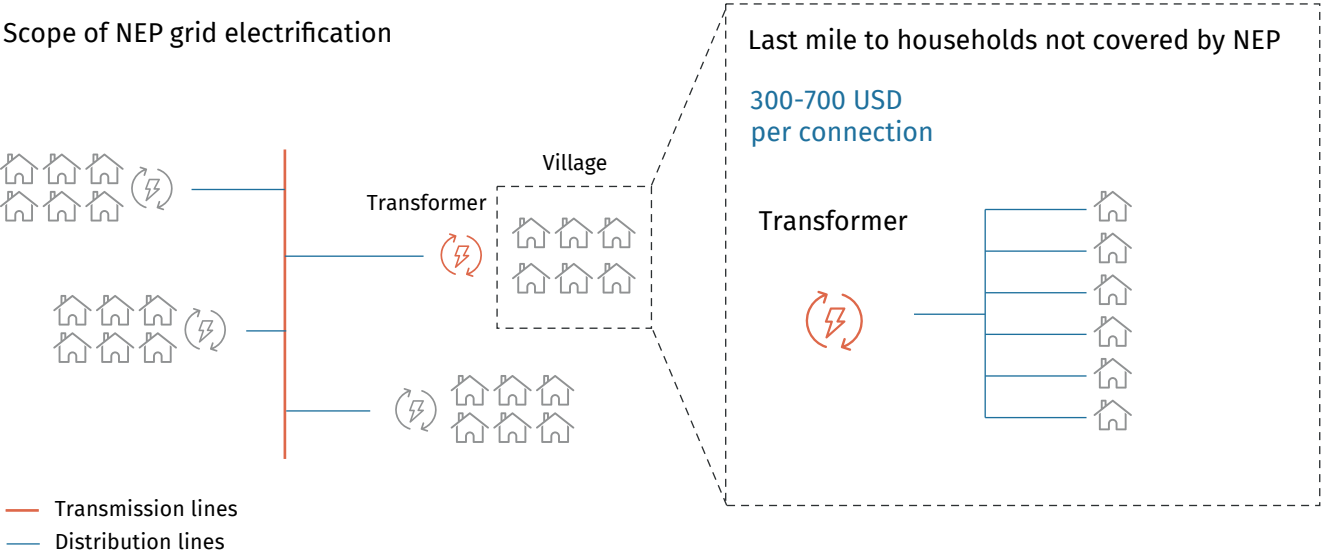
Assuming that Myanmar maintains the current fuel mix in installed capacity generation, building 2.5-3 GW of new generation capacity would require 5.5-6.6 billion USD investment (only considering capital costs).<sup>25</sup> It should be noted that these estimates of additional generation capacity are highly conservative. For example, according to research by the Asia Foundation, the latest pipeline for expansion of generation capacity in Myanmar includes about 12.7 GW worth of power plant projects, with roughly half the projects

<sup>25</sup> Fuel mix in generation capacity: 60% hydroelectric, 36% natural gas, 4% other (mainly diesel) Source: MOEE; assumes 2,948 USD/kW (hydro), 999 USD/kW (natural gas combined cycle) and 1,371 USD/kW (diesel) capital costs for generation as per US National Energy Administration estimates in 2019

having received a Notice to Proceed, and half projects the project undergoing feasibility assessments.<sup>26</sup> It should also be emphasised that subsidised tariffs for grid electricity generate vast annual losses in government budget.<sup>27</sup>

Thirdly, the NEP roadmap only defines a programme for the expansion of the distribution network infrastructure down to transformers located at the village limits — the “last mile” low voltage connections to homes and businesses are not included. Villages, households or businesses already pay for the last mile infrastructure. Interviews with stakeholders suggest that households typically need to pay 300 to 700 USD for each connection depending on the population density and morphology of the village site.<sup>28</sup> Based on DRD-subsidised mini-grids so far, the cost of connection may need to be subsidised by the government, as approximately 50% of households are unable or reluctant to pay the connection costs.<sup>28</sup> Therefore this will result in an additional 2.2-5 billion USD required (for ~7 million households) to fund grid electrification. If the cost of “last mile” connections is not covered by NEP, there is a risk that NEP will result in grid-connected villages with a significant portion of off-grid households.

Figure 11. Scope of NEP electrification and the last mile problem



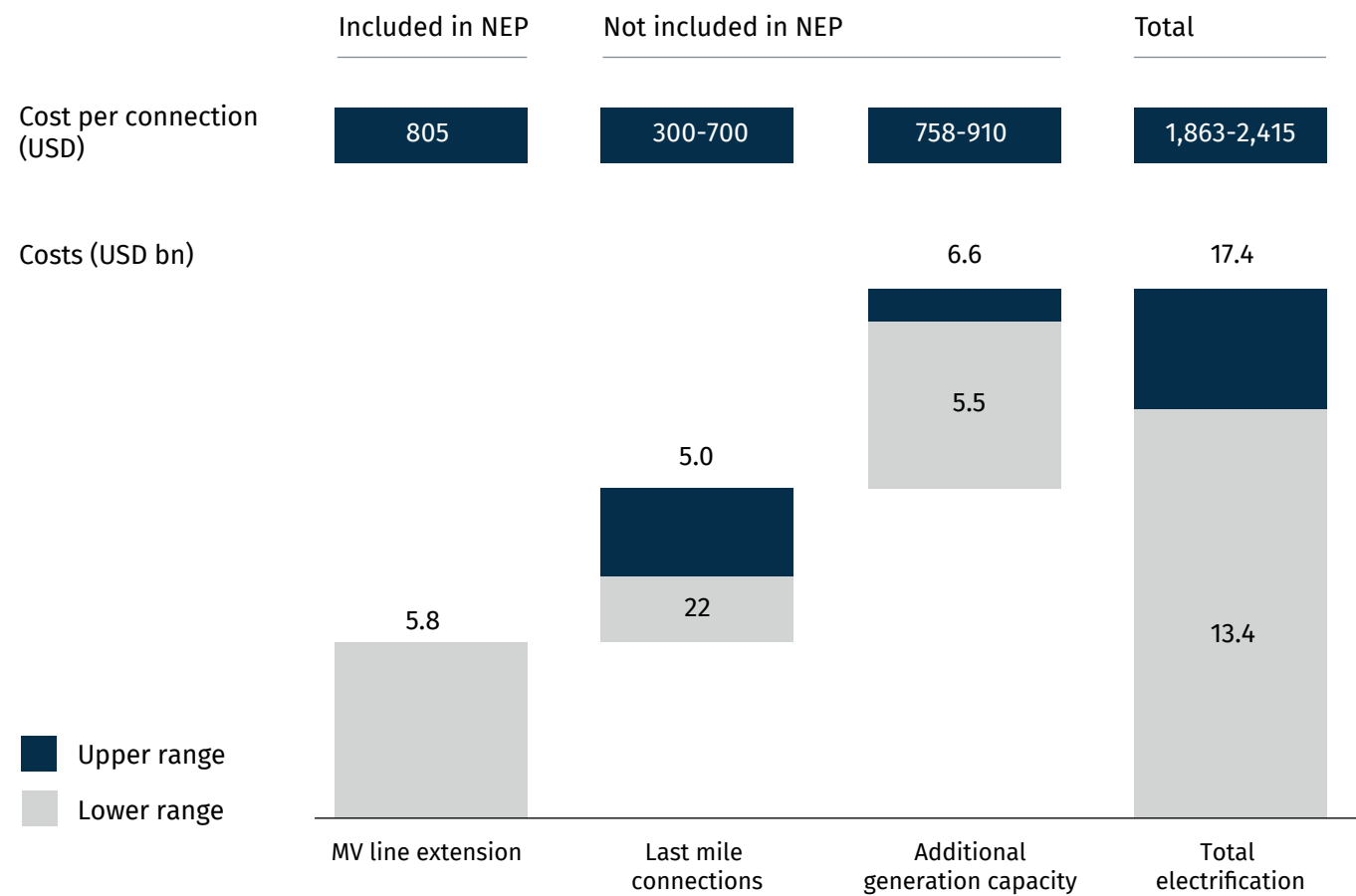
Source: Interviews with local market players

<sup>26</sup> The Asia Foundation, “The Role of States and Regions in the Myanmar Energy Sector”, 2019

<sup>27</sup> Ministry of Electricity and Energy lost ~ USD 300 million in 2017 and nearly USD 500 million in 2018 due to subsidised electricity tariffs . Losses are projected to be grow to USD 1 billion by 2020 source : <https://www.mmmtimes.com/news/real-cost-myanmars-electricity.html>

<sup>28</sup> Interview conducted by Roland Berger with Ministry of Electricity and Energy (MOEE)

**Figure 12.** Grid electrification costs and cost per connection — portions included in NEP, not included in NEP and total estimated budget

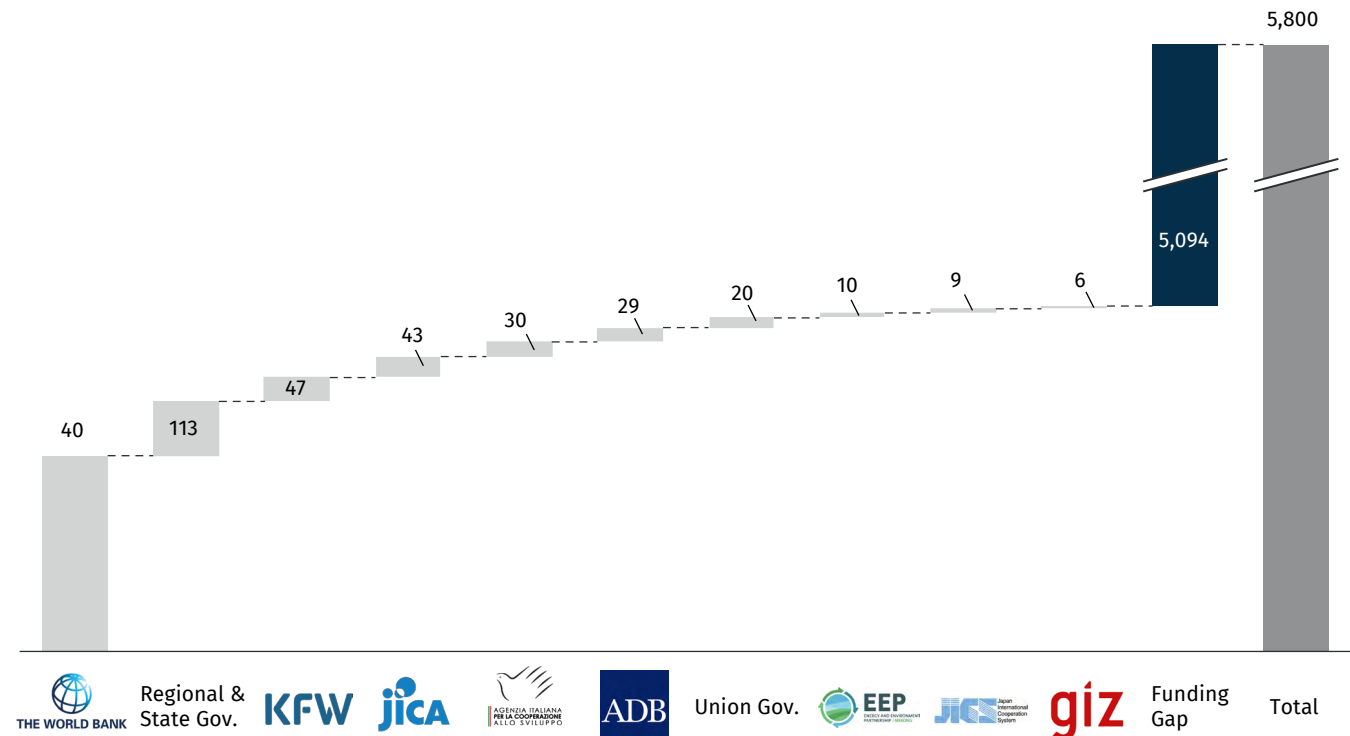


Source: Roland Berger

In terms of funding, so far only 706 million USD has been secured from Union and State/Region governments, multilateral and bilateral institutions (see Figure 13). In addition, subsidised tariffs for grid electricity generate vast annual losses in government budget. The World Bank is currently the largest contributor and approved a 400 million USD loan to support NEP projects.

Taking into account only the 5.8 billion USD investments required to extend medium-voltage lines, a funding gap of approximately 5.1 billion USD exists.

**Figure 13.** Funding already secured and funding gap for NEP [USD million]



Source: World Bank; GIZ; KfW; Rockefeller Foundation; Press releases; Roland Berger

Going forward, a number of multilateral, bilateral and development organisations are considering increasing funding for electrification in Myanmar,<sup>29</sup> for instance:

- AFD is considering a loan for renewable mini-grids and rural energy (biomass)
- EU is considering grant funding for rural electrification (budget not confirmed)
- United Nations Development Programme (UNDP) is considering funding for rural electrification projects through Global Environment Facility (GEF)

<sup>29</sup> Interview conducted by Roland Berger with Agence Française de Développement (AFD)





In addition, direct investment into private developers has been implemented, such as the IFC and Norfund investment of 28 million USD into Yoma Micro Power to develop solar powered off-grid solutions.<sup>30</sup>

Taking into account these funding sources, an additional budget of approximately USD 25 million is expected to become available for electrification in Myanmar. However, this is still insufficient to fill the 5.1 billion USD funding gap.

### Evolution of electrification to 2030 in Myanmar

Analysis of previous electrification programmes in other countries indicates that the NEP target of increasing electrification by 58% points, from 42% to 100% in 12 years is unlikely to be achieved.

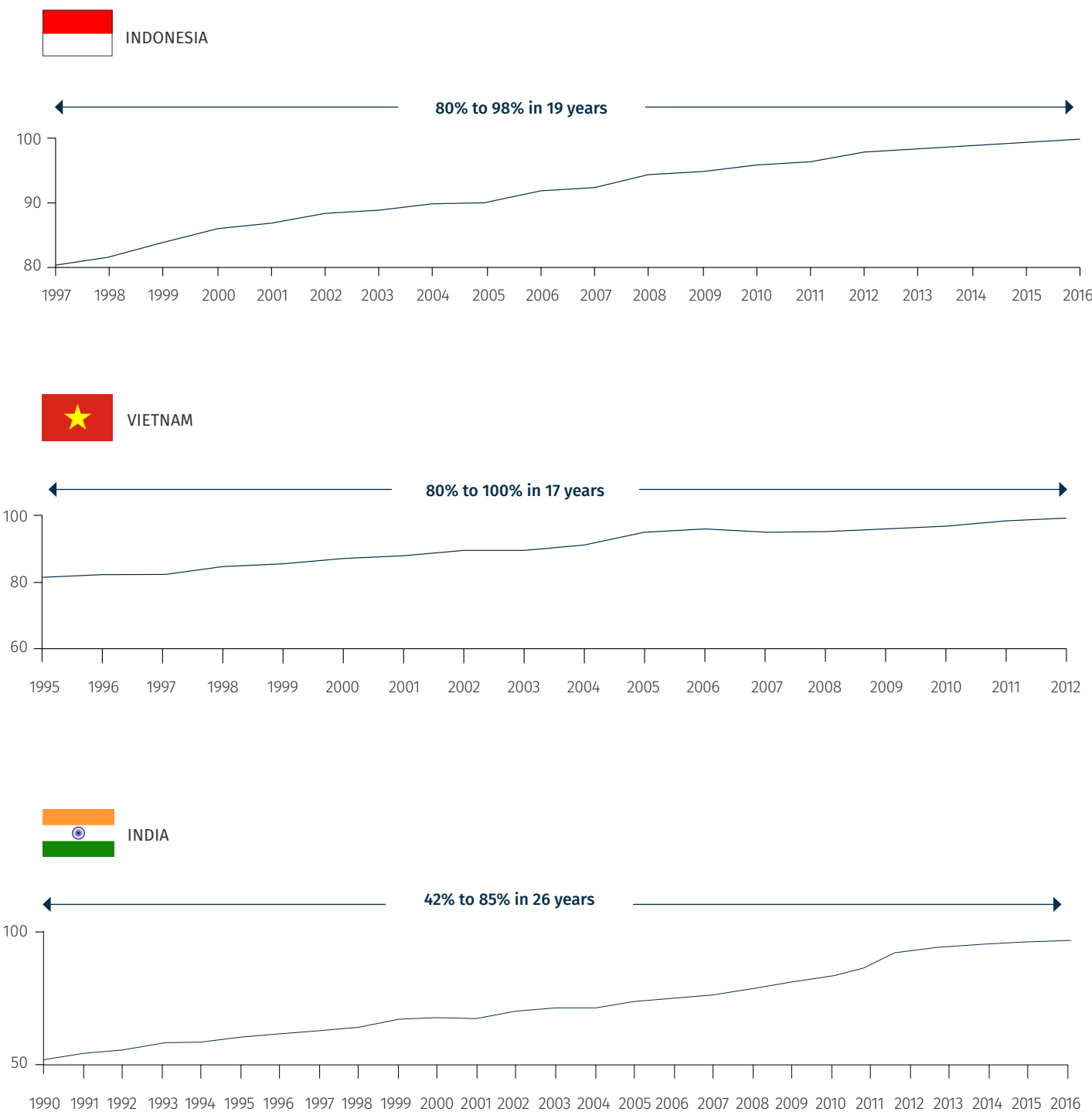
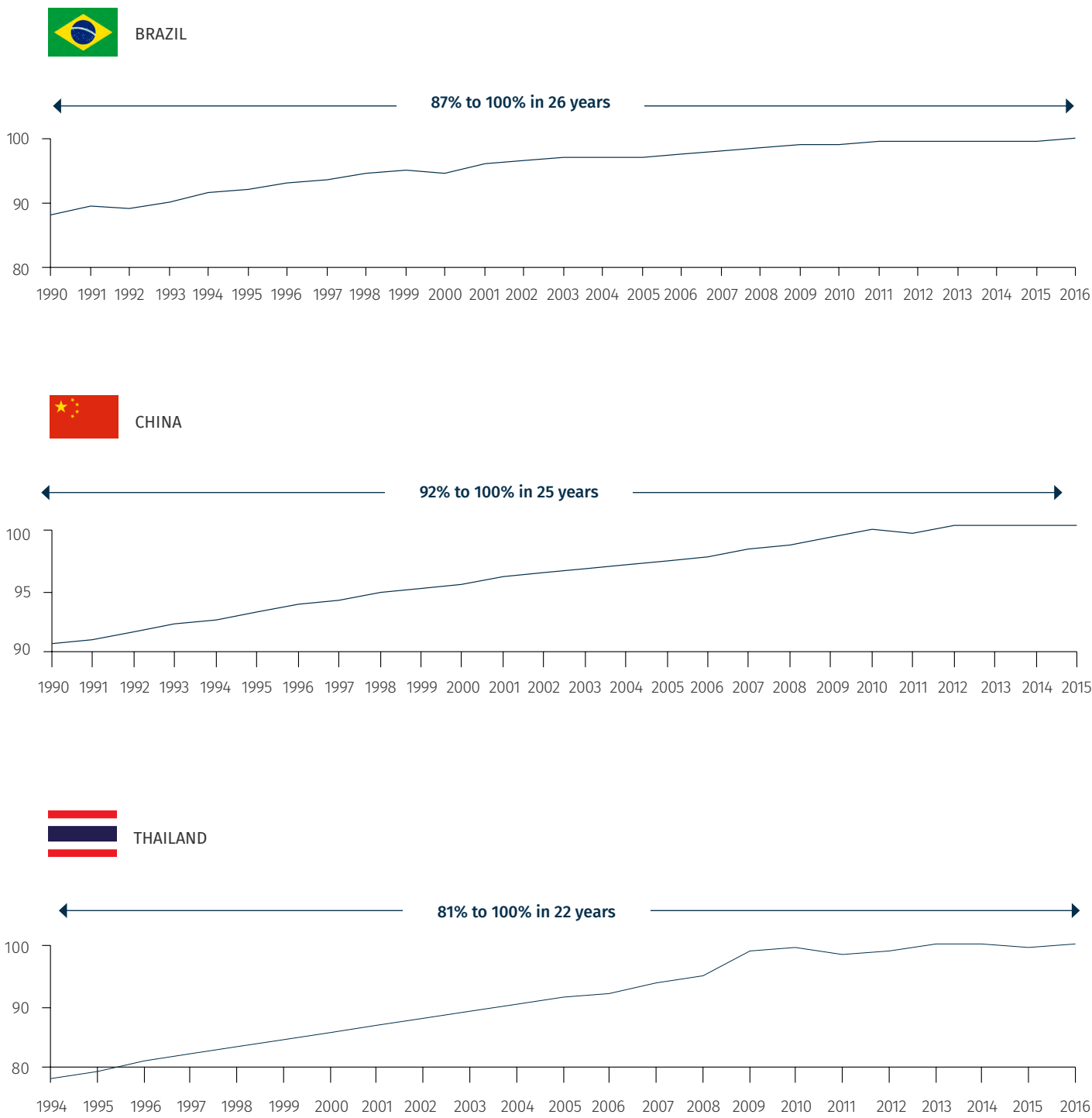
Past electrification programmes in China and Brazil show that it can take more than 20 years to connect the last 10-20% of households in the most remote areas. This is consistent with the electrification rates in Southeast Asian countries such as Thailand, Vietnam and Indonesia.

For further comparison, it took 27 years to reach 85% from 42% in India. This is because grid expansion in remote areas is more costly and investment cannot be recovered easily through electricity sales as these areas have low demand potential (see Figure 14).

<sup>30</sup> Business Times, "Yoma Strategic's Myanmar project nets funding from International Finance Corp", 2018



Figure 14. Time required to increase electrification for benchmark countries

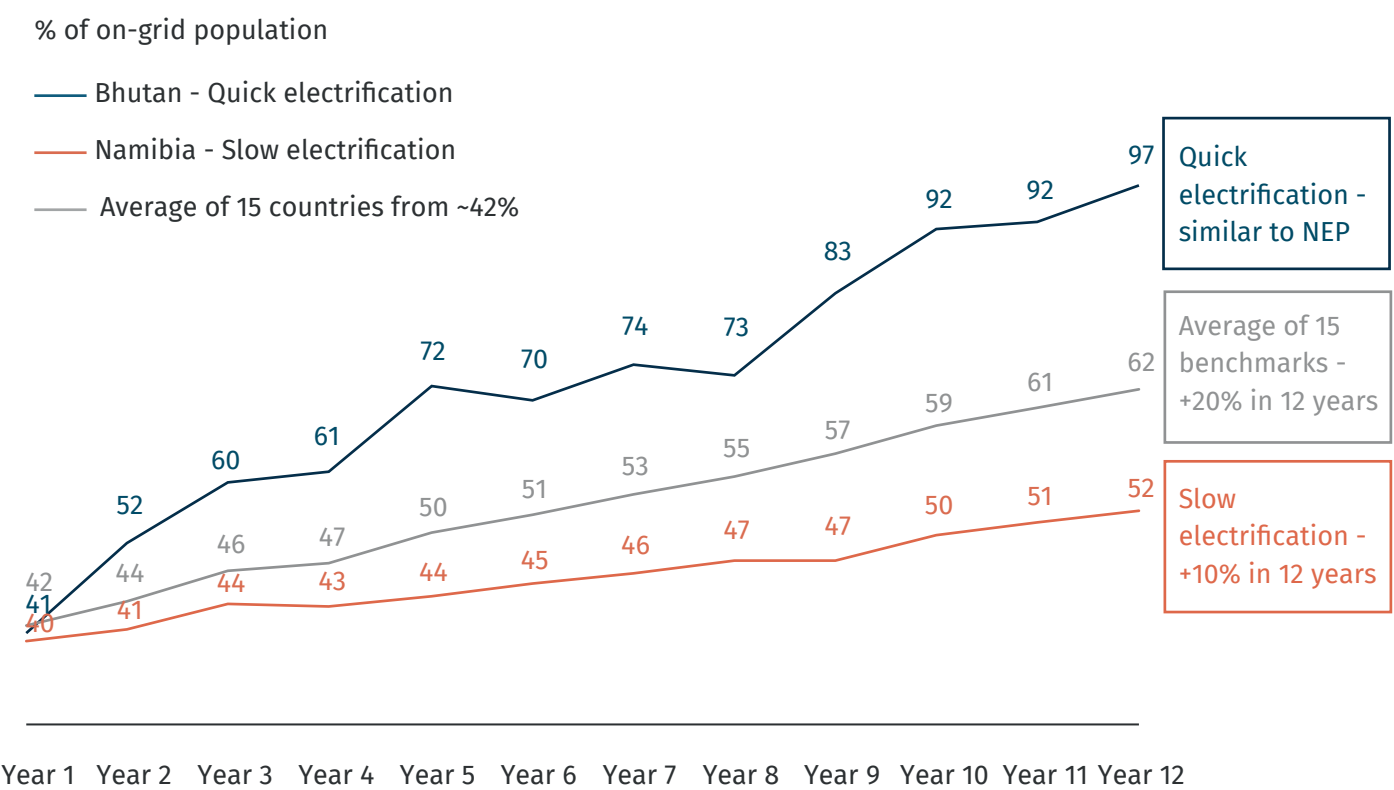


Source: World Bank Sustainable Energy for All Database;  
For Thailand 1999 and 2006 data points interpolated due to inconsistencies in source data set

In order to assess future electrification to 2030 for Myanmar, the evolution of electrification over 12 years in 15 benchmark countries starting from the same level of electrification as Myanmar today (~42%) was examined. Based on these benchmarks, three possible evolutions were identified:

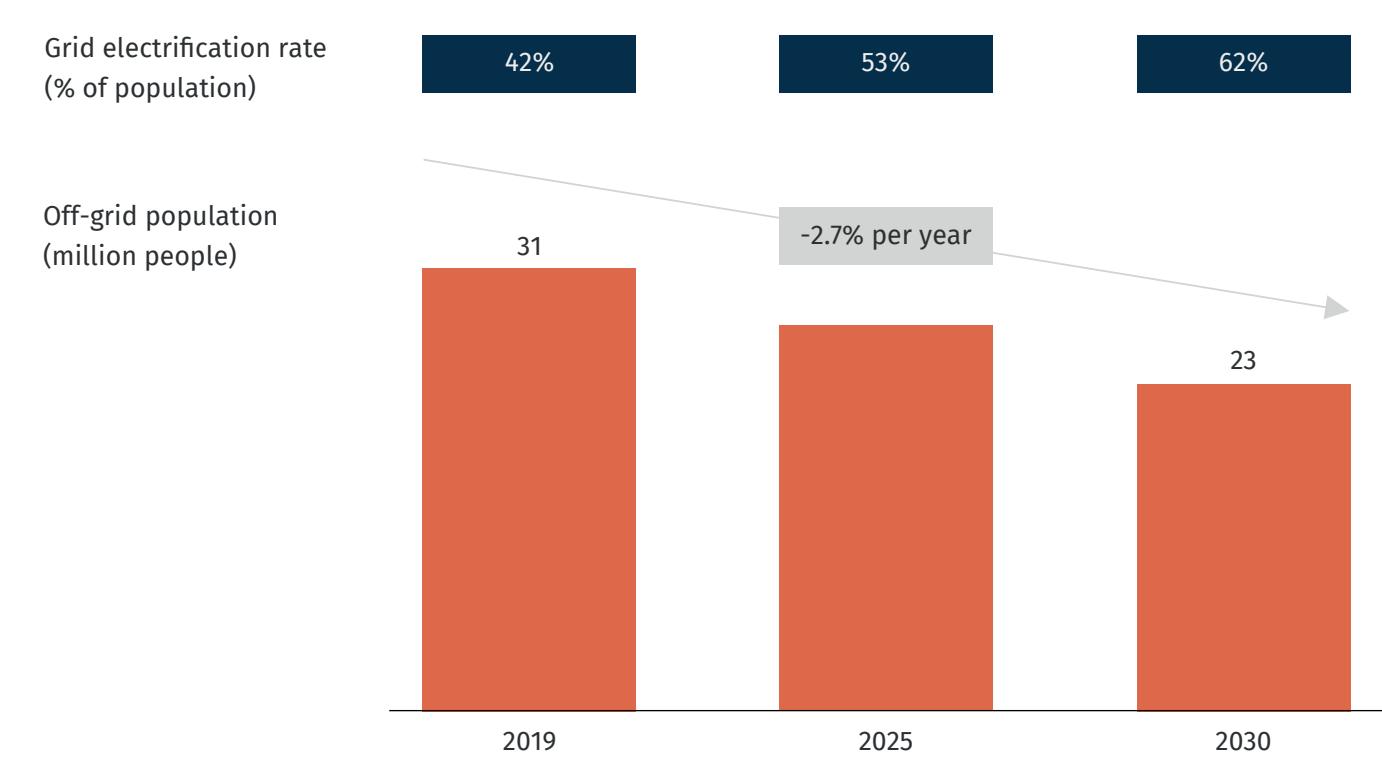
- **Quick electrification similar to NEP leading to nearly 100% electrification from 42% in 12 years.** This has been observed in one case (Bhutan) where the electrification rate increased to 97% over the observed period. However, Bhutan’s population is only approximately 800,000, covering a significantly smaller geographic area
- **Average electrification** using the average of the 15 benchmark countries considered. In this case, the rate increases by approximately 20% points to reach 62% after 12 years
- **Slow electrification** based on Namibia, the worst performer in the benchmark group. In this case the rate increases only by 10% points to 52% after 12 years

Figure 15. Evolution of electrification rates from approximately 42% over 12 years for 15 benchmark countries globally



Source: World Bank Sustainable Energy for All Database, Roland Berger<sup>32</sup>

Figure 16. Estimated evolution of grid electrification rate and of off-grid population in average electrification case



Source: Roland Berger analysis based on Census data<sup>33</sup>

In subsequent market modelling conducted in this study, the electrification rate is assumed to follow the average case (i.e. +20% points electrification rate by 2030 from 42% to 62%).

Assuming 62% electrification rate by 2030 and an overall population growth<sup>31</sup> rate of 0.8% per year,<sup>32</sup> it is estimated that the off-grid population would decrease at an annualised rate of 2.7% from 31 million people in 2019 to 23 million people in 2030.

31 Data reporting inconsistencies may account for year-on-year fluctuations seen in some of the data

32 The 2014 Myanmar Population and Housing Census



## 2.4 Market driver 2: Off-grid power demand

Power demand in off-grid areas in Myanmar is driven by four key components:

- Residential demand — i.e. demand for domestic use by households
- Productive use demand — i.e. demand form agricultural, and small-scale industrial and commercial activities
- Public demand — i.e. demand from public buildings such as libraries, hospitals, monasteries and from public lighting
- Demand from anchor loads — i.e. demand from larger commercial or industrial facilities or telecommunication towers (typically above 50 kWh per year)

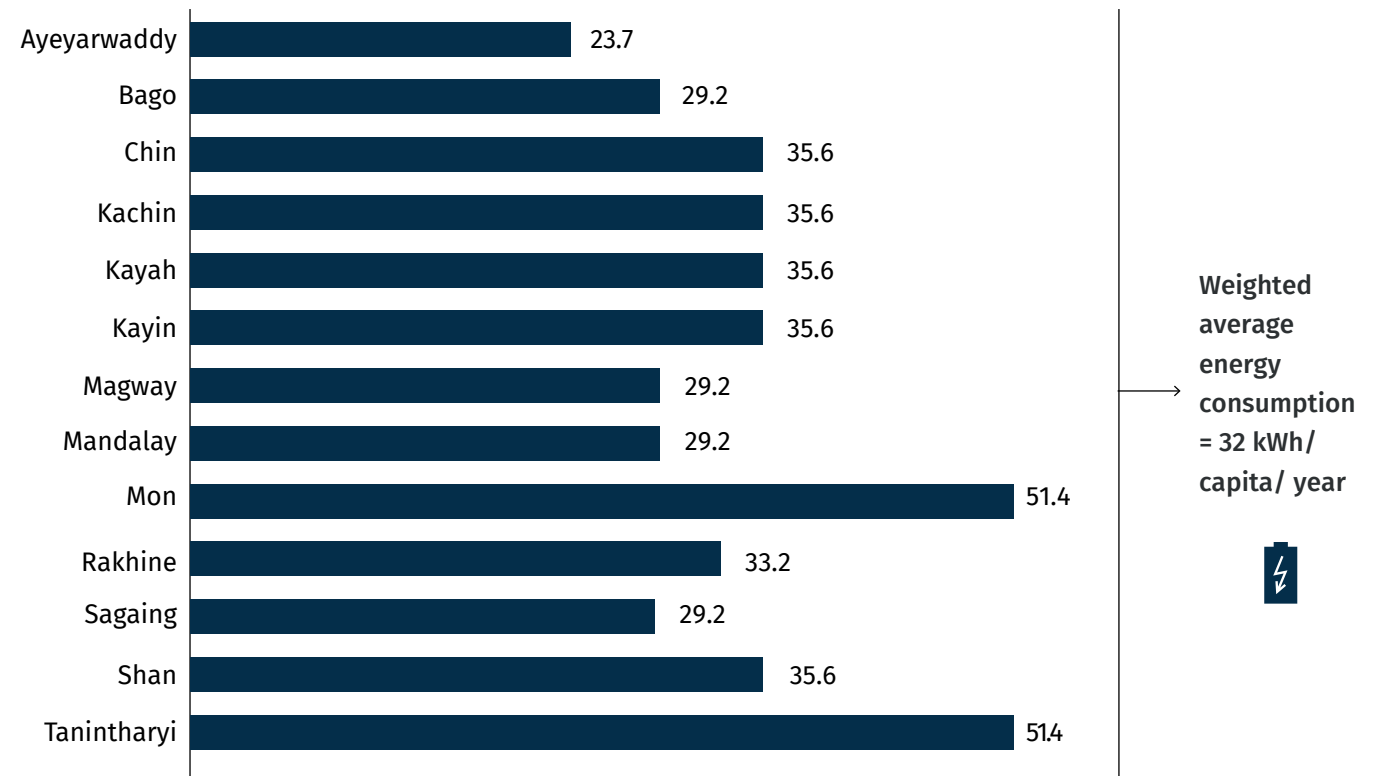
Mini-grids can potentially cover all these four components of power demand, and by combining supply to different demand sources, mini-grid viability can be increased. Systems serving primarily anchor loads can be extended to serve residential, productive and public loads in villages if these are located in the vicinity of anchor loads (see Section 2.4.4).

### 2.4.1 Residential off-grid demand

A review of energy consumption in Myanmar was conducted by the Asian Development Bank (ADB) in 2017.<sup>33</sup> This resulted in an assessment of the potential for residential electricity demand in off-grid areas depending on the unit price of electricity.<sup>34</sup> For a price level of 510 MMK/kWh (see discussion in Section 3.1 for rationale of this price level), the assessment indicates yearly per capita demand between 23.7-51.4 kWh depending on the State/Region. Taking into account the off-grid population of each State/Region, the resulting weighted average of the electricity demand is approximately 32 kWh per capita. This average demand for the population with access to off-grid electricity can be used as a proxy to estimate the latent demand for the off-grid population without any access to electricity.

This level of per capita electricity demand (32 kWh per year) corresponds for example to a total average power rating of 100 W, and usage patterns between 2 and 6 hours per day.<sup>35</sup>

Figure 17. Average yearly off-grid electricity demand per capita in Myanmar for 510 MMK/kWh electricity tariff



Source: DRD based on ADB “Myanmar Energy Consumption Surveys”, 2017

Typical use cases consistent with this demand level include lighting, a radio, a small fan and a small TV that would be used mainly in the evening. The per capita demand level (32 kWh per capita per year) is consistent with benchmarks of 11 mini-grids in Asia and Africa showing average yearly residential consumption of 29 kWh per capita.<sup>36</sup>

It is expected that Myanmar’s per capita electricity consumption in rural areas will increase rapidly (see Section 2.4.5 for demand projections) with increasingly large appliances and longer usage patterns developing beyond the current levels.

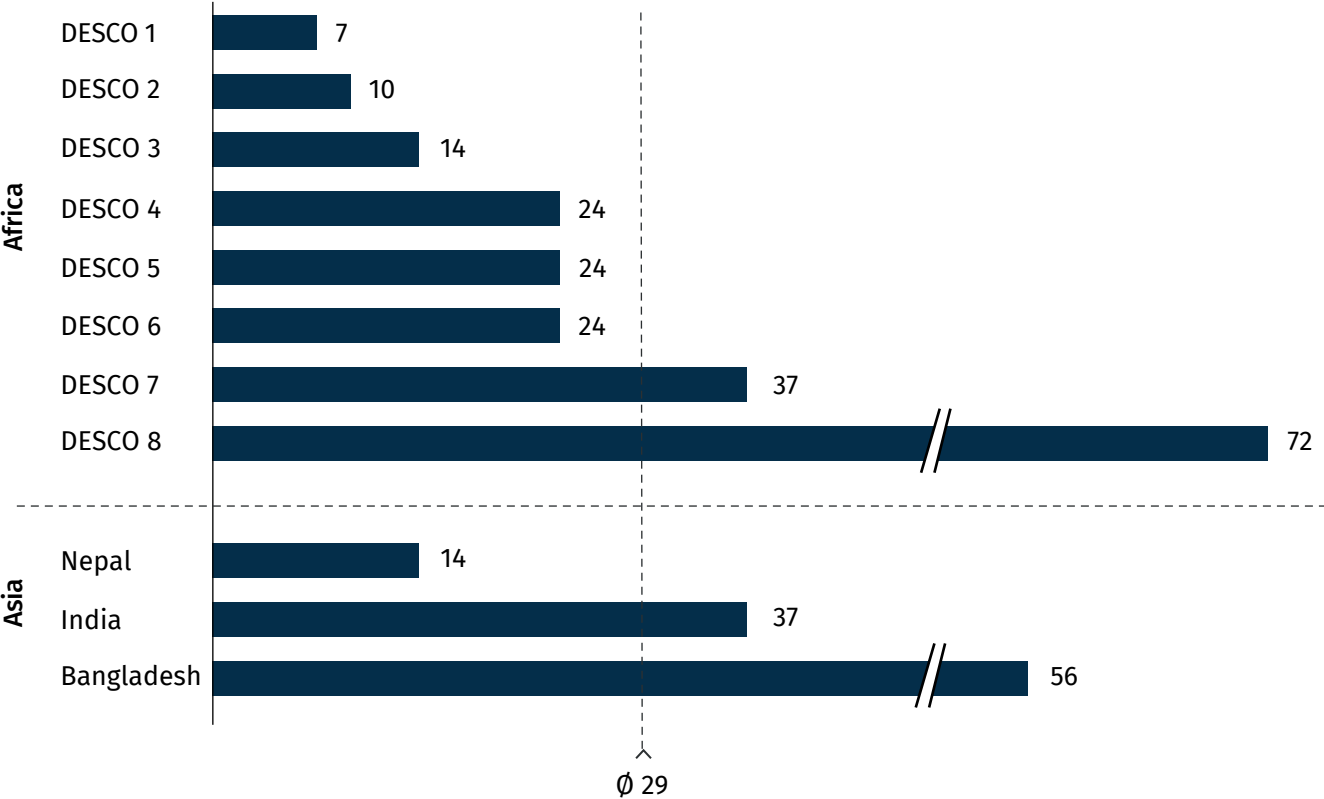
33 Asian Development Bank, “Myanmar Energy Consumption Surveys”, 2017

34 Available on DRD website as part of documentation for Call for Proposals for Engineering, Procurement, Construction and Operation of Mini-Grid Projects in Rural Villages (<http://drdmyanmar.org/index.php?page=bmV3ZGV0YWlsJmlkPTE3Nw>)

35 Average use of 4 hours per day x 100 W x 365 days / 4.6 persons per household

36 IFC “Benchmarking Mini-grid DESCOS”, 2017

**Figure 18.** Residential consumption per capita for distributed energy service companies (DESCOs) in Africa and benchmarks in Asia (kWh/capita year)



Source: IFC “Benchmarking Mini-grid DESCOs”, 2017

2.4.2 Productive use off-grid demand

Productive use demand in off-grid areas in Myanmar is driven by agriculture, processing of agricultural commodities and commercial activities, e.g. welding, carpentry workshops. A demand study across 43 villages in different locations in the dry region of Myanmar conducted by TFE Consulting in 2018 revealed that productive demand per capita<sup>37</sup> is on average approximately 41 kWh per year and varies between 31 kWh per year in villages with low productive loads to 63 kWh per year in villages with high productive loads.

The findings are consistent with other benchmark developing countries. In Tanzanian villages where productive use is driven by agriculture (53% of productive loads are for maize milling, while sunflower oil pressing, poultry

<sup>37</sup> TFE Consulting, “Bridging the Energy Gap: Demand Scenarios for Mini-Grids in Myanmar”, 2018; based on total village population

farming and fruit processing are also key activities), a demand study found that productive loads accounted for 58% of electricity sold to households and businesses in rural villages;<sup>38</sup> which corroborates with estimates of 49% to 66% (the range for low to high productive load cases) for rural villages in Myanmar.

Productive demand is crucial for mini-grids viability as the level of demand per connection is typically much higher than for residential demand. Thus, productive demand drives higher “density of demand”. Mini-grids with high density of demand tend to be more viable than mini-grids where demand is dispersed, because they require less distribution infrastructure per unit of demand therefore reducing costs. On the other hand, some of productive use cases are seasonal (e.g. linked to agricultural harvest) requiring sizing of capacity based on peak demand hence driving lower utilisation.

A recent study by the Rocky Mountain Institute focusing on mini-grid projects in Sub-Saharan Africa also emphasized the importance of projects to promote productive use of electricity, such as financing water pumps for farming or other equipment, to help maximizing mini-grids viability.<sup>39</sup>

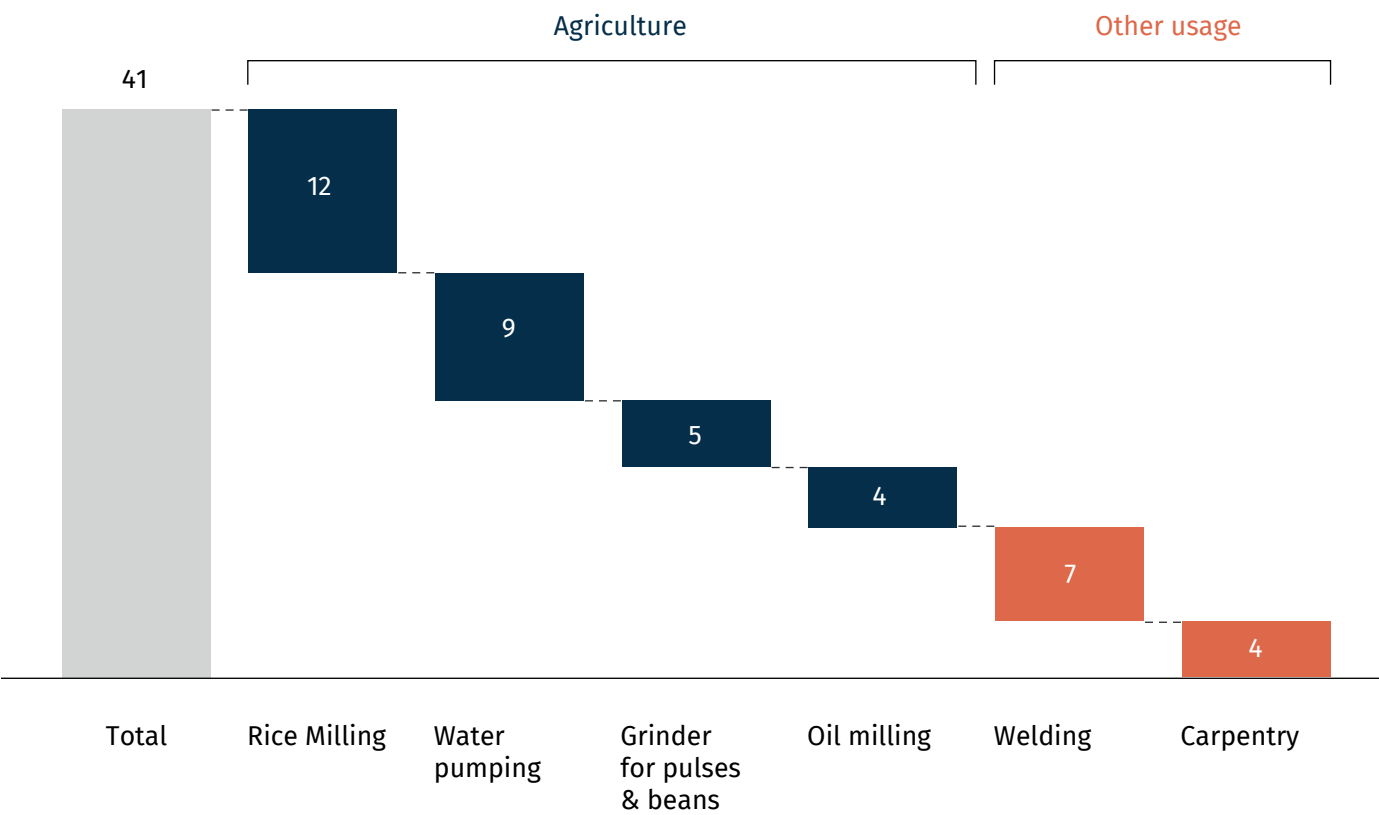
The largest portion of productive demand is driven by agricultural machinery, currently powered mainly by diesel or petrol generators. Welding and carpentry are the main non-agricultural productive uses (Figure 19). Interviews with DRD confirmed that main agricultural uses are related to rice milling, pumping of irrigation water and grinding machinery, while non-agricultural uses include welding and small mechanical/carpentry workshops.<sup>40</sup>

In other developing countries, more sophisticated productive use cases have emerged through electrification. For instance, mini-grids in Guinea-Bissau support productive activities such as zinc processing and juice production, while in Gambia electricity is used to power milling machines, tailor and welding shops.<sup>41</sup> Another key use case example is the purification and chilling of drinking water in India.<sup>42</sup>

Similarly, other productive use cases are expected to emerge in rural Myanmar through electrification. Currently, in coastal regions such as

<sup>38</sup> Energy Research & Social Science, “Small-scale hydropower in Africa: Socio-technical designs for renewable energy in Tanzanian villages”  
<sup>39</sup> Rocky Mountains Institute, “Minigrids in the Money”, 2018  
<sup>40</sup> Interview conducted by Roland Berger with Department of Rural Development (DRD)  
<sup>41</sup> United Nations Industrial Development Organization, “Renewable Energy-based Mini-grids: The UNIDO Experience”, 2017  
<sup>42</sup> Interview conducted by Roland Berger with Smart Power India

Figure 19. Productive use of power in off-grid regions in Myanmar (kWh / capita year)



Source: TFE Consulting, “Bridging the Energy Gap: Demand Scenarios for Mini-Grids in Myanmar”

Tanintharyi, new applications in fish processing and conservation are under study. Ice making and water purification are also potential new cases being explored. As electrification in rural villages matures, increasingly higher value-added businesses such as larger-scale agro-processing and factories are expected to emerge.

Productive use demand in off-grid areas is determined by the following factors:

- Economic activity is an important driver of productive loads. In areas of high economic activity, higher demand for goods and services drives energy consumption. In addition, in these areas, businesses are able to afford electrically-powered machinery with higher power rating
- As agriculture is an important contributor to productive loads in off-grid areas, crop production, livestock are drivers of productive loads
- Potential for fisheries, estimated as % of townships with access to water bodies suitable for fishing activity, is taken as an additional parameter to assess productive load potential

- Areas where local businesses are connected to other regions by a reliable road network (e.g. paved roads not subject to flooding during the wet season) or waterways tend to have higher productive loads. This is because local businesses can serve not only the local village community, but can also provide their products or services to neighboring villages and towns

Based on these four factors, productive load demand of off-grid areas has been estimated by State/Region (see Figure 20).

High potential regions include locations such as Tanintharyi, Ayeyarwaddy, Magway, Sagaing, Mon and areas with a flourishing agricultural economy such as Bago. These locations have a good combination of GDP per capita levels and agricultural/fisheries activity. Mon and Tanintharyi also have high GDP per capita driven by e.g. trade with neighbouring Thailand and local small businesses enjoy a good level of access to paved road facilitating trade.

2.4.3 Public use demand

Public use demand is driven by electricity demand for public buildings and for public lighting.

In rural villages in Myanmar, public buildings typically include religious buildings such as monasteries, local clinics/hospitals, schools and libraries. A typical village of 200 households has 1 load for each of these typologies. Public lighting can be rather sparse, with typically 1 street light every 5 houses. Interviews indicate that under the above scenarios the public-use yearly demand per capita in rural villages in Myanmar is approximately 2.5 kWh.<sup>43</sup>

2.4.4 Demand from anchor loads

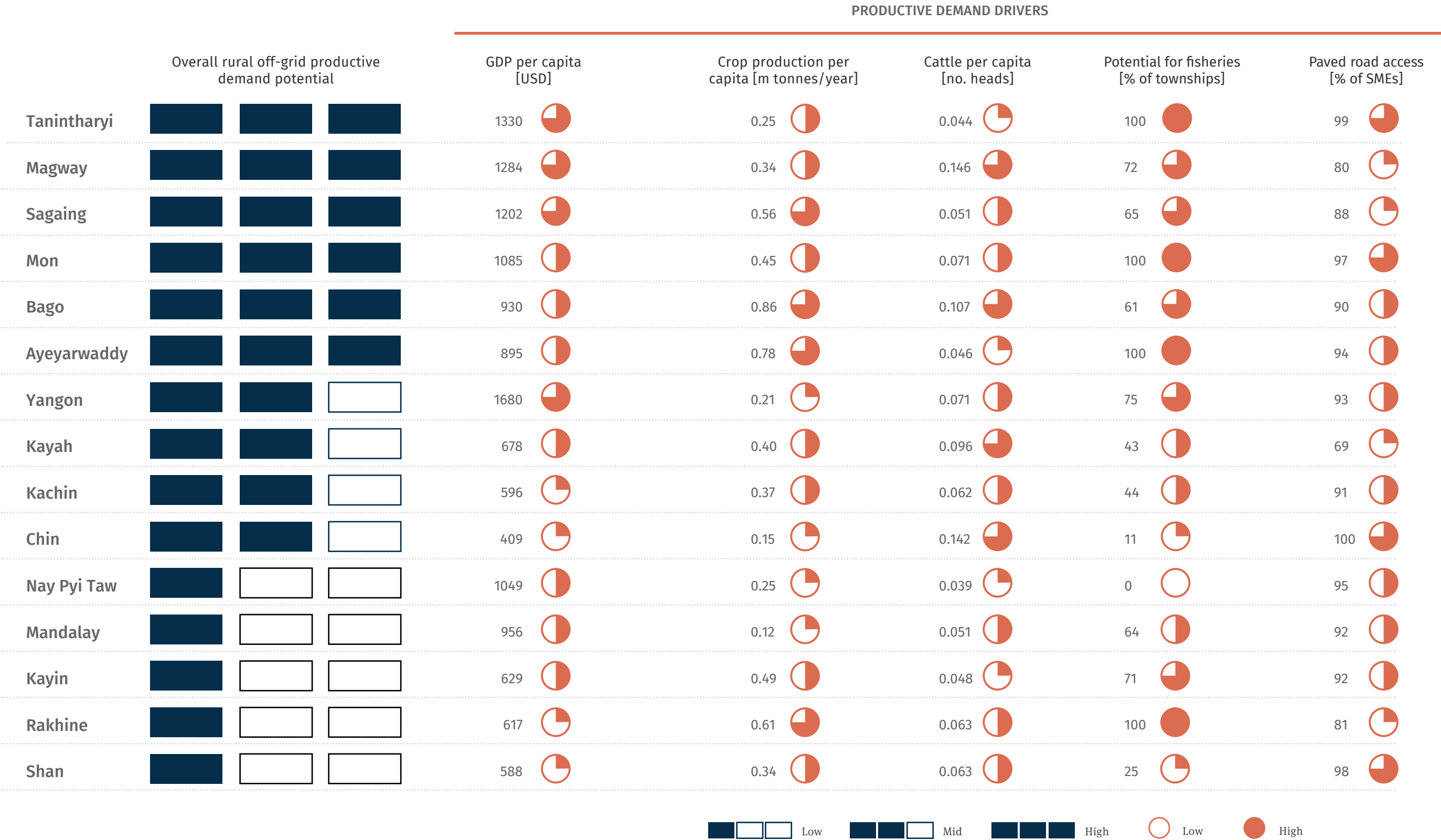
Anchor loads typically include industrial loads and loads from telecommunication towers. Connecting a village mini-grid to anchor loads has several advantages both for the private developer and for the anchor load owner/operator:

- For the mini-grid private developers, anchor loads increase demand, enhance predictability of demand and lower bill collection and counterparty credit risk, thereby increasing viability and bankability of mini-grid projects
- For the anchor load owner/operator, connecting to a mini-grid allows to decrease investment and operating costs compared to building and operating own power generation facilities. It also enhances reliability of power and facilitates the shift to renewable energy from diesel generation

<sup>43</sup> Interviews with multilateral institutions and private developers conducted by Roland Berger



Figure 20. Analysis of rural off-grid productive demand potential by State/Region



Source: Roland Berger

In off-grid areas in Myanmar industrial loads are very limited as almost all manufacturing is located in areas with grid connectivity.<sup>44</sup> However, new anchor loads in off-grid areas may emerge upon mini-grid electrification (e.g. water irrigation systems, financial institutions, ATMs, fuel stations, etc.),<sup>45</sup> as electricity supply becomes more reliable in these regions.

On the contrary, a large portion of telecommunication towers in Myanmar is located in off-grid areas. Of these towers located in off-grid areas, currently mostly powered by diesel generators, 70% can be potentially targeted as anchor load for mini-grids (actual feasibility depends on the distance of towers from villages).

Another advantage of utilising telecommunication towers as anchor loads is potential scalability. Tower design and power requirements are essentially standardised and most towers are managed only by a few operators. As a result, once mini-grid configurations utilising towers as anchor tenants are proven, they could be replicated nationwide enhancing scalability.

Load per telecommunication tower varies heavily depending on the number of tenants that share the tower under colocation agreements: single-tenant towers have typically 2 kW load, towers with 2 tenants have 3.5 kW load and towers with 3 tenants have 5 kW load. On average, an off-grid tower has a 2.2 kW load, leading to around 164 GWh yearly electricity demand from off-grid towers in Myanmar.

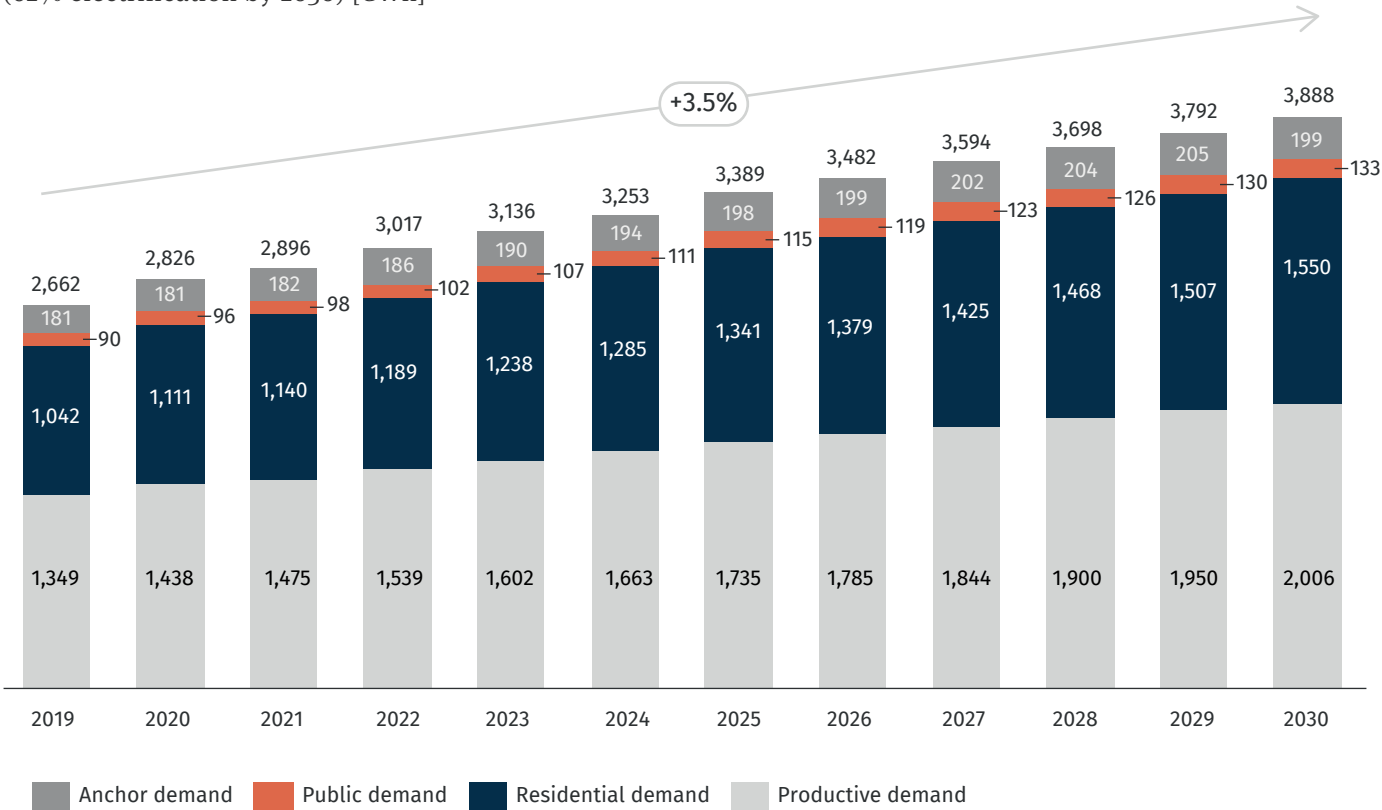
2.4.5 Projections of off-grid power demand in Myanmar

Based on the grid electrification evolution outlined in Section 2.3 and on the analysis of off-grid power demand outlined in Sections 2.4.1 to 2.4.4, projections for the evolution of the total potential off-grid power demand have been developed.<sup>46</sup>

Off-grid potential demand in 2018 is estimated at 2.5 TWh, corresponding to about 16% of actual on-grid power demand in Myanmar in 2016/2017.<sup>47</sup>

<sup>44</sup> Interviews with private developers, mobile network operators and tower companies conducted by Roland Berger  
<sup>45</sup> Shared Value Initiative, “Smart Power for Rural Development”  
<sup>46</sup> Key assumptions utilised for projections: power demand grows in line with GDP per capita (+ 6.6% annual growth rate between 2018 and 2030, estimate by Fitch Ratings); the population of rural villages is assumed stable: this results from balancing out of population growth trends with migration from villages to urban areas. In addition, based on interviews with network operators and tower companies, we assume that the number of off-grid anchor loads (telecommunication towers) increases at 5 % annual rate, while consumption per tower remains stable  
<sup>47</sup> MOEE data for 2016/2017 indicate 15.3 TWh actual on-grid demand

Figure 21. Projection of potential off-grid demand in Myanmar in the average electrification case (62% electrification by 2030) [GWh]



Source: Roland Berger

It should be noted that this potential demand may not be fully satisfied as of today, as approximately 4 million households remain without access to power and households with simple power solutions, e.g. solar home systems, may not be adequately supplied. Therefore, this off-grid potential demand is an important driver for the Myanmar mini-grid market sizing.

This off-grid potential demand is proportionally smaller than the ratio of off-grid population because power demand per capita among the off-grid population (~75kWh per year) is lower than that of the on-grid population (~217kWh per year). However, as described in Section 4, off-grid power demand is expected to grow rapidly.

It is estimated that approximately 37% of this off-grid potential demand (0.9 TWh) is due to off-grid households with access to electricity through off-grid solutions, while 63% (1.6 TWh) is potential demand from off-grid households without access to electricity.<sup>48</sup>

<sup>48</sup> Estimated by Roland Berger through interviews with private developers

In the average electrification case (62% on-grid electrification by 2030), potential off-grid demand is expected to increase by 3.5% per year to 3.9 TWh in 2030 – the effect of consumption per capita increase and stable demographics in off-grid areas means that demand growth overpowers the pace of electrification. For projections in the slow electrification case (52% on-grid electrification by 2030) and quick electrification case (97% on-grid electrification by 2030), please refer to Annex 2.

2.5 Market driver 3: Subsidies and contributions

An attractive subsidy and contribution system is in place, but funding earmarked for mini-grids is scarce

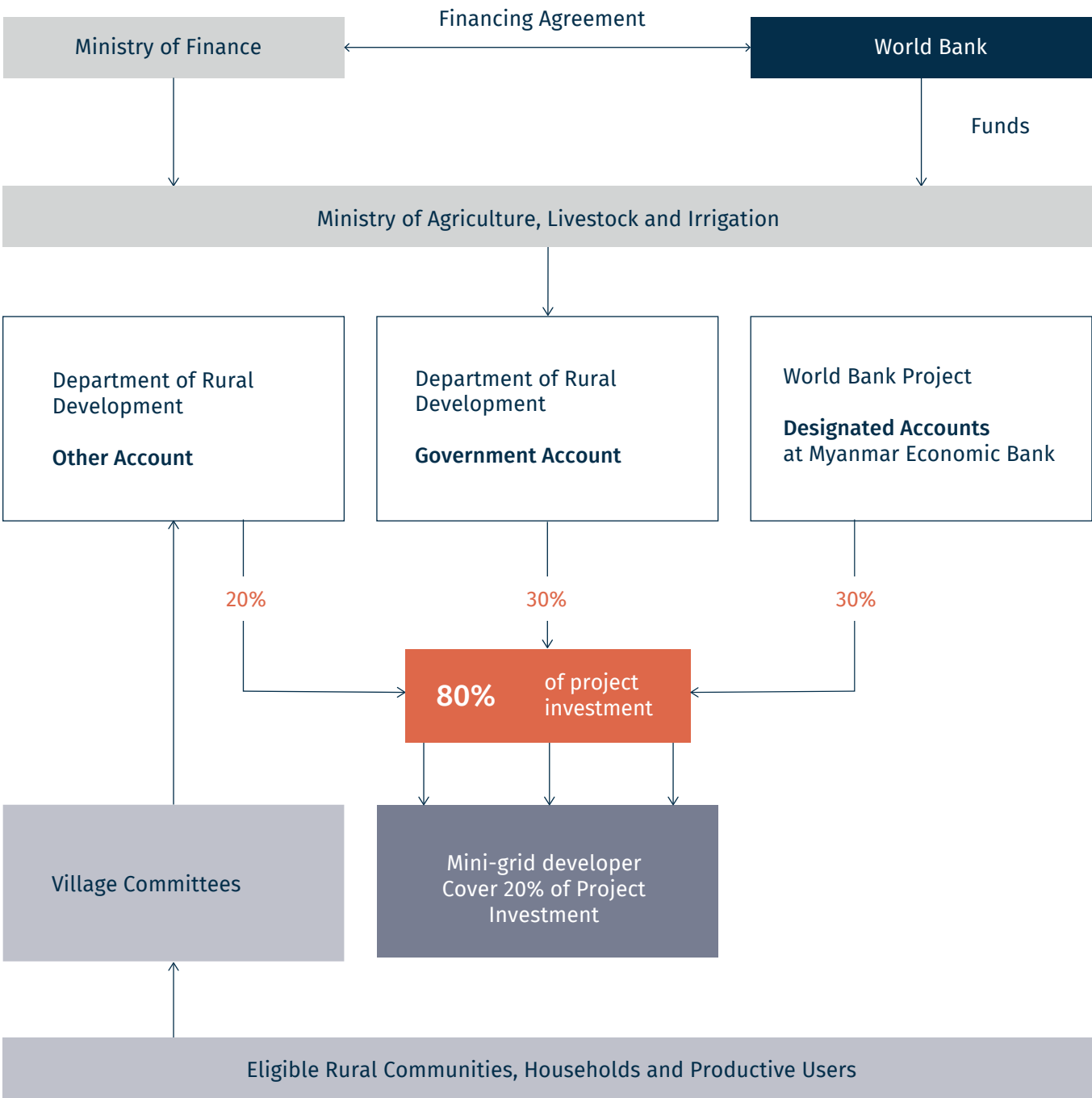
In the context of NEP, a subsidy system was put in place to finance mini-grid projects. The primary targets for subsidies are mini-grid projects in areas that are unlikely to be reached by on-grid electricity in the next 10 years. Eligible projects have less than 1MW capacity.

The current system involves three flows of funding complementing the investment by private developers:

- Communities, through village committees raise funds to pay part of mini-grid investment, typically 20% of total investment. The funds are channelled through a dedicated account managed by the Department of Rural Development
- The Department of Rural Development funds subsidies from a loan obtained by the World Bank contributing typically to 30% of project investment
- The Department of Rural Development funds subsidies from its own budget contributing typically to 30% of project investment, thereby matching the contribution from the World Bank loan.

Therefore in the current system, selected mini-grid projects are subsidised at 60% by DRD through own budget and World Bank loan; communities typically cover 20% of investment in cash or in kind, while mini-grid developers cover the remaining 20% of investment.

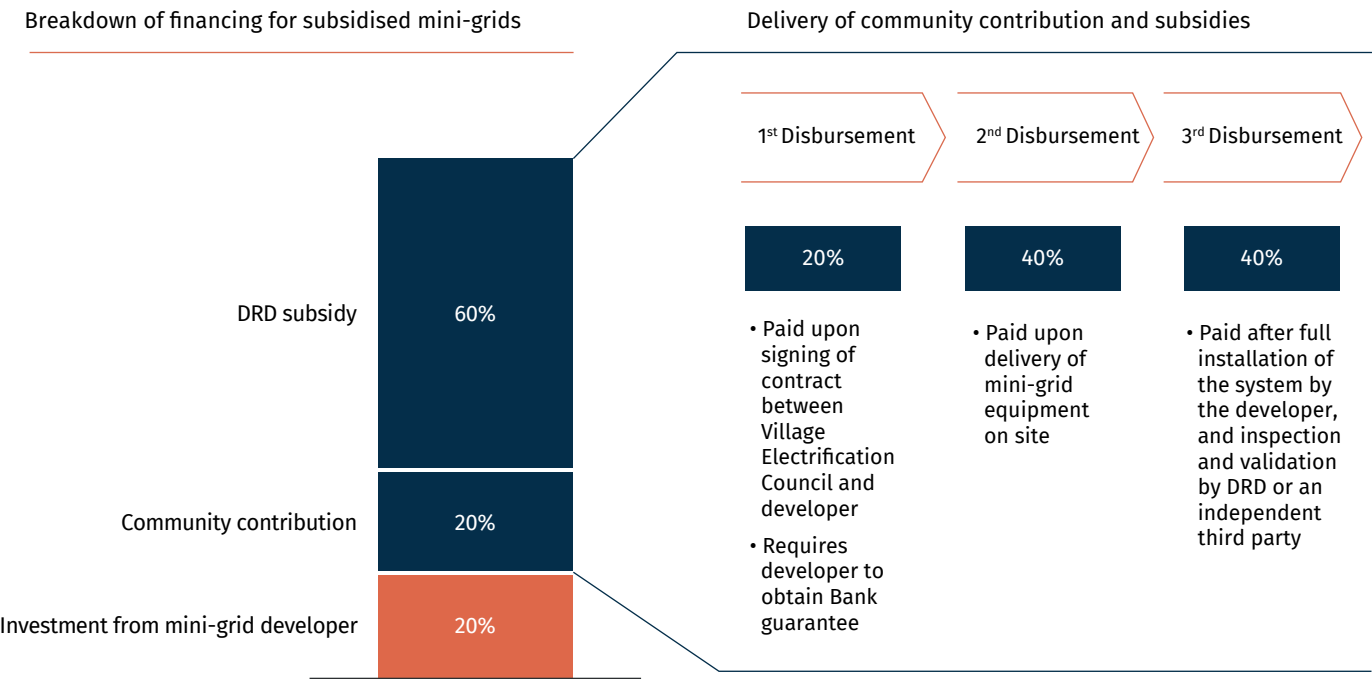
Figure 22. Money flows in Myanmar’s mini-grid subsidy system



Source: World Bank Project Appraisal Document Report No: PAD1410; Roland Berger



Figure 23. Mini-grid financing breakdown and schedule of disbursements for community contribution and subsidies



Source: World Bank Project Appraisal Document Report No: PAD1410

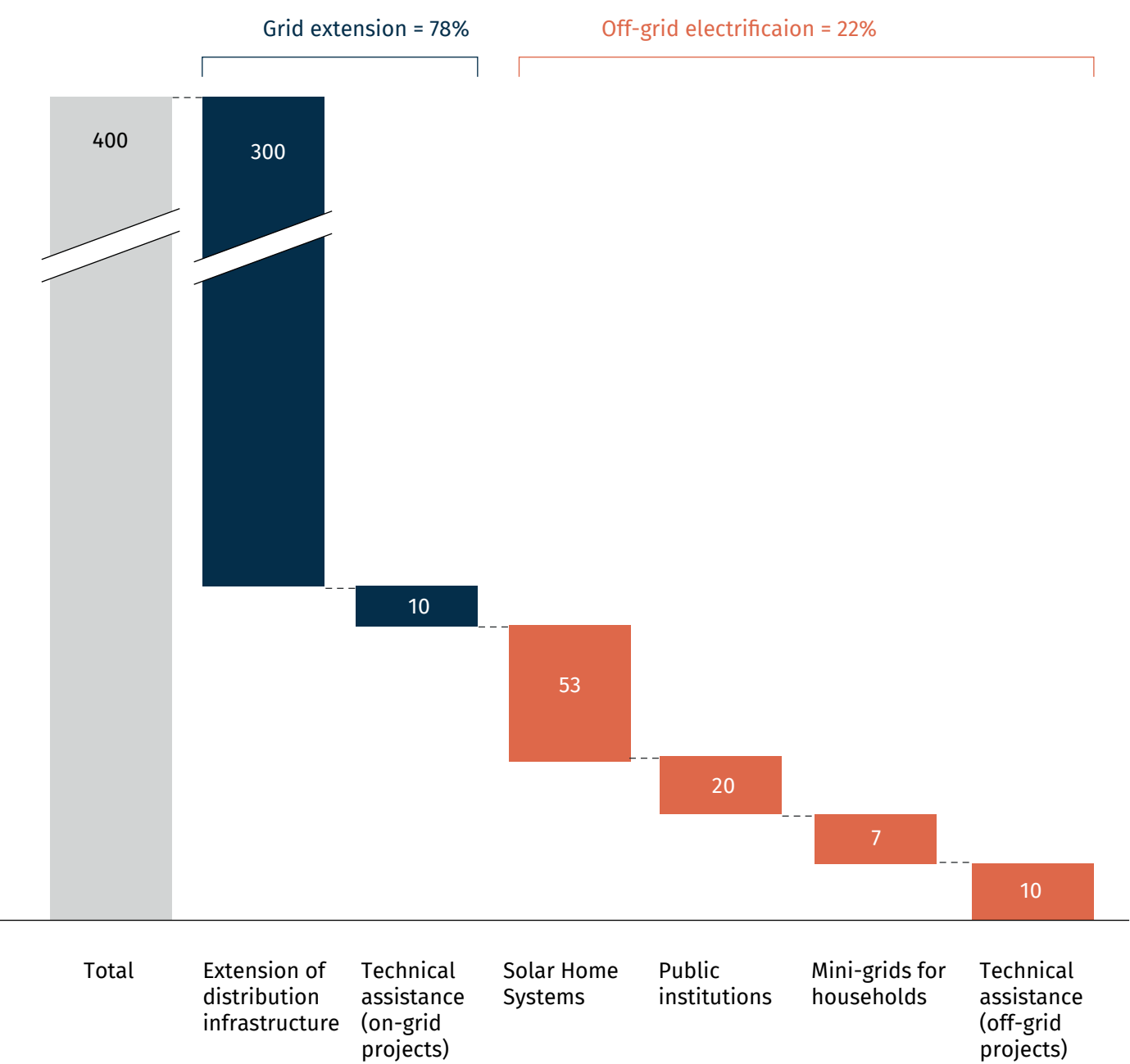
The subsidies and community contribution are delivered through three separate disbursements (see Figure 23). The full amount of community contributions and of subsidies is paid prior to project commissioning.

The World Bank had earmarked 7 million USD over the period 2016-2021 to support the mini-grid subsidy system. Most of the World Bank 400 million USD loan for electrification in Myanmar has been allocated to supporting expansion of the national grid. Among off-grid measures, most of the funding (53 million USD) has been allocated to solar home systems. Increasing funding for mini-grids is currently under discussion.

In the absence of increased government budget and/or greater commitment from the World Bank and other bilateral or multilateral organisations, the current subsidy scheme has limited potential to support large scale deployment of mini-grids.

For example, the World Bank loan programme’s target was to finance mini-grids covering 35,500 households (~0.5% of total off-grid households) by 2021 — this would support 175-350 mini-grid projects assuming projects are deployed in off-grid villages with approximately 100-200 households.

Figure 24. Allocation of World Bank loan by category of electrification measures [USD million]



Source: World Bank Project Appraisal Document Report No: PAD1410

Figure 25. Scope of measures covered by the World Bank loan and 2021 targets for the support program

Categories	Outline	2021 Targets
Grid extension	<ul style="list-style-type: none"><li>• <b>Extension of distribution infrastructure</b><ul style="list-style-type: none"><li>- Expansion of existing medium voltage (MV) substations and construction of new MV substations</li><li>- Construction of ~12,900 miles of MV and low voltage (LV) lines, and 772 MVA of MV/LV transformers</li></ul></li><li>• <b>Technical assistance</b> : Standards, technical specifications and procurement, projects design, project management and implementation support, training and capacity building</li></ul>	<ul style="list-style-type: none"><li>• 750,000 households</li><li>• 1,600 community connections<ul style="list-style-type: none"><li>- Clinics, schools, public buildings</li></ul></li><li>• 132,000 public lights</li></ul>
Off-grid electrification	<ul style="list-style-type: none"><li>• <b>Off-grid electrification targeting communities unlikely to receive grid based access in the next 10 years</b><ul style="list-style-type: none"><li>- Solar Home Systems(SHS)</li><li>- Mini-grids including solar photovoltaic (PV) systems, mini-hydropower, wind, biomass and hybrid systems (e.g. diesel/solar )</li></ul></li><li>• <b>Technical assistance projects:</b> support to local technical advisors, companies providing renewable energy systems, support to DRD on technical specifications, procurement documents and bid evaluations, project management and implementation, assistance to the financial sector, training and capacity building</li></ul>	<ul style="list-style-type: none"><li>• 465,500 households (SHS) and 35,500 households (Mini-grid)</li><li>• 11,400 community connections<ul style="list-style-type: none"><li>- Clinics, schools, public buildings</li></ul></li><li>• 19,000 public lights</li></ul>

Source: World Bank Project Appraisal Document Report No: PAD1410

Number of villages selected for screening of subsidised mini-grids is increasing, but still in the order of 100 villages

In order to select projects, the DRD, with support from GIZ, put in place a screening process. Initial eligibility criteria are:

- The village is not among those listed for phase 1, 2 or 3 of the recommended sequence of grid roll out under the NEP (see Section 2.3)
- The village has not received solar home systems for over 40% of households from a prior DRD programme
- The village is willing and able to pay electricity tariffs
- The village is willing and able to meet at least 20% of the project cost in cash or in kind
- The village has productive uses for the electricity generated
- The village has at least 50 households that are also clustered
- There are strong indications of the community’s ability to work together
- There is demonstrated energy resource potential, such as year-round hydropower resource, plentiful source of agro-waste for biomass etc.
- To limit potential negative environmental and social impacts, mini-grids larger than 1 MW in generating capacity shall be subject to a case-by-case approval process by DRD

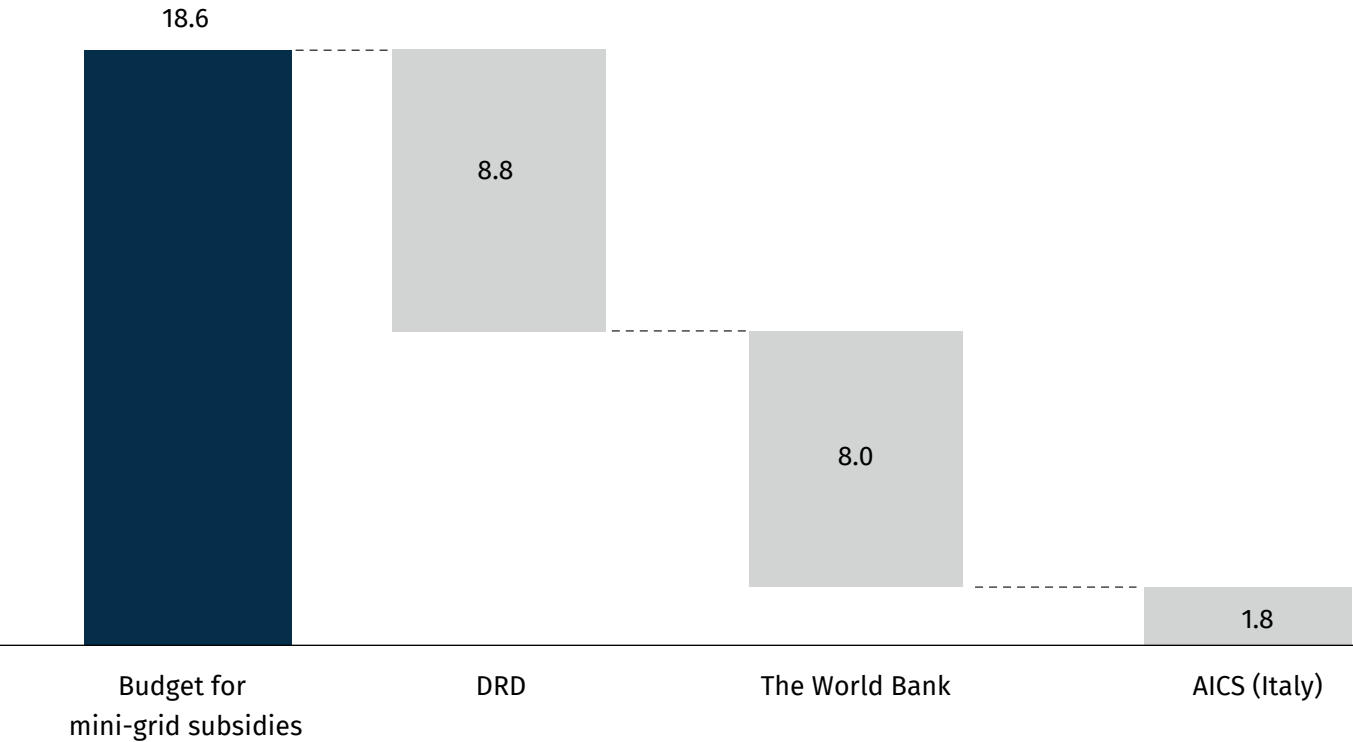
The DRD has organised so far three Calls for Proposal (CFPs) to solicit mini-grid project proposals. The number of proposed sites has been increasing steadily from 40 in CFP1 to 93 in CFP3 (see Section 2.1).

As explained in Section 2.2, mini-grids are typically not financially viable on a stand-alone basis. Therefore, the structure and amount of subsidies is an important driver for the mini-grid market sizing.

New budget availability for mini-grid subsidies

Based on interviews with DRD and bilateral institutions,<sup>49</sup> the total funding available for the mini-grid subsidy scheme has been increased and between 2019 and 2021 is expected to reach approximately 18.6 million USD per year. The mini-grid subsidies budget comprise of funding from three sources: (1) DRD, (2) The World Bank, and (3) AICS (Italian Cooperation Agency).

Figure 26. Estimated annual budget availability for mini-grid subsidies for next 3 years (2019 to 2021) [USD Million]



Source: Interviews with DRD and bilateral institutions

49 Interviews conducted by Roland Berger with DRD and bilateral institutions



The budget for mini-grids from DRD for 2018 was 13.6 billion MMK, which corresponds to 8.8 million USD. According to DRD, this budget is likely to be maintained over the next few years.<sup>49</sup>

The World Bank has a budget of 80 million USD for mini-grids and Solar Home Systems up to 2021. As of the end of 2018, 30 million USD of the 80 million USD budget has been spent. For the remaining 50 million USD, the budget allocated to mini-grids was increased from 7 million USD to 24 million USD, which translates to 8 million USD per year from 2019 to 2021.<sup>49</sup>

AICS is expected to deploy additional budget of 30 million USD for SHS and mini-grids, to be rolled out over the next 3 years (2019 to 2021). This budget targets 90,000 household connections for SHS, and 6,500 household connections for mini-grids. Assuming 1,369 USD per connection and 60% coverage, the budget for mini-grids would be 5.3 million USD. This translates into 1.8 million USD per year.<sup>49</sup>

2.6 Market driver 4: Regulatory environment

Regulatory jurisdiction and allocation of funding & subsidies is split between different authorities

In Myanmar, the Electricity Law enacted on the 27th of October 2014 introduced separate jurisdictions for regulation of electric power businesses depending on their size. Three categories are defined in the law: (1) “Small Electrical Business” that can generate power up to 10 MW, (2) “Medium Electrical Business” — from 10 MW to 30 MW and (3) “Large Electrical Business” that can generate power over 30 MW.

The Government of Myanmar, through the Ministry of Electricity and Energy (MOEE) issues permits to invest in and operate projects classified as Large Electrical Businesses (more than 30 MW) and for all other projects that are connected to the national grid.

Permitting and regulation of Small and Medium Electrical Businesses (less than 30 MW) not connected to the national grid are under the authority of the Regional and State governments where the projects are located.<sup>50</sup>

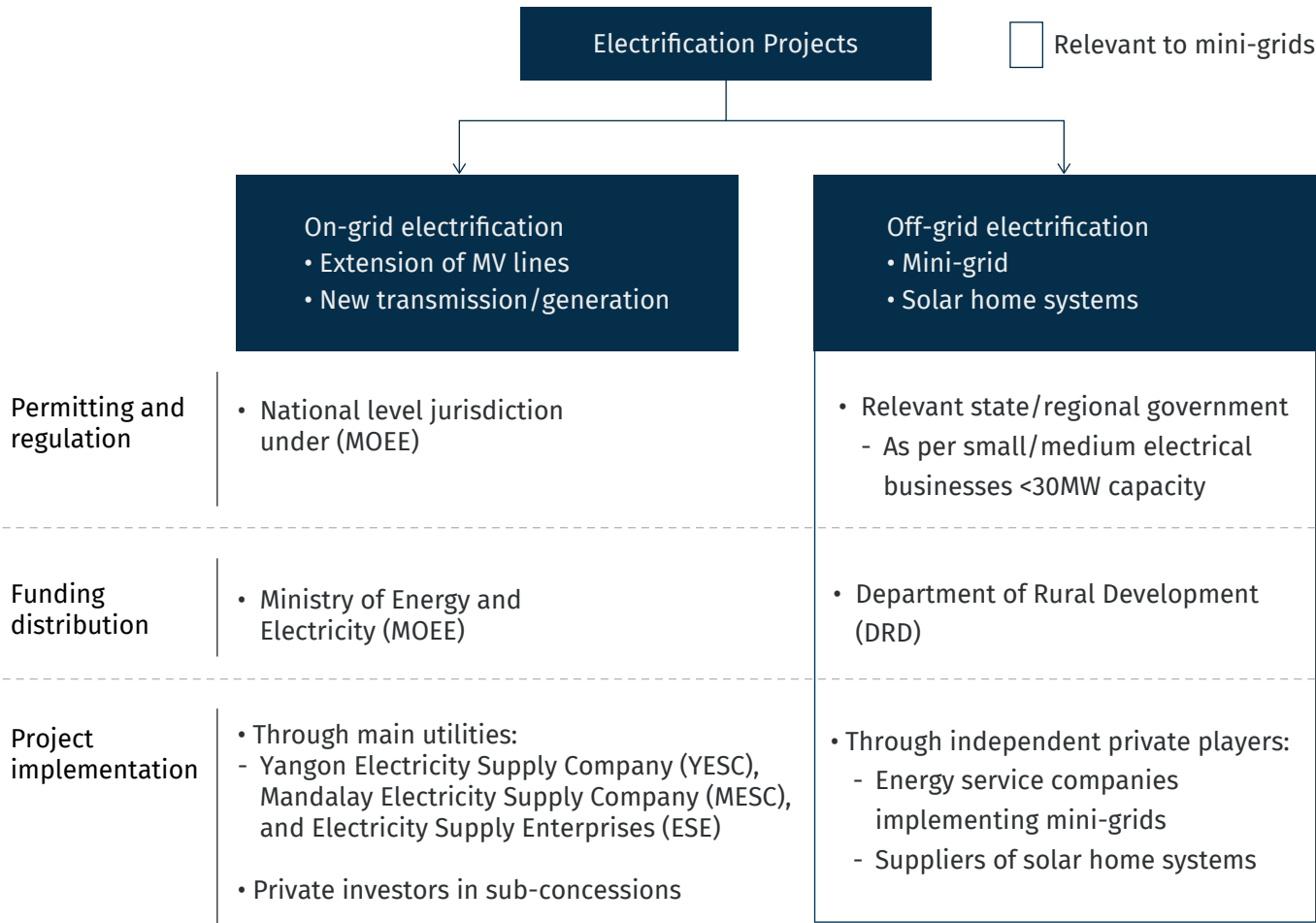
Hence, mini-grids in off-grid areas fall under the jurisdiction of Regional and State authorities. At the time of grid arrival, negotiations to integrate the mini-

50 VDB Loi, “ The legal and regulatory framework of foreign investment in Myanmar’s power sector”, 2017

grid into the national grid have to be undertaken with MOEE. While on-grid electricity prices are regulated and include government subsidies, there are no explicit regulatory provisions on the tariffs that private developers can charge for electricity supply through mini-grids.<sup>51</sup> This provides freedom to optimize tariffs, but adds uncertainty to the future cash flows of mini-grid projects.<sup>52</sup>

In addition to the split in regulatory jurisdiction, a similar split exists in the distribution of funding for electrification projects. As outlined in Section 2.3, the NEP roadmap implementation hinges on a two pronged strategy with both on-grid electrification and a programme of off-grid solutions (solar home systems and mini-grids) to be rolled-out in the interim for isolated areas.

Figure 27. Regulatory, funding and project implementation roles for on-grid and off-grid electrification projects



Source: VDB Loi

51 Interview conducted by Roland Berger with bilateral institutions  
52 For a review of State role in energy policy and regulation see The Asia Foundation, “The Role of States and Regions in the Myanmar Energy Sector”, 2019

Investment for on-grid electrification projects is managed by MOEE and projects are carried out by the public utility companies controlling the medium-voltage infrastructure in different areas of Myanmar: the Yangon Electricity Supply Company (YESC), the Mandalay Electricity Supply Company (MESC) and the Electricity Supply Enterprises in other regions (ESEs).<sup>53</sup>

In addition, private players known as Distribution Franchises invest directly in construction, management and operation of power distribution lines under franchise contracts with YESC, MESC and the ESE. Franchise contracts are typically Build-Own-Operate-Transfer schemes for 15 years periods after which the franchisee transfers the assets to the state-owned utility company.<sup>54</sup>

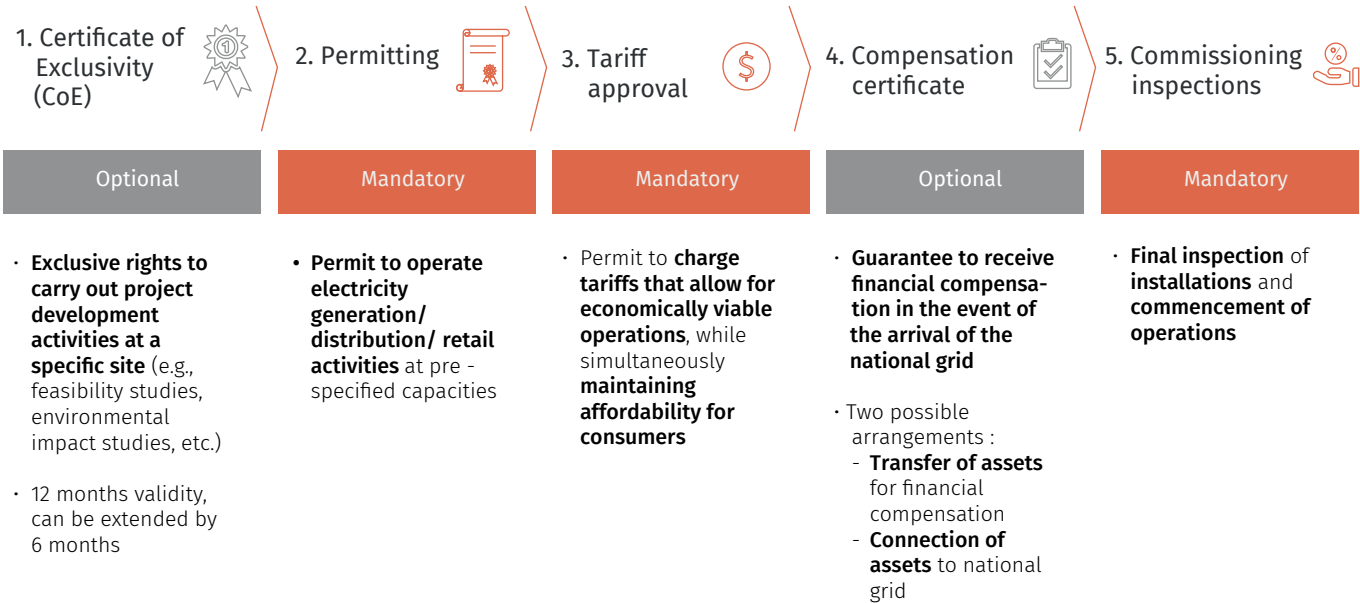
A comprehensive regulatory framework for mini-grids is under discussion

At present, the regulatory framework surrounding mini-grids in Myanmar is not defined; however the following scheme has been promoted by DRD and is under discussion with the Government of Myanmar. In the DRD proposal, mini-grids would fall under regulation by the State/Regional government as non-grid connected entities with less than 30 MW capacity. DRD also proposes a mini-grid licensing process including 5 steps:

- Steps include traditional permitting to undertake power generation, distribution and retail activities
- A certificate of exclusivity for undertaking development in specified locations is under study to de-risk development activities.
- A certificate to ensure transition in case of national grid arrival with two possible mechanisms: (1) transfer of asset to national grid operator upon payment of compensation, (2) connection of asset to national grid under independent power producer status for generation assets and under a distribution franchise for distribution assets

53 World Bank, “Myanmar: Towards Universal Access to Electricity by 2030”, 2014  
54 Interview with a Distribution Franchise in Yangon conducted by Roland Berger

Figure 28. Proposed 5 Step process for permitting, certification and inspections (off-grid regulations)



Source: GIZ

One of the key hurdles for the viability of mini-grids is the regulatory treatment of the transition in case of national grid arrival. Global case studies in developing countries show a variety of solutions that can be classified under three categories:

- The mini-grid private developer transfers assets to the national utility and receives compensation; the operator is protected against stranded investment, however it has to abandon the mini-grid project
- The mini-grid private developer leverages existing generation assets to sell wholesale power to the national utility becoming an independent power producer; this scheme is sometimes difficult to implement as it may require additional equipment to synchronise generation assets with the national grid. In case of solar generation, synchronisation is already ensured by the inverter so no additional equipment is required
- The mini-grid private developer leverages existing distribution assets to become the local distribution system operator; this scheme has proven successful in some cases, most notably in Cambodia (See Annex 3)

For more detailed discussion on the impact of a clear transition mechanism upon grid arrival please refer respectively to Sections 3.2 & 4.4.2. For recommendations, please refer to Section 5.1.

## 2.7 Market driver 5: Technology potential

As outlined in Section 2.1 the majority of mini-grids currently installed in Myanmar (69%) are powered by diesel generators, followed by small hydroelectric systems (25%) and biomass gasification or biogas systems (2%). Solar mini-grids represent a minority (~4%) of the total number of mini-grids.

These technology choices reflect the fact that mini-grids were developed by local communities, on an ad-hoc basis utilising available hardware — at the time of development of these mini-grids, the availability of equipment necessary for solar PV mini-grids (PV panels, batteries and inverters) was low and the cost of these technologies was relatively high.

The same reason led to the initial introduction of diesel generators as the main technology for supplying off-grid telecommunication towers 10 to 15 years ago.<sup>55</sup> Nowadays they are gradually replaced by hybrid solar/battery/diesel systems.

As mini-grid development shifts from local communities to private developers and rapid evolution of solar technology costs occur, a similar shift in technology towards solar PV is expected.

In Figure 29, a comparison of the three renewable mini-grid technologies along five criteria is shown.

- **Costs:** Small hydro and biomass gasification mini-grids are cost-competitive compared with hybrid solar/diesel/battery mini-grids. However, while hydroelectric and biomass generation are mature technologies showing slow cost evolution, the combination of multiple factors at global level is driving rapid cost decline in solar PV systems.<sup>56</sup> It is expected that by 2020 solar mini-grids will be cost competitive compared to other mini-grid technologies and in the following few years solar PV equipment are expected to fall further due to the following factors:
  - » **Policy optimisation.** The introduction of competitive auction systems for utility-scale solar system in major global markets such as Europe, the Middle East and India is promoting competition, pressuring suppliers to slash equipment costs

- » **Innovation.** New PV cell designs with higher efficiency reduce cost per unit of capacity for panels. Equally, innovation is bringing costs down for inverters. Innovation in automotive batteries is also helping reduce energy storage costs
- » **Scaling up.** Increase in annual newly installed capacity (~60 GW per year) and consolidation of solar panel markets around very large manufacturers helped building large economies of scale across the value chain, from raw material procurement to cell manufacturing and assembly. For inverters, the transition from mid-sized regional suppliers to large global suppliers exporting out of Asia is now occurring — hence further cost reduction is expected
- » **Shift to low-cost manufacturing locations.** In parallel with scaling, the bulk of manufacturing activity in solar equipment is shifting to low-cost locations in Asia, including China and Southeast Asia
- » **Treatment to decrease pollution.** The biomass gasification process produces organic compounds that are toxic to humans and the environment, and thus require treatment systems to reduce pollution. However, solar PV and hydro mini-grids have low environmental impact and do not require additional treatment to decrease pollution, hence minimizing treatment costs

- **Scalability.** Development and construction of solar PV mini-grids is quick and highly replicable using standard designs across multiple sites, hence mini-grid private developers can potentially develop multiple solar PV mini-grids in parallel, rapidly scaling up capacity and reducing costs through economies of scale in procurement. On the contrary, for small hydro and for biomass, lengthy site-specific development and design is required. For example for small hydro, prior to civil work and installation, validation of site potential and initial development can take more than 1 year. System design is highly site-specific with little potential for economies of scale.<sup>57</sup> For biomass mini-grids, although system design is more standardised than for small hydro, development involves multi-year on-site collection of raw material availability to understand seasonality and build raw material procurement plan, which poses significant challenges.<sup>58</sup>

<sup>55</sup> See for example GSMA “Green power for mobile”, 2014

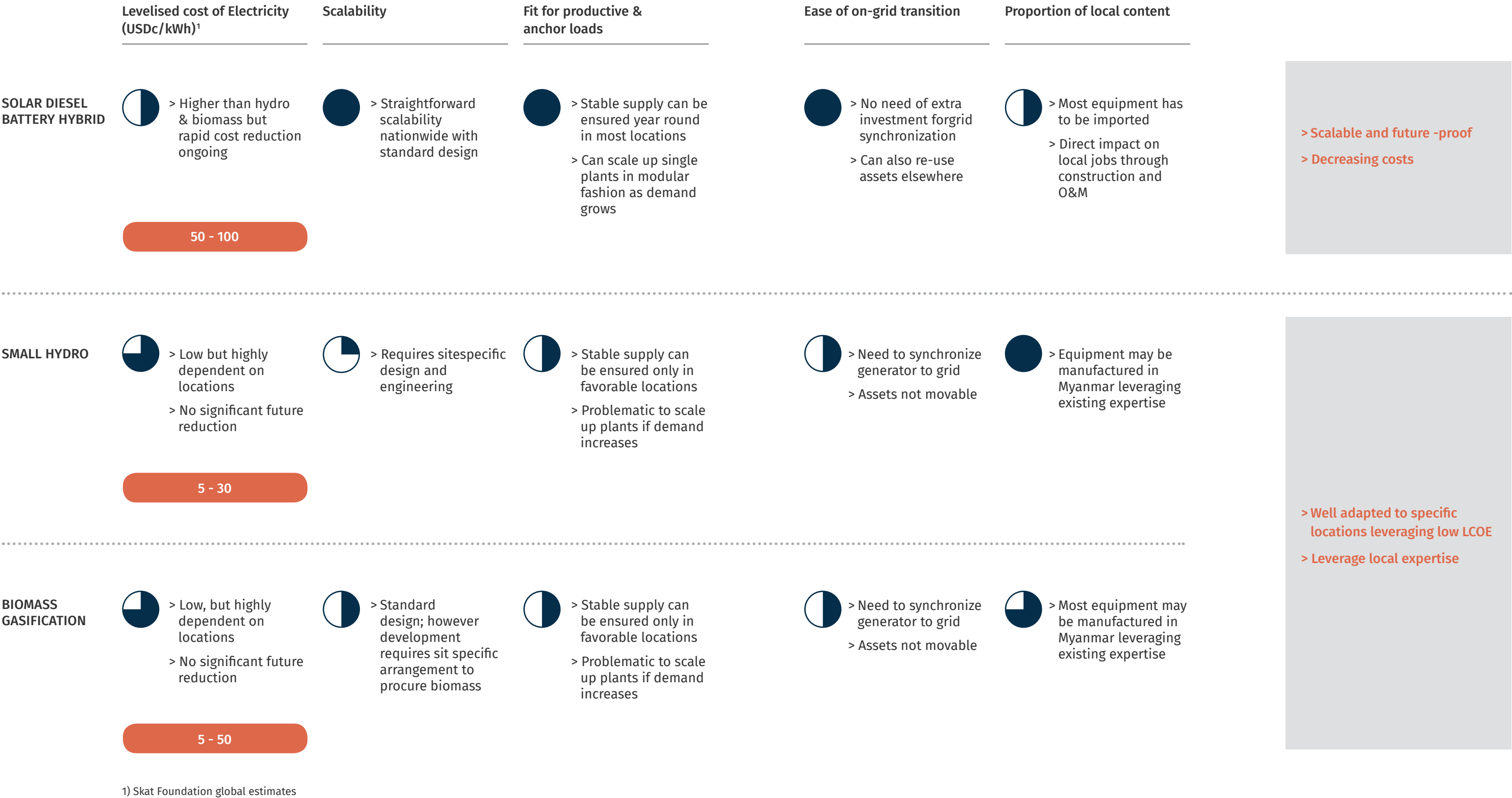
<sup>56</sup> IRENA, “Electricity Storage and Renewables: Costs and Markets to 2030”, 2017

<sup>57</sup> Interview conducted by Roland Berger with mini-hydro experts

<sup>58</sup> Skat Foundation Webinar Series on Mini-grids, 2017



Figure 29. Comparison between mini-grid technologies



Source: Skat Foundation Webinar Series on Mini-grids, 2017

- **Ability to serve productive and anchor loads now and in the future**

- » **Reliable supply.** While all the technologies examined here can in principle supply productive and anchor loads, these loads require high reliability of supply to guarantee business continuity. Reliability of solar/diesel/battery hybrid generation has been proven through multiple case studies in various regions globally related to supply to telecommunication towers.<sup>59</sup> For small hydro, as systems work in run-of-the-river mode, reliable supply throughout the year can only be ensured in favorable locations with stable hydrological conditions. For biomass, year-round availability of reliable supply of raw material at reasonable distance from the mini-grid location is required — this can only be ensured in favorable locations

- » **Future proof solution.** As off-grid areas are electrified, a positive impact on economic growth<sup>60</sup> can generate increase in electricity demand requiring mini-grids capacity expansion. Expansion of solar/diesel/battery hybrid is straightforward as systems are highly modular. For small hydro, capacity is constrained by hydrological conditions of the project site and by the initial design, so any increase in demand needs to be built-in the initial system design. This can potentially lead to low utilisation if demand increases more slowly than expected. Biomass system have intermediate degree of modularity and can be gradually scaled-up to meet increasing demand

- **Ease of transition at grid arrival:** In case of grid arrival, depending on regulatory provisions, private developers may have the opportunity to connect the existing mini-grid generation assets to the grid. Alternatively, they may decide to recover the residual value of the generation assets by selling the assets or re-using the assets in other locations. In the former case, connecting rotating generation equipment such as hydro turbines generators and biomass generators to the grid requires additional equipment for synchronisation.<sup>61</sup> For solar/diesel/battery hybrid mini-grids, the existing inverter can provide synchronization to the grid without additional extra costs. In addition, most of the generation assets (PV panels, inverter, diesel generator and, partly, batteries) can be easily sold or re-used in other locations. In contrast, for small hydro assets are essentially fixed and cannot be leveraged in different locations; for biomass, assets can be moved, but with much less ease compared to solar assets.

<sup>59</sup> GSMA “Green power for mobile”, 2014

<sup>60</sup> See Section 4.7 for a full socio-economic impact analysis

<sup>61</sup> World Bank, “ Mini-grids at the arrival of the main grid — Lessons learned from Cambodia, Sri Lanka and Indonesia” , 2018

- **Local content use:** Most of the equipment used in solar PV mini-grids is imported (e.g. solar panels, inverters, batteries etc.). Direct impact on local employment is mainly through installation of equipment and operation & maintenance jobs (for a full analysis of the direct and indirect socio-economic impact of mini-grids, please see Section 4.7). On the contrary, especially for hydro-powered mini-grids, but also for biomass mini-grids, local firms in Myanmar have developed expertise in manufacturing of original equipment and spare parts<sup>62</sup>. Hence these technologies have higher potential in terms of local content use compared to solar PV.

Although at present solar/diesel/battery hybrid mini-grids are less cost-competitive than hydropower and biomass mini-grids, in terms of expected cost evolution, scalability, ability to serve anchor loads and easiness of on-grid transition, they represent the most attractive technology to support growth of the mini-grid market.

In specific locations with favorable hydrological conditions and stable supply of raw material, small hydro and biomass mini-grids can represent the most cost-effective and viable way to deliver electrification. In addition, these technologies can provide further opportunities to utilise local equipment thus potentially offering greater direct support to rural economies in specific locations. Hence hydro-powered and biomass mini-grids can play an important role alongside solar/diesel/battery hybrid mini-grids in the growth of the mini-grid market in Myanmar.

<sup>62</sup> Interview with market experts

# 3.0

## Assessment of the Financial Viability and investability of Mini-Grids in Myanmar

### 3.1 Definition of viability of mini-grids

#### Key metrics utilised for viability assessment

In this study, two perspectives are combined to define viability of mini-grid projects: cost-competitiveness and financial viability.

Firstly, the cost of electricity from a mini-grid is assessed versus current off-grid electricity supply costs. For this, the Levelised Cost of Electricity (LCOE) is used: this metric reflects the sum of the capital costs for building the mini-grid and of the operational costs to run the mini-grid divided by the expected electricity supplied over the lifetime of the mini-grid. Hence the LCOE represents the average cost per unit of electricity supplied by the mini-grid. A mini-grid is cost-competitive if its LCOE is lower of equal to the cost of electricity currently paid by customers in off-grid areas.

Secondly, to assess financial viability, Internal Rate of Return (IRR) is used: this metric reflects the annualised return on investment generated by the mini-grid. A mini-grid project is viable if its IRR is higher than or equal to the cost of capital (discount rate) shouldered by the investors to build the mini-grid.

#### Thresholds for viability of mini-grids

To estimate the cost of electricity currently paid by customers in off-grid areas, data from a variety of studies focusing on price of electricity from

Figure 30. Definition of viability of mini-grids used in this study

	Outline	Criteria for Viability
Levelised Cost of Electricity (LCOE)	• Reflects the <b>overall cost of supplying electricity over the lifetime of the mini-grids</b>	• LCOE (USD/kWh) is <b>equal or lower than the tariff</b> in USD/kWh the mini-grids operator can charge for electricity supply
Internal Rate of Return (IRR)	• Reflects the <b>annualized rate of return on the investment</b> in the mini-grids project	• IRR (%) is <b>greater than the cost of financing</b> the investment in the mini-grids project
Depending on cost of capital conditions for MG projects, even if LCOE is lower than tariffs, project may not be viable from a rate of return perspective		

diesel generators (the most common source of electricity in off-grid areas as outlined in Section 2.1) are used:

- Estimates by the ADB in 2015 for low consumption use cases (1 lightbulb or 2 lightbulbs and 1 TV set with 3 hours/day supply) indicate a range of equivalent tariffs between 0.85 USD/kWh to 1.23 USD/kWh for electricity provided by diesel generators<sup>63</sup>
- A 2016 study of 10 diesel mini-grids conducted by Pact considering 1 lightbulb and a TV set found equivalent tariffs ranging from 0.37 USD/kWh to over 1 USD/kWh<sup>64</sup>
- A 2018 study covering over 44 off-grid villages conducted by TFE Consulting<sup>67</sup> including residential and productive loads indicates a range between 0.16 USD/kWh to 0.77 USD/kWh and average tariffs of USD 0.37/kWh

As the 2015 ADB and 2016 Pact studies took into account only low consumption use cases, equivalent tariffs per kWh may be comparatively high, thus likely overestimating willingness to pay for larger loads.

63 Asian Development Bank “Off-Grid Renewable Energy Program in Myanmar”, 2016  
64 From World Bank, “Upscaling mini-grids for low-cost and timely access to electricity services”, 2017



Therefore, 0.37 USD/kWh (approximately 510 MMK/kWh<sup>65</sup>) is used in this study. This threshold has been confirmed as a realistic tariff for mini-grids in off-grid areas through interviews.<sup>66</sup> Currently, private mini-grid developers charge tariffs ranging from 350 MMK/kWh to 700 MMK/kWh which is consistent with the threshold of 510 MMK/kWh used in this study.

Note that the threshold is much higher than electricity prices in on-grid areas (ranging between 35-50 MMK/kWh depending on consumption level — most households fall into 35 MMK/kWh rate or 0.03 USD/kWh) for multiple reasons: (1) on-grid electricity prices are heavily subsidised by the Government and do not reflect actual cost of generation and supply, (2) small diesel generators such as those typically used in rural Myanmar are highly inefficient compared to large grid-connected power plants, (3) size and operation of diesel generators are rarely optimised in off-grid villages — typically generators are used under capacity to power small loads which adversely impacts efficiency and hence generation costs.<sup>67</sup>

The appropriate threshold for IRR<sup>68</sup> has been estimated through interviews with stakeholders and market players — typical target for mini-grids in Myanmar is around 20% IRR. This IRR level is high due to the inability for developers to access debt finance and to the high perceived risks today, including:

- Myanmar country risk
- Risk specific to mini-grid investment in Myanmar (e.g. uncertainty related to grid arrival, uncertainty in actual power demand and willingness to pay in rural areas)

Structure of LCOE and IRR for Mini-Grids and key drivers

As stated above, the LCOE is calculated by summing all capital and operational expenses and dividing the sum by the expected generated energy. The sum is carried over the lifetime of the project and each term is annualised using a discount rate.

The IRR represents the rate at which initial investment in the project is recovered through returns generated by the project. It is calculated as the

65 1USD =1378 MMK (2018). Lower tariff of 0.29 USD/kWh (approximately 400 MMK/kWh) used for telco towers.  
66 Interviews conducted by Roland Berger  
67 TFE Consulting, “Bridging the Energy Gap: Demand Scenarios for Mini-Grids in Myanmar”, 2018  
68 Interviews with multilateral organisations and private developers conducted by Roland Berger; this IRR is in real terms

discount rate that makes the annualised sum of cash flows generated by the mini-grid equal to zero (see Annex 5 for details).<sup>69</sup>

In addition to the project lifetime, there are four categories of components that impact LCOE and IRR and therefore viability of mini-grid projects. (see Annex 5 for more details.)

Revenue

Revenues are determined by the amount of electricity supplied and tariffs. Key parameters are types of loads supported by the mini-grid (residential, productive, public and anchor loads), population and number of loads covered by the mini-grid.

Capital costs

Capital costs include key equipment for power generation, energy storage (batteries), inverters, energy management system and other components, distribution network costs, cost of billing and payment IT system and “soft costs” such as project development costs (pre-construction surveys, due diligence etc.). Key parameters are the size of the equipment, which is determined by the scale of the mini-grid and environmental conditions (e.g. for solar mini-grids in areas with low irradiation, a larger solar generation system is needed to supply a given load). In addition, cost of equipment per unit of size is a key parameter that is expected to change over time due to technology and manufacturing advances reducing unit costs.

Operational costs

Operational costs include fuel costs for diesel generation, operation & maintenance costs related to generation and distribution equipment, customer service costs and land rental costs. Key parameters are the scale of the mini-grid and variation in labour costs and crude oil prices impacting fuel costs.

69 Formulas for calculation of LCOE and IRR:  
$$LCOE = \frac{\sum_{t=1}^N ((CAPEX_t + OPEX_t) / (1+r)^t)}{\sum_{t=1}^N ((E_t / (1+r)^t)}$$
$$0 = NPV = \sum_{t=1}^N ((CF_t / (1 + IRR)^t)$$
where, CAPEX is capital expense, OPEX is operational expense, t is year, r is the discount rate, E is the energy generated, N is the lifetime of the mini-grid, NPV is the net present value and CF is cash flow

Regulatory and macroeconomic drivers

As described in Section 2.5, regulatory drivers include subsidies and community contributions. Subsidies and contribution schemes can vary in terms of scope and degree of support. For example, in the current mini-grid scheme, subsidies cover 60% of total investment required and community contributions typically cover 20%. In addition, the total budget available for subsidies is an important driver — the current subsidy scheme is supported by an expected USD 18.6 million budget for 2016-2021 backed by DRD and the World Bank.

3.2 Investibility of mini-grids and de-risking of grid arrival

In addition to viability, investibility of mini-grids from a private developer’s perspective must be considered to assess the potential market. At present there is no clear licensing system regulating mini-grids and formalising “the right to exist”, and there is no mechanism in place to compensate developers or to ensure business continuity in case of grid arrival. Hence villages located in areas closer to the main grid are considered non-investible by mini-grid developers as risks are too high.

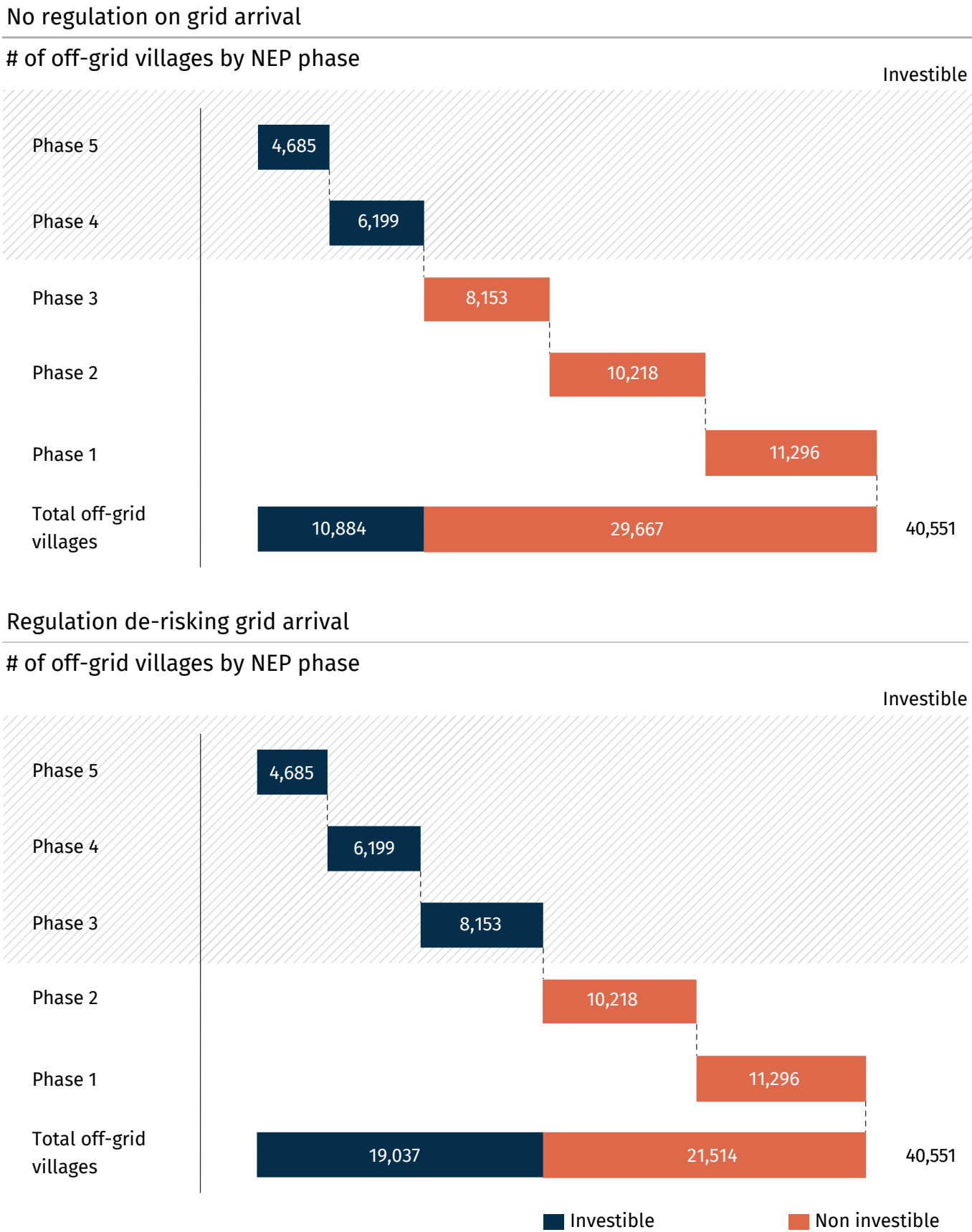
For the purpose of this study, the likelihood of grid arrival in the next 10 years and the existence of regulatory provisions de-risking grid arrival are taken as the key criteria determining investibility. Potential mini-grid sites (i.e. off-grid villages) can be segmented along these criteria to establish investibility by site<sup>70</sup>:

- In case no regulation de-risking grid arrival is introduced, only off-grid villages with low likelihood of being reached by the grid in the next 10 years are considered investible. In practice, these correspond to villages under Phase 4 and 5 of NEP amounting to almost 11,000 villages
- In case regulation is introduced to de-risk grid arrival (see also discussion in Section 2.6 and recommendations outlined in Section 5.1), additional villages with mid likelihood of grid arrival in the next 10 years may also be considered as investible by private developers. In this case, villages under Phase 3 of NEP are also included in addition to villages under Phase 4 and 5 resulting in 19,000 potentially investible villages, almost twice as much as in the case without regulations

Thus the regulatory environment plays a crucial role in determining the pool of villages that are potentially suitable for mini-grid investment.

70 Criteria were chosen after consultation with GIZ

Figure 31. Number of off-grid sites investible for mini-grids depending on regulation on grid arrival



Source: National Electrification Plan; Roland Berger

### 3.3 Simulation results for different mini-grid configurations and subsidy contributions

**LCOE and IRR simulations for different configurations, subsidies/ community contributions and year**

LCOE and IRR simulations are calculated for various types of mini-grids by:

- Village population size. Our modelling assumes three population sizes, namely small population cluster of 250 people, mid-sized cluster of 470 people or large cluster of 850 people<sup>71</sup>
- Customer type, namely residential customers only, residential and productive load, or residential, productive and anchor (telecom tower) load; and
- Geography (dry zone, mid-dry zone or non-dry zone)<sup>72</sup> impacting solar irradiation

In the case of no subsidies or community contributions, LCOE in 2020 varies from approximately 1.5 USD/kWh (small population cluster, residential-only loads and location in the non-dry zone) to 0.46 USD/kWh (small population cluster, residential, productive and anchor loads, location in the dry zone). IRR can reach up to 11.1%. These figures show that, given LCOE threshold of maximum 0.37 USD/kWh (around 510 MMK / Kwh) and IRR threshold of minimum 20%, without subsidies and community contributions, none of the mini-grid configurations are viable as of 2020 on a standalone project basis (i.e. assuming no economies of scale).

Incorporating subsidies of 60% and community contributions for an additional 20% of total investments, as per the current DRD scheme, substantially decreases LCOE and increases IRR. IRR becomes as high as 38.5% for large population clusters in the dry zone with residential and productive loads in 2020.

These results are in line with the current market status, where there is little private investment in projects not supported by the DRD subsidy scheme, however numerous private developers propose projects to be subsidised by DRD.

<sup>71</sup> Village population tiers from Gaussian fitting distribution of off-grid villages by population (see Annex 6)

<sup>72</sup> Solar irradiation levels determine the amount of CAPEX required — in high irradiation zones, less CAPEX is needed per unit of power generation. The solar irradiation levels for the three zones (dry, mid-dry and non-dry) are based on the average horizontal solar irradiation each month in regions representative of each zone (Magway for Dry, Yangon for Mid-dry and Kachin for Non-dry). Refer to Annex 9 for solar irradiation per month curves in the three regions.

For both the unsubsidised and subsidised cases, a key determinant of LCOE and IRR levels is the inclusion of productive loads. The effect of productive loads is much more important than the size of the population cluster. For example, for the subsidised case, in the dry zone, increasing the population cluster from small to large in a mini-grid with residential-only loads increases the IRR to 4.0%. Instead, adding productive loads to the same mini-grid configuration increases the IRR to 9.2%. This is explained by two reasons: (1) productive loads support higher demand per connection than residential loads — hence revenues are maximized for a given level of investment in distribution infrastructure, (2) productive demand is concentrated during daytime and matches solar generation profile better than residential demand — hence increasing productive loads requires comparatively lower investment in battery storage capacity. Interviews with market players and stakeholders also confirm this conclusion.<sup>73</sup>

Simulations for 2030 take into account the evolution of project costs and of consumption per head. As solar PV develops into one of the key power generation technologies globally, the cost of solar panels is expected to decrease by 7.2% on average per year and that of inverters by 8.5% on average per year until 2030.<sup>74</sup> In addition, consumption per capita is expected to increase in line with Myanmar’s GDP per capita growth of 6.6% per year, thereby increasing revenue generation per connection. This impacts especially the viability of mini-grids in the unsubsidised case. By 2030, it is expected that in favourable configurations (large and mid-sized villages in the dry zone, representing ~3,000 sites) mini-grids become viable even without subsidies and community contributions.

<sup>73</sup> Interviews with private developers conducted by Roland Berger

<sup>74</sup> IRENA, “Electricity Storage and Renewables: Costs and Markets to 2030”, 2017



**Figure 32.** Viability of mini-grids in 2020 based on cost, size, and climate; LCOE [USD/ KWh], IRR [%], No subsidies or community contribution

IRR N/A when configuration does not generate positive cash flows; For key assumptions refer to Annex 7

TYPE OF LOAD

POPULATION CLUSTER



X

 IRR > 20%

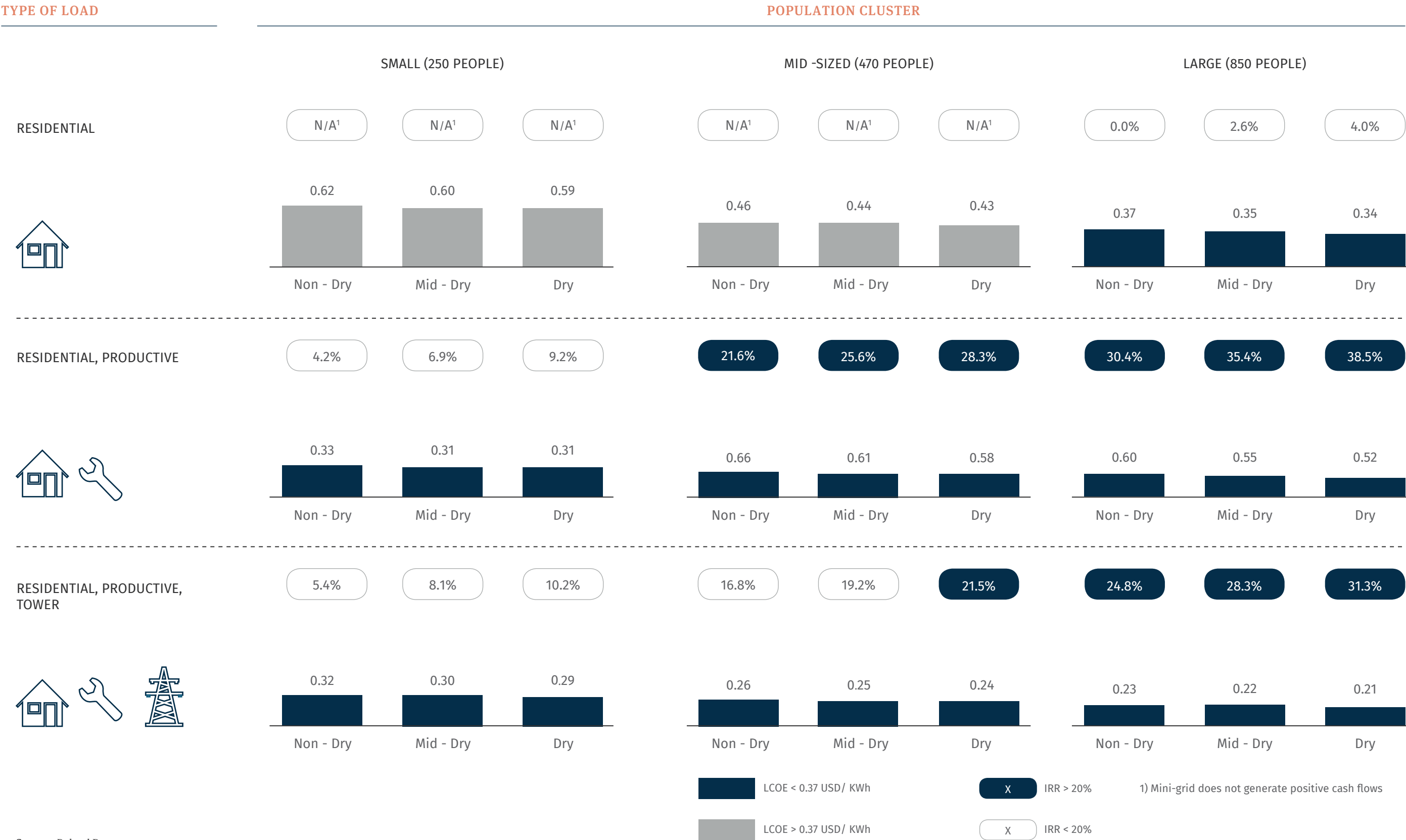
X

1) Mini-grid does not generate positive cash flows

Source: Roland Berger

**Figure 33.** Viability of mini-grids in 2020 based on cost, size, and climate; LCOE [USD/ KWh], IRR [%], 60% subsidies and 20% community contribution

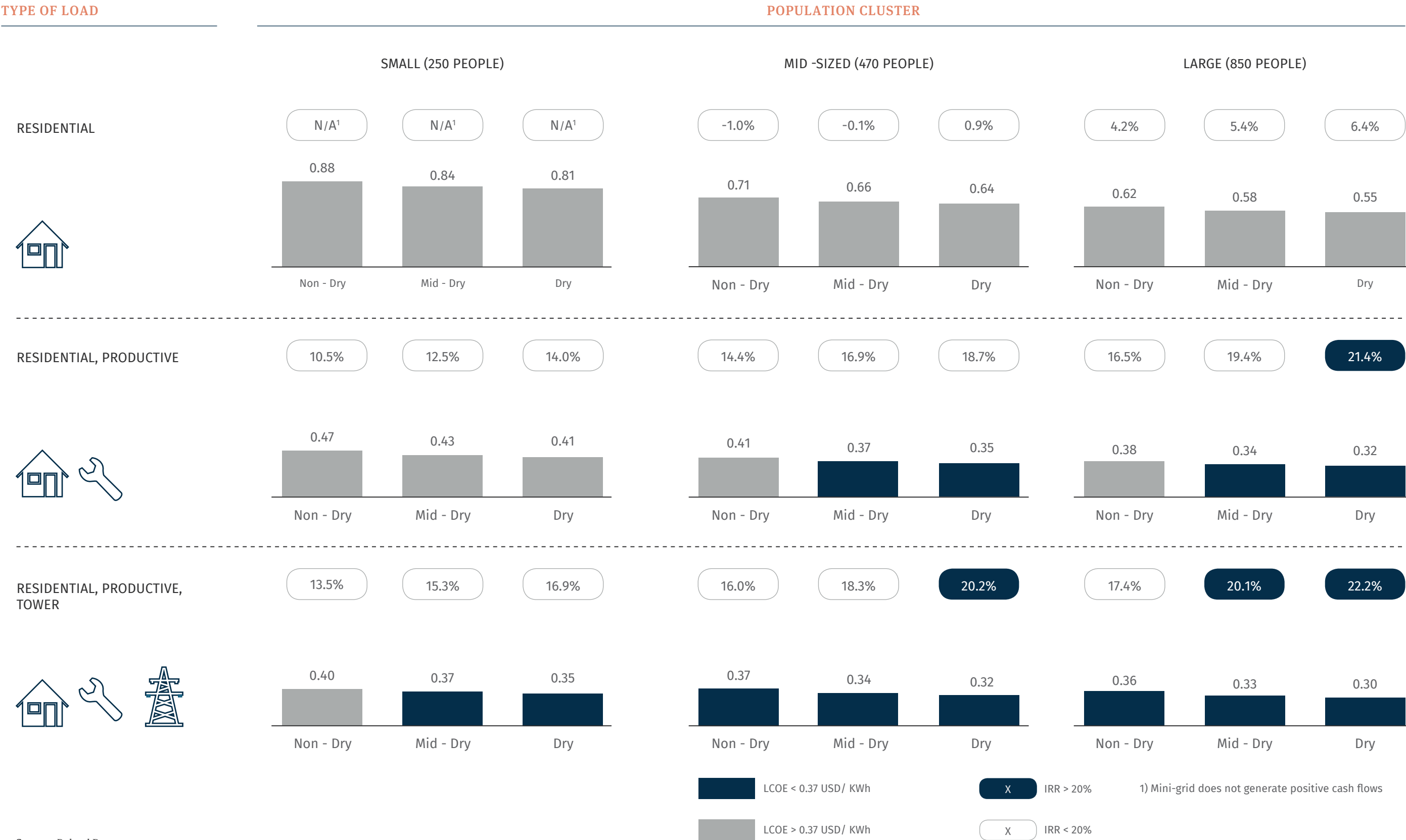
IRR N/A when configuration does not generate positive cash flows; Note that viability deteriorates as anchor loads are added because it is assumed that CAPEX related to equipment to supply power for anchor loads is not subsidised or covered by community contributions



Source: Roland Berger

**Figure 34.** Viability of mini-grids in 2030 based on cost, size, and climate; LCOE [USD/ KWh], IRR [%], No subsidies or community contribution

IRR N/A when configuration does not generate positive cash flows; For key assumptions refer to Annex 7



Source: Roland Berger



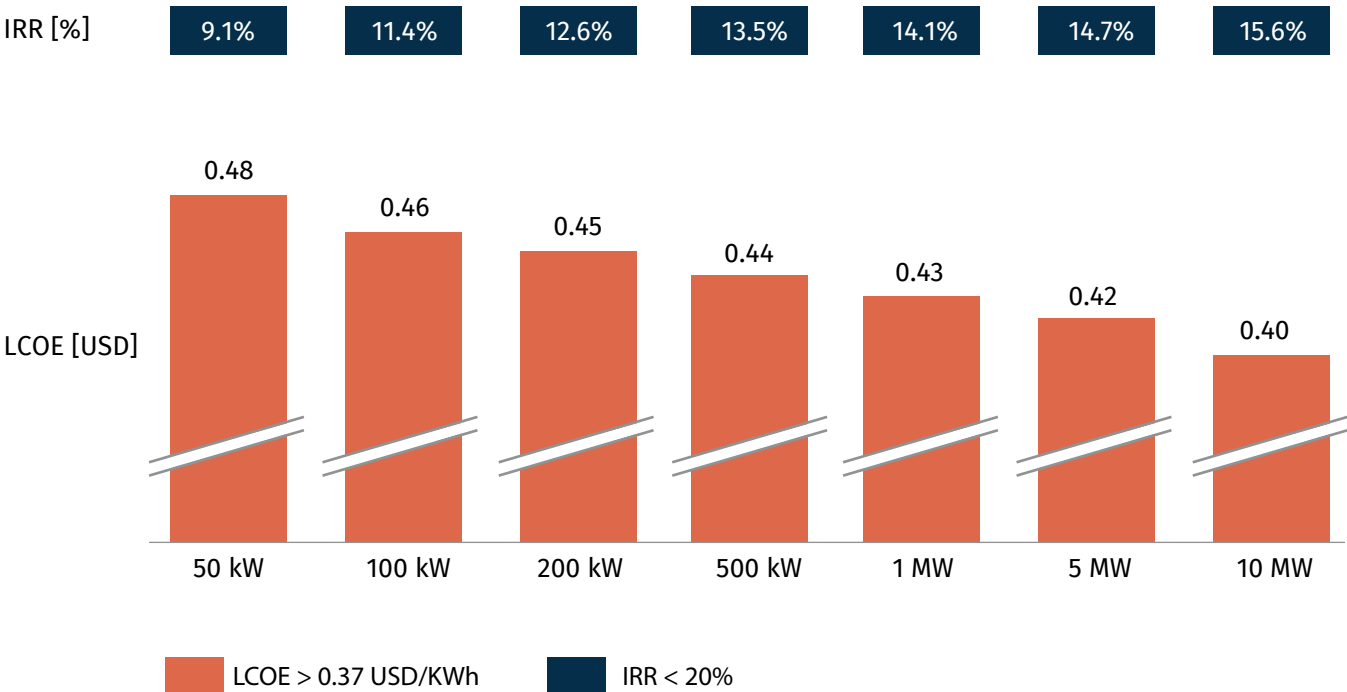
Impact of mini-grid size on LCOE and IRR

The size of a mini-grid is an important factor and positively impacts IRR because of the ability to spread fixed costs over a greater number of customers and hence generate efficiencies. However, for non-subsidised mini-grids, an increase in size alone is not sufficient to drive viability. This is because as mini-grid size increases, residential demand for electricity also increases. As residential use is primarily at night, this drives the need for larger batteries to store the electricity generated in the day. Thus, the increase in battery CAPEX partly offsets the increase in revenues, limiting the positive impact on IRR.

However, larger mini-grids may be favoured in any potential transition to distribution franchises at the time of grid arrival due to their ability to provide last-mile connections to a greater number of households simultaneously.

Existing examples of large (MW-scale) mini-grids that were successfully integrated into the grid include the systems in the cities of Myeik (12 MW generation capacity mini-grid), Kawthaung (8 MW generation capacity

Figure 35. Viability of mini-grids at different mini-grid capacities; LCOE [USD/ KWh] and IRR [%]. For key assumptions refer to Annex 7



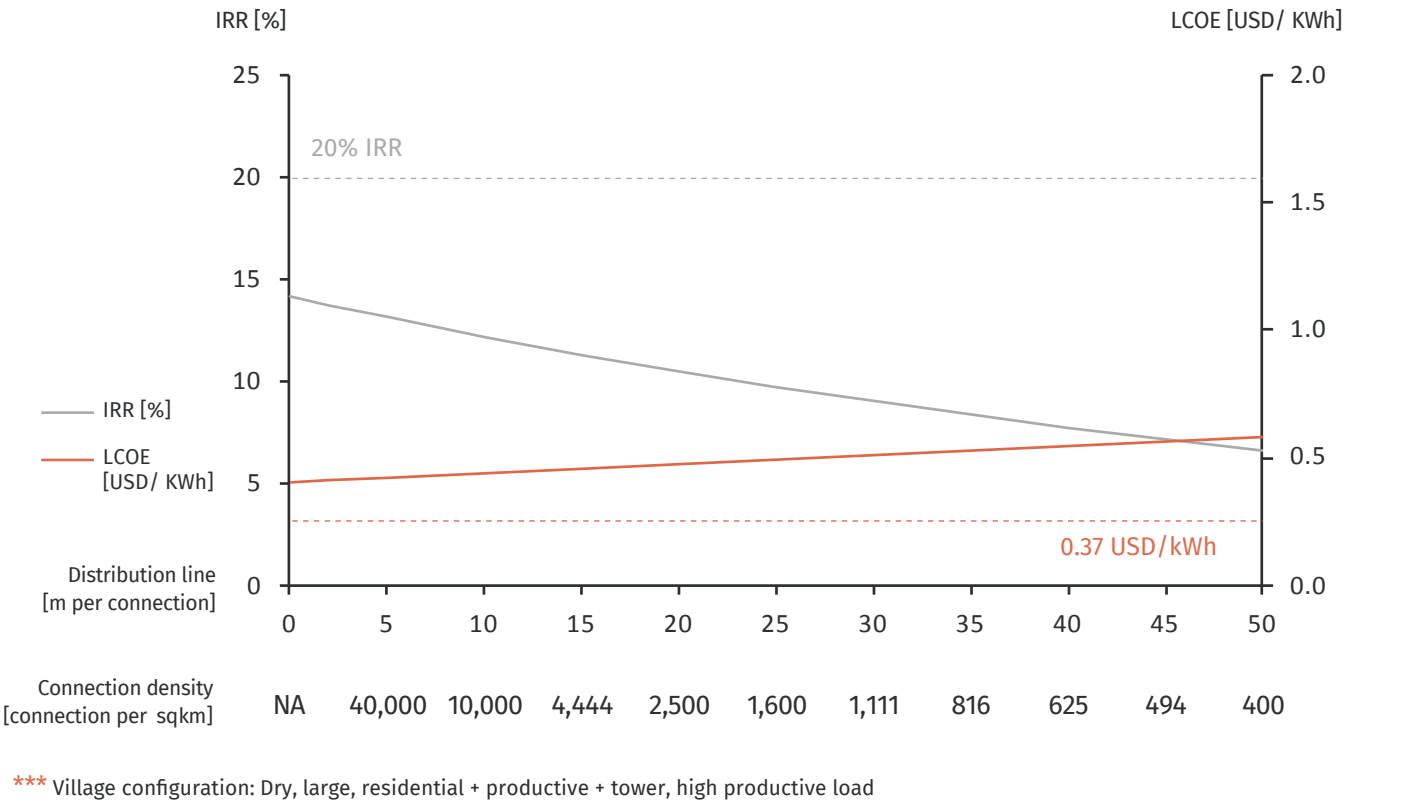
Source: Roland Berger

mini-grid) and Dawei (6 MW capacity mini-grid).<sup>75</sup> The mini-grids in these cities were built independently and scaled-up over time by local citizens. Eventually they were connected to the regional distribution grid upon payment of compensation to the original developers. In the case of Dawei, the generation system was upgraded to gas-fired asset supplied through piped gas from nearby off-shore assets. These case studies illustrate the potential of MW-scale mini-grids to be readily integrated into the grid, thus offering a potential solution enabling rapid electrification.

Impact of population density on LCOE and IRR

An increase in population density is expected to positively impact LCOE and IRR as the capital costs related to the distribution infrastructure decrease.

Figure 36. LCOE [USD/ KWh] and IRR [%] as a function of connection density 2020, No Subsidies or Community Contribution, mini-grid in dry zone, in large population cluster, with residential, productive and tower loads; For key assumptions refer to Annex 7



Source: Roland Berger

75 Interview conducted by Roland Berger with the World Wildlife Fund (WWF)

A simulation was conducted to assess whether at very high population (or connection) density, mini-grids in favourable locations (dry zone, in large population cluster, with residential, productive and tower loads) could become viable even without subsidies.

As shown in Figure 36, although increasing the density of connections has a positive impact on LCOE and IRR, it is insufficient to drive viability of mini-grids. This is because the required investment in distribution grid per connection varies as the inverse of the square root of the connection density — thus even a large increase in density results in comparatively small capital cost savings.

**LCOE and IRR simulations for hydropower mini-grids**

As outlined in Section 2.7, although solar/diesel/battery hybrid mini-grids are expected to emerge as the key configuration for mini-grid applications in Myanmar, hydropower mini-grids are currently the most widespread type of renewable mini-grids in Myanmar and can play an important role if suitable locations with exploitable hydrological potential can be identified.

Hydropower LCOE and IRR depend critically on the morphology of the exact location of the mini-grid and capital expenses per kW for the generation system can vary considerably. In this study, a range between 3,600 USD/kW (Low CAPEX locations) and 4,000 USD/kW (High CAPEX locations) is considered for suitable locations based on data from IRENA (See Annex 7).

As shown in Figure 37, in the case of mini-grids with investment subsidies, most configurations are viable. LCOEs vary between 0.16 and 0.45 USD/kWh slightly lower than for solar/diesel/battery mini-grids, consistent with the fact that hydropower mini-grids are cost competitive (see also discussion in Section 2.7).

However, as in the case of solar, without subsidies, most mini-grid configurations are not viable as of 2020 (Figure 38).

Hence as of 2020, hydropower mini-grids may be developed under the DRD scheme if suitable locations with CAPEX in the range outlined above are identified.

It should be emphasised that in the context of this study viability is defined using paramaters and required thresholds typical of private developers.

Existing hydropower mini-grids built and managed with significant involvment of local communities may be considered viable without government subsidies as shareholders may have markedly different requirements in terms of rate of returns compared to private developers.<sup>76</sup>

As outlined above, site-specific conditions are important to determine actual viability of hydropower mini-grids. Two key determinants of viability are the local topography and the hydrological conditions. Areas with low topographical gradients require large civil works to achieve suitable level of heads to drive hydro-powered system, driving high investment costs. Locations with irregular water flows (e.g. low flows during the dry season) are also unsuitable as stable supply cannot be guaranteed.

In order to estimate the approximate number of potential sites for hydropower mini-grids, off-grid villages with likely favourable conditions are identified. To determine favourable topography, off-grid villages in mountainous areas with high topographical gradients are selected using maps. It is estimated that approximately 7,000 off-grid villages lie in favourable areas. As there are no available data at the national level defining hydrological conditions, rainfall statistics are used as a proxy to assess stability of water flows — villages in areas where the driest month has at least 10 mm average precipitation are selected.

Using the filtering approach described above yields an estimated 1,100 sites potentially suitable for hydro-powered mini-grids corresponding to 3% of off-grid villages. This admittedly rough estimate is consistent with expert opinions gathered through interviews.<sup>77</sup> The potential sites identified are concentrated in Chin (especially in the northern part of the State), Kachin, parts of Sagaing and Shan and would cover 290,000 households. The corresponding mini-grid capacity would be 54 MW.

It is worth noting that the potential areas identified here do not overlap with areas most favourable for solar/diesel/battery mini-grids (dry and mid-dry zone). Thus, although the estimates above suggest that hydro-powered mini-grids can potentially cover only a small fraction of off-grid villages, this technology may play an important role in enabling electrification in specific areas that are not favourable to solar mini-grids.

<sup>76</sup> See for example Pandey, B., A. Reddy, D. Vaghela “Assessing the Impact of Community-Managed Structures on the Economic Viability of Small-Scale Hydropower in Nepal and Myanmar, Working Paper, Hydro Empowerment Network”, 2018

<sup>77</sup> Interview conducted by Roland Berger with GIZ

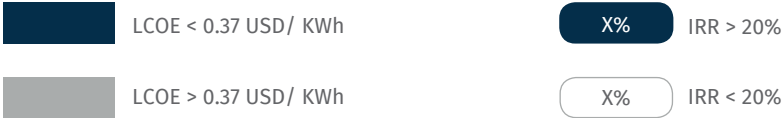
Figure 37. Hydropower mini-grids LCOE [USD/ KWh], IRR [%], 2020, 60% Subsidies and 20% Community Contribution

TYPE OF LOAD

POPULATION CLUSTER



Source: Roland Berger





**Figure 38.** Hydropower mini-grids LCOE [USD/ KWh], IRR [%], 2020,  
No Subsidies or Community Contribution. IRR is N/A when configurations do not generate positive cash flows; For key assumptions refer to Annex 7

TYPE OF LOAD

POPULATION CLUSTER



Source: Roland Berger

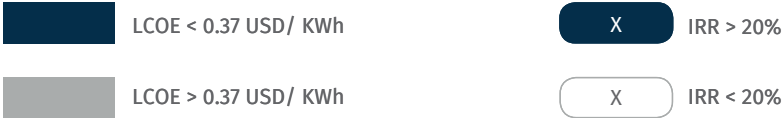
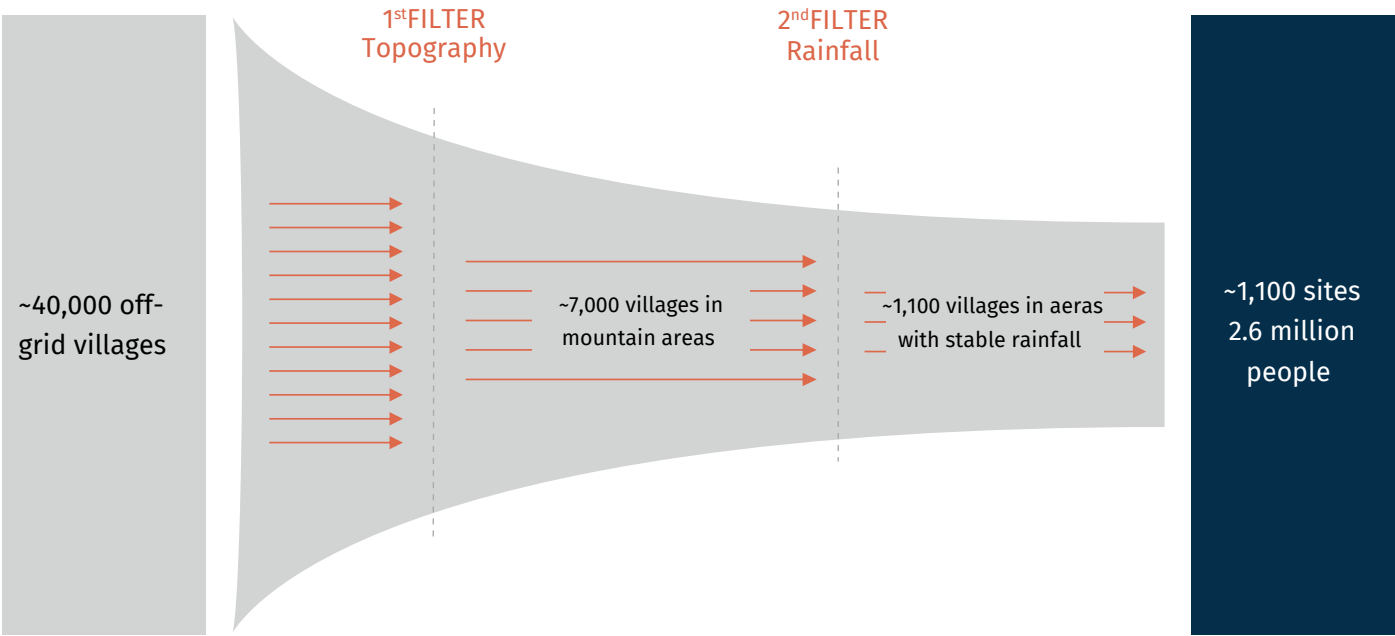


Figure 39. Estimation of approximate number of potential hydro mini-grid sites



Source: Roland Berger

### 3.4 Cost per connection

In Figure 40, a comparison of electrification costs per connection between on-grid electrification (as planned in the NEP) and mini-grids is presented.

As outlined in Section 2.3, estimated costs per connection for grid electrification range between 1,863 to 2,415 USD per connection, including average costs of extending MV distribution lines, cost of last mile connections and cost to increase installed generation capacity to supply newly-electrified areas.

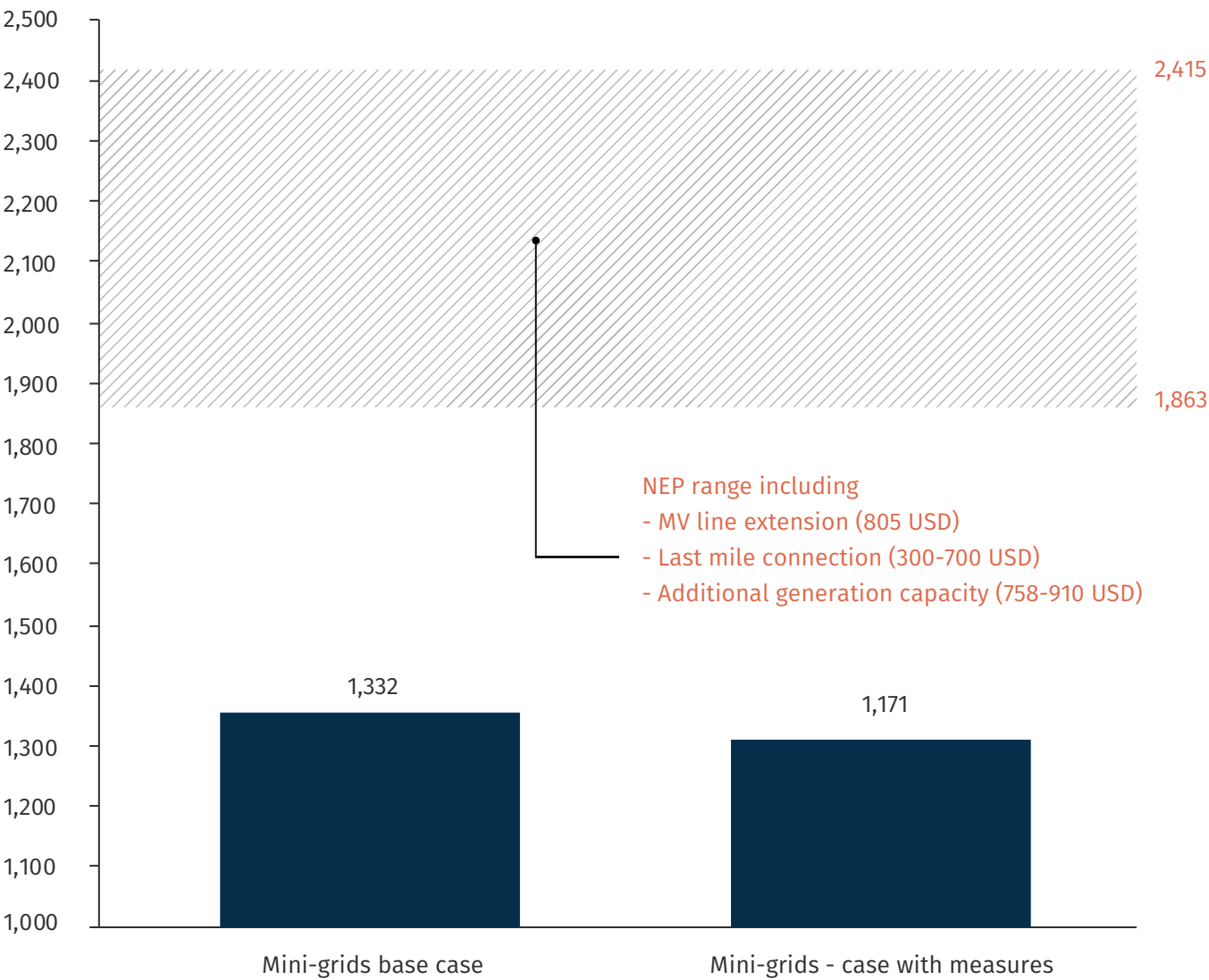
Scenarios for mini-grid development show much lower costs per connection. In the base case for 2020, estimates indicate cost levels of 1,332 USD per connection. Note that this is consistent with World Bank estimates of 1,400 USD per connection for mini-grids in Myanmar.<sup>78</sup> In the case with measures (i.e. when (1) investment subsidies budget is increased to 100 million USD, (2) economies of scale is achieved, (3) IRR threshold is decreased to 15%, and (4)

<sup>78</sup> World Bank, “Myanmar: Towards Universal Access to Electricity by 2030”, 2014

productive load is increased by 20% and (5) grid arrival is de-risked through regulatory reform), cost per connection decreases to 1,171 USD or approximately 40% less than grid electrification.

Hence these scenarios provide strong evidence that mini-grids can offer a cost-effective solution to electrification of off-grid areas in Myanmar while the main grid is extended.

Figure 40. Comparison of cost per connection between mini-grid (base case), mini-grid (case with measures) and NEP



Source: Roland Berger

Note that NEP cost include average costs for extension of distribution lines (805 USD), cost of last mile connection (300-700 USD) and cost of additional generation capacity needed to supply electrified areas (estimated at 800-960 USD)







# 4.0

## Projections of Potential Market for Mini-Grids in Myanmar Under Different Scenarios

### 4.1 Definitions and methodology

In this chapter, a quantitative assessment of the potential market for mini-grids in Myanmar is provided for 2020, 2025 and 2030 and different scenarios for market evolution are explored.<sup>79</sup>

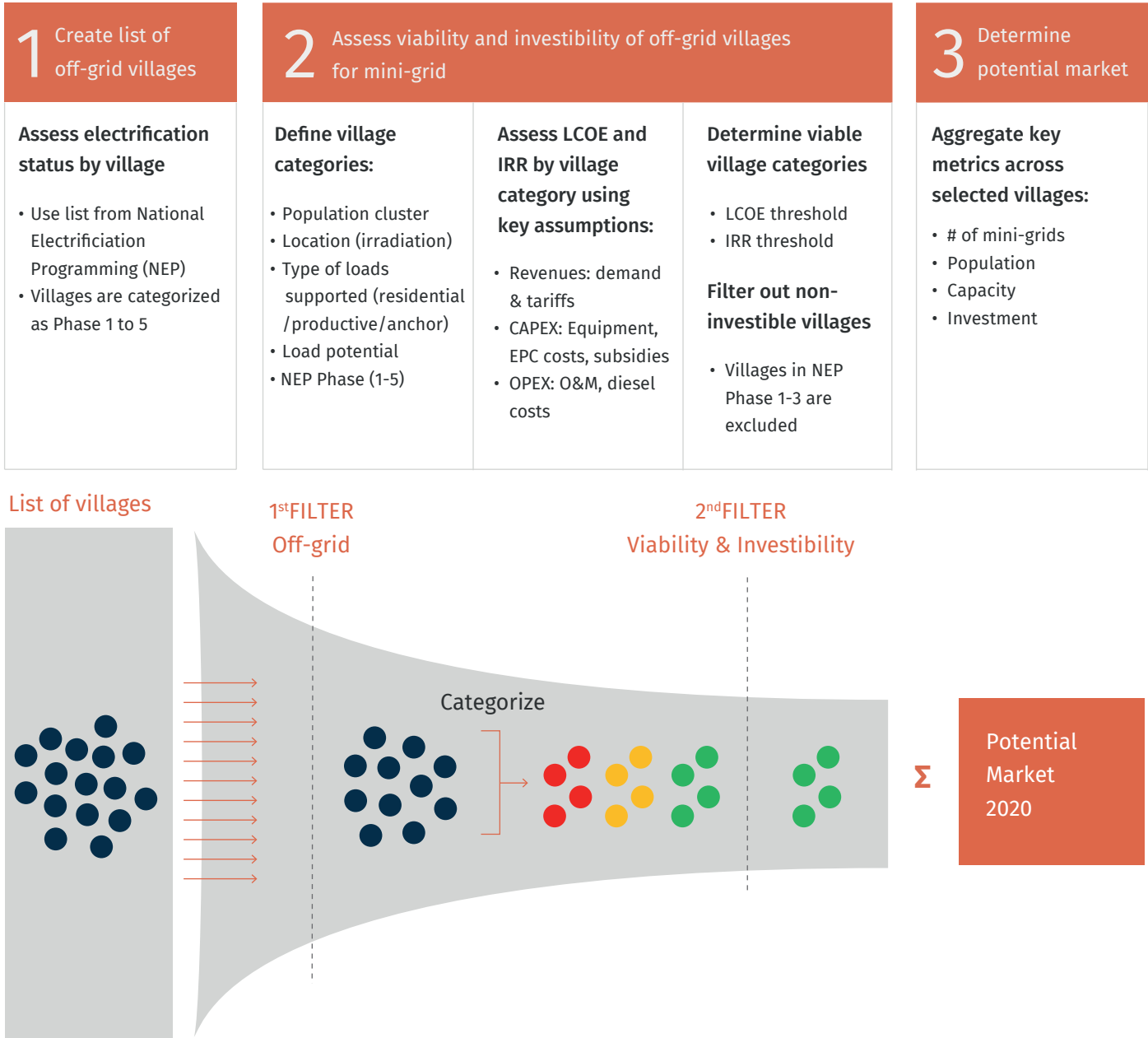
The potential market size is based on the number of mini-grids that would become financially viable and investible for mini-grid developers at certain a point in time (2020, 2025 and 2030) and the corresponding coverage of off-grid population as well as the amount of investment that would be required to build all the potential mini-grids identified.

It should be stressed that the actual number of mini-grids that will be built by 2020, 2025 and 2030 could differ substantially from the potential market estimated here as implementation of mini-grid projects depends on numerous factors such as availability of private financing and of resources to build mini-grids as well as likelihood of obtaining consensus and buy-in from local communities.

Criteria for financial viability and for determining investible mini-grids are presented in detail in Section 3.1 and 3.2 respectively. Briefly, financial viability is based on Levelised Cost of Electricity and Internal Rate of Return thresholds (i.e. LCOE < 0.37 USD / kWh and an IRR> 20%).

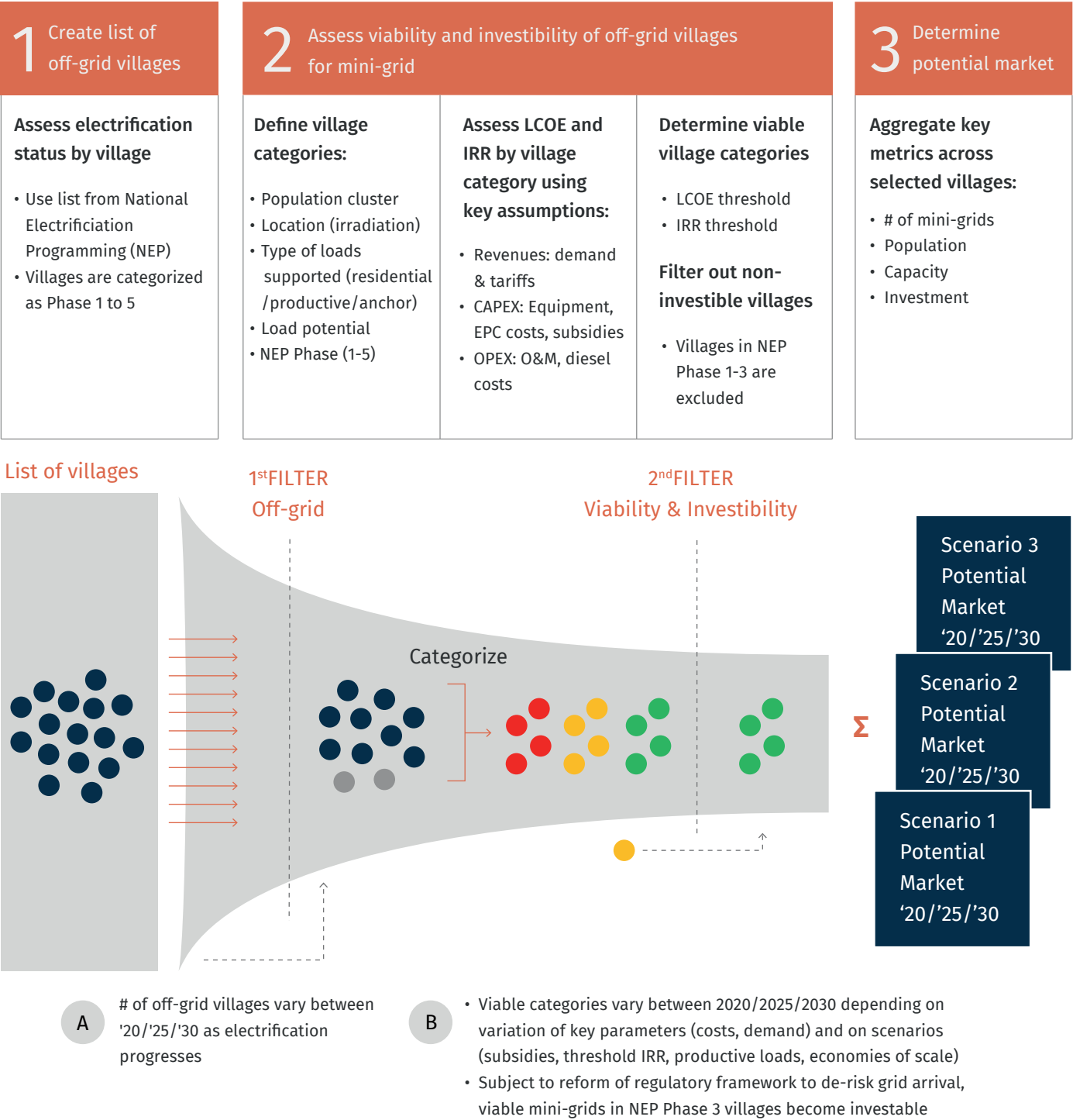
79 Focusing on solar/diesel/battery hybrid mini-grids

Figure 41. Filtering approach used to estimate potential market



Source: Roland Berger

Figure 42. Approach to generate potential market projections and scenarios



List of villages

1<sup>st</sup>FILTER  
Off-grid

2<sup>nd</sup>FILTER  
Viability & Investibility

Categorize

Scenario 3  
Potential Market  
'20/'25/'30

Scenario 2  
Potential Market  
'20/'25/'30

Scenario 1  
Potential Market  
'20/'25/'30

A

# of off-grid villages vary between '20/'25/'30 as electrification progresses

B

- Viable categories vary between 2020/2025/2030 depending on variation of key parameters (costs, demand) and on scenarios (subsidies, threshold IRR, productive loads, economies of scale)
- Subject to reform of regulatory framework to de-risk grid arrival, viable mini-grids in NEP Phase 3 villages become investable

Investible mini-grids are defined based on their categorisation by National Electrification Planning phase (mini-grids in villages under NEP Phase 4 and 5 are considered investible; mini-grids in villages under Phase 3 are considered investible only if regulations on transition upon grid arrival are put in place; mini-grids in villages under Phase 1 and 2 are considered not investible).

The market potential is assessed using a filtering approach, building on the analysis outlined in Chapter 3 (See Figure 41) and including three steps:

- **Create a list of off-grid villages**
  - » The list of off-grid villages from the National Electrification Programming is utilised. This list contains 42, 110 off-grid villages and also specifies the NEP Phase for each village (Phase 1-5, with Phase 1 villages planned for early electrification).<sup>80</sup> The list is then updated to 2020/2025/2030 following expected electrification rate (see Section 2.3)
- **Filter out non-viable and non-investible off-grid villages**
  - » Following the analysis at 3.1, each village is categorized based on its potential mini-grid configuration given its population cluster size (small, mid-sized or large), location (dry zone, mid-dry zone or non-dry zone), proximity to anchor load (whether it is located within 1.4 km from telecommunication tower) and productive load potential (high, mid, low as categorized in Section 2.4.2)
  - » Based on the categorisation above and on the analysis at 3.1, mini-grid viability in each village is assessed and non-viable villages are excluded
  - » Villages in early phases of NEP are excluded as in these locations mini-grid developers may not be ready to shoulder the risk of early grid arrival (villages are deemed non-investible). Assuming no specific regulation on transition upon grid arrival is introduced, villages in Phases 1 to 3 of NEP are deemed non-investible<sup>81</sup>
- **Determine overall potential market by aggregating key metrics across selected villages after filtering**
  - » Sum potential market metrics over all viable and investible villages identified in step 2: number of mini-grids (assuming one mini-grid per village), population covered, generation capacity, investment required to build mini-grids in all selected villages

Source: Roland Berger

80 Columbia University, “Myanmar — Geospatial based Least Cost Modeling Output”, 2014

81 Based on interviews with GIZ

Market projections and scenarios are built by taking into account changes in the filtering process described above due to (1) impact of electrification, (2) impact of the evolution of key parameters (e.g., capital costs, demand per capita, etc.), and (3) impact of the evolution of scenario drivers (See Figure 42):

- **Impact of electrification**
  - » The status of electrification for each village is projected to 2020, 2025 and 2030 based on the expected evolution of electrification rate outlined in Section 2.3
  - » Hence, as a result of electrification, the pool of off-grid villages that go through filter 1 becomes smaller
- **Impact of evolution of key parameters**
  - » Evolution of key parameters affecting revenues and costs is taken into account to determine evolution of LCOE and IRR of mini-grids thus impacting the viability assessment performed at filter 2
- **Impact of scenario drivers**
  - » As outlined in Section 4.3, five scenario drivers are considered in the current study: (1) Subsidies and contributions, (2) Regulatory framework, (3) Access to finance, (4) Demand per load (5) Economies of scale
  - » Drivers (1) Subsidies and contributions, (4) Demand per load and (5) Economies of scale impact directly LCOE and IRR of mini-grids, thus impacting the viability assessment performed at filter 2
  - » Drivers (2) Regulatory framework and (3) Access to finance, impact the required internal rate of return to make mini-grids viable from an investor perspective thus lowering the IRR threshold required for filter 2
  - » In addition, driver (2) Regulatory framework, which includes proposed regulations to de-risk grid arrival, crucially impacts the criteria used for selecting investible mini-grids. In case regulatory provisions to de-risk grid arrival are introduced, viable mini-grids in NEP Phase 3 villages would also become investible by developers and can be included the quantification of the potential market.

## 4.2 Potential market forecast to 2030 in base case scenario

In the base-case scenario, it is assumed that the current investment subsidy and community contribution system is maintained, ensuring coverage of 80% of the initial investment required to develop mini-grids (60% through investment subsidies and 20% through community contributions). An 18.6 million USD budget is assumed for the investment subsidy scheme which is the expected budget available in the foreseeable future derived from interviews with DRD and bilateral institutions. Evolution of electrification is assumed to be in line with the average of 15 benchmark countries as outlined in Section 2.3 — by 2030 electrification rate is expected to reach 62% implying an off-grid population of 22 million people. To define mini-grids viability, a LCOE threshold of maximum 0.37 USD/kWh and an IRR threshold of minimum 20% are utilised.<sup>82</sup> All other assumptions on key parameters for LCOE and IRR calculation are outlined in Annex 7.

As outlined in Section 3.3, under the existing investment subsidy scheme, most mini-grid configurations are viable. In addition, based on simulations using our model, by 2030, thanks to the decrease in key equipment costs and increase in demand per capita, mini-grids in large villages in the dry zone with productive and tower loads are expected to become viable even without investment subsidies.

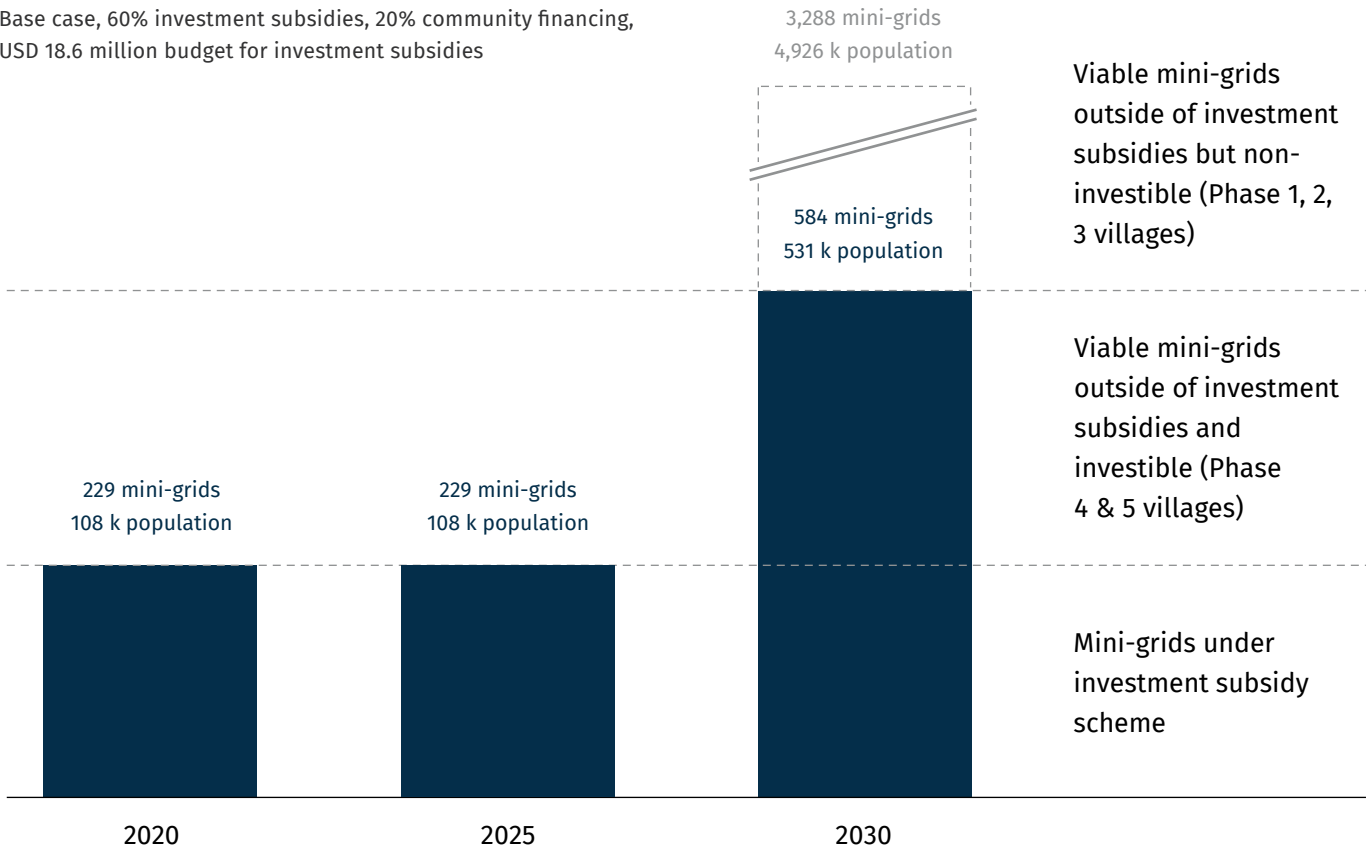
Consequently the market projections show that for 2020 and 2025, the number of viable mini-grids is determined by the budget available for subsidies under the DRD scheme. By 2020, an estimated 229 mini-grids could be developed given the expected 18.6 million USD subsidy budget. The total investment required would be 31 million USD.

By 2030, in addition to 229 mini-grids that could be developed using investment subsidies, mini-grids that are outside the investment subsidy scheme become viable in large and mid-sized villages in the dry zone, and in large villages in the mid-dry zone, generating an increase in the potential market to 584 mini-grids. This would allow coverage of approximately 2.3% of the off-grid population or 531,000 people at a total investment of 204 million USD (See Figure 43).

<sup>82</sup> The IRR threshold used is much higher than for utility-scale solar (7-12% depending on Country). This is because utility-scale solar projects typically sell generated power through long-term power purchase contracts with fixed volumes and prices. Hence, project cash flows are de-risked. On the contrary, mini-grid projects still carry cash flow risk as customer demand and sales volumes are difficult to predict.



**Figure 43.** Mini-grid market potential in Myanmar in base case scenario with current subsidy scheme and 18.6 million USD subsidy budget



Source: Roland Berger

Market projections show that unsubsidised mini-grids become viable in 2030 in 6 States/Regions that can be grouped into two categories<sup>83</sup> :

- States/Regions combining high irradiation levels (dry zone)<sup>84</sup> with high potential for productive loads: Magway, Sagaing.
- States/Regions with average irradiation levels (mid-dry zone), but high potential for productive loads: Ayeyarwaddy, Bago, Tanintharyi, Mon<sup>85</sup>

<sup>83</sup> In this analysis mini-grids developed by private developers outside of the investment subsidy scheme under the anchor-focused business model (see Section 2.2) are not taken into account as they only cover selected parts of villages nearby telecommunication towers to maintain viability

<sup>84</sup> Refer to Section 2.4.2 for analysis of productive load potential by State/Region

<sup>85</sup> Refer to Annex 9 for average irradiation level for each type of zone

These market projections suggest that with the current subsidy scheme and budget levels, only a minority of off-grid villages can be reached by newly-developed mini-grids in the short to mid-term up to 2025. Only in the longer term (from 2030), coverage in regions with high productive demand potential and mid-to-high irradiation levels may increase.

Consequently, in order to reach significant electrification through mini-grids in the short to mid-term, different options should be explored to increase subsidy budgets and/or enable development of mini-grids by complementing the current investment subsidy scheme with other support measures. In order to inform recommendations on the possible options, a number of scenarios have been developed as outlined in the following sections.

### 4.3 Selection of scenario drivers and definition of scenarios

As discussed in Section 3.1 and 3.2, the following four categories of key drivers have significant impact on the viability and investibility of mini-grids: revenue drivers, capital and operational costs drivers, regulatory/ macroeconomic drivers.

In this study, scenario drivers are selected among these four categories using two criteria: (1) Drivers whose evolution is uncertain at present, (2) Drivers that may be influenced through deliberate policy and regulatory action.

In this way, five scenario drivers with high uncertainty and potential to be shaped by policy and regulations are identified:

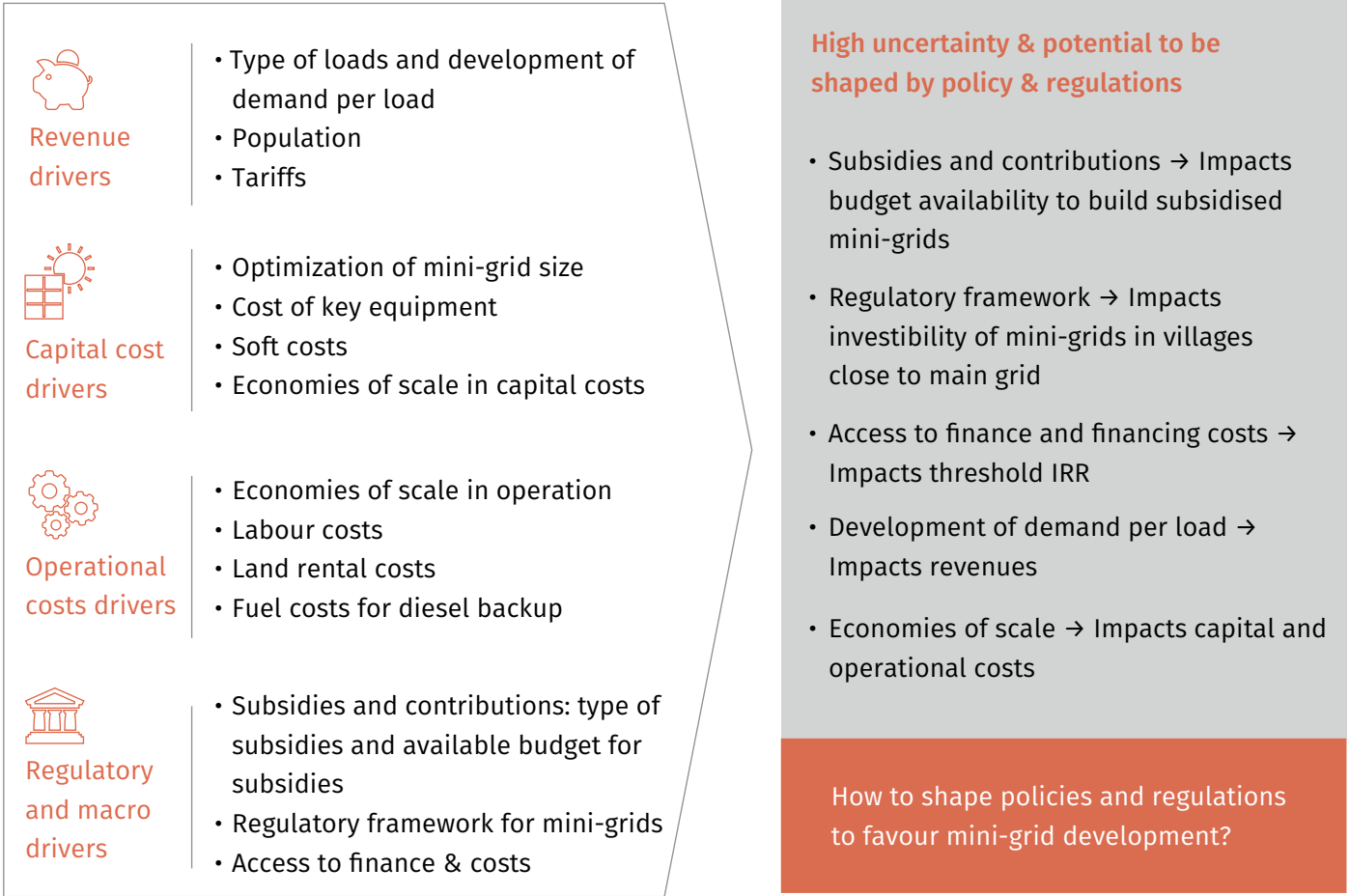
- Subsidies and contributions
- Regulatory framework
- Access to finance and financing costs
- Development of demand per load
- Level of economies of scale in development of mini-grids

Based on the selection of scenario drivers, the following quantitative scenarios can be defined (these scenarios are discussed in Section 4.4):

- **Subsidy Scenarios:** Determine potential market as a function of total available budget for subsidies assuming the current investment subsidy scheme remains in place (i.e. DRD covers 60% of capital costs, community contribution covers 20% of capital costs and private developer covers remaining 20% of capital costs). These scenarios would inform recommendations to optimise subsidy budgets to promote greater coverage of off-grid population through mini-grids. In addition, impact of reducing subsidies contribution as a percentage total investment from current 60% can also be explored.
- **Regulatory Scenarios:** Determine impact on potential market of introducing a comprehensive regulatory framework, including a clear mechanism for transition at the time of grid arrival. This regulatory framework would reduce overall risk perception and most importantly allow investment from developers in villages closer to the main grid that, without certainties on grid arrival transition, would be considered too risky and non-investible.<sup>86</sup>
- **Financing Scenarios:** Determine potential market size as a function of IRR threshold (%) reflecting possible changes in access to finance, financing costs for private developers as well as lower perceived risk for mini-grid projects. These scenarios would inform recommendations for actions to facilitate access to lower-interest finance by private developers, for example through two-step loan schemes, whereby bilateral/multilateral institutions would support local financial institutions through loans, enabling the latter to issue loans to mini-grid private developers at attractive conditions. In addition it would support further regulatory reform to de-risk grid arrival as a lever to decrease perceived risk of mini-grid projects.
- **Demand Scenarios:** Determine potential market size as a function of demand per load. These scenarios would inform recommendations for demand-side support actions such as new forms of subsidies to end-customers to stimulate electricity demand in addition to the current supply-side-focused investment subsidy scheme.
- **Economies of scale Scenarios:** Determine market size for different levels of economies of scale driving capital and operational cost reductions. These scenarios would inform recommendations for: (1) Actions to centralise project development and procurement for “blocs” of projects

86 Interviews with GIZ

Figure 44. Key drivers for scenarios



Source: Roland Berger

and (2) Actions aiming at favouring more market consolidation thereby allowing the development of sizeable private developers that would be able to develop multiple projects in parallel enhancing economies of scale.

## 4.4 Estimate of potential market in 2020 by scenarios

### 4.4.1 Standalone scenarios for 2020

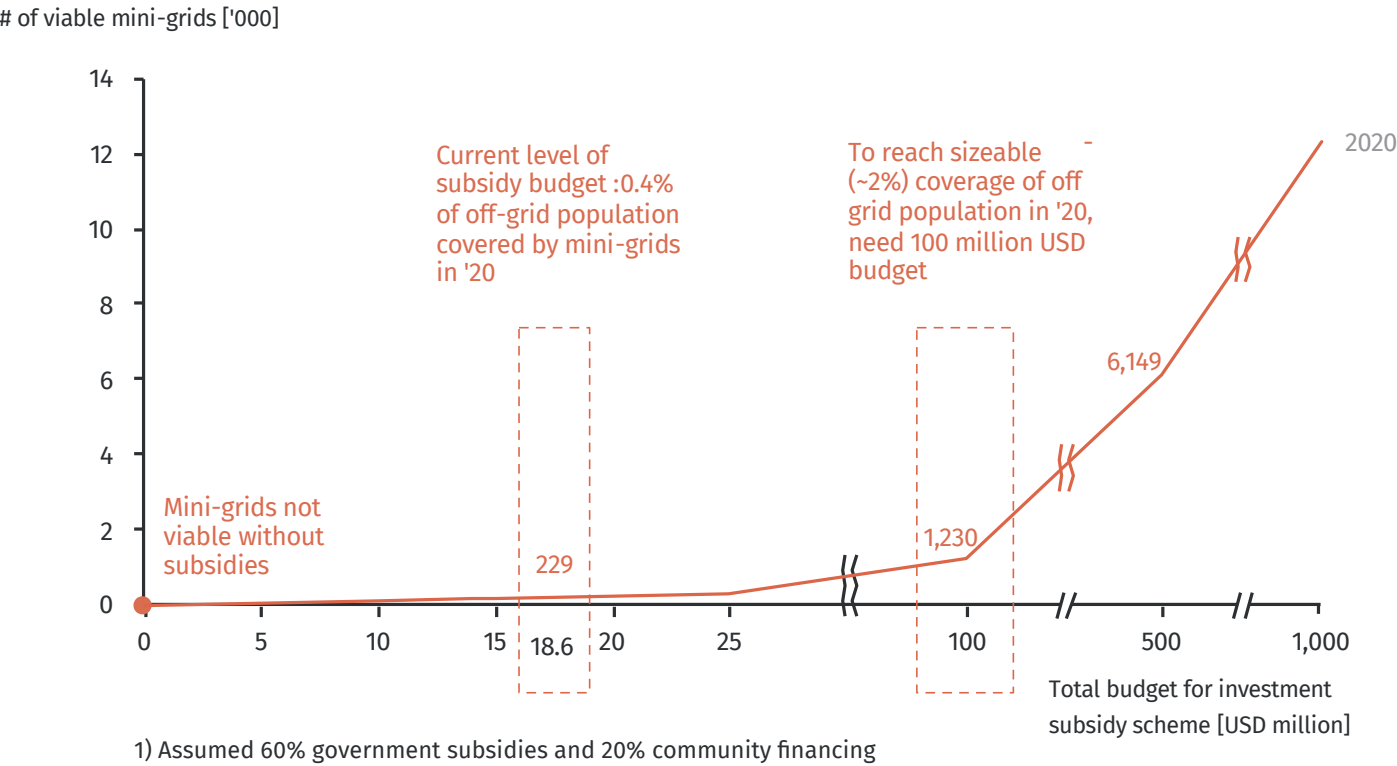
In this section the impact of varying individual scenario drivers on the potential market are explored for 2020. In these simulations only one driver is varied at a time while all the other drivers are kept constant.

Subsidy budget scenarios

In this sub-section, simulations of the potential market size for different levels of available subsidies are presented. Here the subsidy budget is the only variable — all other parameters and scenario variables are kept constant. In particular, the potential benefits of economies of scale as the market grows in size with increasing subsidy budget are not taken into account and are examined separately in Section 4.4.4.

As shown in Figure 45, in the absence of other support measures, in order to reach a sizeable potential market covering at least 2% of the off-grid population utilising the current investment subsidy scheme alone, a significant increase in subsidies budget to at least 100 million USD is required.

Figure 45. Simulation of number of viable mini-grids for different levels of total available investment subsidy budget in 2020; assumes current investment subsidy scheme where DRD covers 60% of capital costs



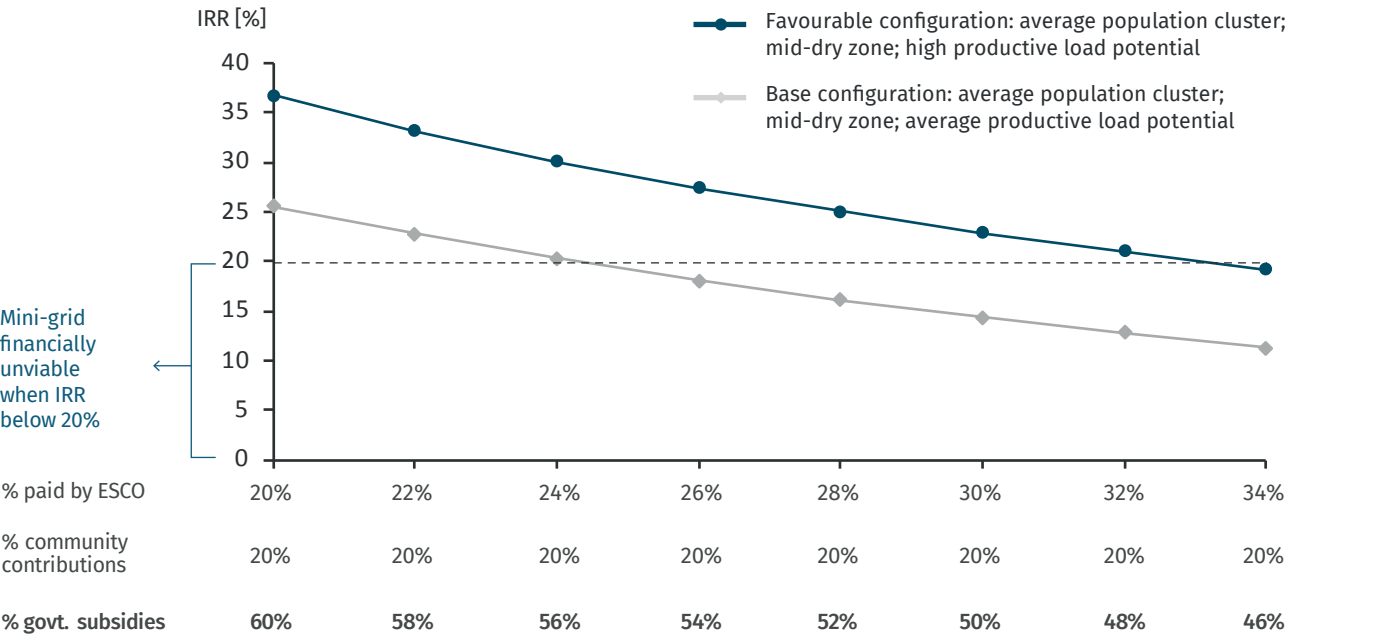
Source: Roland Berger

Subsidy contribution scenarios

In this sub-section, the impact of reducing investment subsidies contributions from current level of 60% of total CAPEX is explored.

As shown in Figure 46, for mini-grids in the base case configuration (average population cluster, mid-dry zone, average productive load potential), subsidy contribution can be lowered to 56% without compromising the viability of mini-grids. If more favourable configurations are taken, for example average population cluster, mid-dry zone, high productive load potential, then subsidy contribution can be lowered to 48% without compromising the viability of mini-grids. These simulations demonstrate that even in the short term, as of 2020, there is room for optimising the investment subsidies contributions.

Figure 46. Simulation of IRR of mini-grids at different levels of subsidy contribution in 2020



Source: Roland Berger



Regulatory scenarios

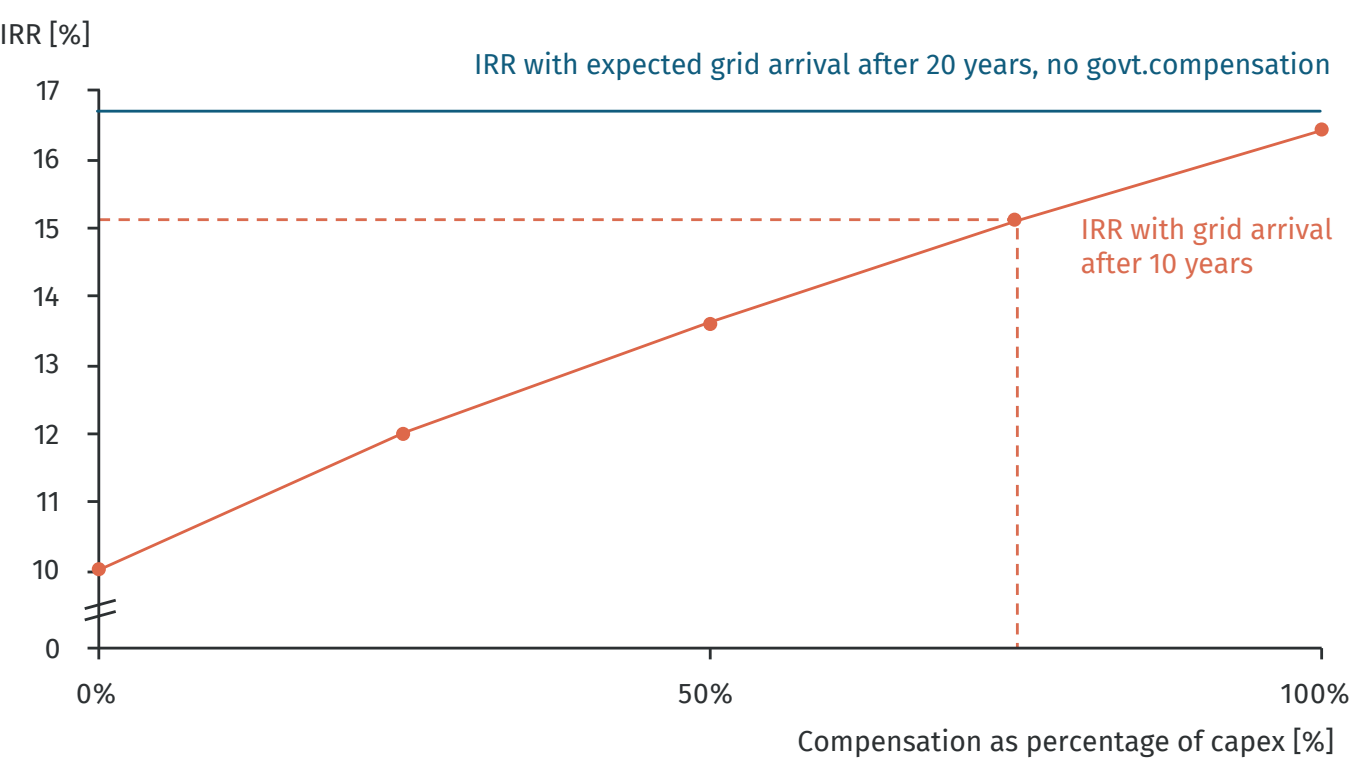
Having a comprehensive regulatory framework, including a clear mechanism for managing the risk of early grid arrival, would significantly reduce overall risk perception, encouraging investment from developers in villages with medium potential for early connectivity to the main grid (i.e., Phase 3 villages).

In the simulations below, the effect of a compensation scheme to be activated in case of grid arrival after 10 years from mini-grid commissioning is explored.

As shown in Figure 47, for mini-grids with favourable configuration (large population cluster, dry zone, high productive load potential), compensating 75% of CAPEX if the grid arrives 10 years early (i.e. if the grid arrives 10 years after mini-grid comissioning) will ensure IRR remains above 15%. Although this is still below the typical 20% threshold for viability, it represents a significant increase in IRR.

These results confirm that if a compensation system is introduced, mini-grid developers may become ready to invest even in villages that have moderate

**Figure 47.** Simulation of IRR of mini-grids at different levels of compensation for grid arrival after 10 years, as percentage of CAPEX, in 2020



Source: Roland Berger

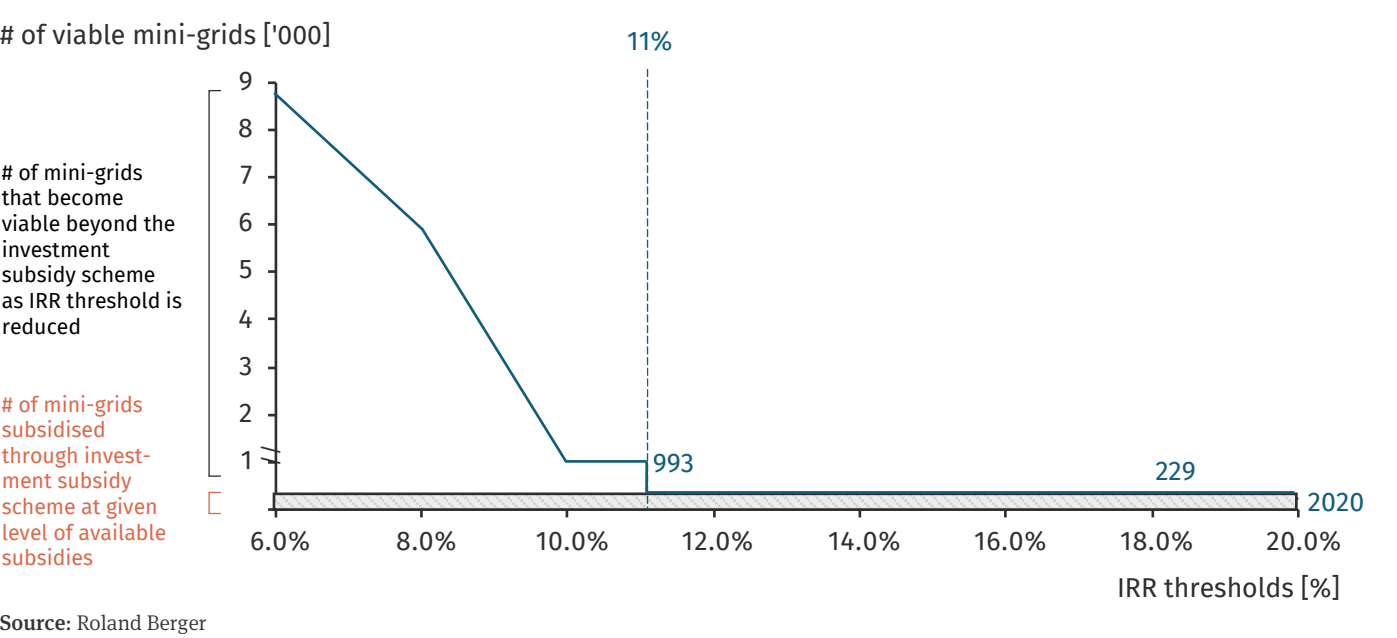
likelihood of being reached by the grid in the next 10 years. This would increase the pool of investible villages to include those under Phase 3 on NEP.

Financing scenarios

Access to finance and cost of financing are key factors in enabling the development of the mini-grid market. Measures to enable access to debt finance and decrease interest rates such as two-step loans have been proposed or are under discussion by bilateral and multilateral organisations.<sup>87</sup> One impact of such measures would be to decrease the required IRR threshold for private developers to invest in mini-grids from the current 20% average level.

Simulations in Figure 48 show that in order to generate impact on market size in 2020 by improving access to finance as a standalone measure, a very substantial decrease in the IRR threshold by 9% points from 20% down to 11% would be required.

**Figure 48.** Simulation of number of viable mini-grids for different levels of IRR threshold in 2020. Assumes current investment subsidy scheme (DRD covers 60% of capital costs, community contribution covers 20% of capital costs and developer covers remaining 20% of capital costs) and 18.6 million USD subsidies budget;



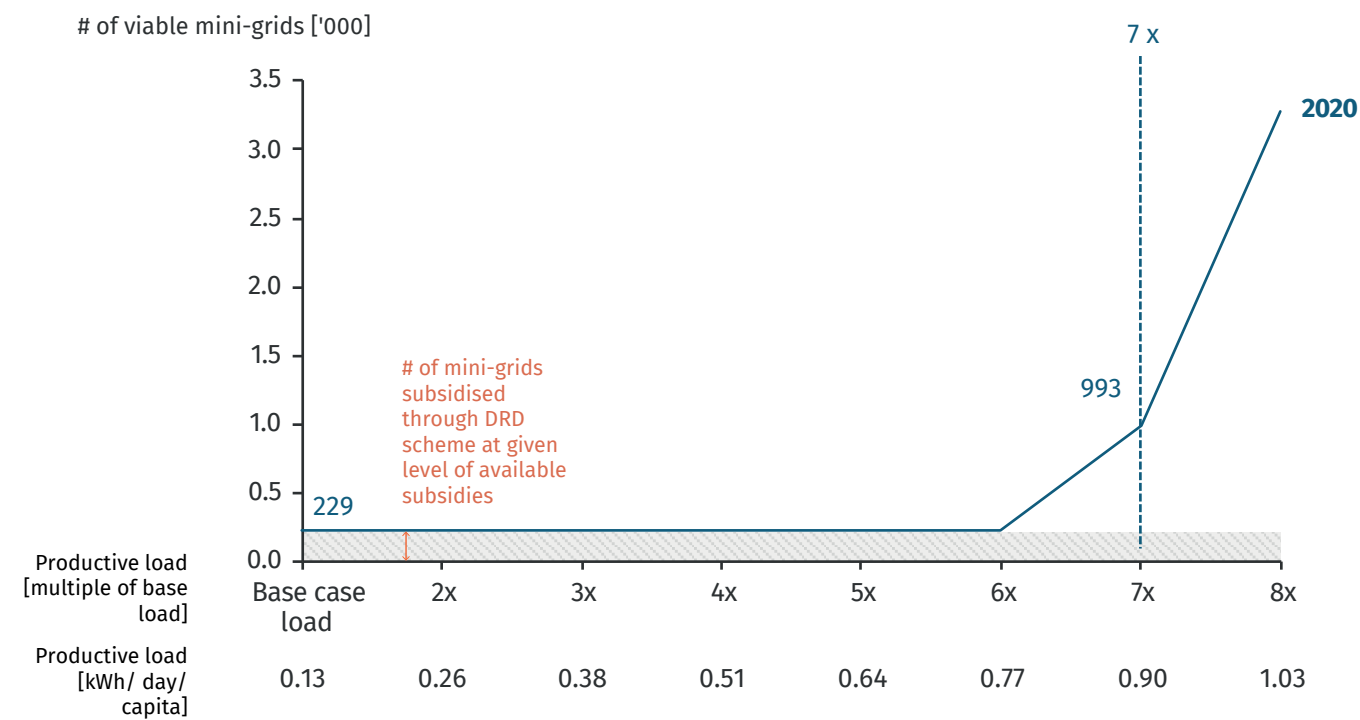
Source: Roland Berger

87 Interviews with multilateral institutions and mini-grid developers conducted by Roland Berger

Demand scenarios

Electricity demand is a key determinant of the viability of mini-grids. As outlined in Section 3.3, increasing total demand improves mini-grid viability, but is less important than increasing the “demand density” which is determined by the average demand per connection. Additional simulations show furthermore that increasing productive demand per connection has the strongest positive impact on mini-grid viability.<sup>88</sup> This is because productive loads, i.e. electricity demand from small businesses and agricultural activities are concentrated during daytime; hence they match solar generation profiles and require proportionately lower additional battery capacity than residential loads.

**Figure 49.** Simulation of number of viable mini-grids for different levels of productive loads per capita in 2020. Assumes current investment subsidy scheme (DRD covers 60% of capital costs, community contribution covers 20% of capital costs and developer covers remaining 20% of capital costs) and 18.6 million USD subsidies budget



Source: Roland Berger

The demand scenarios presented here focus on variation of productive loads as a standalone measure and show that in 2020 only a very large increase in productive loads by at least 7 times (i.e., 600% increase) the base case levels would impact the number of viable mini-grids.

88 Simulations performed by Roland Berger

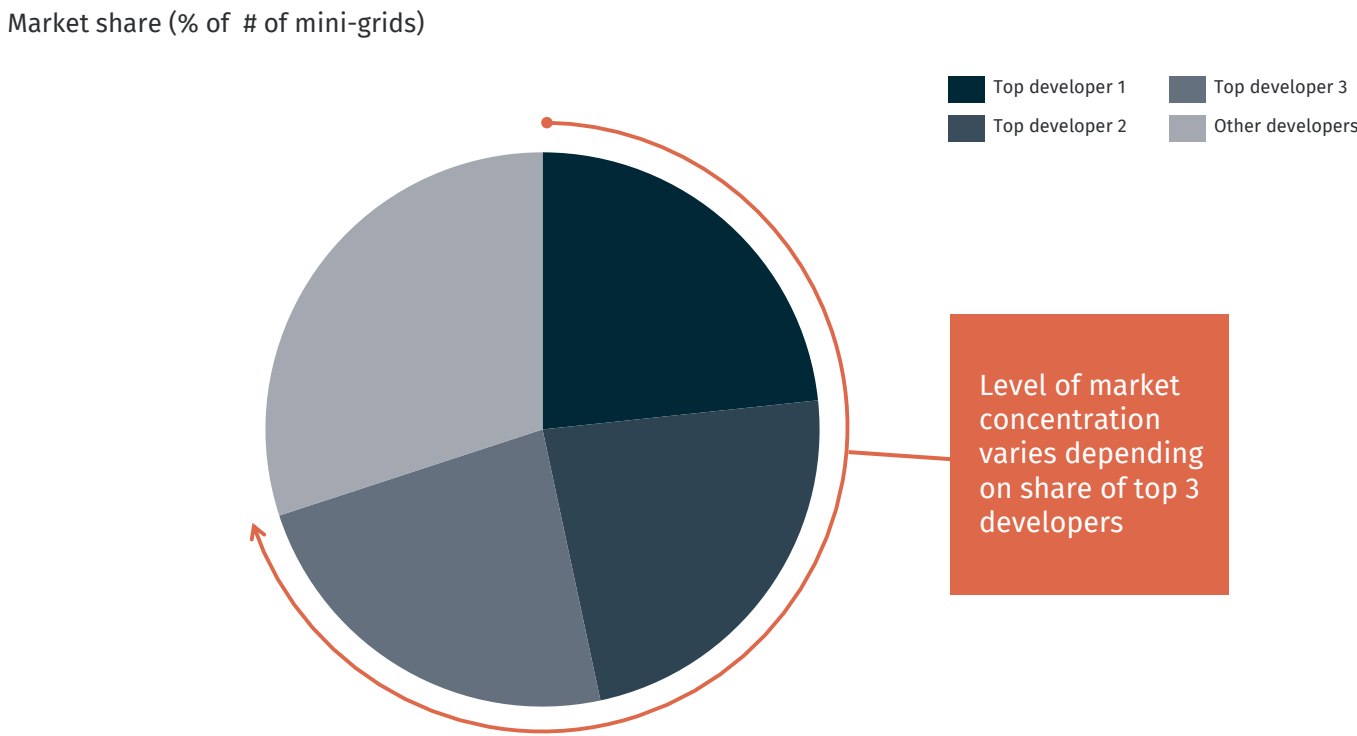
Economies of scale scenarios

Economies of scale can represent an important lever for increasing viability of mini-grids and can be generated in multiple ways. In the scenarios presented here, it is assumed that economies of scale are driven by market concentration allowing private developers with significant market share to develop multiple projects in parallel. To simulate different levels of market concentration it is assumed that three larger players with equal market share would emerge. In Section 5, recommendations on how to generate economies of scale through pooling of key processes in project development and procurement / collaboration of smaller private developers are outlined.

From a financial impact perspective the latter measures are similar to the market concentration scenario presented here.

The level of savings achievable through economies of scale is estimated based on numerous interviews with suppliers.<sup>89</sup>

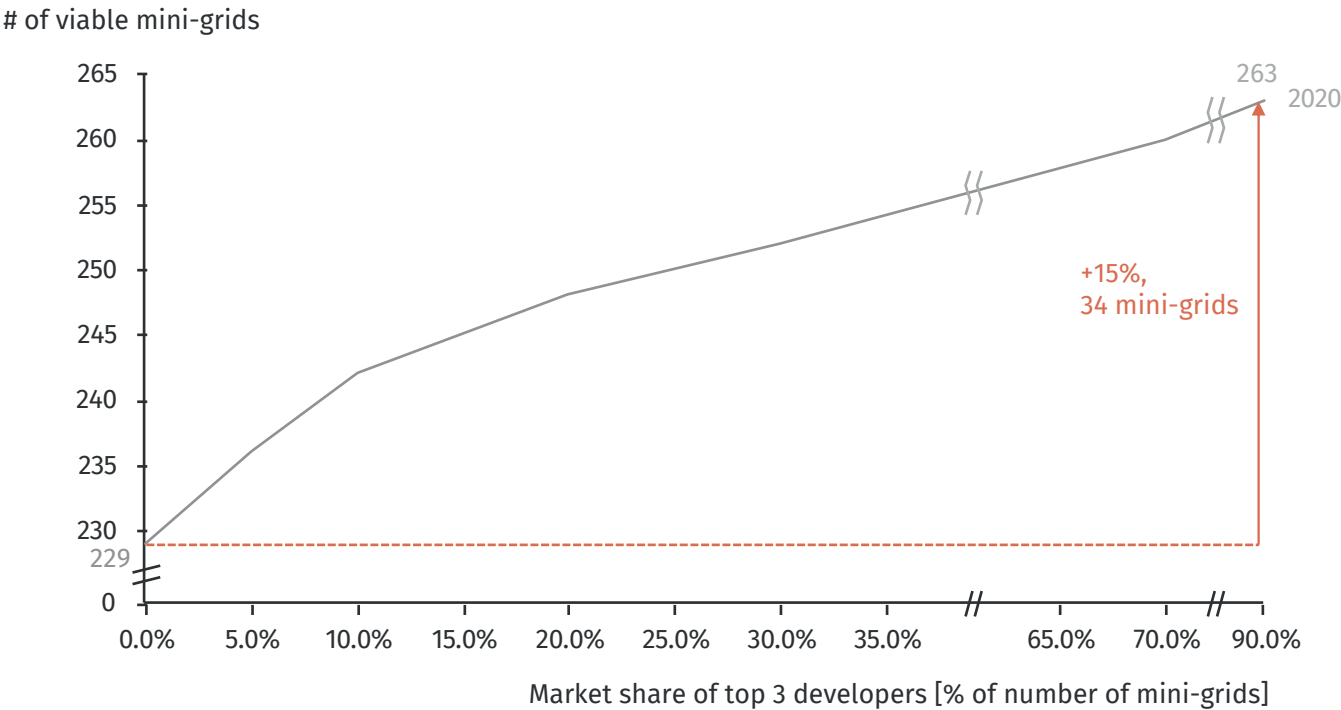
**Figure 50.** Illustrative concept to simulate economies of scale through varying market concentration



Source: Roland Berger

89 Estimated savings of: 20% for solar PV costs, 10% for diesel generator costs, 75% for lithium battery costs, 7% for diesel fuel, 30% for grid distribution costs, 30% for EMS assuming portfolios of at least ~ 500 minigrids per developer.

**Figure 51.** Simulation of number of viable mini-grids in 2020 for different levels of market share of top three players. Assumes top three players have equal market share; assume current investment subsidy scheme (DRD covers 60% of capital costs, community contribution covers 20% of capital costs and developer covers remaining 20% capital costs)



Source: Roland Berger

Simulations show the following results:  
For a subsidy budget of 18.6 million USD, 263 mini-grids can be developed including benefits of economies of scale (+15% compared to case without economies of scale).

4.4.2 Combined scenarios for 2020

The simulations outlined above show that, as of 2020, if measures to impact market drivers are taken individually, only very large variations of the scenario drivers, that are unlikely to be realised, would enable development of viable mini-grids beyond the current investment subsidy scheme. Consequently, to inform actionable recommendations, the combined effect of variations of key scenario drivers should be considered.

Potential market triggered by 5 combined scenarios in 2020

The effect on potential market size of implementing a combination of the following five measures is explored:

- Increasing investment subsidies budget to 100 million USD to ensure sufficient initial market volume to support economies of scale
- Enabling economies of scale by pooling of development processes or through market concentration
- Decreasing Internal Rate of Return (IRR) threshold to 15% through financing support measures and by de-risking mini-grid development
- Increasing productive loads per capita by 35% on average through demand-side measures
- Enabling private developer investment in viable mini-grids in NEP Phase 3 villages through regulatory reform de-risking grid arrival

Simulations show that by 2020 the combined effect of the five measures above would trigger a potential market of 2,253 mini-grids,<sup>90</sup> including 754 mini-grids that would become viable outside of the current investment subsidy scheme (see Figure 52).

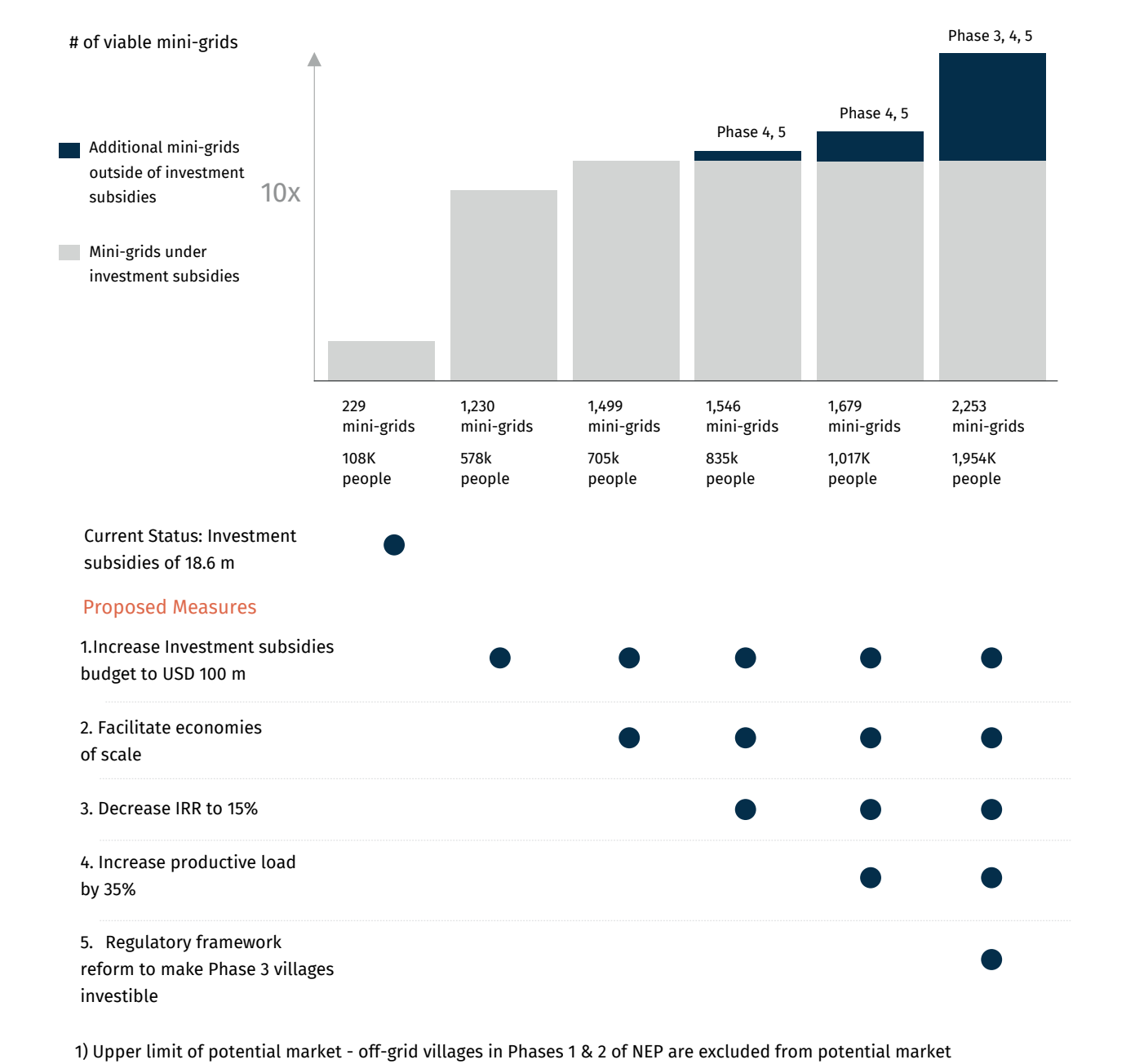
Potential coverage for these mini-grids would amount to 2 million people or 6.4% of the total projected off-grid population in 2020. Total investment that would be required to realise all these mini-grids is estimated at USD 537 million.

It should be emphasised that combined implementation of the five measures is required to trigger a large potential market. In particular, the simulations in Figure 52 show that in order to fully leverage the impact of demand-side and access to finance measures, it is crucial to introduce clear regulations on transition at grid arrival that opens up the potential market to villages under NEP Phase 3.

<sup>90</sup> These 2,253 mini-grids represent the potential market size in 2020, i.e. the number of sites in which minigrids would become viable and investible from a private investor's perspective as of 2020. This can differ from the actual number of mini-grids that will be realised.



**Figure 52.** Simulation of number of viable mini-grids in 2020 with combined actions on investment subsidies budget, economies of scale, financing support, demand-side support and regulatory framework reform to make NEP Phase 3 villages investible. Assumes top three players have equal market share; assumes current investment subsidy scheme (DRD covers 60% of capital costs, community contribution covers 20% of capital costs and developer covers remaining 20% of capital costs)

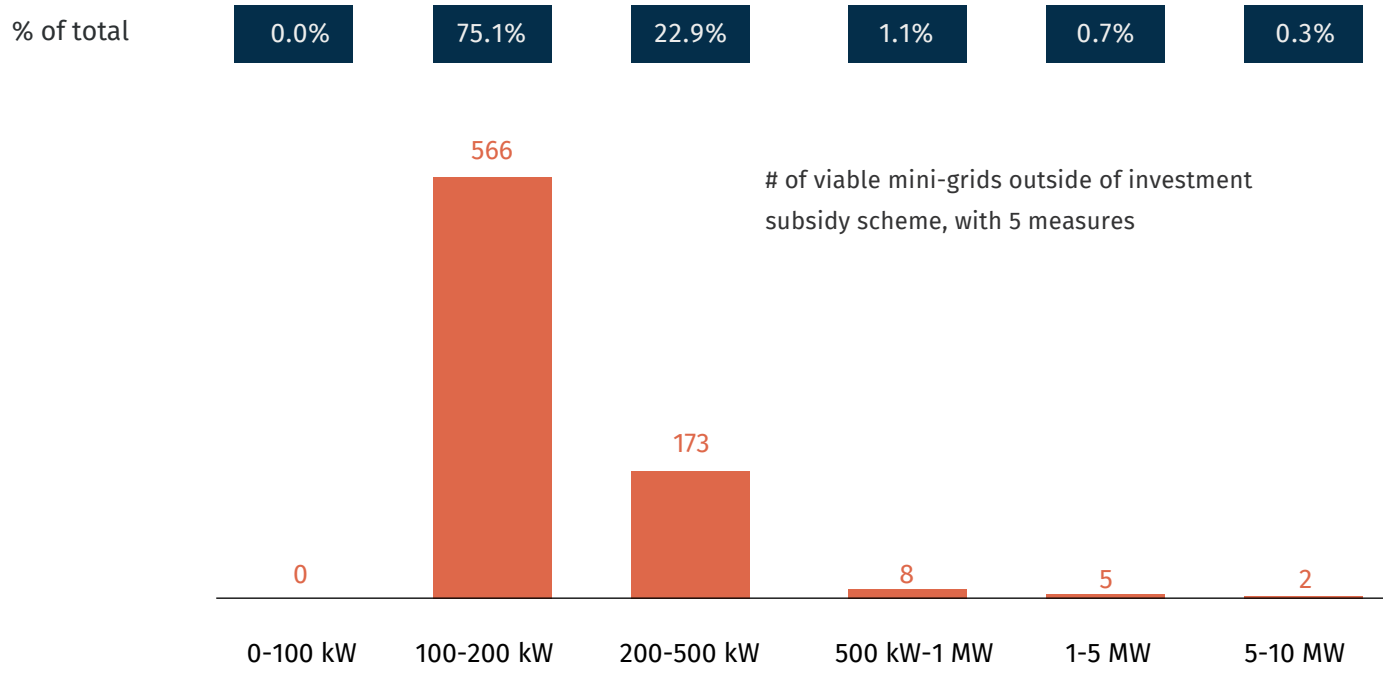


Source: Roland Berger

Distribution of viable mini-grids by capacity

Mini-grids developed without investment subsidies would be viable in Regions and States with high irradiation and high potential for productive loads. The median size of these mini-grids would be 157 kW, and 75% of mini-grids are expected to be between 100 to 200 kW. The median size of mini-grids estimated here is relatively large because viable mini-grids are located in large villages. A large mini-grid capacity is important because it allows a large number of people to benefit from a single mini-grid project. Furthermore, larger mini-grids may be favoured in any potential transition to distribution franchises at the time of grid arrival due to their greater number of connections.

**Figure 53.** Simulation of number of viable mini-grids in 2020 outside of investment subsidy scheme by capacity, after the five measures



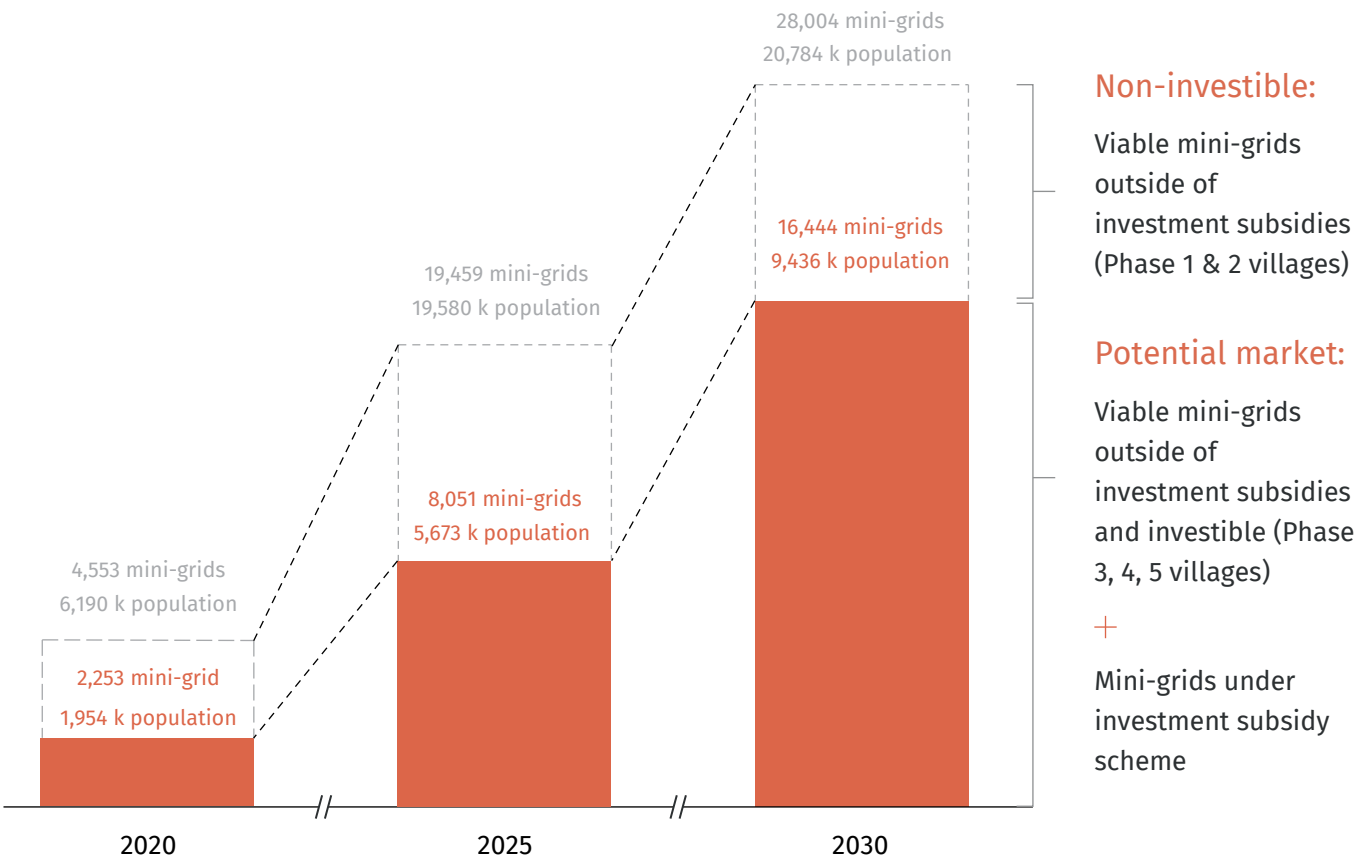
Source: Roland Berger

### 4.5 Potential market forecast to 2030 under combined scenarios

Projections of the potential market size to 2025 and 2030 after implementation of the five measures described in Section 4.4.2 show that these measures can stimulate a vast potential market for mini-grids covering large portions of the off-grid population.

By 2025, the potential market would grow to more than 8,000 mini-grids (from 2,253 mini-grids in 2020), covering 5.6 million people or 21% of the projected off-grid population in 2025.

**Figure 54.** Mini-grid market potential forecast to 2030 in Myanmar with combined actions on investment subsidies budget, economies of scale, financing support, demand-side support and regulatory framework reform



Source: Roland Berger

By 2030, the potential market could be approximately twice as big as is 2025: more than 16,000 mini-grids, covering 9.4 million people corresponding to 41.7% of the projected off-grid population in 2030. Thus, despite progressing grid electrification, thanks to cost reductions / technology improvement in equipment and economies of scale, the potential market for mini-grids is expected to be very large in 2030.

In order to actually implement these very large portfolios of mini-grids, substantial investment would be required, in addition to building resources and capabilities. To realise all potential mini-grid project as of 2025 an estimated 1.8 billion USD would be required. For the projects becoming viable in 2030, 3.6 billion USD would be required.

### 4.6 Implications

Analysis of combined scenarios outlined in Section 4.4 and 4.5 indicates that targeted measures to increase subsidy budget availability, de-risk mini-grids in order to increase the pool of investible mini-grids and decrease IRR hurdle rate, support generation of economies of scale and productive demand, could kick-start viable mini-grids outside of the investment subsidy scheme.

As of 2020 this nascent mini-grid market would be confined to a few areas in favourable locations, but by 2025 and, even more so by 2030, the additional impact of falling equipment costs and increase in per-capita demand would allow nationwide market to develop.

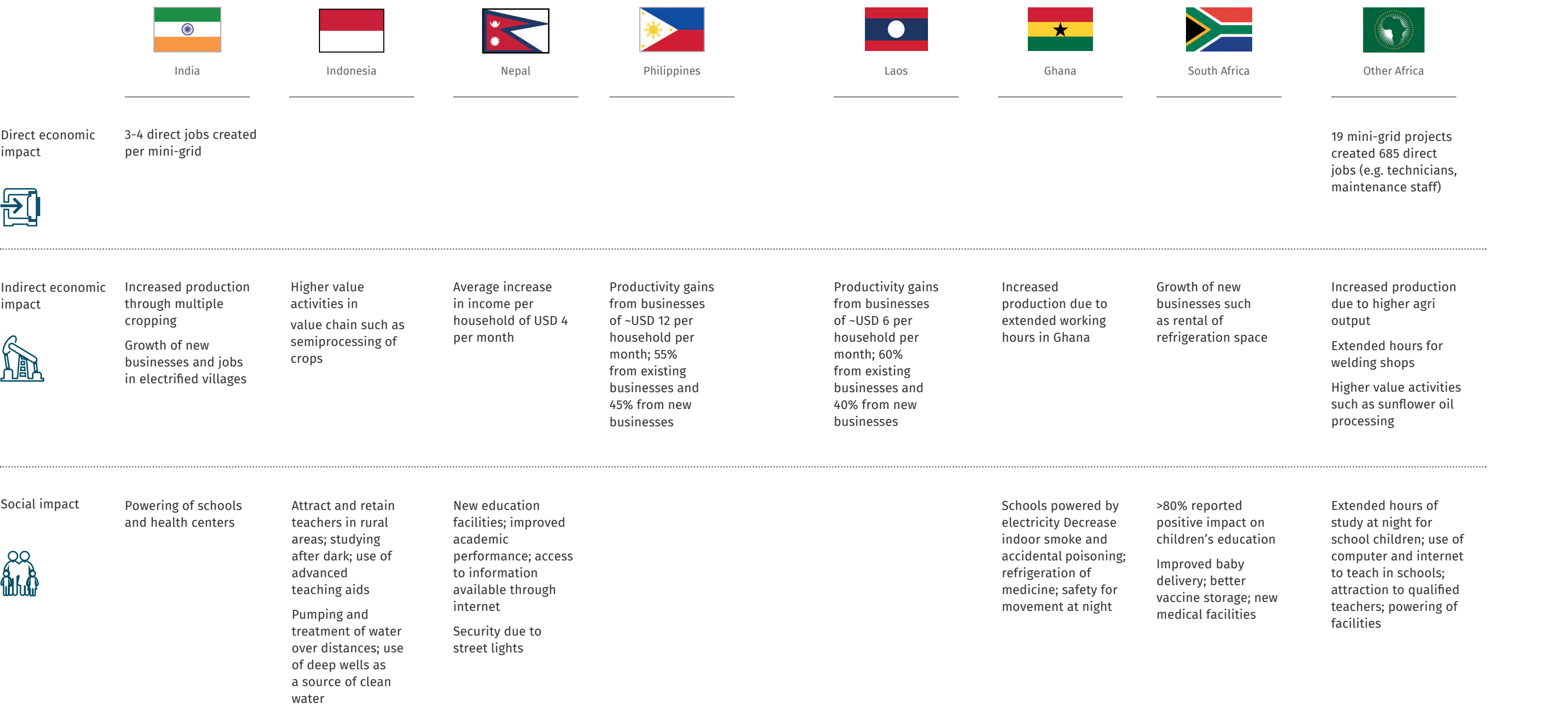
Hence, given supportive policies and measures (see Section 5 for actual recommended action), between now and 2030 large off-grid areas in Myanmar could be electrified through mini-grids developed by private investors while the expansion of the national grid is underway.

### 4.7 Economic impact assessment by scenario

A review of global case studies on the impact of rural electrification indicates that mini-grids can accelerate socio-economic development in Myanmar in three key ways.

Firstly, mini-grid projects have a direct economic impact on Myanmar’s economy through investments into the installation and operation of mini-grids, greater consumer expenditure on electricity produced by mini-grids, and creation of mini-grid related jobs.

**Figure 55.** Selected case studies: socio-economic impact of electrification via mini-grids



**Source:** Desk research; Interviews with market participants; Roland Berger



Secondly, electrification has an indirect impact on the wider economy by accelerating growth. Electricity facilitates the growth of existing and the creation of new businesses, thereby increasing GDP and creating new jobs indirectly.

Thirdly, electrification also creates societal value, particularly in education and healthcare.

4.7.1 Direct economic impact

Mini-grid projects directly impact the economy in terms of GDP growth and job creation. GDP grows because of increased investment into power generation and storage equipment, energy management systems and construction. Another direct impact on GDP is the increase in consumer expenditure in off-grid non-electrified villages, as households and businesses start to consume electricity which was previously unavailable or at higher cost. Jobs are also directly created in addition to GDP growth. For example, in case studies in Africa, residents were offered temporary employment during the construction phase, and permanent jobs were created to operate and maintain the system. Sales and payment collection jobs, many of which employed local women and youth, were also created.<sup>91</sup>




In terms of investment impact, most of the equipment and software for the construction and management of mini-grids may not be developed in Myanmar and thus not contribute significantly to Myanmar’s GDP. Interviews conducted with leading equipment vendors suggest that most of the key equipment such as solar panels, inverters, batteries and diesel generators are imported, with Chinese and Indian imports accounting for approximately 70% of total value.<sup>92</sup>

Therefore, installation and logistics activities (estimated as 13% of the cost of mini-grids excluding EMS costs — see Annex 7) are expected to be the main contributors to GDP growth. For consumer expenditure, villages with no access to electricity prior to mini-grids (approximately 62% of villages not connected to the national grid — see Introduction Section) are expected to dominate incremental consumer expenditure on electricity.

91 Energy and Environment Partnership, “Opportunities and Challenges in the Mini-grid Sector in Africa”, 2018  
92 Interviews with equipment vendors conducted by Roland Berger

In terms of job creation, interviews with market participants indicate that, on average, 4 jobs are expected to be created per mini-grid.<sup>93</sup> These jobs include construction & installation, operation & maintenance, and customer service for the mini-grids, and do not include the number of jobs created by local enterprise due to electrification, which will be explored in the next section.

Figure 56. Direct economic impact of electrification via mini-grids

	Key impact drivers	Explanation	Assumption
Impact on GDP	 Investment expenditure by developers and government into mini-grid projects	<ul style="list-style-type: none"><li>Investment expenditure by developers and government directly contributes to GDP; includes spend on equipment, software and construction &amp; installation</li><li>Most equipment and software expected to be procured outside of the country and not contribute to GDP; only construction &amp; installation to be captured in GDP</li></ul>	~13% of the cost of mini-grids to impact GDP (estimated percentage of cost that is attributed to construction & installation)
	 Consumer expenditure by villagers on electricity produced by mini-grids	<ul style="list-style-type: none"><li>Increase in consumer expenditure on electricity directly contributes to GDP</li><li>Villages with off-grid electricity (e.g. diesel, solar home systems) will not generate incremental expenditure when electrified by mini-grid, as spend on mini-grid electricity assumed to be same as spend on prior systems</li></ul>	~62% of villages (i.e. villages with no access to electricity prior to mini-grids) to generate incremental consumer expenditure and impact GDP; revenue of mini-grids in these villages a proxy for consumer expenditure
Impact on jobs	 Jobs created in order to build and operate the mini-grids	<ul style="list-style-type: none"><li>Construction &amp; installation of mini-grids and infrastructure</li><li>Operation &amp; maintenance of the mini-grid system</li><li>Sales &amp; payment collection/ customer service for electricity produced</li></ul>	~4 direct jobs created per mini-grid based on interviews with market participants





Source: Desk research; Interviews with market participants; Roland Berger

93 Interviews with multilateral institutions and private developers conducted by Roland Berger

4.7.2 Indirect economic impact

In addition to direct economic impact, significant indirect economic impact is expected from mini-grid electrification especially through supply of electricity to local businesses. Case studies show that the electrification of business activities (1) spurs the growth of existing businesses, and (2) facilitates the creation of new businesses.

Figure 57. Indirect economic impact of electrification via mini-grids

Key impact drivers		Description/ case studies (non-exhaustive)
 Growth of existing businesses	 Increased production	<ul style="list-style-type: none"><li>• Higher agricultural output (e.g. multiple cropping in India; improved crop yields in Africa)</li><li>• Longer working hours (e.g. extended working hours in Ghana; extended operating hours for welding shops in Kenya)</li></ul>
	 Higher value goods & activities	<ul style="list-style-type: none"><li>• Sale of higher value goods to customers (e.g. cold drinks and fresh foods in South Africa)</li><li>• Perform higher value activities in the value chain (e.g. processing of sunflower seeds to get sunflower oil in Tanzania; emergence of semi-processing of crops in Indonesia)</li></ul>
 Creation of new businesses		<ul style="list-style-type: none"><li>• New businesses directly related to the use of electricity (e.g. electrician, battery charging stations, and photocopier shops in India; rental of refrigeration space in South Africa)</li><li>• New businesses enabled through the electrification of households and villages (e.g. betel leaf cutting and manufacturing of craftworks in households in India, made possible by time saved and indoor lighting through electricity)</li></ul>

Source: Desk research

Growth of existing businesses — Higher value goods & activities

Existing businesses will grow faster thanks to mini-grids, because of the opportunity to engage in sales of higher value goods and activities. Electricity enables businesses to focus on selling greater volume and variety of high-value goods to customers. In South Africa for instance, grocers and restaurant owners were able to sell more cold drinks and fresh foods due to cost-effective electrical refrigeration.<sup>94</sup> Besides higher-value goods, electricity has also enabled several rural communities to perform higher-value activities in the production value chain. Villagers in Tanzania, through the use of electrical tools, were able to process sunflower seeds to get higher-value sunflower oil instead of merely harvesting sunflower seeds for export.<sup>95</sup> In Indonesia, the emergence of small scale industries for semi-processing of crops was facilitated by electrification, thus enhancing value addition.<sup>96</sup>

Creation of new businesses

Electrification via mini-grids also creates new income generation and entrepreneurial opportunities. For example, in the Sunderbans region of India, 11 out of 40 electrified households in grid connected villages and 9 out of 40 electrified households in solar mini-grid villages started new businesses or jobs after electrification.<sup>97</sup> The availability of stable electric power made it possible for some households to run small businesses such as electrical equipment repair, battery charging stations and photocopier shops. The time saved on household chores and the availability of electrical lighting enabled other households to engage in home businesses such as producing betel leaf and craftworks.

A similar evolution is expected in Myanmar. For example, aquaculture and fish processing in southern Myanmar is currently limited due to a lack of reliable electricity supply. Raw fish is being exported to Thailand, instead of being processed in Myanmar. Mini-grids will create opportunities for new businesses in Myanmar, including fish processing.

<sup>94</sup> Malardalen University, “Sustainability and Development Impacts of Off-grid Electrification in Developing Countries”, 2016

<sup>95</sup> World Resources Institute, “Accelerating Mini-grid Deployment in Sub-Saharan Africa”, 2017

<sup>96</sup> United Nations Development Programme, “Supporting Indonesia’s Renewable Energy Development in Remote and Rural Areas Through Innovative Funding”, 2018

<sup>97</sup> Independent Evaluation Group, “The Welfare Impact of Rural Electrification”, 2008

Impact on GDP

Benchmarking of other developing countries and interviews with market participants in Myanmar were conducted to estimate the incremental impact on GDP from the growth of businesses.

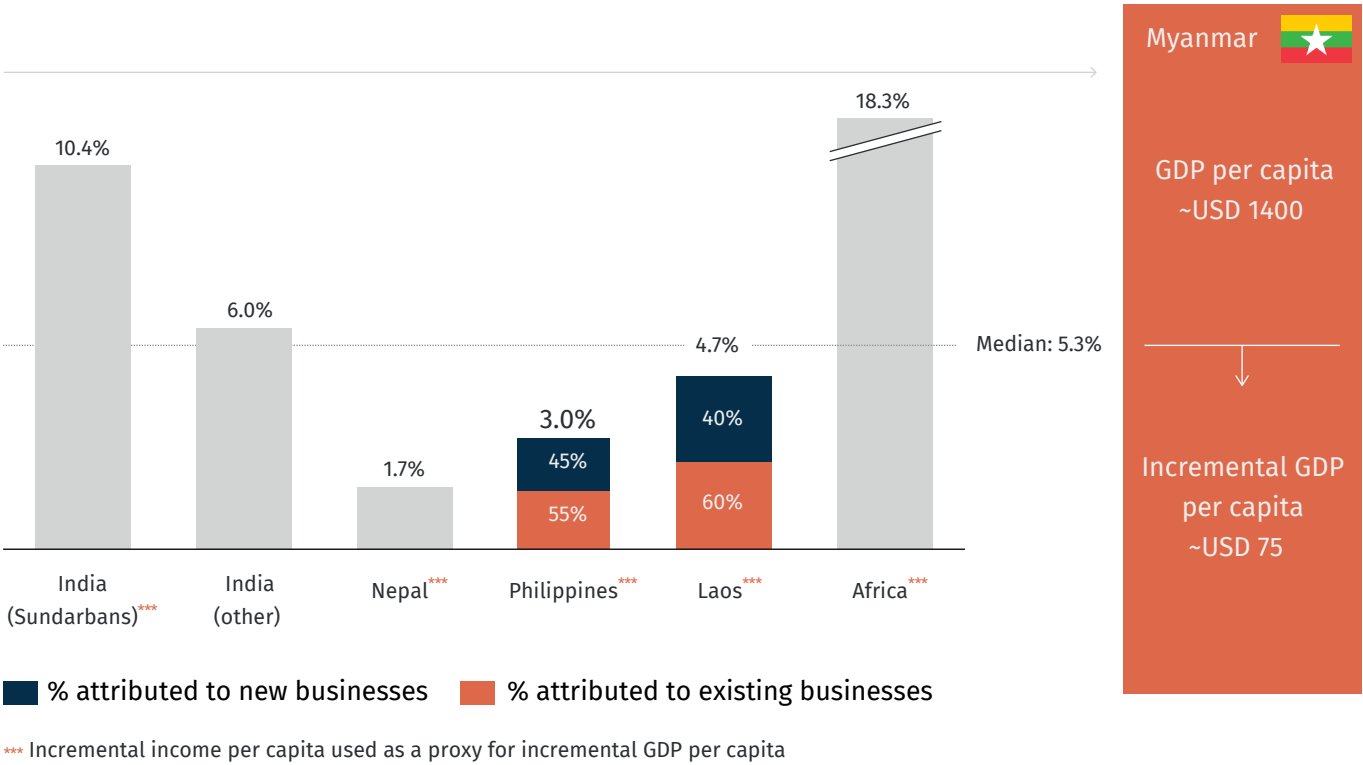
Based on benchmarks, the incremental impact on GDP is estimated to be USD 75 per capita per year. It is also estimated that ~60% of the impact from businesses is due to the growth of existing businesses, with the remaining due to creation of new businesses. This is in line with impact studies conducted in the Philippines and Laos, which suggest 55-60% of productivity gains from businesses are from existing businesses, while the remaining 40-45% are from new businesses.<sup>98</sup> Mini-grid case studies in Africa (e.g. Engie in Tanzania) also confirm that the impact on existing businesses is the main driver of economic benefits.<sup>98</sup>

Studies indicate that the impact of electrification via mini-grids on GDP per capita vary by region and project. For example in Sunderbans region of India, the average monthly income of electrified households in grid connected villages increased by ~68% (~34 USD) whereas the average monthly income of electrified households in solar mini-grid villages increased by ~98% (~53 USD).<sup>99</sup> Another impact study conducted in rural India by Mlinda found that GDP per capita increased by 10.6% in eight villages with mini-grids, versus 4.6% in group of similar villages without them.<sup>98</sup> In Africa, electricity increased household per capita income by 39%,<sup>100</sup> while in Nepal the average increase in income per household was measured to be ~4 USD per month.<sup>101</sup> In the Philippines, rural electrification benefits per household per month were estimated at 6.30 USD for existing businesses and 5.25 USD for new businesses.<sup>102</sup> In Laos, the same study estimated benefits per household per month to be 3.40 USD for existing businesses and 2.35 USD for new businesses.<sup>103</sup>

Interviews with market participants indicate that most of the economic benefits observed in other developing countries (i.e. increased production, higher-value goods & activities, growth of new businesses) will also be realised in rural villages in Myanmar,<sup>103</sup> thus suggesting that the quantitative economic impact would be similar.

98 The Economist, “Mini-grids could be a boon to poor people in Africa and Asia”, 2018  
99 The International Journal of Environmental Sustainability, “Impacts of Electrification with Renewable Energies on Local Economies: The Case of India’s Rural Areas”, 2015  
100 The Rockefeller Foundation, “Access to Electricity is Critical to Africa’s Growth”, 2015  
101 International Journal of Precision Engineering and Manufacturing, “Socio-economic impact of renewable energy-based power system in mountainous villages of Nepal”, 2017  
102 Independent Evaluation Group, “The Welfare Impact of Rural Electrification”, 2008  
103 Interviews with multilateral institutions and private developers conducted by Roland Berger

Figure 58. Incremental GDP per capita due to electrification



Source: Desk research; Roland Berger

Impact on jobs

New jobs from businesses (either expansion of existing businesses or growth of new businesses) are expected to be created for 15% of households in electrified villages. This is in line with studies in Sunderbans region of India that indicate 27.5% electrified households in grid connected villages, 22.5% of electrified households in mini-grid villages, and 10% of non-electrified households (in both grid connected and mini-grid villages), started new businesses or jobs.<sup>104</sup>

104 The International Journal of Environmental Sustainability, “Impacts of Electrification with Renewable Energies on Local Economies: The Case of India’s Rural Areas”, 2015



4.7.3 Social impact

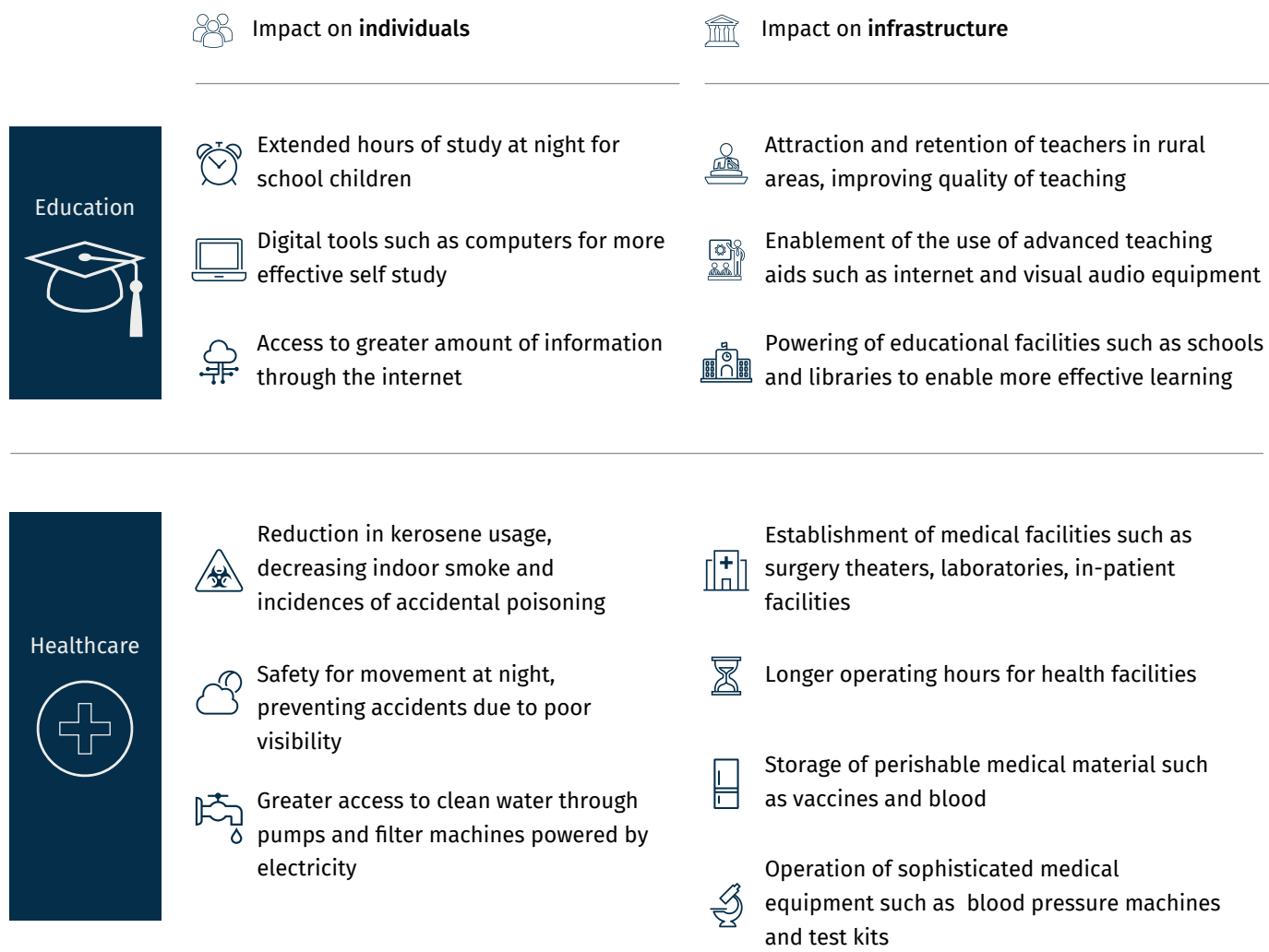
In addition to the economic impact, electrification will also create societal value, particularly in education and healthcare.

Electrification can directly improve the education of individuals. Electrical lighting enables extended hours of study at night for school children, while electronics such as computers enables more effective self-study as well as

access to greater amount of information through the internet.<sup>105</sup> Furthermore, electrification may also indirectly improve an individual’s education by attracting quality teachers to rural areas, enabling the use of advanced teaching aids (e.g. visual audio equipment) and powering education facilities.<sup>105</sup>

In terms of healthcare, the reduction in kerosene usage due to electrical lighting can decrease indoor smoke and incidences of poisoning via accidental ingestion.<sup>105</sup> Better visibility from electrical street lights can also improve safety at night.<sup>105</sup> Electrically-powered pumps and filter machines also provide villagers with greater access to clean water, reducing health problems associated with drinking non-potable water.<sup>106</sup> Besides its direct impact on individuals, electricity also enables the establishment of advanced medical facilities (e.g. surgery theatres, laboratories), and longer operating hours. Medical practitioners can also store medical material such as vaccines and blood, as well as operate sophisticated equipment such as blood pressure machines, to improve health-related outcomes for patients living in electrified villages.

Figure 59. Selected examples of socia impact of electrification



Source: Desk research

4.7.4 Quantitative impact on GDP and jobs

The quantitative impact of mini-grid electrification on GDP and jobs is simulated in two mini-grid market scenarios:

- The base case scenario assumes that the current investment subsidy and community contribution system is maintained, ensuring coverage of 80% of the initial investment required to develop mini-grids (60% through investment subsidies and 20% through community contributions). A 18.6 million USD budget is assumed for the investment subsidy scheme which is the existing subsidy budget (7 m USD from the World Bank loan and matching budget from DRD’s own budget as outlined in Section 2.8)

<sup>105</sup> University of Jyvaskyla, “The Potential Socio-economic and Environmental Impacts of Solar PV Mini-grid Deployment on Local Communities: A Case Study of Rural Island Communities on the Volta Lake, Ghana”, 2016

<sup>106</sup> United Nations Development Programme, “Supporting Indonesia’s Renewable Energy Development in Remote and Rural Areas Through Innovative Funding”, 2018

- The scenario with measures includes the following measures as outlined in Section 4.4:
  - » Increasing investment subsidies budget to 100 million USD to ensure sufficient initial market volume
  - » Allowing 70% market share for the top three players to generate economies of scale leveraging market volume, or pooling of activities of smaller private developers to the same effect
  - » Decreasing IRR threshold to 15% through financing support measures;
  - » Increasing productive loads per capita by 35% on average through demand-side measures
  - » Introducing regulatory measures to de-risk grid arrival thereby extending investible mini-grids to villages under Phase 3 of NEP

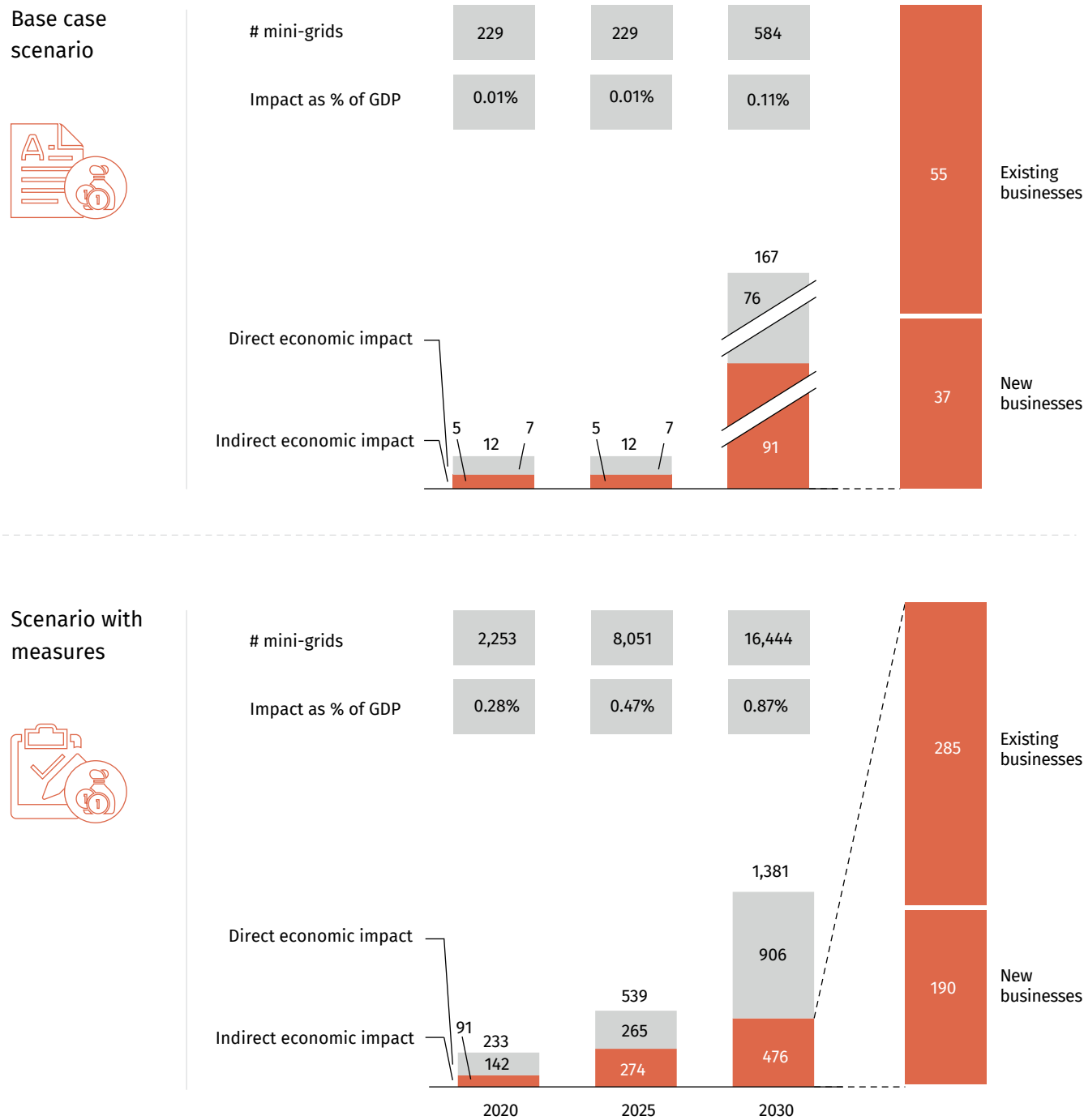
For 2020, implementation of all the viable and investible mini-grid projects would result in a GDP increase of 12 million USD in the base case scenario (229 mini-grids), and 233 million USD in the scenario with measures (2,253 mini-grids), respectively 0.01% and 0.28% of the overall GDP. For 2030, implementation of all the viable and investible mini-grid projects in the scenario with measures (more than 16,000 mini-grids) could generate USD 1.38 billion USD or almost 0.87% impact on GDP.

For 2020, potential impact on jobs would be ~3,100 in the base case scenario, and ~48,300 in the scenario with measures. For 2030 the scenario with measures could potentially have a substantial employment impact with more than 270,000 additional jobs created.

This analysis indicates that much of the economic benefits of mini-grid projects would be derived indirectly from the impact of electrification on businesses. In particular, existing businesses would be the main driver of economic growth due to electrification.

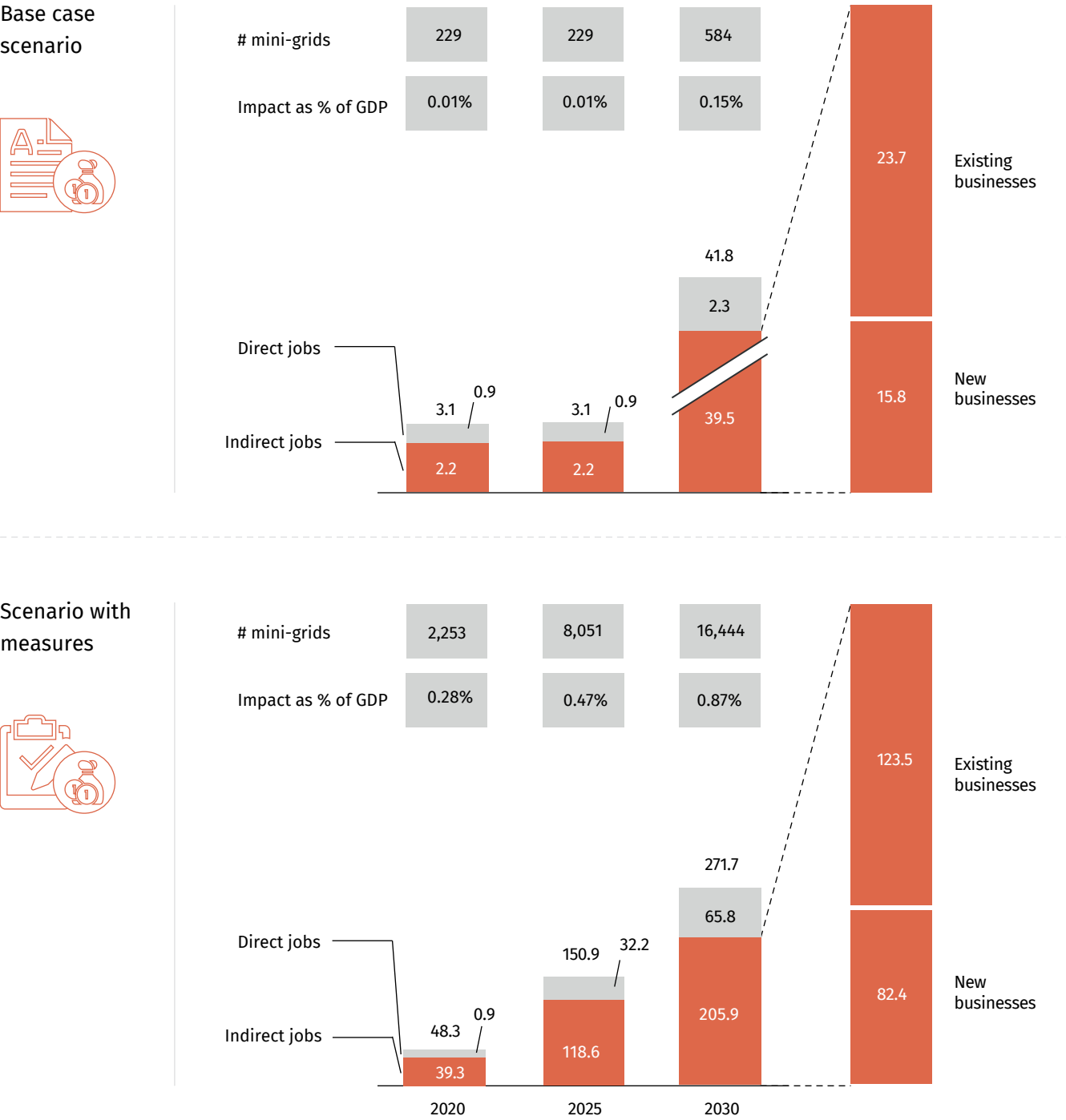
The significance of businesses to the economy reinforces the importance of productive loads. Productive loads are not only important in ensuring the viability of mini-grids by increasing IRR and decreasing LCOE, they are also important in contributing to the growth of GDP and creation of jobs in the economy. In contrast, while the social impact from residential loads should not be understated, it is not as easy to measure. Thus, emphasis should be placed on ensuring that electricity from mini-grids can be used for commercial activities during project implementation, in order to realise maximum economic benefits from electrification of rural villages.

Figure 60. Estimated increase in Myanmar’s GDP from mini-grid electrification [USD m]



Source: Roland Berger

Figure 61. Estimated employment impact from mini-grid electrification [‘000 jobs]



Source: Roland Berger

4.7.5 Environmental impact

Solar mini-grids may have a positive impact on the environment by reducing (1) diesel fuel and kerosene usage and (2) dependency on firewood.

Rural electrification via solar mini-grids may yield long-term benefits in terms of pollution abatement and climate change mitigation, due to their relatively low environmental impact. Current fossil fuel energy sources used in rural areas such as diesel fuel and kerosene contribute to climate change by emitting not only greenhouse gases, but also pollutants such as black carbon. The environmental impact is significant, as 7% to 9% of fuel from kerosene lamps converts to almost pure black carbon.<sup>107</sup>

In addition, solar mini-grids can have positive impact by reducing dependency on biofuels. Many rural communities without access to appropriate energy sources depend on biofuels (such as firewood) for heating, cooking and lighting, thus contributing to deforestation and degradation of the environment. In Ghana, the dependency on biofuels between 2000 and 2008 was estimated at 72%.<sup>108</sup> Increase in solar PV electricity and lighting systems in the country allowed reduction of biomass dependency to 64%.<sup>108</sup> Moreover, utilising renewable energy sources for mini-grids will help to support carbon financing and actively contribute to reduced greenhouse gases (GHG) on top of achieving 100% electrification target.

Although solar mini-grids are recognised for their light ecological footprint, they also carry risks that could negatively impact the environment. One major potential source of adverse environmental impact is inappropriate battery disposal. For instance in Nepal, used batteries were disposed indiscriminately on the ground, resulting in damages.<sup>109</sup> Therefore, measures should be taken in the operation and maintenance of solar mini-grids to ensure the net impact on the environment is positive and that they remain an ecologically viable alternative to large-scale generation options to drive energy access in Myanmar.

<sup>107</sup> Environmental Science & Technology, “Household light makes global heat: High black carbon emissions from kerosene wick lamps”, 2012  
<sup>108</sup> University of Jyväskylä, “The Potential Socio-economic and Environmental Impacts of Solar PV Mini-grid Deployment on Local Communities: A Case Study of Rural Island Communities on the Volta Lake, Ghana”, 2016  
<sup>109</sup> University of Montana, “Socio-cultural dimensions of cluster vs. single home photovoltaic solar energy systems in Rural Nepal”, 2010



# 5.0

## Key Recommendations

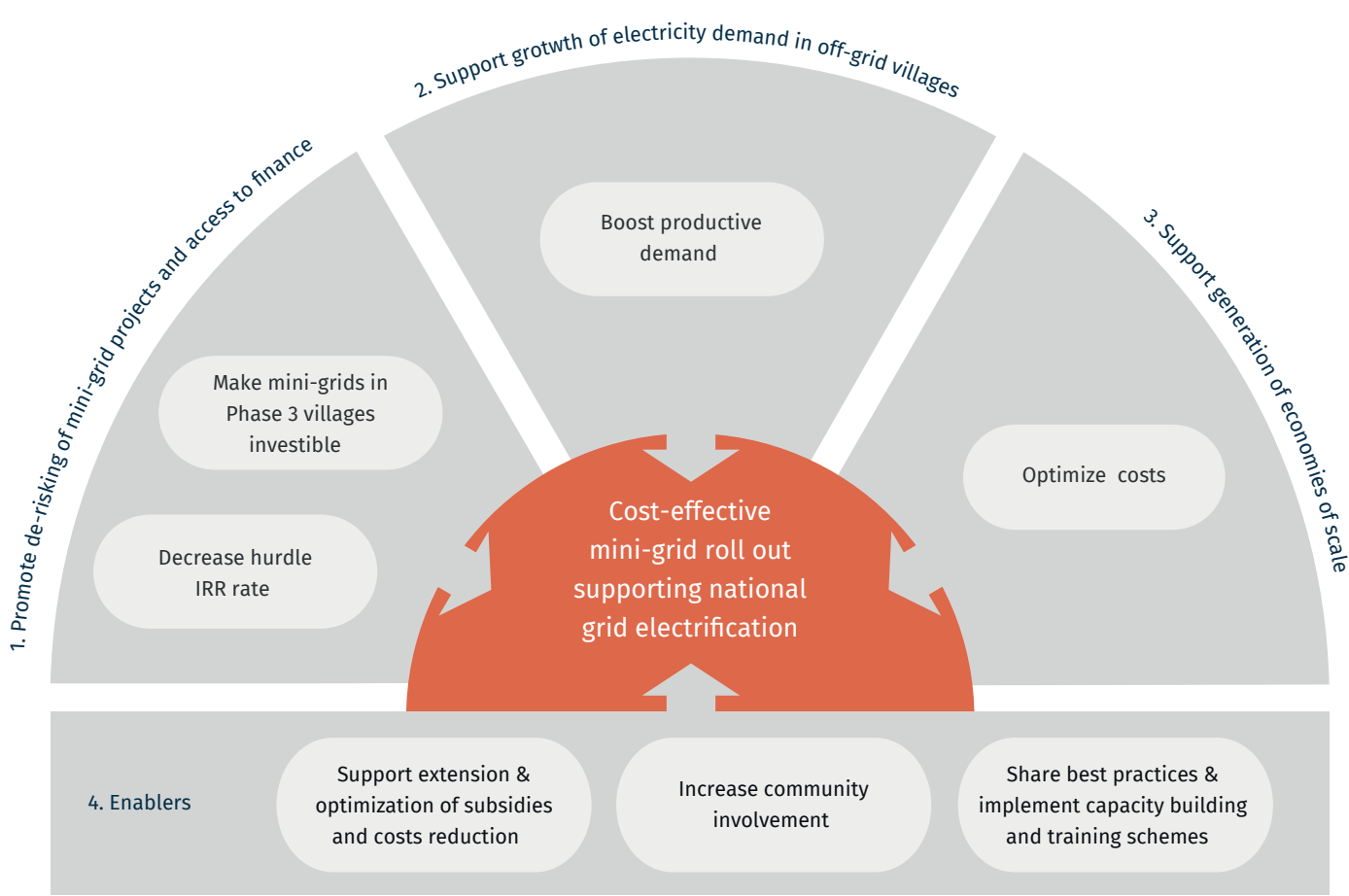
Based on the findings of the scenario analysis, key recommendations are developed to achieve a cost-effective roll-out of mini-grids.

The proposed recommendations are structured along a strategic framework supported by three key pillars and enabling initiatives:

- **Pillar 1:** Promote de-risking of mini-grid projects and access to finance; the goal of this pillar is to put in place comprehensive initiatives to maximize the number of investible mini-grids, including villages in Phase 3 of NEP, by de-risking grid arrival and to decrease the hurdle IRR rate required to develop mini-grids
- **Pillar 2:** Support growth of electricity demand in off-grid villages; the goal of this pillar is to boost demand to increase viability of mini-grids — following results of scenario analysis and of economic impact assessment, the focus should be on productive demand
- **Pillar 3:** Support generation of economies of scale; the goal of this pillar is to enable the development of large mini-grid pipelines of projects to optimise overall costs through economies of scale

**Enabling initiatives** - these include (1) extension of subsidies scheme in order to kick-start economies of scale and support to reduce equipment costs, (2) support to increase involvement of communities to maximise socio-economic impact and (3) development and sharing of best practices to enable continuous improvement and education and training schemes.

Figure 62. Proposed strategic framework



Source: Roland Berger

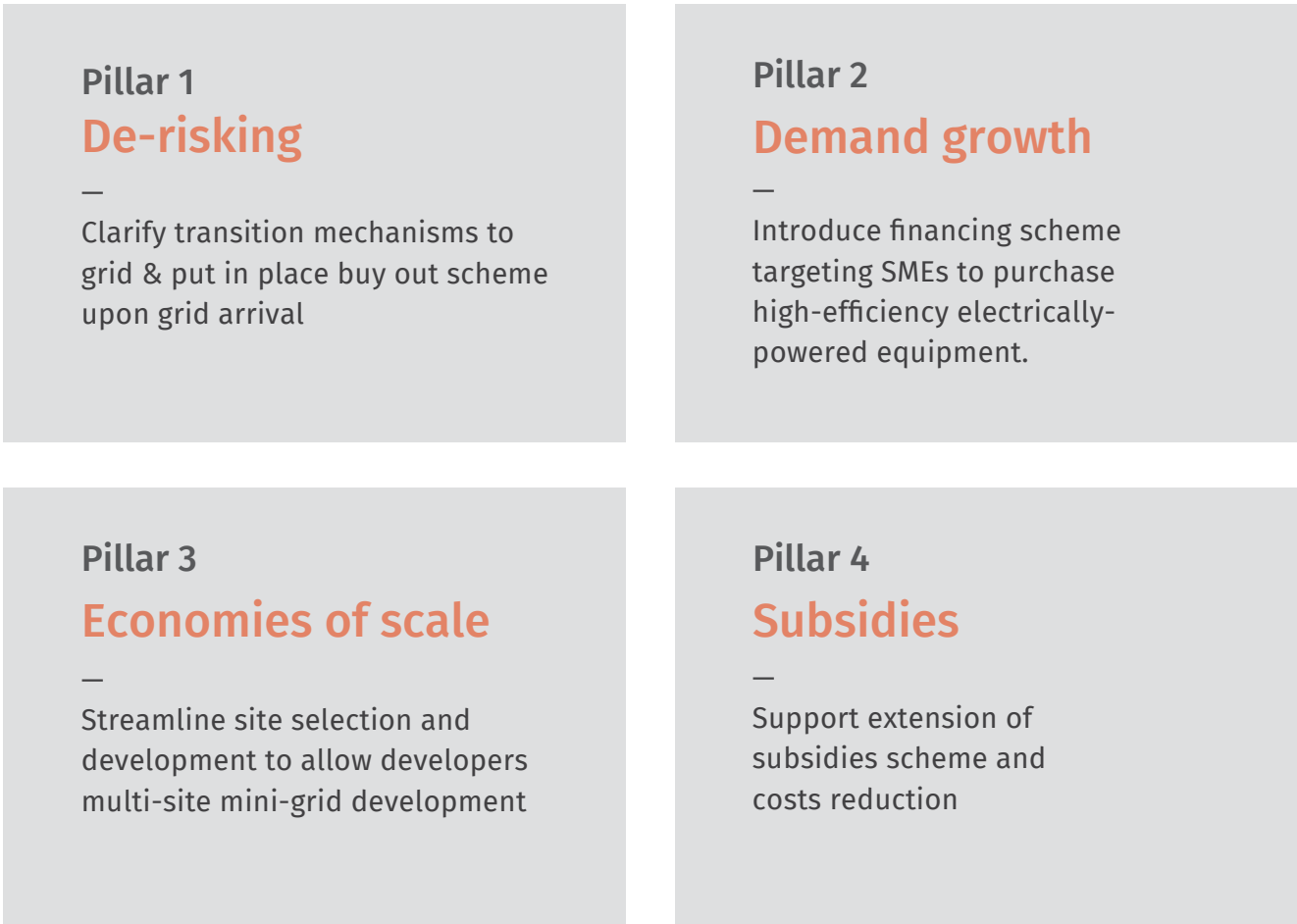
We recommend prioritising measures covering the three key pillars and the enablers as follows:

- **De-risking:** take action to mitigate the most important uncertainty, namely the impact of grid arrival on mini-grid projects. To do so, introduce a clear mechanism defining transition of the mini-grid from private developers to distribution system operators or independent power producers upon grid arrival. In addition, define a buy-out scheme or compensation mechanism whereby the private developer could optionally sell the mini-grid assets to the grid operator at the time of grid arrival
- **Support growth of demand,** prioritising productive loads. To do so, set up financing schemes targeting SMEs to help them purchase high-efficiency electrically-powered equipment

- **Enable economies of scale.** To do so, streamline site selection and development to allow private developers multi-site mini-grid development This could involve the government and/or other organisations selecting and conducting pre-development of sites and then handing over sites to private developers, thereby enabling private developers to build multiple mini-grids in parallel
- **Support extension of subsidy scheme.** In the short term this may involve allocating greater budgets to mini-grids as well as defining extension of the subsidies beyond 2021

In the following Sections (5.1 to 5.4), priority measures are further detailed as well as complemented with additional recommended action.

**Figure 63.** Recommended priority measures  
Details and additional recommendations are outlined in Sections 5.1 to 5.4



Source: Roland Berger

## 5.1 Pillar 1: Promote de-risking of mini-grid projects and access to finance

As outlined in the previous sections of this study, currently, only villages in Phase 4 &5 of NEP are considered investible by mini-grid developers, which considerably limits the pool of potential mini-grid sites. In addition, the hurdle IRR rates for private developers are high — around 20%. Such high IRR hurdle rates hinder the development of projects that are not subsidised through the DRD scheme. Three main categories of issues drive limit the pool of investible villages and drive high IRR hurdle rates:

- High perception of risks surrounding mini-grid projects, particularly regarding risks and impact of grid arrival in the absence of a clear regulatory framework and transition mechanism. In addition to uncertainty over schedule of the NEP, investors fear that lack of coordination between Union and State/Region Government may result in unplanned electrification initiatives at the State/Region level.<sup>110</sup>
- Uncertainty over actual demand in off-grid villages. Early evidence from mini-grid projects backed by investment subsidies indicate that actual demand is often lower than expected, implying high perceived risk on future cash flows.
- Difficulties in accessing debt finance with sustainable interest rates and conditions for private developers (mostly local small companies), driving high average cost of capital and hence high IRR hurdle rates.

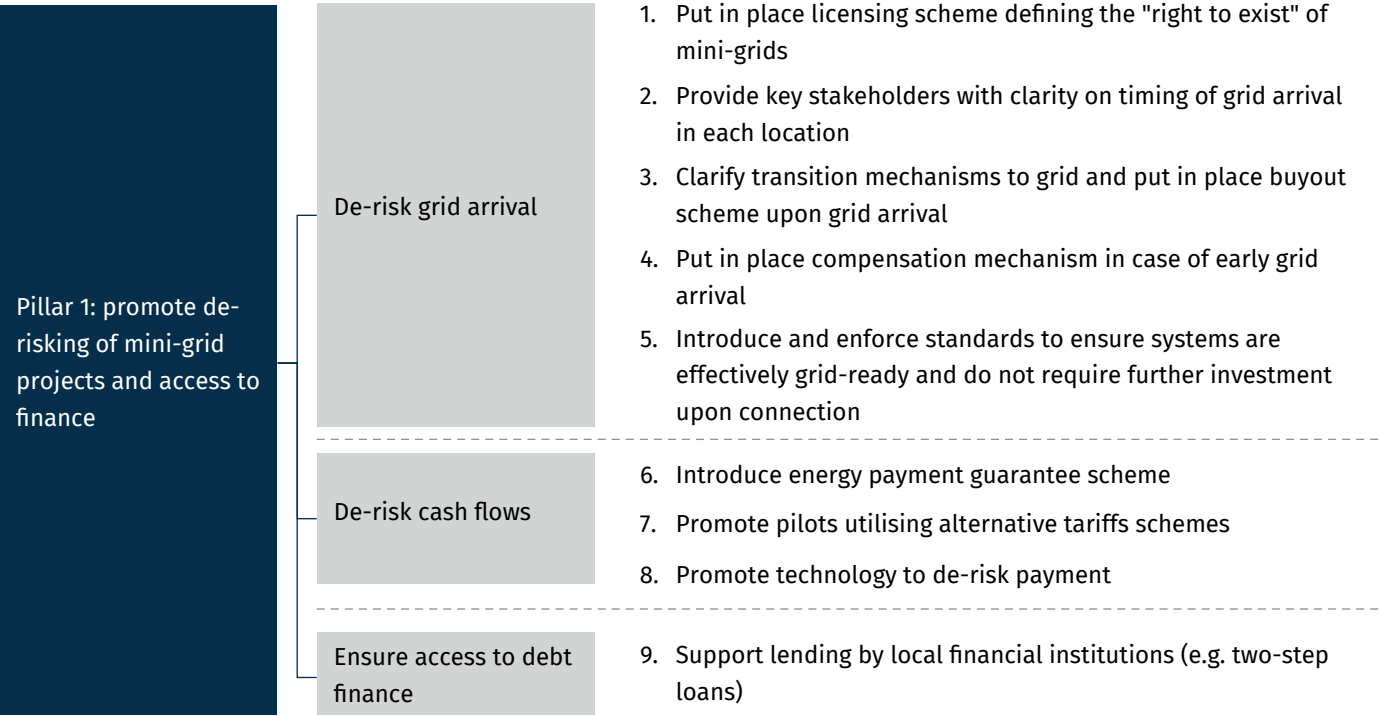
9 initiatives are identified to tackle these 3 categories of issues:

- **Initiatives to reduce risk perception of private developers, investors and debt finance providers on timing of national grid arrival and subsequent transition options**
  - » **Put in place licensing scheme defining the “right to exist” of mini-grids.**<sup>111</sup> Currently, mini-grids’ legal status and rights are unclear as they are not licenced under any of the existing categories of power system actors under the Electricity Law enacted on the 27th of October 2014. Introduction of a system defining mini-grids legal status and rights is a pre-requisite for de-risking grid arrival. This has been proposed by DRD and is currently under discussion (see also Section 2.6)

<sup>110</sup> Interview conducted by Roland Berger with multilateral institution

<sup>111</sup> Interview conducted by Roland Berger with GIZ

Figure 64. Initiatives identified for Pillar 1



Source: Roland Berger

» **Provide key stakeholders with (more) clarity on timing of grid arrival in each off-grid location.** The Government of Myanmar is currently updating the National Electrification Planning with new geospatial information and a new roadmap for extension of the grid infrastructure is expected to be completed by 2020. It will be crucial that this information is available to key stakeholders including private developers, investors and financial institutions

» **Clarify transition mechanisms to grid and put in place well-defined buyout scheme upon grid arrival.** Two different transition schemes to distribution system franchisee and to independent power producer can be recommended based on global case studies. In addition, an “exit mechanism” whereby the mini-grid private developer would sell the assets upon grid arrival should be provided

- ♦ Transition of mini-grid operator to distribution system franchisee. This scheme proved successful in Cambodia (See Annex 3). Based on the Cambodian case study, regulation of distribution franchises should include regulated tariffs that ensure appropriate return

on investment in the long term; in this way, former mini-grid private developers that become franchisees are given long term business prospects beyond grid arrival and are incentivised to invest in extension of distribution grids thereby supporting overall electrification through private investment. As outlined in Section 2.6, independent distribution franchisees known as Distribution Franchises already exist in Myanmar, which could facilitate the transition of mini-grids to distribution system franchisees

- ♦ Transition of mini-grid developer to independent power producer leveraging mini-grid generation assets to sell power to the grid. This scheme proved difficult to implement in Sri Lanka and Indonesia as mini-grid generation infrastructure was not grid-ready.<sup>112</sup> However, if grid readiness standards are introduced and enforced, mini-grid generation assets can be readily integrated into the grid and can contribute to growing overall installed capacity to supply off-grid areas.<sup>113</sup> The case of Thailand, where Small and Very Small Power Producers (<10 MW installed capacity) contributed to almost 70% of installed capacity growth in the past 10 years, shows that small and distributed generation can be important in increasing installed capacity (See Annex 4)
- ♦ Exit mechanism. In case the mini-grid developer chooses not to transition to a distribution franchisee or independent power producer status, a mechanism for the national grid operator to buy out the mini-grid assets should be put in place. The buyout scheme may be inspired by the typical provisions included in IPP schemes worldwide. In these schemes, upon handover of assets, the national utility settles any outstanding debt borne by the IPP to the financing banks and pays the IPP the residual value of the assets<sup>114</sup>
- ♦ With reference to the on grid-transition, it should be noted that global case studies (e.g. Indonesia) for subsidised mini-grids that were handed over to local communities show that the transition to grid-connected franchises is often unsuccessful and mini-grids end up being abandoned. In case private ownership is (at least partly) maintained and future profitability supported as in the case of Cambodia, mini-grids may successfully transition to grid connected distribution franchises or generation entities and further grow through private investment<sup>112</sup> thereby supporting electrification in the long term

112 World Bank, “Mini-grids at the arrival of the main grid — Lessons learned from Cambodia, Sri Lanka and Indonesia”, 2018

113 Interviews with equipment manufacturers conducted by Roland Berger

114 Interview with conducted by Roland Berger



- » **Put in place compensation mechanism in case of early grid arrival.** Alternative to the transition and buyout schemes proposed above, and/or in the interim, a mechanism to compensate mini-grid private developers in case of grid arrival should be put in place. This could be funded in two ways:
  - ♦ Create a fund to compensate the developer through government budget and/or donors contributions. The key point of this system is that funds are disbursed only in case of grid arrival so it may be a more effective way of utilising government/donor budgets than direct subsidisation of mini-grid projects.<sup>115</sup>
  - ♦ Create a fund to compensate developers financed through a fixed contribution by private developers. According to interviews, this scheme has been proposed in one of Myanmar’s States/Regions.<sup>116</sup>
- » **Introduce and enforce stricter standards** to ensure systems are effectively grid-ready and do not require further investment upon connection. Even if measures are in place to ensure smooth transition to the national grid, investors are still concerned that mini-grids may not be grid-ready.<sup>117</sup> Interviews with overseas equipment manufacturers highlighted the same concerns for existing systems and systems under construction as grid-readiness may not be effectively enforced. MOEE<sup>118</sup> is currently working on new standards to be introduced: <sup>119</sup>
  - ♦ Introduce strict “grid-readiness standards” covering not only distribution infrastructure, but also generation assets
  - ♦ To ensure enforcement, make renewal of license dependent upon meeting technical standards (See best practice from Cambodian case study outlined in Annex 3)
- **Initiatives to reduce risk perception of private developers, investors and financial institutions on future mini-grid cash flows**
  - » **Introduce energy payment guarantee scheme whereby external funding is provided to cover potential shortfall in revenues from mini-grid projects.** The scheme can be funded through government/donor subsidies budgets and also complemented by a sharing scheme in case of higher than expected revenues. Note that funds are disbursed only in case of suboptimal revenues, so it may be a more effective way

<sup>115</sup> Interview with investor conducted by Roland Berger  
<sup>116</sup> Interview with private developer conducted by Roland Berger  
<sup>117</sup> Interview with investors and equipment manufacturers conducted by Roland Berger  
<sup>118</sup> Ministry of Electricity and Energy  
<sup>119</sup> Interview with multilateral institutions conducted by Roland Berger

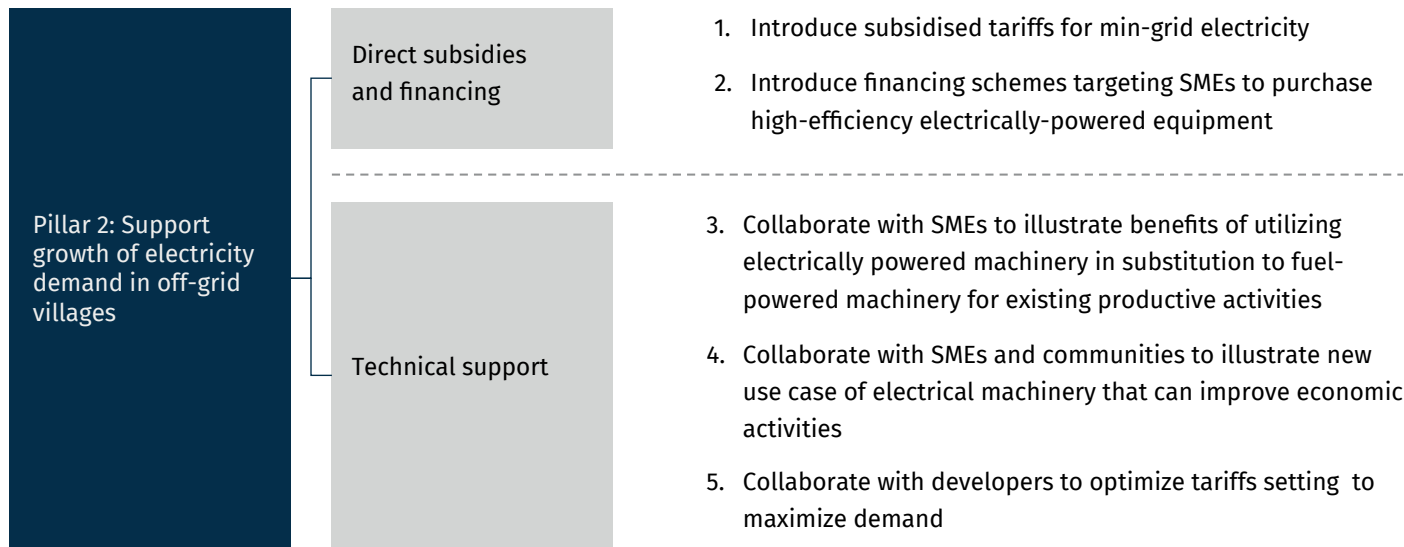
- of utilising government/donor budgets than direct subsidisation of mini-grid projects<sup>120</sup>
- » **Promote pilots utilising alternative tariffs schemes.** Some private developers partly de-risk cash flows by utilising fixed monthly tariffs irrespective of consumption levels<sup>121</sup>
  - » **Promote technologies to de-risk payment.** Currently, private developers utilise pre-paid tariffs to simplify and de-risk billing. This could be further enhanced by smart metering technologies that could also enable tariff optimisation (e.g. time-of-use tariffs). Smart metering systems could be introduced individually by private developers or, a third party could manage procurement and management of metring and billing systems on behalf of multiple private developers as proposed in the context of Pillar 3 initiatives
- **Initiatives to promote availability of access to debt financing**
    - » **Support lending by local financial institutions.** Schemes have been implemented or are under study to support local banks through two-step loans whereby bilateral/multilateral institutions would support local financial institutions through loans, enabling the latter to issue loans to mini-grid private developers at attractive conditions.<sup>122</sup> These schemes would enable private developers to finance part of the mini-grid through debt finance, increase financial leverage and greatly decreasing hurdle rates for IRR. As shown in the scenario analysis, this could kick-start large-scale development on mini-grids

## 5.2 Pillar 2: Support growth of electricity demand in off-grid villages

As outlined in the previous sections of this study, a key lever determining mini-grid viability is productive use demand. Five initiatives are proposed to boost productive demand:

<sup>120</sup> Smart Power Myanmar, “Mini-grids in Rural Myanmar — Unlocking the Potential for Decentralised Energy” Presentation at 5th Myanmar Power Summit 2018  
<sup>121</sup> Interviews with private developers conducted by Roland Berger  
<sup>122</sup> Interviews with unilateral institutions conducted by Roland Berger

Figure 65. Initiatives identified for Pillar 2



Source: Roland Berger

• **Direct subsidies and financing**

- » **Introduce subsidised tariffs for mini-grid electricity. Subsidies could cover both connection costs and unit price of electricity. Differentiated subsidies to specifically support productive loads** could also be considered. The subsidy system could be **financed from government/donor budget instead of or in addition to current subsidy budget**. Payment of subsidies to private developers would require accurate and certified measurement of energy sales volumes — in this context, management of metering and billing systems by a single third party independent from private developers (as proposed within Pillar 3 initiatives) could be advantageous to guarantee accuracy resulting in lower tariffs to final users
- » **Introduce financing schemes targeting SMEs to purchase high-efficiency electrically-powered equipment.** This scheme allows to specifically target productive loads and is attractive as it allows to achieve two objectives: (1) increase productive load demand as businesses add new electrically-powered machinery and/or substitute existing fuel-powered machinery and (2) increase socio-economic impact of mini-grids as it allows businesses to finance growth and become more energy-efficient

• **Technical assistance to users and suppliers**

- » **Collaborate with SMEs to illustrate benefits of utilising electrically powered machinery in substitution to fuel-powered machinery for existing productive activities.** This scheme, together with financing to purchase machinery, has been successfully implemented for example in Tanzania by Engie.<sup>123</sup> Indeed, case studies show that a **combination of productive use incentives and technical assistance put in place by private developers may help increasing productive demand**<sup>124</sup>
- » **Collaborate with SMEs and communities to illustrate new use case of electrical machinery that can improve economic activities.** This scheme was successfully implemented in Kenya for example to promote use of electricity for fish chilling and pumping and purification of water<sup>125</sup>
- » **Collaborate with developers in setting tariffs to optimize demand.** Best practice can be based e.g. on pilot projects or “Demand Labs<sup>54</sup>” where price elasticity and willingness to pay of SME customers could be explored systematically

5.3 Pillar 3: Support of economies of scale

As shown in the previous sections of this study, economies of scale can generate enough cost savings to boost significantly mini-grid viability. Five initiatives have been identified to promote economies of scale through two mechanisms: (1) by streamlining and pooling key processes into shared platforms managed by the government or by third parties, (2) by supporting a certain level of market concentration allowing large players with sufficient size to emerge.

• **Initiatives to streamline and pool key processes**

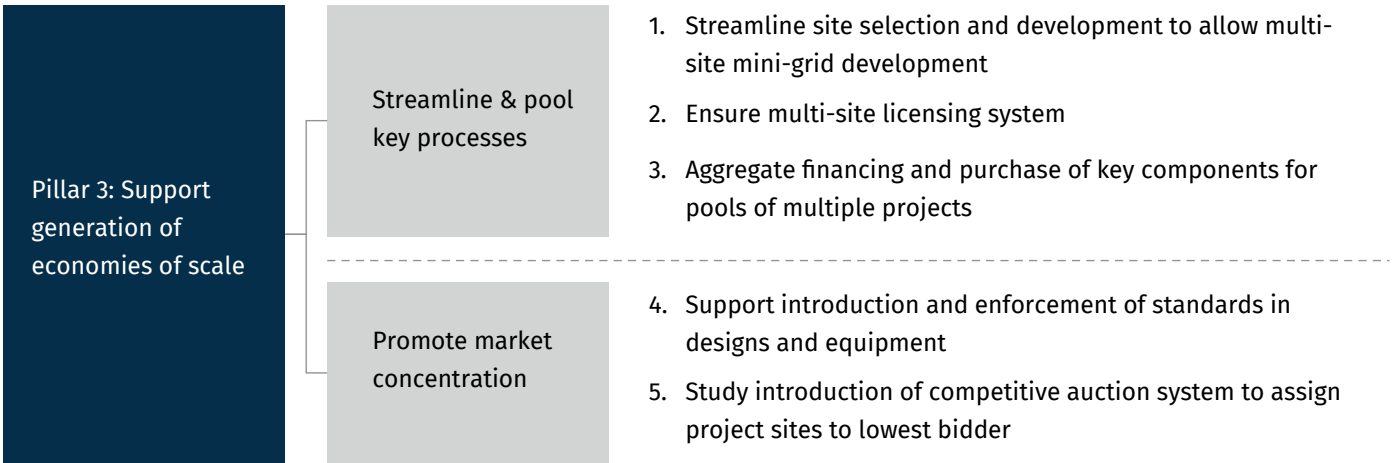
- » **Streamline site selection and development to allow private developers multi-site mini-grid development.**
  - ♦ **Capacity could be built to ensure speedy and effective site selection.** This would greatly reduce the effort required to develop sites for private developers especially the lengthy legal processes needed to secure land rights to build mini-grids. These processes are

<sup>123</sup> See for example The Economist “Mini-grids could be a boon to poor people in Africa and Asia”, 2018

<sup>124</sup> Interview conducted by Roland Berger with multilateral institutions

<sup>125</sup> International Institute for Environment and Development, “Energising local economies — Experiences of solar start-ups in Kenya’s small-scale fishing and agriculture sectors”, 2016

Figure 66. Initiatives identified for Pillar 3



Source: Roland Berger

the key bottleneck that currently prevent private developers from being able to develop multiple projects in parallel<sup>126</sup>

♦ **Alternatively, site selection and development** for “pools of projects” **could be done by multilateral or other independent stakeholders on behalf of DRD.**<sup>127</sup> In this case support from DRD to streamline development processes would be crucial

» **Ensure multi-site licensing system**

- ♦ **Introduction of multi-site rather than site-specific licensing is crucial to streamline development** and facilitate building of a large pipeline by private developers using a single licence
- ♦ **Licensing provisions to transition to distribution franchisee or IPP upon grid arrival should also be given at developer level covering multiple sites.** This may also generate further cost optimisation through “regional strategies” whereby private developers are incentivised to develop portfolios of adjacent mini-grids in the same area in view of transitioning to regional distribution franchises or regional IPPs upon grid arrival<sup>128</sup>

- » **Aggregate financing and purchase of key components and systems for pools of multiple projects**
  - ♦ Platforms **aggregating financing and procurement** of key components could help **generating economies of scale**. Estimates based on interviews with suppliers indicate that pooling of a few hundred projects would be sufficient to generate significant economies of scale
  - ♦ In addition, opportunities to **centralise design, procurement and management of metering, billing systems, communication systems and data centres should be explored.** A similar approach was implemented, albeit in a different context, for the roll-out of smart meters in the UK where a single actor (“**Data Communication Company**”) led the design, build, test and integration of the data and communications infrastructure to secure connection between customers and different energy suppliers<sup>129</sup>

• **Initiatives to support scale of players**

- » **Support introduction and enforcement of standards in designs and equipment.** In addition to de-risking mini-grids as outlined in Pillar 1, introduction and enforcement of strict standards can also favour larger private developers<sup>130</sup> with sufficient capabilities to roll-out standard designs and to optimize procurement of grid-ready equipment
- » **Introduce competitive auction system to assign project sites to lowest bidder.** In combination with site selection by Government or third party, an auction system assigning sites to the lowest bidder for development could be put in place. This typically **favours more efficient bidders that can leverage economies of scale to bid competitively.**<sup>131</sup> A similar system has been put in place in multiple jurisdictions globally to assign utility-scale renewable energy projects (wind, solar PV) resulting in significant tariff reductions.<sup>132</sup>

<sup>126</sup> Interviews with private developers conducted by Roland Berger

<sup>127</sup> Smart Power Myanmar, “Mini-grids in Rural Myanmar — Unlocking the Potential for Decentralised Energy” Presentation at 5th Myanmar Power Summit 2018

<sup>128</sup> Interview with private developers conducted by Roland Berger

<sup>129</sup> See for example <https://www.smartdcc.co.uk/>

<sup>130</sup> Interview with equipment manufacturer conducted by Roland Berger

<sup>131</sup> Interview with Myanmar conglomerate conducted by Roland Berger. For example, site assignment could be based on lowest proposed mini-grid electricity tariffs in MMK/kWh

<sup>132</sup> For example in India introduction of competitive auctions for utility-scale solar development resulted in decrease of feed-in-tariffs by 80% from 2010 to 2018. Source: Mercom



## 5.4 Enabling initiatives

In addition to initiatives related to key strategic pillars, enabling initiatives are recommended

- **Support extension of the current subsidy scheme and cost reductions**

- » As outlined in the scenario analysis, the existing investment subsidy scheme is attractive, but with the current level of budget availability can only support development of a few hundred mini-grids
- » To kick-start market development beyond this subsidy scheme by proving mini-grid business models and by generating economies of scale, a budget increase is needed.
- » In order to ensure alignment of priorities between developers and the end-users, consider introducing result-based subsidies (subsidies payment linked to pre-defined and measurable objectives)<sup>133</sup>
- » As mentioned in Section 5.1, complete handover of subsidised mini-grid to local communities may compromise their long term sustainability after the grid arrives. It is therefore recommended to study options to maintain part-private ownership and management of subsidised mini-grids.
- » In addition to increasing budget availability, measures should be taken to increase the capability of implementing agencies within the Government of Myanmar to effectively and rapidly implement the subsidy scheme<sup>134</sup>
- » In addition, support cost reduction through e.g. improvement in import duties and taxation for key equipment used in mini-grids
- » Furthermore, carbon pricing and emission trading may be explored in conjunction with other renewables incentives as an additional source of financing to support renewables mini-grid

- **Increase community involvement**

- » Community involvement is crucial for the success of mini-grid projects as demonstrated in pilot deployments.<sup>135</sup> Getting consensus from the community to support the project is a key hurdle to implementing subsidised projects. Private developers need to put effort into engaging communities to facilitate buy-in. A two-pronged approach is recommended to increase involvement:

<sup>133</sup> For example subsidy could be linked to actual number of connections to households. This approach has proven successful in other geographies — see e.g. ESMAP “Results-Based Financing in the Energy Sector — An Analytical Guide”, 2015

<sup>134</sup> Interview conducted by Roland Berger with multilateral institutions

<sup>135</sup> ADB, “Developing renewable energy mini-grids in Myanmar — A Guidebook”, 2017





- ◆ Promote participation of communities<sup>136</sup> as stakeholders in mini-grid projects. This can be achieved by (1) allowing partial ownership of mini-grids through direct investment by communities (this would be further strengthened by mechanism to support communities financing their stakes in mini-grid projects) and (2) involving the local population in the operation and maintenance of mini-grids as employees or sub-contractors of private developers — this should also include active training of professional workforce throughout the off-grid communities
- ◆ Involving communities through communication and engagement activities throughout the mini-grid project lifecycle: planning, design, construction, operation, extensions, grid connection
- **Develop and share best practices and key data**
  - » In order to kick-start a sizeable mini-grid market and ensure continuous improvement is achieved it is crucial to develop and share best practices and key data
    - ◆ Gathering, analysis and sharing of key data and information on mini-grids is crucial to raise interest, secure buy-in and commitment by investors thereby supporting access to finance
    - ◆ Best practice and data sharing would allow continuous improvement of mini-grid planning and design and private developers operational performance by allowing benchmarking and setting of targets based on best-in-class operators
- **Support capacity building and training**
  - ◆ Development of a specialized workforce for planning, financing, engineering, developing, building and operating & maintaining mini-grids is crucial to enable large-scale development of mini-grids
  - ◆ University-level training or vocational training schemes could be supported by Government, donors and private players

<sup>136</sup> Smart Power Myanmar, “Mini-grids in Rural Myanmar — Unlocking the Potential for Decentralised Energy”  
Presentation at 5th Myanmar Power Summit, 2018

## 5.5 Possible roles of key stakeholders

Implementation of the initiatives proposed above requires concerted action of all key stakeholders, in particular:

- 1. Government**, including ministries and regulators, State/Region-level authorities and government-owned companies (utilities and financial institutions)
  - 2. Multilateral/national organisations and international development organisations**
  - 3. Private developers**, including local players and large international utilities
  - 4. Equipment & software vendors**
- Possible roles of government
    - » In Pillar 1 provide a clearer and smarter regulatory landscape to de-risk mini-grid development, e.g.
      - ◆ Providing clarity on grid arrival to key stakeholders
      - ◆ Introducing a licensing system for mini-grids and a clear mechanism for the transition of mini-grid developers to distribution system operators or IPPs, in line with lessons learned from global case studies
      - ◆ Introducing and enforcing strict standards to ensure all mini-grids have grid-ready equipment and designs
    - » In Pillar 2, lead the introduction on “smart subsidies”, for example subsidies on mini-grid tariffs or revenue guarantees schemes
    - » In Pillar 3, take the lead in selecting and developing mini-grid sites, facilitating streamlined development in particular with reference to land-use regulation. In addition, consider introducing and managing auctions for the assignment of mini-grid sites to private developers
    - » Finally, consider increasing substantially budget earmarked for electrification through mini-grids and channel additional funds to subsidies. As outlined increased budget for subsidies can support generation of economies of scale



- Possible roles of multilateral/national organisations and international development organisations
  - » In Pillar 1, consider supporting various stakeholders
    - ◆ Support the Government in regulatory reform, e.g. by advocating best practices from global case studies
    - ◆ Support introduction of a compensation scheme in case of grid arrival either through donations/loans financing the scheme and/or through technical advisory
    - ◆ Support private developers introducing latest smart metering technologies to de-risk payments; In addition, consider playing leading role in creating a centralised platform for procurement of smart meter equipment and software and for management of data on behalf of private developers
    - ◆ Support local financial institutions provide loans to private developers for mini-grid development (e.g. through 2-steps loan schemes)
  - » In Pillar 2, can take a leading role in setting up micro-financing schemes to allow SMEs purchase of high efficiency electrically-powered equipment

- » In Pillar 3, consider acting on behalf of Government for the selection and development of pools of mini-grid sites. In addition, take a leading role in creating platforms to aggregate procurement of key equipment on behalf of private developers
  - » Support gathering and sharing of best practice and data, e.g. through commissioning and dissemination of research work, pilot projects, seminars bringing together stakeholders from different markets
- Possible roles of private developers
    - » In Pillar 1, consider the creation of a fund financed through a fixed contribution to ensure compensation in case of grid arrival. In addition, take a lead in rolling out smart meter technologies to de-risk payments; alternatively consider outsourcing smart metering systems to third parties that would aggregate procurement and management of these systems across multiple private developers
    - » In Pillar 2, explore new tariffs schemes to optimise productive loads. In addition, collaborate with Multilateral/National Organisations and International Development Organisations in providing support to SMEs introducing new electrically-powered equipment
    - » In Pillar 3, actively pursue strategies to develop economies of scale such as implementation of standard designs, development of large pools of projects, “regional roll-out strategies” etc.
    - » Actively engage communities, and consider options to involve local communities as shareholders in mini-grid projects
  - Possible roles of equipment and software vendors
    - » In Pillar 1, equipment vendors could play a crucial role in advocating the introduction of stricter standards to ensure that mini-grids are fully grid-ready
    - » In Pillar 2, smart metering vendors would be essential in ensuring the roll-out of the latest technologies allowing de-risking of payments. In addition, consider collaborating with Multilateral/National Organisations and International Development Organisations in setting up procurement platforms
    - » In Pillar 3, consider partnerships with private developers to develop standardised designs and aggregate procurement across multiple projects
    - » Share best practices from other markets and inform community about technical development that could enhance mini-grid viability.



## Annexes

### Annex 1

## Definitions and Scope of the Market Assessment

### What are mini-grids?

Mini-grids are systems integrating all the key components of the electricity supply chain on a small scale, typically covering a village community:

- A power generation facility
- A low voltage (<11 kV) network of power cables to distribute power to households, businesses and other customers
- Power retail operations to measure the customers' power consumption, issue bills and manage payments

Power generation in mini-grids relies mainly on renewable sources such as solar PV; a battery and a diesel generator may also be integrated to secure reliable supply when renewable generation is not available — e.g. at night or during cloudy periods in the case of solar PV generation.

The size of the mini-grid generation facility is typically in the order of 10 kW or larger — in the case of solar PV in rural Myanmar, this is sufficient, in combination with a battery and diesel generator, to power a typical off-grid village with approximately 100 households.

The ability to provide power for typical village communities is the key feature of mini-grids.

- Although the distinction is not always clear-cut, systems with less than 10 kW power generation capacity are commonly classified as micro-grids
- Systems with limited distribution infrastructure such as solar home systems, systems serving factories or individual/groups of buildings are usually classified as on-site generation systems

### Off-grid versus on-grid

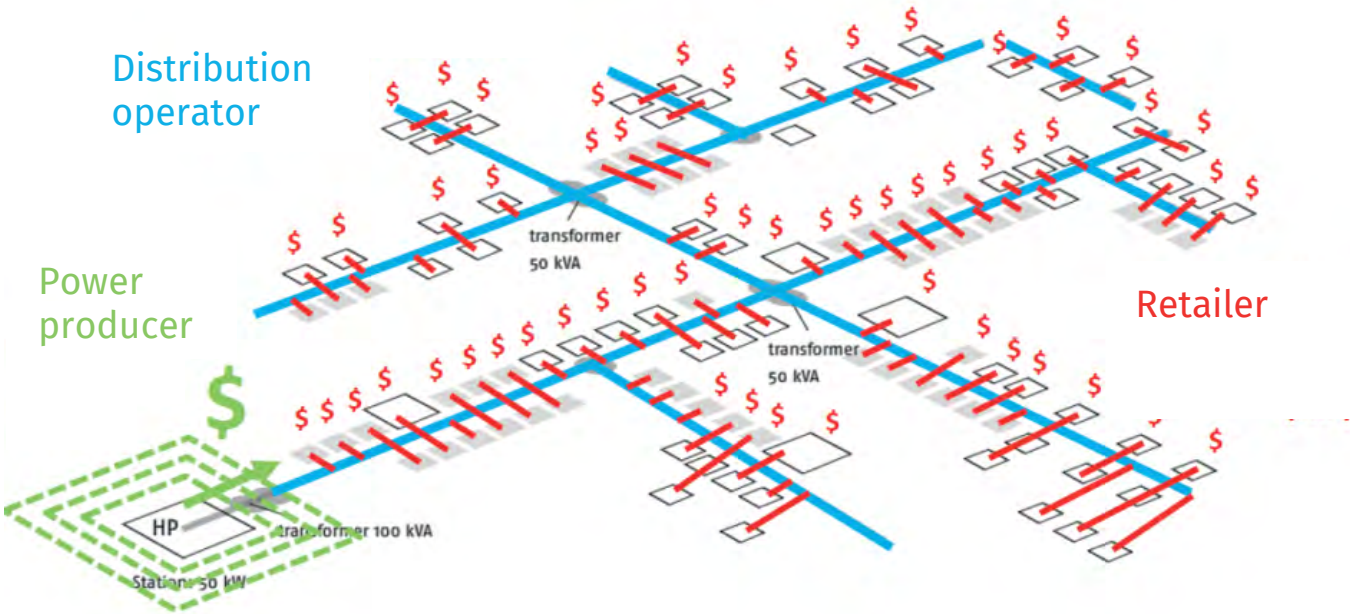
In developing countries with large areas not covered by the national grid, mini-grids are typically not connected to the grid and provide power to off-grid rural communities. In addition to Myanmar, examples of developing countries with existing mini-grids in off-grid areas include Nigeria, Kenya, Rwanda, India, Sri Lanka, Cambodia and Indonesia.

In developed countries, mini-grids that are not connected to the national grid are typically found on small islands that are too far from the mainland to be connected through power cables — notable examples include the Azores islands in Portugal.

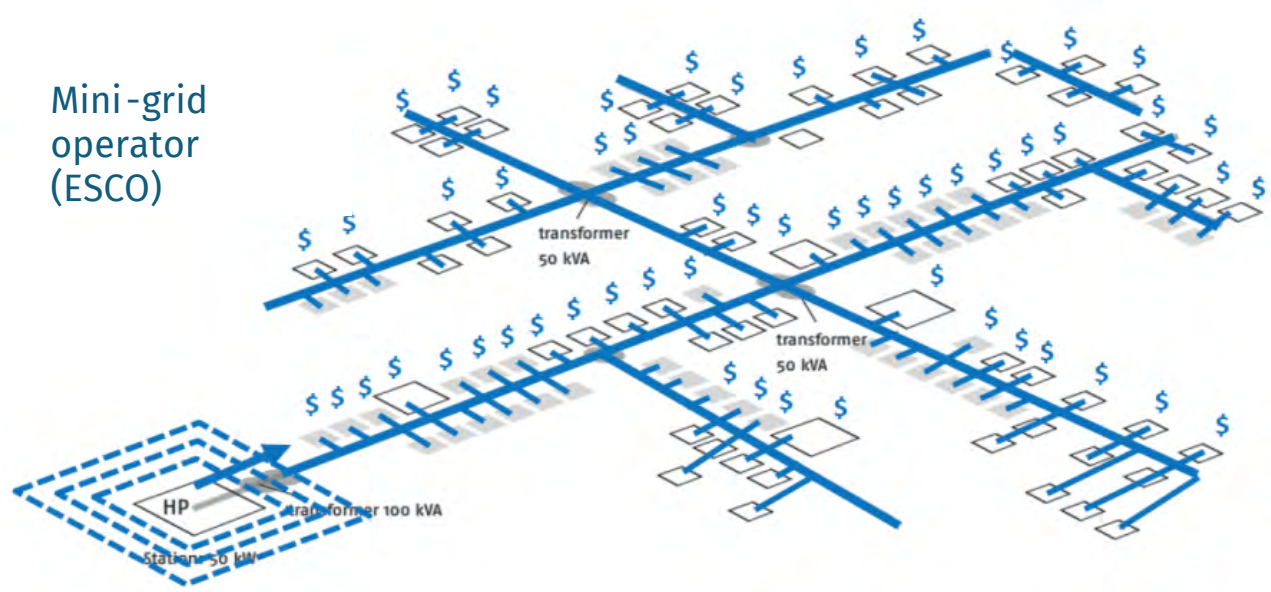


Figure 67. Illustration of mini-grids

Key roles in power supply chain



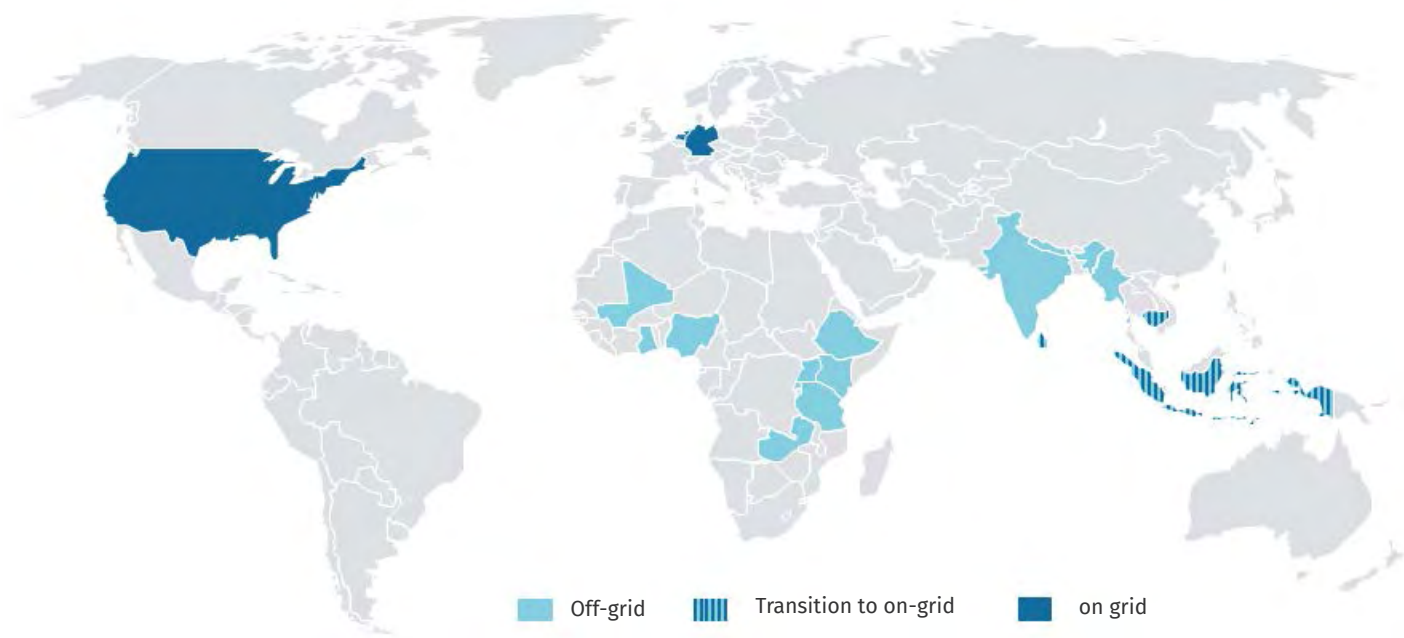
Mini-grid operator integrates roles in supply chain



- > Mini-grids integrate a power production facility, a distribution network and a retail system allowing to supply power to households, commercial customers and other loads.
- > Power generation capacity for mini-grids is typically in the order of 10 kW, however larger systems exist
- > Power generation mainly relies on renewable sources, coupled with backup diesel generator

Source: GIZ

Figure 68. Maps of mini-grids examples worldwide (non-exhaustive)



Source: Roland Berger

A new trend is also emerging in Europe and the United States where residential communities equipped with rooftop solar PV generation and battery systems pool power generated by members of the community to satisfy demand. These communities are physically connected to the grid. However, they form virtual mini-grids that are energetically independent from the rest of the power grid.<sup>137</sup>

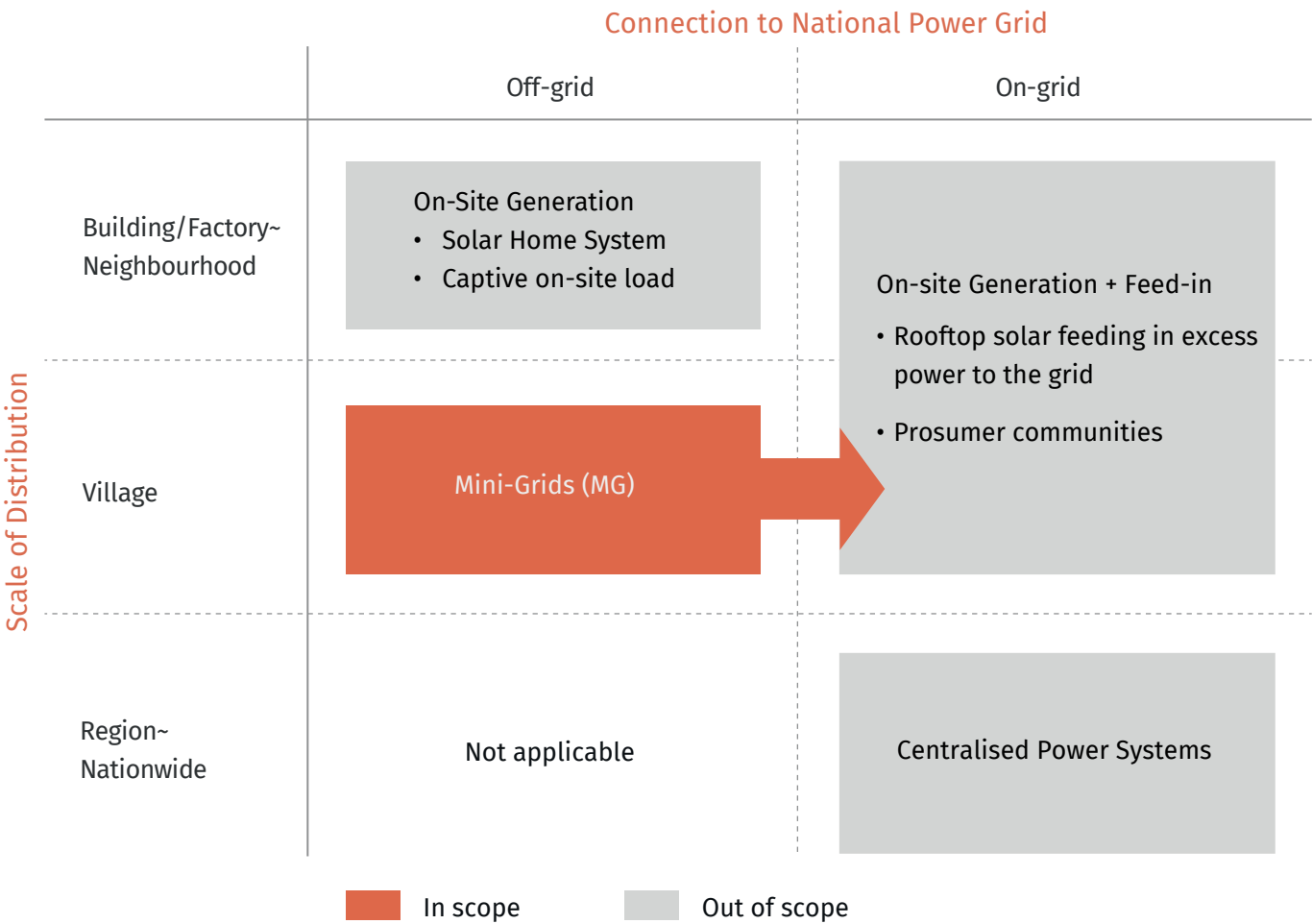
Although at the time of construction, mini-grids may not be connected to the national grid, there are multiple examples of transitions from off-grid to on-grid systems at the time of national grid arrival.<sup>138</sup> The most successful transition occurred in Cambodia, where more than 100 private mini-grids originally built in off-grid areas have been connected to the national grid and granted long-term distribution licences as private sector franchisees (Small Power Distributors – SPD). This allowed to leverage the initial investment into mini-grids and to accelerate expansion of the national grid into rural areas.

In this study we focus primarily on the market potential for mini-grids in off-grid locations of Myanmar, bearing in mind that they may transition to on-grid systems at the arrival of the national grid, subject to introduction of policies and regulations.

137 See for example Sonnen virtual mini-grid in Germany connecting 20,000 households

138 The World Bank, “Mini-grids and the arrival on the grid — Lessons from Cambodia, Sri Lanka and Indonesia”, 2018

Figure 69. Scope of systems discussed in this study



Source: Roland Berger

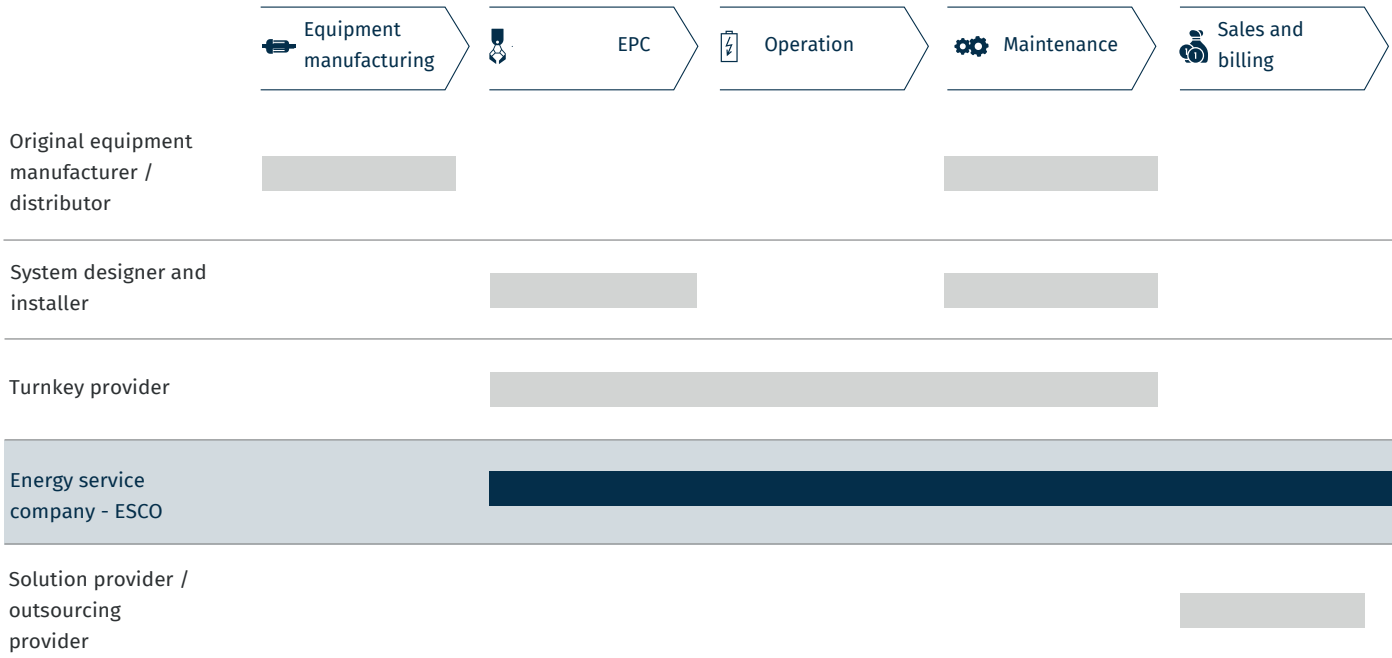
The importance of Energy Service Companies (ESCOs)

Mini-grids combine all the key components of the electricity supply chain – power generation, distribution and sales /billing. In addition, for mini-grids powered by renewables, integration and optimization of renewable sources with batteries and diesel generators is typically required.

Hence, from an engineering and business perspective, mini-grids are far more complex than other off-grid power solutions such as on-site power generation and solar home systems. The latter can be sold or leased to the customer and require only provision of installation and maintenance services as they can be operated by the user.



Figure 70. Key players and roles in various off-grid power solutions



Source: Roland Berger

Instead, specialised players are best placed to optimise mini-grid design, engineering and operation and to manage key business processes professionally. These specialised players operating along the value chain are known as Energy Service Companies (ESCOs).

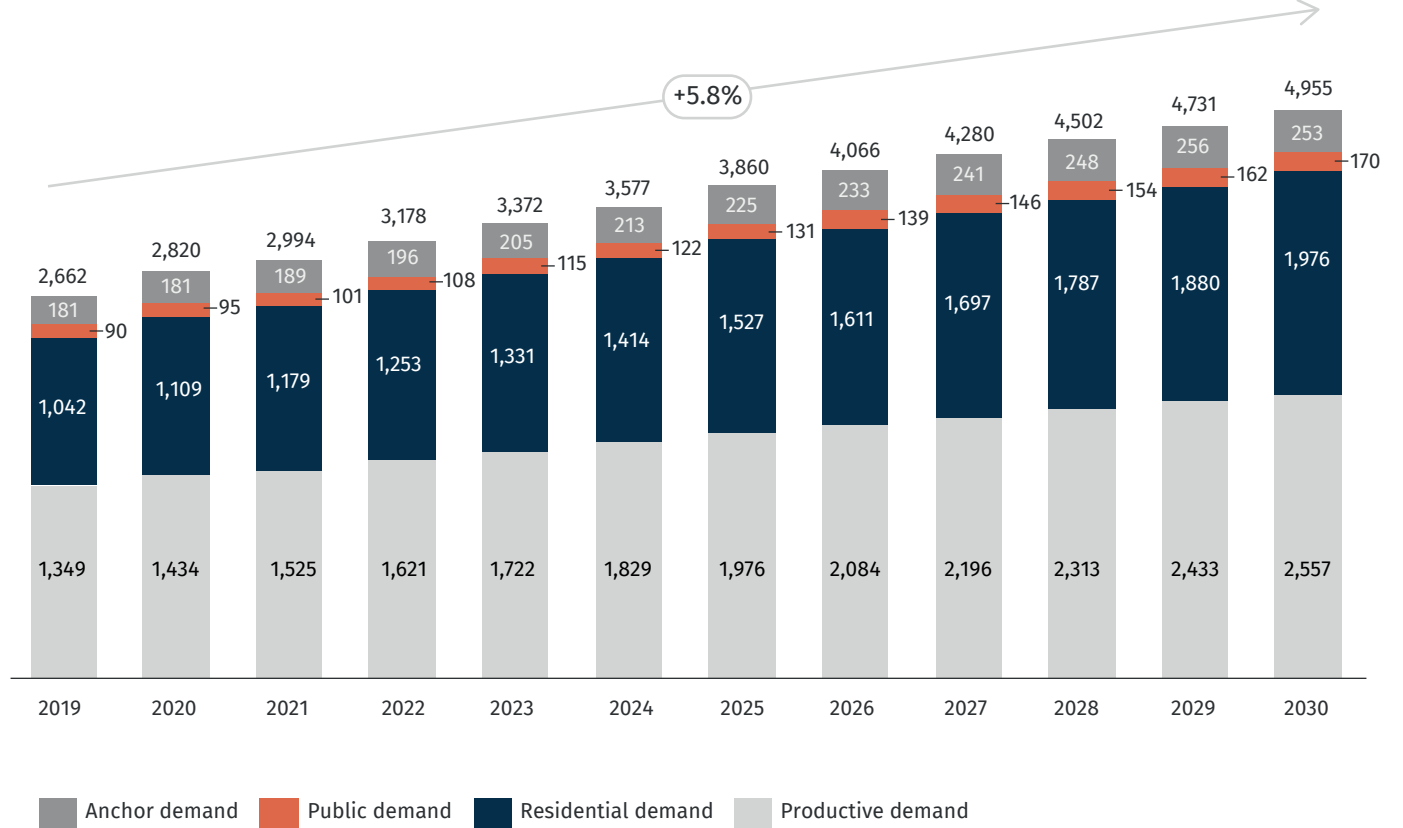
After purchasing equipment from Original Equipment Manufacturers (OEMs), ESCOs typically lead the design, engineering and construction of the mini-grids, including integration and optimization of the various components. In addition, they operate and are responsible for maintenance of the power generation, distribution, metering and billing infrastructure. Finally they manage all key business processes related to sales and billing.

Annex 2

Projections of potential off-grid demand in the slow and quick electrification cases

Increase in off-grid demand is very rapid (+5.7% per year) in the slow electrification case (52% grid electrification by 2030; see Section 2.3).

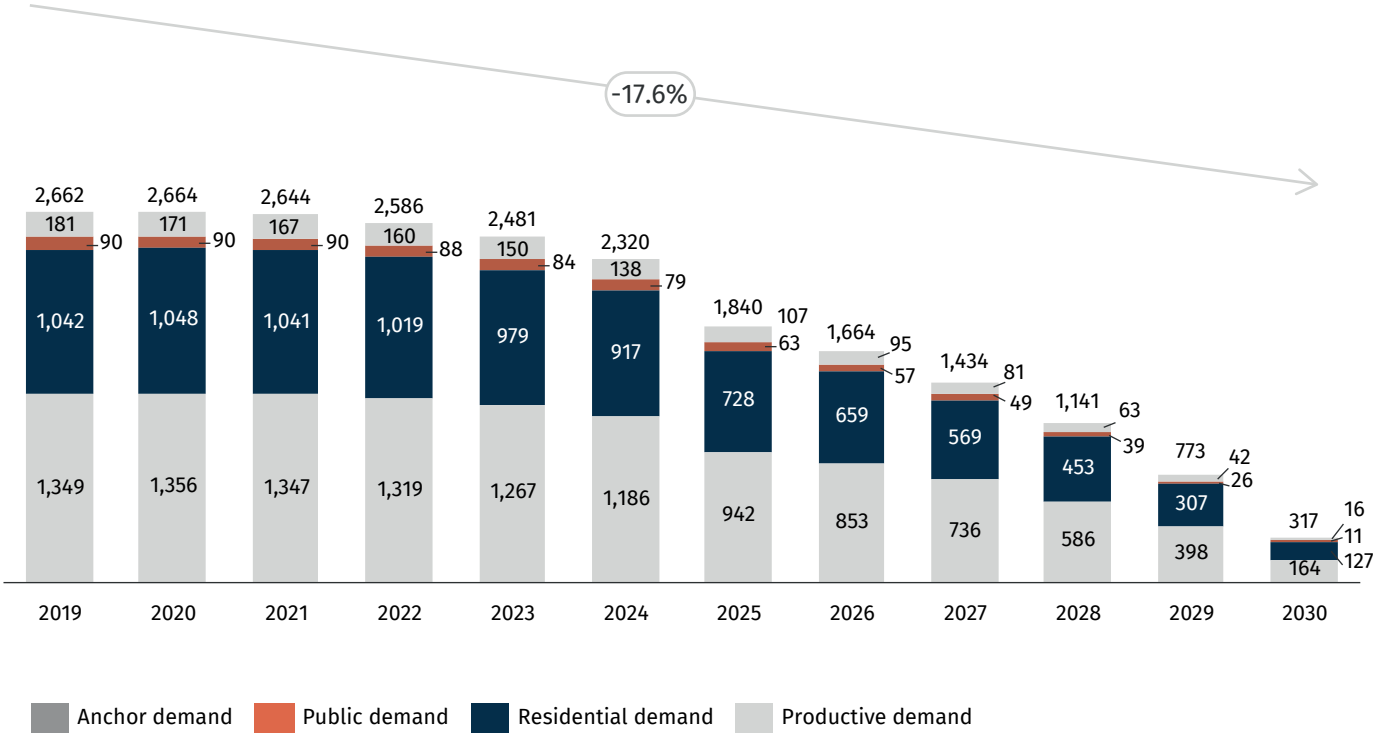
Figure 71. Projection of potential off-grid demand in Myanmar in the slow electrification case (52% electrification by 2030) [GWh]



Source: Roland Berger

In the quick electrification case (97% grid electrification by 2030; see Section 2.3) the pace of electrification is fast enough to compensate increase in demand – by 2030 off-grid demand goes virtually to zero.

**Figure 72.** Projection of potential off-grid demand in Myanmar in the quick electrification case (97% electrification by 2030) [GWh]



Source: Roland Berger

Annex 3

Cambodia: a case study showing successful transition from isolated to grid-connected mini-grids

In Cambodia, mini-grids played a crucial role in electrification of rural areas. Currently 56% of the population has access to electricity: 20% or 3.5 million people, mostly in urban areas, access electricity through the national grid infrastructure built by the national utility Electricité du Cambodge and more than 30% or 4.8 million people in rural areas are supplied by grid-connected or isolated mini-grids.<sup>139</sup>

Mini-grid development in Cambodia followed three phases: an initial unregulated bottomup development phase, then introduction of a stricter licensing system and technical standards, and currently a transition to regulated tariffs.

**Figure 73.** Three phases of mini-grid development in Cambodia

Phase 1 (1990's to 2001)	Phase 2 (2001-2016)	Phase 3 (2016-)
<ul style="list-style-type: none"><li>• Mini-grids in rural areas developed independently by local communities and entrepreneurs</li><li>• No strict licensing and standards requirements<ul style="list-style-type: none"><li>- Poor technical standards and power supply service - mostly diesel generators and improvised distribution infrastructure</li><li>- High electricity costs</li></ul></li></ul>	<ul style="list-style-type: none"><li>• Introduction of strict license system &amp; standards<ul style="list-style-type: none"><li>- Isolated MGs: consolidated generation+distribution license</li><li>- Technical standards enforced</li><li>- Upon grid connection: mini-grid shifts to distribution license and decommission generation assets</li></ul></li><li>• Regulated tariff based on costs recovery system ensuring return on investment for isolated and grid-connected MGs</li></ul>	<ul style="list-style-type: none"><li>• Reform of tariff system<ul style="list-style-type: none"><li>- Grid connected MG must charge same tariff as main grid</li><li>- Subsidies from REF cover difference with cost based tariffs</li></ul></li><li>• Possible consolidation going forward as pressure on earnings increase</li></ul>
<ul style="list-style-type: none"><li>• 5% population w/electricity access</li><li>• Supply only few hours/day</li><li>• 0.5-1 USD/kWh tariffs for MGs</li></ul>	<ul style="list-style-type: none"><li>• Increase to 56% el. access</li><li>• Supply few hours to 24 h/day</li><li>• 0.29 USD/kWh av. tariffs for MGs</li></ul>	<ul style="list-style-type: none"><li>• 56% population w/electricity access</li><li>• Supply typically 24 h/day</li><li>• Tariffs up to 0.2 USD/kWh</li></ul>

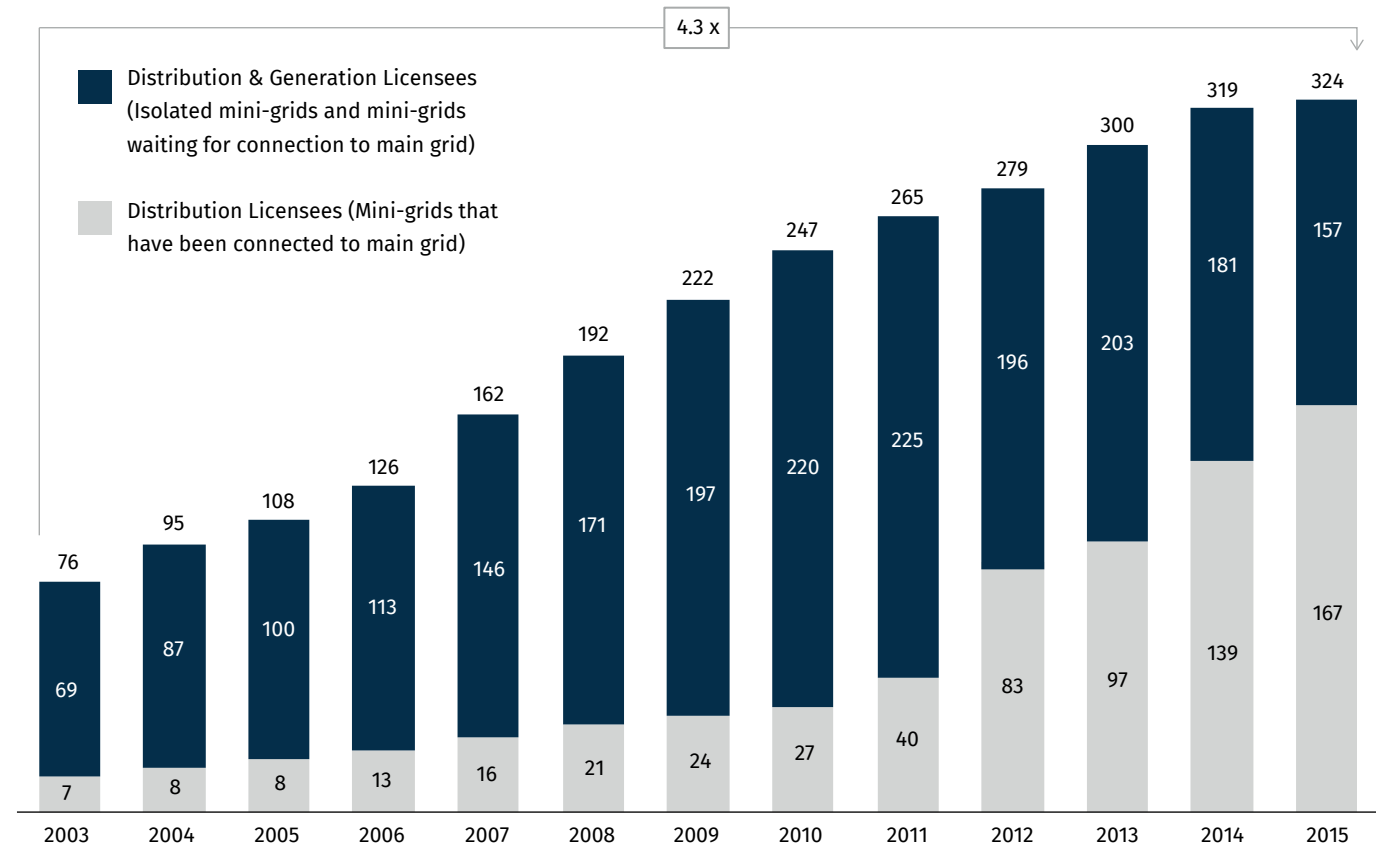
Source: World Bank, "Mini-grids in Cambodia, a Case Study of a Success Story", 2018

<sup>139</sup> The World Bank, "Mini-grids and the arrival on the grid — Lessons from Cambodia, Sri Lanka and Indonesia", 2018

The licensing system introduced in the early 2000’s includes a “consolidated licence” for mini-grids combining generator and distribution licences. Technical standards for grid readiness are enforced as a key requirement to obtain and to periodically renew the licences. Upon grid arrival, the mini-grid operator can convert its licence to become a distribution operator and decommission the generation assets. A regulated tariff system for mini-grids ensures a certain level of return on investments, incentivising further expansion of the distribution network after grid connection.

As a result of this system, the number of licencees for isolated and grid-connected minigrids has more than quadrupled from 2003 to 2015 and the number of grid-connected licencees is increasing even more rapidly. As a result of continued scaling up of infrastructure after grid connection, the average population covered per licencee is now almost 15,000 people.

Figure 74. Evolution of number of isolated and grid-connected mini-grids licencees in Cambodia

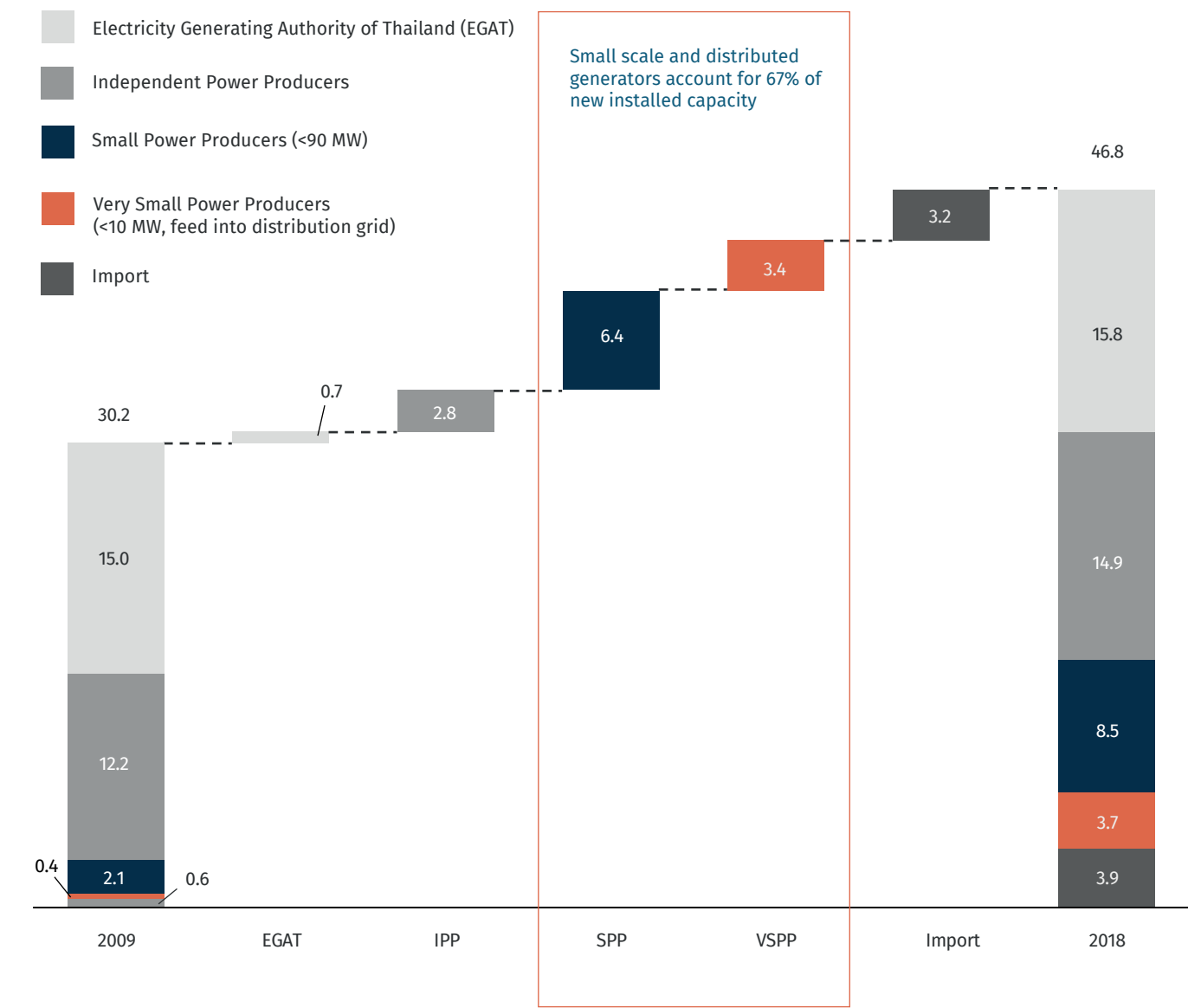


Source: World Bank, "Mini-grids in Cambodia, a Case Study of a Success Story", 2018

Annex 4

Contribution of small scale and distributed generation to growth of installed capacity in Thailand

Figure 75. Evolution of installed power generation capacity in Thailand 2009 - 2018 [GW]



Source: Ministry of Energy of Thailand, Energy Regulatory Commission of Thailand



Annex 5

Calculation of LCOE and IRR

Figure 76. Definition of Levelised Cost of Electricity and its key components

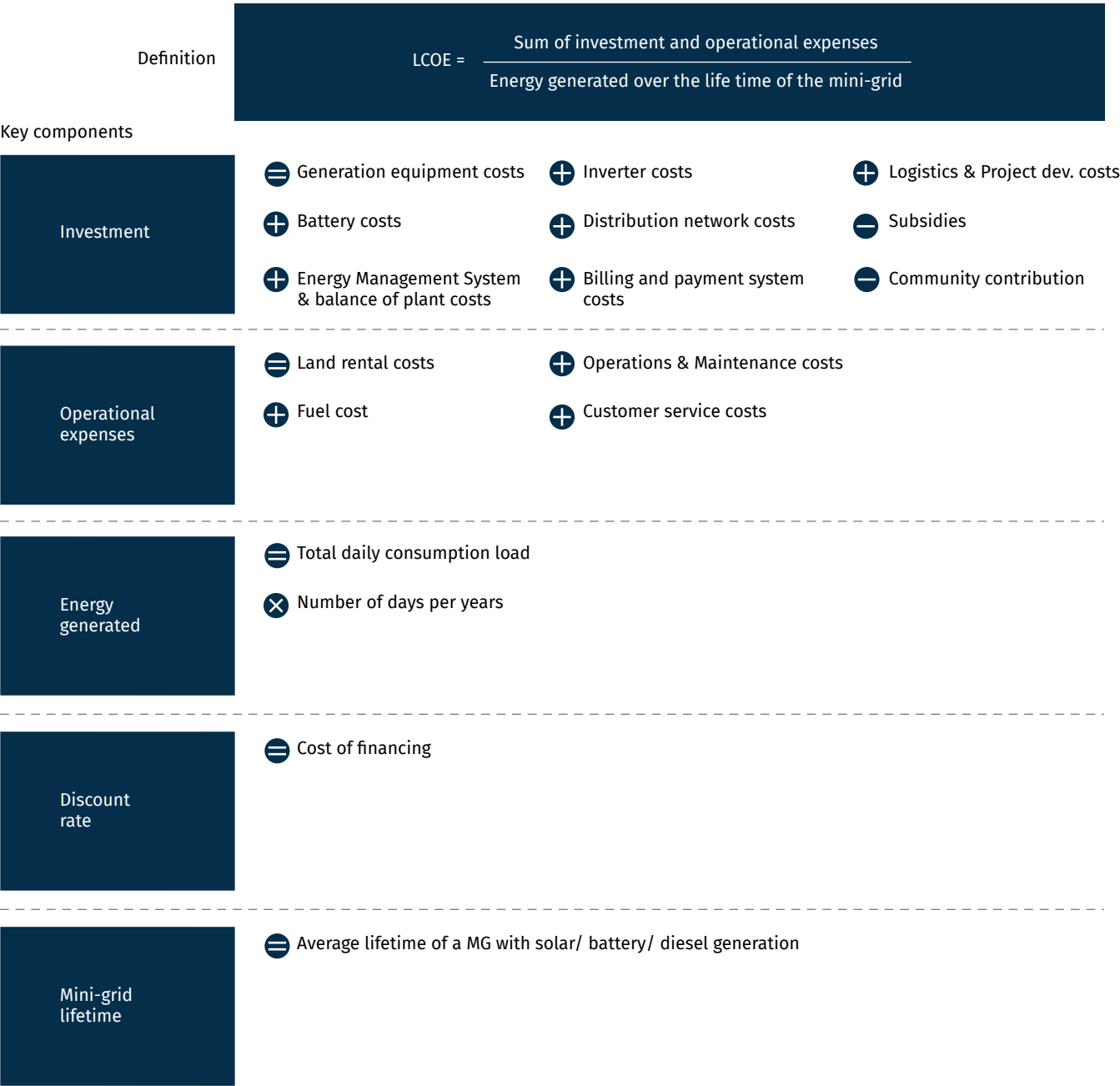
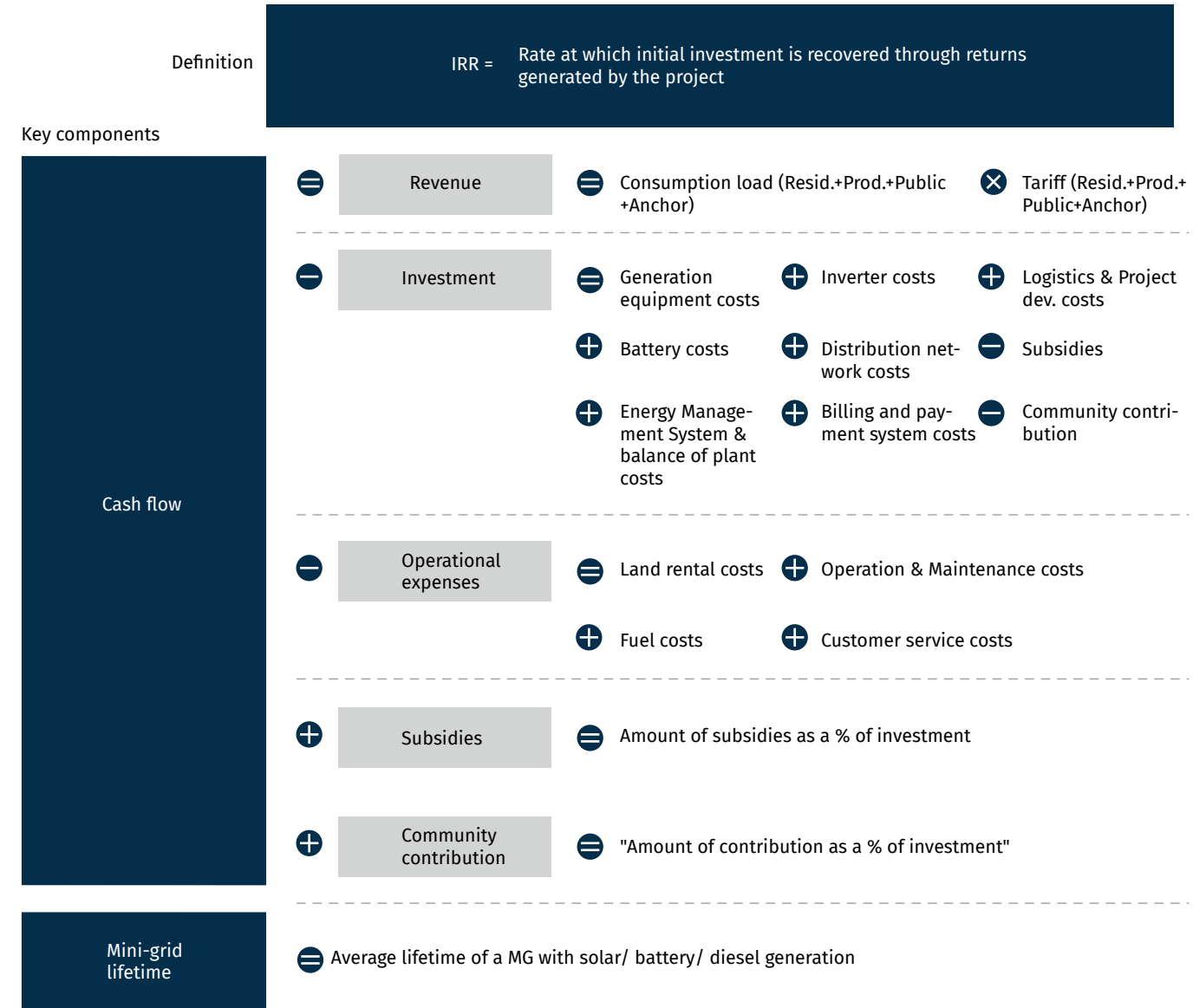


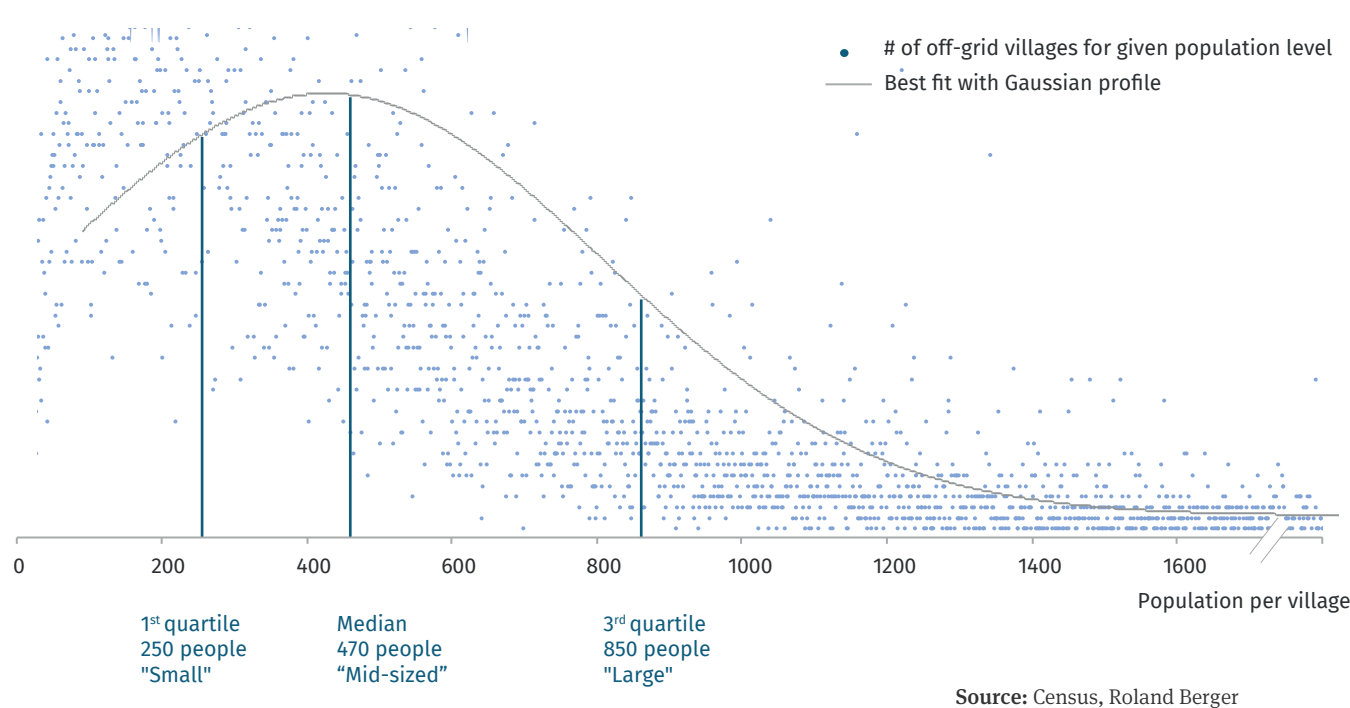
Figure 77. Definition of Internal Rate of Return and its key components



Annex 6

Distribution of off-grid villages by population in Myanmar

Figure 78. Distribution of off-grid villages by population



Annex 7

Key Assumptions

Figure 79. Key assumptions for revenue calculations

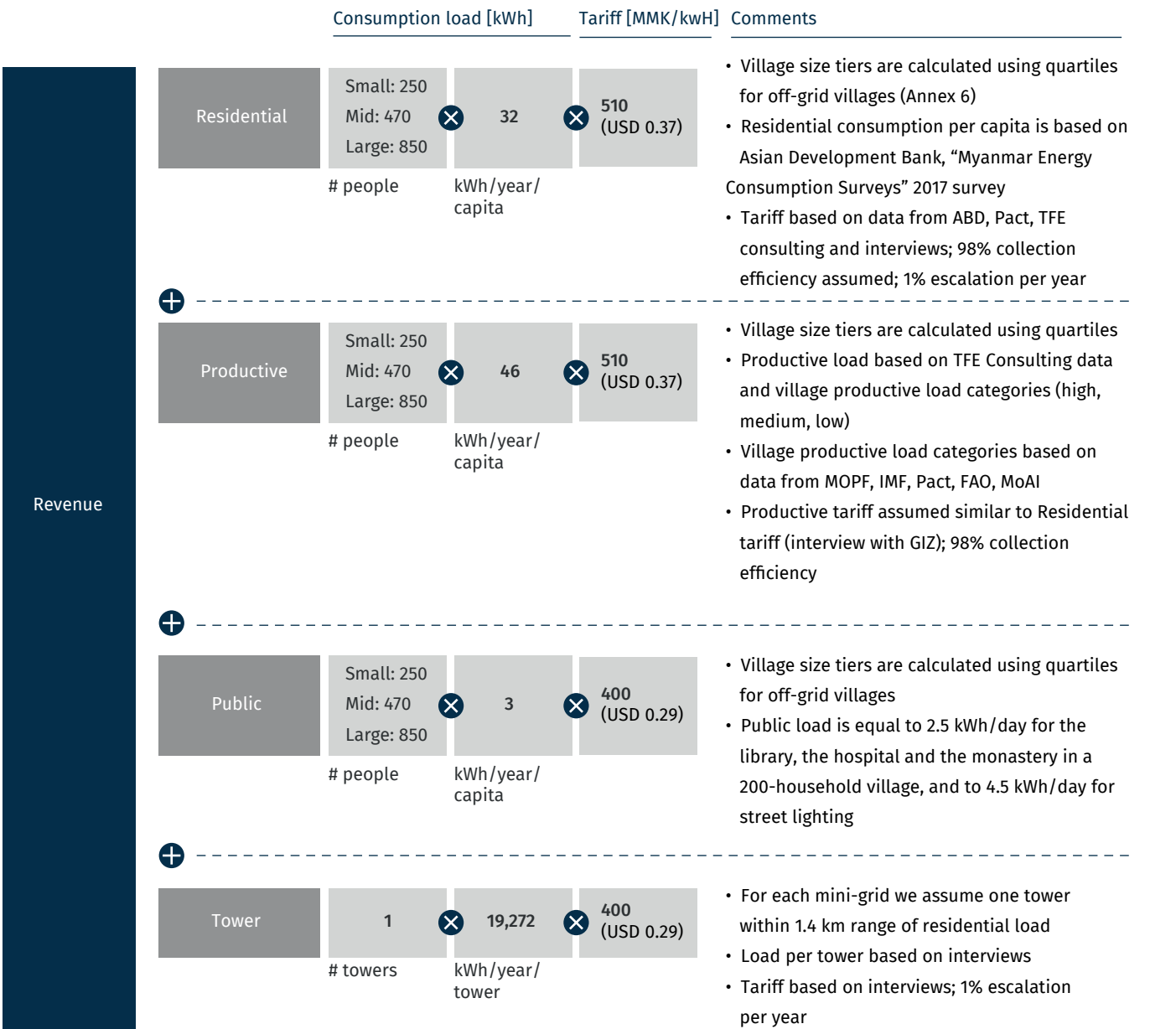


Figure 80. Key assumptions for CAPEX calculations for solar/diesel/battery hybrid mini-grids (1/2)

	Equipment size	Unit costs	Comments
CAPEX (1/2)	Generation equipment : Solar PV	$\frac{\text{Consumption load} \times \text{Solar}}{\text{Energy yield}} \times 600$	<ul style="list-style-type: none"><li>• Formula from GIZ</li><li>• Solar fraction = 60% as per threshold for subsidies</li><li>• 3 yield categories based on irradiation in Magwe (Dry), Yangon (Mid-dry), Kachin (Non-dry). We also apply 90% factor for generation efficiency</li><li>• Panel &amp; structure costs from interviews; -7.2% CAGR as per expert interviews</li><li>• 3% distribution losses assumed based on interviews</li><li>• 0.5% decrease in output per year for degradation</li></ul>
	kW	USD/kW	
	+		
	Generation equipment : Diesel generator	$\frac{\text{Peak load}}{\text{DG capacity factor}} \times 550$	<ul style="list-style-type: none"><li>• Formula from GIZ</li><li>• Peak load based on sum of Residential, Productive and Tower load profiles</li><li>• DG capacity factor = 80% from interviews</li><li>• DG unit cost from Interviews</li></ul>
	kW	USD/kW	
+			
Battery	$\frac{\text{Sum of electricity surplus}}{\text{Battery efficiency} \times \text{Depth of discharge}} \times 415$	<ul style="list-style-type: none"><li>• Formula from GIZ</li><li>• Surplus = Total power requirements – Solar PV generation (assume 60% solar on average)</li><li>• LiB cost from interviews; -7.7% CAGR as per expert interviews</li><li>• Battery efficiency = 99%; Depth of discharge = 80%</li></ul>	
kW	USD/kW		
+			
EMS & balance of plant	1 unit $\times$ 20,000 USD/unit	<ul style="list-style-type: none"><li>• Assumes 1 EMS per mini-grid</li><li>• Quotations from vendors, interviews</li></ul>	
kW	USD/kW		

Figure 81. Key assumptions for CAPEX calculations for solar/diesel/battery hybrid mini-grids (2/2)

	Equipment size	Unit costs	Comments	Hard costs	Soft costs	
CAPEX (2/2)	PV Inverter costs	PV panels capacity × 200	<ul style="list-style-type: none"><li>• Inverter capacity based on PV panels capacity and battery capacity</li><li>• Inverters costs based on interviews; -8.5% CAGR as per expert interviews</li></ul>			
		kW		USD/kW		
	Battery Inverter costs	Battery capacity × 600				
		kW		USD/kW		
	+					
	Distribution lines costs	0.016 × 89 + 0.7 × 5,253	<ul style="list-style-type: none"><li>• Assumes conservatively ~0.7 km/tower as max distance to village = 1.4km</li><li>• Unit costs from benchmarks, expert interviews</li></ul>			
		km/ HH    HH <sup>1)</sup> km/tower    USD/kW				
	+					
	Billing/ payment - CCS	Distribution lines CAPEX × 15.0%	<ul style="list-style-type: none"><li>• Central Customer System (CCS) cost assumed equal to 15% of the total Distribution network costs (Expert interviews)</li><li>• Unit costs from benchmarks</li></ul>			
		Ratio of CCS cost to distrib. costs				
	Billing/ payment - Metering	1 meter per household 1 meter per productive asset × 20 USD/ household				
	+					
	Project dev. costs	11.0% of Hard costs		<ul style="list-style-type: none"><li>• Hard costs take into account: Generation, Storage, Inverter, Distribution and Billing &amp; Payment; Source: Expert interviews</li></ul>		
Logistics costs	6.0% of Hard costs					



Figure 82. Key assumptions for Opex calculation for solar/diesel/battery hybrid mini-grids

OPEX

	Size or volume	Unit costs	Comments
Land rental costs	Required size of land	✖ 0.05	<ul style="list-style-type: none"> <li>Land size: Solar PV capacity x Solar conversion efficiency + 50 m2 for DG/Battery/BoP</li> <li>Monthly rental price based on interviews that indicate 5-15 USD cents; 5% escalation per year to reach upper end of price at the end of 20 years</li> </ul>
	sqm	USD/ sqm/ month	
+			
Fuel costs	Diesel volume required for DG Generation	✖ 0.69	<ul style="list-style-type: none"> <li>Based on interviews</li> <li>1% escalation per year in line with tariff escalation</li> </ul>
	liters	USD/ liter	
+			
O&M costs	Solar PV capacity	Solar PV: 1.50 USD/ kW	<ul style="list-style-type: none"> <li>Equipment capacity assumptions same as for CAPEX calculation; O&amp;M costs per kW from interviews</li> <li>0.17% OPEX/CAPEX ratio based on interviews</li> <li>1% escalation per year in line with tariff escalation</li> <li>EMS and billing &amp; payment system O&amp;M deemed negligible (minimal maintenance and common to have warranty coverage by vendor/ system integrator)</li> </ul>
	DG capacity	DG: 4.00 USD/ kW	
	Battery capacity	✖ Battery: 0.83 USD/ kW	
	Inverter capacity	Inverter: 0.44 USD/ kW	
	Distribution CAPEX	0.17% of Distr. CAPEX	
+			
Customer service cost	240	✖ 210	<ul style="list-style-type: none"> <li>Interviews with knowledgeable locals; salary of basic staff in rural areas (2-3 years experience)</li> <li>1.5 FTEs and 1 additional staff for every 480 connections</li> <li>Includes payment collection</li> <li>5% escalation per year for wages based on interviews</li> </ul>
	Households served per staff per month	Monthly salary [USD]	

Figure 83. Key macro/regulatory assumptions

		Value	Comments
Macro/ Regulatory	Subsidies as a % of CAPEX	No Subsidy	<ul style="list-style-type: none"><li>• 2 scenarios: subsidy/ no subsidy</li><li>• Subsidy applicable to Residential + Productive CAPEX only (tower CAPEX not eligible)</li></ul>
		Subsidy = 60 % of CAPEX	
	<hr/>		
	Community financing as a % of CAPEX	No financing	<ul style="list-style-type: none"><li>• 2 scenarios: financing/ no financing</li><li>• Financing applicable to Residential + Productive CAPEX only (tower CAPEX not eligible)</li></ul>
		Financing = 20 % of CAPEX	
	<hr/>		
Discount rate	20%	<ul style="list-style-type: none"><li>• Real discount rate based on interviews</li></ul>	
<hr/>			
MG lifetime	10 years	<ul style="list-style-type: none"><li>• In subsidised case assume handover of mini-grid assets to village after 10 years</li><li>• In non-subsidised case, assume 20 years lifetime based on average lifetime of a solar-battery-diesel MG system</li></ul>	
	20 years		

Figure 84. Key assumptions for CAPEX calculation for hydropower mini-grids

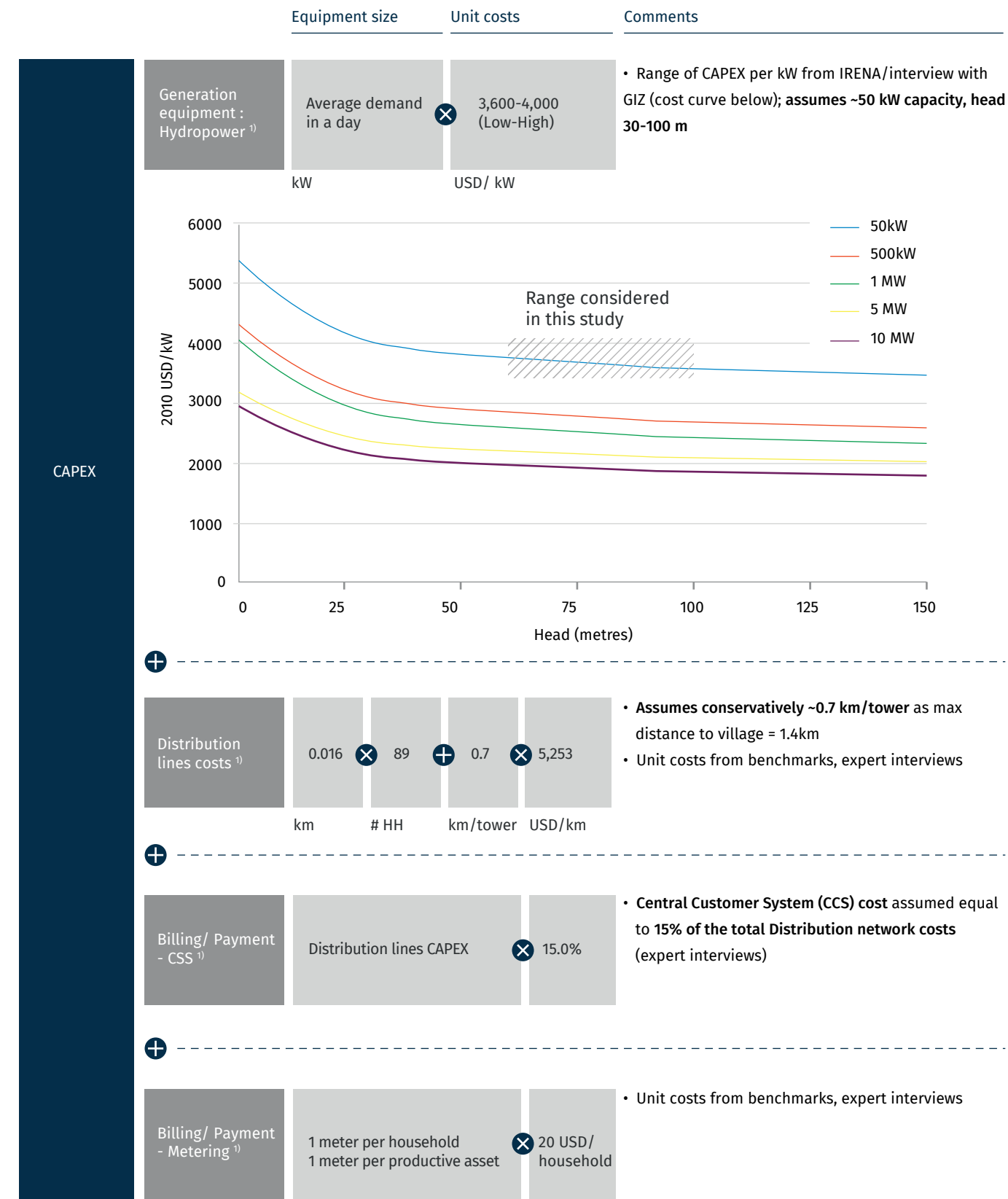
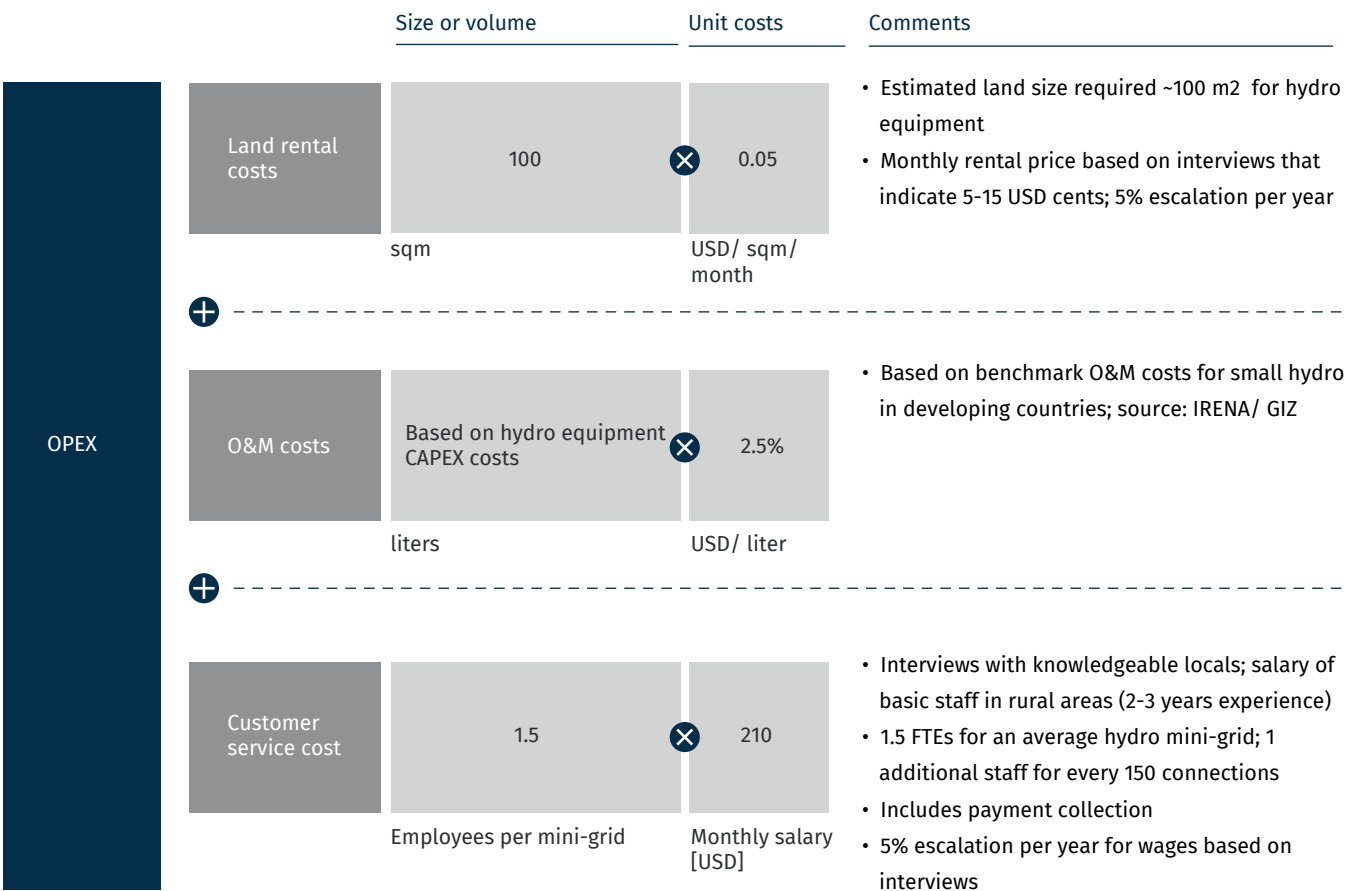


Figure 85. Key assumptions for OPEX calculation for hydropower mini-grids



Annex 8

List of mini-grid projects

The table below contains a list of known mini-grid projects, their technology, involved players, capacity and status to date. It is based on publicly available information and interviews and is not exhaustive.

	Location	Technology	Developer	Financial backing	Capacity [kW]	Status
1	Thayet township, Magway	Solar PV	SolaRiseSys	ADB	7.2	Existing
2	Sinbaungwe township, Magway	Solar PV	SolaRiseSys	ADB	8.7	Existing
3	Minbu township, Magway	Solar PV	SolaRiseSys	ADB	4.9	Existing
4	Yenangya-ung township, Magway	Solar PV	SolaRiseSys	ADB	13	Existing
5	Salin township, Magway	Solar PV	SolaRiseSys	ADB	6.5	Existing
6	Pauk township, Magway	Solar PV	SolaRiseSys	ADB	6	Existing
7	Kyaukse township, Mandalay	Solar PV	SolaRiseSys	ADB	10.8	Existing
8	Nyaung-U township, Mandalay	Solar PV	SolaRiseSys	ADB	9.8	Existing
9	Kyaukpadaung township, Mandalay	Solar PV	SolaRiseSys	ADB	4.9	Existing
10	Taungtha township, Mandalay	Solar PV	SolaRiseSys	ADB	4.9	Existing
11	Sagaing township, Sagaing	Solar PV	SolaRiseSys	ADB	6	Existing
12	Khin-U township, Sagaing	Solar PV	SolaRiseSys	ADB	7	Existing
13-24	11 locations in Shan and Chin States	Solar PV	Sunlabob Renewable Energy	Japan International Cooperation System (JICS)	700 (11 projects)	Existing
25	Island in Tanintharyi Region	Solar PV	Myanmar Eco Solutions	EAM Solar, PPT, World View International	300	Existing

	Location	Technology	Developer	Financial backing	Capacity [kW]	Status
26	Sagaing	Solar PV	Yoma Micro Power	n.a	n.a	Existing
27	Sagaing	Solar PV	Yoma Micro Power	n.a	n.a	Existing
28	Sagaing	Solar PV	Yoma Micro Power	n.a	n.a	Existing
29	Sagaing	Solar PV	Yoma Micro Power	n.a	n.a	Existing
30	Yin Ma Chaung village	Solar PV	Panasonic	Mitsui & Co.	2.82	Existing
31	Baingbin Senna Village, Ayeyawady	Solar PV	Panasonic	Association for Rengein Tanjoji International Cooperation (ARTIC)	n.a.	Existing
32	Yesago Township, Magway	Solar PV	Parami Energy, EEP Mekong	(DRD) Development (DRD)	300	Existing
33	Pindaya town, Shan	Micro-hydro	Sea Pelicon Co. Ltd	Department of Rural evelopment (DRD)	n.a.	n.a.
34	Ton Lon village	Diesel	Village Electrification Committee	Department of Rural evelopment (DRD)	10	Existing
35	Ayeyarwaddy Delta	Solar PV	Indigo Energy	Constant Energy	<500	Existing
36	Ayeyarwaddy Delta	Solar PV	Indigo Energy	Constant Energy	<500	Existing



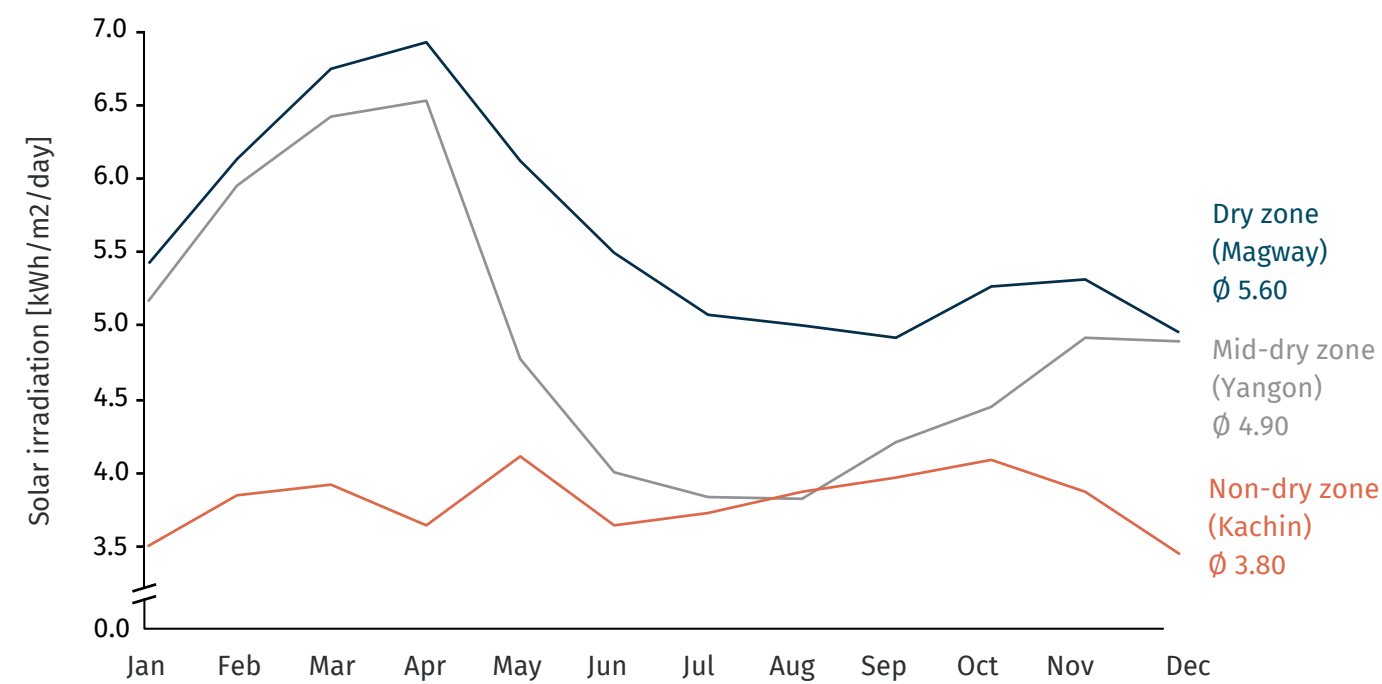
	Location	Technology	Developer	Financial backing	Capacity [kW]	Status
37	Tanintharyi	Solar PV	Indigo Energy	Constant Energy	80.46	Existing
38	Bago and Ayeyarwad-dy regions	Solar PV	Voltalia	MNTI	342	Announced
39	Shan State	Micro-hydro	Sai Htun Hla Brother Co.	n.a.	150	Existing (multiple projects)
40	Magway	Solar PV	Mandalay Yoma	DRD	n.a.	Under construction
41	Mandalay	Solar PV	Mandalay Yoma	n.a.	510	Under construction
42	Lay Tup Village, Chin	Micro-hydro	Anna Service	DRD	150	Under construction
43	Mae Za Taw Village, Sagaing	Solar PV, Diesel	Kinetic Myanmar Tech	DRD	81	Under construction
44	Chaung Shay Village, Sagaing	Solar PV, Diesel	Sun Power	DRD	189	Announced
45	Kaw Yar Village, Sagaing	Solar PV, Diesel	Sun Power	DRD	236	Announced
46	Bant Gway Village, Sagaing	Solar PV, Diesel	Mandalay Yoma	DRD	103	Under construction
47	Kyar Si Village, Sagaing	Solar PV, Diesel	Mandalay Yoma	DRD	103	Under construction
48	Kwin Sat Village, Sagaing	Solar PV, Diesel	Mandalay Yoma	DRD	103	Under construction
49	Hse Pin Kyun Village, Sagaing	Solar PV, Diesel	Mega Global Green Automation	DRD	189	Under construction
50	Than Pyar Chaung Village, Magway	Solar PV, Diesel	Pro-Engineering	DRD	79	Under construction
51	Yayzagyo Township, Magway	Solar PV, Diesel	Parami Energy Service	DRD	448	Announced
52	Sa Bar Yin Dwin Village, Magway	Solar PV, Diesel	Mandalay Yoma	DRD	98	Under construction
53	Yay Nan Chaung Township, Magway	Solar PV, Diesel	Mega Global Green Automation	DRD	156	Announced

	Location	Technology	Developer	Financial backing	Capacity [kW]	Status
54	Kyaunk Pan Taung Township, Mandalay	Solar PV, Diesel	Innovative Systems	DRD	115	Announced
57	Byat Ka Lay Village, Bago	Solar PV, Diesel	Talent & Technology	DRD	55	Under construction
58	Kouk Kine	Solar PV, Diesel	Talent & Technology	DRD	55	Under construction
59	Htan Ta Pin Township, Bago	Solar PV, Diesel	Kinetic Myanmar Tech	DRD	146	Announced
54	Kyaunk Pan Taung Township, Mandalay	Solar PV, Diesel	Innovative Systems	DRD	115	Announced
57	Byat Ka Lay Village, Bago	Solar PV, Diesel	Talent & Technology	DRD	55	Under construction
58	Kouk Kine	Solar PV, Diesel	Talent & Technology	DRD	55	Under construction
59	Htan Ta Pin Township, Bago	Solar PV, Diesel	Kinetic Myanmar Tech	DRD	146	Announced
60	Taat Thit Kyun, Bago	Solar PV, Diesel	Mega Global Green Automation	DRD	190	Under construction
61	Kalarma Kaung Village, Tanintharyi	Solar PV, Diesel	Techno-Hill	DRD	64	Under construction
62	Lat Pat Village, Tanintharyi	Solar PV, Diesel	Techno-Hill	DRD	156	Under construction
63	Kan Maw Gyi Village, Tanintharyi	Solar PV, Diesel	Techno-Hill	DRD	121	Under construction
64	Taung Kaung Laung Village, Tanintharyi	Solar PV, Diesel	Techno-Hill	DRD	64	Under construction
65	Pyin Gyi Village, Tanintharyi	Solar PV, Diesel	Techno-Hill	DRD	64	Announced
66	Kanti Village, Tanintharyi	Solar PV	Techno-Hill	DRD	49	Announced
67	B Tupt Village, Ayeyarwady	Biomass	Royal Htoo Linn Manufacturing	DRD	160	Under construction
68	Yesagyo township, Magway	Solar PV	Parami Energy	DRD	n.a.	Announced

Annex 9

Average solar irradiation

Figure 86. Avarage solar irradiation each month for each zone



Source: ADB, World Bank





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