SMART VILLAGES
New thinking for off-grid communities worldwide

Business models for mini-grids

Tayyab Safdar

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Smart Villages

We aim to provide policymakers, donors, and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries—technological, financial and political—and how they can be overcome. We have chosen to focus on remote off-grid villages, where local solutions (home- or institution-based systems and mini-grids) are both more realistic and cheaper than national grid extension. Our concern is to ensure that energy access results in development and the creation of “smart villages” in which many of the benefits of life in modern societies are available to rural communities.

www.e4sv.org | info@e4sv.org | @e4SmartVillages

CMEDT - Smart Villages Initiative, c/o Trinity College, Cambridge, CB2 1TQ

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1. Introduction

There are more than 1 billion people globally who lack access to electricity. Many people without access to electricity are based in rural areas. Apart from those without access to electricity, estimates suggest that there are a further two billion people who have access to electricity; however, it is highly unreliable. Reliable access to electricity is one of the pre-requisites for improving people's lives across the developing world (ARE, 2015).

There are three major modes of increasing people's access to electricity. One is to extend the national grid. While this may work in some cases, estimates of the International Energy Agency (2011) suggest that though grid extension might be the cheapest way of providing electricity to 30% of rural people without access, for the rest, extending the national grid may not be the most economical solution because of remoteness, difficult terrain, or high cost of connections due to low population densities.

To deal with these issues, it is estimated that off-grid solutions, particularly those using renewable energy, will be the most cost effective in providing electricity to the remaining 70% of the rural population. Within the ambit of off-grid electricity solutions, there are two main approaches. On the one hand are smaller home-based systems that are comprised of either diesel-gen sets or increasingly, solar-based systems. Solar-based systems can further be classified as pico-solar (up to 10 Wp) or solar-home systems (Up to 150 Wp) (Franz et al., 2014). Estimates of the International Energy Agency (IEA) suggest that for 25% of the remaining rural population for whom extending the national grid is uneconomic, electricity can be best provided using stand-alone systems. While such systems can meet household level electricity needs and support lighting and electronic equipment in schools and health clinics, they can only support a very limited range of low power productive enterprises. This means that although there could be positive impact on health and education outcomes, opportunities for income generation are limited.

At the other end of the off-grid spectrum are mini-grids that can provide electricity to a village or cluster of villages through a centralised generation system at the local level. Typically, mini-grids can have generation capacities of 10 kW to 10 MW (Franz et al., 2014). They can either be stand-alone grids or connected to the national grid depending on the location. Mini-grids have been defined as: "Integrated energy infrastructure, with loads and energy resources, including generators powered by energy sources such as solar PV and wind turbines; energy storage devices such as lead-acid batteries; power-conversion equipment such as inverters; and control, manage and monitor equipment, including battery supervisor and meters among others. Loads and energy resources are interconnected with users through a distribution system" (IRENA, 2016a: 19). Lilienthal (2013) defines mini-grids as: local producer networks that use distributed energy resources and manage local electricity supply and demand.

This report focuses on mini-grids that generate a substantial portion of electricity using renewable energy sources. The IEA (2011) estimates that mini-grids are the best solution for providing electricity to 45% of the rural population without access to electricity. Mini-grids can utilise locally available energy sources such as wind, solar, biomass, and hydro. Using locally available renewable energy sources has the advantage of low running costs, greater energy security, and lower environmental pollution.

Deploying mini-grid systems also has greater welfare impacts than home-based electricity systems. Mini-grids can provide electricity both for domestic use as well as for local businesses. They can therefore have a positive impact on the local economy and contribute to sustainable development (ibid.), and if appropriately designed, they can allow for demand growth in the future. Evidence suggests that a "meagre" provision of electricity that only supports lights and domestic appliances is not enough. Access to electricity needs to be linked with opportunities for its productive use. This realisation has meant that there is an increasing emphasis on developing business models for mini-grids that are more sustainable (Safdar and Heap, 2016). In addition to the IEA (2011) projections referred to above, estimates suggest that mini-grids represent the lowest cost option to supply electricity to almost 120,000 towns and villages in the regions of sub-Saharan Africa, South Asia and Southeast Asia (Exel, 2016).

Despite the opportunities presented by mini-grids and improvements in the technology as well as business models, they generally remain more expensive to deploy, operate, and maintain than grid-based electricity supplies for urban communities.

2. Deployment of mini-grids

While there are obvious benefits of mini-grids based on renewable energy sources, mini-grids using solar, wind, and biomass have accounted for a small portion of the mini-grid market to date. Many of the mini-grids in operation today continue to utilise expensive and polluting fossil fuels such as diesel, and there is a long history of providing electricity to remote rural and island -based communities using these systems. Diesel-based generation accounts for the second largest share of the installed off-grid generation capacity (IRENA, 2015). One of the advantages of diesel is that electricity can be generated at any time subject to the availability of fuel.

This situation is however changing and cost compulsions as well as demands to improve reliability of supply have led to an increasing trend towards the coupling of existing diesel based mini-grids with renewable energy based power generation systems. Hybrid mini-grid systems combine two different technologies for power generation, for example, renewable energy sources and a diesel based genset as a back-up.

A report by the Alliance for Rural Electrification (ARE, 2014) shows that converting diesel-based mini-grids to hybrid systems is perhaps the most competitive and cost-effective option for providing electricity to many rural areas. A study by the Frankfurt School of Business based on an analysis of seven case studies showed that hybridisation could reduce the average cost of generation in five of the seven case studies by 0.3 – 8% assuming market-based financing rates. The savings are higher at all sites if there is an assumption of subsidised financing from the public sector and the price of oil remaining the same (FSB, 2014). It also presents an excellent opportunity to increase the share of renewables in generation.

The total market size for diesel-based mini-grids that can be converted to hybrid mini-grids is in the range 50 GW to 250 GW. There are 100 GW of diesel gensets in operation worldwide that are smaller than 0.5 MW (IRENA, 2015). The total market size for mini-grids is growing and estimates suggest that it could potentially be worth more than US$200 billion per annum. China is the global leader in the development of mini-grids, however, most of these systems are connected to the national grid, with generation decentralised. India also has a significant number of rice-husk gasification mini-grids. Other countries where there are a significant number of mini-grids include Bangladesh, Cambodia, the Philippines, Morocco, and Mali (IRENA, 2015; PWC, 2016). In the Philippines, there are 108 autonomous, primarily diesel-based mini-grids spread across different islands. In sub-Saharan Africa, Mali has been the most successful country in the deployment of autonomous diesel based mini-grid systems. As the cost of renewable technology reduces, there are moves to convert many of these systems to hybrid mini-grids (PWC, 2016).

Apart from diesel-based mini-grids, installed capacity of renewable energy based mini-grids varies with respect to the technology and its maturity. Hydropower based power systems account for the lion's share of investment in renewable energy based mini-grids and the installed capacity of these small hydropower systems (1-10 MW) is about 75 GW. Installed capacity of wind, solar, and biomass based mini-grids is much lower than that of diesel and micro-hydro. It is likely that innovations will improve the transition towards 100% renewable mini-grids by increasing the penetration of renewable energy sources (IRENA, 2016a).

3. Operation models

There are four main mini-grid operation models being implemented in different parts of the world. These operational models differ in the way in which mini-grids are deployed and organised. It is important to note that there is no gold-standard operating model. The success or failure of mini-grid operation models will be context specific and will depend on many different variables such as: the environment; geography; socio-economic variables; as well as the policy/regulatory environment. Mini-grids can be comprised of two operational entities, i.e., a small power producer (SPP) and a small power distributor (SPD). An operator usually fulfils both roles, they generate electricity and then sell power to customers.

The four main mini-grid operation models are:

- Utility operated
- Private sector operated
- Community operated
- Hybrid models combining aspects of the other three models

Utility operated: The basic concept behind this model is that the national or regional electricity utility owns and operates the mini-grid. It is responsible for the installation, repair and maintenance, and operation of the mini-grid. Tariff collection is also the responsibility of the utility staff. To meet social objectives, the government may require the utility to charge prices at similar levels to those paid by customers connected to the national grid. If so, tariffs paid by larger consumers linked to the national grid may be used to cross-subsidise mini-grid consumers (Franz et al., 2014). Initial financing is likely to be provided by the utility and subsidised by actors such as the government or donors (IED, 2013).

Private-sector operated: The private sector is responsible for building, managing, and operating the mini-grid. Potential sponsors are likely to generate funding from various sources including equity and commercial loans. Subsidised funding for such mini-grid operations is also provided by the public sector (governments) and donors through grants, subsidies, or loan guarantees. Currently, there are a limited number of examples of models in which the entire funding comes from private sources. The capacity of mini-grids set up in the private sector is likely to be lower than those established by national utilities. Improvements in technology, innovations in finance and development of customer-management platforms as well as dedicated support from donors and national governments have contributed to an increasing focus on private sector operated mini-grids (IRENA, 2016a). Yadoo (2012) observes that entrepreneurs working to establish mini-grid operations in the private sector are likely to require substantial subsides as well as an anchor load.

Community operated: The mini-grid is operated and managed by a group of end-users. The local community is organised in a cooperative that is governed by government regulations. Evidence suggests that community participation contributes to the success of mini-grids. Financing for these enterprises is primarily grant based and the local community provide contributions in-kind (Smart Villages, 2015). Examples of in-kind contributions include providing land and labour as sweat-equity. In some circumstances, community-managed and -operated mini-grids may be able to provide cheaper electricity to rural communities (Yadoo, 2012). They also give the opportunity for multiple advantages to accrue to the local population such as: empowerment through local management; payment for feedstock; or, if grid-connected at a later stage, income from feed-in tariffs and the potential to leapfrog into a more resilient electricity network (Yadoo and Cruickshank, 2012).

There is usually a lack of technical expertise within the community, therefore planning, design, and implementation is done by third parties. To ensure the sustainability of such models, it is important to charge tariffs that at least cover some of the main operation, maintenance, and depreciation costs. Decision making is likely to be localised in such models, however, this depends on the scale of operation. Furthermore, it is important to ensure that the requisite skills to operate and maintain the mini-grids are available in the local area. In the absence of adequately trained human capital such grids are likely to be unsustainable. It will provide opportunities for what Tenenbaum et al. (2014: 25) refer to as "boutique electrification", which implies that it does not lead to sustained and significant electrification (ibid.).

Hybrids: These models combine different aspects of the models given above. Different entities could be involved in investment, ownership, and operation of a mini-grid. There is a division of labour between the responsibilities of various actors involved in the mini-grids through joint ventures or other contractual arrangements. The generation and distribution of electricity can be divided between government companies, private firms or local communities in the form of small power producers (SPPs) and small power distributors (SPDs). The success of these models is dependent on the regulatory framework and clarity of property rights.

Examples of contractual arrangements that are a part of hybrid models are:

- Public-private partnerships: Public sector could build, operate and manage the mini-grid with the private firm responsible for maintaining the system

- Renewable energy service companies (RESCOs): Assets are owned by the government and the machinery is operated and maintained by RESCOs. They are also responsible for tariff collection

- Concessions: Beneficial terms are given to the concessionaire to provide electricity to rural areas. These terms could be in the form of geographic monopolies or preferential tariffs

- Power purchase agreements: Distribution and generation assets are owned and controlled by different entities and a power purchase agreement is signed for providing electricity (Franz et al., 2014).

4. Operation models: Evidence from the field

Kenya presents an interesting case study showcasing the challenges facing the growth of renewable mini-grids in developing countries. In 2014, the total installed capacity of mini-grids in the country was 19.16 MW. The majority (18.1 MW) of the installed capacity was fossil fuel-based with the rest coming from diesel generation hybridised with solar or wind. The mini-grid system in the country has traditionally been managed by the national utility. Over the last few years there has been a change in the policy framework and, like most countries in sub-Saharan Africa, the government has set-up a rural electrification agency. There are now moves to convert diesel based plants generating electricity in these mini-grid systems to hybrid systems and nine of the 21 mini-grids in operation have been hybridised (solar/wind)[1] (ECA, 2014).

The government of Kenya through the Privatisation Commission has also tried to develop a public-private partnership model for hybrid mini-grids. In the absence of clear plans regarding grid extension, the success of these moves remains questionable. Low tariffs (US$ 0.10/kWh) are also a barrier inhibiting private sector interest in investing in these mini-grids. There are also examples of some private sector mini-grids that are operated by tea and coffee plantations. However, rather than servicing the local rural population, these mini-grids prefer to supply the national grid (IED, 2013; Franz et al., 2014).

China represents one of the most successful instances of state-directed electrification by utilising mini-grids. Off-grid systems in the country were primarily based on small-hydro power generation systems. In 2001, the Chinese central government launched the Township Electrification Program with a target of supplying electricity to 1,000 townships, which is equivalent to almost 1 million people. Within a span of 3 years, 377 villages were electrified using small hydropower (264 MW) and 688 villages with PV and PV-wind hybrid mini-grids (20 MW) (Zhang and Kumar, 2011). Local communities also have some agency in the system as tariffs are decided on by village committees (Bhattacharya and Ohiare, 2012). Furthermore, there was a major focus by central planners on developing the local capacity for designing, operating and maintaining systems. The Chinese programme remains one of the biggest decentralised generation programmes implemented. It also shows that there is no inherent in-built inefficiency in government-sponsored and -operated mini-grids.

The **Nigerian** Federal Government is piloting a programme to provide electricity to rural areas in different zones of the country. Communities in many of these areas are inaccessible and remote, therefore traditional grid extension projects are prohibitively expensive. As part of this initiative, a solar-based mini-grid project has been installed in one such community. In this example of a **hybrid** operation model, the local community provided land and is also supposed to provide ongoing security for the site with the rest of the funding coming from the Federal Government of Nigeria. Through the project, 120 households have been provided with electricity.

On the island of Santo Trigo in **Cape Verde**, a solar-diesel mini-grid installed with funding from the European Union and some equity finance provides another example of a hybrid operating model based on concessions. The mini-grid provides electricity around the clock to 60 households as well as local businesses and public buildings, including a school and a medical centre.

In some countries, the deployment of mini-grids in rural areas has been quite successful based on **public-private partnerships**. Mali presents an

1 These hybrid sites are: Lowdar, Hola, Marsabit, Mandera, Wajir, Merti, Habaswein, Elwak, Mfangno example of such a case: in 2015, there were more around 160 standalone mini-grids in operation being supervised by the Malian Agency for the Development of Domestic Energy and Rural Electrification (AMADER). Each mini-grid on average serves around 500 connections. The development of the market for private mini-grids was supported by the government through AMADER with support provided by the World Bank and the German development bank, KfW. While the mini-grids are operated by the private sector, AMADER plays an important role as it provides potential investors in smaller mini-grids with a substantial percentage of initial capital costs of up to 80% of the project value. Grants are released based on potential investors reaching certain milestones. To ensure that the investor has a stake in the business, they are supposed to cover the remaining amount within 60 days of the start of construction. Recently AMADER has also started providing capital cost support for hybridisation of the diesel based mini-grids. Potential investors are granted revenue certainty as they are provided monopoly rights to sell electricity for 15 years in the area. Private operators are also allowed to set their own tariffs; however, final approval is provided by AMADER (Rai et al., 2015).

In **Tanzania**, there are quite a few examples of **private sector**-operated mini-grids. Private companies have been involved in establishing solar-diesel hybrid mini-grid systems to provide electricity to rural communities. E.On Off Grid Solutions (EOGS), using their brand name Rafiki Power, developed and installed a containerised hybrid system which is comprised of a 6 kWp PV array and battery storage with a capacity of 20 kWh. The system installed in Itaswi village with a population of 1,000 people also includes a kiosk with various services such as a refrigerator and battery charging station. The mini-grid system is connected to 130 households in the village and it includes a smart metering system.

In other areas, such as Terrat in northern **Tanzania**, the mini-grid system is community owned and managed. Electricity is generated by a 380 kW Jatropha seed based biodiesel plant. The plant provides electricity through a mini-grid system to 224 households in the village along with several small and medium-sized enterprises. Households and businesses are metered and are charged at higher rates than the national grid. There are plans to augment biofuel based generation with a biogas plant (SVI, 2015). The government is also trialling hybrid operational models through public-private partnerships.

India has witnessed some success in the deployment of private renewable energy based mini-grids. Estimates of the Climate Group (2015) quoted in Safdar and Heap (2016) shows that there are around 40 mini-grid operators working in the country. The dominant technology in the Indian case seems to be solar followed by biomass- and hydro-based grids. Public policy has played an important role in the dominance of solar, a theme that returned to later in the brief.

Biomass based mini-grids have also played an important part in increasing decentralised energy access to communities in rural areas of India. Husk Power Systems (HPS) and DESI Power are two companies that are working in this area and have established biomass-based mini-grids. Both companies began their operations by installing plants that utilise rice husk as the basic fuel and have now diversified their fuel sources to other biomass sources including wheat husks, elephant grass, mustard stems, corn cobs etc. (GNESD, 2014). A typical plant of HPS supplies electricity to 300-400 households in a cluster of two to four villages in a radius of 1.5 km (Bhattacharya, 2013; GNESD, 2014). Husk Power Systems has been funded by several social venture capital investors such as Acumen Fund and Bamboo Finance, corporate foundations like the Shell Foundation, multilateral institutions such as the International Finance Corporation and Ministry of New and Renewable Energy (MNRE), Government of India (Husk Power Systems, n.d.).

The community-based mini-grid model has been operating in **Nepal**. There are more than 200 community-based organisations (CBOs) operating in the country under the ambit of the government supported National Association of Community Electricity Users Nepal (NACEUN). Local community members are trained to operate and maintain the infrastructure. Electricity is sold at rates that are fixed by the National Electricity Authority. CBOs also provide their members with small loans to buy equipment to set up productive enterprises so that they can take advantage of access to electricity.

Community-based mini-grids are also being operated quite successfully in other countries in South Asia such as **Pakistan**. Similar small-scale systems are also working in South America. In northern **Peru**, Practical Action installed a small 40 kW hydro based mini-grid to serve 160 households in Tamborapa Pueblo. The project was part of an initiative by the Inter-American Development Bank to promote mini-hydro based power systems. Capital was provided by local and state agencies while the community contributed in kind through unpaid labour. Electricity is available 24 hours per day and has been used for many productive and household activities.

Similar examples can also be found in **Sri Lanka** where the private sector and other stakeholders like non-governmental organisations have played an important role in organising communities to deploy mini-grids. Local communities have been organised into "Electricity Consumer Societies" and the model has been highly successful (Ariyabandu, 2005).

5. MINI-GRID GENERATING COSTS

Compared to stand-alone off-grid solutions, more planning and institutional support is required for the deployment of mini-grids. Historically, the government has provided the main impetus for the deployment of mini-grids with the support of donors, while the involvement of the private sector has been far more limited (PWC, 2016). Many systems that are in operation today continue to rely on some subsidies and support. While there has been a focus on socio-economic and technological aspects of mini-grids, sustainable business models have often been missing (Franz et al., 2014). For many governments, social and political considerations of extending electricity have been more important than recouping the full economic cost of mini-grids.

The potential advantage of mini-grids over stand-alone systems is that apart from providing lighting services, electricity generated by these systems can also be utilised to power appliances and machinery. In this scenario mini-grids are likely to have a more positive impact on sustainable local development than stand-alone systems. However, most mini-grids to date have provided levels of service that correspond to Tiers 1–3 of energy access as defined by SEforALL. At this scale, these mini-grid systems are likely to be more expensive than stand-alone solutions like solar-home systems for providing electricity services at Tiers 1–3 (PwC, 2016).

There has been a consistent reduction in the cost of renewable energy-based mini-grids over the last decade. The reduction in cost has meant that mini-grids are increasingly seen as a viable alternative to the traditional grid expansion model. Utilising appropriate renewable resources in the mini-grid can reduce cumulative energy cost. Costs will depend on local conditions as well as those in the international markets. Other variables that have an impact on costs include: access to finance, technology deployed, regulatory environment, reliability of supply required, and demand for electricity.

The reduction in cost of mini-grids is especially important in the context of sub-Saharan Africa as it could make these systems increasingly competitive with traditional grid extension. Economies of scale inherent in national grids and central generation may be more than offset by the cost of grid extension to rural communities. A report by the Alliance for Rural Electrification (ARE, 2011) showed that these costs could be as high as US$31,500 per kilometre for transmission lines and US$16,600 per kilometre for distribution lines. Transmission and distribution costs of mini-grids are highly sensitive to population densities. Depending on local conditions, mini-grids are likely to be cost competitive as compared to solar home systems at population densities of 100 households per square kilometre (Nerini, et al., 2016).

A recent study in Burkina Faso by Moner-Girona et al. (2016) highlighted the problems associated with relying on a traditional grid extension model based on subsidised thermal power generation in sub-Saharan Africa. The scale of subsidy can be gauged by the fact that despite the meagre resources the country has, it provided subsidies of US$277 million on fossil fuels (Whitley, 2013). Despite the heavy subsidisation of fossil fuel based generation, SE4All's Global Tracking Framework shows that there has been no increase in access to electricity in the country from 2010–2012. Based on their analysis, the authors observe that the best way to increase energy access especially in rural areas in the country is to introduce mini-grids powered by renewable energy sources (Moner-Girona et al., 2016).

There are a limited number of studies looking at the cost of mini-grids based on renewable energy sources. A study conducted by the World Bank (2005) observed that the levelised costs of energy (LCOE) for mini-grids fell in the range of US$0.43 per kWh to US$0.63 per kWh in the case of a 25 kWp solar photovoltaic (PV) mini-grid. The study also showed that wind and hydro usually had lower costs; however, these systems are limited in their potential deployment to a few areas.

A more recent study by Norplan (2013) showed that in sub-Saharan Africa, the LCOE of a PV-diesel hybrid system serving around 100 consumers varies between US$ 0.46 per kWh and US$0.74 per kWh. In the case of a fully solar PV based mini-grid system, costs will vary from US$0.467 per kWh to US$0.714 per kWh. Other studies such as the RECPs mini-grid tool kit show that the retail tariffs of mini-grids in the sub-Saharan Africa vary between US$0.14 and US$1.66 per kWh. One point that does come to the fore is the big difference between mini-grid and grid-connected tariffs. In Mali, the average tariff for mini-grids is US$0.61 per kWh while the tariff for grid connected customers is much lower at US$0.15 per kWh (Franz et al., 2014).

Some studies have also looked at the cost impact of converting diesel-based mini-grids to hybrid ones. One such study was undertaken by the Frankfurt School of Business (FSB, 2015) using seven case studies from different parts of the world. The study calculated LCOE of systems with greater than 1MW peak hour demand with 30% of the energy coming from solar PV. The study showed that the cost of electricity varied between US$0.34 and US$0.51 per kWh. In another study, Blum et al. (2013) undertook a detailed comparison of the LCOE of different options for providing electricity to a generic Indonesian village comprising of 1475 people and 350 households with electricity available 24 hours. Their analysis compared the following mini-grid technological systems: micro-hydro, solar PV with battery storage, and conventional diesel-powered systems. The results of their analysis shown in the table below:

System	Capacity (kW)	LCOE (US$/kWh)
Diesel	69.6	0.23 – 0.49
Micro-hydro	69.6	0.18
Solar PV and battery system	232.5kWp and 716kWh battery	0.69

Source: Based on Blum et al. (2013)

While the solar PV and battery-based system seems to be the most expensive option available, Blum et al. (ibid.) highlight that diesel is subsidised in Indonesia. If they use world prices to calculate LCOE of the diesel-based mini-grid it increases to US$0.35–0.80 per kWh.

Another study (ARE, 2014) prepared by the Alliance for Rural Electrification (ARE) for USAID also analyses the cost options of different hybrid mini-grids for rural energy supply. Using the Homer system developed by the U.S. National Renewable Energy Laboratory (NREL), they conducted this study in the context of a village in Ecuador on the island of Bellavista at the Jambeli Archipelago in El Oro province. The village has an average demand of 266 kWh/day with peak power demand of 26 kW. The system provides electricity 24 hours a day to 52 users, which includes a school and naval station. They analyse the cost of the following hybrid solutions: 100% diesel based generation; a diesel and solar PV hybrid; a diesel and wind hybrid; a solar PV and wind combination; and a hydro and diesel hybrid. The results of their study show that the hybrid hydro system has the lowest LCOE while the 100% diesel system is the most expensive and has the highest LCOE. The next least costly solution is the hybrid

PV and wind system followed by the hybrid small wind and hybrid PV systems.

As with earlier studies, this study highlights the difficulties associated with long-term dependence on diesel based mini-grids. While the upfront cost of diesel gensets is low, they need to be replaced regularly over the lifetime of the project (after 25,000 hours of operation). The cost of transporting diesel to many locations that are remote is also high and adds significantly to the cost of generation. Furthermore, an increase in the price of diesel in the global market can seriously hamper the continued operation of these grids and have a negative impact on local development.

Szabo et al. (2011) compare the financial viability of three rural electrification technologies in the context of sub-Saharan Africa. These are: diesel generators, PV systems, and the extension of the national grid. They use a cash flow model for their analysis that compares the LCOE of the three different options. In the case of PV based mini-grids, their analysis shows that the cost of electricity generation varies between US$0.277 per kWh and US$0.76 per kWh across the region. For diesel-based systems, their analysis shows that the cost of generation varies between US$0.41 per kWh and US$3.28. Fuel subsidies have a major impact on the financial viability of diesel- versus PV-based systems and make diesel based systems more competitive.

6. Mini-grid tariffs

Some of the major challenges facing the successful deployment of mini-grids based on renewable energy sources are: high capital costs, low capacity factors, high tariffs as compared to the national grid, financing and investment bottlenecks, lack of regulatory clarity and institutional support, and operations/maintenance constraints. Tariffs need to be affordable to customers but also need to be at levels at least able to generate adequate revenues to meet recurring expenditures and other liabilities, generate an adequate profit (Deshmukh et al., 2013), and recover the capital cost of the system to be fully commercial.

Regulated tariffs can ensure that electricity is affordable for consumers in rural areas and, driven by government concerns with equity and/or catalysing rural development, they may require that they are supplied with electricity at parity with tariffs charged by the central electricity grid. In such cases, the cost structure of mini-grid systems means that revenue has to be augmented by some subsidy from the government to ensure that the project remains financially feasible. It is important to ensure that these payments, either in the form of subsidies or incentives, adequately meet the requirements of the mini-grid operator and are disbursed in a timely manner (ibid.).

The roles of regulators in setting tariffs for mini-grids vary in different countries. In Brazil, the regulator Agência Nacional de Energia Elétrica has the responsibility of setting the tariff for both grid-connected and off-grid consumers that are served by concessionaries. In India and China, in the case of mini-grids established by the government, it is the responsibility of local communities through village committees to decide tariffs. In Tanzania, there is both an aspect of community approval as well as regulatory approval in setting tariffs. Retail tariffs are determined by the project developer after approval by the community, after which the regulator approves the project. In Cambodia, a consolidated license is provided by the national regulator, Electricity Authority of Cambodia, for distributed systems which gives rights to generate, distribute and retail electricity in a fixed geographic area. If the grid is extended to this region, the licensee can continue to play the role of a small distributor (Deshmukh et al., 2013).

Mini-grids deployed in India under the Remote Village Electrification Programme (RVEP) and the Village Energy Security Programme (VESP) have been heavily subsidised by the government. Palit (2014) reports that for remote areas, 90% of the project costs have been met by subsidies from the central government. The balance has been provided by state governments, Members of Parliament, or by corporates as a part of their Corporate Social Responsibility (CSR). Other government projects also provide substantial subsidies for mini-grid projects aimed at remote rural areas.

In the case that mini-grids in India are sponsored by private companies, project costs are met through bank financing and equity. There have also been instances where the government has provided subsidy. Tariff rates vary in different states, however, a similarity in most of the projects is that the rate is flat (i.e., a fixed monthly charge is made). Tariffs range from INR 30 – 150 per connection per month (US$0.5–2.43 per month). In many cases, however supply remains limited for a certain portion of the day rather than 24 hours. For example, solar grids in the Sunderbans region in West Bengal charge US$1.6–2.43 per month for electricity supply for 5 hours for 3-5 light connections.

In the private sector, Husk Power Systems (HPS) has set up 80 mini-grids servicing 200,000 people in 300 villages. Typical systems installed by HPS are comprised of biomass gasifier plants used to fuel generators producing around 300 kWe on average. A system serves 300–400 households in a village. HPS charges customers on a load basis (kW) as opposed to energy (kWh) to compare with the expenditure by customers on kerosene. In this model, every household pays a flat rate of INR 45 (US$0.729) per month per CFL of 15 W. Small businesses and shops pay a rate of INR 80 (US$1) per CFL. Households that want to operate appliances such as fans or televisions etc. are charged according to the wattage of their appliances. Another private company, Mera Gao Power or MGP, has developed small mini-grids especially in Uttar Pradesh state and charges a tariff of INR 25 (US$0.4) per household per week for two light points and a mobile charging point.

There is a difference in the tariff rates for government-sponsored mini-grids and those established by the private sector. This is because private sponsors depend on some form of financing from banks and investors who require higher returns as compared to the high level of subsidies provided by the government. This means that private mini-grids primarily operate in areas where customers have higher ability to pay and tariffs meet the economic cost of production (ibid.).

Despite the social benefits, utility operated models at times support the continued operation of inefficient mini-grids that can have a marked negative impact on the long-term financial viability of the utility. This can be best illustrated by an example from Tanzania. In 2012, there were 16 autonomous diesel-based mini-grids operating in the country. These plants generated electricity at US$0.4–0.45 cents per kWh while the state distribution company, TANESCO charged a flat rate of US$0.037 per kWh to customers using less than 50 kWh per month and US$ 0.14 for customers using more than 50 kWh. This meant that TANESCO lost US$0.3 per kWh supplied from the mini-grids leading to financial difficulties for the state-owned distribution company.

Schmidt et al. (2013) show that in rural Indonesia the cost of micro-hydro powered systems can be recoverable using local resources measured by local consumers' willingness to pay (WTP). In this scenario, there is no need for national support (redirecting subsidies) or international support (carbon credits), and investors can recoup their investment based on available revenue sources. On the other hand, local resources can only cover between 17–36% of the cost of generation in the case of a solar PV and battery system. This higher cost is problematic. However, Schmidt et al. (ibid.) argue that a re-distribution of the existing substantial financial and fuel subsidies can contribute to covering the higher cost of generation in the case of solar PV and battery systems.

Willingness to pay is likely to vary between different geographical areas. Availability of electricity is also likely to spur the growth of productive enterprises and have a positive impact on the economy. The results of Schmidt et al. (ibid.) are also interesting as they show that the local electricity monopoly in Indonesia, PLN, charges for electricity at a flat-rate of US$0.09 per kWh while the willingness to pay is much higher than that value. This highlights the political nature of tariff setting, especially in rural areas, that contributes to high subsidies, low operational quality and reliability of systems, and under-investment in expansion as well as upkeep of the system. This study also highlights how overly subsidised access to electricity can hinder the development of mini-grid based solutions, especially for consumers who are based in villages that are connected to the national grid. Structuring purchase tariffs that enable rural energy subsidies to support the deployment of mini-grids based on renewable energy sources can provide a successful financing model for these solutions. Evidence suggests that these tariff models are already being considered in a diverse set of countries such as China, Colombia, Tanzania, and Uganda (IRENA, 2016).

7. BALANCING REVENUES AND COSTS OF MINI-GRIDS

For prospective mini-grid developers there are three broad funding streams available, these are: financial incentives and subsidies, financing (debt and equity from banks and investors), and consumer tariffs. To be fully commercial, revenues of the mini-grid need to cover investment as well as the operations and management costs. Major costs associated with mini-grids include: project development and investment, generation and distribution equipment, and running costs of operations, maintenance and management.

Revenue streams of mini-grids are comprised of the following main components: connection fees, electricity sales and grants/subsidies (Franz et al., 2014). Revenues of mini-grids are dependent on the following main variables: demand for electricity, affordability of connections in the community, and tariffs for consumers including households, businesses and the public sector (willingness to pay). Areas that are closer to larger population centres are likely to have more vibrant economies which means that the private sector is going to be more willing to invest there (Schmidt et al., 2013). It is likely that mini-grids operating in such areas are going to be more profitable as compared to those operating in remote areas. In case revenues do not cover costs, subsidies can be an important source of funding. Based on their requirements, different tariff models can be implemented by mini-grid developers. Some of these models are:

- **Energy based tariffs:** These tariffs are based on consumed energy in kWh
- **Power based tariffs:** These tariffs are based on the expected power consumption. They are calculated on a Watts basis. HPS uses such a system for their consumers in India.
- **Fee-for service tariffs:** Charges are taken for services provided. Price of services may be calculated according to the cost of alternate fuels such as kerosene and diesel that have been avoided.

Studies also show that it is more challenging to collect revenues in rural as opposed to urban areas as demand for electricity and ability to pay in these areas are lower, and it needs to be ensured that the design of the system is affordable for low-income consumers (PwC, 2016). To reduce some of these challenges for prospective investors in mini-grids policy-makers can provide the necessary regulatory framework such as implementing appropriate tariff structures and developing streamlined mechanisms for obtaining permits and licences (Franz et al., 2014).

Low operating margins mean that not only is it difficult to maintain a decent cash flow but it is also challenging to recover the initial investment. In the case of Tanzania, Tenenbaum et al. (2014) show that the cost of constructing a mini-hydro plant and electricity supply network capable of reaching 1800 households, a few public institutions and private enterprises is projected to be approximately US$ 1.6 million. Raising these funds can be a challenge for private mini-grid developers. Palit (2014) observes that in India, one of the main challenges facing mini-grid operators is getting funding from commercial banks because of the risk aversion of banks and low revenue base. Developers also face a challenge in attracting equity investment because potential investors do not consider it to be a scalable business. Even if the government is not able to provide subsidised funding for potential developers, the problem can be alleviated by ensuring that there is a long-term tariff structure in place, there is a generation and distribution license policy in place, and there are clear plans regarding extension of the national grid.

Tennenbaum et al. (2014) identify some measures through which regulators can help private mini-grid operators achieve greater profitability. These are:

- Allow them to charge tariff rates above the national tariff rate

- Cross-subsidisation between different customer groups as is done in national grids

- Require operators to charge tariffs which include depreciation on equipment

- Allow mini-grid operators to enter power sale contracts with corporate customers without getting approval from regulators regarding the terms of contract

- Allow mini-grid operators to decide tariff structures which are the most applicable to their technology and business models.

8. BUSINESS MODELS FOR PRIVATE MINI-GRIDS

Developing scalable business models for private mini-grid developers remains a challenge, however, evidence suggests that there are many innovative business models that can help operators achieve scale. These business models have evolved keeping in mind the challenge of low revenue generation from end users while facing operations and management costs (Franz et al., 2014).

They are:

- **The franchise approach:** Management costs are borne by the franchiser with minimum cost for the franchisee. If the franchiser has many franchisees, the marginal cost of managing an additional franchisee becomes low because of the economies of scale (ibid.). Dade et al. (2014) observe that franchising has the potential to improve market efficiencies and help achieve scale. This approach has been implemented to the greatest extent in India and estimates suggest that by 2012 there were 37,000 franchises operating in the country covering more than 200,000 villages (Mukherjee, 2013). Many of these franchisees have been working with the state electricity boards, however, mini-grid operators in the country are also using the model.

  Husk Power Systems has already begun to pilot the franchise model in India (Palit and Sarangi, 2014). As part of these models, HPS motivate and train a local entrepreneur to own and operate the mini-grid (ibid.). To help develop and adapt the franchise model, HPS has received valuable support from the Shell Foundation. Changes in the business model have helped HPS expand and the company is now looking to develop technologies and tweak their business model to expand their operations in India and Africa (Desjardins et al., 2014).

- **Anchor, businesses, and consumers: “ABC” model:** In this model, the operator aims to develop sites with certain characteristics. There is an **anchor** customer at the site which could be a stable load such as telecom towers, agro-processing factories or gas stations that can provide a stable cash flow. Access to stable revenue can have a positive impact on the sustainability of mini-grids and help improve their bankability (SE4All, 2016).

  Local **businesses** can also be supplied by the mini-grid and household **consumers** are an additional source of revenue to augment revenues from the first two sources. The ABC model has been reasonably successfully implemented in India. OMC Power, a private mini-grid operator is pioneering such an anchor load based business model in rural areas in Northern India. The mini-grid provides electricity to a local anchor load, which can be a mobile tower, ATM, or a gas station that requires access to reliable power throughout the day. OMC then uses the remaining energy to provide electricity to households and businesses in the surrounding areas. Besides solar, the company is also using other renewable technologies like wind and biogas (Safdar and Heap, 2016).

  A recent study by GIZ (2014) highlights the potential for this model to be implemented in sub-Saharan Africa. There are almost 150,000 telecom towers in the continent and many of these are located in rural areas, with little or no electricity. As mobile coverage increases in the continent, there is going to be further expansion in this number. This robust growth presents an opportunity for mini-grid operators to tap into a growing revenue stream and expand coverage in rural areas. Long-term contracts that ensure a stable revenue stream are also likely to improve access to capital. Mining and agro-processing facilities present further opportunities for the successful deployment of the ABC model. GIZ has already trialled the installation of such an operating model in Kabunyata village in Uganda. Electricity is supplied to the mobile tower in the village using a solar-diesel hybrid mini-grid system. This has translated into 40% cost savings for the telco operator in terms of cost of fuel. Local businesses have also gained from access to electricity and have been able to save fuel costs as they were also reliant primarily on diesel (GIZ, 2014). Corporates can be incentivised to become anchor loads by providing tax cuts or by offering other benefits.

One of the problems of the ABC model is that households are most likely to receive the residual power available after consumption by the anchor load (Gollwitzer et al., 2015). This is unlikely to meet the requirements of the local community and the positive impact on people's lives that comes with access to electricity will be rather limited. Another problem with the model is that not all sites have anchor customers as a recent study by the International Finance Corporation (IFC, 2015) in Kenya shows. This would mean that potential investors are likely to ignore those areas.

- **Clustering approach:** Non-interconnected mini-grids supply electricity to villages located close to each other. These mini-grids are then bundled together as part of one operational unit to economise on overhead costs. HPS has been implementing this approach and the company appoints cluster managers to manage multiple plants, usually around 5 to 10 (GNESD, 2014). The cluster managers play an important role as conduits between operating plants and the higher management of the company (ibid.).

There is some evidence that clustering has also been implemented in mini-grids installed and operated by the government. In the state of Chhattisgarh, the local Renewable Energy Development Authority (CREDA), which is operating mini-grids in remote areas of the state, has taken a cluster-based approach to reduce transaction costs (Palit and Sarangi, 2014). In the CREDA model, each cluster is comprised of 10–15 villages. A team in each cluster is comprised of one technician, an assistant technician and an operator as well as a village energy committee. These teams are supervised by higher officials through monthly reports and they are expected to meet customer requirements such as replacing lamps (GNESD, 2014).

The clustering approach can also help lower the cost of capital for mini-grid operators. Development finance institutions are increasingly encouraging operators with proven track records to bundle multiple mini-grids into large transactions to reduce transaction costs. As mini-grid operators establish their track records, this model is likely to accelerate and help operators achieve scale (Franz et al., 2014).

A recent report by ENEA in the context of Zambia shows that a cluster approach is most likely to work best for mini-grid development. They use the example of a cluster of small-scale, hydro-powered mini-grids operated by a social enterprise (MEGA) in Mulanje, Malawi. The business model is based on managing a cluster of 9 mini-grids that are located on the same river. The proximity of these mini-grids will contribute towards reducing MEGAs operating costs (enea, 2015).

While clusters might help economise on operating costs, management of clustered mini-grids requires high levels of both technical and management skills. This will be especially true as load factors increase. The lack of trained human capital in developing countries, especially in sub-Saharan Africa, could pose a problem in the success of this model in the region. Deploying such a business model successfully will also require regulatory support from the government for example in granting exclusive access to certain basins/river parts (ibid.).

Tanenbaum et al. (2014) observe that in the case of private mini-grids, commercial viability is least likely in cases where the only customers are local households in one or two villages. They identify the following solutions to improve commercial viability based on lessons from different mini-grids. These are:

- Mini-grids that receive an operating subsidy from the government or other stakeholders.

- Mini-grids that charge higher tariffs to households than the tariff charged by the national utility—if the retail tariff charged by the utility is not high enough to cover the costs. This model is being implemented in different countries including Cambodia, Mali, and Senegal.

- Mini-grids that charge higher tariff rates to commercial and industrial enterprises within the village. This is a form of cross-subsidisation.

- Mini-grids that develop other revenue sources and increase the number of connected households with the ability to pay higher tariffs.

9. Policy framework to support deployment of mini-grids

Historically, across the developing world, governments were at the fore-front of developing and installing mini-grids for populations located in remote areas where the national grid could not be extended due to cost or technical considerations. With some exceptions, this policy has been largely ineffectual in reaching people without access to electricity. Other factors like growing fiscal burdens have contributed to a reduction in financing for electrification projects, and many governments are now trying to attract private capital into the mini-grid sector. To do so, governments need to create and implement a supportive policy and regulatory environment. Most bilateral and multilateral donors have been advocating these policy changes and have actively supported the transition from a state-led to a private-sector mini-grid development model. The literature identifies the following main policy and regulatory conditions that can support the deployment of mini-grids:

Laws and licencing arrangements

For the private sector to invest in deploying mini-grids, laws and licencing arrangements must be in place that allow firms to develop projects that can generate as well as distribute electricity to consumers. These laws govern the entire range of activities that a prospective sponsor needs to fulfil, including: company registration; suitable land; building permits and access to utilities and licenses to generate, distribute, and sell electricity. While they might be straightforward on paper, evidence suggests that obtaining licences and permits is not a simple process and is costly and time consuming (IRENA, 2016b). A recent study suggests that licencing costs at times can be greater than 10% of a project's capital cost (ibid.).

For governments that are interested in promoting private sector investment, it is important to ensure that the roles of various stakeholders and bureaucratic agencies are clearly defined. They also need to ensure that regulations covering mini-grids are streamlined and potential investors can easily obtain the required licences. Dedicated platforms can provide an invaluable source to provide such information. An example of such a platform is Tanzania's mini-grid portal (www.minigrids.go.tz), which is operated by the government and provides information to potential investors, thereby reducing the cost of information gathering. Donors have also supported the development of renewable energy agencies (REAs) for rural electrification which can act as nodal agencies for development of off-grid solutions. There are around 30 REAs operating in different countries in sub-Saharan Africa. In India, the government of the state of Uttar Pradesh has created the Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) to promote off-grid energy projects by providing a one-stop shop for issuing licenses in a timely manner (UPNEDA, 2016).

One of the main areas where accurate information is extremely important for mini-grid developers is in the domain of national grid extension plans. Uncertainty about the extension of national grids is likely to have a negative impact on investment in mini-grids (IRENA, 2016a). This risk is especially severe if the grid is extended before the mini-grid has been amortised (IRENA, 2016b). To provide certainty to potential investors, there is a need to develop rural electrification master plans that provide adequate information about location and potential timeframes of grid extensions. While these plans might be developed, it is important to update them periodically to provide confidence to potential investors. One potential solution is to add a clause in the agreement between mini-grid operators and government agencies which puts in place a compensation mechanism or an assurance of grid inter-connection if the grid does arrive in an area. For these mechanisms to succeed, there is a need to ensure transparency in information sharing with potential private stakeholders.

Cost-recovery and tariffs

The issue of tariffs is likely to be extremely politically sensitive for governments in developing countries. The regulatory framework governing tariffs has a substantial impact on the viability and sustainability of mini-grids by controlling what potential operators can charge end users (IRENA, 2016). While governments must ensure that people in rural areas being serviced by mini-grids are not being exploited by being charged exorbitantly high tariffs for electricity supply, they also need to ensure that regulations governing tariffs are not prohibitive for potential investors. Some governments in sub-Saharan Africa, for example, Tanzania and Nigeria, have exempted small-scale grids (under 100 kW) from tariff approval. Mini-grid operators in these countries can settle tariff levels in consultation with the local communities. In Uttar Pradesh, India the Electricity Regulatory Commission also allows mini-grids powered by renewable sources and not funded by public subsidy to set tariffs that are mutually agreed with consumers.

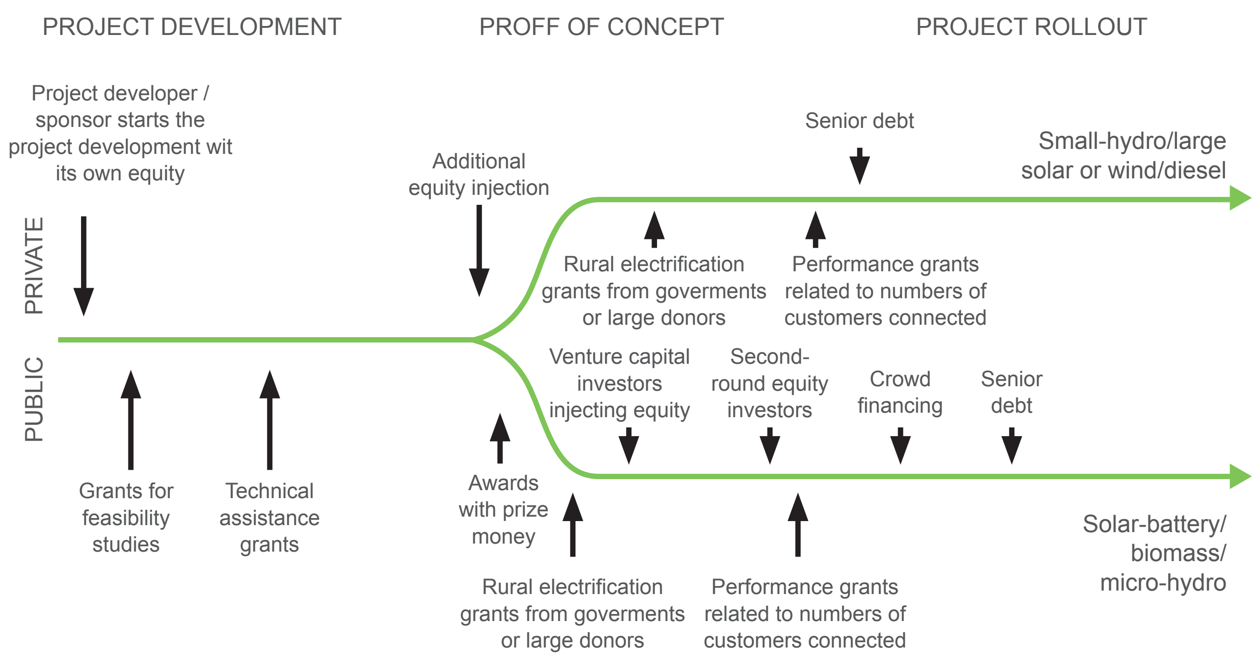
As system size increases, potential operators are likely to call for formal mechanisms for tariff setting that reduce the risk of disputes in the future (ibid.). Determining tariffs through standardised methodologies, for example a cost-plus method, is likely to make the process more transparent and provides potential investors with some certainty. In the case that mini-grid operators are not allowed to charge consumers above national tariffs for grid connected consumers which are usually subsidised, governments need to introduce mechanisms to provide financial support. A recent study by ESMAP (ESMAP, 2016) in Ghana for a 140 kW solar PV mini-grid with a 100 kVA diesel back-up system showed that keeping the cost of electricity at a level that local people could pay would require subsidies of more than 50% of capital costs. If tariffs were set at the national level, in addition to ongoing operational subsidies, 100% of the capital cost of the project would have to be subsidised.

Despite the improvements in technology, there is a clear disjuncture between equity concerns of governments and the expected financial returns for potential private investors. There are some examples where donors and national governments have developed mechanisms to deal with these problems, however, long-term sustainability remains questionable. In Bangladesh, IDCOL applies a tariff cap (the maximum tariff that can be charged based on certain variables such as technology, size of the system and location) for mini-girds of US$0.43/kWh, and provides capital subsidies as well as subsidised debt finance to potential mini-grid operators (IRENA, 2016b).

Facilitating access to finance

The financing needs of mini-grids are likely to be dynamic, and different phases of privately operated grids will require different kinds of financing support. The ability to successfully attract capital is impacted greatly by the regulatory and risk environment and the design/delivery of financing support from the public sector. For their part, governments as well as multilateral and bilateral development agencies can provide support by facilitating the access of entrepreneurs to debt, equity, or grant financing. While, in theory, financing is available in the form of debt and equity, access remains an issue (Franz et al., 2014).

Financing requirements at various phases are shown in the figure below:



Source: IRENA(2016b)

Project development phase: The typical project-development phase is comprised of variables such as the site; initial contact with the community; developing demand projections and designing the system; analysis of the legal frameworks and development of the business models. The initial background work is likely to be supported by capital from the sponsors, however, there are examples where grant financing is available for this stage as happened in Mali. Grants can also help the private sector in undertaking environmental impact studies and map the area's demand profile. Grants can be provided by development banks or funds and can also be channelled through national rural agencies.

Proof of concept: Financing needs for mini-grids have been divided into two streams/strings based on the capacity of the mini-grid project in the study undertaken by IRENA (2016). In the case that the mini-grid project is of a larger capacity, there is likely to be a proof-of-concept study which looks at the theoretical and commercial business case. This study is likely to inform the main feasibility study. This is especially true in the case of mini-hydro and in the hybridisation of already existent fossil fuel powered grids. The due-diligence process is likely to be expensive and sponsors will likely require support in the form of grants during this phase (ibid.).

For smaller mini-grids, there is an extended proof-of concept phase which forms a substantial part of the due-diligence process. Funding during the initial phase is likely to be either in the form of equity provided by potential sponsors or to come from small grants. Funding at this stage for smaller grids can come from the public sector or other multi-lateral forums. For example, financing has been provided for several renewable mini-grids in Burundi, Cape Verde, and Guinea Bissau, etc. by the EU-ACP energy facility (IRENA, 2016a). These mini-grids are playing an important role as demonstration sites for mini-grids in the region.

Project rollout: After a successful proof-of concept, the project is ready to be rolled out. This is a capital-intensive phase and usually requires funding from multiple sources such as debt, equity and grants. Koh et al. (2012) observe that to meet the financing requirements at this stage mini-grid operators will require access to multiple sources of capital.

In the case of large-scale mini-grids, especially projects where diesel based grids are being hybridised, it is important that the project is commercially attractive from the perspective of potential equity investors and commercial lenders such as banks. This attractiveness is dependent on the terms and conditions of existing or new power purchase agreements (IRENA, 2016b). By this stage, there should be a clear tariff structure in place that has been agreed with the regulator which ensures a return that is commensurate with the risk profile. This process is simplified if there is an established anchor load or if there is an agreement to sell excess electricity into the national grid.

Potential **sources of finance** for mini-grids are summarised in the following paragraphs.

For smaller mini-grids, once there is an established proof of concept and there is evidence of a viable business model, entrepreneurs can look for **equity financing** from venture funds (ibid.). While this might be possible for sponsors based in developed countries, for entrepreneurs based in developing countries accessing such sources of equity is difficult as capital markets are less developed. Impact investors could emerge as an important source of equity. Dichter et al. (2013) observe that it is estimated that the impact investment sector will grow from an estimated size of US$4 billion in 2012 to around US$1 trillion in a decade. There has been an increasing interest in alternative sources of capital such as crowd funding. There have been some examples of companies that have successfully utilised this funding platform such as Mera Gao Power (India) and SunFunder in Tanzania and Uganda (IIED, 2015). Development finance institutions also provide facilities that can be a source of equity finance. Funds operated by organisations such as the Overseas Private Investment Corporation, the Netherlands Development Finance Corporation, FMO, and multilateral agencies like the African Development Bank and the OPEC Fund for International Development provide equity for larger energy projects (Franz et al., 2014).

Grants can provide an effective mechanism to reduce tariffs for consumers based in isolated communities and present an important source of concessional capital. There is a need however to ensure that there is a transparent procedure and set criteria for providing grants (IRENA, 2016b). For example, in Tanzania, the Rural Energy Agency provides grants to developers of mini-grids if they connect new customers in rural areas. The grants have been designed to reduce the initial cost of connection (Franz et al., 2014; Tenenbaum et al., 2014). To ensure that the grant is utilised for the intended purpose, the Rural Energy Agency undertakes an audit. In Uganda, a follow-up audit has been incorporated into the project design to ensure that new customers continue receiving electricity after several months of being connected (ibid.).

While grants might be an important source of capital, to ensure sustainable operations and for scaling-up, mini-grids will also require access to capital through other instruments. **Debt capital** is an obvious source, however, there are very few mini-grids that have been able to access commercial loans and access to debt is a major constraint facing mini-grid operators. Most commercial banks are reluctant to lend to private mini-grids because of a variety of factors such: lack of information; lack of an established track record; poor understanding of the revenue streams and value proposition, and lack of collateral. Even if operators can access the commercial debt market, the interest rates are high. Evidence suggests that many banks in Africa have limited cash-flow lending experience and require high levels of collateral to consider lending to corporates (SEforALL, n.d.). They usually charge interest rates of 16-24% (Franz et al., 2014). As operators are highly unlikely to be able to pass on these costs to consumers in the form of higher tariffs, lack of access to debt is a key constraint for mini-grid operators.

The government and development actors have an important role to play in this regard as specialised debt instruments can be developed for private mini-grids. IRENA (2016b) has highlighted some instruments that can be implemented to improve access to capital for mini-grid operators. These are:

- Subordinated debt: Debt which is paid after the main debtors have been paid. Public funds can be provided to mini-grids in the form of subordinated debt or debt that can be converted into equity (mezzanine finance) (Franz et al., 2014). Debt in this form can help give confidence to commercial banks and help operators access senior debt from these institutions (IRENA, 2016b).
- Nonperforming debt by-outs: An organisation which could be the government or a development organisation guarantees to buy any bad debts from commercial banks which secures their balance sheet. This reduces the risk for banks and in theory should allow them to lend to mini-grids.
- Third-party collateralisation: The assets of a third party, for example the national utility, can be used as collateral to help a mini-grid qualify for finance from local banks.
- Syndicated loans: For large mini-grids, because of the high capital costs, several organisations could come together and offer a syndicated loan. This allows for risk and competence sharing among organisations.

10. Conclusions

This technical report has highlighted the potential of mini-grids to provide access to reliable electricity for a substantial portion of those who are based in rural areas that are not connected to the national grid. Mini-grids have the advantage of providing electricity for both domestic as well as commercial uses. Access to electricity can have a positive impact on local development. Despite the potential positive impact of mini-grids, this report highlights that their commercial deployment has not been robust. Multiple challenges continue to affect the successful deployment and operation of mini-grids.

These challenges along with some potential solutions are as follows:

- High capital and operational costs coupled with a lack of access to affordable capital

  Improve access to affordable capital, for example:

  - Grants – provided by governments, development finance institutions and other actors for project financing
  - Improve access to alternative sources of capital such as venture capital and impact investors
  - Improve equity options for Development Finance Institutions (DFIs)
  - Diversify risk for local banks by developing specialised debt finance instruments

- Lack of regulatory clarity and laws:

  - Involve stakeholders in the framing of laws affecting mini-grids
  - Simplify licensing requirements for potential investors
  - Ensure access to information, especially in relation to grid extension

- Tariffs that are either too high that local communities can't afford them or are too low to pique the interest of private investors:

  - Ensure adequate returns to potential investors without tariffs being prohibitively high
  - Involve the community in setting tariffs even in the case of private grids
  - Allow cross-subsidisation between different consumers

- Lack of commercial sustainability:

  - Encourage corporates to act as anchor loads by incentivising them through instruments such as tax breaks
  - Offer loans for entrepreneurs interested in setting up local businesses
  - Invest in training adequate human capital to operate and maintain mini-grids

Mini-grids are operating based on several different models. It is important to stress here that there is no one-size-fits-all model that will work everywhere and there is likely to be a high level of context specificity both across countries and within countries.

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SMART VILLAGES

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