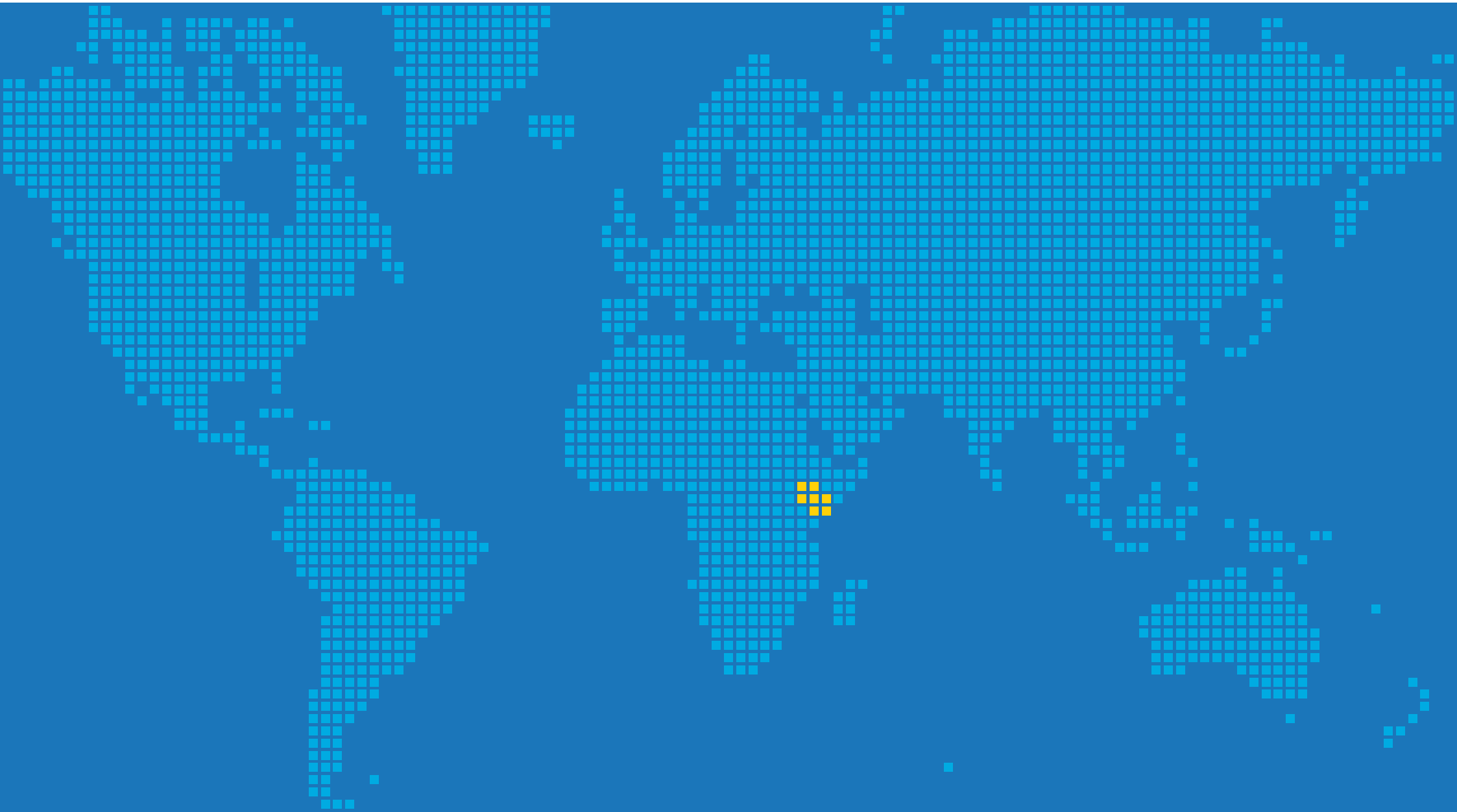
TFE Consulting

Kenya:

The World's Microgrid Lab



EXECUTIVE SUMMARY

Kenya shows that the global microgrid market is ready for significant private investment. While there still remain some challenges - especially around the regulatory framework and aggregation of projects - there are now enough businesses with viable business models to provide early stage, strategic or even crowd investors with commercially attractive opportunities.

The medium-term growth potential for the microgrid market in Kenya, as well as in other energy access markets including in Africa, South and South-East Asia, is very high. We base our analysis on the following observations from Kenya:

1 Businesses create commercially viable returns: The microgrid[1] industry is becoming less and less driven by development organisations and NGOs and increasingly by private companies. Microgrid developers have learned from the growing number of successful as well as failed projects. There are now a number of localised and proven microgrid business models. Many of them proactively catalyse the productive use of electricity for new, electricity-based enterprises that in turn bolster the revenues of microgrid operators. We also see specialisation in the sector, from dedicated investment instruments to companies specialising in microgrid specific technical hardware.

2 Technology drives down cost: Whether it is locally designed smart meters, rapidly falling solar module costs, mobile payment solutions or the use of satellite imagery - technology plays a key role in bringing down the costs of microgrid systems as well as those of running the business. This reduces the cost of electricity for the end consumer, speeding up adoption rates and encouraging greater electricity consumption. As a result, microgrids offer higher returns to investors and become a more attractive option for governmental electrification strategies.

3 Technology drives down risk: The best potential sites and customers can be identified through data analytics and remote mapping. Power usage and payments are easily tracked using metering and control technologies. Tariffs can be adjusted in real-time to optimise the use of installed assets and increase operator revenues. In general, technology makes "remoteness" less remote by bridging the informational, operational and psychological gap between the end customer, the microgrid developer and the investor.

4 Government drives down risk: Governments, including Kenya's, increasingly see microgrids as a key piece of their electrification strategies. They understand that this requires proactive risk reduction and the development of dedicated regulations and planning for a transparent, stable intersection between the microgrid and national grid expansion. It also means giving microgrid operators a clear legal status and operational freedom. Should governments decide to subsidise microgrid power, there are technological and regulatory ways to achieve this that avoid excessive bureaucratic interference.

$4 customer willingness to pay per kWh

$5-10 per Watt cost of microgrid

20% of Kenyans have access to grid power

88% of Kenyans have mobile phones

65+ number of microgrids in Kenya

$1,377 GDP per capita in Kenya 2015

$1.5bn Kenya microgrid market opportunity in the next 5 years

6bn mobile money transactions in 2016

Donors also still have an important role to play. They can maximise their impact by focusing on the remaining regulatory and financial pain points in the sector. This might take the form of helping national governments develop a decentralised renewable energy strategy, including microgrids, and supporting them with technical assistance, best practise examples and funding to develop local (or even cross-boundary) risk mitigation and financing instruments. There is also still a need for developmental risk capital to initiate and accelerate the spread of microgrids by providing early stage investment to new businesses, new business models, new technologies, as well as in new markets.

Although some countries (like India) have more energy access microgrids than Kenya and a number of countries (like Senegal) have been using microgrids for considerably longer, Kenya has seen a unique proliferation of different commercial approaches to microgrids which arguably has caused the sector to evolve more rapidly than anywhere else in the world. Kenya, therefore, is a great example for assessing the factors that determine the success of using microgrids to provide energy access.

Kenya has seen a unique proliferation of different commercial approaches to microgrids

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LEAPFROGGING

Kenya is the economic lion of East Africa. Its GDP almost quadrupled from $16.1 billion in 2004 to $63.4 billion in 2015[2], growing twice as fast as the average rate of Sub-Saharan Africa. Its growth has been driven by a relatively stable currency, low inflation, low fuel prices and substantial public investments in energy and transportation. This has boosted an expanding middle-class with steadily rising incomes. Between 2004 and 2015, GDP per capita grew from $467 a year to $1,377 (current US$), rising from just 7% of the global average to 14%[3]. Within Kenya, the vibrant start-up and services sector in the capital, Nairobi, stands out. It is home to numerous start-up hubs, buzzing with highly educated, technology savvy local and international entrepreneurs. This sector has brought forth innovative businesses, geared specifically to the conditions and aspirations of the African market.

> Mobile money is the catalyst of Kenyas energy access revolution

Some of the most impactful and innovative businesses are based on mobile money. Kenya has been at the forefront of the sea change in financial inclusion. In 2016, 6 billion mobile money transactions were recorded from 25 million users, transferring almost $150 million every day[4]. According to data from the Central Bank of Kenya, mobile money makes up almost 67% of all (cashless) transactions via the National Payments System[5].

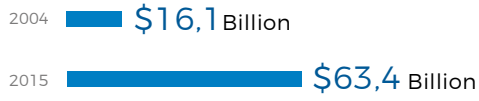
The most widely used mobile money platform is "MPesa" (see box: Mobile Money and MPesa). Almost all Kenyans are familiar with MPesa or similar platforms. This is key. The ubiquity, social acceptance and simplicity of these mobile payment platforms has encouraged people in even the remotest areas to pay for all sorts of services using their mobile phones and thereby, for the first time, connecting to the formal economy. This revolutionary technology has given rise to new development avenues, creating jobs and sales channels for many goods and services along the way. It has also become the catalyst of Kenya's energy access revolution.

Most successful private energy access companies in Kenya, including suppliers of solar home systems (SHS) and microgrid operators rely on MPesa or similar mobile money platforms such as

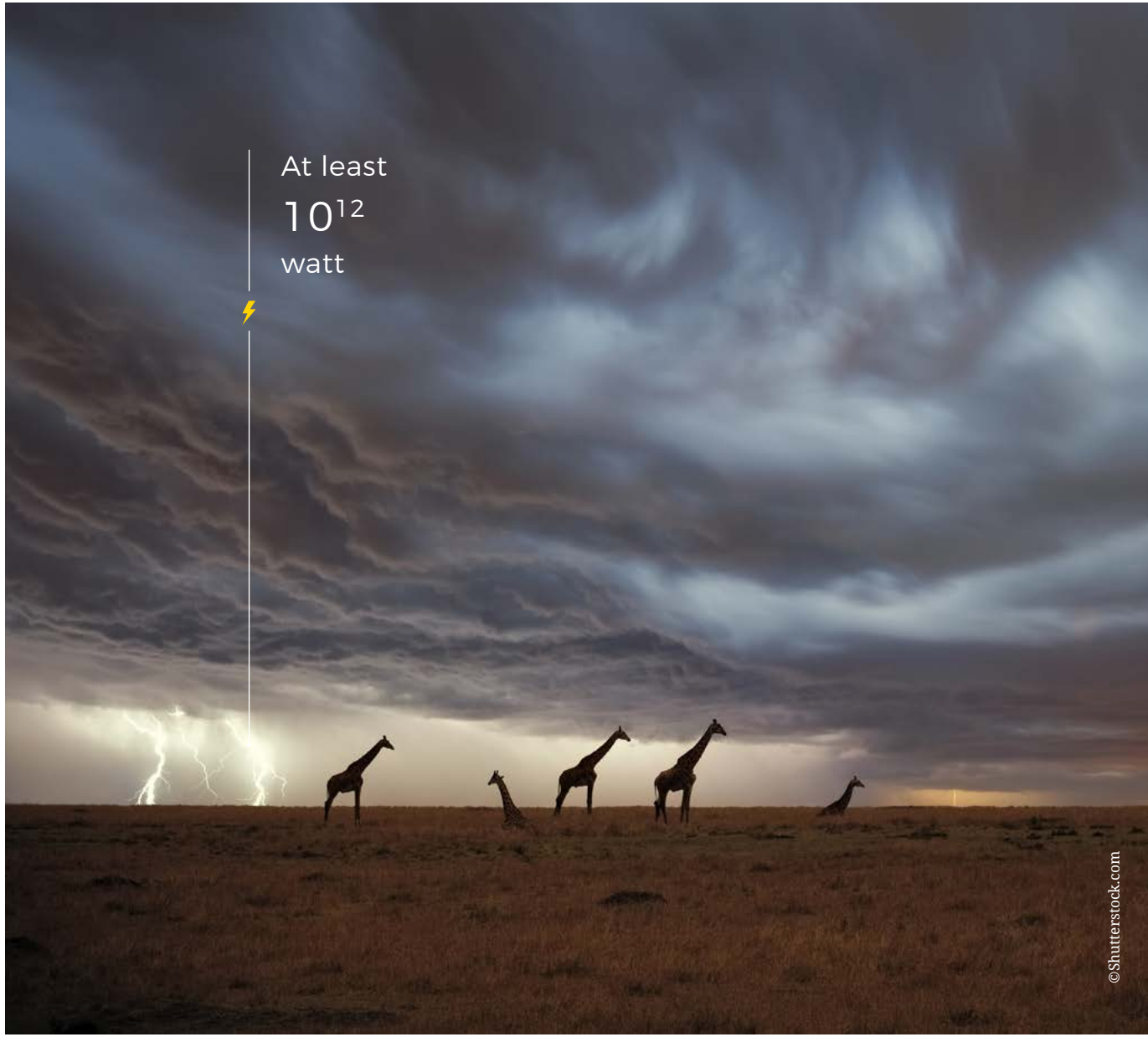
HIGHLIGHTS

1. Kenyans are getting richer fast and demand for modern, electricity-based lifestyles grows
2. Mobile money platforms have driven a revolution in financial inclusion
3. The ability to pay for services remotely is the basis for Kenya's electrification business models

GDP of Kenya



Airtel Money or Orange Money. Customers use them to incrementally pay for a solar system or to pre-pay for energy services (buying kWh) from a microgrid operator. Mobile money alleviates many of the drawbacks associated with earlier cash or scratch-card systems. For one, it vastly simplifies revenue collection: no cash changes hands. Cash-based revenue collection is a significant administrative challenge for energy access businesses, as seen in other energy access markets such as India. In Kenya, the cashless payment system unlocks the possibility of running remotely located "energy vending machines". This reduces transaction costs, lowering electricity costs for consumers and bringing down business expansion costs for the solution providers.



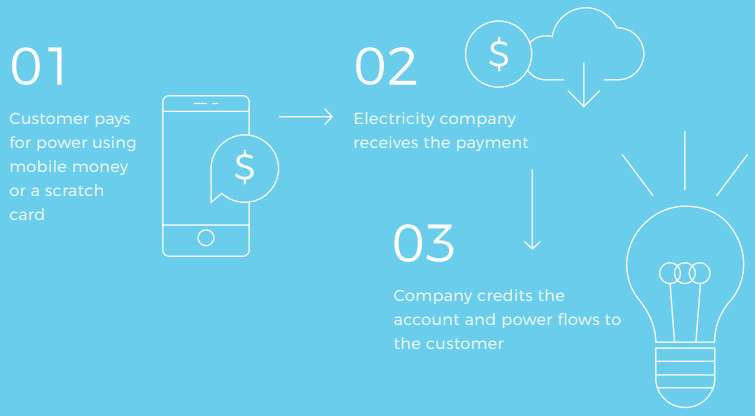
Lighting releases huge amounts of energy. Capturing it with giraffes is not advisable.

Mobile Money and MPesa

MPesa[6] is a mobile payment platform provided by the Kenyan telecom company Safaricom. Before the advent of a specific payments platform, phone users already used mobile phone airtime as a unit of liquid, easily transferable value. With support from the UK Department of Foreign and International Development (DFID), Safaricom formalised and developed this into the sophisticated platform that exists today. In its most simple form, MPesa, allows users without bank accounts to transfer funds using even very basic phones and interface with the cash economy using the ubiquitous green MPesa shacks.

For example, at the end of a day selling fruit in a remote village, rather than carry around newly earned cash, the vendor can visit a green MPesa shack to make a deposit. The vendor gives her cash to the MPesa agent who converts it into mobile money using their phone. The deposited money is now safe "in the cloud", even if the phone is stolen. Most importantly, the vendor can now instantly make mobile payments, such as sending money to a supplier (who can withdraw this as cash from another MPesa agent), buying electricity credit or paying her children's school fees. This mechanism of "banking the unbanked" and providing a very simple, safe and accepted way to transfer money has had an enormous impact on the economy and the financial inclusion of rural Kenyans and many other telecom companies have been rolling out similar services around the developing world.

> The deposited money is now safe „in the cloud", even if the phone is stolen...



The proliferation of mobile phones in Africa exceeded all expectations.

SIZING THE MARKET

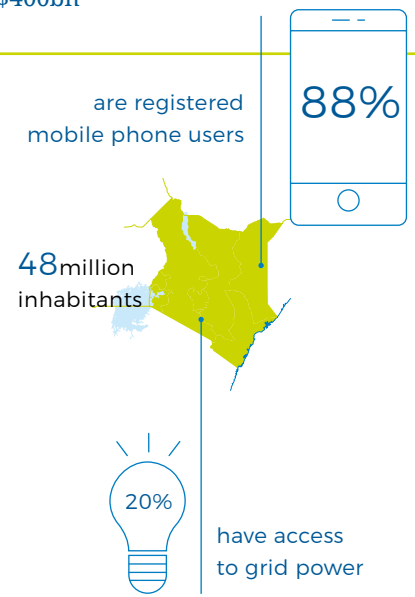
For many of Kenya's 48 million inhabitants, access to electricity is still a distant pipe dream. Only about 20% have access to grid power [7]. This is a stunningly low number, especially when compared to the 88% of people registered as mobile phone users. [8] The limitations of the current grid and the geographic dispersion of Kenya's population make the universal supply of grid power a difficult and costly proposition. It is highly unlikely that the vibrant fishing islands in Lake Victoria or remote communities in Marsabit will be connected to the national grid anytime soon. In other cases, the user-borne costs of a last-mile connection to the national grid is prohibitively high. [9] As a result, many still rely on kerosene or candles for lighting and occasionally pay to charge their mobile phone using a petrol generator run by a local entrepreneur.

However, as the population grows and people in even the most rural settings are turning into electricity users (if only to charge their phones), there is an increasing demand for modern energy services. As a result, the demand-supply gap continues to grow. The frailties of the legacy infrastructure including aging electricity transmission lines and limitations in supply (often exacerbated by factors such as low rainfall reducing the output of Kenya's hydroelectric power stations) mean power supply in even grid-connected rural areas is unreliable. The unpredictability of supply makes it very difficult to start businesses that rely on power. Incubating hen eggs for example is a popular small business in Kenya. This is impossible if one cannot rely on a consistent supply of power for your incubator. This gap between access to high quality energy services and the rise in demand opens up the market to microgrid solutions.

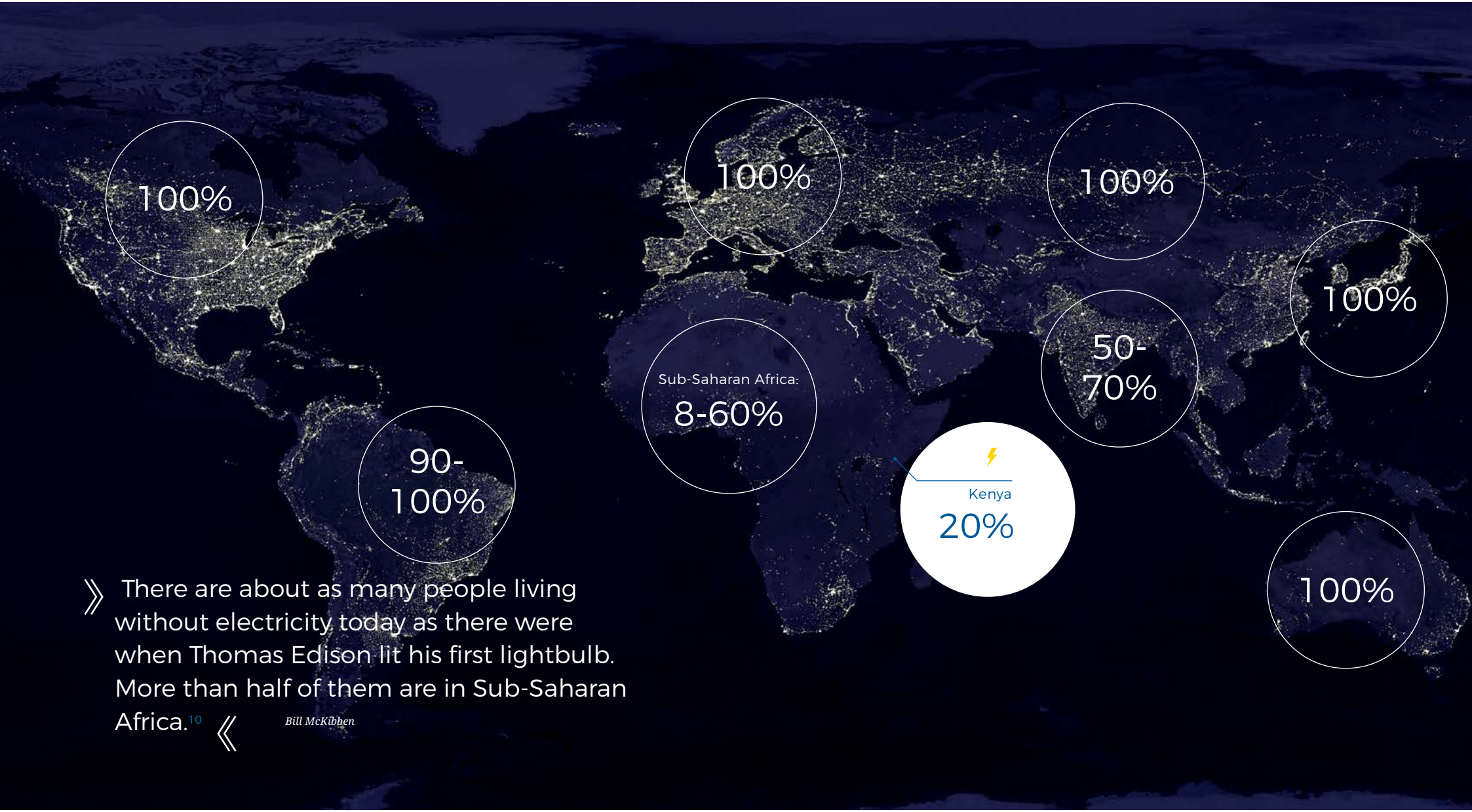
» Many still rely on kerosene or candles for lighting and occasionally pay to charge their mobile phone using a petrol generator «

HIGHLIGHTS

1. 80% of Kenyans lack access to reliable grid power
2. The market will grow to an estimated 2,000-3,000 microgrids in the next 5 years, offering a $1.5bn opportunity
3. Globally, microgrids for electrification have a market potential of $400bn



Access to electricity worldwide



» There are about as many people living without electricity today as there were when Thomas Edison lit his first lightbulb. More than half of them are in Sub-Saharan Africa.[10] «

Bill McKibben

Source:
http://gtf.esmap.org
map: https://visibleearth.nasa.gov/view.php?id=55167

Today, there are at least 65 microgrid projects of 5-100 kW operating or under construction in Kenya. This is more than 40% of the approximately 150 commercial microgrids operating in the whole of Sub-Saharan Africa. [11]

As in other countries with many isolated, off-grid communities, the national power utility has been running diesel-based microgrids in Kenya for many years. Our research shows that there are currently more than 20 of these projects with a collective capacity of almost 25 MW. These are generally operated by agencies of the national government. It is only in the last six years that private players have made their mark too. The most active operators and developers are PowerHive and PowerGen. They are joined by a growing number of new developers including RVE.SOL and General Microgrids.

The Rocky Mountain Institute estimates that the current market for microgrids in Kenya, Senegal, Tanzania and Uganda combined is $750 million in annual revenue. [12] Based on our conversations with developers, investors and lenders, if the recommended regulatory changes are made, we expect the number of microgrids in Kenya to reach 2,000-3,000 by 2021. By comparison, we expect around 7,000 by 2021 in all Sub-Saharan Africa. More than one in every three new Sub-Saharan microgrids will therefore be built in Kenya. India, with an unelectrified population 8-10 times that of Kenya and one of the world's most aggressive microgrid expansion policies plans to develop only 10,000 microgrids with a combined capacity of 500 MW by 2021. [13] The numbers show that the Kenyan market has a particularly high concentration of microgrids with fast growth expectations. The companies and business models currently developed in Kenya can provide patterns of success for global growth.

> The Kenyan market has a particularly high concentration of microgrids and huge growth potential.

To assess the Kenyan market potential, let us assume that the microgrids currently planned by the Kenyan Rural Electrification Authority in the north of the country are of a typical size and type. Most of these will be diesel-solar hybrid grids of approximately 60 kW [14] each. Assuming a total installed cost of $10 per watt [15] the market opportunity for Kenya alone is around $1.5 billion by 2021. This would be 38% of the total Kenyan electrification market opportunity of an estimated $3.9 billion. [16]

Microgrids have the potential for rapid scale, globally. There are 1.2 billion energy poor in the world. [17] Assuming that one third of them will be electrified via microgrids (the rest through grid extension and solar home systems), and assuming that the average demand would be similar to those of a Kenyan microgrid user, and assuming that the cost of each user connection would be similar to that of a Kenyan microgrid (around $1,000 per person [18]) this represents a $400 billion market opportunity [19]. The Sustainable Energy for All (SE4All) initiative estimates a need for 350,000 microgrids in Africa alone [20]. Given that most microgrids are built around renewable energy power generation, this would vastly reduce local pollution as well as offer a climate friendly growth path.

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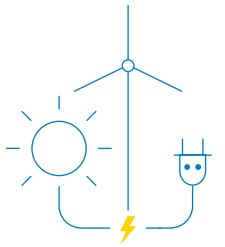
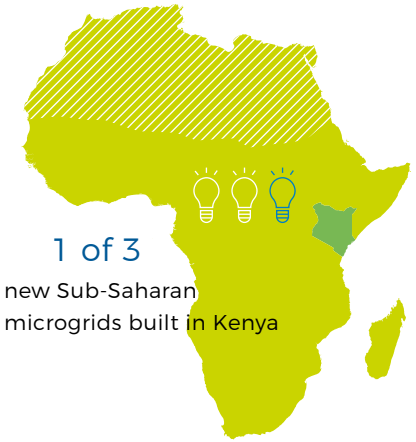


2.000-3.000
microgrids expected in Kenya by
2021



1 of 3
new Sub-Saharan microgrids built in Kenya

MOVING UP THE ENERGY LADDER

HIGHLIGHTS

1. Microgrids and solar home
2. systems (SHS) are complimentary solutions
3. SHS owners are usually good microgrid customers
4. Moving up the energy ladder takes time and requires business activity to grow

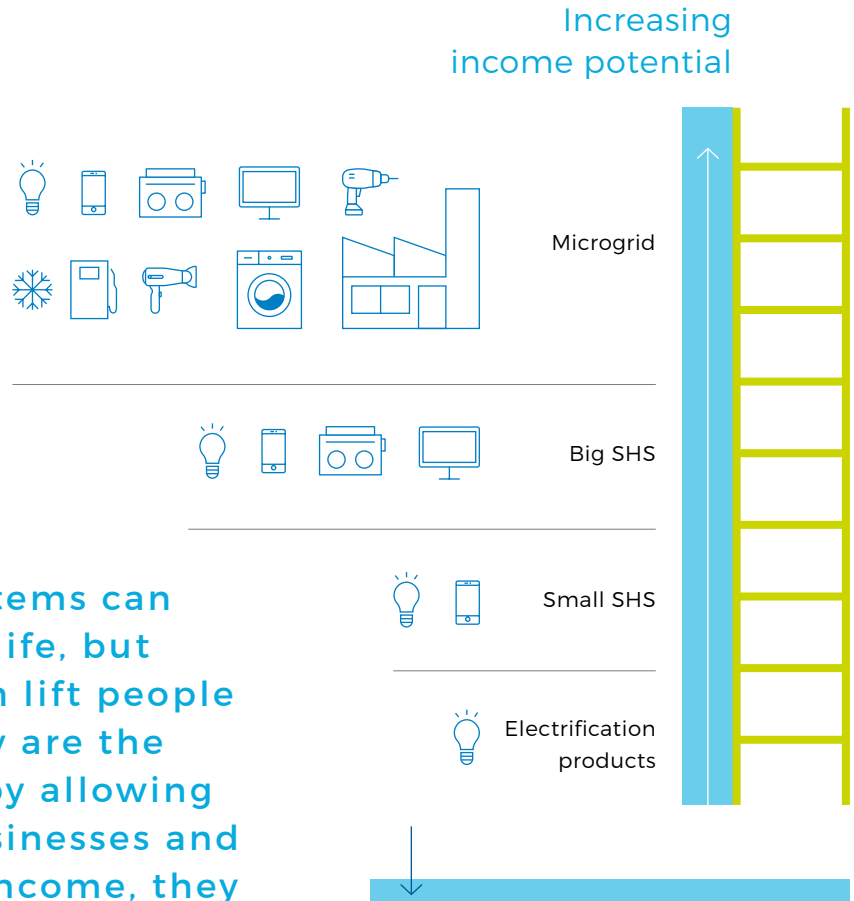
Electrification by itself does not automatically lead to development. Electricity is a crucial but not a sufficient condition. A recent study of small microgrids in India showed that lifestyles changed little in many locations where solar microgrids were installed. Users just replaced one source of energy (burning fuels) with another (electricity). To facilitate development, electrification should go hand-in-hand with other activities such as microfinance and local business capacity building [21]. The starting point for electrification in the past has often been the provision of individual electrical products (like solar or mechanically charged lanterns) or solar home systems (SHS).

The market for SHS in Kenya is already dynamic and lucrative. Microgrid operators are often asked how and why they would compete with such an obviously successful energy access model. The answer is very simple: the two approaches to energy access do not compete. They are meeting different needs and can complement each other.

> A rural power user will often have a microgrid connection to their business and an SHS at home

The best way to understand this is through the concept of the "energy ladder", where increasingly sophisticated and heavy uses of energy are found at each rung of the ladder. For example, a kerosene lamp might be at the bottom rung as it provides a very basic (and very expensive) lighting service. SHSs are a few rungs up this ladder as they usually allow a user to charge mobile phones

Energy ladder



As you go up the ladder you have access to more energy. This means more opportunity for **productive uses** of power, more income generation potential, a stimulated local economy and reduced outward migration of people looking for work elsewhere.

Light from roof systems can improve quality of life, but only microgrids can lift people out of poverty. They are the next step up. And by allowing people to build businesses and another source of income, they improve the resilience of rural communities against drought or climate change.

Emily Moder, SteamaCo

MARKET VOICES

Daniel Becker

Managing Director at E.ON Off Grid Solutions GmbH

What is the biggest challenge facing the uptake of microgrids worldwide?

Becker: The biggest challenge is a lack of strong and clearly implemented regulation regarding tariffs, integration when the grid arrives, standards, permitting and licensing. Given that mini-grids are public infrastructure and are significantly cheaper than grid extension they need financial support, for example a strong subsidy scheme that allows scale.

What single change, technological, regulatory or otherwise could really catalyse the industry?

Becker: A rethinking at Government level that mini-grids can speed up electrification at a lower cost while yielding the same benefit as the national grid (flexible load, AC, productive use) and that as a result they should be subsidised.

Some estimates put the number of completed off-grid microgrid projects in Sub-Saharan Africa at about 150. How do you expect this to increase over the next 5 years? Which countries do you think will see the biggest growth?

Becker: I expect strong growth over the next few years as the technology matures, costs come down and governments realise the importance of mini-grids. Several markets such as Tanzania, Nigeria, Rwanda, Benin, Sierra Leone and DRC are working on regulation that goes in the right direction.

as well as provide lighting and low voltage DC power to offset kerosene lamps. Most microgrids would be several rungs further up. A microgrid is typically able to provide much more power than a SHS, allowing users to power their businesses whether that be a hair salon or fish refrigeration. Another crucial difference is that most microgrids in Kenya deliver 220 V AC power to the end user rather than the low voltage DC output of most SHSs. This enables a consumer to run the same appliances as someone connected to the national grid, be that a fridge, a TV or a subwoofer. It is far from uncommon to find rural consumers with a microgrid connection to their business premises and a solar home system on the home roof. Studies in Kenya on the revenues generated by solar microgrids suggest that the average revenue per user was 1.9 times higher for microgrid customers who also owned an SHS or other solar products [22]. This makes sense as the different technologies are meeting different needs and the user already has a familiarity and appreciation for the value of solar technology.

Microgrids can provide sufficient power and reliability for rural communities

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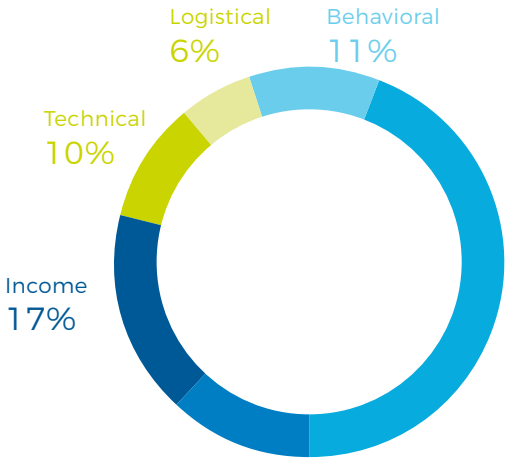

Demand:
Appliances
44%
Users would purchase more electricity, if they could afford the upfront cost of appliances.

Source: Vulcan Philantrophy "Powering Productivity" www.vulcan.com/MediaLibraries/Vulcan/Documents/Kenya-Mini-Grids-White-Paper-VI2.pdf

Caleb re-winding a car alternator to turn it into a home-made wind turbine.

BUSINESS MODELS

In general, rural customers in Kenya seem to be willing and able to pay tariffs as high as $4 per kWh of power. In fact, many of them currently pay at least as much for equivalent power from a generator. Our experience shows that microgrid costs can fall rapidly with size. However, making a business case work will depend on "right-sizing" the microgrid in order to achieve a high utilisation rate of the system and not wasting electricity. Too big a system will lead to underutilisation and higher per unit costs. Too small a system will forego revenue and scale effects, again leading to higher per unit costs.

Right-sizing requires an understanding of the following parameters [23]:

» Likely energy consumption in a village, which crucially depends on commercial customers. There will usually be more commercial customers the larger a village is, the closer to a main city it is and if it is on a busy route.
» Likely energy demand growth in the village (and how to accelerate that). See the discussion of the "Energy Ladder" above.
» Energy patterns need to be addressed through the system design. In many places, peak consumption is during the evening hours. This requires some amount of storage. Flexible tariffs (based on smart meters) can change consumption patterns to match generation more closely.
» Seasonal fluctuations can be mitigated through a balanced (e.g. residential/agricultural/commercial/industrial) customer mix.

The variety of commercial microgrid business models in Kenya signals a healthy and dynamic business ecosystem. Many microgrids are locally built and managed. For instance, on the Lake Victoria islands, there are crude, informal microgrids, where the owner of a diesel generator will distribute power locally and charge people a flat rate, depending on what appliances they plan to run. These grids typically operate only for a few hours

HIGHLIGHTS

1. Customers are willing to pay as much as $4 per kWh for reliable power
2. Right-sizing the system is crucial for profitability
3. Making use of microgrid sales channels for additional, non-electricity products can strengthen the business case

in the evening. There are examples of locally built micro-hydro schemes like the one in the picture below that was built by a teacher and uses old barbed wire to distribute power to a few local households, shops and a school. These users pay a flat rate for a service that covers all maintenance.

There are cases, where the microgrid assets are owned by a community and decisions about investment of profits and new connections are made by an elected community council. Several such microgrids are run in fishing communities around Lake Victoria by the UK Comic Relief funded RESOLVE[24] project. This model has faced some challenges in the form of powerful community members controlling and monopolising the system for their own benefit and to the detriment of the community as a whole. Al-

This home-made hydro-electric microgrid provides power to several houses, shops and a school.

MARKET VOICES

Emma Miller

Emma Miller, Microgrid focused Business Development Advisor at the Shell Foundation

What is the biggest challenge facing the uptake of microgrids worldwide?

Miller: I see policy as the biggest challenge – adverse or lack of policy impedes investment, financial viability and slows progress in implementation.

What single change, technological, regulatory or otherwise could really catalyse the industry?

Miller: Regulatory changes to allow operators to negotiate tariffs (or receive subsidy to buy down the tariff) and secure, long term concessions or predefined exits when the grid comes. If governments add mini-grids to their electrification plan, we're all pushing towards the same goal. We see mini-grids as a method to extending the grid faster, not as an alternative.

What are the most exciting new business models you've seen?

Miller: There's a lot of buzz around demand stimulation and productive use, which is really important for viability. I also have to mention the new Husk solar/biomass hybrid model which offers 24/7 3 phase AC power at a very low cost in India. 24/7 power means business customers can get rid of the diesel generator, which really helps increase demand.

Is the market ready for purely commercial investment?

Miller: From what I've seen, it takes a mini-grid company 5-7 years to come to a point where they can attract commercial investment. We hope this will decrease exponentially. At the moment, the market is not viable purely commercially for either new developers and or for any developers in markets where tariffs are controlled or there is very little commercial activity. I do believe we can get there over the next 5 years for many areas, but we should not be afraid to organise subsidy to fill the gap in the meantime. The sector truly needs to pull together and collaborate on blending the right capital mix.

Over the next 5 years where in the world do you think will see the biggest expansion of microgrids?

Miller: India. The government wants to push 10k microgrids over the next 5 years. Once it becomes a government target, policy becomes much easier. The population density and commercial activity also help.

though the idea of community ownership, revenue sharing and maintenance is intriguing, our experience suggests that a straightforward commercial model can better ensure scalability, speed of deployment and cost efficiency. Of those commercial models, there is a wide variety. SteamaCo [25], for instance, has managed grids which rely on the presence of a local site agent to fix any small technical issues and be the first point of communication for customer assistance. PowerGen, on the other hand, runs grids which are designed to be utterly standalone, with maintenance being carried out by staff who visit periodically or as required.

There is also an opportunity to strengthen the microgrid business model by adding products other than electricity to the portfolio. A microgrid operator thereby makes broader use of existing customer channels. For instance, in the projects run by RVE.SOL [26], the microgrid hub also offers biogas for cooking and clean water.

Another way is to help build new businesses to grow on top of the provision of electricity rather than alongside it by offering products that run on electricity, such as refrigerators, phones or TV sets. Simpa Networks, operating in India, has turned the business proposition around, using a TV as the sales pitch for selling the power needed to run it. They call it the "pay as you go solar television" [27].

Going further towards becoming services providers, the microgrid operator could establish a workshop or an internet connected 'cyber cafe', for example [28]. Rather than paying for a kWh of energy, users of power pay for time on a computer or a day spent using a power tool. This is often in keeping with existing local business models where, for example, a fisherman will pay a boat owner a flat rate to use their boat for a day. If the microgrid operator shifts focus from selling kWh to selling a service and is providing the appliances used to deliver it, he is also incentivised to use efficient appliances. This idea is supported in a recently published report from the Rocky Mountain Institute [29] which suggests that microgrid operators can improve their cost effectiveness and the utilisation of installed assets by exploring more service based payment approaches.

Electrification can be coupled with other technology investments to provide all kinds of services, such as entertainment (cinema, bar, music), cold storage (medicine, vaccination, food), local transportation, or water pumping and irrigation - to name just a few. Around Lake Victoria, the provision of a fridge or freezer to a fishing community can make a huge difference to livelihoods and businesses as fishermen are no longer forced to immediately sell their catch; thereby substantially increasing their incomes. Often, the most profitable businesses are not the most obvious. For example, in rural Kenya, hair salons can be very lucrative.

We believe that there are great gains to be made for operators who start to use the readily available real time usage and system data to responsively stimulate or reduce demand. For example if, during an unusually sunny period, the system recognises that the battery storage becomes full and excess PV generation could be wasted, it could automatically send a text message to the phones of selected heavy users, offering them a discounted electricity for a limited time. Likewise in periods where demand outstrips supply, heavy users could be offered an immediate incentive to shift their usage to a different time. Also, time shiftable appliances such as large refrigerators, could be automatically and briefly switched off in times of high demand. All of this can lead to better asset utilisation and lower costs as peak demand is shaved and overall demand is better matched to supply reducing costly energy storage requirements.

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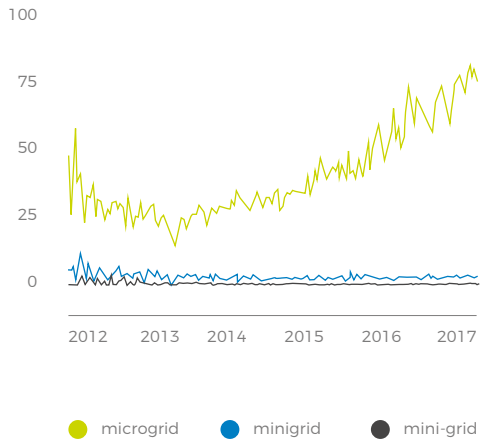
Microgrids or Minigrids?
Google search trends
2012 - 2017



Source: www.trends.google.com/trends

Entesopia: A (Small) Microgrid Case-Study[30]

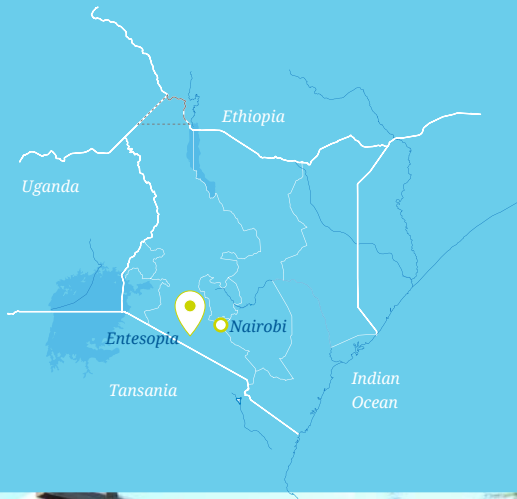
Entesopia is a village near Lake Magadi in the south of Kenya. Nestled against the hills, it has the rare blessing of a good water supply, a huge advantage in an otherwise very dry part of the country. Despite being a bustling place with multiple tribes represented, Entesopia is not supplied by grid electricity. Instead, the community is powered by an 8.5 kW modular solar microgrid, owned by Vulcan Philanthropy and managed by SteamaCo [31]. It supplies more than 60 homes and businesses, including a petrol pump operator, a small cinema and a number of welding shops.

In response to the increasing electricity demand on the site, the microgrid has been upgraded several times, adding power generation and storage capacity as well as distribution hardware. A local site agent handles basic maintenance such as cleaning the solar panels and is the first point of contact for existing and would-be customers.

The average monthly revenue from each microgrid customer at Entesopia is just under $12, with customers paying between $1.80 and $4 per kWh. Heavy users pay less per kWh as discounts are given at higher power consumption. Over time, revenues per customer have increased by around 10% per year. This has corresponded to an even greater increase in electricity consumption.

The annual revenue of the system at Entesopia is around $9,000. The conservative estimation for project payback is 22 years. It should be acknowledged, however, that this site was designed more for impact and speed of installation and less for profitability. It is estimated that by 'right-sizing' the system, the payback period could have been halved. Likewise, installing bigger sites with the right mix of commercial and residential users and offsetting some of the battery storage capacity with a small diesel generator would further reduce the pay-back period.

An appliance leasing program is currently being trialled on site. After a survey was carried out to ascertain which appliances were most in demand, either a television or a fridge was offered to selected customers on credit. Repayments are made monthly via the same mobile payments mechanism customers used to top up their power credit. Results so far are very positive with no defaults to date. Crucially, both revenues from the site and energy usage have increased.



The Power Hub at Entesopia contains all the energy storage and control technology.

RUNNING THE NUMBERS: A MICROGRID BUSINESS CASE

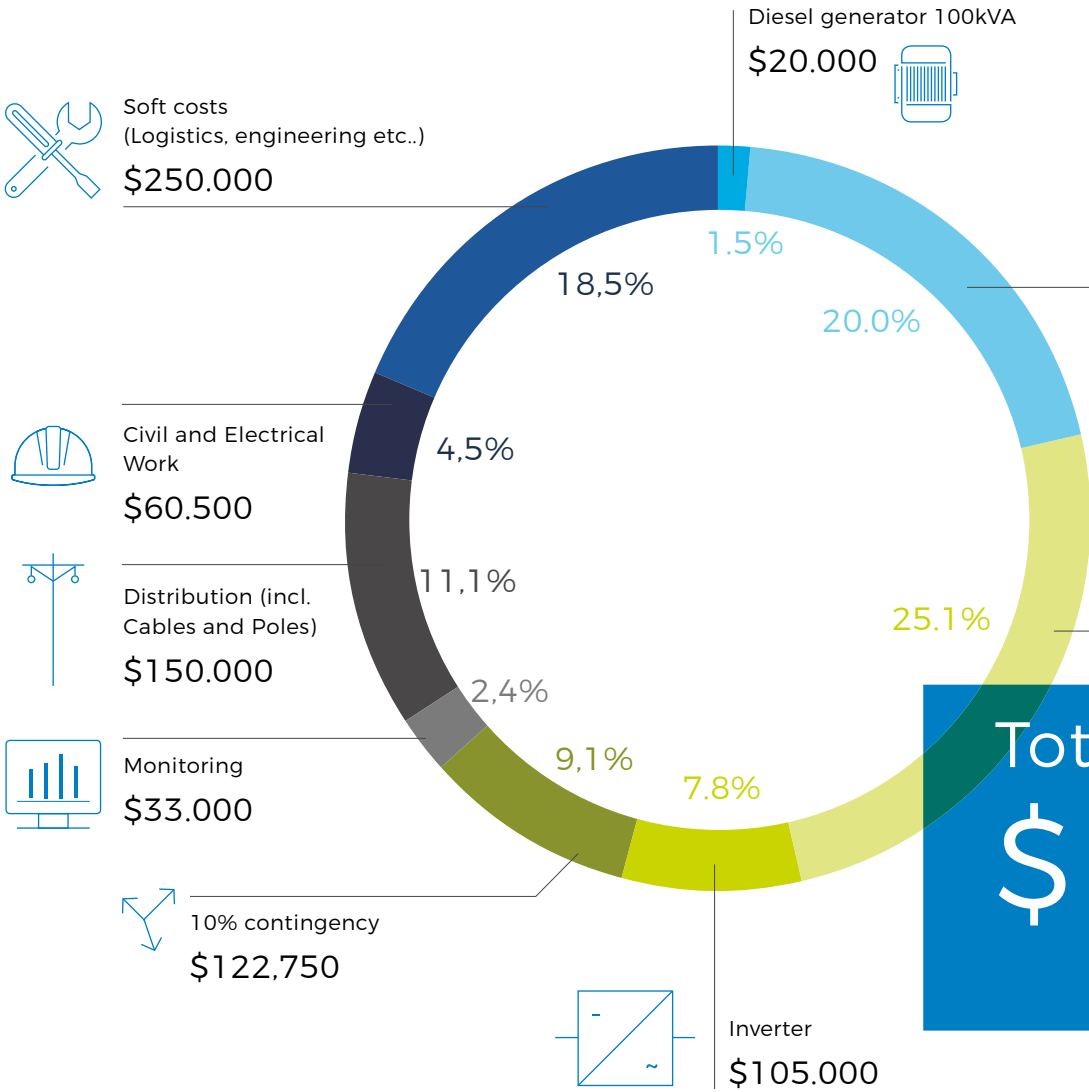
HIGHLIGHTS

1. Microgrids can grow with demand in a modular manner
2. Low connection fees ensure faster growth
3. Commercial, heavy users make the business case work

The example below describes typical, if simplified, financials for a hybrid solar/diesel microgrid microgrid in Kenya. To provide indicative values, we have cross-referenced a number of models and studies. In reality, investment costs can vary widely depending on a variety of factors such as the remoteness and accessibility of the site, availability of materials and labour, the cost and ease of securing land and permits and local perceptions of the services being offered. Costs will also vary according to the standard to which the infrastructure conforms; strict safety and compatibility standards to ensure later grid compatibility, for example, will be more expensive than the infrastructure set up by informal local grid operators. As more microgrid investors, EPCs and operators are making available their actual costs, numbers and sensitivities will become more substantiated. We are strong advocates for sharing best practices and bad experiences. We also suggest industry collaboration for bulk purchasing.

The microgrid model described below is unsubsidised. This suggests that, under the right conditions, there is a valid business case. In our experience, initial customer uptake on microgrids is slow. We have seen that there is a certain amount of suspicion when a microgrid is first installed and people are often unwilling to pay even a very small connection fee. First movers tend to be people who are already familiar with solar technology, often in the form of a solar home system. Once it becomes clear that these first movers are benefitting from the services provided by the microgrid the increase in new customer sign-ups is substantial[32]. An important implication, and one that is not captured by the model above, is that from a financial perspective it makes sense to add capacity to a microgrid incrementally and in response to increased demand. One of the advantages of solar PV based microgrid systems is that generation and storage capacity can be built-up in a modular manner to match growing user connections and demand. While this increases the set-up costs, and as a technician

The example below describes typical, if simplified, financials for a hybrid solar diesel microgrid in Kenya.



Total Capex

$1.350.250

...gives LCOE* of $0.77/kWh

*Levelised cost of energy

Pole-mounted metering boxes on an off-grid microgrid in Tanzania.

is required to visit sites more frequently the economies of scale are reduced, it ensures much better system utilisation, keeping overall costs per kWh low. Building up local expertise can significantly reduce the cost of sending in technicians.

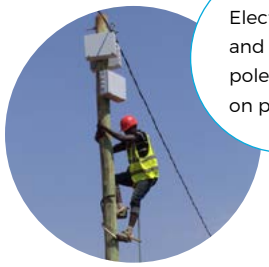
Connection fees in our model are set at $10. This is comparatively low for microgrids. For reference, national grid connection fees in Kenya have historically been $412 (with users often having to pay extra for additional power poles), although more recently this has been reduced by half. In our experience, keeping the connection fee (the "barrier to entry") low is essential to getting the microgrid business up and running quickly. Any losses in connection fee revenue can be easily recouped through higher tariffs. This idea is borne out by Tenenbaum et al [33]. who suggest that once rural microgrid customers get over the connection cost hurdle they can afford to pay electricity tariffs that will produce monthly expenditures equal to or less than their prior (significant) expenditures on non-electricity energy sources such as kerosene or candles.

The model assumes an average customer usage of approximately 1.9 kWh per day. In our experience this is high[34]. Whilst some customers will use this much (and more), many residential customers will use less than 50 Wh per day. This suggests two things: the first is that for a microgrid model to work, there needs to be some heavy (usually commercial) power users in the portfolio. This could be a single anchor load, like a telecom tower or a small industry or shop. Or - to reduce risk - could be a variety of heavy users such as maize mills and welding shops. The second implication is that the microgrid operator stands to benefit through proactive interventions that increase electricity usage across the site. This could be something along the lines of appliance leasing or service based mechanisms.

Running the numbers: A microgrid business case

Expected demand growth:

5% p.a.



Electricity distributed as AC (single- and 3-phase) via overhead wires and poles. Meters are also often mounted on poles.

250 Customers

6km total

Distribution Loss: 10%

Diesel generator
Capacity: 100 kVA
Energy: 15 MWh/year

Lead acid battery
Capacity: 1.18 MWh
Depth of Discharge: 60%

Photovoltaic system
Capacity: 180 kWp
Energy: 320 MWh/year

Power is generated by a solar PV array and supplemented by a diesel generator. Excess electricity is stored in a battery bank. In some cases the system is integrated with the National Grid

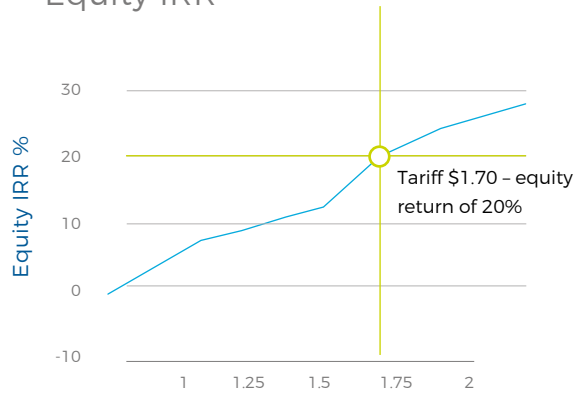
Commercial
Connection Fee: $10
Commercial Tariff: $1.00/kWh
Commercial power use: 65%

SHOP

Residential
Connection Fee: $10
Residential Tariff: $2.50/kWh
Residential power use: 35%

Productive uses such as a shop or maize mill provide better revenues, Resendential users provide necessary diversification of customer type and add to socioeconomic impact

The Effect of Tariffs on Equity IRR

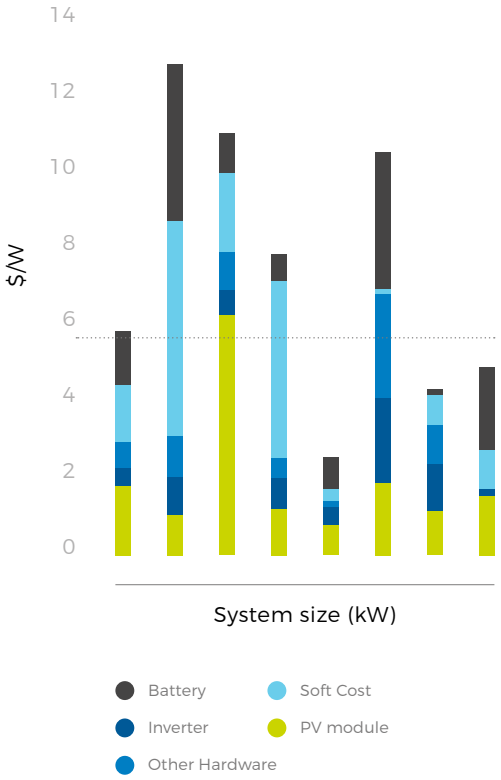


Source: Allotrope Partners "Microgrid Market Analysis

Business Plan

Project/ Equity IRR:	12%/ 16% p.a.
Equity/ Debt:	40%/ 60%
Interest rate:	10% (12 years)

Installed costs of micro-grids by region in $/kW, off-grid (2015)



Source: Microgrid Investment Accelerator

This graph shows how for a microgrid system of a given size with no subsidies (we've used the example above) tariff adjustments affect equity IRR [35]. The weighted tariff takes into account the different rates paid by residential and commercial power users. If the equity IRR expectation is 20%, the tariff would need to be at least $1.70 per kWh. In our experience, this is absolutely feasible. To show how the cost base of a microgrid varies, Allotrope Partners, investment advisors, published data from a range of projects across India, Indonesia and Tanzania. The data from 2015 shows, in particular, the impact of batteries (and storage amount/time) on the installation cost. Off-grid, battery-powered microgrids with a size of up to 120kW had an installation cost of between $2.5 and $12 per W in 2015 [36].

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MARKET VOICES

Sam Slaughter

CEO PowerGen, leading African microgrid developer

What is the biggest challenge facing the uptake of microgrids worldwide?

Slaughter: In a global context, the greatest single barrier is the cost of battery storage. In an African context, the greatest barrier is lack of regulatory clarity around grid interconnection, lack of subsidy parity with the public utilities, and the resulting wariness from project financiers.

What single change - technological, regulatory or otherwise – could really catalyse the industry?

Slaughter: Reforming donor and government behavior so that private utilities get the same subsidies that public utilities already enjoy. This would have a massive positive impact on the African energy system.

Some estimates put the number of completed off-grid microgrid projects in Sub-Saharan Africa at about 150. How do you expect this to increase over the next 5 years?

Slaughter: I guess, as a sector, we'll have more than 1,000 grids installed in Africa in 5 years.

MAKING THE MOST OF TECHNOLOGY

It is the innovative use of technology by microgrid developers that really makes Kenya the laboratory for global rural electrification solutions. The linking of microgrids to mobile money platforms like MPesa has been discussed earlier. But there are many more examples. PowerHive, for instance, uses satellite imagery, and sophisticated automated algorithms to find and characterise potential microgrid sites. Theoretically this concept could be taken as far as optimally designing microgrids based on village patterns and sizes/types of houses.

> The goal is to avoid any costly over-engineering

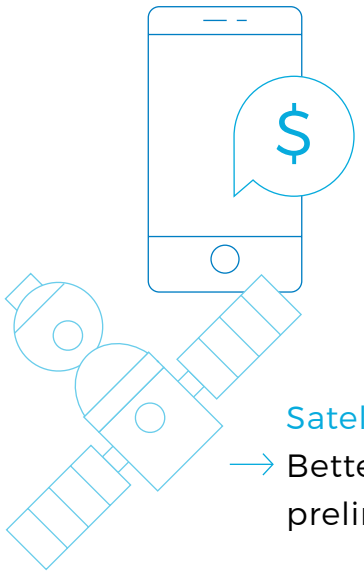
A number of companies have also developed their own metering technology. SteamaCo, for example, offers locally designed smart meters to operate even in areas with very poor connectivity. The technology can transmit and receive simplified data on the most basic mobile communication channels. Emphasis was placed on affordable, robust service provision. This localised design approach could be applied to other areas of microgrid technology, such as inverters. The goal is to avoid costly over-engineering.

Another interesting use of technology promoted by Vulcan Philanthropy is to look at SMS usage data to extrapolate likely electricity consumption. They found that potential customers tend to overestimate their own electricity requirements. Customers who always read their SMSs have an Average Revenue per User (ARPU) that is 2.6 times higher than those who only read them occasionally. Their data strongly supports the idea that a few commercial, high-use customers are critical to operator revenues, with the top 10% having an ARPU five times higher than the local average. They generate 40% of the revenue and consume 50% of the power [37]. The data also suggests, however, that commercial customers are fickle and it is important to hedge against this uncertainty with a steady base of residential users.

HIGHLIGHTS

1. Digital technologies can make the business case much stronger and make leapfrogging from no power to a smart microgrid possible
2. Local adaptation of technologies avoids over-engineering and keeps costs low
3. Rural microgrids need access to better energy storage technology

How digital technologies boost microgrids

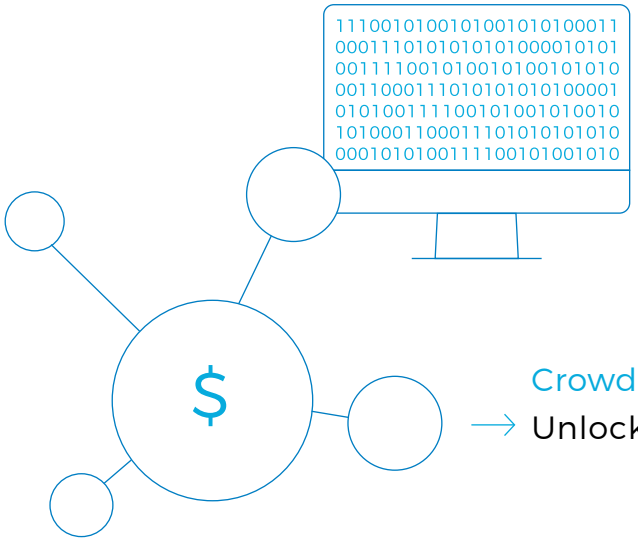


Mobile money
→ Simple and secure cash-less transactions

Satellite imagery and algorithms
→ Better, faster site selection and preliminary grid designs

Smart meters
→ Fewer defaults, user data analysis and smart demand management

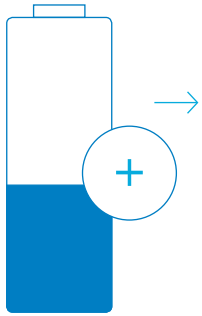
Digital currencies
→ Lower transaction costs and easier international investments



Data analytics
→ Reliable risk profiles and usage projections

Crowdfunding
→ Unlocking new investor groups

Blockchain
→ Easy and cheap peer-to-peer transactions and enabling organic interconnections



Better energy storage
→ Less maintenance, fewer replacements, cleaner technology and reduced project costs

Source: TFE Consulting

There are many other exciting ideas for applying digital technologies to accelerate the spread of microgrids whether that be highly reactive demand management at the site level or providing innovative finance routes at the macro level. The South African company Sun Exchange, for example, organises crowdfunding for microgrids. They offer investors the opportunity to buy individual solar cells in specific microgrid projects[38]. Another example of crowdfunded microgrids comes from the Swedish Trine[39] platform. Making use of digital currencies such as Bitcoin or Ethereum can reduce transaction costs to near zero. They can also help channel international funding into developing markets with cumbersome foreign exchange regulations. (Keeping in mind, however, that their exchange rates are highly volatile.)

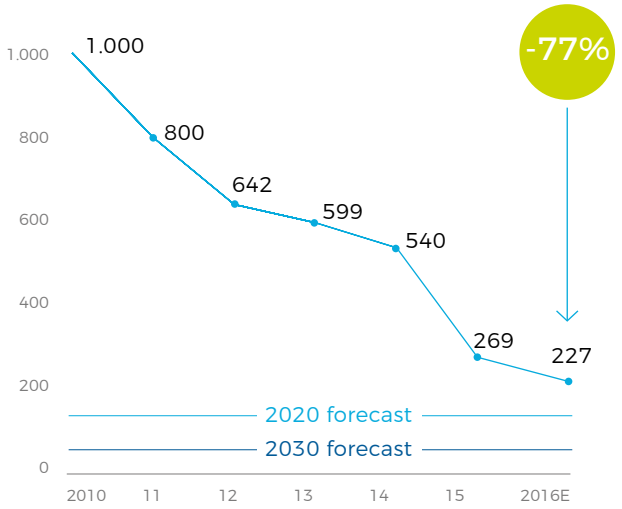
> Microgrid to boost renewable wind energy in remote areas of Northern Kenya
>
> *Tweet by ABBgroupnews*

Blockchain transactions can allow various distributed power generators and consumers to trade power directly from peer to peer, without going through a centralised operator. This could be applicable to community-owned microgrids, to microgrids that absorb existing solar home systems, or to microgrids as they integrate with each other or with the national grid. A global pioneer in this is LO3 Energy who built the platform behind the Brooklyn Microgrid[40]. They now want to apply this model internationally. The South African startup Bankymoon[41] plans to launch a blockchain enabled smart meter. Their prototype technology was showcased with a bitcoin transaction from the US, paying for electricity in a South African school.

The Kenyan-US startup Lendable[42] wants to use big data analytics in order to better assess payment risks from rural customers in Africa to improve the bankability of both the end consumers and the companies serving them. In addition, they want to systematically aggregate and professionalise investment communication in order to make it easier for international, institutional investors to take decisions on businesses serving rural African consumers.

Willis, Ninja and the 700W 'Night Heron' wind turbine they built from scratch.

The falling costs of solar PV modules as well as enabling digital technologies are steadily improving the financial models of microgrid operators. There is, however, a core technology for which innovation is lagging: energy storage, often the largest cost component of a microgrid. Most solar-based, off-grid microgrids rely on energy storage systems to provide power when the sun does not shine. In Kenya, the only widely available storage technology are lead acid batteries. These are not ideal for the remote African setting, where high temperatures and poor maintenance reduce the expected lifetimes of these batteries considerably[43], forcing operators to replace costly battery banks more often than manufacturer documentation suggests. There are a number of new storage technologies maturing and commercialising including flow-batteries and lithium-based cells, which promise considerable improvements over lead acid batteries, but these are not yet readily available in the Kenyan market. Bringing low-cost battery technology could play a transformative role. Globally, the cost curve of new battery technology, driven by the massive global investments into electric mobility, is falling fast.



Source: McKinsey „Electrifying Insights", January 2017, https://goo.gl/K1s3iQ

Smart Feed-in-Tariffs for Off-Grid Power

Feed-in-tariffs, which provide a preferential tariff – above market price – for each unit of renewable electricity generated, have been instrumental in incentivising renewable electricity deployment across the world. However, the feed-in tariff model has so far been restricted to grid connected projects. In addition to preferential tariffs for renewables, many developing countries have preferential tariffs for rural customers - but again, only those who receive grid power in the first place. In India, for example, farmers pay much less than commercial and industrial power consumers and the price of power typically increases with the amount of power consumed. Tariff structures are thus a key political tool in incentivising new generation technologies as well as in supporting the poorer population.

The problem is that often the poorest members of the community, those without any access to electricity, cannot be reached with this tool. Their choice is between expensive energy sources or no energy at all. They end up paying much more than grid-connected, much more affluent consumers for each unit of useful energy, whether it comes from kerosene, biomass, solar products or microgrids.

What if there was an off-grid version of feed-in-tariffs? A system where the provider of an off-grid energy solution could be subsidised according to the actual power consumed and payments made by their end-user? Recent advances in data-based service delivery could make this a reality. In this model, the funder (which could be the government or a donor) would agree to ‚top-up' the pay-as-you-go electricity provider with an agreed amount for every documented dollar paid by a customer. This would strengthen the business case of the provider allowing them to attract investment and lead to a faster roll-out of projects. If the support budget is fixed, the subsidy could be capped at a maximum amount or at a maximum per provider, microgrid or consumer. As microgrid operators in Kenya almost invariably use a third-party payment platform, the data on customer payments for electricity usage could be forwarded directly to the funding entity who would then top-up the provider on a transparent transaction by transaction basis[44].

ENABLING A MARKET FOR MICROGRIDS

ACCELERATING – 1

Kenya's Rural Electrification Agency (REA), which receives a 5% levy charged on all electricity bills, has the mandate to "accelerate the pace of rural electrification in order to promote sustainable socio-economic development"[45]. REA has begun looking into microgrids as part of their Kenya Off-Grid Solar Access Project (K-OSAP)[46], targeting unconnected households in areas identified as being "underserved". The agency wants to achieve this mainly through public sector institutions like the Kenya Power and Lighting Company (KPLC) who have already built a number of microgrids around Kenya. Local microgrid developers, who could arguably achieve the same results faster and at a lower cost, complain that they were not sufficiently consulted and that, as the scheme stands, it might damage the nascent but flourishing private utility sector. The example shows how governments - used to their role as providers of public infrastructure - struggle to take on a new role: that of a market enabler.

A number of internationally supported and funded initiatives promote microgrids and assist the development of the sector in Kenya. The World Bank and the Carbon Initiative for Development are supporting Kenya Power and the Rural Electrification Authority in their Kenya Off Grid Solar Access Project (K-OSAP)[48] targeting specific, underserved regions of Kenya. The World Bank also set up a Global Facility on Mini-Grids in April 2016 and the UN have a Clean Energy Minigrids initiative. The British and French development agencies (DFID and AFD), offer a "Green Mini-grids" £30 million support facility[49] for developers in the East African region. Another important initiative is "Power Africa", which includes microgrids in their "Beyond the Grid" scope of projects to support.[50]

Financial investment from donors and agenda investors is still a major market enabler for microgrids. Yet, there could - and, indeed, should - be much more. According to a recent Power For All report[51] for example, from 2011 to 2014 only 11 percent of World Bank energy access funding and 1 percent of African Development Bank funding went to decentralised renewables, with the majority going to direct central government support or infrastructure improvement projects such as distribution grids.

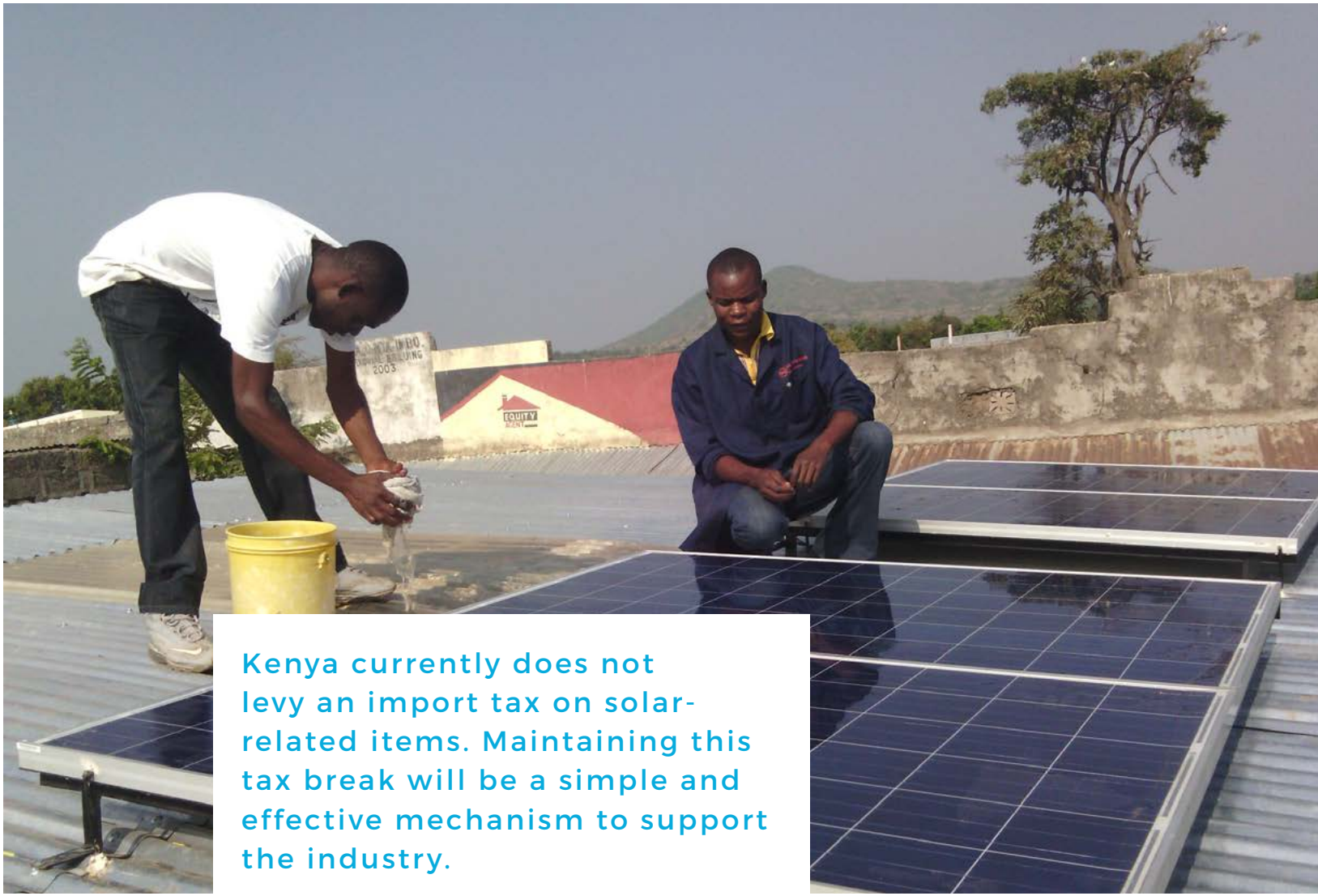
This bias is hard to change, even if it is attempted. The ACP-EU Energy Facility[52], for example, is an European Commission (EC) funding mechanism specifically targeted at improving energy access for the world's poor. According to a report by Practical Action[53], in the first (and at the time of writing the only) phase of the project, most of the funding went to government bodies and less than 25% of the spending went to private initiatives. As such, the report concludes, "the EC has diverged from its stated priority areas".

HIGHLIGHTS

1. Governments and donors are too focused on large energy infrastructure - to the detriment of often smarter distributed solutions
2. There is a skills gap in governments when it comes to enabling markets
3. Bureaucratic hurdles should be kept to a minimum in the emerging microgrid market

The challenge, from the perspective of donors and investors is, that it requires considerably more effort - read: higher transaction costs - to fund multiple small projects (such as microgrids) than to fund fewer large projects (such as grid expansion). In addition, it might be easier or simply more habitual for donor or banking professionals to interact with a handful of government agencies around specific, large, centralised infrastructure measures, than it is to create a new, modern, distributed electricity market place - something, to be fair, few understand how to do. We believe, however, that this institutionalised preference for centralised electrification is at odds with what would best serve the purpose of fast and affordable electrification.

In practical terms, a lot of this boils down to risk reduction and market "nudging". Kenya, for instance, currently does not levy an import tax on solar-related items. Maintaining this tax break will be a simple and effective mechanism to support the industry. It could take this further and lighten the duties on smart meters and distribution equipment.



Kenya currently does not levy an import tax on solar-related items. Maintaining this tax break will be a simple and effective mechanism to support the industry.

Keeping solar panels dust-free is a daily task.

In addition to import rules, governments typically use direct capital subsidies or grants, tax breaks, or preferential loans to support electrification. Perhaps the most important point of leverage is electricity sector regulations. Although Kenya does not forbid the private generation and onward sale of electricity specifically, regulation is still unclear on the legal position of small independent companies who typically operate microgrids. According to the Energy Act of 2006[54], all projects with an installed capacity of more than 3 MW need a license, whereas projects with a smaller installed capacity require only a permit. In practice, most of the smaller microgrid projects do not have such a permit. The bureaucratic complications of getting formal recognition for an independent power project are a common complaint for many local operators. In February 2015, PowerHive East Africa were the first private company to be granted a concession to sell power privately[55]. Its success will likely make it easier for new organisations to apply and also be granted a permit.

In general, all bureaucratic hurdles - including on issues such as quality and safety - should be pragmatic (i.e. strictly need-based), standardised, streamlined and transparent. Excessive regulation will increase the electricity cost for the end user and might even stall the entire emerging microgrid market.

Programmatic licences would help

In an effort to inform the public sector of the alternative energy access approaches available and to address the regulatory challenges of the industry, a nascent industry association of microgrid developers has been set up in East Africa. The African Minigrid Developer Association or AMDA (as yet without a website) is engaging with government agencies to provide suggestions for streamlining regulation procedures for private, independent mini grid operators and sharing best-practice. One suggestion is to grant a compliant company a license to develop multiple sites on a programmatic basis (i.e. in a repeatable manner) rather than having to apply for a license for each site or batch of sites separately as if they are one-off projects.

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MARKET VOICES

Steven Hunt

Senior Energy Innovation Advisor
at Department for International Development (DFID)[47]

What is the biggest challenge facing the uptake of microgrids worldwide?

Hunt: Achieving a public-private settlement between governments/national utilities and mini-grid owners/operators is essential for a market-driven roll-out of mini-grids. Such a settlement would provide regulatory and revenue clarity for the developers, while ensuring appropriate protections and price competition for the consumers and any public rural electrification subsidy.

What are the most exciting new business models you've seen?

Hunt: Models integrating wireless internet connectivity with electricity production are very exciting. They boost the development value and impact, can bundle a range of services and allow for differentiated pricing. I am also interested in the potential of mini-grid auctions as a way to crystallise the public-private settlement mentioned above, creating a platform for competition that will drive down consumer prices and achieve best value for any public co-funding.

Is the market ready for purely commercial investment?

Hunt: This will depend on the scale and security of future revenues compared with the costs. Tariffs are fundamental. Either they must be cost reflective or involve a systematic cross-subsidy, as we see in grid extension. There is a good case to extend existing rural electrification cross-subsidies to mini-grids where these are clearly the most cost effective electrification approach. In the bigger picture, that can still make the business case "commercial", just not on consumer receipts alone. Where there is no clear and reasonable exit condition for mini-grid operators if the grid arrives, investment can only be speculative and high risk (so high cost).

MICROGRIDS VS. »THE GRID«

ACCELERATING – 2

HIGHLIGHTS

1. Waiting for cheaper grid power is not a good reason to hold back microgrid markets
2. Microgrid developers need a clear legal framework for the event of the arrival of the grid to the village in which they operate
3. There are win-win opportunities when connecting a microgrid to the national grid

Another important way in which governments can support the microgrid market is through clearly outlining grid extension plans and providing a clear legal and commercial framework for any future integration of specific microgrid sites with the national grid. This is important, because for many investors in the microgrid space the biggest threat is the national grid expanding and offering cheaper power to the same customers, making the microgrid obsolete. Given that the payback period of a microgrid is typically between 5 and 10 years, this risk is substantial (See box: "Grid Creep" and the chapter "Running the Numbers").

One might argue that consumers should have the right to access the cheapest power available, wherever that may come from and that being left out of grid expansion plans is discriminatory (in fact, grid expansion is a highly politicised subject). This argument, however, does not hold in practice. Such an approach can often leave an off-grid customer without electricity as the grid fails to arrive and the microgrid investor is paralysed by uncertainty. Additionally, even if the grid arrives, it often fails to supply adequate or reliable electricity to households[56].

The biggest issue with the argument rejecting higher-cost microgrid power is that the economics are skewed. The comparison is between an unsubsidised industry (microgrids) and a hugely subsidised one (grid power). In Kenya, private microgrid operators are making a strong push for the government to 'level the playing field'; to extend the significant subsidies enjoyed by the national utility operator to private sector players looking to achieve the same end, namely, that of affordably electrifying rural Kenyans. Private microgrid operators receive none of this public aid. This is inefficient, because in many instances, it would be cheaper, less risky and faster to electrify people using local

microgrid solutions. To level the playing field, a subsidy based on verifiably delivered kWh could be used (See box on page 27: "Smart Feed-in Tariffs for Off-Grid Power")[57]. This would ensure that support is directly linked to impact and that off-grid customers do not have to pay more for electricity than more affluent grid consumers do.

Our experience in Kenya has also shown that rural microgrid users are willing to pay more for their energy services than is commonly believed. This is one of the strongest arguments against the notion of a universal energy tariff which, despite having presumed political merit (particularly at the local level) is neither conducive to increased energy access (as significant subsidies are required to compensate operators for the increased costs of delivering electricity in a rural location), nor fair on rural people eager for the development that access to modern energy services can bring. In our experience people in remote centres need electricity more than they need low tariffs and are willing and able to pay significantly more for a kWh of electricity than their urban counterparts. A key concept here is utility. Microgrid power is cheaper, safer and cleaner than alternative sources of energy like the typical kerosene, candles or dry cell batteries.

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Grid Creep

Grid creep is the unexpected expansion of the national grid into areas where off-grid microgrids are already operating. It is an oft-cited threat to the security of microgrid investment. However, it does not need to be a threat. Microgrid infrastructure and projects can readily be integrated with a national grid to the benefit of both. For example, the microgrid could sell excess power into the national grid, adding a secure revenue stream while diversifying the national grid's generation capacity and improving local reliability. Another is using microgrid infrastructure, with its metering and remote payments functionalities, to provide a bridge finance mechanism to facilitate access to the national grid. If the microgrid company pays for the connection to the Kenya Power and Lighting Company (KPLC), in the case of Kenya, and can sell the power through their own local distribution network (essentially a standard microgrid with the generation component replaced by a metered grid connection), over time they can amortise the original costs of connection. This is beneficial for KPLC as the number of connections increases, especially in poorer areas, the local market is proven, and all downstream customer management is handled by a third party. The slightly greater costs per kWh to the end user can be further justified, by including a battery storage component to the project and thus providing 'better-than-grid' services with energy supply maintained through blackouts.

SUPPORTING ENTREPRENEUR-SHIP

ACCELERATING – 3

HIGHLIGHTS

1. Microfinance and capacity building for business development can accelerate the demand side of electrification
2. Women entrepreneurs, already successful in selling solar products, can boost microgrid businesses

Further areas in which national governments, possibly in cooperation with international donors, can support the microgrid market are capacity building and microfinance. Technical capacity building would help local companies or entrepreneurs with relevant skills and existing reputations or sales channels to set up microgrid operations. Often all this would require is an awareness of or training in the missing pieces of enabling technology such as smart meters and distribution architecture techniques and basic training on how to commercially manage a site remotely.

National grid regulators will need support in understanding the opportunities and implications of a large-roll out of microgrids and their eventual linkage to the national grid. Local banks will need to be able to assess the technology in detail in order to eventually offer non-recourse infrastructure loans.

Linking electrification with microfinance is a key enabler. Finance and electricity together can catalyse the growth of small businesses which are key to development and economic growth. They are mutually reinforcing and thrive on successful businesses that ensure a steady payment stream. This should ideally become a virtuous cycle that helps the power consumer earn more income with increasing energy demand, thus stepping up the 'energy ladder'. As economic activity increases so does the number of opportunities available to young people. This in turn reduces outwards migration.

An interesting further angle is to make the businesses, the microgrids and the microfinance women-centric. Research has shown that investing in women is smart economics and that they are vehicles for sustainable financial returns and deep social change. As the primary users of traditional energy sources, women are

the most impactful stakeholders in a sustainable energy access revolution. They have a deep understanding of the challenges and a strong interest in solutions that improve their own living conditions and those of their families and communities. They also make great entrepreneurs. Studies show that women entrepreneurs in Kenya selling electrification products outsell their male counterparts 3:1 and invest 45% more of their savings back into their businesses[58]. Amongst the most well-known initiatives working on electrification through women, are Frontier Markets[59] in India and Solar Sister[60] in Africa. To expand such activities from selling and maintaining electrification products to building and operating microgrids would require capacity building.

◊◊◊

Peter and Talbot getting a panel ready for installation on the Organic Health Response Clinic roof on Mfangano Island.

INVESTING IN MICROGRIDS

There has been a lot of investment - mostly from US and European impact investors - into businesses catering to an earlier step in the energy ladder, namely selling solar products and solar home systems in Africa. Companies that received investments include d.light, M-Kopa, PEGAfrica, or Burro. The German startup Mobisol has raised over $20m from Investec. British BBox raised a similar amount from the French utility Engie[61]. Off Grid Power, which operates mostly in Tanzania, has recently closed a funding round worth $55m[62]. One of its anchor investors is Ceniarth from San Francisco. In a widely noted article, three Ceniarth executives argued that they view the energy access market more critically now. They consider it oversupplied with venture capital, which creates potentially detrimental incentives for electrification companies and, by extension, their customers. They are concerned that the investment may be "too much, too fast for a sector that still has not fully solved core business issues and may struggle under the high growth expectations of many venture capitalists."[63] According to Bloomberg New Energy Finance, investment in pay-as-you-go solar companies globally has grown from almost zero to $223m by 2016.

From one perspective, growth in investment is indeed very fast. From another perspective, however, the overall amount is still small - especially when compared to the size of the electrification need (keeping in mind that a need is not a market). According to Persistent Energy, another energy access focussed venture capital investor, $200 million will have provided power to around 1.3 million households - a small fraction of the world's unelectrified households. Persistent Energy argues that far from overheating, the energy access market is just getting started and that investors need to work through the challenges together with the growing number of solution providers[64].

The mismatch between actual investment and electrification requirements is much larger still, when we take into account not only the basic energy supply a solar product or a home system can provide, but look further up the energy ladder, at microgrids. However, there is now growing interest from investors in this sector, too. The Microgrid Investment Accelerator (MIA) initiative, backed by a number of mostly US companies and investors, including Facebook, Microsoft, and Allotrope Partners wants to raise $50m between 2018 and 2020 for investment into microgrids in East Africa, India and Indonesia. The goal is to "test the

HIGHLIGHTS

1. The rapid uptake of mobile technology is an encouraging example of market-led rapid transformation in Africa
2. More actual cost and usage data of successful microgrids will help make the investment case
3. The government can strengthen the investment case by creating a level playing field with utilities

commercial opportunity for microgrids and demonstrate how concessionary finance can unlock progressively larger proportions of private capital as risks are discovered, priced, and mitigated."[65] The funds will initially be blended - grants, soft loans and commercial finance. Deutsche Bank's Universal Green Energy Access Fund for Africa targets to reach $300 million in its first phase to fund energy access solutions across Sub-Saharan Africa. In October 2016, the Green Climate Fund has provided a $78.4 million anchor investment into the fund[66].

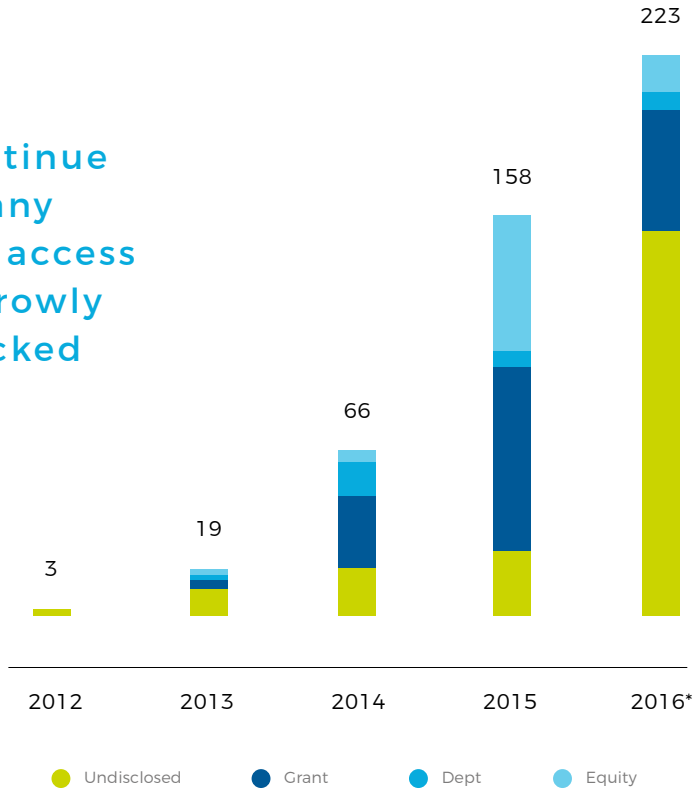
In addition to the venture capital, impact investment and banking scene, the African microgrid market is closely watched by a number of European utilities seeking new business models in new markets and with new technologies. These include Italy's ENEL, Engie from France or E.On from Germany. The French oil company Total is also involved.

> If not clear, we continue to actively fund many areas of broader energy access sector. Critique was narrowly focussed on venture-backed SHS. *Tweet by Ceniarth*

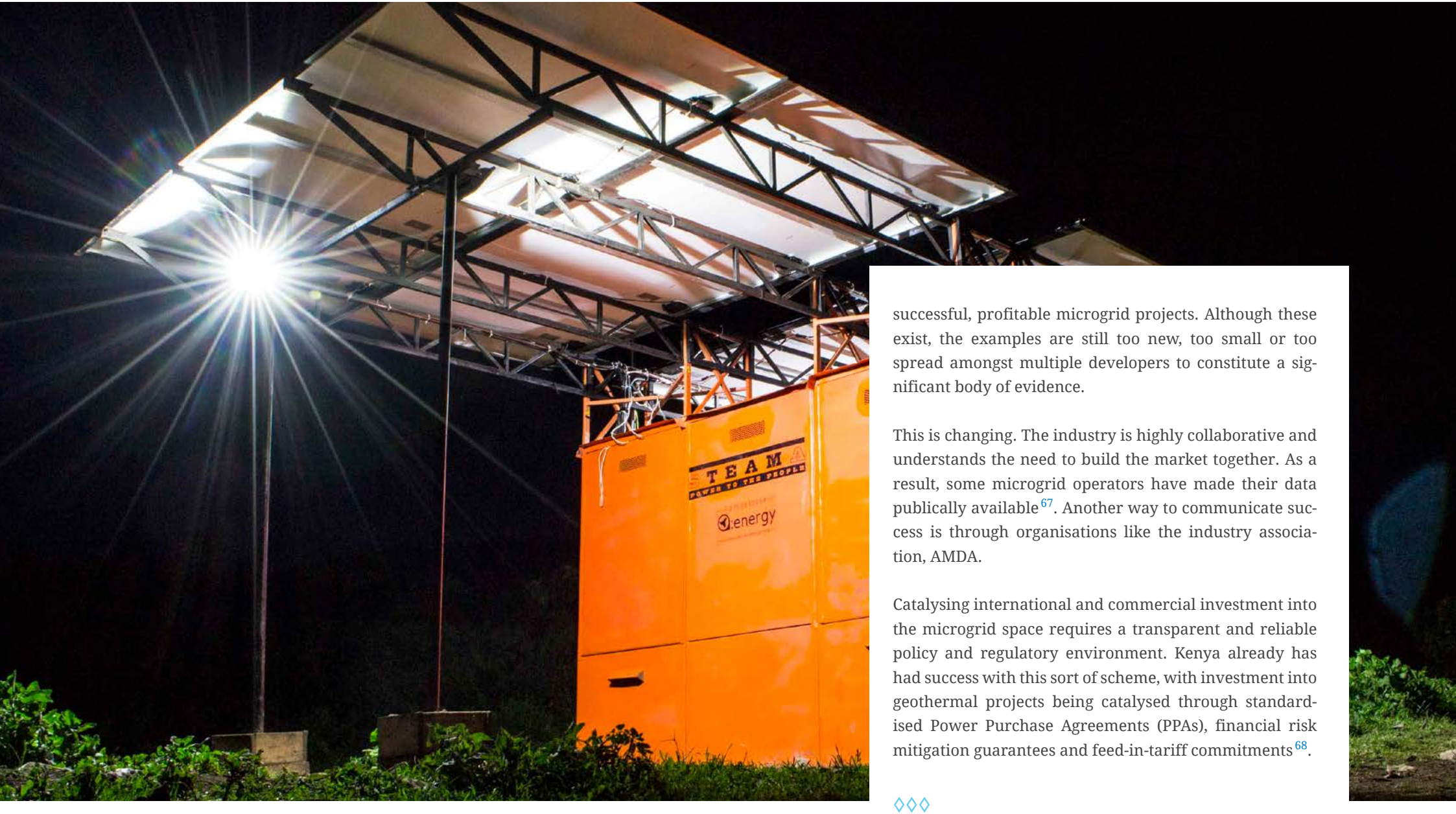
A number of barriers stand in the way of increased investment in microgrids in Kenya and in similar markets. The most important one is market risk. Energy in Africa is considered a frontier market with all the inherent challenges that that implies, including unpredictable politics, currency fluctuations and widespread corruption.

Fortunately, there are previous examples of huge technological successes in frontier markets. The most obvious being that of telecoms companies in Africa. The most central investor question is whether there is enough evidence that microgrid projects are economically viable. Proving this requires case studies of

Investments in pay-as- you-go solar companies ($m)



Source: Bloomberg New Energy Finance



Although security lights such as these on a Power Hub at Olturoto definitely help, bringing tangible value to a community seems to be the best security of all.

successful, profitable microgrid projects. Although these exist, the examples are still too new, too small or too spread amongst multiple developers to constitute a significant body of evidence.

This is changing. The industry is highly collaborative and understands the need to build the market together. As a result, some microgrid operators have made their data publically available[67]. Another way to communicate success is through organisations like the industry association, AMDA.

Catalysing international and commercial investment into the microgrid space requires a transparent and reliable policy and regulatory environment. Kenya already has had success with this sort of scheme, with investment into geothermal projects being catalysed through standardised Power Purchase Agreements (PPAs), financial risk mitigation guarantees and feed-in-tariff commitments[68].

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A NEW ELECTRIFICATION PARADIGM

More than 10 years ago, Kenya published its "Vision 2030" goals that included a commitment to electricity for all by 2030. Early successes, increasing rural electrification rates from 4% in 2003 to 12% in 2010 led the then REA Chief Executive Zachary Ayieko to claim: "At this rate, I'm certain we will meet our targets under Vision 2030[69]." However, research conducted by Innovations for Poverty Action and published in 2016 suggests that the electrification rate for rural households in Kenya today is still at only 5%[70]. In fact, according to Kenya's own National Energy Policy 2015, "going by the current pace at which connections are being erected, achievement of 70 percent and universal access to electricity by 2017 and 2020, respectively, will not be possible without a paradigm shift in the electrification strategy."

Government infrastructure projects tend to be expensive, bureaucratic, political and, importantly, time consuming. The same can be said of large donor energy investment projects into traditional power infrastructure for which, according to World Bank data, the median project duration is nine years.

In our view, the only way that Kenya can hit its ambitious target is to embrace distributed electrification technologies - and especially microgrids. The independent advocacy group for the promotion of decentralised renewable energy (DRE), Power For All, presented data[71] to suggest that DREs can meet basic electrification targets in half the time and at a tenth of the cost of the 'business as usual' approach of traditional centralised power generation and distribution.

Change will remain slow as long as policymakers continue to think of electrification as a top-down, government-driven initia-

> We are on course to improve electricity access rate in Kenya to 70% this year and universal access by 2020.
>
> *Tweet by Charles Keter, Cabinet Secretary, Kenyan Energy and Petroleum Ministry, 18th February 2017*

(⟶ Unfortunately, this optimism is not supported by the data)

tive. Instead, they should view it more as a market opportunity. Their task will then be to enable this market, which is something that they are often unfamiliar with. For microgrids, as for other infrastructure markets, it is not an option to grow "at night"[72], under cover and in spite of the government, as was the case with consumer products such as mobile phones. It will require the government to engage in the right way. That, in turn, will require government learning and a readiness to give up some control over the supply of power, which is, of course, a favourite source of political capital.

The role of private players is to innovate and take risks, the role of government is to reduce systemic risk and give the market breathing room, and the role of the international donor community is to support both and provide start-up and growth funding until the industry can stand firmly on its own feet and commercial investors take over. All these dynamics are currently at play in Kenya and success there will provide a template for other rapidly developing economies.

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Installing a home-made wind turbine at a clinic in Homa Bay county.

APPENDIX

EXAMPLES OF PROGRESSIVE MICROGRID POLICIES

Nigeria

Similar regulatory reform has been announced by the Nigerian Electricity Regulatory Commission (NERC). In a statement on the proposed reform in 2015 they declared that the new regulation was designed "to minimize major risks associated with Mini-Grid investments such as: (1) Sudden tariff changes, as tariffs would have been agreed in advance by the relevant parties; and (2) Stranded Mini-Grid operator investments due to extension of main grid (into mini grid geographical locations). In such cases, a fair compensation mechanism would be applied for Mini-Grid operators that choose to exit."[73] The Deputy General Manager of national electricity regulatory commission (NERC) also suggested that the licensing burden would be drastically reduced and that the geographic exclusivity of distribution companies would be removed.[74]

A sizeable PV array provides power for a large village in southern Tanzania.

Uttar Pradesh (India)

In the Indian state of Uttar Pradesh, with a population of over 200 million, only 37% of households are electrified.[75] This is one of the lowest rates in a country where the average is nearer to 70%. Uncertainty about grid extension plans and timelines meant that investors have considered the region too risky for microgrid investments. To address this risk, the state government enacted a new policy on microgrids in early 2016[76] which provides a 30% subsidy from the state government to renewable energy based microgrid projects—usually solar-powered—with a capacity of up to 500 kW that fulfill specific conditions. For example, the microgrid must provide at least 8 hours of electricity (3 in the morning and 5 in the evening) to any household in the area that is willing to pay. For production and commercial consumers, the microgrid must provide at least 6 hours of stable electricity. Furthermore, the policy specifies that developers can charge Rs 5 ($0.08) per kWh, a price greater than the grid rate of Rs 2-5 ($0.03-0.08). To specifically combat the risk of grid extension for these microgrid developers, the Uttar Pradesh policy provides two clearly defined options: Either, the developer can retain ownership and the distribution company will buy the energy generated at a tariff either agreed upon by mutual consent or determined by the Uttar Pradesh Electricity Regulatory Commission. Or, the project can be transferred to the distribution company at a mutually determined cost based on potential profit lost by the developer.

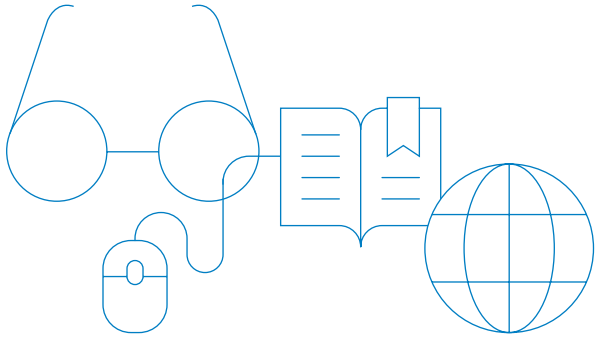
In India, microgrids are an essential part of one of the most aggressive national electrification strategies in the developing world.

Uganda

An excellent example of positive government regulation is Uganda's GET FiT program. In this scheme, special renewable energy feed-in-tariffs provide a premium for the energy supplied by small-scale renewable energy generation projects. This makes it more likely that projects will attract investment and achieve financial self-sustainability rapidly. The scheme also provides access to a Partial Risk Guarantee mechanism supported by the World Bank which would be used to "facilitate the provision of short term liquidity support"[77] to projects that are able to benefit from the special feed-in-tariff. Further, the scheme offers insurance in the case of political uncertainty and mitigates risk associated with early project termination.

READING LIST

SMART ANALYSES WE HAVE DRAWN ON



1

The impact investor Vulcan Philanthropy has built a number of small microgrids in Kenya (like our case study in Entesopia is one). They work together with the remote metering technology company Steama.co to generate data-driven analysis in support of the microgrid investment case. Their first publication (more are planned), "Powering Productivity: Early Insights Into Mini-Grid Operations in Rural Kenya", looks at issues such as choosing the right location, system sizing and demand growth.

→ Kenya-Mini-Grids-White-Paper-VI2.pdf

2

The industry association World Business Council for Sustainable Development (WBCSD) has written a report on "The Business Case for Low Carbon Microgrids", based on the work of the member companies First Solar, Schneider Electric, ABB, EDF and EDP. The report to describes success factors and addresses policy challenges. Their case studies include one on Kenya.

→ Low-Carbon-Microgrid-Report.pdf

3

US environmental activist and author Bill McKibben travelled to Ghana and Tanzania in 2017 to meet the entrepreneurs behind energy access companies such as Black Star and Off-Grid Power. The focus of his article "The Race to Power Solar in Aftrica" in the New Yorker is on solar products and solar home systems rather than microgrids, but there are very relevant broader insights into the customers and the business dynamics

→ The-race-to-solar-power-africa

4

Allotrope Partners, which is part of the Microgrid Investment Accelerator initiative, has published a report in 2017 on microgrid markets and businesses cases from an investment perspective. They looked at India, Indonesia and Tanzania. Their overall assessment is positive.

→ MIA_Market_Report_2017.pdf

5

Persistent Energy publishes regular analysis on the African electrification market. Recent papers included a deeper look at Pay-as-you-go business models, the African market, as well as securitization, financing and business models for distributed energy service businesses.

→ https://www.persistent.energy/

6

In a February 2015 report, "Brighter Africa" the consultancy McKinsey explores how power demand will evolve in the region, along with the associated supply requirements; how much it will cost to supply the needed power, plus the options available to manage the expense; and what is required to ensure that the new capacity gets built.

→ http://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa

7

The Rocky Mountain Institute has made a strong case for why microgrids are in many places in Africa the lowest cost option for electrification - especially after a further cost reduction, which they consider very likely. The report looks in depth at Senegal, Uganda, Kenya and Tanzania.

→ https://rmi.org/insights/reports/energy-within-reach/

8

Power for All is a global campaign to accelerate the deployment of distributed/decentralised renewable energy (DRE). They continue to publish excellent reports making the case for DRE technologies and their ability to meet the needs of the rural un-electrified, faster and more cost effectively than traditional approaches.

→ http://www.powerforall.org/reports

It is not uncommon for a flood lit Power Hub to become a gathering point after dark, providing an opportunity for children to study and improving local security.

IMPRINT

Authors

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Sam is an influential technology developer and Africa expert with many years consulting and publishing in clean-tech and robotics. Six years ago, Sam co-founded the Ashden Gold Award winning SteamaCo Ltd in Kenya, which provides the tools required to build and manage financially viable power grids in remote areas of emerging countries. Sam has worked across the spectrum of renewable energy resarch in academia, consulting firms and start-ups in the developing world.
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In 2016, he founded TFE Consulting to provide consulting services on industries that are undergoing rapid transformation.
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ABOUT TFE CONSULTING

TFE Consulting is a strategy consulting firm focusing on accelerating the clean energy transition in emerging markets. Headquartered in Munich, with additional teams in India and South Africa, we support clients to navigate the rapidly changing energy landscape in developing countries. Our strength is in our analytical and financial models, first hand project development experience and deep understanding of the interplay of government and markets. We utilize this to provide market assessment, risk analysis, business model adaptation and policy advisory to our clients.
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END NOTES

1. For the purposes of this report we have used the term 'microgrids'. It is synonymous with 'mini-grids'.
2. Source: World Bank, https://goo.gl/T9RC71
3. Source: World Bank, https://goo.gl/z9htSn
4. Sources: Vodafone, https://goo.gl/6KfbD5; Safaricom, https://goo.gl/8hywBW
5. Source: Central Bank of Kenya, see this infographic with data up until early 2014 https://goo.gl/QfiaPo
6. For details, see the MPesa website: https://goo.gl/Cs8hbt; The Center for Public Impact wrote a case study in March 2016, https://goo.gl/BgoJkx
7. Source: International Energy Agency: World Energy Outlook 2016, http://goo.gl/xybBf6
8. Source: Communications Authority of Kenya: Quarterly Sector Statistics Report, http://goo.gl/1Qd1Py
9. In Kenya, the costs of connecting a property to the national grid are often borne by the household. This includes the costs of any necessary distribution infrastructure such as transformers or power poles. Connection costs are around $1,000, well out of reach of the average household. This has been reduced in some cases through various energy access programs, but connection costs still remain prohibitively high.
10. Bill McKibben: "The Race to Solar-Power Africa", The New Yorker, June 26th 2017: https://goo.gl/mFdWmf
11. Based on market conversations with developers, investors and lenders. For a good classification of microgrids by sizes and their different regulatory requirements read Steven Hunt's blog piece "Mini-Grids: Towards a Scalable Model": https://goo.gl/kNsbSe
12. Source: Rocky Mountain Institute, https://goo.gl/oeGnL5
13. Source: Ministry of New and Renewable Energy, https://goo.gl/yBUPM5
14. Source: Rural Electrification Authority - Kenya, https://goo.gl/5fqGtr
15. Based on market conversations with leading microgrid developers; including energy generation and storage, distribution and metering.
16. Data from Solar Energy Foundation. Source: Sun Connect News, https://goo.gl/5xLgcU
17. International Energy Agency: World Energy Outlook 2016
18. Based on market conversations with leading microgrid developers; including energy generation and storage, distribution and metering.
19. By comparison, the African Development Bank estimates the cost of achieving universal electrification by 2025 at $60bn per year. Source: https://goo.gl/Pdr7m6
20. Source: SE4All, https://goo.gl/DrnQdA
21. Aklin, Bayer, et. al., Science Advances: "Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India", May 2017 https://goo.gl/ROrmUu
22. Source: Vulcan Impact Investing, https://goo.gl/PsvG3c
23. The issues of site selection, right-sizing, and profit maximisation for microgrids in Kenya are discussed in some detail in the report "Powering Productivity" by Vulcan Impact Investing: https://goo.gl/PsvG3c
24. See more at: https://goo.gl/rGGivG
25. See more at: www.Steama.co
26. See more at: www.rvesol.com
27. Source: Reuters: "India's first solar satellite televsion service brings "magic" to the villages, https://goo.gl/gJTn9c
28. With suitable training, access to the internet would also open up a potential new revenue stream for end users of power by unlocking access to the online market for simple outsourced jobs offered through sites like Amazon's Mechanical Turk or Fiverr. This work is available year-round and would provide a hedge against the uncertainties of seasonality: reduced fish populations or failed crop harvests for example.
29. Source: Rocky Mountain Institute, https://goo.gl/6RcLpz
30. For further case studies of larger microgrids in Kenya and elsewhere, see the report "Business Case for Low Carbon Microgrids" by WBCSD from 2017: https://goo.gl/n7hfqS
31. Note: the system is comparatively small, both in aggregate as well as per customer.
32. Across the Vulcan portfolio of sites in Kenya for example, demand grew 16% in the first year and 25% in years 2 and 3.
33. Tenenbaum et. al. "From the Bottom Up: How Small Power Producers and Mini Grids Can Deliver Electrification and Renewable Energy in Africa" 2014 https://goo.gl/byFGkz
34. Another way of looking at this is that with the same generation capacity, more customers could be connected to the same system than this model suggests.
35. Internal Rate of Return
36. Source: Allotrope Partners "Microgrid Market Analysis and Investment Opportunities in India, Indonesia and Tanzania"; https://goo.gl/W1H4Tc

37. See more at: www.minigrids.vulcan.com/#intro
38. See more at: www.thesunexchange.com/about-us
39. See more at: www.jointrine.com
40. See more at: www.brooklynmicrogrid.com
41. See more at: www.bankymoon.co.za
42. See more at: http://lendablemarketplace.com/
43. A lead acid battery is designed to give optimal performance at 20˚C. At 40˚C lifetimes can be reduced by 40%.
44. See more at: https://goo.gl/cKGNdx
45. Source: REA, https://goo.gl/c3PLD2
46. Source: KPLC, https://goo.gl/iCXWGF
47. Source: KPLC, https://goo.gl/iCXWGF Steven Hunt also writes a blog on his experience with electrification: https://medium.com/@stevenahunt
48. The aim of the K-OSAP project is to target 14 out of the 47 counties in Kenya that have been defined as marginalized by the Commission on Revenue Allocation (CRA). Communities in these areas will be provided with modern electricity services using solar as the primary generation source. The World Bank is supporting K-OSAP with $150 million. See more at: https://goo.gl/6zZwP5
49. Source: DFID, https://goo.gl/FK1QXY
50. "Beyond the Grid has partnered with over 40 investors and practitioners that have committed to invest over $1 billion into off-grid and small-scale solutions to this market. These private sector commitments will be significant in helping Power Africa achieve its target of 60 million new connections for households and businesses." See more at: https://goo.gl/ivzZiH
51. Source: www.powerforall.org/reports/
52. "The ACP-EU Energy Facility (EF) was established in 2005 to co-finance projects on increasing access to modern and sustainable energy services for the poor in African, Caribbean and Pacific (ACP) countries, especially in rural and peri-urban areas." See more at: http://energyfacilitymonitoring.eu/
53. Source: Practical Action, https://goo.gl/cXXfS1
54. Source: Energy Act, https://goo.gl/e4c3CX
55. Source: PowerHive https://goo.gl/wGiduC
56. This can be seen in India, where a large number of villages has been "officially" connected to the grid. In reality, however, last mile connection to households is often missing and the power supply is highly erratic. Utilities often lose money for every kWh sold to a rural customer due to high grid losses and due to very low tariffs. Undersupply is often intentional.
57. Kenyan government officials often mention the justice of a universal or unified tariff. It means that people in rural or urban areas should pay the same amount for their power and not be penalised for living away from infrastructure. In a 'mini-grid policy toolkit' for Kenya, several organisations including the Africa-EU Renewable Energy Cooperation Program, suggest that such a unified tariff would require a subsidy.
58. Understanding Impacts of Women's Engagement in the Improved Cookstove Value Chain in Kenya, Global Alliance for Clean Cookstoves Research Report, May 2015; Savings Constraints and Microenterprise Development: Evidence from a Field Experiment in Kenya, American Economic Journal, January 2013.
59. See more at: www.frontiermkts.com
60. See more at: www.solarsister.org
61. Source: https://goo.gl/KzBzxX
62. See: Bill McKibben "The Race to Solar-Power Africa", The New Yorker, June 27th 2017 https://goo.gl/iPGQP3
63. See: "An Impact Investor Urges Caution on the Energy Access Hype Cycle" https://goo.gl/nwxDaj; A similar hype cycle, busting ultimately at the expense of the poor, has been witnessed in the microfinance market around 10 years ago. As microfinance companies raised ever more investment, they found themselves struggling to keep up the pace with sustainable business structures. Instead, many chose to concentrate on the most easily accessible customers (in the least remote locations), who suddenly went from unbanked to overbanked, repaying one company's microcredit with another company's, much like some people might use one credit card to pay off another credit card debt. At the end, many poor were stuck with stifling debts.
64. Source: Next Billion, "Hype in the Energy Access Sector (Finally!)", https://goo.gl/uK1H4R
65. Source: Microgrid Investment Accelerator, Press Release, April 3 2017: https://goo.gl/p6PRS1
66. Source: Deutsche Bank Press Release, October 17 2016: https://goo.gl/Zjo8xf
67. Source: Vulcan Impact Investing, https://goo.gl/PsvG3c
68. Source: Climate Policy Initiative, https://goo.gl/WakxsQ
69. Source: https://goo.gl/8VxTGS
70. Source: https://goo.gl/gzQpXu
71. Source: Power for All, www.powerforall.org/reports/
72. See: Gurcharan Das: "India grows at night" (Penguin, 2012)
73. Source: https://goo.gl/B5YkhU
74. Source: Solarplaza, https://goo.gl/JT5cM4
75. Source: Uttar Pradesh Village Electrification Program, https://goo.gl/ojFhXw
76. The policy document can be found here: https://goo.gl/YxyVKk
77. Source: GET FiT, https://goo.gl/EsdfSN

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