Norwegian School of Economics
Bergen, Spring, 2017

Scaling-up access to energy solutions in Eastern Africa

Overcoming the barriers to the large-scale deployment of clean energy mini-grids

Simon Poitrimolt

Supervisor: Gunnar Eskeland

Master's Thesis in Economics and Business Administration
Major in Energy, Natural Resources and the Environment

NORWEGIAN SCHOOL OF ECONOMICS

Foreword

Over 1 billion people. Nearly 1/6th of the world's population. That is the figure I kept on reading as the number of people without access to electricity globally. In 2017.

It is a reality difficult for me to grasp. In my personal experience access to energy has never been a daily issue. The longer power outage I have experienced might not have lasted longer than 48 hours. Yet, it is almost only in these rare occasions that myself and most people in my circumstances start to think about the lights not turning on, or the shower not warming up, or our electronics not recharging. For most of us the access to electricity is a given fact to which we do not bother giving much thought. I too often forget about the consequences it has on our livelihoods. Nevertheless, that reality is not shared by all.

In a few occasions I have witnessed people living a different reality. Vivid memories bring me back to remote villages in the mountains of Java, Indonesia, to small communities in the jungle of northern Malaysia, or to the slums of Kampala, Uganda. These precise experiences have shaped my interest for the issue of access to energy and its impacts on human livelihoods.

My entire post-secondary education was focused on environmental questions and the immense threat that represents a fast changing climate. During this time, I have developed a strong interest for renewable energies in all their forms. The coupling of my interests for the energy transition and the access to energy gap have lead me to this work. Using renewable energies to power the lives of non-electrified communities appears today as logical and necessary. Despite significant progress in this direction, the process remains slow with many hurdles left be to overcome.

This Master's Thesis marks the end of my higher education. It has been a humbling and true learning experience. I would like to thanks all of the people who have contributed to this research, with a particular thought for my supervisor Gunnar Eskeland. I would also like to thanks my friends and family who have always supported me throughout my entire educational journey that I feel so fortunate to have received.

List of Acronyms

ADFD	Abu Dhabi Fund for Development
AFD	Agence Française de Développement / French Development Agency
ARPU	Average Revenue per User
CAPEX	Capital Expenditure
CEGM	Clean Energy Mini-Grid
DESCO	Decentralized Energy System Company
DFI	Development Finance Institution
FX	Foreign Exchange
IMEX	Import-Export
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
GCL	Green Credit Line
GOGLA	Global Off-Grid Lighting Association
GTF	Global Tracking Framework
HDI	Human Development Index
KPLC	Kenya Power and Lighting Company
MNC	Multinational Companies
MTF	Multi-Tier Framework
OECD	Organization for Economic Co-operation and Development
OPEX	Operating Expenditure
PAYGO	Pay-as-you-go or pre-payment
PE	Private Equity
PUE	Productive Use of Energy
SDG	Sustainable Development Goals
SHS	Solar Home System
VC	Venture Capital

List of Figures

Table of Contents

1. Executive Summary

With over 130 million people still lacking access to clean and modern sources of electricity, the access to energy gap is still wide open in the five countries of East Africa's Great Lakes region. The national strategies revolving around a central grid have failed to achieve electrification rates exceeding 30%. Advancements in renewable energy technologies and the emergence of innovative delivery models are challenging the old centralized paradigm. Off-grid, autonomous solutions at the household or community levels offer new perspectives for a fast-paced electrification.

Among the most promising solutions to off-grid electrification are solar mini-grid systems. Private developers are currently piloting trial models throughout the region. Significant barriers remain to the viable scale-up of these systems. Governments have an important role to play by promoting more stable regulatory frameworks, license agreements, and offering the subsidies which may still be needed in some cases. Business model orientations need to be tailored to the context served, and demand must be promoted and sustained to reach acceptable levels of revenue in order to break even.

The financing sector must also play a part by recognizing the need for patient sources of capital with limited return expectations. Delivering a basic service to low-income households via capital-intensive infrastructures will not result in exponential profits. Developing appropriate financing sources would limit the costs of capital the risk of private developers being pressured to scale too fast.

If the sector can address these policy, business model and financing barriers, mini-grids could realize their fantastic potential and electrify millions in the next few years. The success of mini-grids could go a long way in achieving the international community objective of universal access to clean and modern energy by 2030.

2. Introduction

Universal access modern and clean of sources of energy by 2030: objective 7 of the United Nations' Sustainable Development Goals. This agenda adopted by the international community in September 2015 is in line with the Sustainable Energy for All (SEforAll) global initiative launched in 2011 to promote universal access to modern energy services, double the improvement rate in energy efficiency and double the worldwide share of renewables (UN SGDs & SEforAll, 2017). These international initiatives are optimistically ambitious when compared to the global situation in 2017.
At the root of these global calls is the recognition that access to energy is a key lever for human development and poverty alleviation, with direct implications on health, education, women empowerment, agriculture and economic activities. A wide number of studies have pointed to this positive correlation, despite widely varying results between countries. In Buthan it was showed in a study of 2,098 rural households that farm income was relatively non affected compared to non-farm income which increased by 63%. For children, years of schooling and daily time spent studying was also positively correlated (Kumar and Rauniyar, 2011). A similar type of study from the World Bank Development Research Group in India showed that non-farm income rose by a more modest 28%, alongside significant positive effects on time allocation for fuel collection, as well as income, expenditure, poverty incidence and children’s schooling (Khandker et al., 2012). At the global level there is an evident correlation between the human development index (HDI) and primary energy demand per capital (IEA WEO, 2004).

Energy therefore plays a central role in most major development challenges the world faces today. Despite this crucial and well understood role, an estimated 1.06 billion people in the world still do not have access to electricity. This represent over 1/6th of the global population. Over 3 billion still rely on biomass and kerosene for cooking and heating. With current progress, it is estimated that by 2030 only 92% of the world would be appropriately electrified, a rate failing short of the international community objective of universal access (SEforAll, 2017).

At the global level, the electrification rate grew from 77.7 to 85.5% over the period 2000-2014. Over the same timespan a number of countries have made tremendous progress, particularly in the Latin America & Caribbean region (rising from 92 to 97%) and in South Asia (rising from 57 to 80%). With constant progress over the next decades, these regions should meet the universal energy access objective by 2030 (ESMAP, 2017). The situation is however largely different in Sub-Saharan Africa where the regional electrification rate only grew from 26.5 to 37.5% over the same 15-year period. With the ongoing demographic trends, the number of people without access to electricity is actually rising, going in the opposite direction than all other regions of the world. In head count numbers, the non-electrified population went from 500 to 600 million over the 2000-2014 period (ibid). As the population keeps on growing in Sub-Saharan Africa, around 1 billion people in that region alone are to gain access to electricity by 2030 for the universal access objective to be met. The sheer size of the challenge is staggering, but lessons from successful countries and a host of other developments are pointing to encouraging signs.

Historically, electrification strategies have followed nationally centralized plans, with one to a few utility companies owning the generating and distribution assets. This central grid approach allowed for the cost of electrification to be shared between the rural and the urban areas, with the most remote and expensive areas to reach being subsidies by the urban areas that are less costly to connect. This approached functioned relatively well in developed countries under a paradigm of large, centralized power generation assets. The generation assets have traditionally been nuclear or fossil fuel-based, the latter being known today as a significant driver of climate change. According to the World Bank, the five biggest challenges to grid-based electrification and are i) the lack of sufficient generation capacities ii) poor transmission and distribution infrastructure iii) the costs of serving rural and remote areas iv) the inability of low-income households to pay connection fees and tariffs and v) the weak financial states of utilities (ESMAP, 2017). In Africa, an unsubsidized connection fee can exceed the average monthly income and the investment required to reach the most isolated and low-density areas are likely to be superior to the possible receipts (ibid). These different elements partly explain why progress has been slow in Eastern Africa, where the central grid approach has failed to reach more than 20% of the population.

In the past decade, however, the advancement in renewable energy technologies combined with innovative delivery models have offered a new paradigm for bridging the electricity access gap in the region. Energy services can now be provided "off-grid" by incumbent players in a very decentralized manner, fundamentally flipping around the historical state-utility controlled model. Such services can be provided at the household level, with solar-based solutions matching the basic needs of one to a few individuals. These solutions are referred to as solar home systems (SHSs) or pico-solar products. Alternatively, energy access can be provided at the level of a village or a community, through small generation and distribution assets called mini-grids. These systems, which come in a wide range of sizes and can by powered by different fuel sources, have the ability to function fully autonomously from the central grids. While fossil-fuel based mini-grids have existed for a few decades, renewable-based assets coupled with batteries and mobile-money payment systems are a much more recent breed capable of changing the pace of electrification. The private sector is playing an increasingly larger role in the development and the deployment of these solutions, which can theoretically reach millions of people much faster than a central grid expansion program could, especially in countries where progress has been meager for decades.

This paper will focus on the deployment of mini-grids in the Eastern African region as a key component of the universal modern electricity access objective. Still in their infancy, these systems are emerging as cost-effective and reliable solutions to electrify areas not reached by central grids. They also hold a promise of much more rapid deployment than central grid expansions, with all the positive consequences this may have on human and economic development.

What is then holding up a large-scale deployment of mini-grid systems?

That is the question this paper sets out to answer. At present the huge potential of mini-grids is still hindered by a host of challenges and barriers. This paper identifies the most pressing and significant ones. Along with explanations of the roots of these barriers, possible solutions are explored.

Starting with a more detailed regional evaluation of the current state of the electrification gap, the first section replaces mini-grids in the spectrum of electrification solutions, contrasting them with central grids and household-level solutions. In a second chapter, this paper explores different barriers: national policies and regulations, lack of proven commercial business models, demand-supply mismatch, and productive loads. Finally, in the last section this paper analyses the issue of financing as a significant hindering factor to a rapid scale up.

3. Methodology

The linkages between energy and human development have long been studied and discussed in the academic field. The starting point of the research was therefore centered on the synergies and the relationship between access to energy and socio-economic development. The literature on the topic is rich and points to a crucial role played by electricity and energy access on human development in its broad definition. The energy access challenge has long been followed and supported by the international development community, with decades of grants and institutional donor programs which have seen mixed results. These program have been tracked and evaluated. As a result, international development institutions are unique resources for data on electrification rates and strategies. For the core of this qualitative analysis on mini-grids, a much more limited body of literature exists on the topic. Two main reasons explain it: firstly, is it a nascent sector in the form that is emerging today, and secondly, it is largely driven by the private-sector, therefore with less public reporting than with institutional agencies.

The analysis was therefore based on a wide variety of resources, from background academic data, to international development reports, company profiles, market research analyses and personal interviews. All of these sources complemented each other to provide an analysis reflective of the most recent development. As an example, the financing of the sector has seen a very recent change of dynamic in 2016. Only the latest market research data could provide numbers and insights into these trends. Given the large role played by private actors, evaluation of future trends and strategies is rarely written publicly. Personal interviews with a wide range of actors (sector analysts, private developers, investors, development finance organisations, etc) allowed to gather thoughts and insights on the current barriers and the anticipated evolution of the sector.

The objective of this research was to cross differing perspectives to identify the most prominent barriers to a large-scale deployment of mini-grid solutions. By understanding the needs of mini-grid developers and comparing it to the current state of policy frameworks, financing options other forms of support, this analysis also explores possible ways to overcome the present barriers. Doing so would unlock the potential of decentralized renewable energy systems as least-cost solutions to bridge the energy access gap.

4. Shifting paradigms in energy access

4.1 Current state of electricity access in Africa

At the global level the electricity access gap has been partly closed since the turn of the century. Progress in the rural areas is evident with a worldwide electricity access rate which jumped from 63% to 73% between 2000 and 2014, year of the most recent available data (ESMAP, 2017). Taking a more regional perspective, significant progress has especially been seen South Asia, Latin America and North Africa, three regions which are on track to meet the universal access objective of 2030. Despite the recent efforts made in India resulting in an access rate which reached 79%, it remains the single country with the largest number of people without access (close to 300 million), far ahead of Nigeria and Ethiopia with a little under 100 million in each of the two countries.

Looking more specifically at Sub-Saharan Africa, the trends are going in the opposite direction than the rest of the world. On the global map, the electrification rates of the region strikingly stand out (see figure 1).

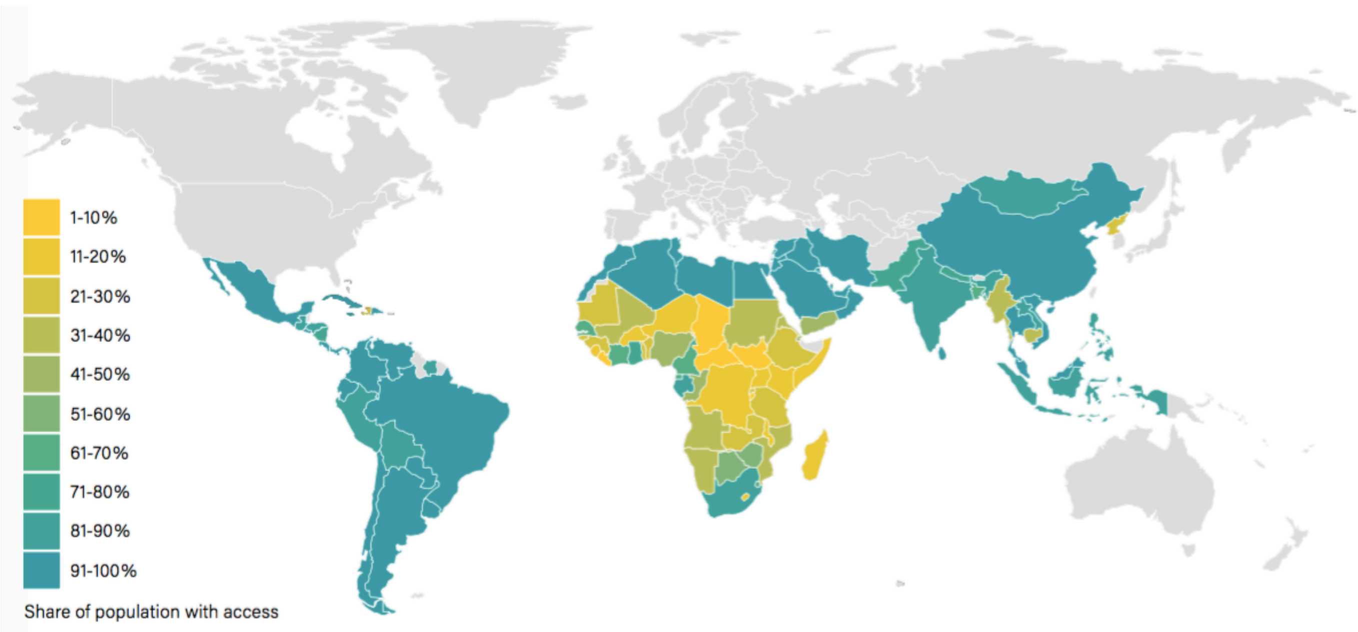

Figure 1 - Electricity access in developing countries, 2014. Source: Renewables 2017 Global Status Report, REN21

Due to population growth, the size of the non-electrified population is on the increase. At the continent level, the dichotomy between urban and rural areas is very pronounced with a 49 percentage point difference in access rates between urban and rural dwellers. The focus of this analysis is placed on the Eastern region, also referred to as the Great Lakes region, where the average electrification rate stood at 19.8% in 2014. This represents a total of 130 million people not connected to a power system. Looking at individual countries, the access rate was in 2014 7% in Burundi, 36% in Kenya, 20% in Rwanda, 16% in Tanzania and 20% in Uganda (SEforAll, 2017).

Breaking up the 54 countries of the continent by income category, an obvious correlation between national income and access rates appear. The five countries of the Great Lakes region belong to the low-income category, where average access rate is far lower than the one of higher income categories (see figure 2 below).

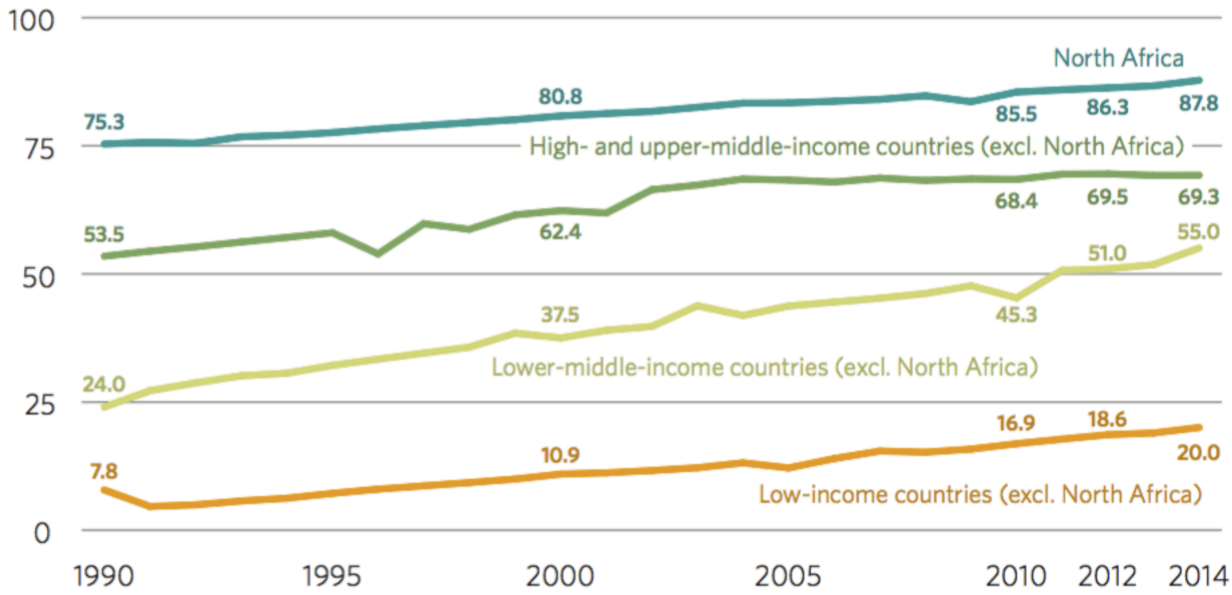

Figure 2 - Share of population with access to electricity (in %). Source: SEforALL Global Tracking Framework, 2017

In the Eastern region, the population still overwhelmingly relies on biomass and solid fuels for cooking. In 2014, 96% of the population was not using clean fuels and technologies such as gas or electricity for cooking (ibid). It must however be noted that the extensive usage of wood fuel and charcoal is not fully due to a lack of alternative because of very strong cultural and social biases (author personal observations, 2013). For many, biomass-based fuels remain the preferred choice, in spite of the health and local deforestation consequences. Habits and traditions play a central role in this phenomenon. Cooking is therefore a different issue than electricity access for lighting, communication, appliances and other productive uses.

4.2 Electricity access: a multi-dimensional notion

The situation depicted above indicates a vast access gap which will require tremendous efforts in the next two decades to be closed. Nevertheless, this analysis ought to be nuanced. Given the different uses of electricity, the numbers that have been used to paint the present situation could actually be considered flawed or at minima not perfectly reflective of the situation. That is because access to electricity has historically and conveniently been reduced to a binary metric. This is a first paradigm of electricity access that must be revisited.

In the development discourse and literature, electricity access is typically defined as the existence of a connection, or the lack thereof, to a central power grid or sometimes a local diesel generator. If a connection exits, the household is considered electrified, and if not, it is counted as non-electrified. This is the approach that allows to easily collect data through household surveys with a limited number of questions in order to calculate the figures on access rates presented in the previous section. It has been used as a reasonable first effort to capture the progress made on electricity access given the constraints stemming from the need of data.

However, this binary approach is too limited for two essential reasons. The first one is that electricity is the quintessential “intermediary product”. It is not the access to a source of power that matters, but rather how the electricity is used and what for. Electricity access shall not be targeted as an end in itself, but rather as a mean to many other ends. In this sense, electricity access should be viewed as a continuum of electricity services. The second limitation of the binary measure is its overly simplistic nature. The approach fails to account for key attributes of a power connection, such as the reliability and the durability of the service received over a period of time. This approach fails to grasp the intricacies electricity usage, reducing it to a physical fact that is the power connection itself.

To replace the imperfect binary metric, a measure of access level shall be preferred. Different elements can help define where a given level of access belongs on the continuum. Thresholds of these different elements can be used to define intermediate levels of energy access.

To measure electricity access in terms of service levels, this paper will follow the Multi-Tier Framework (MTF) recently developed by the Sustainable Energy for All initiative. This framework, developed over two years of consultations and field testing, defines 6 levels of electricity access (zero being the lowest and five being the highest). A total of 8 attributes need to be assessed for an access level to be defined. The eight components of this framework are: capacity, availability (day and night), reliability, affordability, quality, legality, and health and safety. By encompassing all energy sources within households, productive uses or community facilities, this approach is technology-neutral and focuses on the energy service received from the user's perspective.

The advantages of the MFT framework over the binary metric are many. The MTF has been developed with the intention to provide i) more accurate data on the actual services households receive and ii) more granular and disaggregated data to facilitate targeted interventions (ESMAP, 2015). The MTF requires several service thresholds to be met for a level of access to be reached.

Today a rural household located hundreds of kilometers from the nearest power line may have access to pico-solar products such as an 8Wp solar home system providing a few hours of clean electric lighting in the evening and the ability to charge a cellphone daily. A variety of small systems can provide households with the basic services defining the Tier 1. Alternatively, this household may be connected to a decentralized mini-grid enabling lighting and charging services, on top of the ability to power low-wattage appliances such as a TV and fan. Such an access level corresponds to the Tier 2 or 3 of the MTF depending on certain attributes of the connection. Under the traditional binary metric these two cases would not be counted as connected to the main grid, yet they still receive some level of electricity services.

On the other hand a household with a poor grid connection will be considered electrified under the binary measure, however frequent outages and limited availability of power in the evening can underscore the quality of the service received. Such a service level may only correspond to the Tier 3 of the multi-tier framework (MTF).

The Tiers of Access definition for electricity services is summarized in the table below:

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Peak Capacity	Power capacity ratings[28] (in W or daily Wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhr/ day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Availability (Duration)	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Afford-ability					Cost of a standard consumption package of 365 kWh/year < 5% of household income		
6. Legality						Bill is paid to the utility, pre-paid card seller, or authorized representative	
7. Health & Safety						Absence of past accidents and perception of high risk in the future	

Figure 3 - Definition of the tiers of electricity access level under the Multi-Tier Framework. Source: ESMAP, 2015

The Tiers 1-4 are the most important ones for our consideration. Tier 0 represent the absence of access to any electricity service. This framework will be particularly useful to evaluate the potential of mini-grid systems to provide energy services, and to contrast this solution with other means of energy access such as solar home systems (SHS) and national grid connections.

It is evident that national power grids, decentralized autonomous mini-grids and individual solar home systems are widely different approaches to provide power access. Yet, from a user's perspective, the services derived from the available power can be surprisingly similar. From the example described above, it is clear that when it comes to electricity access, the means matter less than the end for the consumers. By accounting for the multifaceted nature of power access, the framework proposed by the UN-supported initiative is particularly useful to compare different solutions based on the services they offer to the end-user. Expending centralized grid to all four corners of a country no longer is the only option to provide universal access to electricity services. The centralized access is also potentially more expensive and longer to deploy than a multi-solution strategy. This is the second major paradigm shift in the access to energy provision.

4.3 Key characteristics of mini-grids

Mini-grid is a term used to characterize a small scale electricity generation system (from a few kilowatts to a few megawatts) which serves a limited number of customers via a distribution network. The system can operate in isolation from national electricity distribution networks (RECP, 2014). Different sources of energy can be used to generate power, from fossil fuels, to a variety of renewable sources, or a combination of the two. A storage component can be integrated to deal with the intermittency of generation, so as to improve the quality and the availability of the power supply.

While the type of power generating technology used is not the focus of this study, it will nonetheless concentrate on mini-grids powered by renewables sources. The most common renewable sources used are solar, wind and biomass. Given the resource potential of the area of focus, and accounting for cost-competitiveness, solar photovoltaic (PV) will be main technology considered. Any decentralized system powered by a renewable resource can be referred to as a clean energy mini-grid (CEMG). Systems using a fuel-based back-up component, typically a diesel generator, are defined as hybrid mini-grids (see figure 6).

While not fully considered clean energy systems, such designs present multiple advantages in terms of quality of supply and economic viability.

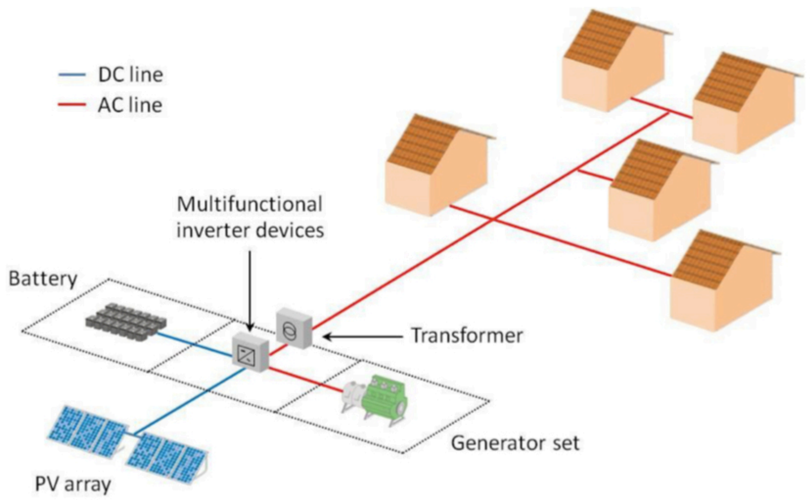

Figure 6 - Schematic view of a solar-diesel hybrid mini-grid. Source: IEA Rural electrification with PV hybrid systems, 2013

Using a definition from the International Finance Corporation, three broad sizes of mini-grid can be identified (IFC, 2017):

- Nanogrids. Low capacity grids offer Tier 1-2 (below 200 Wh/day) of access levels (e.g. lighting and phone charging). Household-focused, these systems are almost exclusively solar with capacities below 10kW, capable of serving a maximum of 100 connections with DC or AC power, and can be deployed rapidly with setup times as short as a few days.
- Mid-size grids. Mid-size mini-grids are capable of supplying customers with a wider set of services, including small appliances (Tier 3, below 800 Wh/day). These grids typically have capacities between 10 and 100 kW, can serve several hundred connections with AC power, and require several weeks to months to set up.
- Large grids. Capable of supplying Tier 4 service (1,600 Wh/day up to "grid quality" service), these larger systems generally have capacities over 100kW and up to several MW, serve thousands of households and take between 12 and 24 months to design and construct.

A key characteristic of mini-grids that is particularly relevant to this discussion is their modularity. Systems can theoretically be sized up or down over time based on the evolution of the demand. Additional generation or storage capacity can be added to a system as electrical appliances spread and demand grows. A system is therefore not permanently capped to a given level of energy service. This is a strong argument in favor of mini-grids over individual solar home systems. With the latter, users who purchase the equipment make a long term investment into a capped power capacity. When connected to a mini-grid, a user can gradually increase its consumption as appliance ownership grows, up to the maximum load capacity of the system.

4.4 The place of mini-grids in the electricity access continuum

Mini-grids can then come in various shapes and sizes. As such they can theoretically provide different levels of energy access. PV-based mini-grids can provide a service level situated anywhere between the Tier 1 and the Tier 4. Depending on the system characteristics (voltage, storage and backup capacity, etc), mini-grids can power from basic LED lights to commercial appliances (Bardouille and Mucnch, 2014). Interestingly, this spans across the spectrum of service levels that can be offered by large solar home systems or central grids. This is additional proof that the mean of access and the technology used are only secondary when evaluating an electricity service. Understanding electricity access in terms of service level supports the idea that mini-grids are just one of the solutions to the electrification challenge, they both complement and compete with other approaches.

CEMG systems have a number of structural differences with individual systems, diesel micro-grids and central grids. Compared to SHSs, mini-grids are at a disadvantage in terms of upfront capital investment which typically is the responsibility of one single actor. However, they can deliver higher intermittent load, use less battery capacity for a given level of service and deliver AC current, accommodating common appliances (Hystra, 2017). The main advantage of CEMG over diesel grids are the lower operating costs. Beyond purely economic aspects, the logistics of running a CEMG are simplified as the need for constant supply of large quantities of fuel is eliminated. When compared to central grids, the major advantages of CEMG are the speed of deployment and the average cost of connection. In a number of low-income countries connection costs of $1,500 or higher have been observed (ibid). When the demand is not high enough to justify such investments, the grid is not extended and remote areas remain non-electrified. Mini-grid projects have average cost of connections which may be higher than this value in the initial loss-making phase, but they aim to achieve significant cost reductions through scale, technological and operational improvements. Ultimately the cost per connection should reach levels below $1,000 (Madry F., 2017).

The focus of the study will be on systems providing Tiers 2 and 3 of access level. This is the most common from the types of infrastructure that are currently being installed in the region, and their capacities best match the present demand for basic appliances. In most rural locations, power demand can be limited by purchasing power and appliance ownership to very basic lighting and charging services. It is worth noting here that basic lighting (such as task lighting) is an individual rather than an household-level service. Small, individual solar home systems (SHSs), consisting of a solar panel, a battery pack and a load management control box can provide the user with the Tier 1 to Tier 2 of energy services based on the size and the capacity of the system. Looking at the figure 4 below, this corresponds to the powering of some lighting during the day and night, the charging of a cell phone and potentially a radio, a fan and/or a television.

Mini-grids can have much higher power rating capacities (in Watts or daily Watt-hours) so as to allow the powering of larger appliances such as a low-wattage washing machine. Thanks to higher storage capacities the night-time availability of the service is also extended compared to an average SHS. In terms of kWh of annual consumption, this corresponds to a daily usage of 300Wh to 1kWh or 100 to 365kWh annually (ESMAP, 2015).

APPLIANCES	WATT EQUIVALENT PER UNIT	HOURS PER DAY	MINIMUM ANNUAL CONSUMPTION, IN kWh				
			TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Task lighting	1/2	4/8	1.5	2.9	2.9	5.8	5.8
Phone charging	2	2/4	1.5	2.9	2.9	2.9	2.9
Radio	2/4	2/4	1.5	5.8	5.8	5.8	5.8
General lighting	12	4/8/12		17.5	17.5	35.0	52.5
Air circulation	20/40	4/6/12/18		29.2	87.6	175.2	262.8
Television	20/40	2		14.6	29.2	29.2	29.2
Food processing	200	0.5			36.5	36.5	36.5
Washing machine	500	1			182.5	182.5	182.5
Refrigerator	300	6				657.0	657.0
Iron	1,100	0.3				120.5	120.5
Air conditioner	1,500	3					1,642.5
Total			4.5	73	365	1,250	3,000

Figure 4 - Indicative service level in annual kWh consumption per level of access. Adapted from ESMAP Beyond Connectivity, 2015

Applying this framework to the mini-grid systems being currently deployed in the Eastern African region, the majority of developers work at offering the equivalent of a Tier 2 and 3 of access level (see figure 5). While the peak capacity of a system does not, alone, give an indication of the service level offered to household customers, a ratio of the peak capacity/number of connections can give a worthy estimate.

Companies installing pico-grids (1-2 kWp) such as Devergy and MeshPower already have a wide portfolio of projects, with respectively 20 and 79 installations as of early 2017 (BNEF - a, 2017). The US-based Vulcan Impact Investing operates 10 mini-grids with an average peak capacity around 4 kWp. After two years of operation, the company reported that most residential customers initially consume less than 250 Wh/day, corresponding to the frontier between the Tier 1 and 2 of access level (Vulcan, 2016). Most companies developing larger grids (>10kWp) are still in the piloting phase with a limited number of installations in their portfolios. Here can be mentioned the example of PowerHive, Power Corner or Jumeme who have all tested a first pilot project in Tanzania in 2016. So far very few large projects have yet been realized as companies are testing out their business models and planning their expansion strategies.

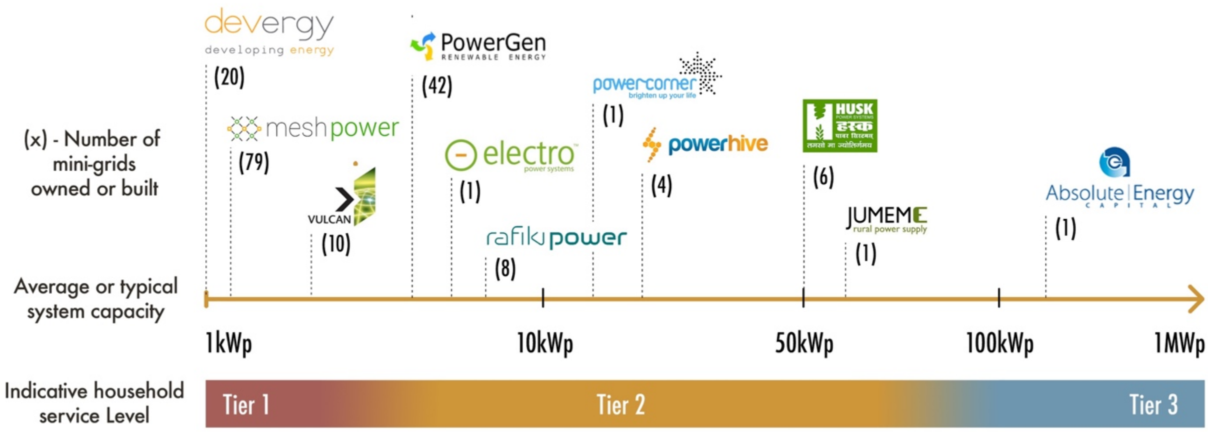

Figure 5 - Indicative service level offered by companies based on typical or average system capacity. Source: author, adapted from BNEF Company profiles, 2017 and ESMAP Multi-Tier Framework, 2015

Depending on the system size and the number of connection served, mini-grids can provide a service level close to the one of larger SHS, or on the other end of the spectrum a service level on par with central grids (thanks to a high reliability and availability).

4.5 Locales of electricity consumption

Broadly speaking we can define three main categories of energy users: i) households, ii) productive engagements, and iii) community infrastructures. The three categories of energy users are also referred to as locales of energy usage. They each have different demand profiles and ability to pay. However, each of these three locales are of distinct and sizable importance in the context of mini-grid development and operations (ESMAP, 2015).

i) Households

Households represent the largest potential in terms of connection numbers. Individuals use electricity for a wide range of applications; the primary ones being lighting and cell phone charging. Other applications include the use of fans, radios, televisions, refrigerators or space cooling. As a primary requirement, cooking is almost exclusively done using solid biomass (wood, charcoal, and briquettes). Therefore, the power requirements for cooking purposes remain limited. Space heating can be a vital requirement even during the winters of many warmer climates. Different solutions are used for this purpose, such as biomass-based fireplaces, gas-based heaters or electric heaters (ESMAP, 2015). Electricity in the households can also provide health and safety benefits by eliminating the need for indoor biomass or gas combustion.

ii) Productive engagements

Productive use of energy can be defined as any usage that increase income or productivity. In the rural areas of developing countries, typical productive uses of electricity include shops, restaurants, food production, agro-processing, or manufacturing industries such as carpentry or welding (Verin and Contejean, 2016). Across these businesses the energy usage go from lighting to motive and thermal applications. The electric needs will be based on the size of the business. Measuring the energy deficit for these businesses is a complex challenge as the lack of appropriate energy access may not be the only barrier to the development or the expansion of an income-generating activity. Other barriers include for example the lack of capital, raw materials, skilled labor, land, operating licences and so forth (ESMAP, 2015). Off the different locales of electricity use, productive engagements are typically the ones with the highest ability to pay.

iii) Community infrastructures

A wide range of public institutions and infrastructures require energy to function properly. We can distinguish five sub-locales of energy use for community purposes: 1) health facilities, 2) educational facilities, 3) street lighting, 4) government buildings (e.g. post office, local administration, etc), and 5) community buildings such as places of worship, community halls, etc.

The access to energy for community infrastructure has direct and obvious human development implications. Street lighting will for example improve mobility and safety during the night. Lighting in educational facilities can extend the learning hours and refrigerators in health facilities can allow for the immediate availability of vaccines. Access to modern energy is therefore essential for the provision of elementary public services.

While the service levels described above relate mainly to individual households, all locales of energy use are of critical importance for the design and the operation of a mini-grid. For example, community requirements for street lighting or local administration buildings can provide stable and consistent demand loads. Of particular importance for the revenue generation are productive uses of electricity (PUE). While productive demand is a cornerstone of the business model, domestic customers are not neglected and remain a key part of the strategy. First of all, the social and human development impact of a project is greatly reduced if no household is connected to the network. Secondly, residential customers provide a stabilizing factor through the number of connections, mitigating the attrition risk of larger customers. A more detailed discussion on demand factors is presented in the second section.

While grid-based electrification will continue to play an important part in the national electrification strategies, particularly in dense peri-urban areas close to existing infrastructure, there is a growing interest and potential for renewable-based mini-grids as a mean to provide adequate access to energy service to communities quickly, eliminating the wait for the extension of expensive high voltage distribution networks. Nevertheless, a host of different challenges remain to be overcome for this potential to be realized. A wide range of technical, regulatory, operational, policy or financial issues must be addressed to ensure that mini-grid become an affordable and cost-effective energy solution over the long term. The following two sections look in more depth at the most significant and pressing barriers.

5. Barriers to large scale deployment

Decentralized energy system companies (DESCOs) in Tanzania and other countries of the region have reported a number of barriers impeding a rapid growth of the sector in the near term. The barriers presented in this section have been identified through a number of industry reports and interviews. That way the most recurrent ones have selected as the priorities that must be addressed for the successful emergence of mini-grids throughout the region. The different aspects that are of greater concern: policy frameworks and grid extension, business model, demand growth and financing.

The first three barriers represent fundamental challenges and will be discussed in this section. The financing obstacle is of equal importance for a successful deployment but is directly influenced by the first three. The policy context and business fundamentals must be addressed as a priority before the financing questions. The discussion around financing could be rendered futile if the other barriers were not addressed satisfactorily first. The financing question also has the potential to be greatly simplified if the policy and business model challenges are overcome. For these reasons the financing discussion will be left to the third and final section.

5.1 Uncertain regulatory context and market size

The size of the mini-grid market in Eastern Africa is a directly correlated to the coverage and the extension of national grids. Primarily due to tariff differentials, mini-grids cannot coexist with the central grid in a given area. Indeed, central grid tariffs are as a rule lower than mini-grid tariffs as a result of economies of scale, regulatory interventions and cross-subsidisation (RECP, 2014). To give a sense of this difference, the subsidized household grid tariff in Tanzania for domestic low usage (category D1 capped at 300kWh/year) from the national utility TANESCO was $0.14/kWh in 2015 (Oxford IES, 2016). An IFC benchmark study across 12 mini-grid DESCO companies showed an average selling tariff of $1.47/kWh (IFC, 2017). The startling difference between the two tariffs explain why a mini-grid is simply not commercially viable in areas covered by the grid.

Similarly, the areas in close proximity from the national grid are also excluded from the potential market of mini-grids because of future or potential extension plans. How far from the main grid can or should a mini-grid be installed? This remains a difficult question to answer for private developers. Straightforward thinking would want the mini-grid as far away from the main grid as possible to mitigate the risk of encroachment. Recent data from a developer in Kenya paints a more complex situation.

Operating 10 different sites across Kenya, the US-based Vulcan recently published some data showing that while their sites are scattered across Northern half of the country, the most successful ones appear to be closest from the capital city Nairobi (Vulcan, 2016). While distance from the national grid is often reported as a critical factor for site selection, the Vulcan experience actually points to a certain level of proximity from an urban center as a success factor. Part of the explanation stems from the fact that customers in peri-urban areas are more accustomed to modern electric appliances and have a greater inclination to use them, on top of potentially higher spending abilities. While the logic would want mini-grids as far away from the central grid to mitigate the risk of encroachment and direct competition, commercial viability could be more easily achieved in areas of stronger demand closer to urbanized areas. Therefore, a balance must be found between the risk of grid encroachment (typically lower in remote rural locations) and sufficient demand for long-term viability.

The operational data from Vulcan also showed that a customer consumption was correlated to its ability to read and respond to automated SMSs. Over two years of data collection, consumers who 'always' read their SMSs generated an average revenue per user (ARPU) around 2.6 times higher than the customers who 'never' or 'sometimes' checked their cellphone text messages. This evidence suggests that the level of digital literacy is also a significant factor of demand side for household customers (ibid). Again this finding points to more urbanized areas where mobile penetration and digital literary rates are higher.

The solar home system sector can be considered more advanced or developed than the mini-grid sector in the sense that SHS DESCOs have been operating for longer and have already reached millions of customers. While the two sectors offer different products and solutions, is it useful to look at the SHSs sector for emerging trends and strategic orientations. Elements from the SHS sector are supporting the observations made by Vulcan in 2016. Having received substantial venture support to scale their operations, SHS vendors are focusing on peri-urban customers or those in more densely populated areas. Under a growing pressure to meet the expectations of investors, SHS vendors have turned to the customers who can afford larger systems, as well as other appliances such as TVs and other low-voltage appliances. More revenue per customer means the possibility of breaking even faster (Hystra, 2017). Whilst this strategic orientation is a drift away from rural electrification objectives, it represents an interesting opportunity to work on the viability of trial models and cost structures before expanding to more remote areas where the demand levels and the average revenue per consumer will be lower.

From the data reported by Vulcan and the SHS market trend it can be concluded that installing a mini-grid system as far away as possible from the main grid is not an assurance of success. The evident flipside of this conclusion is that the risk of encroachment increases with proximity from the grid. Clarity and visibility over the national grid extension plans are therefore critical to reassure developers and financiers alike. Recent announcements of grid extension in Tanzania from the government and the World Bank in 2016 have recently casted doubts over the potential market size. Some developers have nevertheless expressed skepticism about the ability of the government to realize the announced extension goals (Allotrope MIA, 2017).

A similar situation can be found in Kenya where the government introduced a Last-Mile connectivity program to improve electrification rates throughout the country. The initiative led by the national utility Kenya Power is aiming at bringing the national connectivity rate to 70% by 2017, as part of the government's goal of universal access to electricity by 2020. The first phase of this program is focused on customers within 600 meters of selected existing transformers. There are 5,320 selected transformers across all 47 counties and 290 constituencies. Given their proximity from the main grid, the targeted beneficiaries are not potential clients of decentralized systems, however the second phase should see the installation of additional transformers and extension of the low voltage network (KPLC, 2017).

The most recent estimates of the electrification rates stood at 47 % in 2016 (BNEF, 2016). This is a significant difference compared to 26% in 2014 according the latest consolidated numbers from the World Bank (ESMAP, 2107). Even when taking the most optimistic numbers, the electricity access deficit in the country still affects between 20 and 25 million people. Despite being the leading Sub-Saharan market for solar home systems with nearly a total of 1,000,000 kits sold in the country by end-2016, the targets are still far from achieved (ESMAP, 2017). In March 2017 the Kenya news outlet *Standard* published a report that raised suspicions on the progress made under the Last Mile Program. The article pointed to unjustified numbers of installed electricity meters reported by the company employees under the pressure to hit the administration's ambitious targets. The report claimed that out of the 3.6 million pre-paid meters installed, up to 1 million 'could be fake or have never been topped up'. According to local newspapers, the government has since denied the allegations (BNEF- b, 2017).

In Kenya electricity access rates are highly political issues in the presidential campaign scheduled for the summer of 2017. The example of the smart meter numbers shows how much uncertainty there is over the capacity of the national government to achieve universal access on its own. The present context makes it difficult for private developers willing to work with a share of the non-electrified population. This period of uncertainty in different countries of the region over potential market sizes and mini-grid sites is evidently deterrent to rapid improvement in energy access rate. Nevertheless, the uncertainty can be mitigated thanks to detailed and positive policy frameworks.

5.2 Mitigating the policy uncertainty

One solution appears capable to overcome this scale-up barrier: operating licenses with compensated takeovers. An operating licence can be defined as an agreement between a developer and a national government or a utility. The agreement grants the developer the rights to build and operate a power generating facility for the sale of electricity and power-based services over a given area. The agreement be can defined for a set period or not.

The company Virunga Power, active primarily in Kenya can be used here to exemplify the benefits of the license model. With a hydro-focused project portfolio, the company has entered into agreements with the national utility Kenya Power and Lighting Company for the operation of its sites. In an ideal scenario for developers these agreements come with subsidies or feed-in-tariff schemes based on actual volumes of electricity sold or performance (Nahmias-Leonard L., 2017)

Licensing agreements are beneficial for private developers as they provide a form of insurance against uncompensated takeover in the event of an extension of the main grid in the area served by the mini-grid. Such an uncompensated takeover would be a commercial disaster for mini-grid project. As seen previously with the example of tariffs differentials in Tanzania, an uncompensated takeover would be catastrophic for the developer, but remains a desirable end for the consumer.

An operating license is not incompatible with the idea of a takeover by the main grid. The financial compensation in the event of an encroachment can be negotiated as part of the licensing process, such that the developer is compensated for the lost ability to commercially operate the electricity generating asset. An alternative option is the upkeep of the generating asset with a sale of the electricity directly to the utility according to pre-set tariffs. Connecting mini-grids to centralized systems can even be beneficial to national utilities when decentralized production assets strengthen the resilience of the grid. Coming back to the idea of demand level, mini-grids could actually prove instrumental in preparing the rural areas for the time when demand levels will be high enough to warrant high voltage transmission lines.

Licensing agreements can also be a favorable option for governments considering the total costs of achieving high electrification rates. The connection and transmission costs to the main grid might prove unsustainable and irrelevant in rural areas where the limited power needs are unlikely to grow to the level where they would justify such grid infrastructure investments in the near future. Even larger clients could be better off in the short term with the service level offered by a mini grid operator over an unreliable central grid (Hystra, 2017).

A consequence of possible encroachment under a license scheme is the requirement to build for integration into a larger system. The infrastructure of the mini-grid needs to be designed so as to be integrated into the main grid. This includes technical requirements such as overall network safety needs, frequency and voltage regulation, integration of the distribution system, ability of the grid to “island” in the event of grid failure, etc (RECP, 2014).

Governments could also work with private renewable developers of small scale projects the same way they have for larger installations. Moving away from the feed-in-tariff schemes that proved costly in many countries, the method of tendering is gaining in popularity and practice. Under a tender process the government offers private developers to bid on the most competitive offer for a given installed capacity. In theory tenders promise to reduce societal costs by limiting the government subsidies to the best performing installation. For companies, aggressive bidding comes at the price of shrinked margins and very low returns. Countries such as South Africa or Peru have extensively used the auction system to drive the cost of large renewable power down. To achieve the cost efficiency promises, appropriate design of tenders from prequalification criteria to execution to after-tender regulation is key (IPEA, 2016).

In the same way tenders are working for larger scale projects, governments in Eastern Africa could design tenders for the servicing of a set of identified localities. Developers would bid on a capital cost basis and the amount of required subsidies can also be defined by the bidder. As such, government can reduce the costs of extending the main grids to costly locations, while ensuring that an electricity access solution will be offered to the population in the short term. For the developers, working under a government-designed program would ensure a license to operate and mitigate the risk of uncompensated grid encroachment.

One consequence of the bidding system is the crucial importance of capital costs. With costs typically coming down with scale, larger companies better able to execute at scale are usually at an advantage under these schemes. As seen in many situations with large solar and hydro project, big utilities have abilities to cut costs that smaller developers do not have. Translating this to the mini grid sector, call for tenders could be more advantageous to the off-grid ventures of larger utilities such as Engie's Power Corner or E.On's Rafiki Power than to the numerous start-ups involved in the field.

5.3 Business model validation

Alongside the regulatory framework and context, a second critical condition for the scale-up of mini-grid operators is the business model itself. As seen in the first section, numerous companies have launched loss-making trial models to develop their products and offers. Mini-grids have emerged in many configurations, often adapted and tailored to the local context. Mini-grid DESCOs have started to understand that uniformity is not the rule. The is no 'one size fits all' solution that will fit all consumers (Bardouille and Sheperd, 2016). The flexibility of the installations and the companies themselves will be necessary. A fine balance between adaptability and standardized cost efficiency gains must be attainted to scale up successfully.

Five main components make up the business model of a mini-grid DESCO, with different options existing for each component. Strategic orientations have to be taken for the following aspects: value chain positioning, site and client focus, system configuration, tariff structure, and operational organization. The table below summarizes the different strategic choices that define a mini-grid business model.

Value chain positioning	Site and client focus	System configuration	Tariff structure	Operational organization
Vertical integration or Specialization	High connection numbers or Anchor and productive uses	Single technology or hybrid – Strict capacity or overcapacity	Flexible or flat rates – Pre-paid or post-paid	Remote monitoring or on-site monitoring – Mobile money or cash payments

Figure 7 - Mini-grid DESCOs business model components. Source: author, adapted from Hystra, BNEF, Bardouille and al.

5.3.1 - Value chain positioning

As a concentrate of software and hardware innovations, consumer financing and servicing activities, a mini-grid requires a wide array of skills and competencies. Many of these competencies are being developed by the private companies themselves as their pilots mature. A minority of activities are being outsourced. Most mini-grid DESCOs have oriented themselves towards a build-own-operate business model, so as to possess a large degree of control across the value chain (Bardouille and Sheperd, 2016). This means that the mini-grids built are retained as income-generating assets and not built for clients. Some of the most striking examples of this vertical integration are Devergy, MeshPower and Powerhive, who cover all activities of the value chain from software and hardware development, to construction, operation and client after-sale servicing (BNEF - a, 2017).

This integrated approach can be a doubled-edged sword for these companies. One the one side it will allow them to develop many different capabilities, including the ones which will turn out to be the most commercially profitable. Software development could turn out to be a much more lucrative and sustainable activity than grid operation and management as the technology can be adapted and sold to other businesses. On the other side, working across the entire value chain prevents companies from specializing right from their inception and from potentially gaining a competitive advantage over their vertically integrated peers.

Here again it is interesting to draw a parallel with the solar home system companies which are a few years ahead in terms of market development and maturity. Much like the mini-grid DESCOs today, SHS DESCOs have pursed a very integrated model. This is partly explained by the fact that off-grid customers are hard to reach and DESCOs had to pioneer in an early-stage market and play across the value chain to make their business work. Analysts have pointed out that with a maturing market, there appears to be room to "rationalize costs and improve overall efficiency through increased focus specialization, localization and the development of joint ventures" (Bardouille, Sheperd and Vanzouilli, 2017).

It is necessary to mention that the consumer-financing aspect is very different between mini-grid and SHS DESCOs. While the former acts more as a traditional utility investing in long-lived income-generating assets, the later acts more as a financial intermediary with a rent-to-own model where the systems distributed must be pre-financed. With this point made, the discussion on value chain positioning remains relevant. While it initially seemed necessary for early-stage SHS DESCOs to 'do it all', there is a today a move away from the vertical integration model by many of the emerging market leaders. More explicitly, some are focusing on product development, and others on distribution and financing.

5.3.2 - Site and client focus

Around the upstream and downstream activities of the value chain, the core activity of mini-grid DESCOs remain the development and construction of mini-grids. Two wide types of approaches exist in the type of sites and clients targeted, which can be understood as the quantity vs quality decision. The quantity choice is the targeting of household clients with limited individual demand compensated by high connection numbers. The quality choice is a much narrower selection of clients with higher demand and loads per connection. Evidently, servicing one type of client does not exclude the other, but a strategic focus is necessary.

Anchor clients such a telecom towers or administrations and productive uses such as businesses or small industries represent the advantage of more consistent and predictable loads. The revenue necessary for breakeven can be obtained with a more limited number of clients. The risk exposure to disconnection and dropping demand is consequently much higher. Households on the other end offer the advantage of more a diluted risk exposure to attrition and individual demand variation. For an equivalent quantity of electricity distributed, a much greater number of households must be serviced compared to a few bankable clients. This has direct consequences on the customer service organization and demand management costs, which increase with the number of connections serviced (Hystra, 2017)

The role of productive uses can be illustrated by the operating experience of Vulcan Impact Investing. Across its ten different sites, the company services both domestic and commercial customers with 12 to 64 connections per grid. After two years of operation and data collection, the company reported that its 10 percent top consumers represented 40% of total revenues and consume just under 50% of the total electricity sold (the discrepancy being a result to its tariff structure). These top consumers are businesses which use high-energy appliances to generate income (Vulcan, 2016).

The company also reported that the more profitable grids are the ones with a higher number of commercial customers. Despite a relatively low number of connections per grid, the company indicated the importance of being in a large population center (>1,500 inhabitants) or a significant traffic area to ensure business activity and electricity demand for its commercial customers. Also critical to a stable electricity demand is the diversity of the commercial customer base. A balance between businesses tied to the agricultural sector and others sectors seems to be essential to ensure stable revenues across seasonal phenomenon, such as drought or harvest periods.

The strategy followed by the local Tanzanian developer Jumeme is a second example of the role of productive uses. For its pilot project, Jumeme picked the Ukara Island on Lake Victoria. This island is densely populated with 37,000 inhabitants (463 inhabitants/km2), and strong of productive agricultural and fishing sectors. For the first phase of the project, the 60 kWp solar system has been connected to 100 customers. Out of all connections, more than 35 were made to businesses. There was a deliberated effort on the part of Jumeme and its partner GVEP to target productive uses as initial customers. Some businesses were even created concurrent with the arrival of the electricity source. A partnership was also created with a local micro finance institution (Ukerewe SACCOS) to channel GVEP's funds through loans for the financing of productive equipment. In the long term businesses should only represent 1/10th of all connections, but the initial phase was centered on commercial customers who represented over a third of all connections (Verin and Contejean, 2016).

Each local of electricity represents a set of advantages to the mini-grid operator. To improve electricity access in the population and electrification rates, a large number of households will need to be connected. However, in the short term, to boost local economies and sustain the commercial viability of mini-grid project, it is becoming evident that a focus must be places on productive uses which represent higher demand loads and revenue potentials.

When it comes to site selection, most developers report site acquisition as a business priority. At least three motivations underline the desire to spread quickly across a wide number of sites. First of all, reaching a critical mass of 200-300 sites is declared a necessary number cover overhead costs and achieve economies of scale in the medium term. Secondly, the 'first mover advantage' is also relevant as there is typically enough room for one installation per village or community. With the additional concerns of regulatory and government program uncertainties, it is clear that active players will compete to settle on the most attractive locations. Finally, investor milestones have also been reported as a driver of quick deployment. Investors, in particular some impact investors, care about the ability to reach a large number of people in the short term, adding pressure on the developers to spread fast (IFC, 2017).

The desire and pressure to spread quickly comes at the risk of jeopardizing long-term profitability. Potential sites and clients must be assessed carefully in order to ensure a significant enough demand (i.e. revenues) in the long-run. Efforts must be made to grow the demand in the short run, which required a focus on productive uses to reach beak-even revenue levels (Bardouille P., 2017). Productive uses of electricity do not appear by themselves. High-energy and productive equipment must be made available and financed. Mini-grid developers shall not fall in the trap of "quick returns and high numbers, by restraining investment and market activation per site" (Hystra, 2017).

5.3.3 - System configuration

When designing the mini-grids, developers have for obligation to carefully assess the local context. No two locations with be exactly the same in terms of demand loads. Two important decisions have to be taken: the choice of technology and the generating capacity. A mini-grid can be powered by a single technology or combination of technologies (the hybrid option). Considerations of solar potential, battery costs or fuel supply logistics will play a part in this decision. Today a growing number of fully renewable systems are being developed.

The second decision will be the maximum capacity of the system. Developers can choose to size their equipment based on the expected short term demand, or oversize their system in the short term, expecting growth in demand volumes. Higher capacities coming with higher costs, the sizing decision will have an impact on the system payback and the financial viability of the project. As mentioned previously, mini-grids have the advantage of being flexible in the sense that they can be sized up through the addition of power generating and storage capacity.

5.3.4 - Tariff structure

Revenues from CEMG can be generated from connection fees, subsidies, the sale of electricity (tariffs) or the sale of ancillary services. Connection fees must strike a balance between a low enough rate that will not be hinder a connection decision, while still remaining a significant enough financial commitment to only attract serious customers. Generally speaking, the connection fee is based on the connection costs made up of the wiring, the metering device, the installation and the administrative fees. As such, connection fees do not represent a significant revenue-making avenue. The main revenue channel will obviously be the electricity payments, which can be accompanied by subsidies. Three tariff structures exist which can be chosen based on the customer profiles (RECP, 2014):

1) Energy-based tariffs simply depend on the actual quantity of electricity consumed. Usually measured on a per kWh basis, energy-based tariffs can either be a fixed rate or fluctuate based on the quantity already consumed over a period, the time of the day or the real-time demand.

2) Power-based tariffs are determined by the expected consumption level and is measured in Watts. A basic tariff would limit consumer to a given level of consumption over a period in exchange for a fixed rate. Such a tariff can also be based on the number of appliances that are used by the consumer.

3) The service-based tariffs are related to the ancillary services that a power producer or a utility can offer. The charge is based on the service provided and not on the unit of energy consumed. One common example is a cell phone charge, which can be offered as a revenue-generating activity by a client of the mini-grid, or by the mini-grid operator itself. Engie's PowerCorner pilot project in Kitumbene (North Tanzania) is running a small kiosk that offers basic services such as cell phone recharges (Madry F., 2017). The most direct alternative being the diesel generator, the service-based tariffs are most often set against the avoided cost of kerosene/diesel.

For the different tariff structures, the payments can be pre-paid or post-paid. With the recent advances in mobile payment technology, the pre-paid option has now been simplified and accepted as the favored option (BNEF - a, 2017). For the mini-grid operator, this has multiple advantages. The risk of payment delay or default on a bill payment is eliminated. Done through a centralized system and without in-person cash payments, mobile pay-as-you-go or PAYGO systems also greatly simplify payment collection and account management.

All firms serving household customers are using a pay-as-you-go or PAYGO model, whereby electricity top ups are made via mobile payments. Mobile-money is seen as a key factor to reaching scale in areas where bank account ownership rates are extremely low and cellphone usage rates conversely high. The electricity consumption monitoring is done through a smart metering device installed upon payment of the connection fee.

5.3.5 - Operational organisation and efficiency

The multiplicity of activities by observed specialization trend in the SHS market should be taken as valuable insights for the growing mini-grid operators who started with very similar integrated "do it all" approaches. It is obvious that the operating costs have a significant bearing on the long-term viability of the business model, and for companies with high CAPEX requirements, slimming down the OPEX could be the make-or-break factor.

It has been pointed out that the most visible of start-ups and companies distributing SHSs are not indigenous to the countries where they operate. This typically increases the costs of goods and services (Bardouille, Vanzouilli and Sheperd, 2017). A similar observation can be made of mini-grids DESCOs whom are typically organised around a foreign management teams. In order to scale efficiently, mini-grid operators should focus on developing local skills and competencies. A third trend identified to improve operational efficiencies is the development of strategic partnership and joint ventures to leverage local expertise and knowledge. The shortage of skilled staff in electrical contracting and maintenance in Africa is acknowledged across industries as an obstacle to growth (Hystra, 2017).

5.4 Demand growth: reaching breakeven revenue levels

Once the company strategy has been established and the sites installed, chief among the conditions for commercial success of the project is the average revenue per user (ARPU) and the evolution of customer numbers. Considering a given level of operational expenditure, the ARPU levels will directly impact the break-even point.

An overestimated demand will inevitably lead to cash flow problems and a revision of the break-even calculation. On the other end, an underestimated demand will result in shortages and blackouts if the system is not oversized, potentially raising problems with the community as the promised service is not delivered (RECP, 2014). Dissatisfaction with the service can lead to disconnections or a non-adoption by customers. More often than not, the demand is initially overestimated more than underestimated as the declared willingness to pay during site assessments can be directly biased by an interest to attract the project. The developer Vulcan shared some insights on its sites under operation in Kenya. The company reported that "virtually all customers initially used less energy than their pre-installation surveys indicated". The overestimation was estimated at 15% on average with the survey method used. This factor can easily be explained be an excessive enthusiasm over the potential appliance and electricity use during willingness-to-pay assessment (Vulcan, 2016). Factoring in for a demand overestimation should be part of the initial revenue prevision. The percentage of overestimation needs to be determined based on the assessment method used.

While the initial consumption levels need to be carefully considered, the evolution of the demand over time is equally, if not more important, for the long run. On average people in the rural areas spend between 5 and 10% of their budget on energy (ESMAP, 2017). The figure for lighting spending in Tanzania and Uganda was estimated at 7%. A sharp decline in this figure was observed for households who switched from fuel-based lighting to solar-based lighting (ibid). For these households the share of available budget spent on lighting dropped to around 1% in Uganda, Kenya and Tanzania (see figure 8).

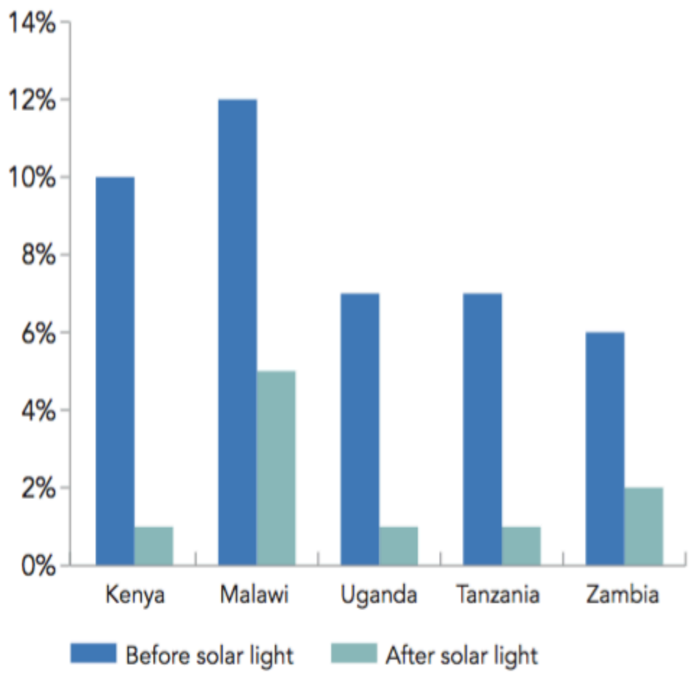

Figure 2 - Proportion of income spending on lighting as a percentage of total income in selected African countries - Source: ESMAP State of Energy Access Report, 2017

Two conclusions can be drawn from this observation. The first one is a confirmation that, on top of being environmentally preferable, solar power is cheaper for the end consumer than fuel-based sources. The second learning is that as proportionally less income is spend on lighting, some disposable income is freed up for some other consumption and expenses, at a constant income level. The number of electricity-based services received by the end user is by the same token increasing.

With a share of income that can be transferred from lighting to other purposes, this is potentially a favorable situation for electricity providers to sustain or improve the demand levels. However, the 1-5$/month of transferable income will not automatically translate in electricity spending. New electrical appliances are required to increase the power consumption level of a household or a business. The purchasing of such appliances is likely to be the main barrier.

The logic of growing appliance ownership to drive the demand upwards rests upon two assumptions: appropriate financing mechanisms and rising incomes. DESCOs can have a direct influence on the first assumption. Today the majority of mini-grid DESCOs are already involved in some form of consumer financing activities (BNEF- a, 2017). In its 2-year operational report Vulcan identified access to appliances as the main barrier to increase consumption (see figure 9). Surveys conducted by the company with their clients indicated that users would use more electricity if they could afford the upfront costs of appliances. As a response the company is exploring options to facilitate the access to appliances. It is therefore assumed that facilitating the access to new appliances will drive demand upwards.

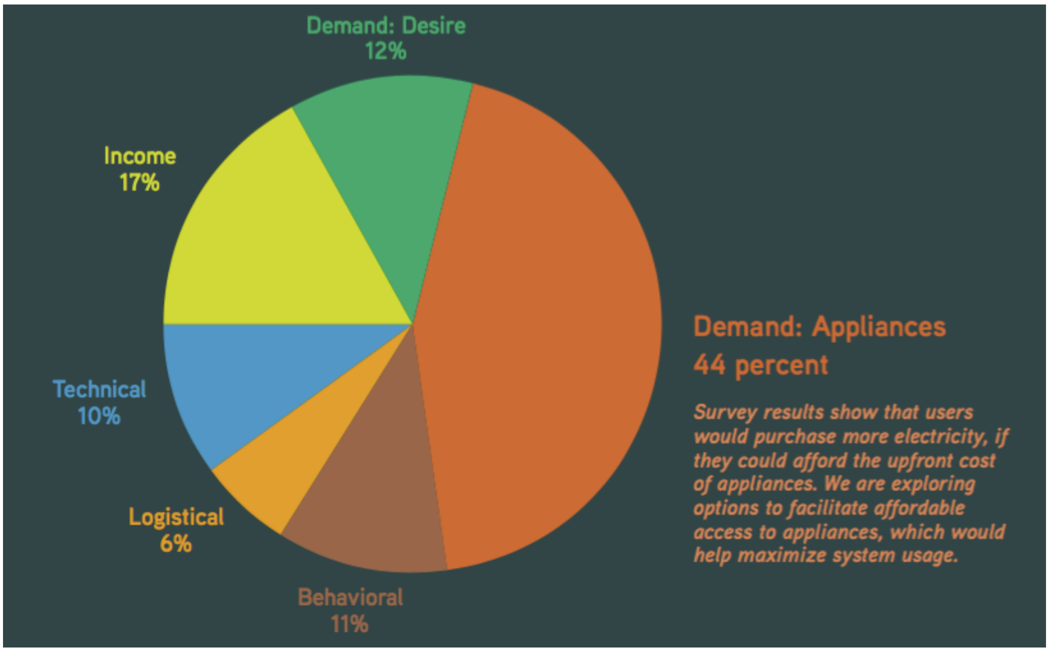

Figure 9 - Barriers to increasing energy consumption, access to appliances is the largest barrier according to Vulcan. Source: Vulcan, Powering productivity report 2016

Here again it is useful to turn to a recent trend in the SHS market. According to Bloomberg, the industry as a whole added about half a million new customers in 2016, up by more than 40% from about 350,000 added in 2015. While this represents impressive numbers, the biggest bulk of 2016 growth came from new market entrants, with the US-based d.Light leading the pack. More established players grew at a slower pace and focused on revenue diversification. Slower growth numbers may be indicative of an effort to create more value from already acquired customers. For instance, the market leader M-Kopa offers television to customers who have been successfully paying for their solar home systems for three months. Off-Grid Electric has similarly indicated that one third of its new systems now comes with a TV (BNEF - b, 2017). This trend is only set to intensity as SHS vendors are continue to offer larger systems (12 to 20W) capable of powering a larger number of low voltage appliances such as a TV combined with a low-wattage fridge (Nahmias-Leonard L., 2017). It remains to be seen if solar system vendors continue to develop consumer financing capacities or if they partner with specialized financing institutions. The trend towards specialization would suggest that both will happen, as some will specialize in consumer financing while other will outsource it to specialized institutions through partnerships (as in the case of JUMEME and GVEP mentioned previously). Regardless of the strategic orientations of SHS DESCOs, this observation substantiates the idea that access to appliances is a critical factor to sustain and grow power demand following customer acquisition.

Even with the emergence of appropriate consumer financing mechanisms, this logic assumes that customers will be experiencing rising incomes. The freeing up of a portion of the disposable income thanks to the switch to solar power will not be sufficient to buy TVs, fans, fridges, etc. The impact investor Ceniarth pointed to the fact that "the availability of solar home systems, in and of themselves, will not lead to this increase in income". They added that this comment was based on an absence of evidence proving the opposite (Ceniath, 2017). Although it may be true that the acquisition of a solar home system or a grid connection will not have a significant direct impact on household income, this analysis falls short of an important factor. Once a consumer as paid off (i.e. acquired) a solar system or paid for a connection to a mini-grid, the SHS device or the smart meter can be used as a collateral for additional loans. If the consumer stops to repay its loan, the solar kit or the metering device is blocked remotely via the GSM connection. The consumer can therefore continue to acquire equipment through small monthly installments. The purchase of a solar kit or mini-grid smart meter offers the consumer both a collateral and the possibility to develop a credit rating, this without an initial rise in income nor the involvement of traditional financial institutions. This needs to be highlighted as a significant and novel financial inclusion mechanism.

To further stress the importance of average return per connection to the long-term viability of mini-girds, a simple sensitivity analysis reveals insightful learnings. Simply considering the capital expenditure, an estimated average installed cost per kW of capacity for a solar + battery system is 3,000$ (IFC, 2017). Assuming an average system of 30 kW serving 220 connections. Recent data compiled by the consultancy firm Hystra showed that 4 operators with sites under 100 kW of capacity had an initial ARPU of $4.40 per month. Considering only the payback of the CAPEX from revenues, different ARPU growth values have a significant influence on the payback period, as can be seen in the figure 10 below:

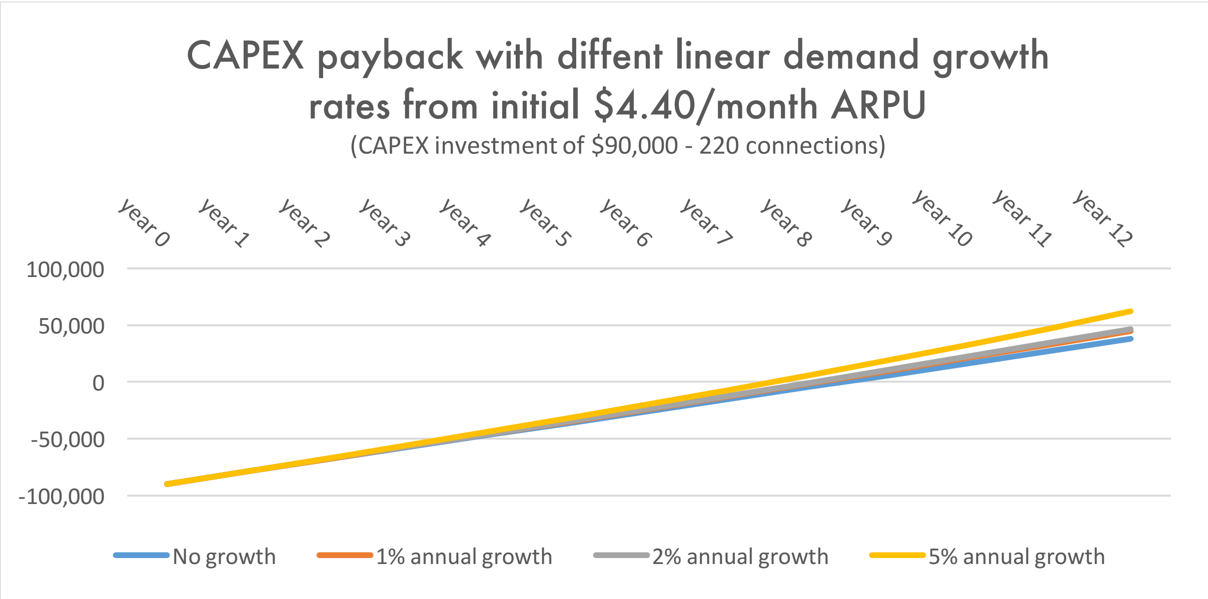

Figure 10 - Source: Author

With revenues staying constant at $4.40 over the entire period, it would take nearly 9 years of electricity revenues to payback the capital investment. With an average revenue per user growing at a constant 5% annual rate, the revenues would take 7.5 years to pay back the capital investment, which is a year and a half earlier compared to an absence of revenue growth. This simplified analysis shall not be regarded are a complete break-even calculation as it omits all operating expenditures, financing costs, depreciation, etc. Rather, it only aims to highlight the importance of revenue growth to reach a state of profitability in the medium run.

Another way to consider revenue growth is by assuming that the demand will initially increase by a significant percentage in the first few years as users acquire appliances and then will continue to increase but at a slower pace in subsequent years (see figure 11). The analysis below models an annual revenue growth rate of 15% in the 2nd and 3rd years, 10% in the 4th and 5th years, then 5% and 3% in the following years. Three different levels of initial ARPUs are considered: $4.40, $5.00 and $6.00.

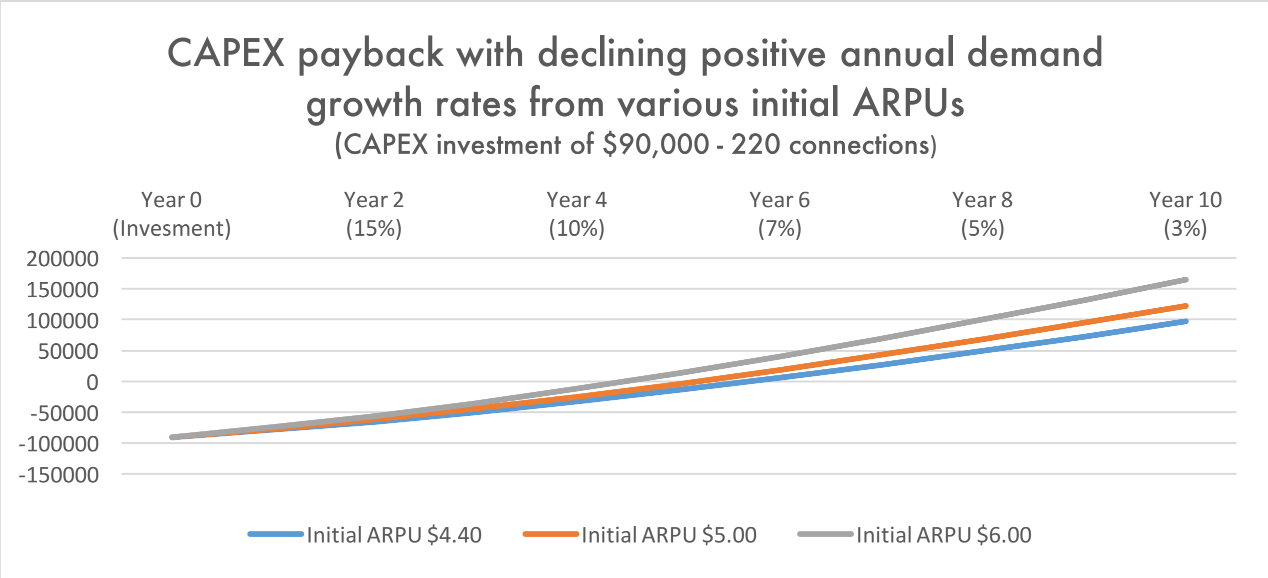

Figure 11 - Source: author

Starting with an ARPU of $5.00 in year 1, and following the demand growth detailed above would result in a $10.40 average revenue per connection in year 10. A doubling of the electricity expenditure in a decade seems theoretically reasonable in this context. More aggressive growth figures could have been considered.

Looking again at how many years' worth of revenues it would take to pay pack the initial CAPEX investment, a starting ARPU of $5.00 would take just over 5 years of revenues to pay back the $90,000 of capital investment.

Compared to the previous analysis, we see that a fast growing demand in the first few years of operation would have a significant impact on the revenue profile, and therefore on the ability to reach a profitable state. These simplified analyses do not represent a comprehensive financial modelling and break even analysis of a mini-grid projects but still explicitly demonstrate how important demand evolution will be for the project developers. Being able to sustain the initial demand level and make it grow, through a focus on businesses and appliance financing for example, will be a crucial element for mini-grid DESCOs.

A recent data from the consultancy firm Hystra confirms this conclusion. Surveyed developers, who remained anonymous in the report for confidentiality reasons, indicated that the initial ARPU level ($4.40) was on average 50% of the targeted ARPU level for breakeven (see graph 11 below). In other words, these developers would have to double the average revenue per user in order break even during the expected period. The timeframe was not mention in the study. One company reported to already be at 70% of the targeted ARPU, while another one is only at 30% of the targeted average revenue per connection.

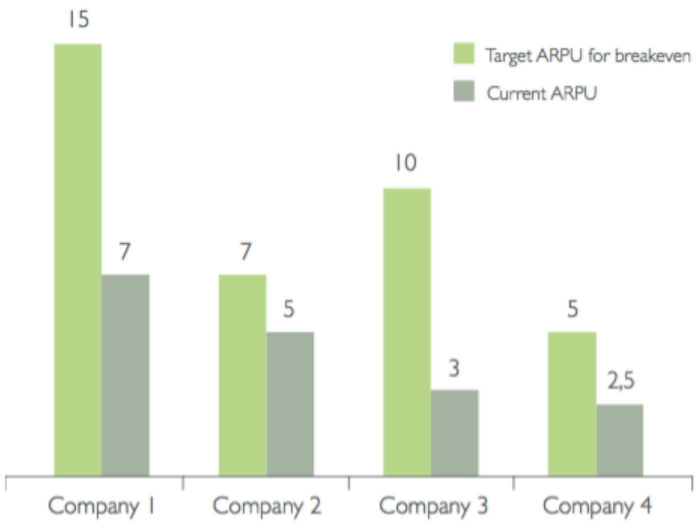

Figure 12 - Current versus target ARPUs observed among four companies ($US per month) - Source: Hystra Reaching Scale in eletricity access, 2017

As a rule of thumb, most companies will need to reach average revenues per connection of $10 to breakeven, which has not yet been achieved. A strong effort on market activation on the part of mini-grid developers will have to be made in the initial phase of every project. This may mean supporting the development of local businesses to retain bankable customers, or provide direct or indirect customer financing services for the acquisition of power intensive household appliances. A combination of both will most likely be required.

With the exploration of a number of policy and operational barriers, it becomes evident that mini-grids are commercially viable only if a number of critical ecosystem conditions and operating parameters are in place. Clear policy framework and government licences would limit the risk of uncompensated encroachment and reassure investors and developers alike. Business model orientations need to be tailored to the context served, and demand must be promoted and sustained to reach acceptable levels of revenues per connection in order to break even somewhere between 5 and 10 years. Once all these conditions are met it will be much easier to finance the deployment of mini-grids in the region. In the meantime, financing remains a true barrier faced by developers.

6. Financing the deployment of mini-grids

From the previous sections it is clear that clean energy mini-grids offer a promising solution for the rapid electrification of small businesses and the emerging rural middle class of densely populated areas. This nascent sector faces a host of challenges that will need to be addressed aptly to develop commercially sustainable and scalable business models. This young and capital-intensive industry possesses so far a limited track record. As a consequence, the first barrier to mini-grid investment is the scale and the complexity of associated risks (UNEP, 2015). In no way inconsequential is therefore the issue of financing. Where will the capital needed to finance the deployment of thousands of mini-grids come from? This final section explores the difference sources of capital and the financing mechanisms that can be leveraged by project developers.

Between local players, international innovators and multinational companies (MNCs), each are seeking different forms of capital that will vary with their level of development. Roughly speaking we can define three distinct phases of a DESCO development: 1) trial model/pilot project, 2) optimized replication/validation of business model and 3) scale up/portfolio expansion. For each of these phases it is also possible to associate some particular forms of financing. The first phase is usually supported by subsidies, grants or some forms of concessional financing or personal equity. The amounts required for this initial phase are typically in the $100K-$1M range. This will allow the company to test a first site and assess its business model orientations. Following this trial, comes the validation period with a handful of sites to optimize and confirm the model. PowerCorner, PowerHive, Rafiki or Vulcan are example of companies currently in this phase. This is a critical phase difficult to finance as the risk factors are comparable to the trial phase, yet the amounts required are much greater with investment tickets ranging between $1-10M. As will be detailed below, a number of funding sources could be leveraged here. The third development phase is a large deployment and scale up of activities, with the installation of dozens of mini-grids. This is the stage that must be reached by all companies who estimate that 200-300 mini-grids will be necessary to achieve economies of scale and reach profitability. This development will cost easily over $10M and could be financed by commercial, Import-Export (IMEX), or development banks. No company in the East African region has yet reached this stage.

Given the current maturity of the sector, the discussion below will focus on the first and second stages. A simplified overview of the financing requirements and stages of DESCO development is summarized in the table below:

Phases of development	1) Pilot project	2) Model validation	3) Scale up
Indicative investment requirements	$100k - $1M	$1M - $10M	> $10M
Types of funding	Grants, subsidies, seed money, personal equity	Mainly equity, limited debt (concessional or tailored)	Mainly debt (consessional or commercial), limited equity
Sources of funding	Governments, foundations, DFIs/ donors, angel investors, impacts funds, etc	Impact funds, ventural capital funds, DFIs, private equity funds, etc	Commercial banks (local or int'nal), EXIM banks, DFIs, PE funds, etc

Figure 13 - Summarized overview of DESCO financing - Source: author

6.1 Financing the start-up phase

The initial phase of development is not the most critical with regards to financing. Grants and public money remain most common for the starting-up of energy access ventures. Government-sponsored programs or international development agencies with ongoing energy portfolio will support private projects on a grant basis. The investment decisions are based on human development objectives and the current funding need of the sector. The depth of the market for this type of funding requirement is large and the risk appetite of lenders/donors is high (RECP, 2014). A host of small private actors have entered the sector in the last few years, proving that financing the start-up phase is not the biggest hurdle faced by companies. The financing of the optimized replication phase following an initial trial model is however much more challenging.

6.2 Financing the business model validation phase

The major difficulty for most players today reside in the ability to raise capital to fund the second phase of development. Several issues have been reported as barriers to access this required capital. It will be important here to distinguish the two types of capital that can intervene here: equity and debt. In simple terms equity financing is an exchange of available capital for an ownership stake the company. Debt on the other hand does not involve a claim on ownership of the business but a loan that must be repaid (the principal) with interests. Debt financing typically involves less risk than equity financing, a critical factor in this discussion (Investopedia, 2015).

Given of all the barriers and the unpredictable environment detailed above, it is obvious that mini-grids today belong to the category of risky ventures with uncertain returns. For that reason, the investment opportunity has so far remained limited to risk-taking financiers. Impact funds, venture capital (VC) funds, private equity (PE) funds and some development finance institutions (DFI) are the financial actors capable of a sufficient a risk appetite to finance mini-grid DESCOs. Investments can take the form of equity or debt, though the former is most common at an early stage of development. Various financing challenges have been reported as limiting factors to a significant inflow of capital into the mini-grid market:

6.2.1 Ticket size and project fundraising costs

A significant barrier to efficient financing are the transaction costs when projects are approached individually. Regardless of the size of a project, the investment will necessarily include a share of fixed costs to cover the identification, the due diligence, and the investment monitoring expenses. When the investment ticket is small, which is the case for the developments of a few mini-grids compared to other private venture investments, the relative costs of the fixed expenses are more important (UNEP, 2015). The two ways to reduce the relative size of transaction costs are to fund larger portfolio at the level of a company or to fund a pooling facility regrouping projects from various companies. In both cases the weight of the transaction costs would be diluted across the projects. The first option has the advantage of an easier execution than the second option, but represent a potentially higher risk for the investor (which in turns drives the variable part of the financing costs upward).

6.2.2 Mismatch in investment timeframe

As seen in the revenue analysis part, mini-grids are essentially infrastructure assets with long pay back periods. This is due to important initial capital investments and non-exponential revenue profiles. DESCOs are seeking long forms of capitals (7-12 year tenure) corresponding to the types of assets being developed, while the vast majority of financiers today are not willing or capable to offer such long loans or equity investments (Jacobson A., 2017).

This issue of timeframe mismatch can be illustrated with the case of Sunfunder, a specialized California-based impact fund. Sunfunder was awarded in 2017 by Bloomberg as one of the top 10 pioneering company in the renewable energy industry (Bloomberg, 2017). With an active involvement in the SHS and solar equipment markets, Sunfunder has not yet made a significant commitment in the mini-grid sector, despite a strong interest. As an investment fund is usually set up for a defined number of years, Sunfunder has to date been limited by their own sources of capital, which are limited to 4 or 5 years (Johnson N., 2017). Comparing this with the 7-10 year breakeven period reported by several developers, we see that there is an evident mismatch between the type of capital available to the market and the financing needs of the sector. Such projects therefore need to be financed with long sources of capital, such as 10-year loans with a one- or two-year extension clause. In an effort to address this issue and enter the market, Sunfunder announced in early 2017 the closing of the 'beyond-the-grid" fund. With a total commitment of $50M, this fund has the longest tenure out of all the funding sources Sunfunder had previously raised (Griffin A., 2017)

Longer loans with 8, 10 or 12-year tenor periods have been difficult to secure for developers seeking more patient capital structures matching the pay back schedule of their assets. This would be a fairly typical financing structure for an infrastructure project, however mini-grids have not yet been accepted in category. Shorter loans have to be repaid faster, putting pressure on revenues in the first years of the operations. These capital-intensive assets with 15 to 20 years of useful lifetime do not have the revenue-generation capacities to be paid back in 5 years. Impact investors will have come up with innovative ways to finance long-lived assets with short capital sources, or accept to commit for longer periods of time (ibid).

6.2.3 Return expectations

The timeframe mismatch is not the only point of discord between investors and investees in this sector. With the risk profile that these investments represent today, the expected returns can vary between 5 and 25 percent. Commercial investors will tend to expect higher returns than impact investors (RECP, 2014). Nevertheless, the profitability of such project is difficult to reach, especially in a short timeframe, and it is obvious that aggressive returns in 5 years cannot be achieved today. Catering to low-income populations and providing a service that is costly to deliver cannot result in the same financial returns as other less capital intensive ventures in different contexts. It must absolutely be recognized that this sector is a long-term game which is not fit for investors looking to make a 'quick buck'. (ibid)

On the topic of expected returns an interesting debate on the financing of the off-grid sector is currently taking place between different actors. While the discussion was based on the expansion strategies of SHS companies, it can easily be translated to mini-grid DESCOS. In 2016 alone, distributed energy system companies using SHS technologies and pay-as-you go business models have raised in excess of $200M, from up to $20M in 2013 (Ceniarth, 2017). The vast majority of this funding has been focused on East Africa. One impact investment fund active in the sector since 2014 and with participation in different companies has recently raised its concerns over this sudden influx of capital. The single-family fund Ceniarth signaled its decision to reduce its participation in the sector on the basis of a misalignment between the intentions of investors and the readiness of the DESCOs to scale up. In an article published to explain the decision, Cerniarth explained that the recent boom in capital inflow would push SHS DESCOs to scale up too fast while they "have not fully solved core business model issues and may struggle under the high growth expectations and misaligned incentives of many venture capitalists". They argue that as more and more funding come, solar equipment vendors will be willing to sell head-to-head, competing to flip customers from vendor to vendor and relaxing credit criteria for new clients, resulting in a drift towards portfolio quantity over portfolio quality. The reasoning is that the pressure to grow quickly will increase the number of default and increase the risk profile of DESCO companies, ultimately jeopardizing their success in the long-run. They also argued that the vendors which have received the most venture capital support had to shift their focus to peri-urban customers who can afford larger systems and other appliances, defeating the initial purpose of electrifying rural areas. Finally, they added that a number of investors entering this sector were not acting with the ambition to deliver the health, education and lifestyle improvements promised by solar electrification. According the Ceniarth the money flooding the sector is not betting on the commercial success of solar-based equipment, but rather on the idea that DESCO companies will acquire sticky customers who in the long-run will be able to purchase a wide range of other equipment. The family-owned fund claims that, to venture funds, this is not only about energy access, but also about platforms to consumer credit for a wide range of other needs. They fear that the assumption of rising income for additional equipment purchases will not be realized and that conflicts of expectations will arise. To them, the fast growth strategy of venture-backed SHSs vendors with imperfect business models will lead to commercial failures, and yet another unsuccessful attempt at addressing the electrification gap. For all the reasons mentioned above, the family-own fund Ceniarth has decided to step out of a sector they fear to be a bubble.

Reactions to this article came flowing shortly after with different actors defending the needs for ever more venture capital in a sector in dire need of funding. For example, the impact investment fund Persistent Energy Capital responded by reminding that the access to energy access sector was by nature capital-intensive and that the $200M raised by the sector in 2016 "would prime the pump to serve around 1M households and businesses in 2017" (with an average investment of $150 per household) (Persistent Energy Capital, 2017). The investment firm underlined that this represent less than a 1 percent of the Sub-Saharan market. To them this recent influx of capital is not an overheated investor base but rather still a situation of capital starvation. Persistent Energy Capital agrees that companies will compete with each other, and that some may be mismanaged with flawed business plans. However, they look at the situation as the natural evaluation of a nascent sector, where the better-performing companies will be able to bring costs down and eliminate the least performant players.

The Global Off-Grid Lighting Association (GOGLA, 2017) also responded to the article by supporting the idea that the investment figures from 2016 represented a drop in the ocean compared to the opportunity represented by the access to energy sector. While the sector association recognizes that irresponsible or misguided investments could be detrimental, they encourage investors to support the industry as it addresses its challenges. On the issue of last-mile communities, GOGLA insists that by their very nature these areas are the most challenging and the costliest to reach. To them, the decision of DESCOs to focus on peri-urban points to two elements; they their current business plans may not be adapted to serve to most isolated communities, and that a real need exists in areas bordering the grid or with unreliable grid access. If some investors such as Ceniarth decide to focus on projects and ventures that specifically address rural populations, they should not diminish the value of other efforts catering to less remote areas still inadequately served.

Using elements from this debate and recent market data, experts from the International Finance Corporation and the World Bank have concluded that both investors and developers ought to take a careful approach. Developers need to focus on addressing pressing issues putting their commercial viability at risk, and financiers need to recognize the particularities of this sector, mainly the need for long sources of capital with a risk profile still rated as high. Investors cannot expect high and quick returns.

Promoting financing mechanism with lower return expectations, patient structures, and standardized procedures or pooling platforms to limit investments costs will be necessary to fund the second development phase of numerous DESCOs. Several of these mechanisms are explored in the following section.

6.3 Promoting adapted financing structures

6.3.1 Ballon loans

One potential solution to long lending structure involves a balloon loan with a refinancing mechanism (Jacobson A., 2017). In simpler terms, the borrower would contract a first short-term loan with the repayment schedule of a longer loan. This is a non-fully amortized loan. Therefore, when the loan comes due, a significant part of the principal is still left to be repaid. In order to repay in full this initial loan, a second loan is contracted with a regular repayment structure. To illustrate this financing mechanism through an example, a $4M 4-year loan is contracted with a 10-year repayment schedule. Disregarding the interests, the yearly repayment of the principal is therefore $400,000, and not $1M as if the loan had to be repaid linearly over 4 years. After 4 years, $1.6M of the principal has been paid back, and

$2.4M still needs to be repaid. The borrower would then contract a $2.6M 6-year loan with a regular, fully-amortized repayment schedule. The available capital would then be redirected towards the final repayment of the first loan (the balloon), while the annual repayments of the second still worth $400,000 are repaid via the revenues generated.

Not yet seen in practice, this complex mechanism has several advantages and disadvantages. The combination of the two short loans through a refinancing is one solution to access a longer source of capital when one single long loan is not initially available. This is a first significant advantage. A second advantage is that as the project matures over the first 4 years, the developers will be able to develop a track record of their clients, demonstrate the viability of their business model, optimize their operational expenditures or develop additional revenue streams through ancillary services for example. This should allow the borrower to negotiate far more favorable financing terms compared to the initial loan. The financing costs of the overall projects are therefore reduced, reinforcing the probability of commercial success. One of flip side, the refinancing part possesses its drawbacks. The risk of not being able to refinance the loan is essentially borne by the first lender. The financier must therefore be confident that the project will be successful enough so that its loan can be refinanced before the final payment is due. This is a significant risk that probably few investors will be willing to take. This is one explaining factor for the fact this is type of financial structure has not yet be since in this industry.

6.3.2 Green credit lines

Not simpler in theory but more common is practice, especially in developing countries, are the credit line mechanisms. Also called financial intermediation, this mechanism involves international development finance institutions (DFIs) and local commercial banks. Under this financial articulation, the DFI opens a credit line or a long-term loan to one or a portfolio of partnered banks, usually at very favorable terms. This loan is however not a grant. For the partnered banks this pool of capital is the resource they will use as lenders to finance loans requested by borrower (or sponsors). The length of these commercial loans has to be shorter than the one contracted between the partnered banks and the DFI. Sponsors repay their commercial loans to the local banks first, and the partnered banks then repay the DFI. One top of providing an access to deployable capital, the international institutions typically offers technical assistance and financial guarantees. The credit lines extended to the local partnered banks can be targeted to certain sectors of the economy, or development focus. When a credit line is designed to finance low-carbon project or companies, is it referred to as a green credit lines (GCL).

To illustrate the mechanism of the green credit line, the initiatives carried by the French development agency AFD provide a good example. First initiated in 2004, the agency's GCL aims at providing local banks "with special partnership conditions allowing them to seize the opportunities of environmental finance." (ADF, 2010). In 2016, the agency created the SUNREF program, a targeted green credit line of more than €35M dedicated to 6 industry sectors in Uganda, Kenya and Tanzania. With the financial support of the European Union, technical assistance is provided free of charge to stakeholders, such as assistance in the evaluation of a commercial project to be financed by a partnered bank (SUNREF, 2016). The schematics below explains the structure of the Sunref green credit line.

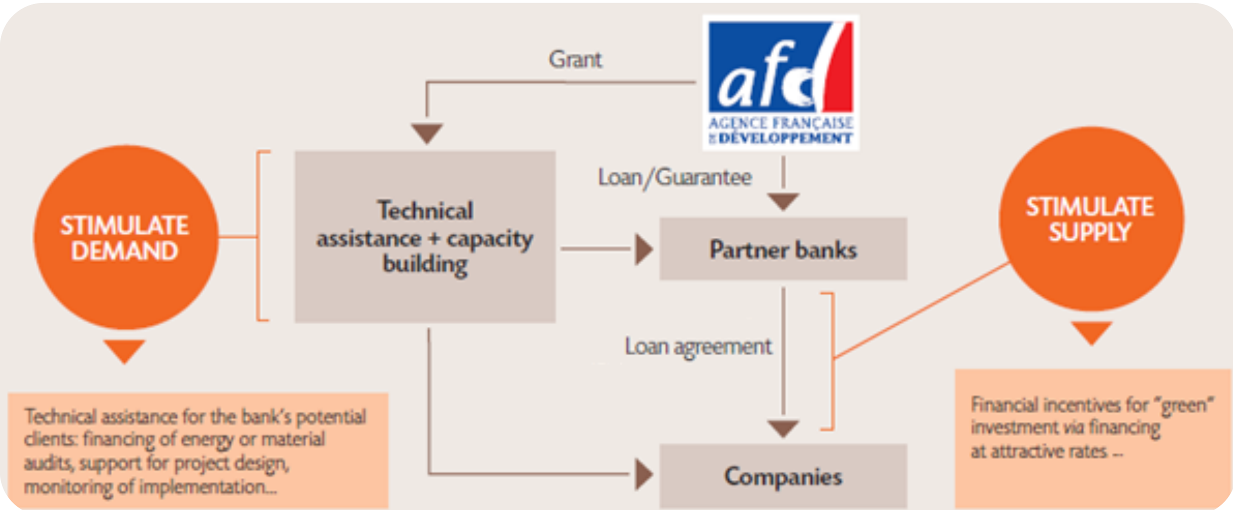

Figure 14 - Schematic overivew of the Sunref Green Credit Line mechanism. Source: Sunref, 2016

The projects or businesses financed with capital drawn from the credit line must meet eligibility criteria. First of all, the loan amount must be between \$300,000 and \$6.5M. Additionally, the project's internal rate of return (IRR) must be between 8 and 50%. For green mini-grid project, who represent their own "project level (4)" in the criteria specification document, the minimum loan tenor is 7 years. This is a very interesting detail as it is much closer, at least in terms of timeframe, to the financing needs of mini-grid developers. The specification document also recognizes that this type of projects "incorporate financial risks that are much higher than for Level 3 projects" (Sunref, 2017).

The advantages of the credit lines are multiple. Because a local bank is the one ultimately delivering the loan, the borrower is able to receive local currency. This has the significant advantage of protecting the borrower against the risk of exchange rate fluctuations, also called currency or FX risk. This risk arises from the change in price of one currency in relation to another (Investopedia, 2017). For example, if the Tanzanian shilling becomes more expensive in relation to the dollar, it is also a devaluation. For a borrower who contracted a loan in US dollars and repays its due from revenues generated in shillings, a devaluation of the Tanzanian currency would increase the cost of capital. Some risk-sharing mechanisms or guarantees also exist to mitigate foreign exchange risk but they represent an additional expense. Borrowing in the same currency as the revenue stream eliminates this risks. Without the support of international financial institutions through mechanisms such as credit lines, local financial institutions are not yet capable of lending to significant enough loans to mini-grid developers. To date, the risk level of mini-grid projects exceeds the risk profile that banking institutions in Eastern African are able to assume on their own (Bernadat C., 2017). Though project evaluation assistance, guarantees and favorable rates from the DFIs, local institutions are able to lend to local players and get actively involved in the clean energy sector. The expertise and the knowledge acquired by of the local financial industry in the context of green credit line is also a critical factor for the long-term success of mini-grids as a pillar of the universal electrification goals. As the sectors matures and the risk profile of the project goes down, the local banking sector will be able to play a much more prominent role in the future if they have acquired expertise through previous DFI-backed loans. Additionally, the loan criteria under the SUNREF program recognizes the importance of long tenors. The fact that mini-grids have their own project category with a minimum 7-year tenor is a strong signal that some financial players are trying to address the timeframe mismatch issue.

The main limitation of credit lines is their availability. A limited amount of capital is available under this type of mechanism and only a small fraction of the mini-grid sector will be able to finance themselves via this avenue. For example, the SUNREF initiative is a $35M program, and only a fraction of it will be redirected towards electrification purposes. Small, individual local projects are more likely to benefit from such sources of capital than large expansion phases for international players. The French Development Agency through its financial arm PROPARCO has already financed a mini-grid project in Rwanda for a tea plantation cooperative who developed its own grid (Bernadat C., 2017).

While credit lines will not be the silver bullet solution to finance this sector on a large scale, they at least address two issues; the involvement of commercial local players and the need for long-term capital. A limited number of projects will be funded through these mechanisms, but they have the potential to be looked at for examples.

6.3.3 Concessional loans

Development institutions can play a significant role by offering adapted financing mechanisms. Development finance institutions will never finance the bulk of the sector needs, nevertheless in the short terms they can adapt to the needs of the developers to offer patient and low-return financial structures to demonstrate the viability of a few projects. A handful of landmark projects can go a long way in attracting commercial lenders willing to commit to long capital structures.

The involvement of the international development institutions is not limited to partnerships with local banks through credit lines mechanisms. DFIs do also extent loans directly to private actors or governments. One form of loans offered by DFIs are coined as concessional, as they are typically extended on terms substantially more generous than market loans. As defined by the OECD, the "concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these" (OECD, glossary terms 2017). Free public money will not help the sector scale up, whereas concessional loans can.

Recent examples of concessional loans include the landmark partnership between the International Renewable Energy Agency (IRENA) and the Abu Dhabi Fund for Development (ADFD). The two institutions are collaborating to fund replicable and scalable energy projects in developing countries. The ADFD "committed USD 350 million in concessional loans, over seven annual funding cycles, to renewable energy projects recommended by IRENA" (IRENA/ADFD, 2017). In the 4th funding cycle announced in January 2017th, $44.5M were committed to mini-grid projects in the Pacific and Niger, including 30MW of new capacity for islands (BNEF - b, 2017).

In the case of government funded programs, the DFIs can provide a long-term loan to the government. Through the creation of a public-private partnership (PPP), the government can redirect the loan to the private developers. Such articulations represent several advantages. First of all the involvement of the government provides a form of de-risking for both the developer and the financier. Secondly, since the government eventually has to repay the loan, it has an interest in the commercial success of the project, increasing the likelihood that it will promote the right policy measures to support off-grid electrification. Finally, it is easier for governments than small private players to borrow money from large development institutions. The money redirected to DESCOs can be part of a larger envelope, reducing the costs of capital for the developers.

Here again the commitments of the Abu Dhabi Fund for Development can be used to illustrate this possible mechanism. The development bank is working with the government of Mauritania to promote rural electrification. The money lent to the government will be directed or channeled to private actors who will be in charge to install and operate power systems in off-grid areas (Wrigley T., 2017)

By providing different adapted forms of capital, either through local banks via credit lines, through government-backed programs or directly to private developers, development finance institutions have the ability to promote successful projects and create a market for longer and more patient forms of commercial capital.

6.4 Financing the expansion phase

To date no DESCO company in Eastern Africa can be said to have reach a true scale up phase. Many are at present building up a couple of grids to validate their model. Portfolio sizes of 200 to 300 grids have been reported by developers has necessary to reach levels of viability and profitability. If or when companies reach the moment when they require much more significant sources of capital, concessional loans and impacts investors will not have the resources to fund this third phase of development.

One field practitioner pointed out to the issue of financing the second development phase as a symptom of a model that is not yet ready to be scaled up. The argument here is that if the commercial viability of the proposition was clearly understood and proven, the complexities of the financial mechanisms described above would not be necessary. In such a situation, either impact investors and other venture capital funds would be less wary of committing resources over longer term, or commercial lenders would offer financing resources more typical of infrastructure projects. This argument implies that developers should focus on the fundamentals of their business model (ratio of cost per connection vs average revenue per connection, channels of revenue generation and productive demand growth, etc) instead of spending time and resources putting together complex financing mechanisms. Whether or not complex financing structures will be needed to finance the business model validation phase remains to be seen.

However, if in the near future companies are able to turn to commercial investors for tickets of $20M to $100M, this will be an excellent sign for the sector, and for the non-electrified communities throughout Eastern Africa. Access to such forms of commercial capital (longer tenures and lower return expectations) will prove that DESCOs have greatly reduced the risk profiles of their portfolio, and demonstrated a much higher chance of commercial success.

7. Conclusion

Over 1 billion people lack access to modern and reliable sources of energy worldwide today, 130 million in the five countries of the Eastern African region alone. The energy access gap is still wide open, and closing it can significantly contribute to a host of human development challenges.

The centralized model of national utilities powering all four corners of a country no longer is the only electrification solution. The advancement of renewable technologies and the emergence of innovative delivery models are challenging the old centralized paradigm. This is an encouraging sign for peri-urban and rural areas which have been waiting to see the main grid arrive for decades. Off-grid, isolated solutions at the household or community level offer new perspective for rapid change.

Among the most promising solutions to off-grid electrification are solar mini-grid systems. Capable to service neighborhoods to entire localities alike, these autonomous power generating and delivering infrastructures are being trialed throughout the region. Thanks to remote monitoring capabilities and mobile payment systems, small private players are entering a sector historically dominated and controlled by large utilities. Also referred to as decentralized energy companies, the latest incumbents of the off-grid energy sector are currently facing a host of challenges to move from trial models to large project portfolios.

The business case for solar mini-grids has not yet been proven and replicated at scale. Financing is therefore difficult to secure as commercial investors are still evaluating the opportunity. A very uncertain policy context is adding to list of risk. Mini-grids are only viable in places where the central grid is not. Even then, high enough revenues will need to be generated in order to recover the high capital costs and provide worthy returns for investors.

The large scale deployment of mini-grid solutions will depend on demand growth and risk reduction opportunities. Within sites, companies should focus on productive uses and higher average revenue per user. Financing services to facilitate the access to productive appliance is an emerging solution. Across sites, companies should look at working in clusters to streamline operational costs and finance bundles of projects to limit capital costs. Governments also have an important role to play by promoting more stable regulatory frameworks and offering the subsidies which may still be needed in some cases. The financing sector must also play a part in the promoting of the sector by recognizing the need for patient sources of capital with limited return expectations. Delivering a basic service to low-income households via capital-intensive infrastructures will not result in exponential profits. Investors with the wrong expectations are a threat to the sector, potentially pressuring companies into non-sustainable strategic decisions.

If the sector can address these policy, business model and financing barriers, mini-grids could realize their fantastic potential and electrify millions in the next few years. The success of mini-grids could go a long way in achieving the international community objective of universal access to clean and modern energy by 2030.

8. Bibliography

Agence Française de Développemnent (AFD). 2010. "Financial Intermediation". Program presentation document. Paris: Agence Française de Développemnent

Allotrope Mini-grid Investment Accelerator (MIA). 2017. *Microgrid Market Analysis & Investment Opportunities.* Oakland: Allotrope Partners.

Bardouille Pepukaye - International Finance Corporation. 2017, February 9th. *Personal phone interview*

Bardouille Pepukaye and Muench Dirk. 2014. "How a New Breed of Distributed Energy Services Companies can reach 500mm energy-poor customers within a decade - A commercial solution to the energy access challenge". White Paper. International Finance Corporation / Persistent Energy Capital

Bardouille Pepukaye and Sheperd Daniel. 2016. "Emergence of a Commercial Market for Mni-grids in Africa". ESI Africa, issue No. 4.

Bardouille, Sheperd and Vanzulli. 2017. "There is Such a Thing as Too Fast: Avoiding 'Mismatch Expectations' in Off-Grid Energy Investing". Discussion Paper. *Web* - NextBillion, nextbillion.net/there-is-such-a-thing-as-too-much-too-fast-avoiding-mismatched-expectations-in-off-grid-energy-investing/

Bernadat Céline - French Development Agency (AFD). 2017, March 17th. *Personal phone interview*

Bloomberg. 2017. "New Energy Pioneers 2017". *Web* - Bloomberg, bloomberg.com/company/new-energy-pioneers/

Blomberg New Energy Finance (BNEF). 2016. ClimateScope 2016 - *The Clean Energy Country Competitiveness Index.* London: Bloomberg

Blomberg New Energy Finance (BNEF - a). 2017. *Company Profiles: Mini-Grid Developers in Emerging Markets. - Building Grids from the Group Up*. Client Report. London: Bloomberg

Blomberg New Energy Finance (BNEF - b). 2017. *2Q 2017 Frontier Power Market Outlook - Micro-grids on the horizon.* London: Bloomberg

Ceniarth Impact Investing. 2017. "An impact Investors Urges Caution on the 'Energy Access Hype Cycle'". Discussion Paper. *Web* - NextBillion, nextbillion.net/an-impact-investor-urges-caution-on-the-energy-access-hype-cycle/

Energy Sector Assistance Management Program (ESMAP). 2015. *Beyond Connections - Energy Access Redefined*. Technical Report 008/15. Washington: The World Bank / International Bank for Reconstruction and Development

Energy Sector Assistance Management Program (ESMAP). 2017. *State of the Electricity Access Report: 2017*. Washington: The World Bank / International Bank for Reconstruction and Development

Global Off-Grid Lighting Association (GOGLA). 2017. "Hype in the Energy Access Sector (Finally!)". Discussion Paper. *Web* - NextBillion, nextbillion.net/hype-in-the-energy-access-sector-finally/

Griffin Andrea. 2017. "SunFunder on encouraging investment and tackling currency risk in Africa". Web - PV Tech, pv-tech.org/interviews/pv-talk-sunfunder-on-encouraging-investment-and-tackling-currency-risk-in-a

Hystra Consulting. 2017. *Reaching Scale in Energy Access - Lessons from Practitioners.* Paris: Hystra Hybrid Strategies Consulting

International Energy Agency (IEA). 2004. *World Energy Outlook*. Chap. 10 Energy and Development. Paris: OECD/IEA

Investopedia. 2015. "What are the difference between debt and equity markets?". *Web* - Investopedia, investopedia.com/ask/answers/071415/what-are-differences-between-debt-and-equity-markets.asp

Investopedia. 2017. "Foreign Exchange Risks". *Web* - Investopedia, investopedia.com/terms/f/foreignexchangerisk.asp

International Finance Corporation (IFC). 2017. *Operational and Financial Performance of Mini-grid DESCOs - Findings and Insights from Pioneer Benchmarking of this Emerging Sector.* Washington: International Finance Corporation.

International Renewable Energy Agency (IRENA)/Abu Dhabi Fund for Development. 2017. "IRENA ADFD Project Facility - Supporting Enegy Transition in Developing Countries". Progress Report. Abu Dhabi: IRENA

European Photovoltaic Industry Association (EPIA). 2016. *Tenders for Solar Projects*. Working Paper. Brussels: EPIA.

Jacobson Avi - Sunfunder. 2017, February 9th. *Personal phone interview.*

Johnson Nathanial - Gigawall Global. 2017, January 30th and February 19th. *Personal phone interviews.*

Kenya Power and Lighting Company (KLPC). 2017. " Last Mile Connectivity Program Q&A" *Web.* - KPLC, kplc.co.ke/content/item/1694/last-mile-connectivity-program-q---a.

Khandker et al. 2012. "Who Benefits Most from Rural Electrification? Evidence from India. Policy Reaearch Working Paper No. 6095, The World Bank Development Research Group

Kumar Santosh and Rauniyar Ganesh. 2011. "Is electrification welfare improving? Non-experimental evidence from rural Bhutan." MPRA Paper No. 31482, Asian Development Bank.

Madry Frédérique - Engie Power Corner. 2017, April 27th. *Personal phone interview.*

Nahmias-Leonard Laurent - Vingunga Power. 2017, February 27th. *Personal phone interview.*

Organisation for Economic Co-Development (OECD). 2017. "Glossary of statistical terms - Concessional loans" *Web* - OECD, stats.oecd.org/glossary/detail.asp?ID=5901

Oxford Institute for Energy Studies (OIES). 2016. *Sustainable Electricity Pricing for Tanzania*. OIES Paper EL20. The University of Oxford.

Persistant Energy Capital. 2017. "Dear Critics: Here's Why the Off-Grid Energy Industry Needs Impact Investment". Discussion Paper. *Web* - NextBillion, http://nextbillion.net/dear-critics-heres-why-the-off-grid-energy-industry-needs-impact-investment/

Renewable Energy Cooperation Programme (RECP). 2014. Mini-grid Policy Toolkit - Policy and Business Framworks for Successful Mini-grid Roll-outs. Eschborn: European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF)

REN21. 2016. *Renewables 2016 Global Status Report.* Paris: REN21 Secretariat

Sunref East Africa. 2016. "Towards a greener future - Program presentation document". Paris: Agence Française de Développement

Sunref East Africa. 2017. "Program Eligibility Criteria" Technical working document. Paris: Agence Française de Développement

Sustainable Energy for All (SEforAll). 2017. *Global Tracking Framework - Progress Towards Sustainable Energy.* Washington: The World Bank / International Bank for Reconstruction and Development / IEA

United Nation Environment Program (UNEP). 2015. *Renewable Energy in Hybrid Mini-grids: Economic Beneefits and Business Case.* Technical Paper. Frankfurt: UNEP / Frankfurt School of Finance and Management

United Nations Sustainable Development Goals. 2017. “Sustainable Development Knowledge Platform.” *Web* - United Nations, sustainabledevelopment.un.org/sdgs.

Verin Louis and Contejean Arthur. 2016. "Integrating Productive Uses of Electricity Within Private Clean Energy Mini-Grids Business Models - The case of Tanzania and Jumeme". Master's thesis - HEC Paris School of Business

Vulcan Impact Investing. 2016. *Powering Productivity - Early Insights into Mini Grid Operations in Rural Kenya*. Working Paper.

Wrigley Tom - Winch Off-Grid Energy. 2017, May 25th. *Personal phone interview*