State of the Global Mini-grids Market Report 2020

Trends of renewable energy hybrid mini-grids in Sub-Saharan Africa, Asia and island nations

MGP MINI-GRIDS PARTNERSHIP

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SUSTAINABLE ENERGY FOR ALL

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About the report

This *State of the Global Mini-grids Market Report 2020* aims to raise awareness about mini-grids, mobilizing investments in the mini-grid sector and serving as a benchmark to measure progress in the sector for decision-makers. It provides the latest updates on the global mini-grids market and highlights key trends in the industry that, together, can stand as the definitive source of information for stakeholders. The authors of this report were commissioned to conduct the research between October 2019 and April 2020 and produce the report on behalf of the Mini-Grids Partnership (MGP).

Goals

This research has three primary goals. The first is to provide stakeholders in the mini-grid sector with the most up-to date information and analysis of the market status and trends in the sector. The second is to propose recommendations for key stakeholders to address the challenges identified in the research in developing the mini-grid market. The third is to build an open source mini-grid asset database.

Scope

The primary scope of this research is mini-grid systems that serve remote and island communities in Sub-Saharan Africa, emerging Asia and island nations. The majority of these systems are isolated, but those connected to the main grid were not excluded. The sizes of the systems are mostly up to 100kW or so as typical consumers are households with low power demand, public buildings and small-scale commercial and industrial (C&I) customers. There are some exceptions of systems above 1MW where the mini-grid serves a number of large power consumers. For the purposes of comparison, the research also investigated mini-grid projects and businesses outside Sub-Saharan Africa, Asia and island nations.

Methodology

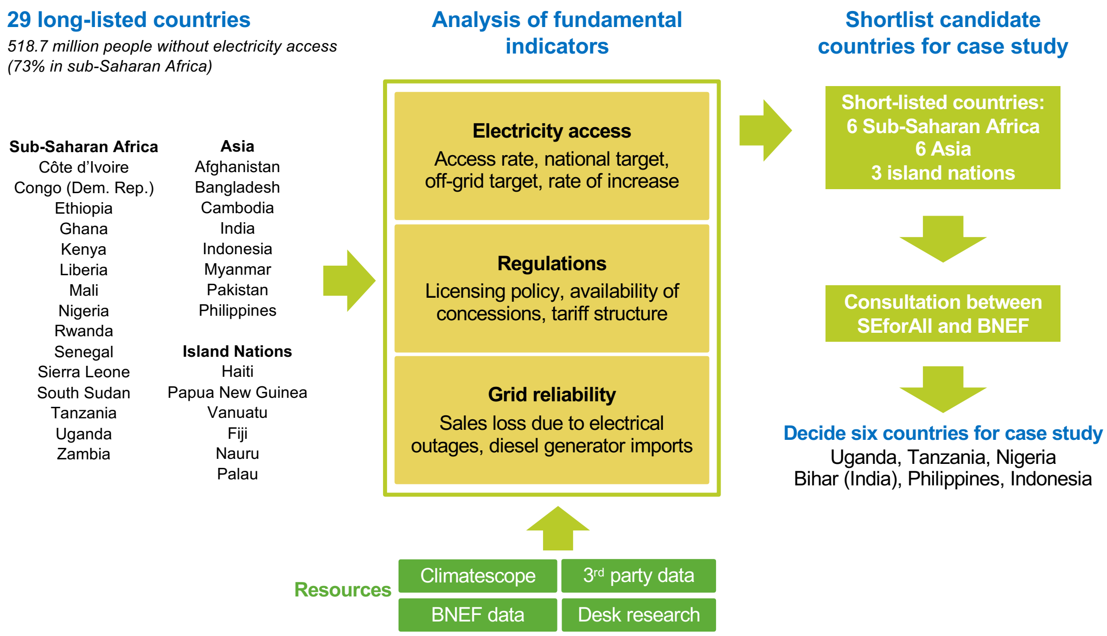
The authors combined various research methodologies to conduct the research. They include literature reviews, semi-structured interviews and quantitative modelling analysis.

The review of existing literature included the authors' existing research publications, academic articles, reports published by other research organizations, news articles and company press releases. The authors conducted structured interviews with 68 organizations to collect information and data from mini-grid developers, financiers, donor agencies, research institutes, non-profit organizations and technology vendors. Information and data gathered were used to analyze the status of the mini-grid market, policy and regulations, financing, economics, impacts and case studies (Sections 4-9 and 11-16). The authors conducted quantitative modelling analysis to calculate levelized costs of electricity (LCOEs) (Section 8) and to analyze the addressable market size of mini-grids by 2030 under business-as-usual and universal electricity access scenarios (Section 10).

The authors also conducted case studies of six countries - Uganda, Tanzania, Nigeria, India (Bihar), the Philippines, and Indonesia (Sections 11-16). The selection process of these case study countries included analysis of fundamental indicators such as electricity access, regulation and grid reliability for 29 countries in Sub-Saharan Africa, Asia and island nations (Figure 1). The authors selected the six countries taking into account opinions from the MGP Advisory Group to ensure diversity of countries across regions, geographies, regulations and coverage by existing research publications. Key findings from the case studies were also used in the analysis contained in other parts of the report (Sections 1-10).

Figure 1

Selection methodology of case study countries



Source: BloombergNEF.

Mini-grid project data collection

A mini-grid is a group of interconnected distributed energy resources (DERs) plus loads or a single DER plus load(s) within clearly-defined boundaries. The main feature of mini-grids is their ability to operate independently, enabling them to be set up in remote locations that the main grid does not reach. Mini-grids can be isolated or connected to a grid.

The primary focus of this research is rural communities in Sub-Saharan Africa, Asia and small island nations. Between October 2019 and February 2020, the authors collected mini-grid project data both for the analysis in this research and in order to build an open-source database. Data were collected on 7,181 mini-grid assets of which 5,544 were operational.

This number of mini-grid assets is much smalller than the 19,000 installed mini-grids for which the Energy Sector Management Assistance Program (ESMAP) collected data in its report, *Mini Grids for a Half a Billion People*. As much as 89 percent of the 19,000 installed mini-grids are in 10 countries: Afghanistan (4,980), Myanmar (3,988), India (2,800), Nepal (1,519), China (1,184), the Philippines (896), Indonesia (583), Russia (501), US (391), and Senegal (272) (ESMAP, 2019). Of these, China, Russia and the US are among the top 10 countries by number of operating mini-grids. The 2,076 recorded projects equate to just over 10 percent of all the projects. In the database built in this research, projects situated in more developed economies including China, Russia and the US were excluded as these mini-grids are most likely used for purposes other than energy access.

In the ESMAP report, the vast majority of the installed mini-grids counted are first- and second-generation mini-grids (e.g., diesel mini-grids and hydro mini-grids). Thousands of these mini-grids are not included in the database in this study, which puts greater emphasis on third-generation systems (e.g., renewable hybrid systems).

In general, first- and second-generation mini-grid systems are often small and not well publicized systems that have been developed by local communities or entrepreneurs. Third-generation systems, by contrast, are far better documented as they often involve non-local investors or others. The data collection for the report focused primarily on renewable mini-grids that are predominant among projects installed in the last five years in order to analyze recent market trends. Mini-grid stakeholders tend to formulate policy/regulation, commit financing, and introduce newer technologies as well as business models with such mini-grid systems in mind.

See Appendix A for more details about the mini-grid database.

Report structure

The report has five parts. The Executive Summary highlights the report's key findings from Parts 1–4 but excludes key points from the case studies (Part 5).

Part 1: Conclusions and recommendations (Section 1) opens the discussion of why the rural mini-grid market has struggled to emerge, by comparing the way in which renewable energy markets for bulk generation have evolved. It points out three fundamental differences between the two markets. It highlights the actions key stakeholders – governments, development finance institutions (DFIs)/donor agencies, financiers and developers – should take for the mini-grid market to scale and provide access to electricity.

Part 2: Mini-grid market status (Sections 2–5) aims to help readers understand mini-grids in general and their relevance to electricity access. It also details the latest status of the mini-grid market including the number of mini-grids installed in Sub-Saharan Africa, Asia and island nations, as well as industry trends, business models and technologies used.

Part 3: Analysis (Sections 6–9) highlights trends in policy and regulation, financing and economics, and describes key challenges that mini-grid developers and investors face. It also describes examples of innovative policies and financing mechanisms. The economic analysis compares levelized costs of electricity (LCOE) of different mini-grid types and discusses why higher utilization of solar hybrid mini-grids is important for mini-grid operators to achieve better economic returns. It also provides a framework to categorize the different impacts that mini-grid projects can have, and highlights impact metrics used in the mini-grid and broader clean energy sectors.

Part 4: Outlook (Section 10) analyzes how mini-grid markets are likely to grow in Sub-Saharan Africa, Asia and island nations. It also analyzes the addressable market size in terms of the number of households that could be connected to mini-grids and the capital expenditure required, comparing business-as-usual and universal electricity access scenarios.

Part 5: Case studies (Sections 11–16) analyzes the current status of the market and key market players, policy and regulations in six selected countries: Uganda, Tanzania, Nigeria, India (Bihar), the Philippines and Indonesia. Findings in the case studies also form part of the basis for the entire research.

Contents

Executive summary

Mini-grids play a critical role in providing electricity to rural communities and businesses and in helping to connect the 900 million people worldwide who currently do not have access. Today the mini-grid market is nascent, despite being the least-cost option for electricity access in many areas. Two challenges need to be overcome for mini-grids to scale up and realize their potential.

5,544
Installed mini-grids in Sub-Saharan Africa, Asia and small island nations with some in Latin America

Firstly, rural customers in need of electricity access often have limited power demand and sometimes lack the ability to pay. Some developers are targeting small businesses and industrial users alongside residential consumers, to increase the average level of revenues and hence profitability. Others are financing appliances to boost demand, or even becoming off-takers.

$0.49-0.68/kWh
Estimated cost of electricity for isolated solar hybrid mini-grids for productive-use customers plus households

Secondly, there is a general lack of policies and regulations that support mini-grids. Almost all rural mini-grids require public funding, with relatively little private finance in evidence. Fortunately, a small number of countries are setting up clear frameworks designed to expand the mini-grid market, and are attracting private sector interest. The governments of these countries have stated a clear goal of expanding energy access dramatically and are pragmatic and flexible about the tools needed to meet that goal.

111 million
Households that can be served by mini-grids in Sub-Saharan Africa, Asia and island nations by 2030

State of the Global Mini-grids Market Report 2020 is an industry-focused report on the global mini-grid market, looking at technologies, businesses, regulations, financing, economics and impact assessments. It targets not only those working directly in the mini-grid sector but also others who are keen to understand the part that mini-grids can play in ensuring electricity access. The report makes recommendations on the actions needed to realize the full potential that mini-grids offer in developing countries.

Market status and outlook

Why mini-grids? (Section 2, 3)

- By the end of 2018, the total estimated number of people who lack access to electricity globally had fallen to about 900 million (789 million in the *SDG7 Tracking Report*, from 1.4 billion in 2010. Grid extension as well as rapid deployment of off-grid solar kits contributed to this remarkable progress, particularly in Asia. In Sub-Saharan Africa, the number of people who do not have access has hovered at around 600 million in recent years. At current trends, and given continued population growth, universal electricity access will not be achieved by 2030. About 620 million people would still be deprived of access, according to the International Energy Agency (IEA, 2019).
- New technologies are enabling electricity to be provided through much more decentralized networks, as the costs of PV and battery energy storage have continued to fall sharply, and remote connectivity, control and data analysis have expanded the range of options available. Solar

Definition of mini-grids and mini-grid asset data

A mini-grid is a group of interconnected distributed energy resources (DERs) plus load(s) or a single DER plus load(s) within clearly-defined boundaries. The main feature of mini-grids is the ability to operate independently, enabling them to be set up in remote locations that the main grid does not reach. Mini-grids can be totally isolated or grid-connected. The most important customer segments in this research are rural communities in Sub-Saharan Africa, developing Asia and small island nations. The authors collected records of 7,181 mini-grid assets, of which 5,544 were operational. Note that this figure does not include thousands of installed mini-grids that are fossil fuel-based or hydro based. The data collection for the report focused primarily on renewable hybrid mini-grids that are predominant among projects installed in the last five years and represent recent market trends. See Appendix A for more details about the database.

hybrid mini-grids that integrate PV and other DER(s) can complement and compete with main grid extensions in terms of the cost of electricity and the speed of deployment.

- Grid extension has been the predominant approach to provide electricity access. However, the areas that the main grid can reach more economically than off-grid alternatives are slowly being exhausted and the incremental costs of adding new rural customers via this route are becoming prohibitive. It is critical for governments and utilities to take a least-cost approach that takes advantage of the breadth of technology options, particularly given that many state-owned utilities are debt ridden and the need for electricity access urgent.

What is the market size today? (Section 4, 5)

- The authors of the report identified 7,181 mini-grid projects in Sub-Saharan Africa, Asia and small island nations with some in Latin America, as of March 2020. As many as 5,544 mini-grids were operational, of which 63 percent were solar or solar hybrid systems, 21 percent hydro, and 11 percent diesel/heavy fuel oil. The mini-grids already installed today represent only a small fraction of the total needed for full rural electrification.

How has the market evolved? (Section 4, 5)

- The fastest growing segment of the global mini-grids market is that of solar hybrid mini-grids.

Figure 2

Installed mini-grids by region

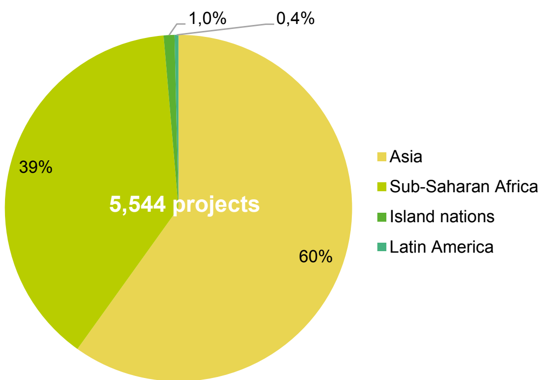
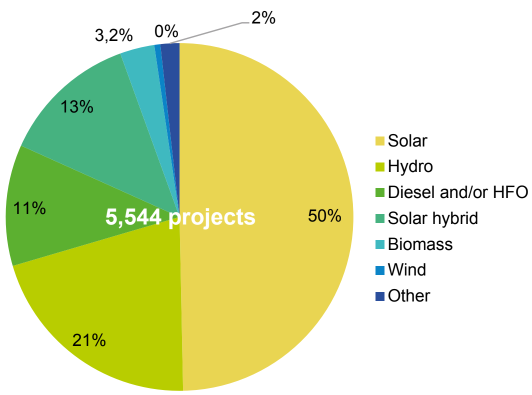


Figure 3

Installed mini-grids by technology



Source: BloombergNEF, GIZ, Carbon Trust, CLUB-ER, surveyed developers.

While 32 percent of installed mini-grids are diesel/heavy fuel oil (HFO) or hydro systems, PV is the generation technology most predominantly used for mini-grids being installed today.

- Typical modern mini-grids installed today combine energy storage with PV. At the moment, developers favour lead-acid batteries because they are more readily available and have a lower upfront cost than alternatives. However, with the sharp decline in technology costs, developers are beginning to use lithium-ion batteries more frequently. The authors estimate that 66 percent of mini-grids with battery storage installed in 2019 used lead-acid while 32 percent used lithium-ion. They do however expect this ratio to change.
- Most mini-grid developers are small-scale companies or start-ups. In recent years, as the solar hybrid mini-grid market has evolved, large and international corporates have also joined their ranks. Some have done this by acquiring companies that offer battery storage systems, uninterrupted power supply (UPS) and control software technologies. Others have partnered with developers or invested in them. Examples include major utilities and oil companies such as EDF, Enel, ENGIE, Iberdrola, Shell and Tokyo Electric. Japanese trading houses such as Mitsui and Sumitomo have also invested in mini-grid developers. Their market participation has partly driven by a desire to contribute to the Sustainable Development Goals (SDGs) adopted by World Leaders at the UN General Assembly in 2015.
- A typical challenge for mini-grid developers is the limited power demand and ability to pay of rural residential customers. Failing to stimulate these customers' power consumption means that it takes longer to reach a breakeven point for mini-grid projects. Business models for mini-grids are diverse, but such models are increasingly looking at ways to stimulate use of mini-grid electricity to make projects viable. In addition to serving residential customers, some developers are also targeting productive-use customers such as small businesses and industrial users, agricultural equipment users and telecom towers that have higher and more predictable power demands than residential customers, to improve average revenue per user (ARPU).
- Some developers have gone beyond selling electricity alone and offer appliance financing that allows customers to use appliances without any upfront costs. Others have adopted a KeyMaker model in which they procure raw products or materials (such as fish) from the local community, use mini-grid electricity to process them, and sell the final product (e.g., processed fish) at higher prices to customers in urban areas.

What is the potential market size of mini-grids by 2030? (Section 10)

- 238 million households will need to gain electricity access in Sub-Saharan Africa, Asia and island nations by 2030 to achieve universal electricity access. Mini-grids can serve almost half of this total – an estimated 111 million households. This will require capital investment of USD 128 billion, 78 percent higher than the estimated capital investment in a business-as-usual scenario. Mini-

Figure 4

Technology use, 2020–30

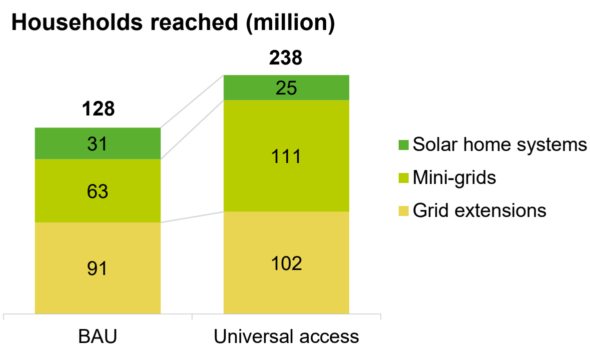
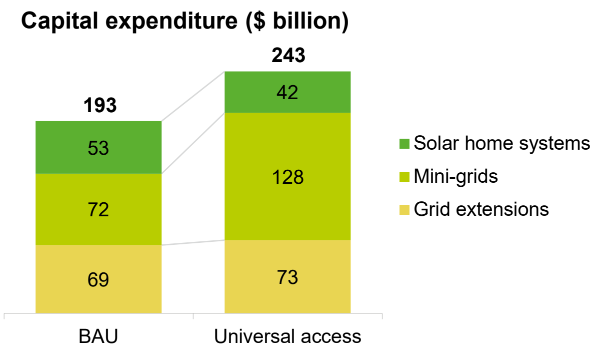


Figure 5

Estimated capital expenditure, 2020–30



Source: BloombergNEF. **Note:** BAU stands for 'Business-as-usual'. Assumes all the mini-grids are solar hybrid systems.

grid technology is the most suitable option for many low- and medium-density areas and can address a larger number of low-income families more economically than the alternative options.

Other findings

Policy and regulations (Section 6)

- ***What is the current status?*** The most impactful policies for mini-grid development are those relating to subsidies, licensing, tariff setting and grid arrival. Two main types of government subsidy have driven mini-grid project development: upfront capex subsidy and results-based financing (RBF). The former is a capex payment disbursed before a mini-grid is installed. The latter pays specified sums on projects only once there is clear verification of a functional electricity connection. This gives the public sector greater control and certainty as it only pays for results. The authors believe that this results-based approach is an important and valuable financing mechanism for the mini-grid sector.
- ***What is working?*** Some governments, such as that of Nigeria, have set regulations to reduce the risks to a mini-grid if the main grid arrives later at the same location. Developers can select from a range of options: receive compensation, continue running and deriving revenue from the mini-grid (including an option that developers receive compensation for only the distribution system), or operate alongside the main grid. Other governments such as that of the Philippines are working on a law that will allow for information disclosure and streamlined procedures for renewable hybrid mini-grids in unserved and underserved areas.
- ***What are the challenges?*** Ambiguous rural electrification policies, lack of flexibility in setting mini-grid tariffs, and complex and lengthy licensing processes are some of the major challenges that hinder mini-grid projects. There is also growing public and political sensitivity to electricity tariffs, making flexible tariff setting difficult (e.g., in Tanzania). In contrast to Nigeria, many governments lack regulations that protect isolated mini-grids if the main grid arrives. Without such regulations, the state may expropriate mini-grid assets with minimal compensation, or in the worst case, they can be stranded. Even when there are regulations in place, governments and state-owned utilities do not always enforce them.
- ***How can these challenges be overcome?*** Governments need to set clear goals for electricity access by technology with strong political initiatives. They need to establish single points of authority with powers to streamline the licensing

Figure 6

Clear rules on the arrival of the main grid across surveyed countries, 2018

Source: Climatescope 2019, BloombergNEF.

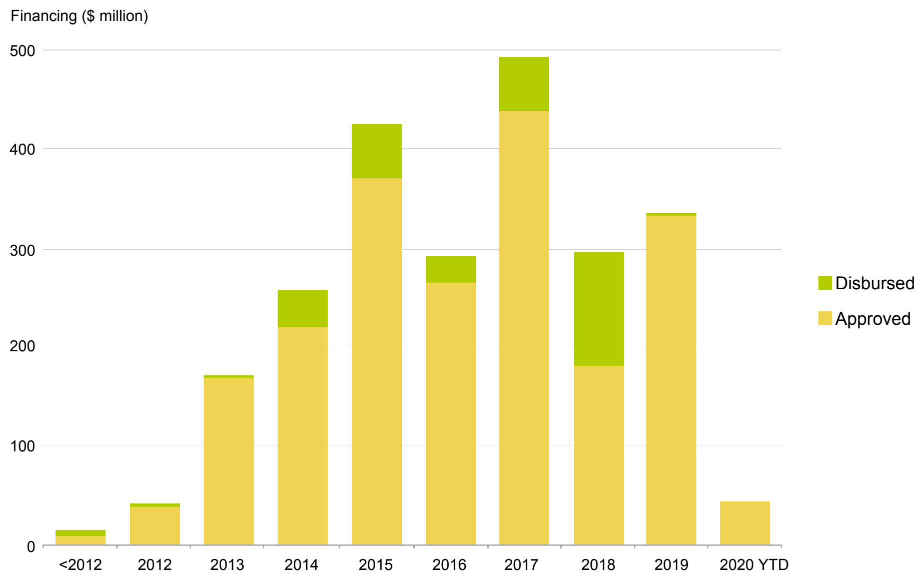
process, relax size thresholds for required licensing, deregulate tariffs, and build a robust set of rules around grid arrival to protect isolated mini-grid assets.

Financing (Section 7)

- ***What is the current status?*** Most mini-grid developers have relied on public funding such as grants from governments, development finance institutions (DFIs), donor agencies and foundations. To date, most committed financing has come from grants and developers' balance sheets, with limited debt financing. RBF has increased significantly and is favoured by developers as well as private investors, because it improves returns, reduces risks of early stage debt or equity finance, and potentially unlocks private capital (e.g., working capital needed to pre-finance connections and project equity needed for pre-development costs), provided the investors are confident of the developer's ability to deliver electricity connections.
- ***What is working?*** Some developers have successfully raised commercial financing. An increasing number of strategic financiers such as utilities, oil majors and trading houses have participated in the mini-grid sector since 2018. In 2019, the first project financing of a portfolio of mini-grid projects in Tanzania was secured (Rockefeller Foundation, 2019). Involvement of public funders for financing (e.g., RBF) or guarantees is critical in encouraging private financiers to participate in the market and in helping them overcome perceived risks.
- ***What are the challenges?*** According to the Mini-grids Funders Group, 14 funders had approved a total of USD 2.07 billion by March 2020, of which only 13 percent had been disbursed. While the picture on the ground is likely to be better than the data suggest, it is clear that there can be significant delays in getting funding, and therefore in projects moving forward. There is also a lack of pure commercial financing as the mini-grid market lacks scale, developers' project track records are limited (hence, project risks are not yet fully transparent), regulations are unclear, and residential consumers have limited power demand as well as limited ability to pay.
- ***How can these challenges be overcome?*** Funding deployment may be quicker as the market matures. This is also linked to the policy and regulations of the countries where recipients of funding are located. Governments need to take strong initiatives and promote robust regulatory frameworks that support the development of

Figure 7

Approved and disbursed financing in the mini-grid sector



Source: Mini-grids Funders Group, Carbon Trust, BloombergNEF. Note: YTD = March 20 2020.

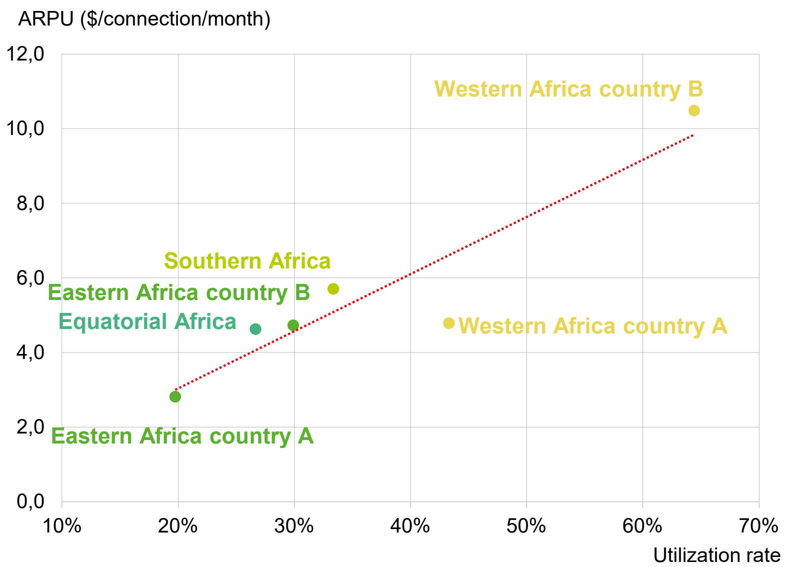
mini-grids. Public funders need to continue and expand financing assistance for mini-grid development, in particular using RBF. These can in turn attract more commercial financing.

Economics (Section 8)

- ***What is the current status?*** Installing PV modules in mini-grids generally improves their economics as compared to just using diesel. Adding day-time demand can cut the overall cost of electricity as it correlates with the generation profiles of PV systems powered by the sun. This boosts the utilization rate of the mini-grid, leading to a lower cost of electricity and higher average revenue per user (ARPU). Levelized costs of electricity (LCOEs) ranged from USD 0.49–0.68/kWh for solar hybrid mini-grids operating in isolated areas and serving both households and productive use customers in the six case study countries. LCOEs are different mainly due to varying prices for diesel, equipment, installation and financing.
- ***What is working?*** Developers increasingly tend to select sites where a certain level of economic activity or anchor load is present within rural communities. Some have adapted their business models to increase revenues by managing tariff structures and stimulating the power demand of their customers (e.g., offering appliance finance) or even becoming productive users of mini-grid electricity themselves (the KeyMaker business model).
- ***What are the challenges?*** The electricity from solar hybrid mini-grids is still expensive for many rural customers who have limited ability and willingness to pay. While rural communities do have productive-use customers (e.g., those using agricultural equipment), who can help boost revenues for the mini-grid, in practice, they do not always use electricity in the day when PV generates electricity.
- ***How can these challenges be overcome?*** Public funding, such as RBF grants, continues to be critical to the economic viability of rural mini-grids. Developers can improve revenues through business models or initiatives that prompt customers to use more electricity in the day. Setting tariff structures that guarantee a certain minimal level of revenue is also an option. Governments should allow developers to set their tariffs flexibly, especially for small-scale projects (i.e., below 100kW). Subsidies for tariffs can be an alternative means to overcome the barrier of high electricity costs to consumers. Such incentives can encourage consumers to increase power consumption, which, in turn, improves the mini-grid operator's revenues.

Figure 8

Correlation between utilization rate and ARPU



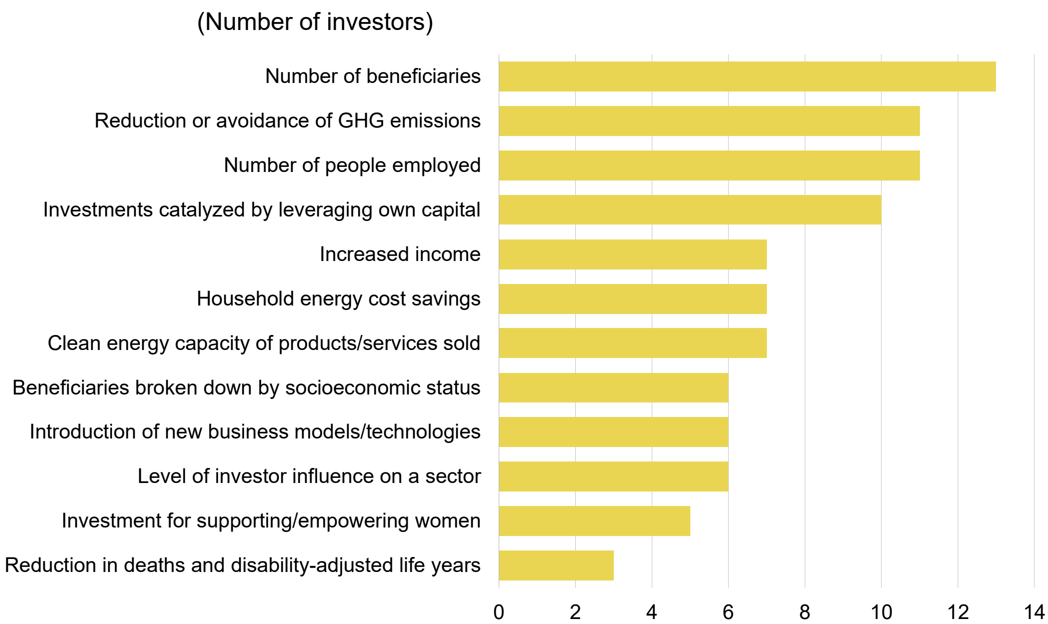
Source: Africa Minigrid Developers Association (AMDA), ECA. **Note:** Each dot represents weighted average ARPU in a specific country in Sub-Saharan Africa. The data were collected from AMDA's member developers who are operating mini-grid projects with 11,882 connections.

Impact (Section 9)

- ***What is the current status?*** Impact metrics that financiers have adopted vary according to their objectives. Metrics are also used selectively for specific transactions for financing according to their relevance to the investee, business model, customers, or type of product or service. Metrics that are easier to measure, for example, the number of beneficiaries, the reduction of greenhouse gas emissions or the number of jobs created are more commonly used.
- ***What is working?*** Some organizations have developed innovative impact assessment metrics for off-grid projects and collected impact data. Acumen developed Lean Data, focusing on changes in the quality of life of the customers who use the products and services of social enterprises, including those implementing mini-grid projects. It invested heavily in remote data collection via mobile phones (i.e., SMS, phone calls and online surveys) to lower the cost and reduce the time needed for gathering data to assess these impacts.
- ***What are the challenges?*** There is no commonly accepted approach to gather and report impact data for electricity access projects. Calculating the number of people with access to electricity is straightforward but does not measure how the lives of rural communities have benefitted from electricity access projects. Some social impacts are difficult to measure as they are complex and may only appear in the long term. More impact data are needed to attract investors who are interested in investing in projects with beneficial environmental and social impacts, and in being able to inform their stakeholders of the results.
- ***How can these challenges be overcome?*** The mini-grid sector needs to assemble impact data for mini-grid projects using some of the established metrics. For example, DFIs, donor agencies and impact investors can insist that the recipients of funds (i.e., developers) collect impact data from the end consumers that they serve. The sector can then use those data in aggregate to understand what is working, and to attract financiers who are interested in investing for impact creation (e.g., in line with the SDGs).

Figure 9

Metrics used for impact assessment by investors in the clean energy sector



Source: GIIN, BloombergNEF. **Note:** Surveyed financiers include Acumen, Bamboo Finance, Calvert Foundation, Deutsche Bank, Doen Foundation, FMO, Global Alliance for Clean Cooking, Gray Ghost Ventures, LGTVP, Lunch Foundation, IDFC (former OPIC), responsAbility, Shell Foundation. Names of some of the metrics have been slightly modified for the sake of simplicity.