Scaling-Up Mini-Grids For Rural Electrification

Lessons from AECF's project portfolio

ABOUT AECF

AECF is a development institution which supports businesses to innovate, create jobs, and leverage investments and markets to create resilience and sustainable incomes in Africa. Launched in 2008, in its first ten years AECF mobilised over US $356m , and leveraged more than US $750m in matching capital. In 2018, AECF improved the lives of more than 17 million people through jobs and increased household incomes. To date, AECF has supported 268 companies in 26 countries in sub-Saharan Africa, working across 40 value chains in agribusiness and renewable energy.

AECF aims to alleviate poverty in Africa by unlocking the power of the private sector to impact rural and marginalised communities. AECF's strategy is to provide early and growth-stage renewable energy and agricultural businesses with:

- ***Catalytic funding***

AECF works to bridge the finance gap for those firms that need significant capital but are not yet large or profitable enough to benefit from commercial finance. AECF's main financing mechanisms are repayable grants and loans. Recently, AECF is launching its own results-based finance scheme in Kenya (still in pilot phase), and is considering other forms of catalytic finance.

- ***Advisory support***

AECF provides technical assistance to private sector firms to help them scale. This assistance is provided through both internal AECF expertise and external consultancy support.

- ***Market linkages***

AECF helps its investees to access commercial finance through AECF Connect. The programme introduces potential investors to AECF investees, helping more advanced companies in the AECF portfolio to scale and grow.

www.aecfafrica.org

ABOUT ENEA

ENEA Consulting is an independent strategy consulting company specialising in energy transition and sustainability. Based in Paris, Hong Kong and Melbourne, since 2007, ENEA has enabled its customers (energy companies, network system operators, investors, industrial firms, institutions, technology companies and start-ups) to take advantage of energy transition and sustainability opportunities. ENEA Consulting is also a leading firm in energy access, through both its social entrepreneur support programme and further consulting missions for investors, energy companies and government institutions.

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INTRODUCTION

Around the world, small-scale, off-grid electricity distribution networks, known as 'mini-grids', play a key role in increasing access to electricity in remote and rural areas. The International Energy Agency (IEA) estimates that up to 40% of future connections could come from mini-grids, making a vital contribution to efforts to achieve universal electrification by 2030. In Africa, where 600 million people rely on expensive, non-renewable, low-quality energy [1], mini-grids can have a transformative impact on households located beyond the reach of centralised networks.

While for decades mini-grids were operated by NGOs, utilities, informal operators and governments, in recent years formal, privately run mini-grid distributed energy service companies, or 'mini-grid DESCOs', have started to emerge. But despite strong growth potential and commercially viable business models, due to underlying economics the private mini-grid sector has grown more slowly than expected. Without public financial support, mini-grids for rural electrification are rarely profitable, and therefore struggle to raise sufficient finance. In Africa in particular, mini-grid DESCOs have only achieved modest results so far, particularly compared to grid connections and solar home systems (SHS).

To drive uptake, a paradigm shift to a new model, where mini-grids receive public financial support, is urgently required. Indeed, such a shift is beginning to occur in several countries across the continent, with new publicly funded programmes emerging in Kenya, Nigeria, Sierra Leone and Benin. But in order for private firms to benefit from such support, these models need to be tested, monitored and evaluated.

The Africa Enterprise Challenge Fund (AECF) is supporting increased public involvement in the mini-grids sector by assisting private actors as they engage with public organisations on new public-private business models. During testing and negotiation, private firms require short-term financing, in the form of equity, or repayable or revolving grants. AECF is well positioned to provide such financing, as well as funding for start-ups and research into innovative business models and technologies. Together, AECF and ENEA Consulting have developed a sector-wide Theory of Change which demonstrates the major actions needed to scale these business models. It is hoped this work will provide insights which help to expand the provision of productive power to rural areas, and support increased access to electricity through mini-grid distribution.

August 2020

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[1] International Finance Corporation, 2017

ABOUT THIS REPORT

This report, which was researched and written by ENEA Consulting, with expert input from AECF, has two main objectives. Firstly, it provides an overview of the key challenges facing the mini-grid sector, and the solutions mini-grid companies, governments and development partners are implementing to overcome these challenges. Secondly, it analyses AECF's future role in the mini-grid sector, assessing the issues AECF will be best placed to resolve.

Stakeholders will be able to use this report to better understand the mini-grid landscape, and the solutions that are being implemented and proposed to drive the sector forward. In addition, this report and the recommendations within it will:

- Provide information to AECF investees on the sector's key challenges and socioeconomic/environmental benefits for discussion with their investors and partners.
- Positon AECF and other donor organisations in the mini-grid sector by scaling up current activities and launching innovations.
- Assist the mini-grid sector to communicate more easily (for example, with local governments or donors) on key sector benefits and challenges.

In producing this report, ENEA and AECF drew on a range of sources, including:

- **A review of existing literature**, including reference reports from Energy and Environment Partnership, ENEA Consulting, IRENA, Hystra, International Finance Corporation, and Rocky Mountain Institute.
- **A performance review of the seven AECF mini-grid investees**, including analysis of annual progress and site visit reports, as well as interviews with three major mini-grid companies in the AECF portfolio.
- **Interviews with key mini-grid industry stakeholders**, whom ENEA and AECF would like to thank warmly for their time and participation. They include:

» Acumen

» Economic Consulting Associates

» CrossBoundary

» African Mini-grid Development Association

» Swedish International Development Cooperation Agency

» European Union (ElectriFi)

» Shell Foundation

- **ENEA's internal expertise**, based on over 10 years' experience working on mini-grids and energy issues in sub-Saharan Africa.

The research for this report was mainly conducted in the second half of 2018, and the content reflects the state of the market at that time. This publication is also accompanied by a summary document, which can be accessed at **www.aecfafrica.org/knowledge-hub**

AECF and ENEA hope you enjoy this report.

AECF AND THE MINI-GRID SECTOR

Through its Renewable Energy and Clean Technology (REACT) Sub-Saharan Africa Programme, AECF provides funding for renewable energy financing, including for mini-grids. The REACT programme is designed to:

- Catalyse the private sector to increase the supply of cleaner fuels.
- Raise awareness of the dangers of indoor air pollution.
- Demonstrate how new knowledge in renewable energy technologies can be implemented to benefit the poor, especially women.
- Provide evidence on challenges in policy formulation and implementation.

REACT target countries include Burkina Faso, Ethiopia, Kenya, Liberia, Mali, Mozambique, Zimbabwe, Sudan and Somalia.

In the early rounds of REACT, AECF invested in seven mini-grid DESCOs in East Africa: Devergy, Dobea, EA Power, Husk Power System, Jumeme, Luponde Hydro and Powergen. Here, as elsewhere, AECF provides catalytic 'bridge financing' to firms during negotiations for the public-private partnerships necessary to receive public financial support.

AECF also supports the design, piloting and evaluation of different subsidy and public-private partnership (PPP) arrangements, and extends its catalytic funding to non-traditional mini-grid business models. These include innovative schemes, such as standalone solar systems or solar kiosk models, with a view to advancing alternative power sources in rural areas without distribution infrastructure.

For more information about the work of AECF, go to: **www.aecfafrica.org**


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CHAPTER 1
THE MINI-GRID LANDSCAPE

MINI-GRIDS

Mini-grids, also referred to as 'micro-grids', are off-grid electricity distribution networks involving small-scale electricity generation. There is no defined size for a mini-grid, but they typically vary from ~1kW up to 1MW. The main characteristic of a mini-grid is its ability to function independently of a centralised grid (i.e. in 'island mode'), and provide electricity to a small, localised group of customers [2]. Power generation for mini-grids encompasses a range of sources, including solar, hydro, biomass, wind and/or diesel. Indeed, the mini-grids in the AECF portfolio use all of these power generation technologies.

In developing countries, mini-grids can provide access to electricity for households outside a central grid's reach. In sub-Saharan Africa, there are 600 million households without grid connection [1], the majority of whom rely on kerosene lamps or battery-powered torches for lighting, and diesel generators for powering other appliances. Kerosene is expensive, has negative health effects, and is a fire risk. Battery torches have emerged as an alternative to kerosene, but require regular replacement and provide poor-quality lighting. For higher energy needs, diesel generation has historically been used, but solar power is now more affordable. For households dependent on such sources, mini-grids can, depending on location, offer a cheaper, cleaner and higher-quality energy alternative, providing both basic and additional power to meet all domestic and business needs.

[1] International Finance Corporation, 2017
[2] African Development Bank, 2016
[3] Solargis, 2018
[4] Hydro Reveiw, 2014

Green mini-grid solutions are particularly suited to Africa, given the continent's strong production potential for renewable energy. In Tanzania, for example, there is 4-7 kWh/m2 of daily global horizontal solar radiation, compared to an average of 2-3 kWh/m2 in Germany, one of the world's leading markets for solar [3]. In addition, Africa currently exploits less than 10% of its abundant hydropower potential [4], while the falling price of solar systems (including battery storage) means that mini-grids are likely to get cheaper and greener over time.

THE BENEFITS OF MINI-GRIDS

There are a range of benefits to the uptake and use of mini-grids. These include:

- ***Household benefits***

Electricity connection allows families without electricity to access modern energy services, including high-quality lighting, radio, television, mobile phone charging and refrigeration. Such services in turn can improve educational, health and economic outcomes.

- ***SME benefits***

Mini-grids also serve businesses, which benefit from having access to high-quality electricity. Thanks to mini-grid access, businesses can offer clients services which require energy, such as printing, hair clipping, and car repairs, agro-processing and entertainment (satellite TV, drinks chilling or loud speakers), which in turn increases revenue.

- ***Employment benefits***

Mini-grid DESCOs directly employ staff, including engineers, community liaison officers and sales teams. Companies that use electricity from mini-grids to provide new services may also employ additional people.

- ***Gender benefits***

Women benefit in multiple ways from mini-grids. In the household, women can access services that improve living standards, such as better-quality lighting and refrigeration. Women-owned businesses that gain access to a mini-grid can also provide energy services. Women may also work in mini-grid firms; all AECF firms employ women, with clear anecdotal evidence of positive socioeconomic impact.

- ***Economic development benefits***

Access to electricity not only creates jobs, but also generates new income for SMEs, which can then be invested into new productive activities. Mini-grids also provide electricity for health and education facilities, improving economic development outcomes.

- ***Environmental benefits***

Mini-grid connections enable households to shift away from fossil fuels such as kerosene, while for SMEs and high-income households renewables-based mini-grids could replace diesel generation. These measures help to reduce C02 emissions and local air pollution. At the same time, mini-grids can support water purification services, which means less firewood being used to boil water, which in turn reduces local deforestation.

MINI-GRIDS VERSUS CENTRAL GRIDS

Compared to centralised grids, mini-grids have the potential to provide a lower-cost, quicker-to-market solution. And in rural sub-Saharan Africa, where over 75% of households do not have access to grid electricity [5], mini-grids can help to address the issue of household connectivity.

The United Nations Sustainable Development Goals (UN SDGs) set a target of universal electrification by 2030. Currently, sub-Saharan Africa electrification levels are growing at only 5.4% per annum, well short of the 8.4% needed to reach the UN's 2030 target. And while utility-scale grids are expected to expand fast, at current rates they will not, on their own, be able to make up the connectivity deficit.

The IEA expects up to 40% of connections in sub-Saharan African to come from mini-grids by 2030. This could represent a US $170bn investment opportunity over the next decade [6]; there are also significant cost saving implications. Expenditure on grid transmission and distribution often results in high connection costs – over US $2,000 per connection on average. Indeed, Africa's connection costs are among the highest in the world. Around 63% of sub-Saharan Africa's population live in rural areas [7], where the marginal cost of central grid extension is often high due to the long distances between villages, with grid extension projects typically costing US $2,500 per household [8]. Mini-grids, by contrast, do not require the construction of long-distance transmission lines, as power generation takes place near the consumption site, leading to 50%-lower connection costs. A recent study of 16 mini-grids highlighted that cost of connection for customers receiving basic energy access (Tier 1 to Tier 3 according to SEforAll's multi-tier framework approach) could be as low as around US $500 per household, with an average level of US $1,273 and likely to fall further. [9] [10] These costs are much lower than grid extension costs, even though more than half of the costs are linked to generation, which is not considered for grid extension projects.

If mini-grids can provide a more affordable option, they can help to further reduce the cost of household connection and increase overall energy access. Based on a Levelised Cost of Energy (LCOE) analysis, in most cases mini-grids make more economic sense when a village is over 5km away from the main grid [11]. Figure 1 (page 12) shows the conditions in which mini-grids are the most appropriate power solutions; inside the red zone depicted, the cost of national grid extension is too high due to the distance from the grid, but communities are dense enough to justify a mini-grid solution rather than a solar home system.

Mini-grid project developers, as small and medium-size companies, are also more agile than central grid operators, with their size and flexibility in theory enabling a shorter time-to-market. A mini-grid can also take just six months to construct [12], compared to the several years required to extend national power lines. In addition, mini-grid project developers are adept at developing solar-plus-battery storage projects, while national utilities currently have little experience of such complex technologies.

[5] World Bank, 2018.

[6] A. Africa, "Sénégal: Harmonisation des tarifs de l'éléctricité en milieu rural - Les acteurs reflechissent sur les modalités," https://fr.allafrica.com/stories/201703010788.html, 2017

[7] Global Growing, s.d.

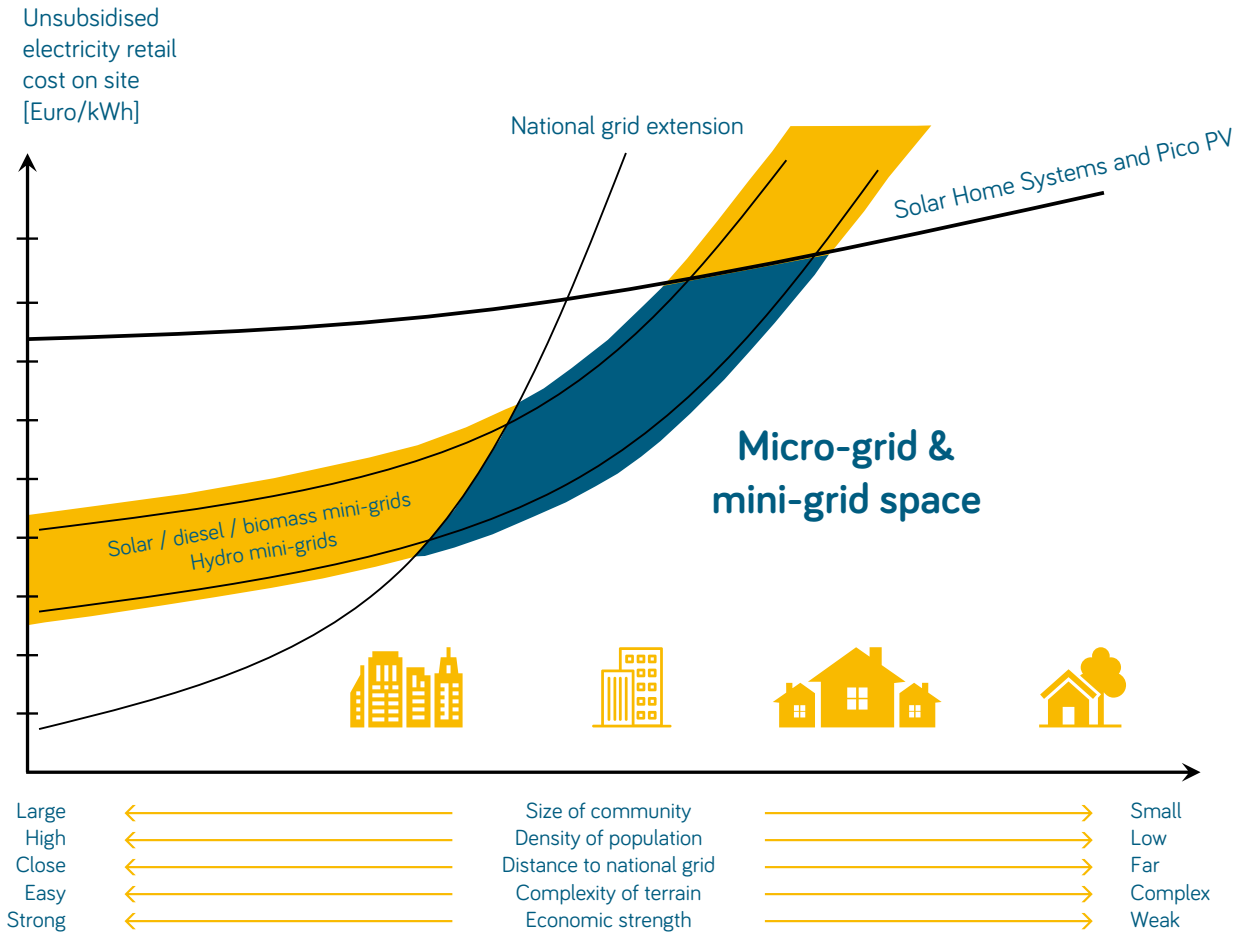
[8] Power for All, 2016. [9] World Bank, 2017.

[10] Costs for Tier 4 customers are, on the other hand, much higher, at US $5,000 per household, hence at US $2,500 per customer for non-generation costs.

[11] Rocky Mountain Institute, 2017.

[12] The Nigerian Economic Summit Group, 2018

Figure 1 - Energy access technology overview



The major challenge for mini-grids compared to centralised grids is that the institutional support mechanisms for grid connections are not available. National grid extension efforts benefit from both financial and regulatory support, whereas mini-grids do not.

MINI-GRIDS VERSUS SOLAR HOME SYSTEMS

Solar Home Systems (SHS) are individual power generation plants based on a solar PV panel, battery and appliances, and are proven to be an effective way of providing customers with basic electricity access. These systems are usually sold to customers on a cash or lease-to-own basis, which means that, unlike mini-grids, SHS distributors do not operate the production unit. Households therefore only benefit from the basic services the solar home system allows.

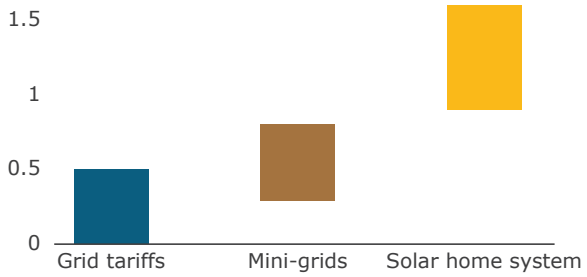
The price of a solar home system is low; the cheapest systems can cost less than US $80, and under a PAYGO model customers pay as little as US $0.40 per day. This low cost means that in the provision of basic energy access, solar home systems are the most affordable solution.

However, given the small size of the solutions, the price per kWh can be high, and comparatively mini-grids provide higher levels

of productive power for less. The average cost per kWh for a Solar Home System is estimated at between US $0.85 and US $1.17 [13], whereas a solar mini-grid costs between US $0.50 and US $0.60/kWh, as shown in Figure 2 graph below.

The lower prices per kWh for mini-grids are driven by the ability to share power capacity between storage systems. Mini-grids effectively 'pool' between different users of the mini-grid. For example, during the day, electricity might be used by businesses to power productive machinery, while in the evening households use electricity for lighting and mobile phone charging. This reduces the overall need for energy storage, providing a lower overall per kWh cost.

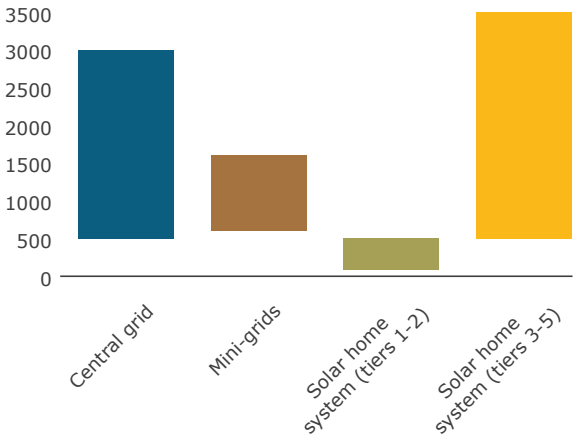
Figure 2 - Cost per kWh per technology (USD) [14]



Unlike SHS, mini-grids can also provide power for a wide variety of productive uses and services. These might include water pumping, refrigeration, cooling, incubation for poultry farming, milking machines, rice and maize hullers [15]. And access to electricity for productive use applications, such as agricultural processing, can create jobs and bring additional revenue to rural areas [16].

However, mini-grids have several disadvantages compared to SHS, particularly regarding business model flexibility. In addition, the upfront connection cost is higher for lower tiers of power. Indeed, connection levels, geography and system size can dictate whether a mini-grid, central grid or SHS will be the most appropriate solution. Figure 3 below demonstrates the difference in connection prices between different technologies, according to a study by Bloomberg New Energy Finance.

Figure 3 Cost per connection comparison (USD) [17]



HISTORICAL MINI-GRID DEVELOPMENT

For decades, mini-grids in Africa have been operated by informal operators, NGOs, major industrial firms and governments. Indeed, according to IFC data from June 2019, there are 19,163 mini-grids in Africa, and 7,507 planned in the coming years. Collectively, these mini-grids have 18.1 million connections.

Informal private sector mini-grids are often established where centralised grids are not available, and where there is a concentration of households with the ability to pay for power. These mini-grid firms rarely manage mini-grids outside their region. NGOs have

[13] RResearchGate, "More Power, Less Cost: Transitioning Up the Solar Energy Ladder from Home Systems to Mini-Grids," 2015

[14] Government of Sierre Leone, 2017

[15] Kyriakarakos P., 2018

[16] Africa - EU Energy Partnership, 2015

[17] Bloomberg New Energy Finance, 2018

also launched pilot mini-grids throughout Africa, developing projects to provide distant communities with access to power. For example, GRET, a French development NGO, runs a rural electrification project based on a hydro mini-grid in Madagascar, providing electricity to 2,500 customers. These NGO models tend to be highly reliant on subsidies and development partner financing. Meanwhile, industries located in remote areas (e.g. mining) use micro-grids to power their operations in off-grid and weak-grid areas.

And finally, several government-backed programmes also exist to support mini-grids, for example, in Mali, where 78,000 households are connected to 250 mini-grids, with 75% of CAPEX covered by a rural energy fund. Indeed in Mali, as in Senegal and other countries, private operators often receive high government subsidies and support [18].

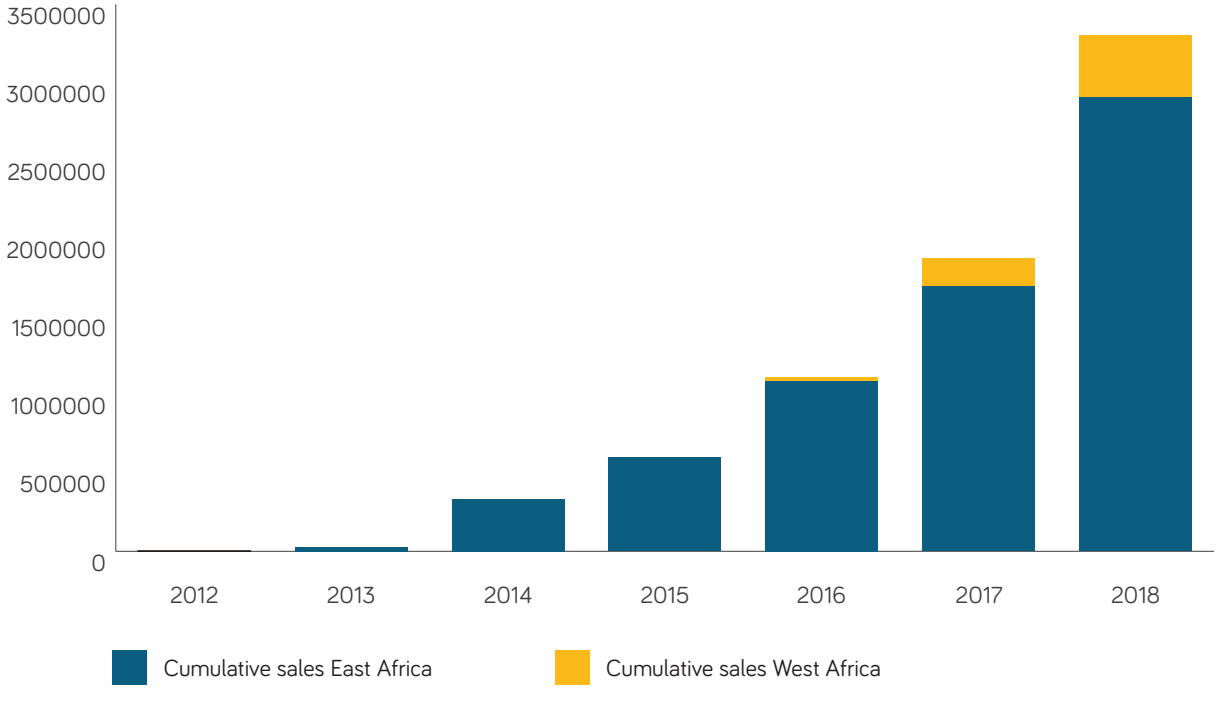
THE EMERGENCE OF MINI-GRID DESCOS

Since around 2005, a new form of formal, private, Distributed Energy Service Company (DESCO) has emerged to provide mini-grid solutions across Africa. These firms aim to build mini-grids not only in one locality, but across an entire country, with a view to establishing a pan-African presence. They are seizing the opportunities presented by falling costs in renewable energy technology and energy-efficient appliances, as well as the increasing use of mobile money technology, to provide mini-grids to off-grid customers.

In recent years, private mini-grid DESCOs have received substantial interest from development finance institutions, and several major energy firms have invested in the

[18] Brookings, 2017

Figure 4 - Cumulative PAYG sales in East & West Africa since 2012 (in units)



sector. Donor agencies and development finance institutions have launched initiatives to stimulate progress, such as the DFID/AFD [19] green mini-grids programme in Kenya, the Africa Mini-Grids Facility from AFD, and GIZ's promotion of solar-hybrid mini-grids. In addition, several multinational firms have been active in this space; French energy firm ENGIE has launched PowerCorner, German utility E.ON has purchased Rafiki Power, and Italian utility ENEL has made investments in mini-grids in Kenya with Power Hive.

AECF has invested in seven mini-grid DESCOs in East Africa. These include Husk Power Systems, a private sector firm based in Tanzania and India, which was founded in 2007 and today operates several mini-grids in Tanzania [20]. Another, Powergen, was founded in 2011 in Kenya, with more than 40 sites in Kenya and Tanzania.

However, up until 2018, the mini-grid DESCO model has been slow to take off. To date, mini-grid DESCOs in Africa have delivered only modest results, particularly compared to grid connections and SHS, and often fail to meet investor expectations. For example, the 11 members of the African Mini-Grid Developer's Association, who represent most of the major mini-grid DESCOs in East Africa, had collectively made 11,000 connections as of April 2018. In a recent study by the Energy and Environment Partnership (EEP), [21] one of the main providers of financial assistance to the sector, the 19 mini-grid projects receiving EEP support had a total of 5,821 connections. And in a recent report by Hystra, four major mini-grid DESCOs were all found to have fewer than 2,000 connections.

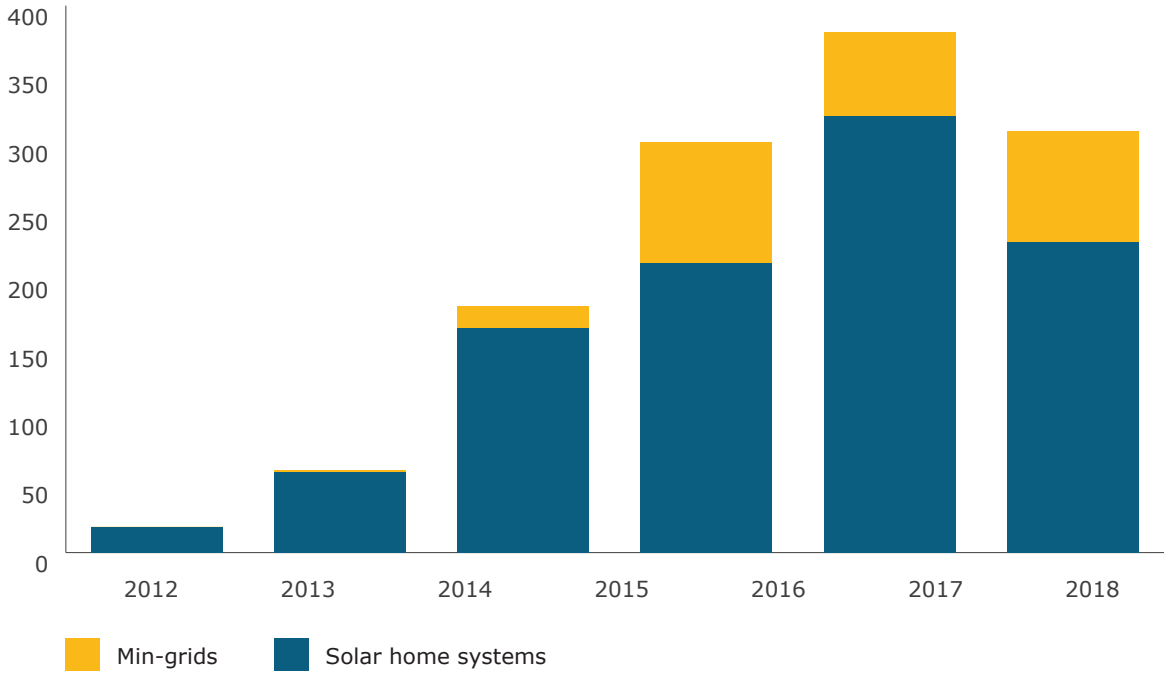
[19] Department for International Development / Agence Française de Développement (French Development Agency)

[20] Husk Power Systems, 2018

[21] The Energy and Environment Partnership (EEP) is is a multi-donor fund providing early-stage grant and catalytic financing to innovative clean energy projects, technologies and business models. More details at https://eepafrica.org/

[22] Bloomberg Climatescope, 2018

Figure 5 - Publicly announced investments in off-grid energy access firms (2013-2018) [22]



The seven companies within AECF's mini-grid portfolio have a total of 4,945 connections (as of December 2019). AECF's initial aggregated goal was to achieve 155,128 connections by 2021. This goal is therefore very unlikely to be reached.

At the same time, the SHS market has grown rapidly, with 2.5m units sold in five years under the PAYGO model [23]. Figure 4 (page 14) illustrates the trend in cumulative PAYGO sales since 2011. As shown, most sales in Africa have been in East Africa, although West Africa experienced growth in 2016 and 2017.

SHS have secured a total of more than US $1bn in funding, compared to less than US $250m raised by mini-grids firms [24]. Additionally, the African Mini-Grid Developers Association reports that its solar mini-grid developers have received less than US $1.5m in donor funding since 2013 [25], as shown in Figure 5 (Page 15).

Within the AECF portfolio, the five major SHS companies have 1.2m connections, almost 700 times more connections than AECF's mini-grid DESCO investees. MKopa has been the historic leader in SHS connections, with over 600,000 sales in 2018. By contrast, AECF's mini-grid DESCOs have less than 2,000 connections each.

Furthermore, beyond the PAYGO model, cash sales of solar products continue to grow, with sales averaging approximately US $3.3m per year in Africa between 2014 and 2018. These products vary from small lanterns to larger SHS, demonstrating a vibrant solar market.

In summary, the experience of AECF and the sector more widely is that mini-grid DESCOs have connected less than expected in the period 2015-2018. To reach universal electrification targets, mini-grid connections will need to increase dramatically. In order for this to happen, a number of key challenges need to be overcome.

[23] ENEA Consulting, 2018

[24] Bloomberg Climatescope, 2018

[25] Bloomberg Climatescope, 2018

CHAPTER 2
MINI-GRID SECTOR GROWTH: THE CHALLENGES

THE ECONOMICS OF ELECTRIFICATION

The main challenge for mini-grid sector development is establishing the economic viability of rural electrification. For both mini-grids and grid extensions, rural electrification is unlikely to be profitable without public financial support. Indeed, connecting large numbers of rural households to an electricity grid is an expensive undertaking, and revenues rarely cover the cost of connection. This is due to the inherent reality of low energy use, public pressure to keep energy prices low, and the high cost of operations and distribution infrastructure.

Throughout the world, governments receive public financial support for universal grid connection. This is the case in developed countries (France, Australia, the UK), as well as developing countries (Nepal, India). As rural areas are often unprofitable, many governments provide subsidies to ensure rural communities can access affordable electricity. Given that African population densities are lower than in Asia and Europe, it is likely that African countries will also need to support rural electrification. Indeed, the economics of grid connection make public financial support a necessity.

When it comes to the economics of rural electrification, mini-grids and grid extensions face similar challenges.

In many cases, mini-grids and grid extensions suffer from low consumption, particularly among households. Across AECF's portfolio, mini-grid revenues have been low, with most firms achieving average monthly revenues per customer (ARPU) of less than US $4 per month [26], but this is not uncommon. According to an IFC benchmark study in 2017, ARPU across 20 mini-grid DESCOs in 12 countries was US $7 on average [27].

Mini-grid DESCOs have put in place innovative measures to increase demand, but still are unlikely to make household connections profitable at scale. The mini-grid firms in the AECF portfolio have used a range of techniques to stimulate demand, including selling appliances, educating customers, and picking better sites. But these efforts have not been enough to drive up profitability.

"In Africa, commercial viability is only possible in a small amount of areas. Subsidies are necessary."
- Mini-grid developer

"Rural electrification cannot be profitable, therefore rural mini-grids cannot be either." ***- Impact Investor***

[26] Africa Enterprise Challenge Fund, 2013-2018. [27] International Finance Corporation, 2017.

Mini-grid firms have also focused on 'anchor' and commercial customers, who use more power, and therefore generate much higher average revenue per connection. But in reality these clients are harder to find in rural areas, and this approach is unlikely to lead to universal electrification. In a recent report by Hystra, one company that investigated 400 mini-grid sites in Tanzania stated that "anchors exist in fewer than 5% of cases" [28]. And as a report by EEP pointed out, "productive users are scarce in rural sub-Saharan Africa, and the existing ones often have inconsistent and seasonally variable demand" [29].

To complicate matters further, the social importance of household energy access means tariff regimes are politically sensitive, and governments are under pressure to keep prices low. This political pressure has led to the introduction of 'lifeline' tariffs, which offer very low electricity prices to vulnerable customers. In several countries, the poorest customers pay significantly less for a basic amount than the standard tariff rate. In Uganda, for example, the lifeline tariff for the first 15 units of electricity consumed is 150 Ugandan Shillings ($0.04)/kWh, half the estimated average cost of providing electricity to households [30]. Figure 6 below shows the applicable rates for Tier 3 customers connected to the grid (consuming around 50 kWh/month). This highlights that in most sub-Saharan countries, rural customers in Tiers 1-3 will pay less than US $10 per month [31].

In some countries, governments have allowed mini-grid DESCOs to apply higher tariffs. In Kenya, mini-grid firms can now negotiate with local government regulators and charge cost-reflective tariffs. This is also the case in Tanzania for mini-grids below 100kW, and in Nigeria for mini-grids below 1MW [32]. But negotiations take time, and on the whole governments are unlikely to allow mini-grid operators to increase charges for rural customers, often insisting on price parity between mini-grids and centralised grid networks. Obtaining permits has therefore been a challenge for AECF portfolio companies.

THE COMPLEXITIES OF COST REDUCTION

Rural electrification involves high levels of capital and operational expenditure. These costs are another barrier to mini-grid expansion, and cost reduction is a key focus for mini-grid firms, many of which design their systems to be as lean as possible.

Solar mini-grids benefit from external help, as most of their CAPEX components decrease over time, thanks to innovation and volume effects. This is the case for PV panels, conversion systems and energy storage, with cost reduction factors ranging between 2 (conversion systems) and 5 (Lithium batteries) since 2010. Vulcan optimistically estimates that costs can be reduced significantly for mini-grids in sub-Saharan Africa, with overall costs (LCOE, which includes CAPEX, OPEX and financing costs) decreasing by 70% by 2025.

However, even with increased innovation, costs are unlikely to reduce enough to obviate the need for public financial support. And cost decreases are much harder to foresee for distribution systems, which already use mature technologies. Even in the Vulcan research mentioned above, the LCOE estimate for 2025 is US $0.44/kWh, which is still considerably higher than lifeline tariffs in several countries.

[28] Hystra, 2017

[29] Energy and Environment Partnership, 2018.

[30] Monitor News.

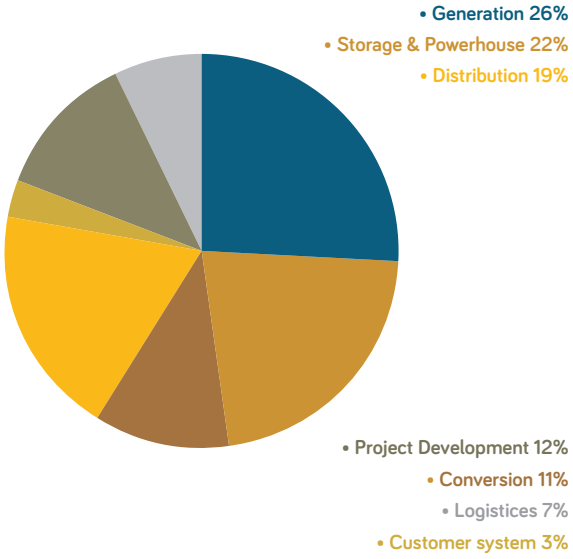
[31] At an average price of 20 cents per kWh, Tier 3 consumers at 50kWh/month pay 50 kWh * 0,20 $/kWh = 10$/month, and Tier 1 & 2 customers necessarily pay less.

[32] IRENA, 2018

Indeed, both rural grid electrification and mini-grids face significant expenditure costs which are notoriously difficult to reduce. Distribution and customer system costs are usually between 20% and 30% of total project costs, at around US $400/connection of the total US $1,200 for a typical grid connection. But these figures depend on the project, and targeting to connect remote customers can lead to increased costs. Though it should be noted, CAPEX is often even higher for grid extension projects to deep rural areas, given the need for transmission lines and the need to meet various quality standards.

Mini-grid and grid OPEX are high as these systems seek to maintain high-quality electricity networks in deep rural settings, where the costs of maintenance and intervention are higher than in cities. In rural settings, additional staff need to be hired close to connections, or maintenance teams have to be called out to sites. This adds significant costs, particularly as all personnel need to be trained technicians.

Figure 6 - CAPEX distribution for typical solar mini-grids [33]



Attempts by mini-grid firms to reduce OPEX are often deemed a 'false economy', with costs increasing after staff numbers are reduced. For example, one AECF portfolio company decided not to employ full-time on-site technicians. But when technical problems occurred, technicians needed to be called in at a considerable cost. The time to repair also undermined customers' trust and impacted revenues. In addition, a lack of staff meant poorer community engagement, leading to equipment theft on several occasions. The company's on-site presence has since been increased.

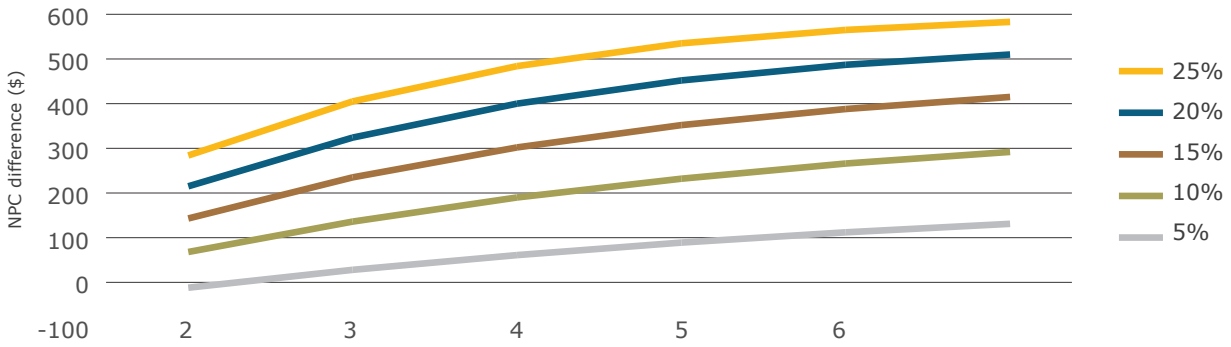
THE CHALLENGE AND OPPORTUNITY OF MINI- GRIDS COMPARED TO SOLAR HOME SYSTEMS

Solar Home Systems (SHS) offer a cost-effective way to provide a basic level of energy service for low-income household electrification. Due to fundamental differences in business model, SHS face fewer challenges to becoming commercially viable than mini-grids.

Unlike mini-grid firms, SHS and PAYGO business models do not require high energy consumption to be profitable. In the SHS model, clients pay to use the kit, and whether they use the maximum energy provided or not, they pay a fixed amount, either upfront or through a fixed monthly payment. The risk of any low electricity consumption is therefore transferred to the customer, and the SHS firm does not suffer from lower-than-expected demand.

Mini-grid operators have responded to this challenge by introducing subscription models, but these are often not well received. For example, several firms have introduced monthly fees for their service, but this has aggravated customers who expect to pay on a 'per-use basis'. In addition, such models are not always allowed by regulators,

Figure 7 - Gains of an SHS then network strategy versus network-only strategy depending on year of network connection and discount rate



who insist that mini-grid providers propose tariffs that align with the grid, or that reflect the cost of installation.

The SHS value proposition is based on a comparison with existing solutions, such as candles, battery torches or kerosene. And unlike mini-grid firms, SHS companies do not face price pressure as they provide services rather than power on a per kWh basis. In this way, they can charge higher monthly prices. SHS firms do not need to 'cluster' homes, and can focus only on those able to afford system repayment. These underlying economics makes SHS commercially viable in many rural cases, allowing the SHS sector to receive investment and grow.

SHS companies can be profitable businesses, attracting commercial equity and debt. In many cases, the SHS model provides positive margins on each product sold, which can lead to financial sustainability if a firm is able to reduce central overheads. In addition, prices are not regulated or comparable with the main grid, and CAPEX and OPEX are kept low.

However, SHS are currently too expensive for providing high levels of power, which are needed for 'productive use' of energy. An SHS currently costs more than US $3,000 for an 800W system, which would provide levels of power needed for productive uses, such as agricultural processing, welding or cooling. This is too expensive for most rural households. And unlike mini-grids, SHS do not benefit from economies of scale or pooling of resources, so are more expensive than mini-grids on a per kWh basis.

It is also worth remembering that SHS can be leveraged to facilitate mini-grid market entrance and analysis. SHS are more affordable in areas of low population density, and can be an option to test customer demand before connecting them to a mini-grid. In 2018, ENEA conducted basic economic modelling to demonstrate the advantages of using SHS to prepare for mini-grid investment. This strategy depends on discount rates, the SHS length of service prior to grid connection, as well as connection costs. For expensive connections (remote customers), this strategy makes sense in most cases even if the SHS is used for only a year.

As can be seen in the above model, at a cost of US $100 for an SHS, and a connection cost of US $1,000, testing the market with SHS is profitable in all cases.

LACK OF PUBLIC FINANCIAL SUPPORT FOR MINI-GRIDS

One of the critical impediments to mini-grid sector expansion is the fact that the mini-grid business model does not receive major public financial support. Without this support, mini-grid DESCOs will struggle to grow.

By contrast, over the last ten years there has been significant national and international public investment in main grid extension programmes in Africa, delivering 25m new household connections. The type of public sector support varies across countries, ranging from direct financial incentive programmes to cross-subsidies and debt restructuring. According to the World Bank, 38 out of 40 sub-Saharan countries studied are in quasi-fiscal deficit [34], meaning the cash collected by utilities is lower than their capital and operational costs. Consequently, they must find other ways to subsidise their activities, including:

- ***Direct financial support:*** In Kenya, the Last Mile Connectivity Project has received a US $32 million grant from the EU to subsidise connections.
- ***Low-cost finance:*** The International Bank for Reconstruction and Development provides loans to utilities at below commercial interest rates. For example, Power Holding Corporation of Nigeria received loans at 5.5%-11.6% from development finance institutions, far lower than the cost of commercial loans.
- ***Cross-subsidies***: Across Africa, utilities cross-subsidise rural electrification by making larger profits on commercial and urban customers. Governments place pressure on utilities to maintain these subsidies rather than providing direct financial support [35].
- ***Support for debt restructuring***: Many African utilities have run for years at a loss. These debts have been restructured and written off with the support of development partners.

While these public financial support mechanisms vary, they are all used to fund rural electrification. For mini-grid DESCOs, such public financial support is not available, and yet operating 'subsidy free', as has been proven in recent years, is not a viable option.

SHS firms were first designed to be subsidy free [36], using their profitability to attract investment, and many mini-grid DESCOs, including several in the AECF portfolio, have tried to emulate this commercial model. While in certain areas mini-grids may be profitable, in rural areas this is not the case and firms have not reached commercial viability. In turn, this lack of profitability has led to lower investment in the private mini-grid sector, with many firms unable to raise equity or debt finance.

"The financial support for mini-grids is microscopic compared to funding for grid connection."
- Mini-grids industry representative

[34] World Bank, 2016.
[35] Tenenbaum, Greacen, Siyambalapitiya, & Knuckles, 2014. [36] SHS firms have benefited from large levels of subsidy from development partners. However, particularly as the technology has matured, these subsidies have likely helped these company grow at a higher pace than if only fueled by private investments. The fundamental economics of solar home systems mean the model can be commercially viable.

In many areas, investment in DESCO-managed mini-grids would be a far smarter use of public finances than grid extension, but a strong case needs to be made to public funding bodies. As seen, mini-grid DESCOs offer advantages in terms of innovation and time-to-market. They are also agile and quick to innovate, in stark contrast to regulated utilities, which tend to be relatively slow-moving organisations.

Mini-grid DESCOs have also developed technical competence at optimising solar-plus-diesel-plus-battery storage hybrid systems. Most new mini-grids use renewable energy, requiring expertise in sophisticated optimisation technologies and energy management systems which utilities have not yet developed.

In addition, Mini-grid DESCOs have the advantage of being purely focused on rural customers. In recent years, many firms have developed innovative tools and practices to encourage energy use in rural settings, for example selling appliances to customers and offering consumer finance solutions.

Collectively, this means that mini-grids have a strong value proposition for providing rural electrification. But national governments will need to be convinced of this value if the sector is to receive public financial and regulatory support.

MAIN GRID ARRIVAL

The arrival of a centralised grid is another major risk for mini-grid developers, whose revenues can be impacted as customers switch to lower, subsidised tariffs. This risk stems from the unpredictability of main grid expansion plans in sub-Saharan Africa. The unforeseen arrival of a main grid can result in mini-grid DESCOs being forced to cede operational activities, and several mini-grid DESCOs have suffered revenue loss in this way.

However, this risk is being reduced as states work to increase the transparency and stability of their main grid expansion plans. For example, a new set of regulations have been implemented across sub-Saharan Africa

offering mini-grid DESCOs compensation upon main grid arrival. Kenya, Nigeria, Sierra Leone, Somalia and Tanzania are among the countries that have implemented or are developing compensation plans. These regulations are relatively new, and therefore implementation has not yet been tested, but they constitute a first step towards hedging mini-grid DESCOs against unplanned main grid arrival.

PERMITTING PROCESSES

In the past, long and expensive procedures for obtaining development permits have been a major hurdle for mini-grid DESCOs. Mini-grid DESCOs operating in Tanzania claim to be impacted by environmental permits that can cost US $30,000 per grid. As well as creating costs, these rules hinder project implementation and require additional management resources. By contrast, national utilities do not face these challenges, and other sectors, such as telecommunications, have benefitted from lighter permitting requirements.

However, long and expensive permitting processes are now being optimised to facilitate mini-grid development. Countries like Nigeria, Rwanda, Sierra Leone and Tanzania are working on establishing clear and standardised administrative rules and processes for mini-grids. Even though most of the simplifications currently only apply for mini-grids with less than 100kW production capacity, they underline a lightening trend for mini-grid permitting. And while regulation generally has presented major barriers to mini-grid DESCOs in the past, these challenges are gradually being overcome.

OPERATIONAL CHALLENGES

Mini-grid DESCOs have faced, and continue to face, certain operational challenges. In the early days of mini-grid development, mini-grids suffered from a lack of community acceptance. This led to equipment damage and theft by customers, which increased operational costs for mini-grid DESCOs.

More recently, local acceptance has improved due to increased number of staff on site. Although on-site presence generates additional costs, it makes economic sense by decreasing overall operational expenses. Some mini-grid DESCOs go even further, employing community relationship managers and village educators to help increase local awareness and acceptance of mini-grids.

Mini-grid DESCOs also face the common challenge of revenue collection. Mini-grids collect revenues from a high number of customers with low average revenue. Consequently, high revenue collection costs can be exacerbated by delayed payments and unpaid bills. Most companies have begun to apply solutions for payment optimisation, with prepaid models being employed to reduce payment delays, non-payments, and revenue collection costs. Prepaid models have other advantages. They allow pricing that incentivises efficient energy management, and they provide a model with which customers are familiar. In fact, despite implementation complexities, prepaid is emerging as the main payment system for mini-grid DESCOs, and is expected to continue to be deployed to optimise revenue collection.

CHAPTER 3
MINI-GRID SECTOR GROWTH: THE SOLUTIONS

As seen, while there are multiple challenges to mini-grid sector growth, the most significant is the lack of public financial support, without which the mini-grid DESCO model is unlikely to succeed. As with other rural electrification efforts around the world, significant public financial support is needed in Africa to increase rural electrification, particularly given the continent's low population density.

National governments and development partners can implement ambitious subsidy regimes that recognise the public good provided by mini-grids. So far, external subsidy schemes for the private sector have been rolled out across Africa, but these have been limited in scale and need to be tested further.

Development partners have acknowledged that the mini-grids sector needs to be supported, and several donor organisations have set up a wide range of financial support programmes. These programmes have typically involved significant results-based financing and capital expenditure subsidies. In Kenya, the US $12m Green Mini-Grid Facility provides results-based financing, as well as technical support. One AECF investee, Powergen, has benefited from this programme. In Tanzania, DFID and SIDA have introduced a finance programme to provide connection grants based on the level of electricity provided. And in Zambia, USAID has supported the development of a mini-grid, while Beyond the Grid, an EU-SIDA programme, has supported the company Standard Microgrids on a results basis.

"Delays by key donor programmes have harmed the sector in the eyes of national government."
- Industry representative

Such programmes have provided much needed funding to the sector, even if the numbers of mini-grids and connections remain relatively low. All the companies in the AECF portfolio have benefited from this public finance support, as have other major firms in the sector. For example, the Kenyan mini-grids programme supports three mini-grid DESCOs – Powerhive, Powergen and RVE.Sol. Meanwhile, EEP has assisted firms such as Ensol, E.On Off-Grid Solutions (Rafiki Power), Husk Power, PowerGen, and Redavia.

In these models, the mini-grid DESCO develops, operates and owns the mini-grid assets on a concession basis, with little operational involvement from the national government or utility. The main schemes highlighted are carried out in close consultation with the national government, including the relevant rural electrification agency. However, these programmes have been relatively slow to implement, causing frustration among key stakeholders, including

those in the AECF portfolio. Both the Tanzania and Kenya GMG programmes suffered significant delays. These delays are often caused by the need for rigorous due diligence, as well as national government sign-off. Other subsidy programmes have also suffered from slow fund disbursement, causing frustration along the value chain.

In addition, these programmes tend to provide relatively short-term subsidies, and do not support projects over the long term. Development partner programmes typically provide financial support for construction (CAPEX grants), as well as payments on the achievement of certain short-term milestones (e.g. finalised construction and installed connections). However, this means that, in the long term, once the initial financing is spent, there is little outside support to fund operational costs, particularly when there is a technical fault. And if average revenue per user (ARPU) is low, there may not be enough to cover costs, and the grid may cease to operate.

As well as capital expenditure subsidies and results-based financing, other subsidy mechanisms are being tested, such as 'per kWh' tariff subsidies. Rockefeller, CrossBoundary and Powergen have tested mechanisms which allow firms to receive a subsidy for the difference between the lifeline tariff and the tariff required by the mini-grid. One developer views tariff subsidies as the best way to subsidise mini-grids, because they incentivise mini-grid DESCOs to increase consumption levels. It is also a legitimate subsidy mechanism because, as with cross-subsidies, the main grid operators can provide clients.

These new innovative tariff mechanisms are currently being tested, but are more complicated than connection subsidies, given the need for long-term support. They also remain relatively small compared to the challenge of providing universal energy access, and may not be sustainable in the long term. Private sector support programmes, while contributing to sector development, have only achieved tens of thousands of new connections, whereas millions will be required to meet the energy access challenge. In addition, short-term development partner programmes will leave companies reliant on external financial support which is dictated by partner priorities and resources.

NATIONAL GOVERNMENT SUPPORT

Mini-grid programmes managed and financed by the government should, in theory, be more sustainable in the long term than development partner schemes. In Africa, these government-led models have been carried out in several geographies, and in most cases have relied on public entities (e.g. communities or public cooperatives). For example, in Mali a government-led programme resulted in the connection of 78,000 people between 2005 and 2012 through a US $600/connection CAPEX subsidy to local organisations, and through differentiated tariff rates. In Burkina Faso, over 100 cooperatives connected 230,000 people through 32,000 connections via a now extinct model.

The problem here is that public entities may not be incentivised to work on increasing energy demand or making projects profitable in the long term. Strongly reliant on subsidies, cooperative schemes have also often failed to generate strong demand. Large utilities are therefore more used to managing load shedding than promoting increases in demand and usage. Indeed, 11 sub-Saharan countries currently suffer from more than 200 hours of power outages a year.

By contrast, mini-grid DESCOs usually start with oversized generation systems, and are strongly incentivised to sell this electricity. They also need to convince communities that their offer is relevant and preferable to waiting for main grid arrival. Mini-grid DESCOs have therefore become experts in identifying the appliances that can best increase use of their assets and benefit the local population.

Nepal provides an interesting example, with a recently redesigned national policy targeting private mini-grid operators. In Nepal, over 1.5 million people have been connected through the public sector-led AEPC mini-grids programme. In this programme, AEPC provides subsidies for community- and cooperative-owned hydro-powered mini-grids, with eligible projects receiving a subsidy that covers 50% of capital costs. As of 2017, privately owned projects are also eligible [38] to participate in the model. But very few communities have been willing to take out loans to fund the mini-grids, and have therefore needed to wait for additional public financial support. In some cases this has meant a wait of several years between the subsidy being granted and the project being built.

"Private sector operators have a strong incentive to work on encouraging productive uses." - ***Industry representative***

THE PUBLIC-PRIVATE APPROACH

It is AECF's and ENEA's strong belief that purely public or purely private mini-grid programmes are unlikely to be the best route forward for the sector as a whole. The advantages and limitations of each are described in Figure 8 and the table on page 31.

Given the limitations and vulnerabilities of both the private mini-grid DESCO model and fully public mini-grid model, a mixed public-private approach is likely to be the best solution. And indeed, innovative public-private partnerships are emerging, whereby mini-grid DESCOs work with national governments to launch decentralised mini-grid networks. These public-private partnerships need to be tested further, but hold huge potential for the mini-grid sector.

Of course, as in any successful and long-lasting alliance, the interests of all stakeholders should be central to every aspect of partnership dialogue and development. For example, in their approach to mini-grid sector development, governments are seeking to reach two main objectives:

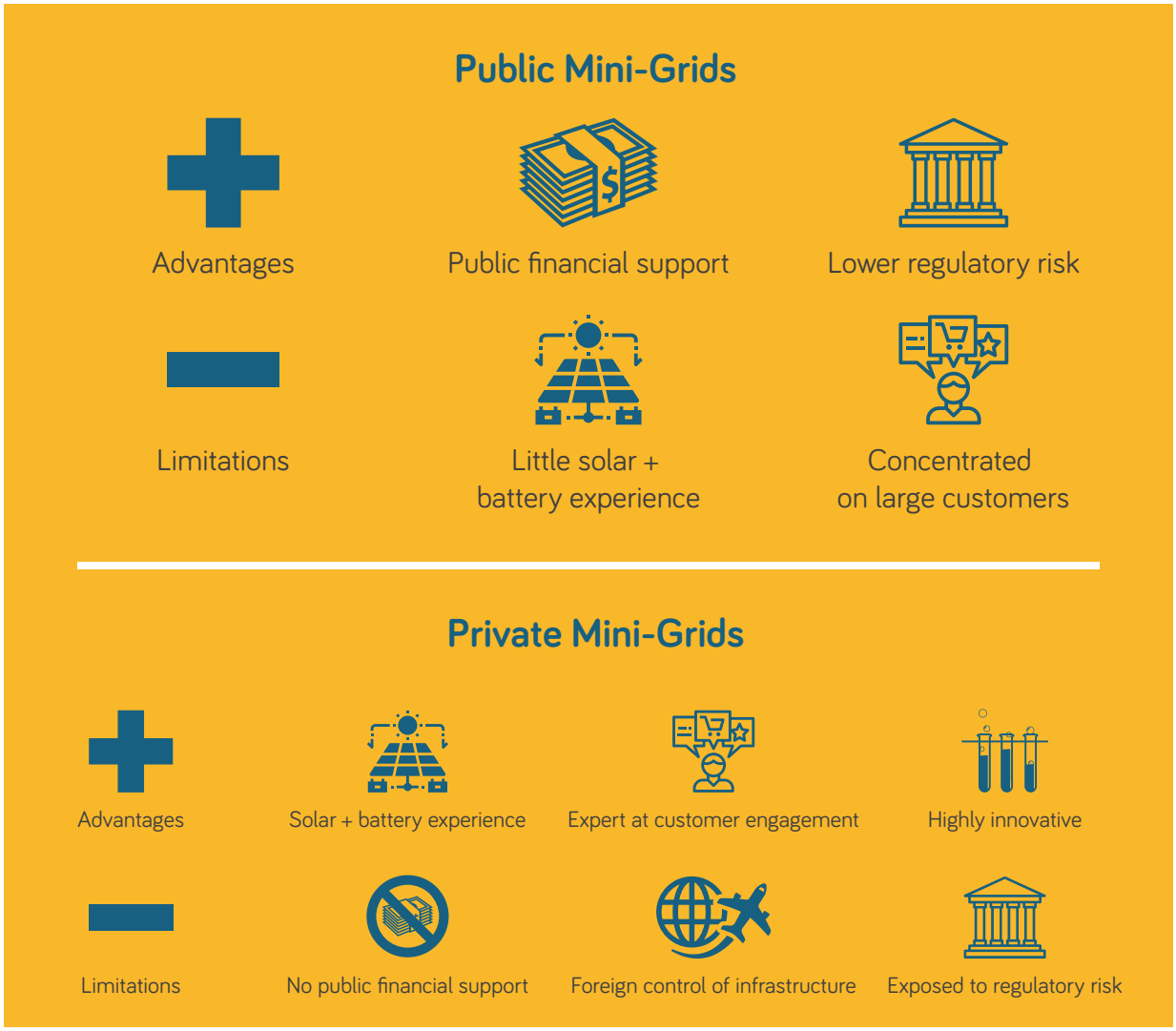
[38] USAID, HYDROPOWERED MINI-GRIDS IN NEPAL, https://www.usaid.gov/energy/mini-grids/casestudies/nepal-hydropower, 2018

- Increase effective electricity access rates in the country at the lowest cost to the community
- Set up sustainable and long-lasting infrastructure

Mini-grid DESCOs, meanwhile, require long-term visibility to engage investors to fund their activities, and as such are willing to change their business models to make partnerships work. It is important to keep in mind that governments will try to benefit from the expertise of existing DESCOs, and in return need to give DESCOs a financially viable role in the value chain, either as IPPs, EPCs or as local distribution companies.

Several new mini-grid programmes, for example in Kenya and Sierra Leone, work on a private-public partnership basis, with mini-grid DESCOs and national entities (rural electrification agencies, ministries or national utilities) sharing responsibility and ownership. Other programmes, as in Nigeria and Benin, still use a mini-grid model, but with the government managing and providing a subsidy for each mini-grid connection.

Figure 8 - The main advantages and limitations of the public and private mini-grid business model



"More coordination is needed between actors in the mini-grid sector – including between financial actors, governments and developers." - ***Impact investor***

In Kenya...

Off-grid Solar Access Project for Underserved Counties, the national distribution company, Kenya Power, and Lighting Corporation share the ownership of mini-grid infrastructure, which is built by private firms [39]. These firms also sign long-term operation and maintenance contracts for the generation and distribution network. After the recovery of the private investments, all assets will belong to the Kenyan government.

In Sierra Leone...

The national government, through the RREP (Rural Renewable Electrification Project), will fund and install electricity distribution networks. Private sector operators are expected to finance, construct, install and commission power generation assets. The private sector firm will then manage the operation of all power generation and distribution assets. But the distribution assets will remain under the ownership of the government [40].

In Nigeria...

The Rural Electrification Agency, with the support of a US $350m facility from the World Bank, is implementing an ambitious mini-grids policy. The funds available for the mini-grid component are US $150m. This component consists of two funding windows: 1) A minimum subsidy tender to connect selected communities that have high economic growth potential, with the grant amount determined competitively through the tender. 2) A performance-based grant programme for the development of mini-grids on a spontaneous basis (developers may connect communities of their choice), with the grant amount set at US $350 per connection. While ownership modalities are not fully defined at time of writing, this model demonstrates the need for the national authority, in this case the Rural Electrification Agency, to be involved in subsidy definition.

In Benin...

The government, in cooperation with the Millennium Challenge Corporation, is also providing a subsidy for mini-grid connections under a concession model. A tender was launched in early 2019 for project developers. Under the terms of the tender, private operators will build, operate and own the assets. The government-managed Millennium Challenge Account-Benin will verify and audit the installations, and provide a series of results-based payments.

"We are open for the government or utility to own the distribution assets." - ***Mini-grid developer***

[39] World Bank, 2018.
[40] Government of Sierre Leone, 2017

Table 1 - The main advantages and limitations of the public and private mini-grid business models

PUBLICLY OPERATED MINI-GRIDS

Advantages	Disadvantages
Public financial support Publicly-owned mini-grids benefit both from cross-subsidy from more profitable customers, and from national and international financial support (e.g. connection subsidies, long-term concessional loans).	**Little solar + battery experience** Public utilities have historically focused on national grid extension, and most public mini-grids have been run on diesel generation. Few utilities in Africa have built mini-grids with battery storage.
Lower regulatory risk As mini-grids will be owned by utilities, there is no competition when the grid arrives in an area. In addition, permitting is likely to be less of a challenge for public authorities.	**Less focus on increasing rural demand** National utilities have a wide client base, and rural customers are often loss-making for them, while their main revenue comes from large industrial clients. Their focus on raising rural demand is likely to be lower in most countries than private mini-grid firms.

PRIVATELY-OPERATED MINI-GRIDS

Advantages	Disadvantages
Solar + battery experience Several firms now have 10 years of experience combining solar with battery and diesel. This often requires mastering energy management software, and other technical innovations. Private mini-grid DESCOs can provide this expertise.	**Limited public financial support** Private mini-grid DESCOs do not have the same ability to cross-subsidise at the national level compared to utilities.
Expert customer management Private mini-grid firms have been proactive in finding solutions to increase customers' energy use, from offering appliances to deploying village-level customer support staff.	**Foreign ownership of infrastructure** Many private mini-grid DESCOs are owned (or part-owned) by investors from outside the countries of operation. This may create a reluctance from national governments to provide too much subsidy or support for firms considered 'outsiders'.
Highly innovative Private mini-grid firms can test new ideas quickly, scale them, or stop. Utilities, given their size, do not have this advantage.	**Exposed to regulatory risk** Mini-grid firms across the AECF portfolio have experienced regulatory problems, from permitting to lack of clarity on tariffs to unplanned grid arrival.

The table below outlines the different ownership models that could exist in a public-private partnership within the mini-grid sector.

Table 2 - Example table of different ownership modalities

<table>
<tr><th></th><th>Generation</th><th>Distribution</th><th>Customer/billing/ demand</th></tr>
<tr><td>Build</td><td>Private sector EPC usually preferred option</td><td>Private sector EPC usually preferred option</td><td>Private sector usually preferred option</td></tr>
<tr><td>Own</td><td rowspan="2">Can be IPP or a government model</td><td colspan="2">Distribution company or government ministry may naturally be best counterpart for ownership of distribution assets</td></tr>
<tr><td>Operate</td><td colspan="2">Private sector usually preferred option under a contract with government</td></tr>
</table>

Many more such ambitious public-private initiatives are also emerging. But within these schemes, the long-term role of mini-grid DESCOs needs to be tested. These programmes are only beginning, and it is too early to determine the optimum role of the different actors involved. The main need is therefore to test these different models to find the optimum task breakdown between public and private developers. Beyond the key questions of who builds, operates and owns the asset, several questions remain regarding the optimum length of contract, which body interacts with clients, the modalities for asset transfer at the end of the project lifetime, and which national entity is best placed to manage these programmes. Further research and evaluation of existing models should also be carried out.

BEYOND TRADITIONAL MODELS

Beyond the traditional mini-grid model, there may be other new innovative models which can provide high levels of power to rural communities, without investing in a distribution grid. This could be in the form of an energy kiosk or large standalone solar system model, which focuses on providing higher levels of energy services to commercial clients.

In fact new business models that provide productive power in a lower-cost way are already being implemented. Productive use in agriculture is at the core of rural community economics, and research shows that

productive use of energy, when associated with equipment and training, is linked to an increase in socio-economic development [41].

These alternative approaches are affordable as they avoid building expensive distribution networks. The strategy is to save costs by connecting only productive use close to a power plant. Designing a plant for dedicated productive uses also makes it easier to plan consumption and size the system which, in turn, effectively pays for itself.

AECF mini-grid firm, Devergy, has developed one such solution, shifting away from large-scale distribution assets to a 'mini-grid in a box' model. Other pioneers include Solar Kiosk, Benoo Energies in Togo, and Heri in Madagascar.

These standalone systems can eventually transform into smaller mini-grids. They can also serve those areas mini-grids are unlikely to reach with productive power, or with services such as water purification. The advantages of such a model are described in figure 9 below.

Finally, there will be a limited number of locations where mini-grids are commercially viable without public financial support. Indeed, several firms are already operating such mini-grids in countries such as the Democratic Republic of Congo (DRC) and Nigeria, where the central grid does not exist, or is highly unreliable, and green mini-grids are replacing expensive diesel generation. But these tend to be in urban and peri-urban areas with dense populations and high levels of commercial activity, which represent the minority of non-electrified areas in Africa. A paradigm shift will be required to scale the use of mini-grids in Africa. To support this shift, AECF and ENEA have developed a sector-wide Theory of Change to show the major actions needed to accelerate and grow these business models.

[41] Government of Sierre Leone, 2017

Figure 9 - Standalone local power systems


OSRAM
O-LAMP
2 in1

CHAPTER 4
THE THEORY OF CHANGE AND AECF'S FUTURE ROLE

THE THEORY OF CHANGE

The Theory of Change articulates the new types of public-private partnership that will be needed to enable mini-grids to benefit from public subsidies, as well as from appropriate regulatory frameworks. It considers the different interventions required for the mini-grid sector to expand and respond to the energy access challenge. The Theory of Change is described in Figure 10 below:

The Theory of Change in founded on the clear recognition that fast adoption of mini-grids is required to speed up rural electrification. It acknowledges that in order to reach universal electrification by 2030, a new mini-grid industry paradigm involving private DESCOs, public authorities and utilities is essential. It is also built on the understanding that the status quo, which involves private mini-grid DESCOs working on a purely independent and commercial basis, is unlikely to deliver growth fast enough to achieve meaningful impact.

Crucially, The Theory of Change headlines the activities, inputs and outputs necessary to achieve the following outcomes: increased financing for mini-grids, enhanced models of public-private partnership to develop and operate mini-grids, and increased use of new technologies and business models. Outcomes which, in turn, support the main goal of poverty reduction through access to affordable, high-quality energy.

Mini-grid DESCOs and their shareholders should acknowledge the transition proposed in The Theory of Change. And they should reinforce their value for the sector as innovation leaders by implementing new financing, contractual and legal models, which will create confidence with investors and local authorities. Only through new business models, ownership structures and approaches will companies and governments work together successfully to achieve rural electrification in Africa.

AECF'S FUTURE ROLE

As The Theory of Change makes clear, different actions will be needed to scale the mini-grid sector. Several of these actions are beyond the scope of AECF's activities. However, AECF can play a critical role in certain areas to ensure the sector develops. The identified priority actions, which AECF is well positioned to deliver, are as follows:

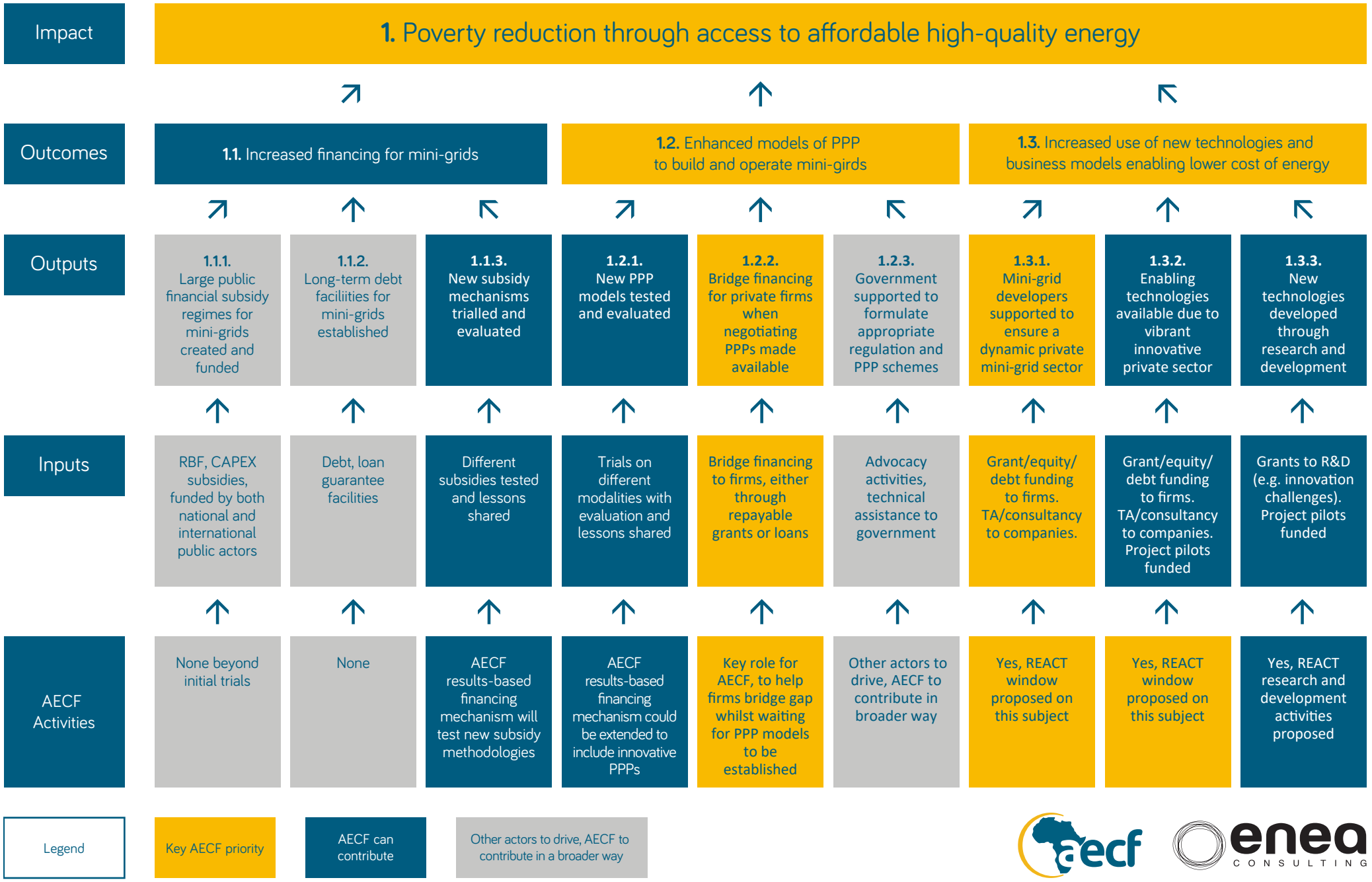
- Provide catalytic finance for early and growth stage renewable energy companies.
- Promote public-private mini-grid partnerships by proivding essential 'bridge financing' to mini-grid DESCOs (both established firms and reputable start-ups) as they wait for larger public finance support mechanisms.
- Carry out monitoring, evaluation and learning activities around these new public-private models.
- Support innovative early-stage firms that are developing new models that use standalone solutions to provide energy for productive use in rural areas.

NAVIGATING THE 'VALLEY OF DEATH'

Within these areas, AECF is best placed to provide the private sector with 'bridge financing' between the moment a public-private partnership is conceived, and the moment public support funds arrive. Each results-based financing facility for mini-grids studied has suffered significant delays. Programmes which require even greater private sector engagement are likely to need even further support from government. Start-ups urgently need financing to get them through this initial phase, which is often referred to as the 'valley of death' for new energy ventures. AECF can help navigate this difficult terrain.

Bridge financing would need to support firms applying for public financial support. The costs would cover feasibility assessments, salaries and community engagement, as mini-grid firms wait for larger public subsidies to be released for construction and operation. It is likely that a bridging facility would need to extend not just to early-stage firms but also established mini-grid companies, who also require such financing as they wait for subsidies. This has been a major bottleneck for several firms to date, and with an increased need to involve the public sector, is likely to increase. The support of several key actors, namely national governments, DFIs, and commercial banks, will also be essential to help address key funding needs in the future.

Figure 10 - Sectoral Theory of Change for mini-grids



ADDITIONAL AECF FOCUS AREAS

In addition to bridge financing, as noted above AECF would be well suited to monitoring and evaluating the success of these different models, piloting new subsidies, and continuing to support innovative companies with early-stage financing. The table below provides an analysis of where AECF could support the sector:

Figure 11 - Areas of support for public-private partnership and potential AECF focus areas

Outputs	Explanation of importance	AECF role?	Other actors
1.1.3. New subsidy mechanisms trialled and evaluated, including incentives to increase energy demand	Some tests ongoing, but few lessons publicly shared yet	AECF can test different subsidy mechanisms through an RBF mechanism.	Utilities, development partners, consultancies
1.2.1. New PPP models tested and evaluated	Projects only just beginning. Little information shared on successes and learning	AECF results-based financing mechanism could be extended to include innovative PPPs	Utilities, regulators, development partners
1.2.2. Bridge financing for private firms when negotiating PPPs made available	No facilities available, and likely to be a major gap for firms	Key role for AECF, to help firms bridge the 'valley of death' while waiting for PPP models to be established	Impact investors, few currently doing this
1.2.3. Government supported to formulate appropriate regulation and PPP methodologies	Regulations improving, but implementation remains a challenge	Policy and Advocacy component proposed under REACT SSA Programe	Governments, development partners, consultancy firms
1.3.1. Mini-grid developers, as well as standalone systems producers, supported to ensure a dynamic private mini-grid sector	Lack of equity finance, given lack of business model viability. Until subsidy regimes are developed, grant funding and soft equity likely required needed	REACT window proposed on this subject. Also supported by bridge financing proposal.	Investors, companies, business support providers
1.3.2. Enabling technologies, such as data, smart meters and efficient appliances available due to vibrant innovative private sector	Interested companies emerging in data (e.g. The Odyssey Project), meters, etc but more likely needed	Specific REACT window proposed on this subject	Investors, companies, business support providers
1.3.3. New technologies developed through research and development	More research needed, particularly on productive use appliances	REACT support to R&D efforts	Research organisations, universities, funders

In the ways outlined above, AECF can support increased public involvement in the mini-grids sector by assisting private actors as they engage with public organisations on new public-private business models. In so doing, AECF is committed to expanding the provision of productive power to rural areas, and reducing poverty through access to affordable, high-quality energy.

CHAPTER 5
CASE STUDIES: DEVERGY

Devergy, a social energy utility, provides **electricity services** to low-income people in developing countries. **AECF supported their scale-up in Tanzania**. Devergy has historically focused on village-sized energy **micro-grids,** which provide **solar power** to households and businesses. More recently, the company began offering larger standalone solar systems, offering a 'mini-grid-in-a-box' solution for local entrepreneurs, and providing a **pay-as-you-go refrigeration system**.

Devergy tries to tailor their grids to the needs of rural populations by ensuring grid capacity is at the minimum necessary to provide exactly the energy customers need. For their mini-grids Devergy uses **adaptive capacity and 24 hour monitoring**, so whenever there is a need to supply more energy, we can expand the grid in the exact location where it is needed. This keeps the investment per connection low, giving our customers an unprecedented, **trustworthy service** that grows with them.

Devergy was founded **in 2010** and began operations in 2012. The firm is active in Tanzania's Bagamoyo and Morogoro districts. Devergy's systems under 1 MW threshold are required to obtain a license. The micro-grids do not exceed the 100 kW limit and thus are exempt from prior regulatory review and approval of retail tariffs. The energy services are offered in packages (daily, weekly, and longer), rather than kWh. At the end of the grid's life, the distribution network of the Devergy micro-grids is not built to the standard of the AC grid and so could not be assumed by the utility.

Devergy's teams work **closely with the local community**. They have dedicated village identification groups to target the correct sites. They then employee community relationship managers, village educators to ensure communities understand the value of the mini-grid. Finally, each village has an Energy Committee to ensure continuing **good relations with the community.**

Customers' feedbacks and experiences, positive stories:

- **Peter in Ifumbo:** "The first time I got Devergy electricity was the same **feeling of happiness** as when I got married. **My status has risen**. At first, I was just transporting Devergy material from Mbalizi to Ifumbo, then he installated electricity"
- **Chipsi Mayay Business Ifumbo:** "The first time I had electricity it was like the first time I had a baby. I am now making **more money, working more hours**...now able to work up to 2 am in the morning"
- **Anonymous customer:** "I had no hope of having electricity even if Tanesco was to come to my village since my house is grass roofed, but with **Devergy I have electricity.**"
- Some customers have been able to **increase their income** using electricity from Devergy. For instance, one shopkeeper has increased profit by 3,000 (USD 1.34) per day while a bar owner has increased the profit by 70,000 (USD 31.3) per week.

Devergy set up a **new refrigeration business line** in 2018. In the first 6 months of 2018, they have installed 17 fridges, using 6 enboxes system. Villages are enthusiastic about the possibility to keep **vegetables fresh for longer**, and **valuable meat from spoiling. Cold drinks** are the cherry of top of this already impactful new venture.

CASE STUDIES: HUSK

Established in 2008, **Husk** pioneered an **off-grid power generation and distribution solution** to serve **rural customers** in Bihar, India. Husk was the first company to use **100% biomass gasification from rice husk** to generate 6-7 hours of electricity for households and small businesses. They have developed a **proprietary gasification process** wherein the producer gas goes through a water-less scrubbing and filtration process. They developed a new heat exchanger process that has eliminated any need for water, making them the only company in the Indian gasification industry that does not waste even a single gallon of clean water.

Husk is one of the world's leading **off-grid utilities**. They **provide reliable power to rural communities and businesses**, entirely from renewable energy sources. They design, build, own and operate the lowest cost hybrid power plant (20-250kW) **and distribution network (mini-grid) in India and Africa**, offering their customers a flexible **'pay-as-you-go' energy service**, using a mobile-enabled smart metering system.

In addition to providing access to off-grid energy, Husk also sells **household and commercial appliances to local communities**, from TVs and freezers to biomass gasification system to power Ag-processing units.

AECF provided USD 750,000 (500,000 grant, 250,000 loan) to help Husk transfer technology, develop local assembly capacity and build Tanzanian operations for the business.

India: They are currently operating over 75 **mini-grids** with a capacity of over 1.75MW in Bihar and UP. They employ ~125 full time employees and ~80 part time women employees across sites in Bihar and UP.

Tanzania: They currently operate **5+ mini-grids** and are converting these mini-grids to a hybrid power plant system. They employ 15+ people in Tanzania across various sites and at the head office in Dar es Salaam.

Success stories:

- In November 2015, they completed their third installation, a 40 kW rice husk based biomass plant that will serve **more than 150 households** and **small trading centers** in Kongwa village, a remote offgrid village in Morogoro district.
- They also secure a grant funding from USAID to install 10 hybrid systems (Solar PV + Biomass) to provide **clean affordable power in the food value chains of Nigeria and Ghana**. The grant financing represents yet another validation of the **viability of their clean energy solutions** to provide power for productive activities.
- Husk electricity is provided at rates such that our clients can retain **significant savings compared to their previous sources of energy**. None of our customers previously had access to grid electricity. Instead of using kerosene, battery-powered devices, or, in rare cases, a small generator to light and power their lives.

CASE STUDIES: POWERGEN

PowerGen was founded in 2011. The firm aims to **increase access to renewable energy** in Africa. Powergen operates and managers its own mini-grids, as well as providing Engineering, Procurement and Construction (EPC) services for other companies. Powergen-operated mini-grids are mostly found in Tanzania and Kenya, but the firm has also built systems in Zambia, Mozambique and other countries.

At the beginning, they used to operate a business focused on engineering, design, procurement, and installation of kW-scale **off-grid solar and wind power systems in East Africa**. Due to high upfront cost, they then entered the **micro-grid business (energy as a service)**. Over the course of 5 years, PowerGen installed hundreds of renewable energy systems across seven countries in East Africa and built a team of more than 50 full-time professionals focused on delivering off-grid power systems to the region. **They built their first micro-grid in 2013 in Zambia, and since then have installed dozens more across Kenya and Tanzania.** Thousands of people benefit from the clean energy they sell to them **on a pay-as-they-go basis** throughout **rural areas of East Africa. In 2015, AECF awarded PowerGen with grants and loans to install over 10 micro-grids.**

PowerGen EPC (Engineering, Procurement, Construction) has been delivering high quality renewable energy systems throughout seven countries in East Africa for over 7 years. **They are experts in integrating solar, battery storage, and diesel generators along with smart metering and control systems** to create sustainable, cost-effective energy solutions for all scenarios

Powergen presence in a village changes the community by giving them several opportunities:

- Have children study at night and do their homework safely rather than using the paraffin lamps
- Businesses operate longer and grow income and village economy
- Hospitals are now able to work 24h and able to purchase electric lifesaving equipment
- Murusagamba health clinic – It is serving more than 2-3 villages around Murusagamba now after getting power from Powergen

Another meaningful example:

- Kasalazi – They have empowered a customer to start a video hall business which they believe in the next few months will enable him to earn more money to improve his life standards. (Mr Chacha bought a sub-woofer and a TV on finance from their DS team, and now he charges people to go watch TV especially football at his venue)

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