ENERGY
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Technical Guide: Mini Grids

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Technical guide: Mini grids

According to the International Energy Agency, decentralised systems – including mini grids – will make up nearly three-quarters of the additional connections to meet Sustainable Development Goal 7: universal electricity access by 2030. Nearly all of these connections will be powered by renewables as a result of falling costs, technological advancements and more efficient appliances.

The World Bank estimates that in 2019, 47 million people worldwide were connected to 19,000 mini grids, mostly hydro and diesel-powered, at a total investment cost of $28 billion. In addition 7,500 new mini grids were planned, mostly in Africa, mostly solar-hybrid, connecting more than 27 million people at an investment cost of $12 billion. In order to reach universal access by 2030, 490 million people will have to be served by at least 210,000 mini grids, mostly solar-hybrids, requiring an investment of $220 billion.

The top 3 Private-Sector Developers in the mini grid space (based on number of mini grids they operate) are PowerGen (in seven countries in Africa) with over 100 mini grids, OMC (India) with 99 operational mini grids and Husk Power (India) with 45 mini grids.

Defining a mini grid

A mini grid is a set of small-scale electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a small, localised group of customers, operating independently from the national transmission grid. They range in size from a few kilowatts up to 10 megawatts. Smaller mini-grids are sometimes referred as "micro-grids", “pico-grids” or "nano-grids".

Mini-grids can serve a wide range of customers. These include private households, commercial businesses such as shops, ice makers and mobile phone chargers, agricultural loads such as irrigation pumping and cold storage, productive loads such as grind mills and wood or metal working shops, and semi-industrials such as telecom towers, processing plants or flower farms.

Mini grids can be developed or operated by state utilities, private companies, communities, non-governmental organisations, or a mix of different players such as public-private partnerships. The generation and distribution assets may be developed and managed by different players, both public and private. The mini grids can run on diesel, renewables (solar PV, hydro, wind, biomass etc) or as renewable-diesel hybrids.

Mini grids are generally the most economically viable option for servicing areas that are too expensive for the

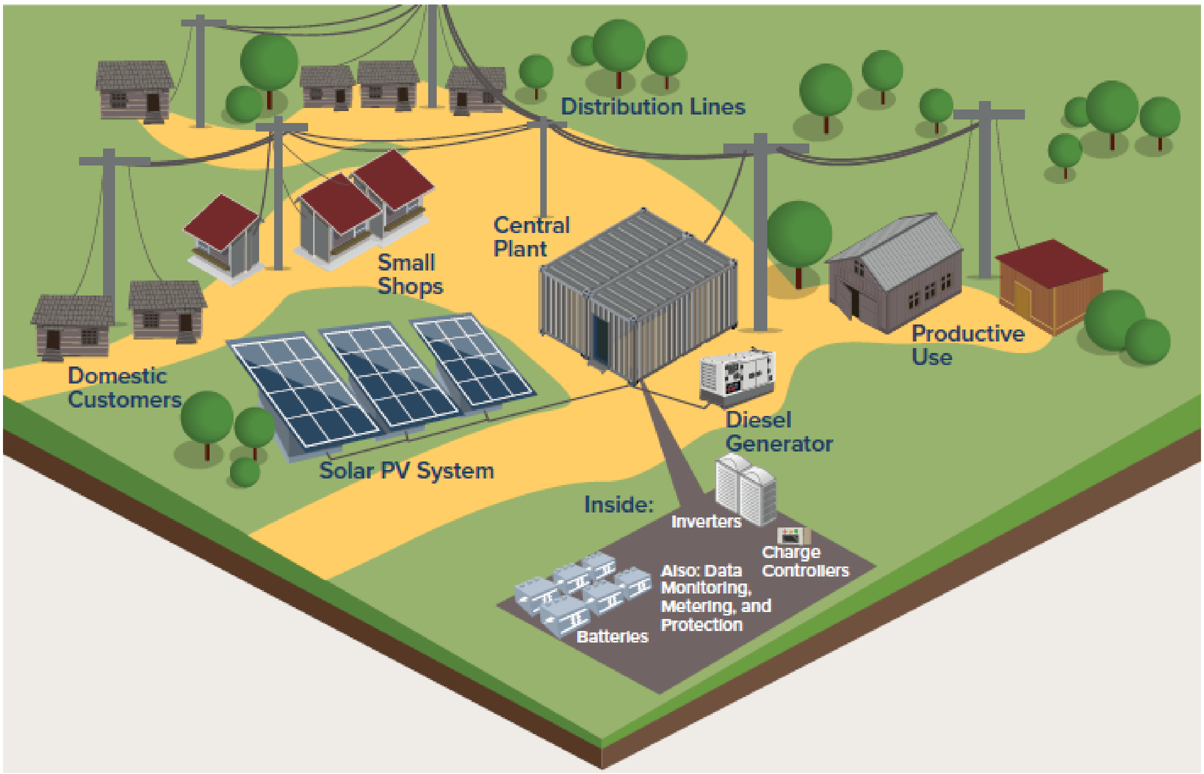

Figure 1 Typical layout of a mini grid (RMI)

main grid to reach in a timely manner, but have high enough demand and population density to support commercial viability. Compared with the main grid and solar home systems, mini grids are a more viable solution for off-grid areas with high population density and demand. Extending the main grid to serve remote communities that consume a limited number of kilowatt-hours (kWh) per month is prohibitively costly in most cases. Meanwhile, solar home systems are ideal for areas with low population density and low demand.

Barriers to scaling-up mini grids

There remain several barriers to the scaling-up of mini-grids, including:

- **Inadequate regulation, policy gaps or uncertainty:** Unclear levels of policy commitment to and the lack of regulatory frameworks for mini-grids are an issue. The inability to charge cost-reflective tariffs is a key barrier, as is uncertainty over whether and when the grid will arrive, and what options are available to avoid stranded assets when the grid does arrive.
- **Lack of proven commercial business models**: Fundamental operational challenges in serving remote and low-income markets (accessibility, distance between residential and commercial users, low or unpredictable demand, reliable income streams, and maintenance) make it difficult to size and operate mini grids on a commercial basis, particularly in the absence of adequate support and de-risking mechanisms.
- **Lack of access to affordable longer-term finance**: Commercial banks and venture capital investors perceive a greater risk in mini grids due to limited sector experience/exposure. Market rate debt is prohibitively expensive and access to project financing is limited. While the situation is slowly changing, with increased interest from Development Finance Institutions, the deployment of concessionary finance to de-risk projects is frequently stymied by the absence of other forms of finance.
- **Lack of local capacity**: There is a lack of relevant technical and commercial skills to scale-up operations and financing. Furthermore, with regulatory, resource and financial situations varying between projects, mini grid types and countries (most clean energy mini grids are currently bespoke), the implementation of mini grid projects often requires external and expensive specialists.
- **Market fragmentation and unmade linkages**: Due to the nascent-stage nature of the market, particularly in Africa, there is a lack of transparent and reliable data to guide decisions (demographics, urbanisation, ability-to-pay, regulation, potential local partners). There is also tension between those driving the demand for electricity (local/national businesses, communities and sectors such as agriculture, health or water), and the international developers, technology providers and financiers, who each hold different reins for the elements needed for successful mini-grid development.

Mini grid ownership models

Mini grids in different settings are owned and managed by different actors for covering the upfront cost as well as the ongoing operation and maintenance cost of the system. Traditionally, the mini grid business models can be distinguished into four types: utility model, private model, community model and public-private model. Recently new business and financing models have emerged, which are also highlighted in this section.

Under the Utility Model, a large or medium-sized state-owned or private utility company is responsible for the installation and operation of the mini grids. This could be the national utility or, for example, the Rural Electrification Agency (or similar). The utility operates the mini grid in the same way as the main grid, with typically the same connection and usage charges as the main grid (and with that cross subsidising the typically higher costs of mini grids). This model has been used quite often for isolated diesel-generator-based mini grids, such as those owned and operated by the Kenyan utility Kenya Power. Another example is the hybrid hydropower and diesel mini grid of Semonkong in Lesotho, which is owned and operated by the national utility LEC. In this case, customers are charged the national electricity rates, although the generation costs of the electricity, particular in periods of extensive diesel usage, are considerable higher than the tariff charged.

Under the Private Model, a private company is responsible for installation, operation and maintenance of the mini grids. They generate electricity and sell it directly to the connected customers. These private companies are mostly small or medium in size and unlike the utility model, do not operate the main grid.

The private companies generate their investment capital from various sources like grants, commercial or concessional loans and equity to run the mini grids. Examples of the Private Model are the 20 villages in Tanzania across Dar es Salaam, Mabeya, Morogoro and Rukwa regions, which benefit from the mini grids owned and operated by Devergy, as well as the mini grids that Husk Power operates in India, which are powered by a combination of gasification, solar PV and battery storage.

In the Community Model, the community owns and operates the mini grid. However, the design and installation is often done by a third party, contracted by the community or on its behalf by a non-governmental organisation (NGO) or development agency. The investment capital generally comes from grants, supplemented by a cash or in-kind contribution from the community. A large number of small hydropower-based mini grids have been developed in this way, particularly in Nepal. In Malawi, Practical Action developed the community-owned MEGA project, while Renewable World, a UK-based NGO, also develops community-owned mini grids and provides the communities with training/capacity building on operating and maintaining them. They have a cluster of seven mini grids in the Lake Victoria region of Kenya.

The Public-Private Model combines different aspects of the models described above, in order to maximise effectiveness and efficiency. Hybrid business models are very diverse and may involve different entities owning and operating different parts of the system. An example of the Public-Private Model is the Mashaba Solar Mini-grid project implemented in Zimbabwe.

There are some cases where a shared assets approach is taken in developing the mini grid. For example, the private utility installs the generation assets while the electricity agency installs the distribution assets. Then the private utility is given a long-term concession to operate and maintain the entire project until they recover their investment. This is quite common in countries such as Mauritius, Nigeria, Rwanda, Tanzania, and Uganda, and is starting to pick up in the SADC region.

Technical considerations

Typically, mini grids consist of the electricity generation systems, a distribution system and end-user systems. Mini grid technical design is the process of selecting the components and configurations for each system that will deliver safe, reliable, cost-effective energy services that meet the needs of end users.

Technical design decisions depend on end users' energy needs, including load demands and times of use, as well as the cost and availability of technologies. Different technical designs have various trade-offs in cost, power reliability, grid-connection potential and load efficiency and flexibility. Computer simulations and modelling can help evaluate the options, while adherence to technical standards helps ensure safety and compatibility.

Critical in the design of a mini grid system is the correct assessment of the electricity demand, as well as the expected increase over time after customers have become used to the availability of power. Energy demand in mini grids has typically been overestimated, resulting in very low capacity factors of the electricity generation units.

From an energy demand and capacity factor perspective, the ABC model is highly preferred for mini grids. ABC stands for Anchor-Business-Community: anchor (A) customers ideally provide a predictable daytime load while requiring a continuous supply of power. There are many kinds of possible anchor

Customers, including telecom towers, petrol stations, agro-processing units, retail chains and mining companies. Business (B) customers represent local commercial establishments for whom electricity is a critical input for expanding operations or improving productivity (retail shops, carpentry shops, irrigation systems, schools, clinics, etc), while community (C) customers are primarily – but not exclusively – households that have a low and variable energy demand. The energy demand of the anchor client will be the determining design parameter for the mini grid and ensures steady, predictable income for the mini grid operator. In the absence of an anchor client or business clients, mini grid operators have resorted to either help establish these clients (existing businesses converting to electricity use or entirely new operations) by promoting productive use of energy (see the specific commercialisation guide on this topic), or even starting their own electricity consuming activities to find a use of excess electricity available in the mini grid.

Financing mini grids

Financing mini grids in developing countries is challenging. Mini grid projects typically require long-term funding (10–15 years) with low cost of capital. Banks in developing countries are often reluctant or unable to offer long-term loans, either because they lack funds or cannot risk losses due to high or uncertain inflation. In developing countries, interest rates for commercial loans may exceed 15% and have high collateral requirements.

Local banks are often not familiar with small-scale renewable energy and may lack the knowledge to assess the risks associated with these projects. This is complicated by the fact that mini grid projects generally require customisation: populations, loads and renewable energy resources vary from village to village. From the bank's perspective, mini grid assets in rural areas offer little collateral, because they are difficult to repossess and have limited value when moved from their installation location.

Mini grid project developers often lack experience in financial analysis, risk mitigation and business plan development, and may not have the resources to hire dedicated financial professionals. Securing loans is more difficult if the project developer cannot meet equity requirements. Project investors require greater financial returns to compensate for the risk of mini grid projects developed in risky political and economic environments. Despite overwhelming interest in the sector, private capital lenders still prefer grid-connected investments, because they are perceived as lower risk and provide features such as off taker insurance, which protect their investments.

A complicating factor in the financing of mini grids is the fact that there is no level playing field when it comes to grid extension. The high costs of grid extension ($1,500 - $2,000 for someone living more than 4km from the grid) require that governments and donors subsidise main grid connections by 85-100% of the capital expenditure (CAPEX), something currently not done for mini girds. For governments and donors aiming to connect rural citizens, mini grids offer a more cost effective means of building AC power systems that can support grid-like energy services, with connection costs of $1,000 per connection and lower, depending on the size and location. Rapid deployment of high-impact, future-proof mini grid electrification projects would be possible if a straightforward, repeatable funding mechanism existed to support such projects in the same way as many main grid connections are supported by bilateral donors.

Results Based Financing (RBF) mechanisms that provide financial support per installed connection might be able to bridge this gap. The World Bank (through their GPRBA programme) and EnDev provide results-based funding for mini grids. In addition, some countries are already starting to adapt an RBF approach through the local REAs. Nigeria's REA, for example, is rolling out Performance Based Grants to mini grids, Tanzania also has an RBF programme, and Uganda is in the process of designing one.

In addition, the Africa Mini-grid Developers Association (AMDA) has proposed Results Based Financing programmes for mini grids across Africa, aptly named SMART RBF: Simple, Measurable, Africa-wide, Repeatable, and Timely.

The new CrossBoundary EA – PowerGen fund

In 2019, a new funding vehicle was established by CrossBoundary Energy Access (CBEA) in partnership with PowerGen Renewable Energy, which aims to pave the way for approximately 60 new mini grids in Tanzania. The funding vehicle will purchase existing and future operating mini grids in Tanzania from the developer PowerGen, which will continue to provide long-term customer and asset management services to the mini grid customers. CBEA has committed to acquiring the mini grids from PowerGen soon after completion, providing PowerGen the certainty to develop and construct projects at scale, continually recycling its capital. As the operator, PowerGen will be incentivised to ensure the efficient operation of the sites and quality customer care via a base services fee, with the potential for a performance bonus where the grids' revenues exceed projections. The agreement also includes a developer premium, in the form of a share of the distributions from the portfolio.

Table 1: Active support programmes for mini grids

Programme	Main activities
The Green Mini Grid Help Desk	Funded by the Africa Development Bank as part of the Green Mini Grid Market Development Programme (GMG MDP). Mini grid developers receive technical assistance, from support on demand assessments to technical sizing, capital raising, procurement and installation support, commissioning, and optimisation of operations.
Beyond the Grid Fund for Africa	Power Africa's Beyond the Grid initiative focuses on unlocking investment and growth for off-grid and small-scale energy solutions on the African continent. Beyond the Grid is accelerating off-grid electricity access, focusing on two strategic priorities – household solar and micro-grids – to add 25-30 million new connections by 2030. Beyond the Grid is active in Zambia, Mozambique, Burkina Faso and Liberia.

Grid integration

Mini grids play a unique role in providing power to small communities with limited needs. But due to their limited size and scale, mini grids are less efficient than larger grids. In remote areas, mini-grids are often a final power solution. However, in peri-urban areas or small towns that grow in economic importance, mini grids are an interim solution that lasts until the national utility can extend the national grid out to them. In these cases, there are important technical, financial and legal considerations that must be addressed so that the mini grid can be integrated into the national grid, to allow local communities to benefit from the greater economies of scale that come from using the larger system. Integration into the national grid has been regulated in very few countries and is an area of constant development. Typically, the national Rural Energy Agency (or equivalent) will be your first point of contact to find out the current status on this.

Industry associations

The Africa Minigrid Developers Association (AMDA) is Africa's first trade association dedicated exclusively to the mini grid industry, and is composed of developers operating mini grids that ensure power reliability of at least 20 hours per day. The trade association aims to combine private sector innovation, efficiency and customer service with public sector support to help end energy poverty across Africa. The association also works closely with a variety of solution providers, including EPCs, hardware and software vendors and integrators, as well as investors and policy makers.

Currently, AMDA has 31 members operating across 15 countries, with staffed chapters in Kenya, Tanzania, Zambia and coming soon in Nigeria.

The Mini-Grids Partnership is a consortium of over 320 like-minded mini grid stakeholders interested in enhancing and complementing each other's work through collaboration and coordination. To this end, the Partnership seeks to be an 'umbrella' group that can bridge discrete but related stakeholders and initiatives, from both the public and private sector. The Mini-Grids Partnership was founded in 2014 under the auspices of Sustainable Energy for All.

References and further reading

GMG help desk country mini grid market assessments
https://greenminigrid.afdb.org/afdb-mini-grid-publications

Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers (World Bank ESMAP)
https://openknowledge.worldbank.org/handle/10986/31926

Opportunities and challenges in the mini-grid sector in Africa
https://eepafrica.org/bfd_download/mini-grid-study/

Power for All Fact Sheet - Mini-grids have strong socioeconomic impact beyond electricity connection and consumption
https://www.powerforall.org/application/files/2815/7355/7333/FS_Minig-rids_have_strong_socioeconomic_impact_beyond_electricity_connection_and_consumption4.pdf

USAID Mini Grid support toolkit
https://www.usaid.gov/energy/mini-grids

Useful contacts

African Minigrid Developers Association (AMDA)
+254 740 10 99 645
http://africamda.org/
communications@africamda.org

Green Mini Grid helpdesk
https://greenminigrid.afdb.org/
greenminigrid@se4all-africa-org

Mini-Grids Partnership
https://minigrids.org/

Please contact your Client Relationship Manager if you want help with introductions to specific individuals within these institutions.