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Digitalization for Energy Access in Sub-Saharan Africa : Challenges, Opportunities and Potential Business Models

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Digitalization for Energy Access in Sub-Saharan Africa : Challenges, Opportunities and Potential Business Models

By Davide Mazzoni, Fondazione Eni Enrico Mattei

Summary

Innovative business models supported by digital technologies, together with the widening connectivity and data collection, are already giving a big contribution in fostering the access to electricity and clean cooking in Sub-Saharan Africa.
This paper gives an overview on the actual state of energy access in Sub-Saharan Africa and the current technologies used to provide it, followed by a description of the key trends and drivers of the ongoing African digital transformation. A deep analysis of the Pay-as-you-go business model in the off-grid solar sector will shed light on how this transformation started some years ago and the way it is affecting society in many ways.
Strengths and opportunities — as well as weaknesses and risks of the model — are provided through a screening of the most representative business experiences in East and West Africa, financial aspects and market analysis. The perspective of both companies and end-users have been considered here.
The last section gives recommendations to policy-makers on how to ride the wave of digitalization to foster the access to clean and reliable energy, by acting on the electrification planning, regulations, business environment, distribution channels and mobile money environment.

Keywords: Energy Access, Digitalization, PAYGO, Business Models, Africa, Digital Transformation

JEL Classification: O13, O33, O55, M13, Q40, Q48

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Introduction

Innovation in the area of digital technology may be a real game changer, as suggested by a number of success stories in Sub-Saharan Africa (SSA), within the energy access sector and beyond. The fast-growing development of electronic devices and software that collects, stores, transfers, and analyses, digital data, showed in recent years a big opportunity in fostering the universal access to clean and reliable energy. Digitalization commonly refers to improving, enabling or transforming business models/processes thanks to digital technologies and digital data, generating new types of value.

Advance in the field of digital technology - and the declining cost of enabling equipment – is leading to the digitalization of many sectors of the economy and affects society in many ways, including by disrupting traditional business models and governance structures. While in some cases digital innovation is purposely sought by policymakers, it may also come quite as a surprise. The "mobile revolution" is often cited as the prime example of technological leapfrog in Africa: the success of mobile phones and mobile connectivity has been so fast that it has effectively overcome the need for landlines. One of its consequences was the creation of "mobile money services" as a bottom-up remedy to the widespread lacking access to banking and financial services.

The first chapter of this working paper will investigate the current status of the energy access in Sub-Saharan Africa, as well as the differences between the available technological solutions (grid connection, mini-grids, solar home systems). It will then analyse the way digital technologies changed in the last decade by explaining which are the innovation drivers that led to revolutionary business models.

In the second chapter the author will give an exhaustive understanding of the pay-as-you-go (PAYG) business model, from its rise in the off-grid solar sector to future applications. It will include a review of market success stories in Western and Eastern Africa with a particular focus on – but not limited to - the solar home systems (SHS) integrated with emerging digital technologies, as this one is the most mature and fast-growing market.

As this solution has shown to be one of the most promising, the third chapter is completely dedicated to the analysis of its strengths and opportunities of PAYG off-grid solar businesses, as well as the identified drawbacks and future risks; both the end-users' and businesses' point of view will be taken into consideration.

Finally, the last section will bring policy recommendations along with the author's conclusions.

The goal of this paper is to lay the groundwork to develop in the future a set of policy recommendations tailor-made for individual African countries, in order to take advantage of opportunities and avoid possible risks of emerging PAYG businesses in the off-grid sector.

1 Digital transformation of energy access solutions

1.1 Status of the energy access in Sub-Saharan Africa

In Sub-Saharan Africa (SSA), electrification is proceeding at a slower pace than in other world's regions. SSA electrification rate has increased from 23% to 43% between 2000 and 2017 (IEA, 2018), but in absolute terms the number of people lacking access to electricity has actually increased –as demographic growth outpaced electrification efforts. To date, 602 million people still lack access to modern electricity in SSA, roughly 80 million more than in 2000. Should this trend continue in the future, reaching universal energy access by 2030 – as mandated by the United Nations' Sustainable Development Goal (SDG) 7 will simply be impossible. Governments have been implementing national electrification strategies which were really successful only in Ghana, South Africa and – in recent years – in East Africa; poor financial support, weak governance and tentative actions produced weak outcomes in most of the other countries (Bhattacharyya, 2012). Considerable improvements were carried out in 2013, when the total number of people without access decreased for the first time since 2000; however, in 2017 it started rising again driven by the population growth (Figure 1).

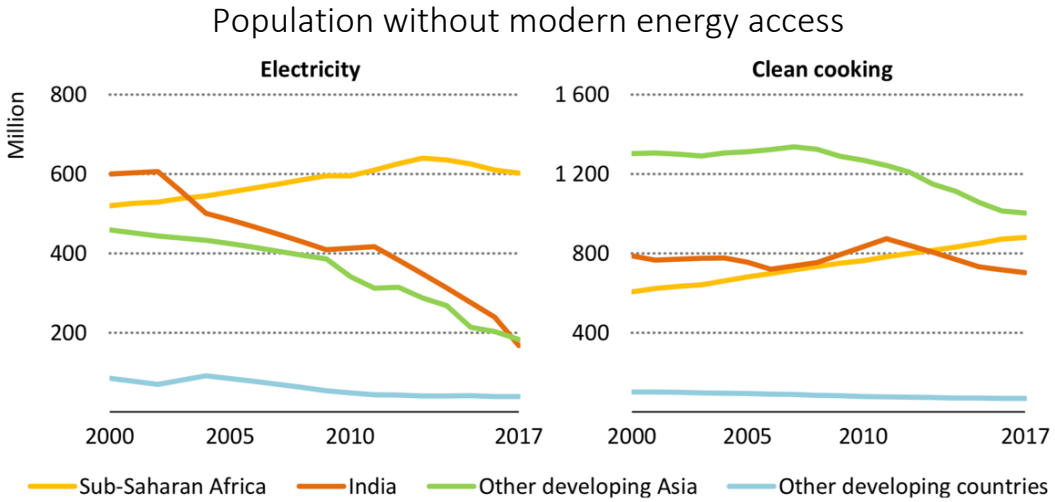


Figure 1: Population without modern energy access - Source: International Energy Agency (2018).

One-third of the SSA's population with no access to electricity is concentrated in Nigeria, the Democratic Republic of Congo and Ethiopia (Figure 2, right) and the first two show an increasing trend with 4,3 million additional people with no electricity access over the last year.

The advancement is particularly uneven across the region: more than half of people electrified from 2011 are concentrated Kenya, Ethiopia, Tanzania and Nigeria, while in some countries the percentage of the population with access has even decreased, due to the high demographic growth. Among the countries that have considerably improved their electricity access rate in the 2010s (Figure 2), Kenya is by far the most virtuous, having jumped from 18% to 65% in 7 years; it is followed by Rwanda, Ghana, and Congo. On the other hand, in Zimbabwe, Guinea-Bissau and Guinea the energy access expansion cannot keep pace with the population growth, and the national electricity access rate diminished in the last year rather than rising as expected.

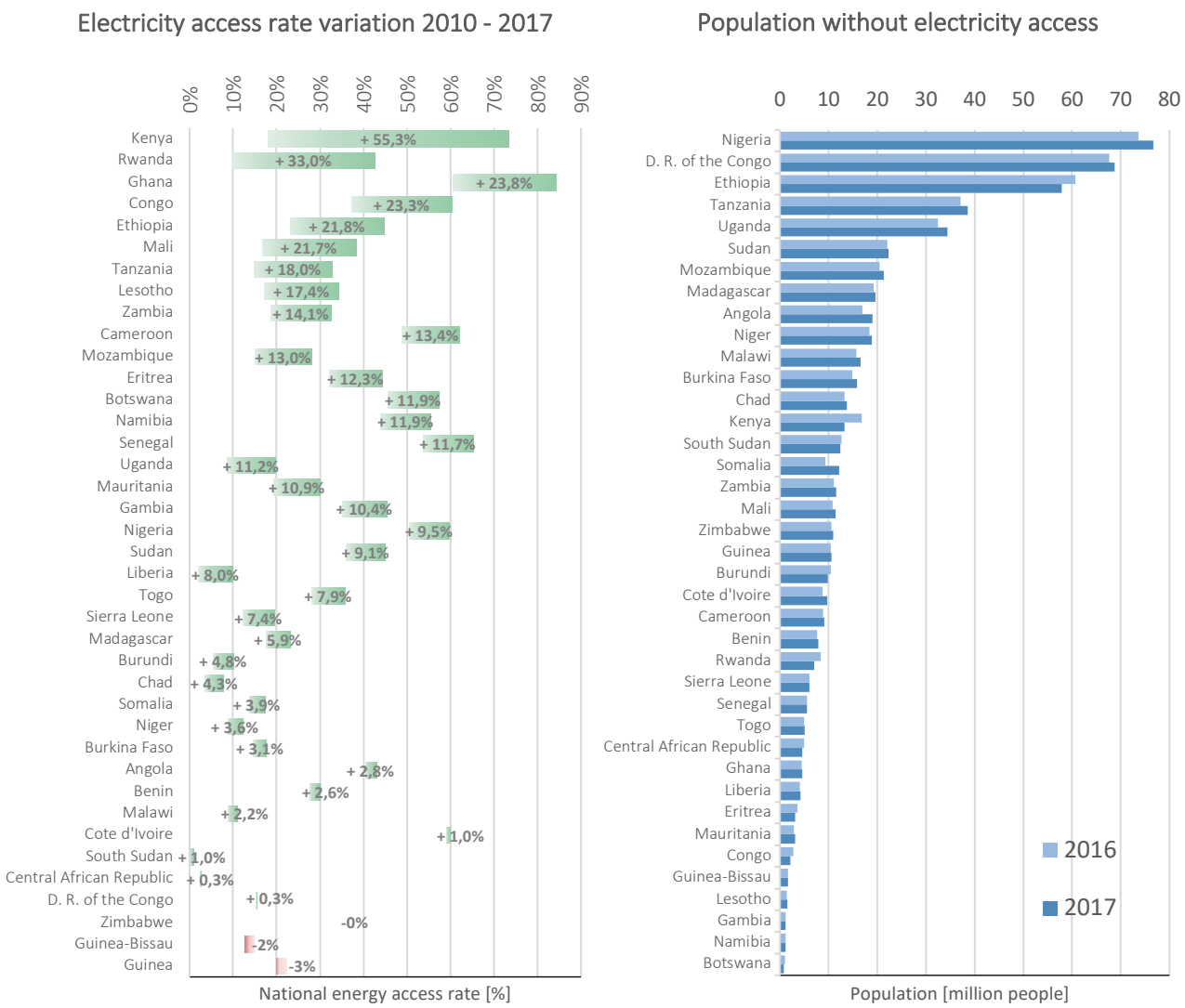


Figure 2: (Left)Improvements in the national electricity access rate between 2010 and 2017. Numbers inside the bars represent the percentage points gained over the period - Data source: International Energy Agency (2018)
(Right)Population without electricity access in Sub-Saharan Africa in 2016 and 2017. Countries with <1 million people are not reported - Data source: International Energy Agency (2018)

In addition, most of the electrification interventions concern urban areas because of the higher cost of bringing electricity to rural areas. Furthermore, urban households are most likely willing to pay for it due to the higher income. The result is that in many countries less than 1% of the rural population has basic access to electricity (i.e. South Sudan, D. R. of the Congo, Chad, Central African Republic, Guinea, Niger, Mauritania, Burkina Faso), and in very few nations it exceeds 20%.
Defining energy access makes sense only if we also provide information about the level of access obtained, which depends on the: i) type of appliances able to run, ii) availability of service, iii) reliability, iv) quality, v) affordability, vi) legality, and vii) safety.
According to the definition of electricity access provided by the International Energy Agency (IEA), an average household is considered to have gained access to electricity when obtaining "access to sufficient electricity to power a basic bundle of energy services – at a minimum, several light bulbs, task lighting (such as a flashlight), phone charging and a radio – with the level of service capable of growing over time".

1.2 Available technology options to provide access to electricity

Before introducing the technology solutions, it is necessary to gain an understanding on what energy access means in terms of minimum requirements. This paper will refer to different levels of energy access on the basis of the World Bank's Multi-tier framework (MTF) for access to household electricity supply (see **Error! Reference source not found.**). The International Energy Agency notes t hat a minimum Tier 2 is necessary for households to be properly considered as electrified.

Table 1: Multi-tier framework (MTF) for access to household electricity supply. The minimum power and energy ratings are indicative – particularly for Tier 1 and Tier 2 – as the efficiency of end-user appliances is critical to determining the real level of capacity required to provide a certain service. - Source: (ESMAP. World Bank, 2015)

Attribute	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Minimum power*	3 W	50 W	200 W	800 W	2 kW
Minimum daily energy consumption*	12 Wh	200 Wh	1 kWh	3.4 kWh	8.2 kWh
Minimum services	Task lighting, phone charging, radio	Previous plus general lighting, air circulation, television	Previous plus food processing, washing machine	Previous plus refrigerator, iron	Previous plus air conditioner
Minimum duration	4 h/day 1 h/evening	4 h/day 2 h/evening	8 h/day 3 h/evening	16 h/day 4 h/evening	23 h/day 4 h/evening
Reliability	-	-	-	Max 14 disruptions/week	Max 3 disruptions/week of total duration <2h
Quality				Voltage fluctuation are safe for the appliances	
Affordability			Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
Legality				Bills are legally paid to the utility, prepaid card seller or authorized representative	
Health and safety				No past accidents and no perception of high risk in the future	

* With standard appliances. Super-efficient appliances provide higher services with lower

As illustrated in Figure 3, the most cost-effective solution depends on a mix of several factors, such as population's income levels, distances from the main grid, sizes and density of population clusters, complexities of terrains.

Grid connection provides the highest Tier of electricity supply being the cheapest answer if there is a distribution network nearby, but its cost escalates exponentially with distances and challenging grid extension through difficult topographies. In fact, the upfront cost for the connection of new users can range from $266 to $2,100 per household, which brings the levelized cost of electricity up to $1/kWh

for low energy consumers (Climatescope, 2018a); For low demands, mini-grids or Solar Home Systems are generally more cost-effective.

Mini and **micro-grids** are powered by a mix of renewable energy sources, diesel generators as a backup system and/or energy storage. In recent years there has been a large uptake in rural regions driven by the falling cost of solar PV technology and batteries. Nevertheless, the cost is still too high in rural areas, primarily because of the sparse and hard-to-reach population.

In this case, **solar home systems (SHS)** are the most suitable way to satisfy the basic energy needs, especially when used with super-efficient appliances. In fact, many companies in the market use a service delivery approach ensuring the energy service rather than selling a generation unit. In order to do this, they provide for a solar kit able to give the same service requiring less power capacity and less amount of energy. Therefore, SHS should not be compared with other technologies only by evaluating the cost of delivered energy ($/kWh), but rather the level and the quality of the energy provision. Alternatively, it is possible to use a modified cost of delivered energy which considers the lesser energy required (Figure 4). “East Africa will become one of the largest markets for solar home systems, with total capital spend exceeding that on grid extensions. Microgrids are expected to play a larger role in Western Africa, where some governments are developing ambitious roll-out plans” (Climatescope, 2018a).

Pico-solar products are small solar-powered devices (<10 W) able to supply a few light points and charge a mobile phone. Since the energy service level they provide lies below the minimum requirements established by the IEA in order to be properly considered energy access, they will not be discussed in this study. Nevertheless, they have a big positive impact on the poorest households, whose quality of life can be significantly improved by basic lighting services. Their affordability was a key factor in the successful diffusion across entire Sub-Saharan Africa.

Electricity access technology solutions

Grid Connection

-**Power range**: >1kW

-Very high **cost of** delivered **energy** in remote and sparsely populated areas (requires grid extension). Low running cost in urban areas.

-High **geographic barrier**: requires T&D infrastructure. Requires high density of population.

-High **political barrier**: depends on governmental policies and electrification strategies.

-Level of access enabled:

Tier 4 - 5, depending on grid reliability

Off-grid (decentralized) energy systems

Hybrid micro- and mini-grids

-**Power range**: 500W-10MW. Generation unit: variable mix of renewables, diesel generator and energy storage

-Medium to high **cost of** delivered **energy. PAYG** is sometimes used to improve affordability

-Medium **geographic barrier**: requires a certain density of population

-Medium **political barrier**: Requires community support and local political endorsement

-**Level of access** enabled: Tier 1-4

Stand-alone

Stand-alone diesel generator

-**Power range**: >1kW

-High **cost of** delivered **energy** (low capital cost but high running cost)

-Low **geographic barrier**

-Low **political barrier**: it is often considered the most viable and quick solution

-**Level of access enabled:** extremely variable, depending on usage and fuel availability

Stand-alone solar PV

-**Power range**: 250W-10kW. Energy storage / diesel backup is required

Medium to high **cost of** delivered **energy.** Lower cost for a single, large electricity consumer

-Low **geographic barrier**

-Medium **political barrier**

-**Level of access enabled**: Tier 2-5

Solar Home System

-**Power range**: 10 W-1 kW

-High unit **cost of delivered energy**($/kWh) , but its cost includes super-efficient appliances

-Low **cost** if considering the wider spectrum of "energy services" at lower capacities ($/service provided**)**

-**PAYG** very common

-Low **geographic barrier**: efficient distribution network, even in remote areas

-Medium **political barrier**: government and institutions can hamper or promote market, depending on policies

-**Level of access enabled**: Tier 1 - 2

Pico-solar system

-**Power range**:1-10 W

-Very high unit cost of delivered energy($/kWh) , but the cost includes super-efficient appliances. Low **cost** if considering the wider spectrum of "energy services" at lower capacities ($/service provided**)**

-**PAYG** used sometimes

-High **geographic barrier**: efficient distribution network, even in remote areas

-Medium **political barrier**: government and institutions can hamper or promote market, depending on policies

-**Level of access enabled**: Tier 1

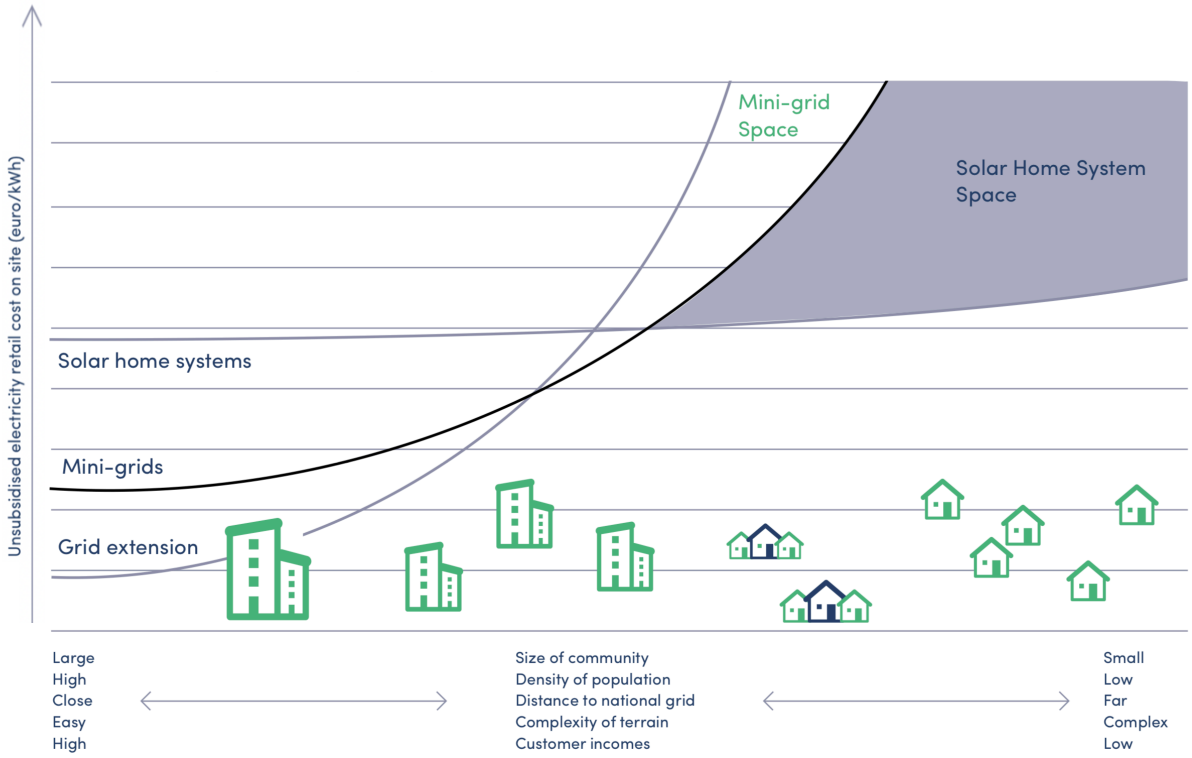
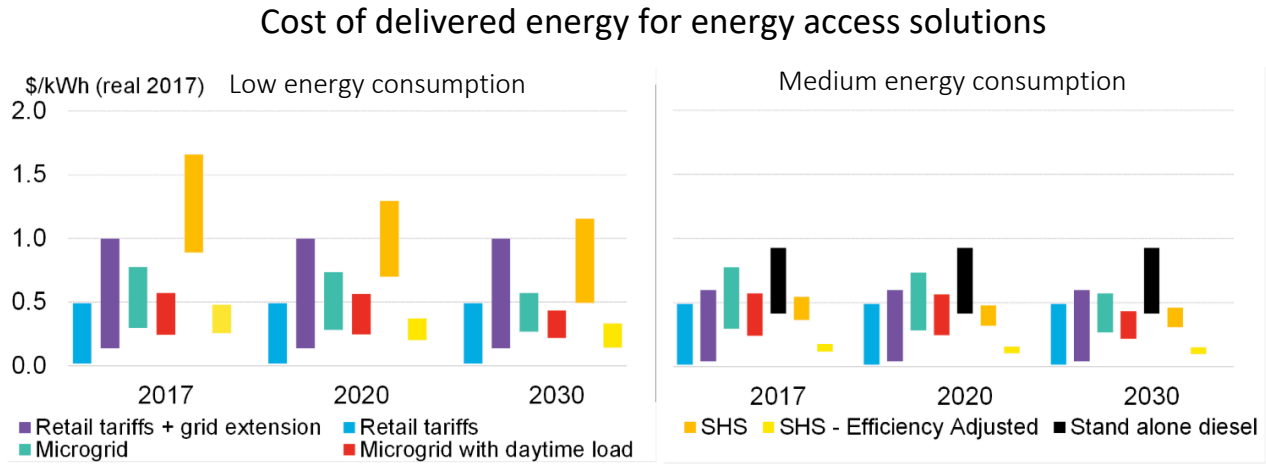


Figure 3: Solar Home Systems are cheaper than other solutions (mini-grids and grid extension) in small communities with a weak economic strength, living in sparsely populated areas, distant from the main grid and difficult to reach. Source: (GOGLA, 2018a)

In a recent study, Bloomberg New Energy Finance compared the cost of delivered energy for rural low energy consumers (Figure 4, left), confirming the connection to the national grid as the cheapest path when it does not require to build additional infrastructure; grid extensions - assuming the case it is reasonably viable - can more than double the cost of electricity; microgrids are competitive with the grid extension, especially in sites where daytime productive consumers serve as anchor loads for renewable energy sources (e.g. agricultural and industrial processes, water pumping) (Climatescope, 2018a).
Solar home systems are economically viable only if used together with super-efficient DC appliances, in which case they even enter into direct competition with the grid.
For higher energy consumption (Figure 4, right), the cost for grid extension is lower as the new infrastructure is going to be better used; microgrids does not follow the same logic as their cost of delivered energy is not very sensitive to the energy demand. On the other hand, solar home systems become cheaper and cheaper for increasing energy demands, representing the most cost-effective technology for medium energy rural households.
The only two solutions which are expected to lower their price appreciably by 2030 are mini grids and solar home systems, driven by the substantial room for technological improvement and business development as they are still at early stage of deployment.



Source: Bloomberg NEF. Note: low-income customers are assumed to use 207kWh per year or a 10-35W solar home system. Medium income refers to a consumption of 985kWh per year and a 200W solar home system. The microgrid with daytime load produces additional electricity for non-residential activities.

Figure 4: Cost of delivered energy for low energy consumers (left) and medium energy consumers (right) – Source: Bloomberg New Energy Finance

1.3 Digitalization in the energy access sector

The use of digital technology in the power infrastructure's operation dates back to the 1970s, being the energy sector pioneering in its adoption and improvement (Sabino, 2018). We are now experiencing a new fast-paced digitalization period, which shows itself in very different ways among developed and low-income countries.
Narrowing it down to the energy access in developing countries, particularly in Sub-Saharan Africa where this issue is critical, we can identify some digital technology-enabled applications with high potential impact and increasingly stepping into the investors' spotlight. They are summarized in the roadmap proposed by the author in Figure 5, which shed light on which developments are most likely to transform the energy access sector thanks to digital businesses/technologies. The next sections will

focus on that solutions which combine the Pay-as-you-go payment scheme with digital technologies, in particular, in the field of solar home systems, microgrids and clean cooking.

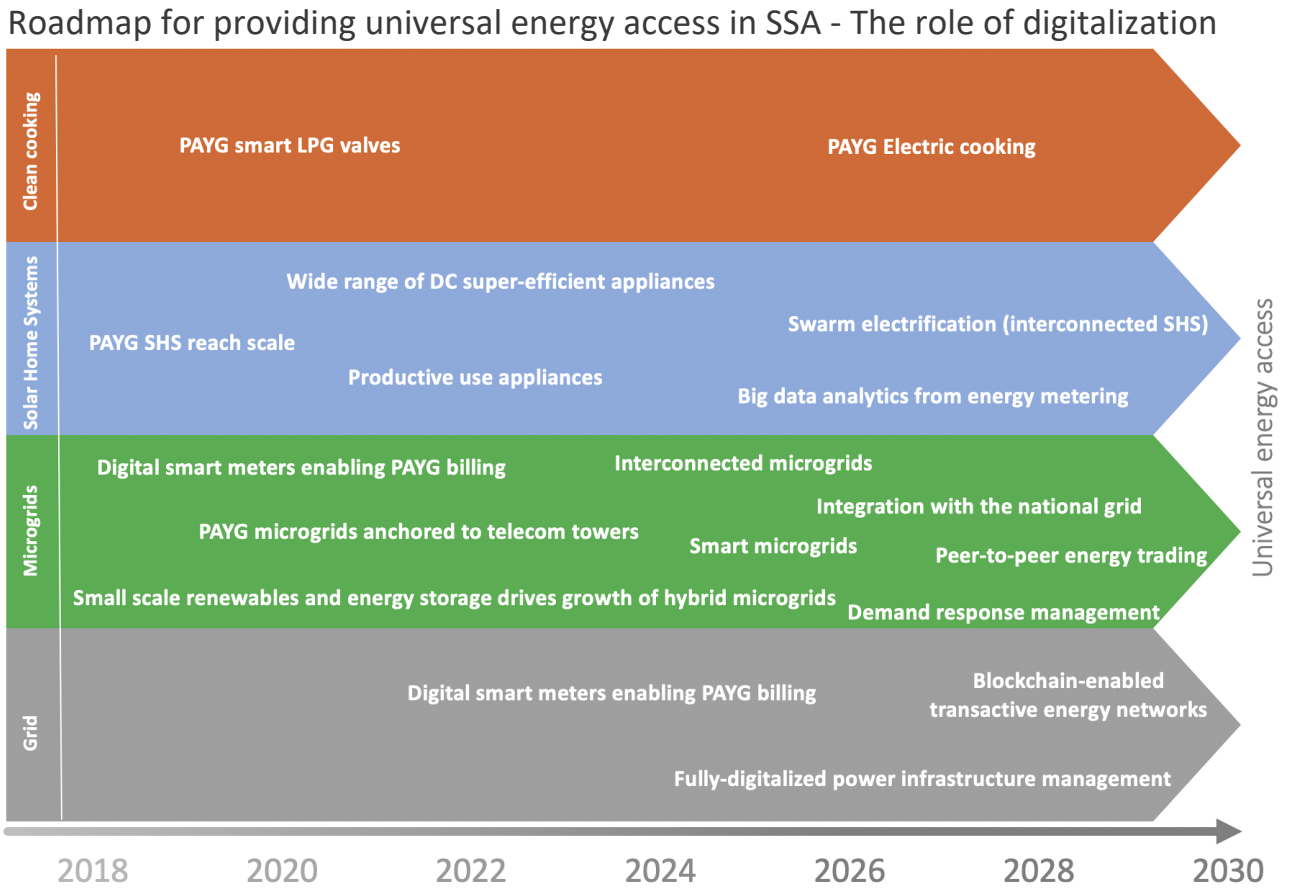


Figure 5: Several developments are expected to bring about a "leapfrogging" digital transformation of the energy sector in SSA. This scenario was made considering the current stage of applications, their potential, and investor's confidence - Author's elaboration.

In Sub-Saharan Africa (SSA) digitalization might play a big role, nevertheless only few African countries have addressed policies to unlock its potential. Since early 2010s companies have been adapting traditional business models to the specific African context which was possible thanks to a fast-growing, "leapfrogging" digital technology development. Small start-ups have tackled the obstacles to energy access with a bottom-up approach, by designed complex, cost-effective solutions. In order to understand the causes of this new wave of digitalization in SSA we will now analyse the drivers which have led to it.

1.3.1 Key drivers of the digital transformation

There are four key game-changer drivers which for the digitalization of the energy sector, which are described below.

1) *Digital finance.* Africa is the world leader in **mobile money** (Chironga et al., 2017). The high percentage of unbanked people and the missing access to finance let the major Mobile Network Operators (MNOs) to progressively take the place of traditional banking systems.

Contrary to what is thought, mobile money penetration is very high even among the Bottom of the Pyramid (BoP) as highlighted in Figure 6: Kenya, Namibia and South Africa are the countries with the higher mobile penetration among the poorest, followed by Gabon, Ghana, Uganda, Zimbabwe, Rwanda and Tanzania. Some countries had an explosive increase in mobile money usage: in Guinea,

Senegal, Togo, Burkina Faso, Benin, Gabon, Madagascar, Zimbabwe and Congo, the percentage of low-income adults with a mobile money account grew by 2-10 times over the last three years. Part of this growth has been pushed by the off-grid solar sector: 98% of Fenix International's customers make a mobile payment for the first time when they purchase its solar home system.

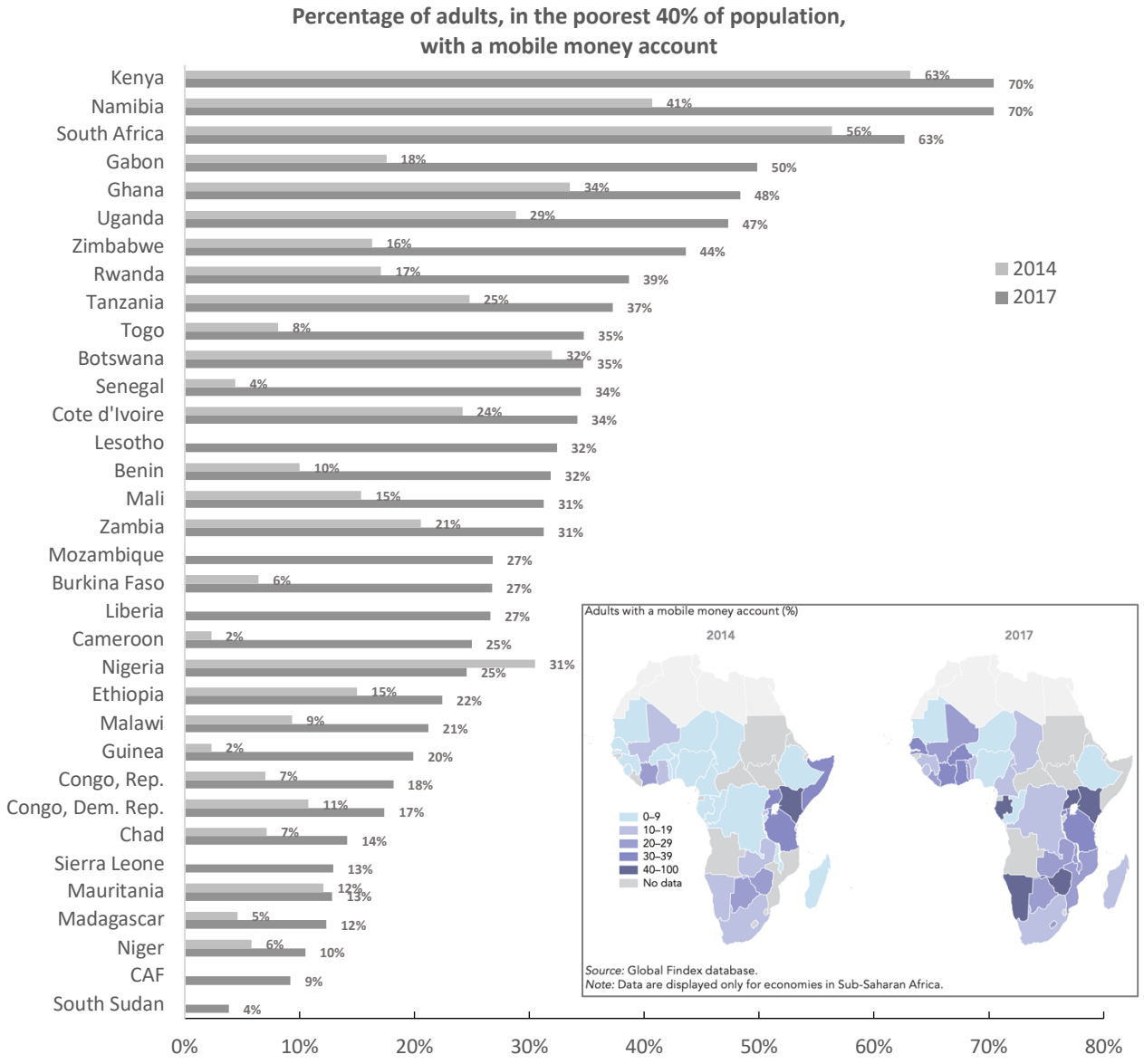


Figure 6: Percentage of adults in the poorest 40% of the population with a mobile money account - Author's elaboration based on Global Findex Database (2017)

2) *Internet of Things (IoT)*. Machine-to-Machine (M2M) connectivity is the technological root for fully-connected PAYG-enabled devices. It allows a GSM two-way communication between electronic devices and the service providers' central servers, as illustrated in the application in Figure 7.

In fact, GSM chips and software installed by the producer on an embedded circuit boards permit the communication, monitoring and the execution of some operations, both by automated or manual remote controllers. Devices with embedded M2M modules can receive a proof of payment via the mobile network (often a 2G network) to unlock the service, which in case of a SHS would enable

electricity flow from the battery to the appliances (USAID, 2018). This technology also make possible to send product performance and customer usage data to the provider via the mobile data network.

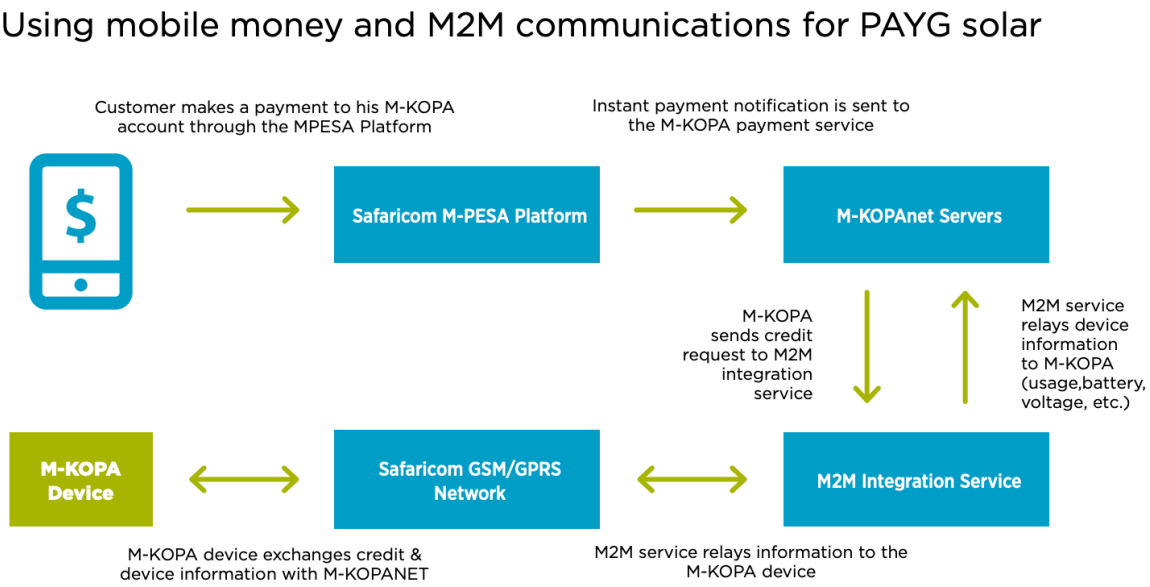


Figure 7: The M-KOPA machine-to-machine communication scheme is an example of how this technology could enable successful business models - Source: (GSMA, 2016)

3) *Connectivity*. The rapid growth of mobile network infrastructure and GSM subscribers in rural areas is progressively broadening the gap between the access to mobile and electricity services. Mobile GSM (2G) connection is fast-growing even in least electrified rural areas (approximately 11% per year in rural areas (GSMA and MECS, 2014)). As illustrated in our analysis (Figure 8), some countries with extremely low rural electricity have a very good mobile network coverage. These places – Rwanda, Mali, Angola, Benin, Tanzania, Congo, Gambia, Malawi, Guinea – are potentially most suitable for developing digital-enabled technologies and business models to foster the access to electricity.

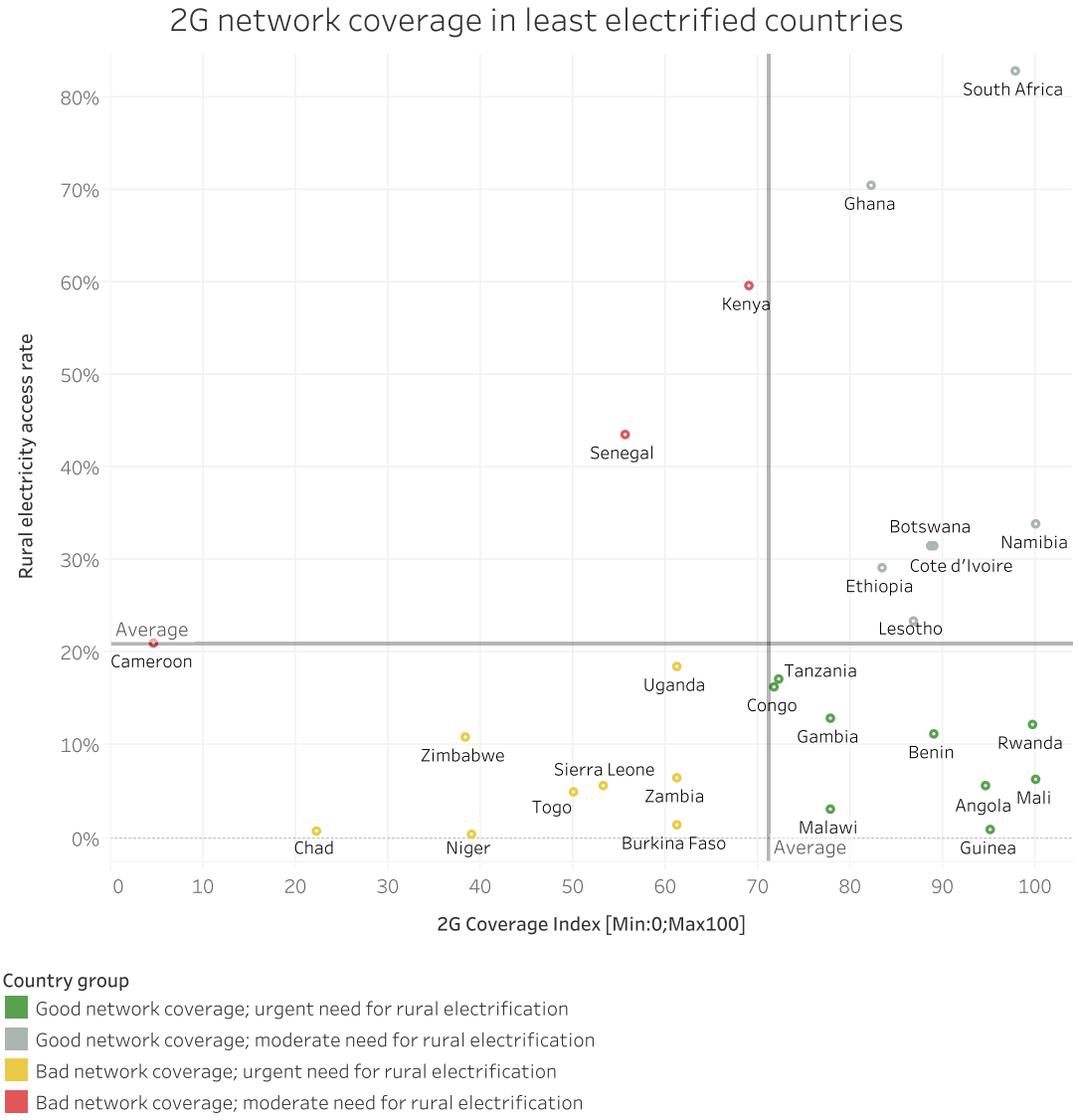


Figure 8: Some countries (Nigeria, Sudan, Mauritania, Liberia, Madagascar, Mozambique, Democratic Republic of Congo, Burundi) are not analysed because coverage data are not available. - Author's elaboration, based on IEA Energy Access Database (2017) and GSMA Mobile Connectivity Index (2017)

4) *Software platforms*. PAYG platforms are an all-in-one solution for off-grid solar companies, having made it possible to overcome the problems related with the challenging distribution of products in remote areas, where the concentration of potential beneficiaries is higher. They provide a fully digitalized Customer Relationship Management (CRM), which is a powerful tool to find potential customers, enable important improvements in sales, distribution and marketing through apps at the service of sales agents. The platforms also take care of Product & Service Management by controlling assets, inventory, and speeding up the after-sales and assistance service. Products'

operational parameters are monitored in real time in order to detect faults, malfunctions and improper use. *Business analytics and big data* are used to monitor the system operation, detect failures and collect several data, like energy consumption patterns battery parameters. Salesforce management address, train and manage sales agents who are equipped with apps. A conceptualization of what PAYG platforms are able to do is shown below in Figure 9.

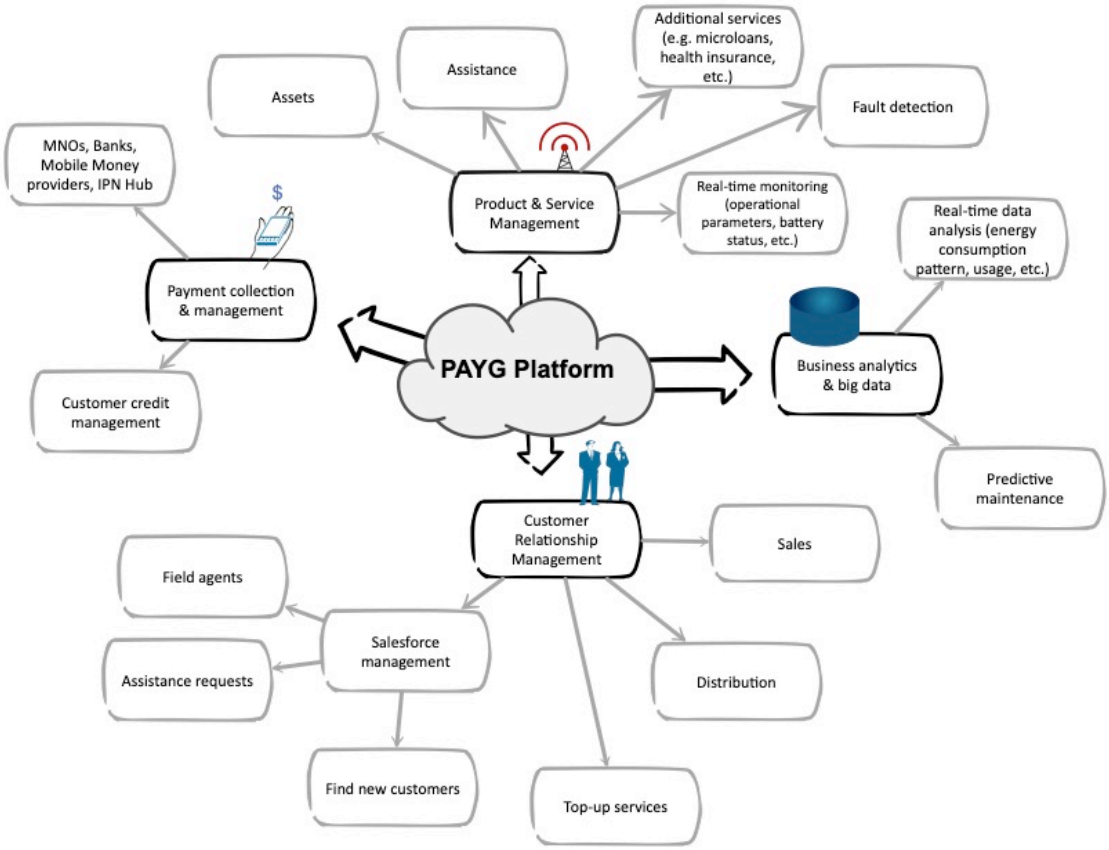


Figure 9: The PAYG digital platform is a core ingredient for every PAYG business. In this picture we tried to outline the role of the complex tool -Author's elaboration

1.3.2 The role of telecommunications companies

Mobile Network Operators (MNOs) – such as Vodacom in South Africa, Safaricom in Kenya, MTN in Ghana and Nigeria, Airtel in Uganda – are playing a major role in the digitalization process of energy (GSMA, 2017a), as they:

- Provide the mobile connectivity through the M2M technology, enabling the smart metering of energy systems, but also the automated control and monitoring of connected devices.
- Retain the mobile-money channels – such as mobile money services, SMS payments, platforms – which are crucial for PAYG and other innovative business models.
- Have a widely spread sales and distribution network (even in remote areas) on which PAYG off-grid solar companies rely to reach customers.
- Provide services – via voice, SMS, USSD and apps – to optimize the supply chain logistics for energy services and products.
- Provides for telecom towers serving as anchor loads for mini-grids that also provide energy to the surrounding households and businesses (emerging concept developing in partnership with Energy Service Companies (ESCO) and mini-grid operators).

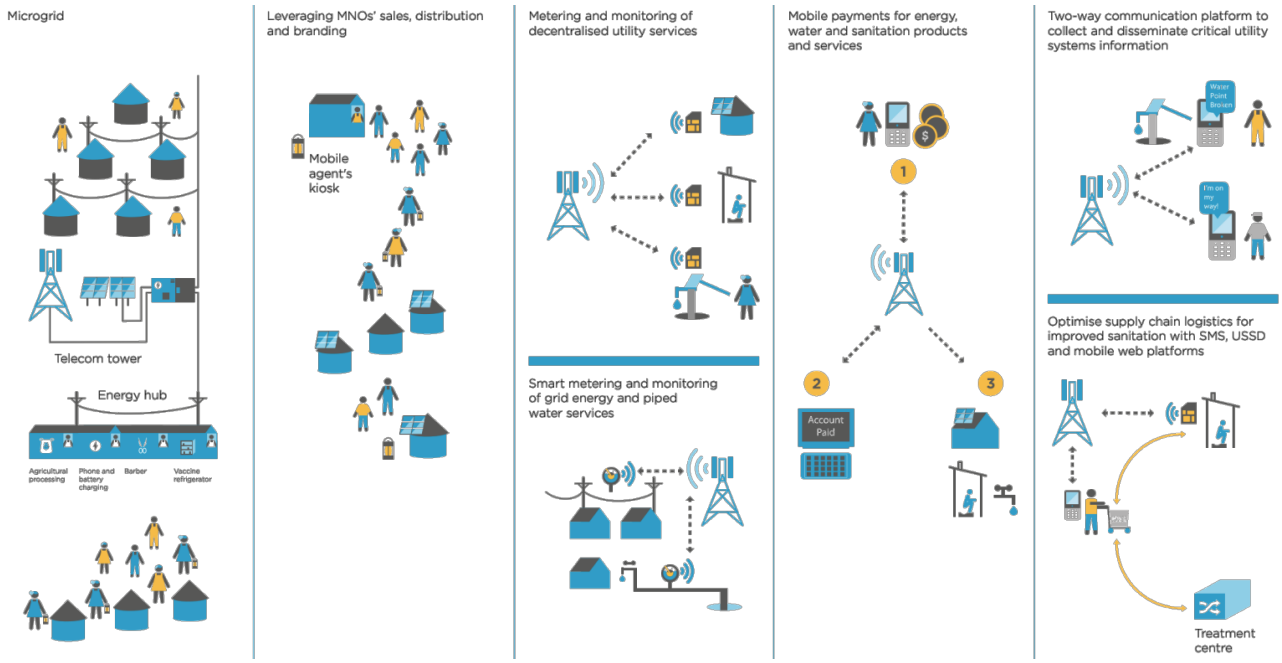


Figure 10: The role of MNOs in digitalizing the energy access sector - Source: (GSMA, 2017a)

2 The current status and prospective of PAYG off-grid solar solutions

Affordability has always been the main barrier for households to obtain access to electricity, especially in rural areas where providing it is more expensive than in urban areas. Stand-alone solar PV systems offer a cheap way to provide basic electricity supply for the households living currently off-grid, however, their upfront cost is still too high for the poorest households. As a consequence, off-grid solar companies have been changing their business model shifting to the pay-as-you-go approach, particularly suited for those potential customers who cannot afford a cash-paid solar system. Also referred to as “PAYG”, or “PAYGO”, the mobile-enabled business model reached a wider range of low-income customers if compared to conventional distribution schemes (USAID, 2018).

We have seen in the past how some private sector innovations - such as mobile phones or mobile banking - have effectively covered the shortage of traditional telecom infrastructures and banks in rural Africa. There is some evidence to suggest that the off-grid solar industry is playing a similar role due to power utilities’ inadequacy to reach the rural population and provide a reliable service.

2.1 Solar Home Systems on a pay-as-you-go basis

Business models based on PAYG mobile payments were originally born as a commercial strategy to sell solar lanterns (belonging to the pico-solar sector) to the poorest people. Companies like M-Kopa, d.light and many others focused their business on selling small solar PV kits (<10 W) which provide a Tier 1 level of access: with an initial down payment, customers could take their system home and make small periodical payments in order to keep it working, getting the ownership after a certain amount of time.

Later on, the number of off-grid solar companies grew increased substantially (today there are about 135 commercial players) and many of them started offering similar but larger systems,

Solar Home Systems are bigger and more powerful kits composed by a solar panel, a charge controller with a battery inside, a mobile charger, several DC ports for other appliances and a few light points. Their recent development enables the possibility to connect bigger and bigger DC appliances, such as refrigerators, fans, TVs, laptops, small-business and agro-processing machines, or even solar pumps (Figure 11). The impact of this technology became significantly higher as soon as it started to supply electricity for productive uses, which could significantly increase small businesses’ incomes. Of course, SHS are not a permanent solution but rather a trigger for breaking the vicious circle of energy-poverty; the economic and health benefits they bring are a first step towards an enhanced economic development for lowest-income populations.

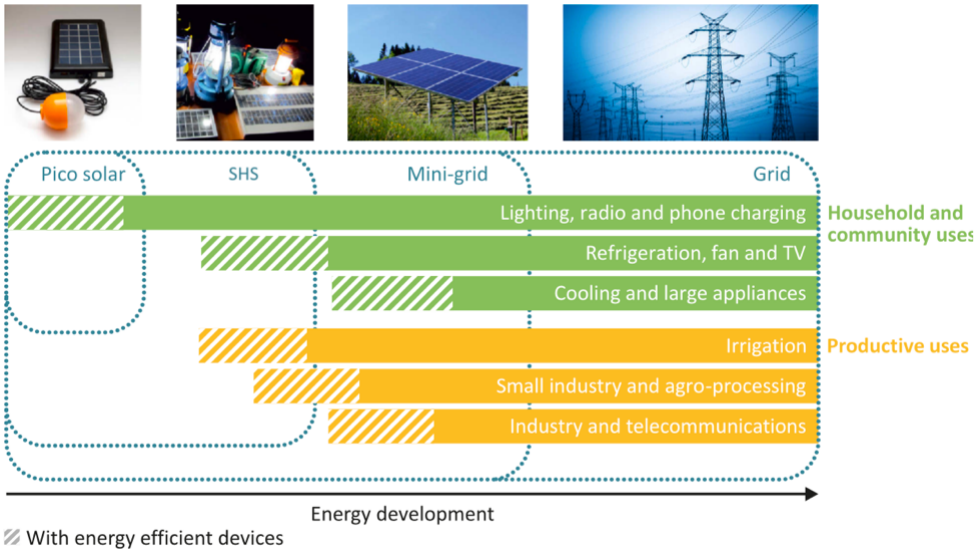


Figure 11: Technologies for providing access to electricity along the energy ladder, with the corresponding uses enabled - Source: International Energy Agency (2017)

According to the data reported by IRENA and showed in Figure 12 and Figure 13, solar home systems and solar lights together supply around 90% share of the population served by off-grid solutions in SSA, but they represent just less than 10% of the total off-grid installed capacity due to the small size of systems (IRENA, 2018). It is also evident that these solutions have had an enormous growth in the last five years; the reasons of this trend are to find in the driving sharp decrease in costs of batteries and solar modules, as well as in innovative business models like pay-as-you-go.
The cumulated installed capacity of Solar Home Systems in SSA was around 100 MW in 2017; 16,3 MW were added in the first semester of 2018 (90% of them sold by the PAYG scheme) (GOGLA, 2018b).

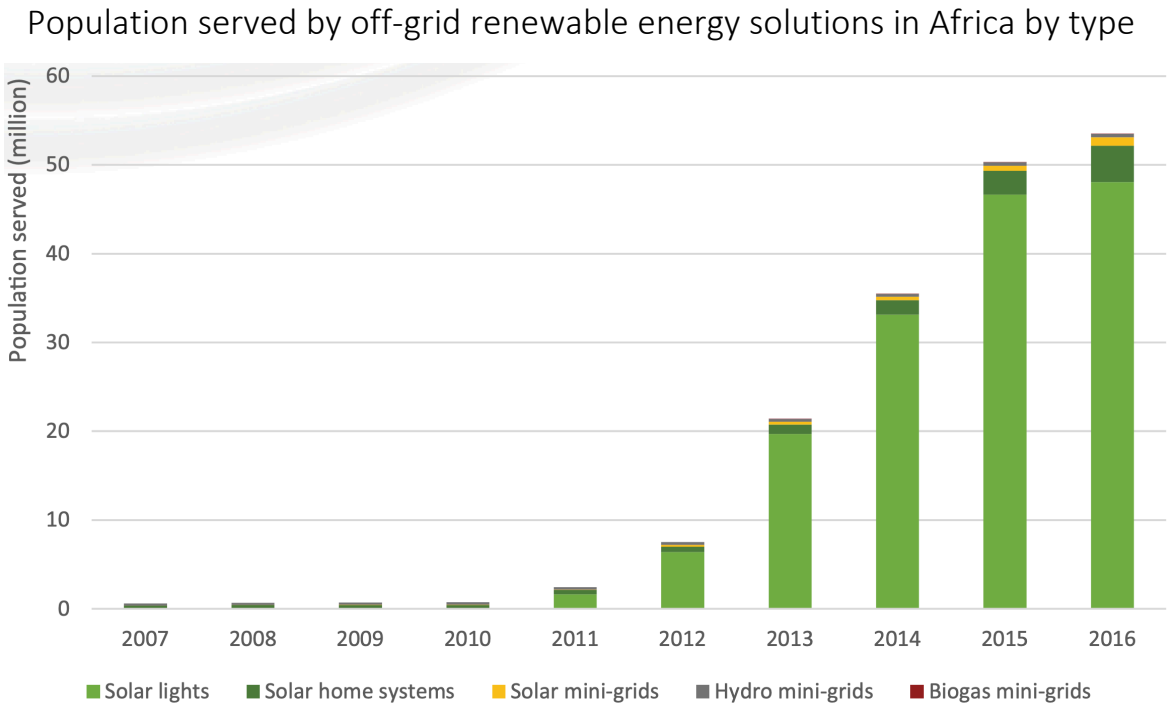


Figure 12: Solar home systems and pico-solar products are the off-grid solutions which serve by far the largest number of people in Africa - Source: IRENA (2018)

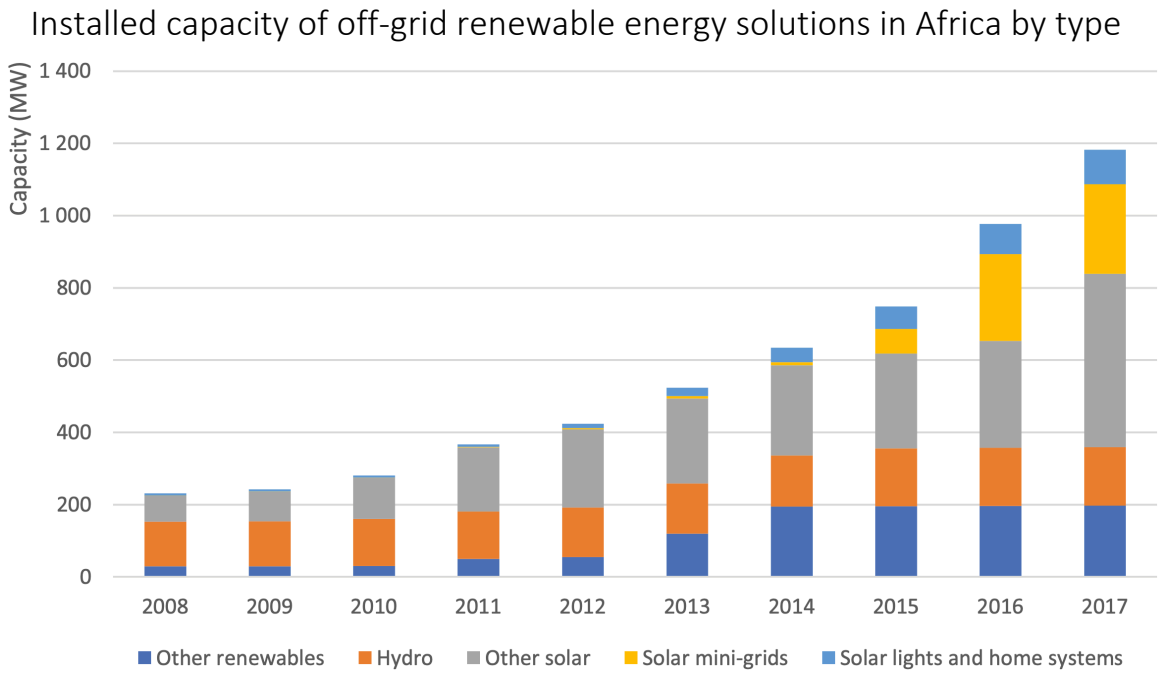


Figure 13: Solar home systems and pico-solar products cannot compete with bigger systems in terms of installed capacity (right) - Source: IRENA (2018)

Solar home systems are categorized by the energy service level provided, following the classification used by GOGLA; four categories with relative size ranges and enabled levels of access[1] are reported in Table 2.

Table 2: Classification of solar home systems by size and energy service level - Source: (GOGLA, 2017)

PV module capacity	Service provided	MTF level of energy access enabled
11-20 Wp	**Entry level**: 3-4 lights, phone charging, powering radio, fan, etc.	Enables **full Tier 1** Electricity Access to a household
21-49 Wp	**Basic capacity**: as above plus power for TV, additional lights, small productive-use appliances & extended capacity.	Enables **full Tier 2** to a household when coupled with high-efficiency appliances.
50-99 Wp	**Medium capacity**: as above but with extended capacities.	Enables full Tier 2 electricity access to a household even using conventional appliances.
100+ Wp	**Higher capacity**: as above but with extended capacities.	

[1] The level of access is defined according to the Multi-Tier Framework (MTF) designed by the World Bank's ESMAP Program (for more information see 1.2.).

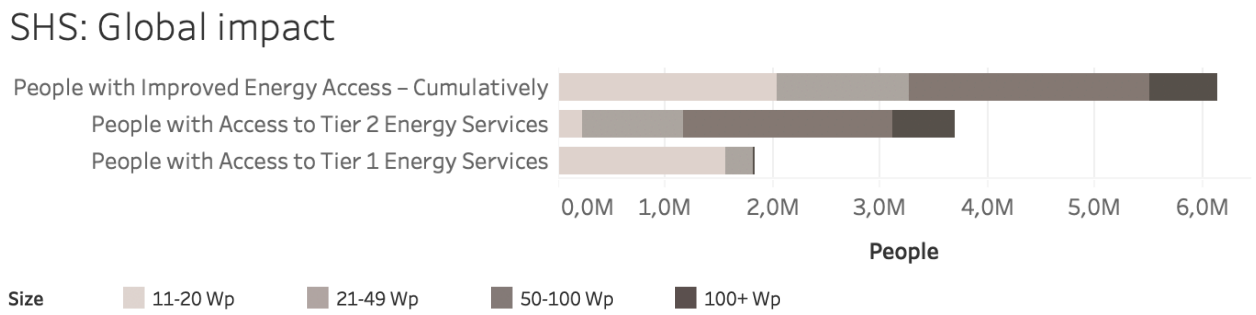


Figure 14: Cumulated number of people[2] who have gained/improved energy access through SHSs, by product size. Data refers to global sales and are calculated through the "Standardized Impact Metrics for the Off-Grid Solar Energy Sector" framework – Author's elaboration on GOGLA (2018)

Solar Home systems are small-scale power kits with a big potential impact on the off-grid households and those experiencing unreliable energy supply. According to the "New Policies Scenario" formulated by the International Energy Agency, around 23% of global electrification investment by 2030 need to be addressed to off-grid solar systems, complemented by micro-grids and grid connections (IEA, 2017). It is the most cost-effective solution in rural areas together with mini-grids. The solution itself is quite long-standing, but in recent years developing countries have seen a huge deployment as their cost-effectiveness has rapidly increased and new business models have shown of the wave of the increasing mobile connectivity. SHSs provide a Tier 1 up to Tier 2 electricity access (see 1.2 for more details), so they fulfil basic electricity needs such as lighting, mobile charging and power supply for DC appliances. Some of them are modular so that as users increase their incomes they can add more PV modules and unlock the possibility to connect bigger appliances like fans, refrigerators, electric cookstoves, barber box, solar pumps, mills and other agricultural appliances.
Products' overall costs (including appliances) range from 100 USD for 3 light points and mobile charging, up to 2000 USD for the most powerful ones able to provide adequate power supply and autonomy for bigger appliances.

2.2 The state of things and future development

2.2.1 Sales

In the business-as-usual scenario, the global SHS sector is expected to grow at an annual rate of 80-90% in the next five years, reaching 25 million units in annual unit sales and led by those companies which have already adopted the mobile payment scheme (Lighting Global, 2018a). According to this growth rate, around 49 million units will be deployed in the period between 2019 and 2022, i.e. bringing access to clean energy to 187 million people[3]. It implies that SHS will provide a Tier 1 or Tier 2 access level to 17% of the current 1.1 billion people without access (IEA, 2017). If the growth trend of this technology is verified, it will be a huge step towards the universal access by 2030

[2] These data come from a detailed market-based analysis which considers only SHSs globally sold by companies affiliated with GOGLA; the real number of people with improved energy access could be considerable higher as products sold by non-tracked companies are not counted here.

[3] **Assumptions**: 5 people per household; discount for loss factor (products for which full usage is not received, e.g., early breaking) =10%; discount for repeat sales (to avoid double counting of households who already owned one) =15%;

provided for in the Target 7.1 of the SDG 7 (Access to affordable, reliable, sustainable and modern energy for all).

Annual sales of SHS increased by five times in three years and big capacity-systems gradually overwhelmed the smaller ones (Figure 15). The 2018 Off-Grid Solar Market Trends Report from Lighting Global foresee the SHS segment – driven by PAYG businesses – "set to achieve growth of 80-90% over the next five years. This would enable it to reach over 20 million in annual sales units and USD 6-7 billion in annual revenues in 2022" (Lighting Global, 2018a). These data refer to global sales, being the geographic share of the PAYG market (% cumulative sales; 2013-2017) 86% in East Africa, 12% in West Africa and 2% in Asia (Lighting Global, 2018a); it means that PAYG systems belong almost exclusively to Sub-Saharan Africa.

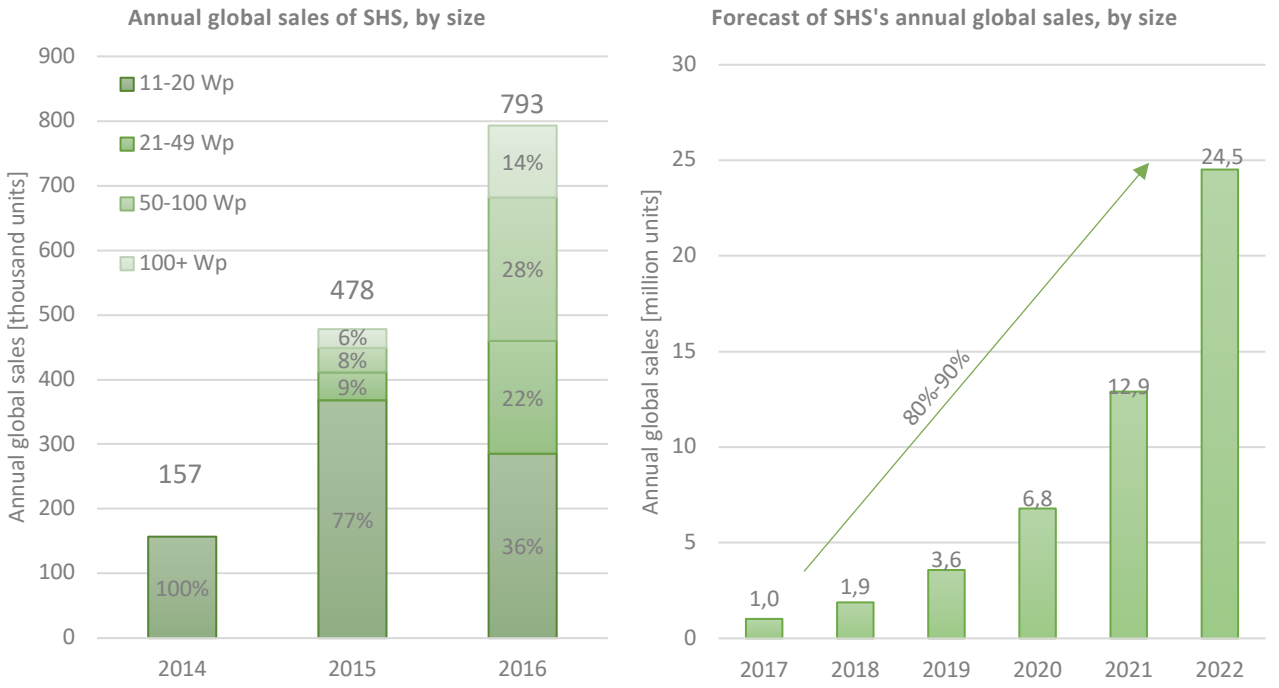


Figure 15: (Left) Growth of SHS global sales from 2014 to 2016, by size. The total sales volume estimates sales from companies affiliated and non-affiliated to GOGLA, while the share by size was calculated just on the basis of affiliate. - Source: Author's elaboration based on (Lighting Global, 2018a);
(Right) Projections of SHS deployment in the next years - Source: Author's elaboration based on (Lighting Global, 2018a).

The Global Off-Grid Lighting Association (GOGLA) published, for the first time in 2018, half-yearly sales data on PAYG sales in Sub-Saharan Africa: during the first semester of 2018, affiliate companies sold 612 thousand units (80% in East Africa), for a total economic value of USD 103,5 million[4] (Figure 16).

[4] Data refers to both pico-solar products and solar home systems.

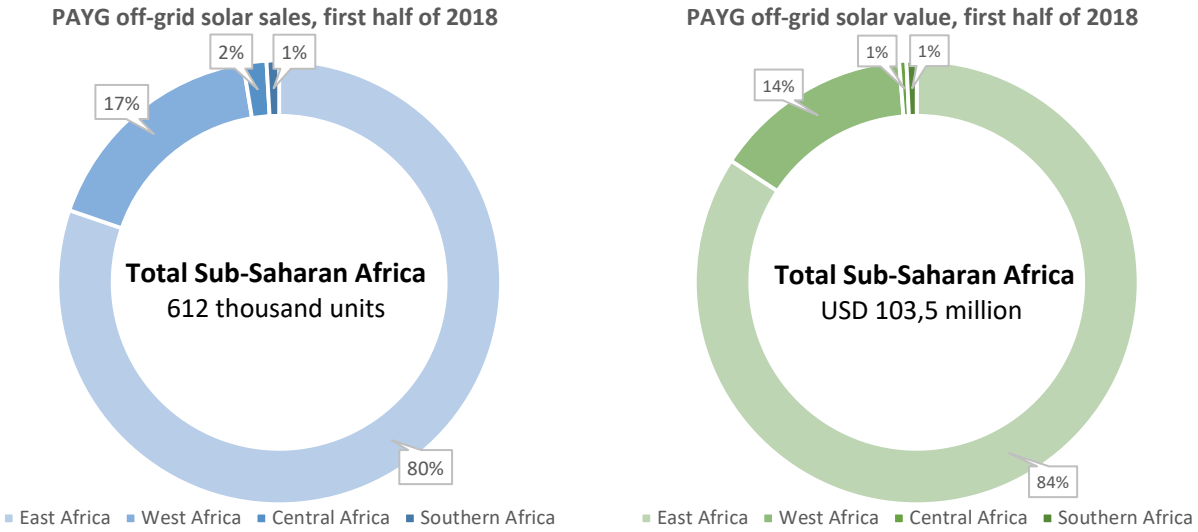


Figure 16: Sales (left) and sales economic value (right) of off-grid solar products in the first half of 2018. The estimation only considers 49 manufacturers and 18 distributors, affiliated members of GOGLA; The effective deployment, including also non-affiliates, is unknown and difficult to evaluate. – Author's elaboration on GOGLA (2018)

2.2.2 Potential market

According to Lighting Global, the current potential market for PAYG SHS in Sub-Saharan Africa amounts to around 170 million households, corresponding to some 850 million people (Lighting Global, 2018a). This number includes off-grid populations but also on-grid households experiencing unreliable and highly discontinuous energy supply. In fact, many grid-connected customers decide to buy a SHS because they need a backup system or a lower-cost alternative. 90% of Nigerian on-grid households have an unreliable electricity supply (MTR IVR 2017), with 32 electric outages in a typical month with a typical duration of 8 hours; the grid is particularly unreliable also in Congo, Ghana, Tanzania, Uganda and Ethiopia.

Another analysis, from McKinsey, estimates a 150 million households-potential market globally, not considering unreliable-grid connected ones and excluding people unable to afford a SHSs.

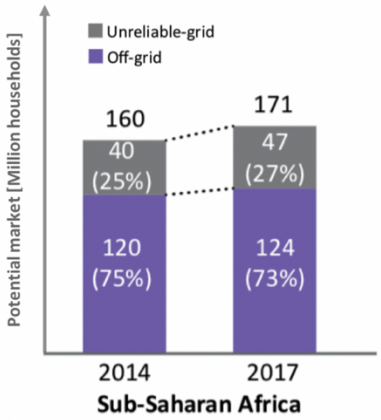


Figure 17: Potential market for Solar Home Systems in SSA.
Source:(Lighting Global, 2018a).

Due to the high penetration of mobile-money, East Africa holds 86% of the global PAYG SHS market in cumulative sales, West Africa 12% (Lighting Global, 2018a): in other words, SSA retains 98% of the technology's global market share. In South-East Asia, there has been a huge deployment of SHSs

compared to Africa, but the PAYG did not take hold due to the fact that digital payments are not as widespread. As shown in Figure 20, the growth of off-grid solar sector (which includes SHS and pico-solar) has been very fast in East-Africa due to the fact that countries like Kenya, Tanzania and Uganda already had an early penetration of mobile money, but there is a future potential in West-Africa, where digital payments have just begun to take root. In fact, MFIs, venture capitalists and other investors moved from East- to West-Africa in 2015, where 34% of the sector's funding was allocated in 2016. There was a sharp decline of West-Africa's funding in 2017, attributed to the devaluation of naira caused by the economic crisis that affected Nigeria, the first potential off-grid market in SSA and second only to India. Ethiopia is another key market, having a large number of off-grid and unreliable-grid households and a growing penetration of mobile money. In addition, the recent peace agreement with Eritrea is expected to create an open market, a better business environment and lower risks for investors.

2.2.3 Investment analysis and future projections

Off-grid solar market has been estimated to become a 8-billion-dollar industry by 2022, overwhelmingly driven by PAYG companies (Lighting Global, 2018a), and such an attractive projection have captured a growing investor's attention over the last five years.

PAYGO solar home system market raised funds for USD 773 million in the period between 2013 and 2017, accounting for 85% of total amount raised in the off-grid solar sector (Lighting Global, 2018a). Large part of investments, however, (mainly grants and equity, with few debt financing) were addressed to just a handful of companies. This "first wave" of PAYG businesses, which now dominates the market, includes M-KOPA, Off-Grid Electric, Fenix International (now a company of Engie), Mobisol, Nova Lumos, BBOXX, PEG Ghana (GOGLA, 2016)((Persistent and Shell Foundation, 2018). They are now in a growth phase and most of them became mature business able to obtain significant debt funding. After this initial wave, the growth of PAYG sector has begun to slow down in terms of investments in 2017.

In April 2018 ENGIE concluded the acquisition of the PAYG SHS provider Fenix International, becoming the first global energy player to invest in the PAYG solar sector; it set the ambitious target of reaching 20 million off-grid people by 2022. Other major energy companies such as Total (target: 25 million people electrified by 2022), Shell, EDF and Iberdrola invested in off-grid solar firms (Climatescope, 2018b) . In particular, Shell announced the important target of providing access to 100 million people by 2030 by continuing to invest in off-grid solar and microgrid start-ups. EDF announced a corporate partnership with Sun Culture to pilot "Pay-as-you-grow" solar irrigation systems in Africa.

Recent investment trends show that financiers are moving towards different technology choices, preferring tiny pay-as-you-go micro-grids also called "nano-grids" or "pico-grids" (Climatescope, 2018c).

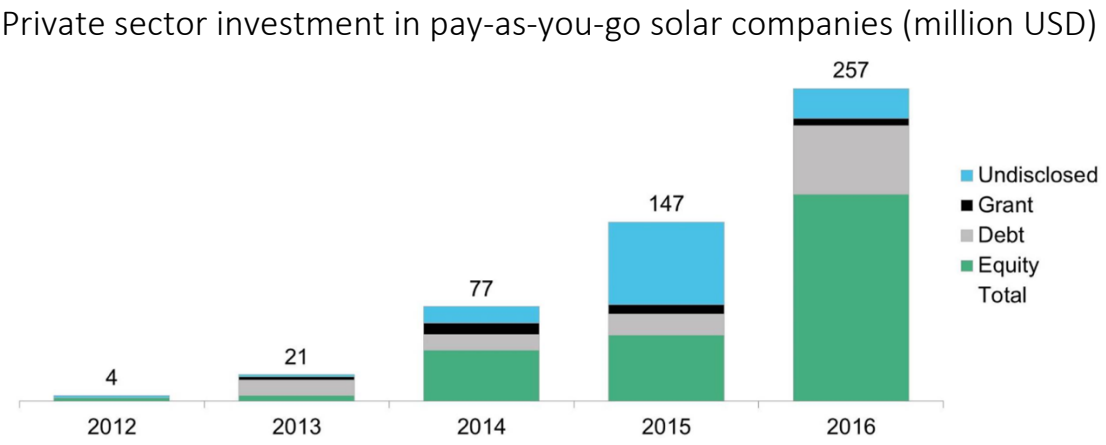


Figure 18: Private sector investment in pay-as-you-go solar companies (million USD) – Source: Bloomberg New Energy Finance

Pioneering start-up started to experience tough times due to multiple reasons (see 3.4 for more details) and investor's interest slowed down for the first time in 2017. It represented the end of the "first wave" of investments (see Figure 19). Climatescope reports - in its last Off-grid and Mini-grid Market Outlook - that "the pay-as-you-go solar funding bonanza is wearing a little thinner, and total announced venture financing for energy access might decline for the first time in 2018. Nonetheless, corporate interest in universal access to energy is broadening, with EDP and Veolia joining other European utilities as participants in the market. The focus has however shifted to smaller deals with novel innovations, rather than lending to solar home system startups". In fact, "the global financing of SHS start-ups may reach some $280 million in 2018, which would be below last year's total of $319 million" (Climatescope, 2018c).

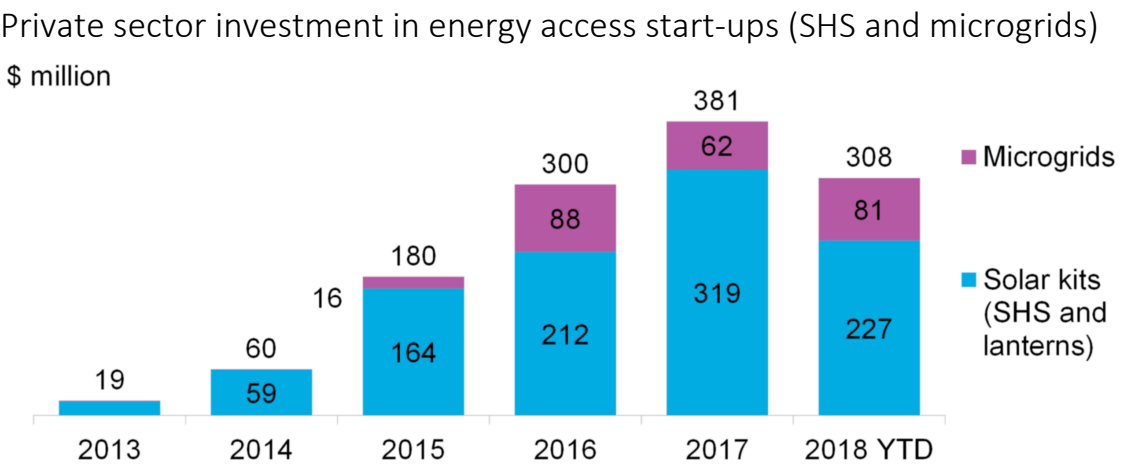


Figure 19: The "first wave" of PAYG SHS investment made by venture financing accounted for USD 695 million from 2015 to 2017; investment in 2018 is expected to reach USD 280 million - below the previous year's total - resulting in a stunting growth. Note: Microgrid financing refers to rural microgrid for energy access only; includes data up to October 1, 2018. – Source: Bloomberg NEF.

Despite nascent companies are suffering a dulled investor optimism over the first firms financed, an upcoming "second wave" of new players is expected to scale-up in the next few years, armed with lessons learned from pioneers, an increased mobile penetration in many countries, fall of PV modules and lithium batteries, and of course improvements in digital technology. However, is suffering dampened investor optimism over the first wave of PAYG companies.

The geographic split of off-grid solar sector's investment sees Africa at the forefront: In 2016, 47% of total funds raised were addressed to East Africa, 34% to West Africa (it was just 9% in 2015), 12% were global investments and only 5% to Asia and Latin America. This is a result of a gradual

saturation of the East African market and the consequent exploration of untapped markets such as Congo and Nigeria (Figure 20). During 2017 the total investment decreased for the first time; West Africa received only 6% of total investment while East Africa obtained the largest share; this trend might be due to the unexpected difficulties to adapt the innovative business models tailored for Eastern countries to the entrant Western markets.

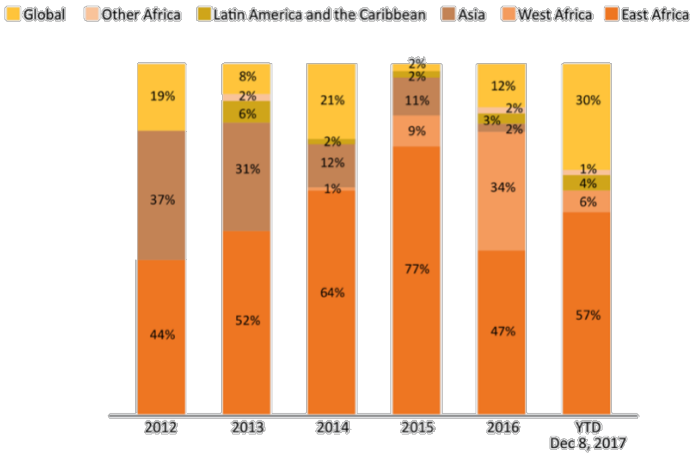


Figure 20: Geographic split of Off-grid solar sector's funding as % of total fund raised - Source: (Lighting Global, 2018a)

If we look at the investment projections over the next 12 years (Figure 21), solar home systems are expected to raise one-third of the capital spend for electrification in East Africa; micro-grids are going to have a larger impact in West Africa, mainly driven by the current governmental policies; grid extension still remains the most financed solution in Central and Southern Africa (Climatescope, 2018a). About 90% of the global investment on solar home systems will go to Africa, where there are the most favorable conditions for its successful deployment.

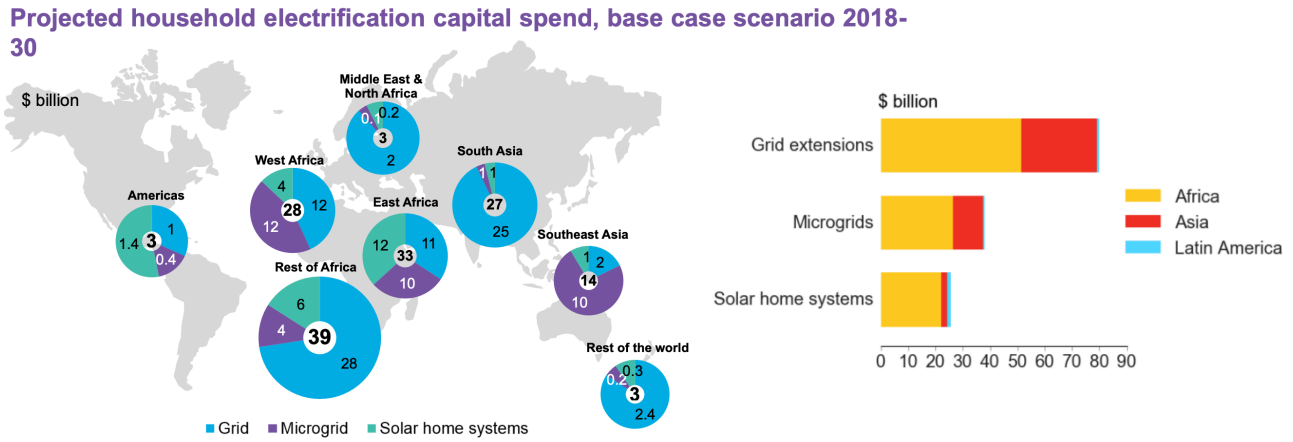


Figure 21: Bloomberg's expected investments for electrification over the next twelve years[5]. — Source: Bloomberg New Energy Finance (2017)

[5] Note: East Africa refers to the six countries of the East African Community. Numbers may not add due to rounding

2.3 Business experiences

2.3.1 East Africa

M-KOPA was created in 2011 by the same founder of M-PESA, one of the largest mobile banking systems in SSA. Their offer includes an 8W Pico-Solar System and a 20W SHS, with an up-front payment of USD 30 and USD 60 respectively, and daily instalments of USD 0,50 and USD 1 respectively. The payment frequency and size are up to the customer's choice, but the entire value has to be paid within the payment period agreed (from 380 to 570 days). The many retailers are encouraged to search for new customers since they receive small sales commissions.

A real-time monitoring and control system is embedded in the control box and sends usage data to a central control station which can detect failures, glitches, incorrect use, battery status, keeps a record of payments and also send an SMS to users if his credit is running low. As it is very common for financial circumstances to change rapidly, M-KOPA gives the possibility to return the product in working order and get the deposit back (Rolffs, P., Byrne, R. and Ockwell, D., 2014). In January 2018 M-KOPA had reached over 600.000 households with a growth rate of 500 new ones a day, in Kenya, Uganda and Tanzania (M-KOPA website).

SOLAPESA, the M-KOPA loan product, offer cash loans to pay school fees for those who have successfully completed the payment plan. They can also have access to a wide range of services or products using the same payment scheme, like bicycles, water tanks, smartphones, stoves, rooftop rainwater collection systems.

Figure 22: Two products offered by M-KOPA: 8W pico-solar system (left) and a 20W SHS (right) – Source: M-Kopa website

Mobisol started its business in 2011 in Tanzania, Kenya and Ghana, but is currently active in 12 countries. Focused on a deep-seated marketing strategy (shops, local agents making presentations in rural villages) they inform people about their products' potential benefits. Questionnaires and energy games are submitted to potential customers who express interest, in order to evaluate their availability to pay and their energy needs (this has the twofold benefit of performing a quick customer risk assessment and collecting precious data about energy use in villages). Products are widely customizable: people evaluate the system and choose the appliances that best fits their needs and budget. Among the others, they offer water filters and highly efficient modern charcoal stove.

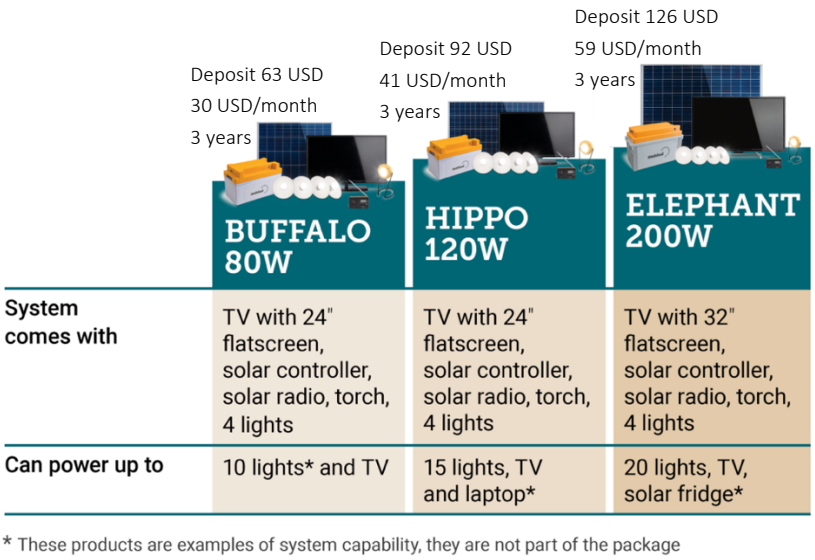


Figure 23: The higher capacity products offered by Mobisol – Source: Mobisol website

After a deposit equivalent to 10-20% of the total value, customers commit to paying the rest within 36 months by periodic M-PESA mobile payments but, differently from M-KOPA, they have to pay in specific days (an SMS is periodically sent as a reminder). The system automatically switches off until the next payment if the customer cannot pay, but a discount is applied if the whole amount is paid off in advance with respect to the 36 months. Mobisol advises customers who have seasonal incomes like farmers to make larger payments during the positive periods. Local staff is properly trained to install and maintain the systems, but it means that potential customers living in areas without prepared technicians cannot receive the product (Rolffs, P., Byrne, R. and Ockwell, D., 2014).

According to their website, they have installed a total of 12MW, impacting on 600.000 people and avoiding 60 kt of CO_2 every year. A third of their end-customers generate additional incomes with their SHS (Mobisol website): for example, shops use charging hubs to allow customers charge electronic devices; hair cutters are useful for barber shops, home stereos, TVs (19”-43”), standing fans for bars and other activities. Moreover, they recently announced a solar welding tool.

The company - fresh with the expertise - also offer a PAYG platform, a solution for those businesses which want to take advantage of this technology improving manufacturing, distribution, sales and customer service. The suite provides remote control and access of PAYG-enabled products in an all-in-one environment which integrates together SMS, mobile payments, business analytics and the interface with financial institutions. They also developed specific apps for technicians, sales agents and customers.

Fenix International (acquired by Engie) has a business model similar to the ones mentioned above. Once completing the payment period, the system is permanently unlocked and customers obtain a score from one to five on the basis of their regularity on payments making them eligible for two types of upgrade. A power upgrade consists of additional PV modules, battery capacity and appliances (cookstove, radio, satellite TV). The other upgrade option is a financial product, basically a cash loan provided to pay school fees, health insurance, agricultural and home improvements. By choosing to purchase one of these upgrades, the system re-locks and the households need to pay off the new load through the same mechanism.

Zola Electric (also known as Off Grid Electric) has to date powered 180.000 homes and businesses across Tanzania, Rwanda, Côte d'Ivoire, and Ghana, with an average growth rate of 50.000 people per month. Zola attracted many big investors such as Total, EDF, Tesla, GE Ventures, Vulcan Capital, Helios Investment Partners, and DBL Partners. In September 2018 they announced the expansion in Nigeria, the second largest off-grid marked after India.

In autumn 2018 **PP Power** tested an innovative SHS solution in Kenya and Tanzania, which stands out from the rest of startups because it promises to be widely scalable adding power capacity and energy storage as the energy needs increase.

There are several other firms – manufacturers, distributors, software developers – operating in Eastern Africa: Mobisol, Off-grid electric, d.light, Azuri, Nova Lumos, BBOXX, Fosera, Solar Now, EDF, Total, Greenlight Planet, Omnivoltaic, Smarter Grid, Easy Solar, Angaza. Some of them have already expanded to Western and Central African countries or are in the process to.

2.3.2 West Africa

The West African market is relatively untapped when compared with East African countries, mainly due to a relatively low mobile money penetration. Even though statistics show a fast-growing trend in digital payments they do not reflect the effective situation in this region: a country may seem to have a high penetration, but it is most likely limited to urban and peri-urban areas. Secondly, those first few solar PAYG experiences in West Africa highlight that customers make small, infrequent payments and are prepared to accept periods of deactivation. This payment flexibility has been one of the reasons for the great success of PAYG in East Africa but, when the payments are too irregular, PAYG operators have to face important financial challenges (LIB Solar, 2018a). Nonetheless, increasingly more firms are looking for their own way to approach this vast potential market.

The main players operating West Africa are reported below, together with key features and peculiarities of their business models.

PEG Africa leads the PAYG off-grid solar market in West Africa, through a PAYG scheme specifically tailored for Ghanaian Ivorian households which have a 3-10 daily income. The payment period is 12 months.

ARESS was the first company to introduce PAYG off-grid solutions in Benin, applied not only to SHSs but also to pico-solar lamps and larger solar systems (up to 4 kWp). In addition, they manage a wide range of energy projects such as solar pumping systems, solar street lights, and mini grids.

Easy Solar (also known as Azimuth) operates in Sierra Leone, a critical country whose access rate is declining rather than growing (passing from 12% in 2010 to 9% in 2016). They have to date brought basic electricity services to more than 50.000 people by pay-as-you-go financing and employed more than 90 people between agents and employees.

Smarter Grid International is a leading young SHS distributor in Nigeria, which in May 2017 received a seed-grant provided from GSMA with the purpose of launching mobile payments for the

PAYG off-grid solar systems in Nigeria. The ongoing project is in partnership with the mobile money operator Airtel. The company is particularly interesting because their systems can be easily upgraded to relatively high capacity, in fact besides the more traditional appliances they also offer vulcanizing machines, a powered milling machine for grains, a solar-powered salon kit-dryer, and a barber kiosk manufactured in Nigeria.

Nigeria has long been considered a difficult market for off-grid energy operators because the low rural Nigerian's average expenditure on energy (about 72$/year according to the Rural Electrification Agency) generates doubts about the market's profitability. Part of the problem is also due to the difficult business environment for startups in the country. Moreover, Nigeria has limited mobile money penetration, in fact, Nigeria's Central Bank (CBN) – threaten by the MNO's entrance in the banking system - imposed provision limitations to Mobile Network Operators (MNO) providing mobile payment service. However, in October 2018 CBN issued draft guidelines for the regulation and licensing of Payment Service Banks (Bassey, 2018) aimed at enhancing mobile money adoptions in order to expand financial inclusion. This is a good new for PAYG players and is probable that Nigeria will experience a gold rush for the electrification of its 72 million unconnected people (OOLU, 2018).

OOLU have sold since 2015 more than 35.000 PAYG solar home systems in Senegal, Mali and Burkina Faso, and in 2018 started expanding into Nigeria's USD 2 billion a year solar home system market (company's estimation). This extension has been taken on thanks to the USD 3.2 million equity funding round led by the venture capital firm Persistent Energy Capital: investors are looking at this country as a huge potential off-grid market, even recognizing the hazard of operating in such a tough and risky context.

In Nigeria, the National Solar Power Authority (**NASPA**) is the first national solar company. It makes use of pay-as-you-go through mobile phones and rechargeable cards (due to lack of popularity of mobile money in Nigeria) for their energy products and services, which include solar lanterns, DC solar home systems but also larger installations such as AC solar systems (with inverter) and mini grids. Nevertheless, it is not clear if they apply the PAYG business model to the whole range of products or just to solar lanterns and DC SHSs. In any case, the company guarantees 40% of savings on customers' current energy bill, coming from the replacement of kerosene for lanterns, or petrol and diesel for generators. Its strategic partnership with Globalcom, Airtel, Paga and Gtb is going to be a key factor to encourage the use of mobile payments and solar systems through a bottom-up approach.

Liberia has an untapped potential, whit 97% of the rural population lacking access to electricity and apparently, no off-grid solar companies currently have already started using PAYG approach. **LIB Solar** - a Liberian off-grid solar company - explains why the model is encountering difficulties to take root here (LIB Solar, 2018b) : besides a low mobile money penetration, the company points out that user interfaces of the widely used PAYG software platforms (e.g. Angaza, Solaris Offgrid, Mobisol) are too difficult to use for Liberian field agents and users, and create confusion among them. Therefore, LIB Solar built a business model based on behavioural economics research, which focuses

on rural communities' ability to collect payments and perform basic maintenance by themselves. It created its own software based on chat interfaces, which is much more familiar to digital illiterates.

2.4 Explanation of the Pay-As-You-Go business model

Pay-as-you-go (PAYG) is a consumer financing approach increasingly used in SSA for a wide range of products and services, which is capable to reduce the upfront cost of off-grid solar systems. The great advantage is that users can decide to interrupt their payments with no additional fees: in fact, the systems get automatically locked when payments are delayed until the further payment. This flexibility is extremely important for low-income rural households since they usually have discontinuous incomes rather than a monthly salary: they can simply suspend the payments when they face hard times, such as droughts in the case of farmers, and start again when they rise up.

Two consumer financing schemes

The *lease-to-own* financing model is the most used approach: after an initial down payment - key to give a sense of responsibility and carefulness – the transfer of ownership is completed by ongoing payments made over a negotiated amount of time, through a flexible payment plan.

This model turns PAYG companies into real financial services providers, arising the need for portfolio management, customer's risk assessment, consistent fundraising; all these financing costs are charged on the end-user (USAID, 2018), in fact, the total overall cost at the end of the payment period is on average 20-40% higher compared to the single cash payment solutions (Lighting Global, 2018a).

The size of installments is identified by a trade-off between customers' availability to pay and the level of revenues needed to sustain the company's financial structure. In any case, the instalments should always be lower than the household's expenditure on existing alternatives, and this represents a key challenge for further business expansions in high-risk locations where incomes are low and significantly fluctuating. The initial down payment serves as a deposit and is generally a 5-15% of the system's overall cost, while the payment period - ranging from a few months up to 10 years – also on the availability to pay and the specific characteristics of the target market.

The *energy-as-a-service* financing is a perpetual lease model, similar to traditional utility services: customers pay an ongoing usage fee without the perspective of owning the device. The model is designed to overcome the customer's fears of breaking and obsolescence; additional appliances and upgrades are provided for free as technology progress goes on, according to the idea to guarantee an energy service rather than an electric device. This model improves affordability as fees are lower than the installments in the lease-to-own case, and also reduces the financial risk of default as the service can be temporary suspended or interrupted in case of insolvency (USAID, 2018). The drawback is that at no point the customer owns the system. Few companies such as Off Grid Electric, Nova-Lumos, and Devergy (PAYG microgrids) adopted this model.

According to country regulations and the availability of GSM network coverage, off-grid companies offer payment mechanisms based on mobile money (full connectivity) or agent-based (off-network) models making use of scratch-cards and local agents to collect payments. There is also a third way which consists in intermittently connected systems. Each of them is illustrated in detail below.

Fully connected payment model

The on-network model is the most appropriate payment mechanism where the GSM network coverage is good enough and the regulation environment permits Mobile Network Operators to deliver mobile money services. It is currently adopted by most of the companies in SSA.

Systems are equipped with a SIM card enabling a GSM (2G) two-way communication between the PAYG provider, retailers and end-users (Figure 24). The machine-to-machine technology (M2M) technology enable data exchanging and real-time monitoring and control of the system. Customers make instant payments through a telecom-backed mobile money platform (e.g. M-PESA, MTN MOBILE MONEY, ORANGE MONEY, TIGO CASH) or a bank-backed one (e.g. MasterPass); when the payment is received by the PAYG provider the system is automatically unlocked thanks to the M2M service, and the device remain unlocked for a certain amount of time depending on the payment size (Alstone et al., 2015).

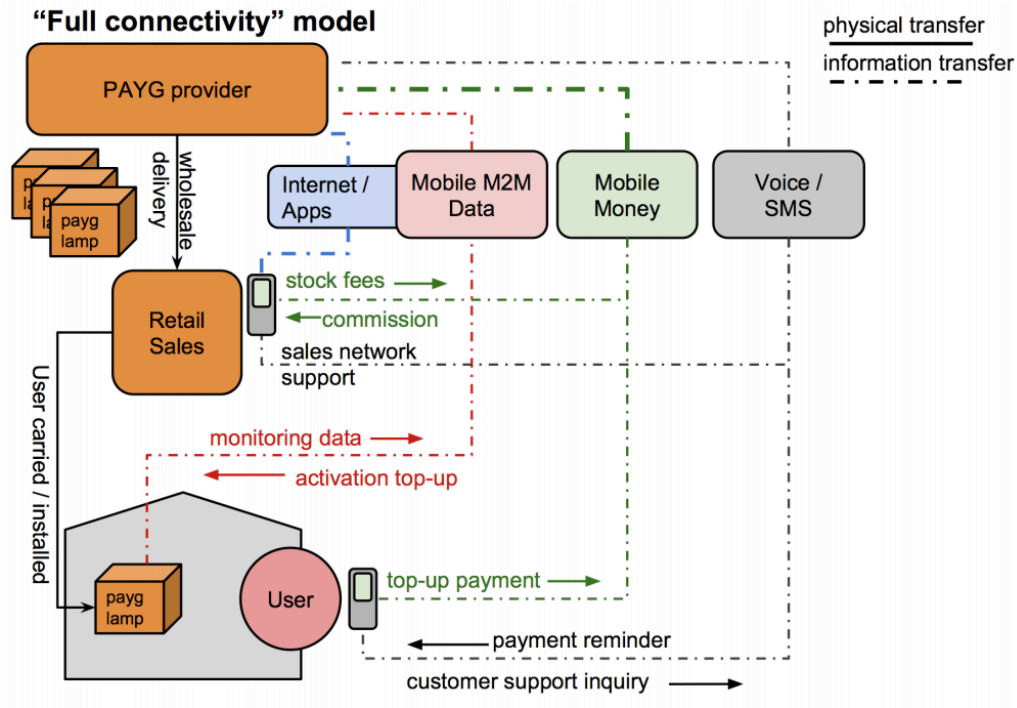


Figure 24: Process flow diagram for the on-network model - Source: (Alstone et al., 2015)

Off-network payment model

This is an alternative PAYG model designed by off-grid solar companies for the areas with insufficient mobile network coverage or low mobile money penetration. In this case the device is not embedded with the M2M connectivity module, so it does not require a mobile network coverage to be activated, but remote monitoring and control is no longer possible, as well as product performance and customer usage data transmission (Figure 25). Customers have three ways to pay the installments and activate their SHS:

1) They pay in cash for a scratch-card in an authorized retail shop, and send the scratch-card number via SMS to an automated system. "That system verifies the scratch-card number, matches the payment to a customer account, and sends back a unique unlock code for entry on a keypad connected to the solar device. An onboard microprocessor in the solar device

recognizes valid unlock codes and independently tracks progress towards full repayment" (Alstone et al., 2015).

2) Obtaining the unlock code to type on the keypad directly from the retail shop staff, who use a mobile phone to generate the unlock code for them.
3) It is still possible to pay by mobile money rather than buy scratch-cards, receiving the unlock code by SMS from the automated system.

Two main issues of this model are the higher cost charged on the end-user due to the distribution network management, and the lack of retailers in remote areas. In fact, some rural customers need to walk many kilometers every time they want to make a payment, and this may induce many of them to stop paying.

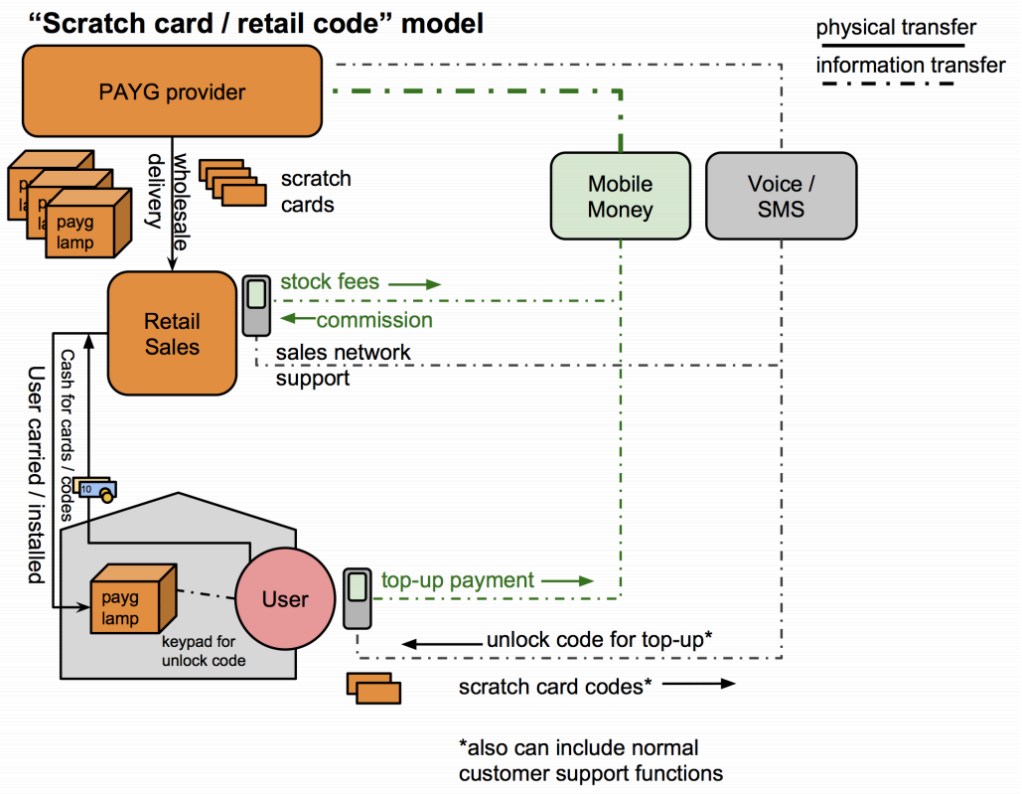


Figure 25: Process flow diagram for the off-network model - Source: (Alstone et al., 2015)

Intermittent-network payment model

This third option – shown in Figure 26 - is a hybrid between the ones previously illustrated. The device is not connected to the mobile network, so GSM coverage is not required. Customers make cash payments to specialized field agents who connect and unlock their systems through a cable, Bluetooth, or entering a code received via SMS (USAID, 2018). Usage and monitoring data keep stored in the SHS and are transmitted to the company's server whenever it is connected by some agent. This model maintain the possibility to make payments by mobile money (Alstone et al., 2015).

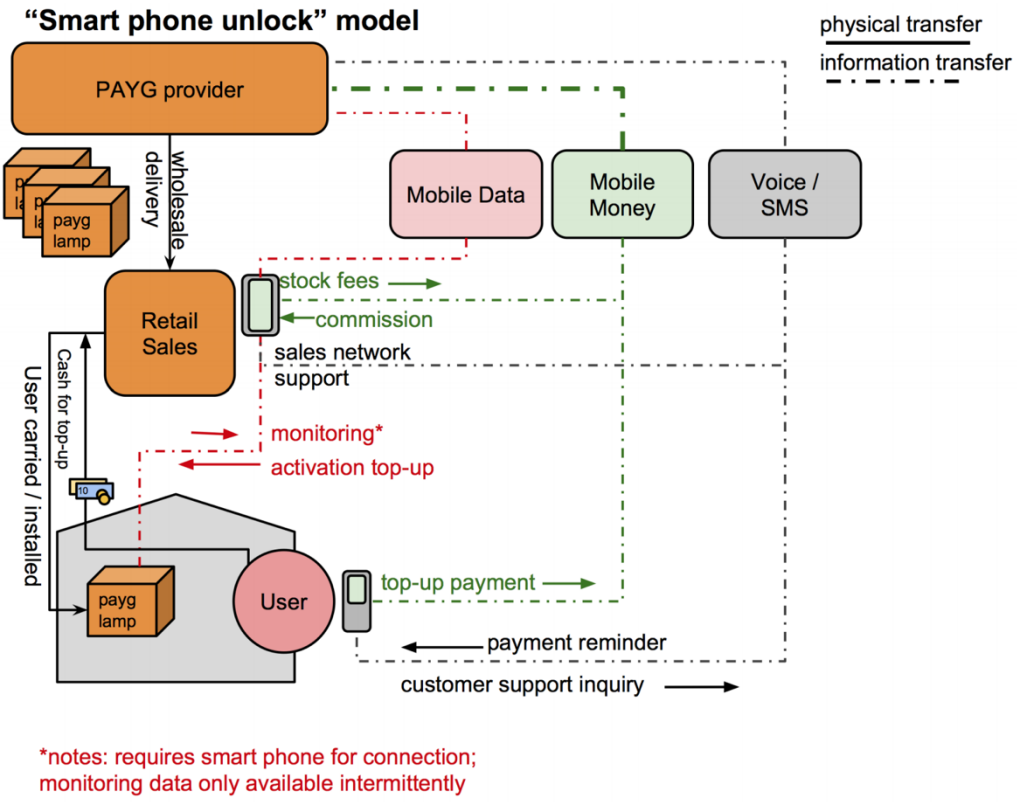


Figure 26: Process flow diagram for the intermittent-network model - Source: (Alstone et al., 2015)

Alternative payment channels

The currently used PAYG model was born in East Africa and designed for this region, and it seems not working out so well in West Africa. To tackle this problem, alternatives to the mobile money channels provided by telecommunication companies are being explored today(USAID, 2018). For example, M-KOPA has established a partnership with MasterCard to create a new payment channel through the Masterpass QR technology, which promises to scale the off-grid business across Africa and overcome additional technology investments. The technology will also connect with MNOs in order to improve the system interoperability and resilience. Mastercard want to extend it to other utilities like water and gas (Moloi, 2018).

Business model based on Mastercard's infrastructure

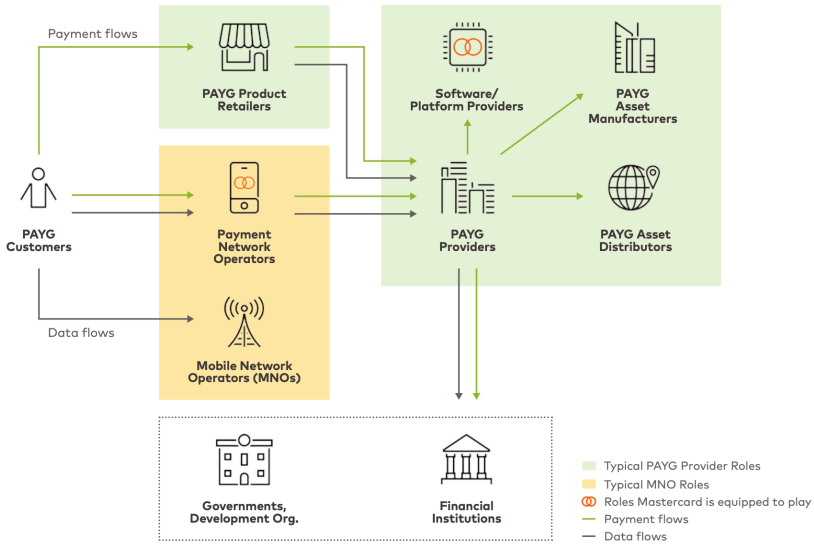


Figure 27: Mastercard developed an infrastructure to facilitate payments, alternative to Mobile Network Operators. – Source: (Mastercard, 2018)

Key success factors

Lessons learned from the SHS electrification programmes in East Asia show that successful ones are those making demonstration, promotional activities and have robust marketing, especially for PAYG systems which are more complex to understand and use. Promoting **community participation** and ownership is also key to success (Sovacool, 2018).

Distribution is for sure the most complex issue but the point is, SHS distributors managed to create the most capillary distribution network in rural East Africa, penetrating to the very remote villages where consumer goods have never arrived. The strength of these companies lies in their solid network of field agents and retailers, which have been possible thanks to the **digitalization of Customer Relationship Management** (CRM). The most successful example is provided by M-KOPA, counting as of 2017 with 165.000 M-PESA mobile money agents spread across the Kenyan provinces (USAID, 2018).

PAYG platforms now integrate apps to schedule field agents' daily tasks in order to provide a fast customer service, repairing, but also to address sales and collect precious usage data about villages and customers. A huge amount of data is collected and analysed and used for business optimization.

The innovating business model introduced by solar home systems is an example of how digitalization can **promote the access to finance** to unbanked people; it makes consumer finance easier and accessible than other traditional ways such as banks and, most importantly, does not require a credit history as collateral. In addition, it encourages customers to pay on a regular basis in order to obtain positive credit scores and thus get access to a variety of other services or products.

Mobile money has a big penetration in many countries of the region, even the poorest ones: it is not unusual to see people living without electricity but owning a mobile phone. Phone companies like M-PESA, in fact, offer payment services linked to a mobile phone account, without the need for opening a bank account. In countries such as Kenya, Rwanda, Tanzania and Uganda, 66% of adults routinely use mobile phones to pay bills, exchange money, receive salaries, pay for goods with merchants and other suppliers (GSMA, 2017b).

Ghana, South Africa and Kenya have the most developed environment for digital payments, but also the highest electricity access rate. For obvious reasons, this technology has the maximum potential impact in countries with high mobile money penetration and low rural electricity access rates, such as Uganda, Tanzania, Rwanda, Zimbabwe and others. For the identification of the most and least suitable countries for the application of PAYG energy access solutions, see Figure 28.

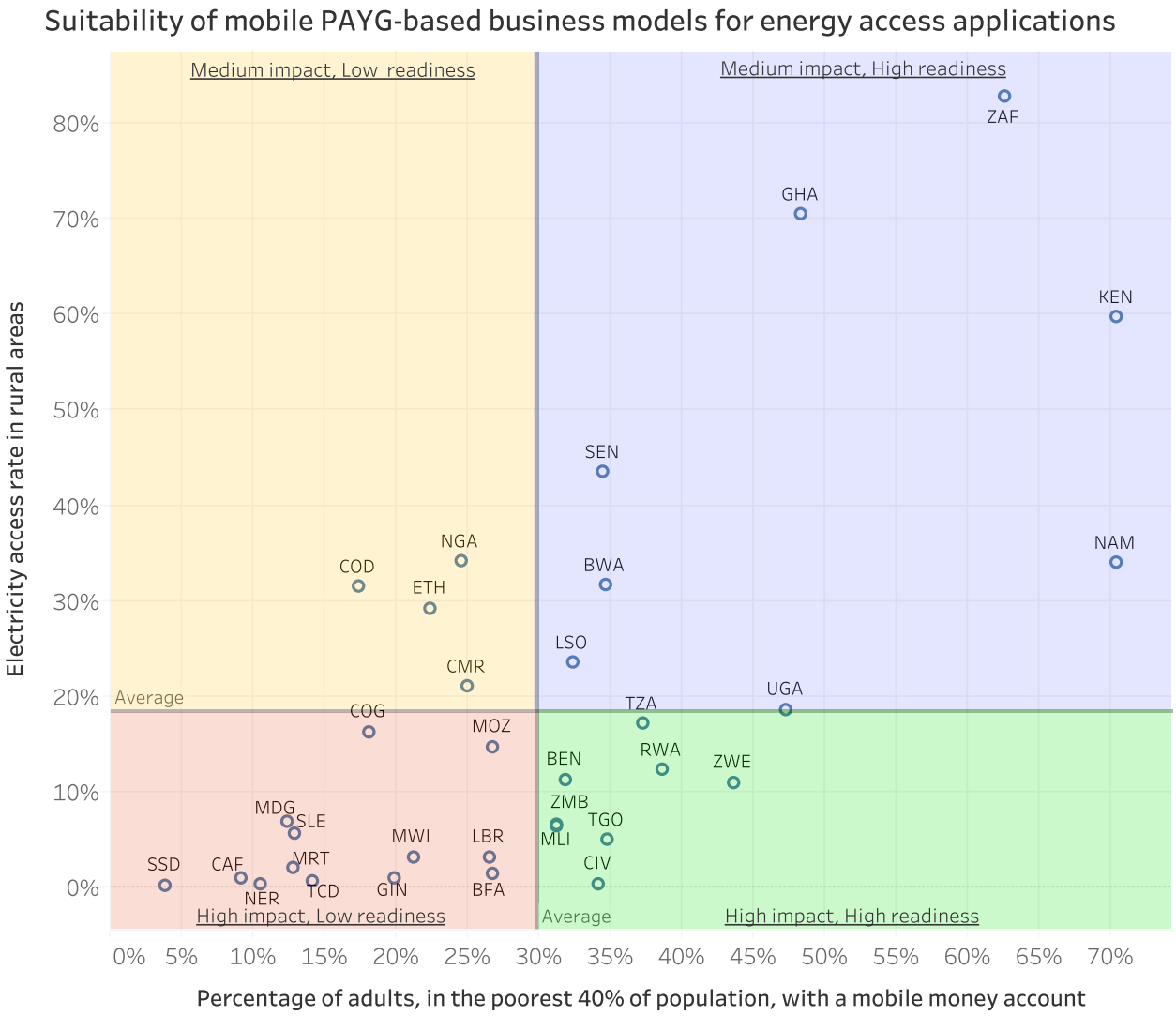


Figure 28: In this graph are identified the most suitable (green quadrant) and least suitable countries (orange quadrant) for PAYG energy access solutions, according to technological readiness and the potential impact. Countries in the red quarter still have poor adoption of mobile money resulting less attractive to business developers. Those in the blue quadrant are technologically mature markets, although the market potential is relatively minor than in other countries. - Author's elaboration based on IEA Energy Access Database (2017) and the Global Findex Database (2017)

2.5 PAYG applications go beyond Solar Home Systems

2.5.1 Clean cooking solutions

Energy access does not concerns only electricity; many efforts are being made in electrification, but still 80% of the population in SSA rely on the traditional use of solid biomass to cook their meals (IEA, 2018). Access to clean cooking has lagged behind as it is a much more complex issue to solve. Household air pollution from solid fuels kills every year about half a million people in SSA, which is an alarming data if compared with the 783.000 deaths from HIV (IHME, 2018). Of them, 213.000 are concentrated in Nigeria, Ethiopia, Democratic Republic of Congo and Tanzania, where the effects are more severe. Solid biomass, together with kerosene and candles are the most utilized fuels for cooking and lighting. According to the World Health Organization, they are extremely injurious to health since they cause poisoning, respiratory diseases and cataracts. In addition, children and women spend an average of 1.4 hours/day collecting traditional fuels, valuable time that could be better used for education and income generation.

LPG represents a modern fuel that could potentially save many lives, however, only 7% of SSA's population make use of it today (IEA, 2017) and its large deployment seems far from reality in most of the African countries. There is a high cost barrier due to the initial expenses for the first cylinder, LPG stoves, gas regulator etc. This fuel is not more expensive than kerosene and charcoal, but so it is perceived because buying and refilling cylinders have an upfront cost that is too high for most of the people, since they do not have such amounts of disposable cash.
Moreover, move heavy cylinders is challenging for rural households living far from the distribution sites; it is not uncommon to see women carrying LPG cylinders on their back for many kilometres. That is due to poor distribution networks in remote areas, and even in some urban centres. Another barrier is the absence of governmental subsidies that, together with a lacking appropriate supply chain, are hampering factors for the uptake of LPG.

In this landscape, PAYG companies are trying to penetrate the market by bringing innovations aimed at solving: 1) the affordability issue for clean cooking solutions; 2) the problem related to the distribution across remote areas. The current market options include:

a) Improved biomass or LPG cookstoves deployed as add-on products for PAYG off-grid solar customers, paid through an extension of their on-going payment plan. The cost barrier (stoves are retailed at around $100) can be easily overcome thanks to the PAYG financing. "Stoves are being sold as top-up loans through pay-as-you-go solar arrangements, paid in installments through existing mobile payment plans, giving the distributor additional leverage to ensure payments are received on time", but only companies have had limited results in using this channel (Winrock International, 2017).
b) Some companies provide charcoal/pellet supply to households to run their improved biomass cookstoves on a pay-as-you-go basis, thanks to a fully digitalized supply chain. That is a potential solution of buying fuel in bulks, but few companies have been piloted this solution so far.
c) Pay-As-You-Cook LPG systems, using M2M-connected smart meters on top of gas cylinders to provide an affordable supply of LPG for cooking. This solution has recently experienced interesting developments and investments, thus it will be analysed in more detail below.

The Kenyan company **PayGo Energy** developed a pay-as-you-go smart metering system locked on top of the LPG cylinders which makes LPG access affordable and easy to use. The hardware consists basically in an industrial IoT smart valve enabling customers to pre-pay for small amounts of gas over time according to their availability to pay (Global Innovation Fund, 2017). This system removes the cost barriers of buying fuel in bulk, as customers pay just USD 0,50 per day for cooking-as-a-service. The distribution issue is also overcome as specialized staff proactively visit the households to change the cylinders before they run out, providing uninterrupted supply (PayGo Energy, 2018); a logistics system adapted to informal settlements made it possible.

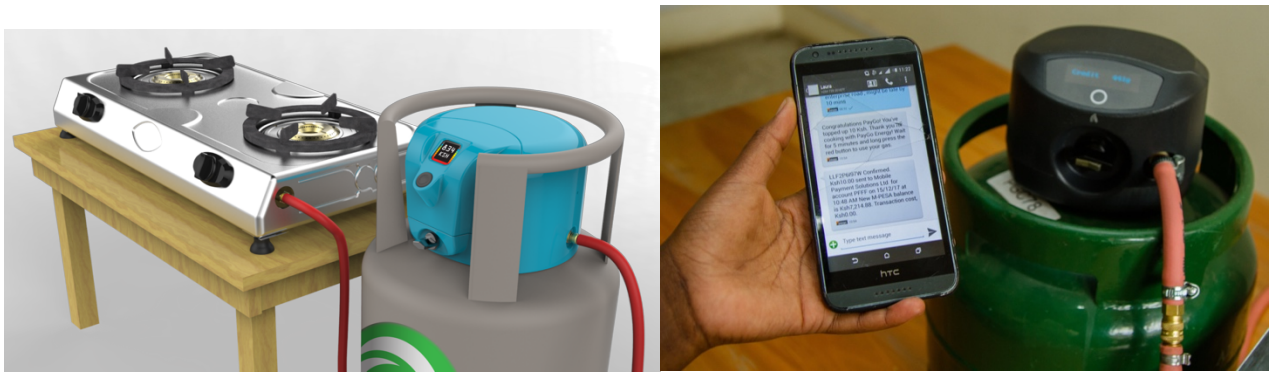


Figure 29: Pay-as-you-go LPG smart meters – Sources: PayGo Energy

KopaGas developed a very similar service in Tanzania making use of M2M technology and mobile money. The company started its business in Tanzania because of the large opportunity market, fairly good GSM infrastructure and favourable business environment for startups. In fact, in the country "investing in a gas cylinder, stove and accessories represents a USD 60 to 100 investment, the equivalent of 20 to 30 days of income for a household living on less than USD 3.10 per person per day, and the refilling costs for a full cylinder represent an additional seven to 15 days of income" (GSMA, 2018a). Adopting the smart valve system customers pay as little as USD 0,45 per day to get the LPG uninterrupted supply at home, plus USD 4.50 for the registration and USD 9 for the stove. 96% of customers save an average of USD 11,7 per month (half of them earn less than 90 USD per month) and the impact is higher for those running a cooking business.
The business model is still in its early stage, needing further improvements in: 1) improving M2M connectivity reducing costs and extending battery life; 2) more intuitive user interface; 3) provide stoves with multiple burners and the ability to use LPG for other uses such as baking or grilling; 4) extend the partnership with other mobile money operators for those customers who do not use M-PESA; 5) addressing the needs of cooking businesses (GSMA, 2018a).

In 2017 **Koko Networks** started mass production of an ethanol cooking solution launching its first network in Nairobi. A fully-digitalized distribution network is made by e-commerce kiosks, similar to ATMs, placed in small neighbourhood shops, where customers can buy a modern ethanol cookstove in instalments and refill their small ethanol canisters by using mobile money (Clean Cooking Alliance, 2017) . It may be a potential alternative to LPG if the company's current expansion strategy will show to be successful.

Envirofit offer the same kind of technology-based business model across both East and West Africa.

Mature PAYG SHS providers such as **BBOXX** recognised the potential of LPG and biogas cooking stoves available on a pay-as-you-go basis, and are currently developing their own in-house solutions.

2.5.2 Mini-grids

Innovative energy start-ups such as Devergy (Tanzania), Powerhive (Kenya) and SharedSolar (Senegal and Mail) and others have long been building affordable pre-pay mini-grids on a pay-as-you-go basis.

Devergy have electrified over 1.266 households and businesses through pay-as-you-go DC mini-grids across Tanzania and Ghana. "When connecting a new village, Devergy installs solar panels and batteries and a meter in the home or small business (usually one solar tripod for 5–10 houses). Software developed in-house allows for remote monitoring and control of electricity use in each home. Customers top up using prepaid cards"(World Bank, 2015). After paying a small installation fee – ranging from USD 6 to 12 – customers can choose to top up their credit by fixed daily, weekly, monthly payments, or truly PAYG mechanism. It represents a notable step forward if compared to a government-led mini-grid connection, or the grid connection performed by TANESCO[6], whose cost is around USD 250 (USAID, 2017).

Powerhive have delivered bigger AC mini-grids in Kenya using a very similar approach. Customers use their mobile money account to add credit to their account, and receive a text message when their credit is running low; after any payment the power supply is immediately unlocked; the in-house platform manages assets, provides real-time data and analytics (World Bank, 2015).

SharedSolar is another mini-grids provider operating in Mali and Senegal, which offers a PAYG payment plan through local agents.

In 2017, Electricité de Madagascar together with Sagemcom (technology provider) and Telma (telecom provider) started a program aimed at building solar hybrid mini-grids using Telma telecom stations as anchor loads. The projects will bring electricity to the nearby off-grid villages, whose households will use smart-metering and mobile money to pay the energy used. Operation costs for the telecom company will be lower and the mini-grid operator itself will gain a faster pay-back due to a better usage of solar energy (Sarin, 2018)

3 SWOT analysis of PAYG Solar Home Systems

In this section the main strengths, opportunities, weaknesses and threats of PAYG solar home systems will be analysed, from the perspective of both end-users and businesses. They come from the analysis of successful experiences of start-ups and electrification programmes, failed projects and previous studies. The key points are resumed in the tables below and thereafter discussed in more detail.

Strengths and opportunities of PAYG Solar Home Systems	
End-users	Companies
1) Improved education 2) Affordability	1) Market opportunity: a) Increasing mobile money adoption

[6] Tanzania Electric Supply Company

3) Increased savings otherwise spent on candles, kerosene or batteries 4) Increased purchasing power after the unlimited unlocking of the device 5) Economic opportunities: a) Better productivity due to the extension of working-hours b) Increased revenues c) Unlock more economic activities d) Help to get a new job 6) Positive credit score and new financing opportunities if payments are completed successfully 7) Remote monitoring and control 8) Improved health 9) Improved safety and security 10) Emissions reduction 11) Employment opportunities and capacity building 12) Ease of use	b) Increasing number of PAYG platforms providers c) Untapped countries d) Large potential market 2) Funders' willingness to invest 3) Solar panels, LEDs and batteries are getting cheaper 4) Security

Weaknesses and Threats of PAYG Solar Home Systems	
End-users	Companies
1) Limited level of service compared to alternatives 2) Quality of products 3) Exclusion from the electrification programs 4) Pure entertainment use over a sustainable economic development 5) High price due to high costs of financing 6) Risk of customers' over-indebtedness 7) Lack of digital literacy	1) Slow expansion process of distribution networks 2) Households are comfortable with stop paying and go without electricity 3) High capital expenditure and management costs Untapped countries 4) Funding availability 5) Small PAYG providers cannot compete with big players 6) Low-margin business

8) Need to own a mobile phone, or to live near a local agent 9) Companies might tend to "follow the money" 10) Vulnerable to vandalization and robbery 11) Privacy concerns about customer's behavioural data 12) SHS may become obsolete when the grid comes	7) Mobile money regulation 8) Solar off-grid market regulation and governmental policies

3.1 Strengths and opportunities: end-user perspective

Improved education. Clean, safe and affordable energy services delivered by solar home systems provide a better quality of life. Extended study hours in the evening improve children's education: Zola electric's customers report, on average, 149% increase in their children's quality of study. A study made by GOGLA found that 84% of households with children report an extension of time to do their homework. Furthermore, SHSs enables social activities at evening as lighted houses tend to be social gathering places in rural villages.

Affordability. Interviews to the main operators in the off-grid solar sector made clear that the high upfront cost for low-income households is a key barrier for the penetration of their technologies. PAYG overcomes the down-stream financing issue direct to consumers, through tailored payment plans. The initial down-payment reflects the target customer's income, and the instalments are designed to be less than or equal to the amount of money spent on alternatives for the same level of energy service. Furthermore, the payment plan's flexibility solves the problem of seasonal incomes which is very common among African off-grid households.

Increased savings otherwise spent on candles, kerosene or batteries. People who are currently off the grid in SSA spend a huge amount of money on lighting alternatives, mostly batteries for torch lights, kerosene, and candles. Off-grid households of Mauritania, Chad, Sudan, Rwanda, Kenya, Nigeria, Tanzania, Ghana and Uganda spend between 150 and 300 USD a year just for lighting and charging mobile phones (Figure 30). It is comparable with the total annualized cost (including financing costs) of a SHS providing the same services (60-250 USD). "M-KOPA estimates a customer saves about USD 750 over the first four years by switching to its basic solar kit" (Faris, 2015). They state that, as of January 2018, they had provided basic access to solar power to 600.000 households, which means a total of USD 450M customers' savings in expenditures for buying kerosene.

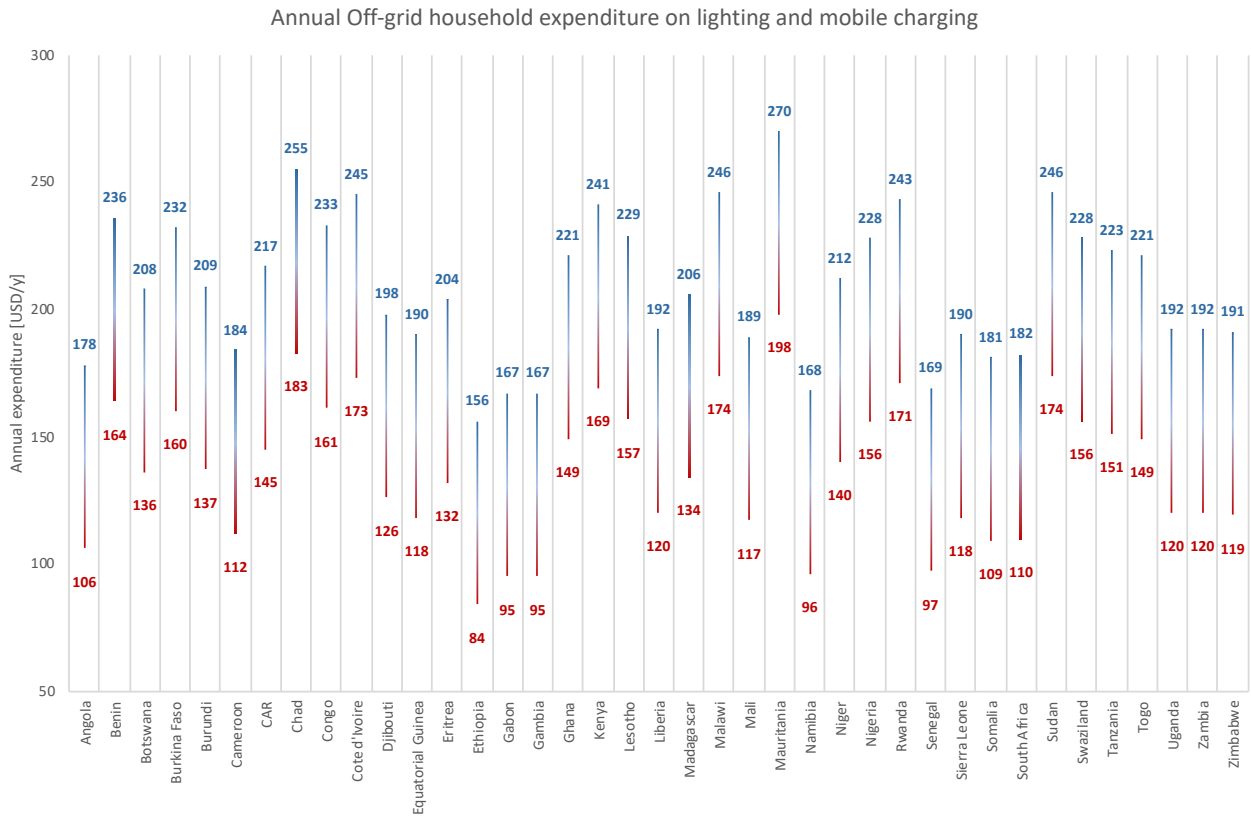


Figure 30: Annual off-grid household expenditure on traditional lighting sources (e.g., kerosene, batteries, candles, etc.) and mobile charging – Data source: (IRENA, 2016)

Pioneering companies realized at the early stage of their activity that a certain amount of down payment as an initial deposit makes the customer feel a sense of ownership and responsibility for the equipment. Though, the amount of money paid as deposit needs to be carefully evaluated for different countries. The size of instalments shall take into account the average amount of money spent by off-grid households for buying kerosene or candles, their budget and willingness to pay (Rolffs, P., Byrne, R. and Ockwell, D., 2014).

An analysis preformed in the Kenyan market – whose results are reported in Figure 31 – suggests that this principle is verified for basic lighting (3 to 4 light points; power capacity <80Wp); bigger systems result instead more expensive than the average household expenditure on lighting and phone charging, especially those coming with a TV or other additional features.

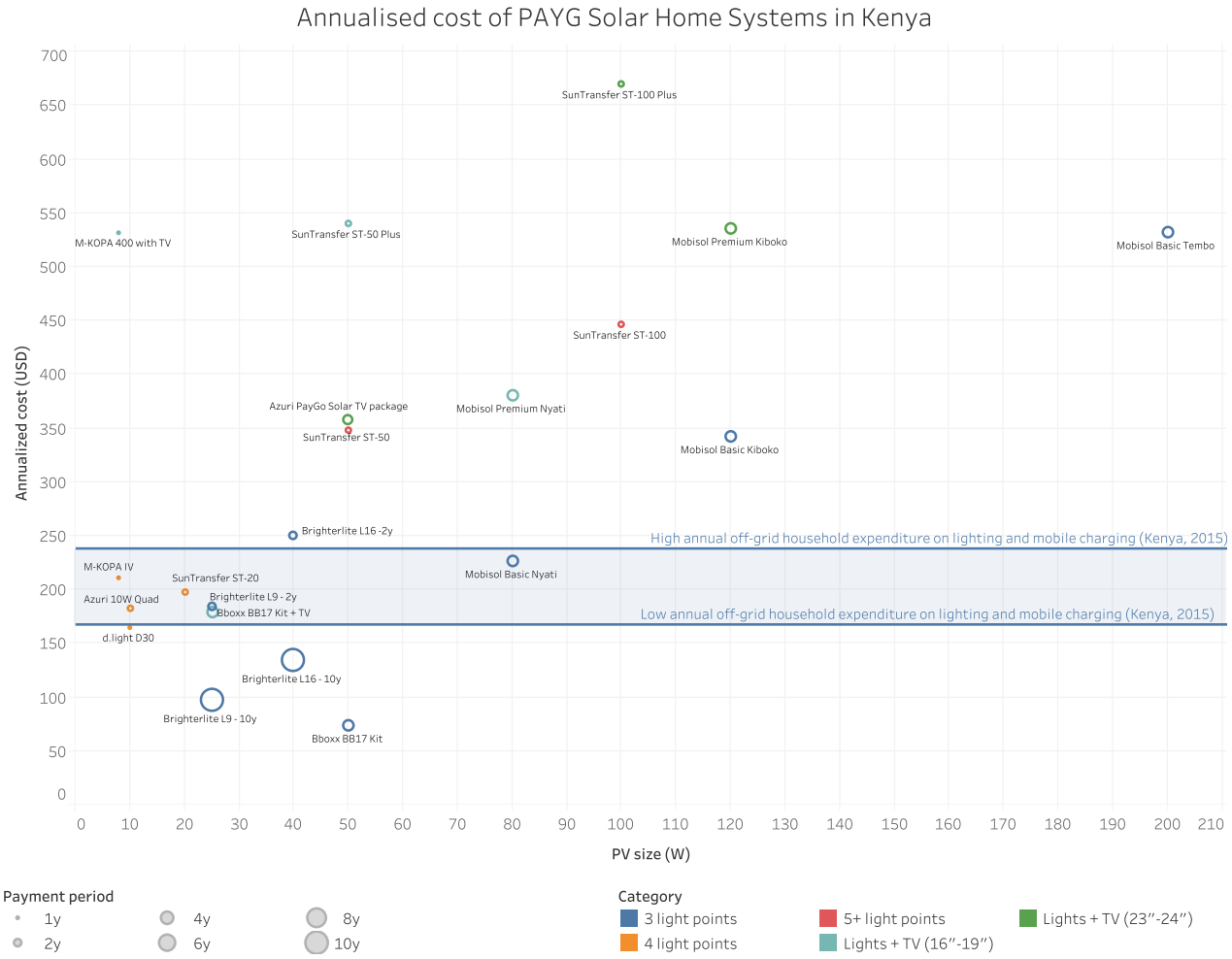


Figure 31: A The figure shows how the annualized cost[7] of SHSs depends on the power capacity, the appliances included and also the payment period (longer periods affect negatively the PAYG financing costs). Most of the SHSs available in the Kenyan market are cheaper than the average expenditure on lighting and mobile charging, except for bigger systems which go well beyond simple lighting – Source: author's elaboration on a web-based market analysis.

Increased purchasing power after the unlimited unlocking of the device. Once the payment plan is concluded, the customer owns the device (only with the rent-to-own approach), which implies he will have an increased purchasing power. It is clear that this is not true for poor-quality devices which are most likely to break after the expiration of the guarantee, and also if there is there is a lack of committed after-sales service: these two factors are essential to ensure sustainability.

Fairly improved economic development (better productivity due to the extension of working-hours; increased revenues; more economic activities undertaken; help to get a new job). Lighting and the possibility to use a mobile phone also mean better productivity at work, especially for in-home workers and self-employed people. Azuri – a solar PAYG pioneering company – claims that 86% of users have been able to work more since installing their SHS.
A recent study about SHS's economic impact has been conducted in East Africa, revealing that 36% of households already generate more incomes (nearly +35 USD/month on average) after three months

[7] The annualized cost has been calculated dividing to the overall cost (initial down payment plus the instalments) by the payment period.

of the solar system's installation. In addition, 44% of customers spend more time at work as they have more light hours, and 58% unlock more economic activities within three months, whether enhancing an existing business, starting a new one (the most common is phone charging service), or enabling a household member to get a new job (GOGLA, 2018c).
Another study (see Figure 32) found that 466.000 have undertaken more economic activity thanks to SHSs[8], 196.000 use SHSs to support enterprises[9] and 338.000 spend more time working (GOGLA, 2018b).

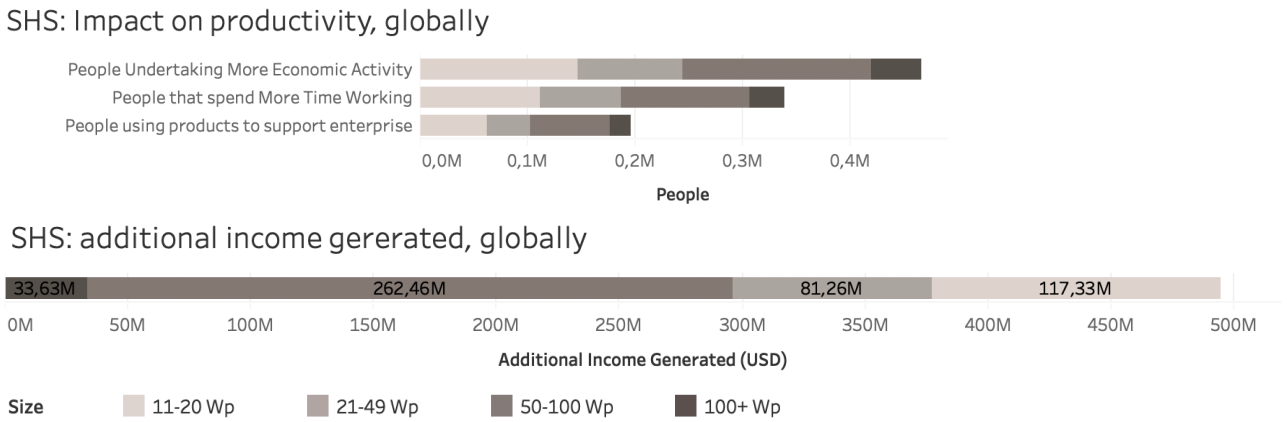


Figure 32: Global impact of solar home systems on productivity and revenues. High-capacity systems seem to have a smaller impact compared to the smaller ones, but it is due the smaller sales volume - Data refers only to products sold by members affiliated with the Global Off-Grid Lighting Association, and are calculated through the "Standardized Impact Metrics for the Off-Grid Solar Energy Sector" framework - Author's elaboration on GOGLA (2018)

Mobisol realized that a large part of their customers started generating income by charging other people's mobile devices as-a-service, so they included a multiple mobile phone-charging hub in their offer. Useful DC super-efficient appliances (e.g. refrigerator, barber box, sewing machine, solar pump, mill etc.) have a substantially higher impact on revenues, although they are still a niche market and they have not reached scale yet.
Field experiences reveal that there SHSs can foster economic development only if accompanied with tailored educational programmes aimed at inciting people to use electricity for productive uses.

Positive credit score and new financing opportunities if payments are completed successfully. Companies offer the possibility to re-finance additional products or services through top-up loans attached to the payment plan. They receive a credit score according to the regularity and continuity of payments, which makes them suitable for a range of products (bigger system, appliances, consumer goods, etc.) and services (cash loans for different purposes, insurances, etc.). It represents a first step towards the financial inclusion of unbanked people, as it proofs their ability to pay off a debt with a certain regularity.
PEG – a leader PAYG SHS provider in West Africa – offer to customers who pay on time free hospitalization insurance, possible thanks to a partnership with the microinsurance companies BIMA and PRUDENTIAL. It is an example of win-win cross-sector collaboration, bringing a new untapped

[8] The impact study only considers customers using SHSs sold by companies affiliated with GOGLA; the real number could be much higher due to non-tracked products.
[9] e.g. charging phones for a fee or running a business at night.

market to insurance companies and solving at the same time the issue of irregular payments of PEG's customers: in fact, one of the top reasons why they couldn't pay on time was that they had some unexpected health expense (Ola, 2017).
Other companies such as Fenix International provide a range of services to customers with high credit rating, offering health insurances and loans for expenditures intended to agriculture, home improvement and school fees. Cash loans benefit from lower interest rates, because the perceived insolvency risk of customers who have already completed a PAYG payment plan is much lower.
Thanks to multiple partnerships with several suppliers, PAYG off-grid companies also provide financing for consumer products, acting as retailers in rural areas. In fact, they take advantage of their robust distribution network and customer base, to sell every kind of products where the normal distribution channel finds its geographical and logistic barriers.

Improved health. According to a study performed by GOGLA in East Africa, 91% of households state their health has improved since they purchased a SHS and stopped using kerosene lamps (GOGLA, 2018c).
A survey conducted in Uganda reveals that 95% of respondents perceived health benefits from improved air quality thanks to the introduction of solar home systems: the most frequently perceived improvements are, in order, fewer eye problems, fewer burns, less smoke poisoning, sleep better at night, fewer respiratory problems, fewer diseases caused by rats/pests and better cognition/less dizziness (Graham and Tevosyan, 2018). In the case of solar lanterns 87% of clients cited at least one of these improvements, while only 70% of cookstove users experienced better health (the study also reveals that "the majority of poor, rural households perceived no health benefits from their cookstoves" because "customers in this segment are struggling with adoption issues; as a result, they have either abandoned their cookstove or are using it infrequently").
Anyway, the uptake of clean cooking solutions on a pay-as-you-go basis would have a significantly higher impact on people's health as compared to SHSs.

Improved safety and security. More than 90% of households perceive a better sense of safety thanks to the SHS (GOGLA, 2018c), due to:

- Safety: Reduction in fire accidents and injuries related to kerosene/candle burns and; reduced fallings in the dark.
- Security: In rural Tanzania people want electricity primarily to have an external light at night as it gives them a sense of better protection, warding off thieves, attackers and wild animals.

Emissions reduction. The contribution on reducing in a significant way the carbon emission from biomass or kerosene is quite controversial. According to the M-KOPA's website, they have avoided 780 kt of CO_2 (based upon 1.3 tons of CO2 reduced per M-KOPA Solar system over 4 years). This number seems to be an exaggeration if it is compared with data published by GOGLA[10], according to which the CO_2 emissions avoided by the use of solar home systems sold all over the world are around 2,6 Mton (Figure 33).

[10] CO2 avoided has been calculated through the "Standardized Impact Metrics for the Off-Grid Solar Energy Sector" framework. The impact study only considers customers using SHSs sold by companies affiliated with GOGLA; the real number could be much higher due to non-tracked products.

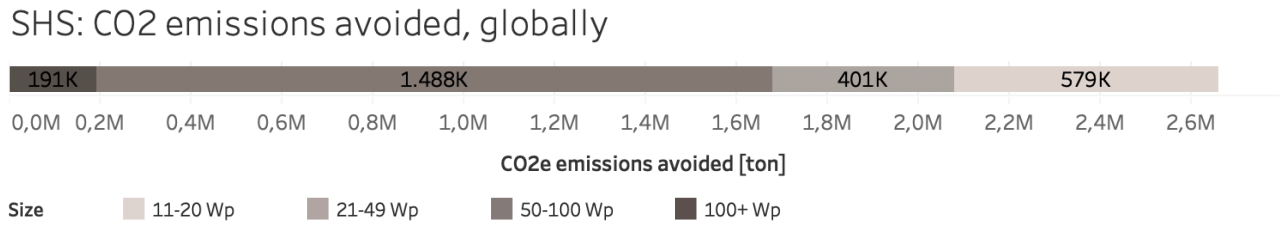


Figure 33: Solar home systems globally sold to date contributed to avoid the emission of 2,66 million tonnes of CO_2 equivalent. Data refers only to the products sold by members affiliated with the Global Off-Grid Lighting Association, and are calculated through the "Standardized Impact Metrics for the Off-Grid Solar Energy Sector" framework - Author's elaboration on GOGLA (2018)

In any case, even though SHS's direct impact on CO_2 emissions will not be significant in the short term (LIB Solar, 2018c), a secondary effect is that their deployment is raising people's awareness on the climate challenge and the importance of using renewable energy over fossil fuels; as a result we may be assisting to the rising of a better-informed society, incline to making responsible decisions during their future development.

Employment opportunities and capacity building

A briefing note by Vivid Economics and GOGLA estimates the current off-grid solar jobs in East Africa to rise from 77.000 to 350.000 in 2022 (Vivid Economics and GOGLA, 2018). Compared to the traditional cash sales, the PAYG model requires more customer support, technicians / maintenance profiles and customer support; on the other hand, less managers sales and distribution are needed (Figure 34).

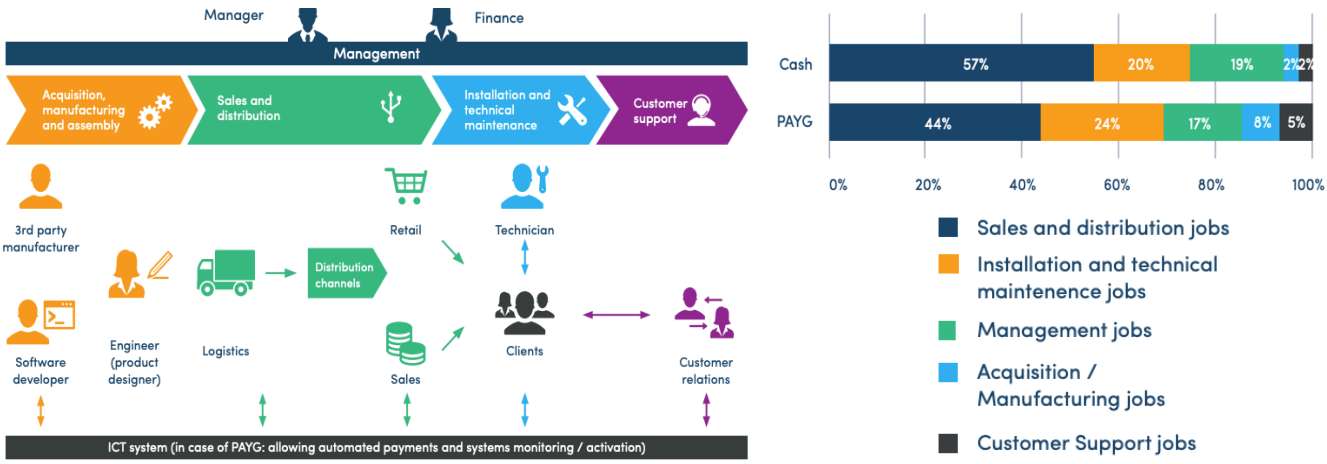


Figure 34: Different jobs created across the value chain (left) and estimates of the employment split by job types (right) – Source: (Vivid Economics and GOGLA, 2018).

The Lighting Africa/Ethiopia program, implemented by IFC, shown the powerful impact of capacity building for the business development of off-grid energy companies. Thanks to nine three-day training, 300 participating Small and Medium Enterprises (SMEs) gained skills about financing their activity, marketing, sales and distribution options, business models and product quality. The result was that a few months later, the participating SMEs had increased their sales volume by almost four-fold (Lighting Global, 2018b). This the perfect case to show how people's technological capability is another key aspect for the expansion of the energy access through digitalization.

Zola Electric created the "Zola Electric Academy" recruitment and training program, adding over 40 local employers per month to their workforce, across Tanzania, Rwanda, Côte d'Ivoire, and Ghana.

Ease of use

Some customers show to even prefer to have stand-alone solutions because they empirically understand how much energy they can use per day (in only depends on to the battery and solar module's capacity). If connected to the national or a mini-grid, people need to learn to "think in kWh" in order to buy the prepaid amount of energy they need, and that has been shown to be a great barrier.

3.2 Strengths and opportunities: business perspective

Increasing mobile money adoption. Mobile payments are experiencing a very fast-growing penetration in many Sub-Saharan countries (see 1.3.1). This is a clear advantage for those companies looking to start or expand a business based on this technology. People can easily adapt to the mobile pay-as-you-go concept as it is being increasingly adopted in their everyday life.

Increasing number of PAYG platforms providers. Off-grid energy companies need a PAYG platform, which is the real engine of this business model; one of the greatest barriers for the pioneers was the lack of commercial software to manage the whole value chain; so, they needed to build their in-house solution, which is complex and expensive. Today this technology is really easily accessible thanks to many software developers specialized in offering turn-key PAYG platforms, customizable for different types of business.

Market potential in untapped countries. Still few countries (i.e. Kenya, Tanzania, Uganda) have a competitive PAYG off-grid solar market. The growing penetration of mobile money and recent improvements in connectivity are turning other nations into a perfect breeding ground to start new PAYG-based businesses. The competitiveness of different markets, evaluated by the presence of PAYG solar off-grid companies, is assessed in the following table.

Table 3:Pay-as-you-go availability for selected countries - Source: Climatescope (2017), partially updated by the author.

Availability of PAYG off-grid solar in selected countries
Benin The SNV's initiative, in partnership with MTN (mobile operator), ARESS and Greenlight Planet, introduced PAYG solar in Benin by developing a solar supply chain and distribution network. The project was closed in 2017 and laid the basis for the development of the PAYG model. Today ARESS adopts the PAYG model for systems ranging from pico-solar to larger solar solutions (+ 4 kWp).
Botswana The system changed some three to four years ago and all domestic customers now use prepaid meters for electricity (although this is not the case for all commercial and industrial customers). There are hundreds of vendors for prepaid electricity, but the major vendors are 1) Botswana Post 2) Ideal Prepaid 3) Lowe Trade 4) Q Muzik 5) Sandulela. They, in turn, partner with sub-vendors thereby extending the options available to grid-connected customers. In August 2015, Botswana Post launched a new mobile app that enables Andriod users to purchase prepaid electricity directly. In terms of off-grid systems, Videre Global are working with various ministries to pilot community energy hubs that involve solar PV powered micro-grids. One of the innovations being developed as part of the pilot scheme includes Botswana's first PAYG community energy scheme.
Cameroon There are no specialist companies offering PAYG packages.

Cote d'Ivoire Cote d'Ivoire has a vibrant mobile money sector. MTN Mobile Money and Orange Money, both subsidiaries of the country's main telecoms companies, offer integration of their mobile money platforms with third-party businesses. A number of smaller players are also active in the sector. Mobile money is used by off-grid renewables businesses to receive payments from vendors in rural areas that have a stock of products. However, pay-as-you-go systems are not in use as this would require the retailer to have a banking licence.

Ethiopia There is only one telephone network operator in the country (Ethio Telecom), and few Ethiopians have bank accounts. This has slowed uptake of PAYG, but there is a small number of PAYG companies trying to gain a foothold in Ethiopia. In 2017 Sun Transfer expanded into Ethiopian market in partnership with Mobisol to start selling solar home systems.

Ghana Azuri Technologies and PEG Ghana both offer proprietary PAYG platforms. They do not offer systems to third-party providers.

Kenya There are many PAYG providers active in Kenya.

Liberia No PAYG platforms are currently in use.

Malawi SunnyMoney and RECAPO provide PAYG platforms. SunnyMoney is a social enterprise run by SolarAid, which sells small-scale solar products throughout eastern and southern Africa.

Mozambique There are mobile payment companies operating in Mozambique, but SolarWorks! Seems to be the only one utilizing this payment scheme for off-grid solar products.

Nigeria It is common for consumers linked to mini grids in Nigeria to use mobile phone credit to buy power, which is tracked using net-metering such as Nova Lumos. Smart Grid International established a partnership with Airtel in 2017 to pilot mobile money for PAYG SHSs in Nigeria. It is an increasingly attracting market due to the lack of competitors and the growing penetration of mobile money.

Rwanda Mobile money is very popular in Rwanda. A lot of companies are involved in the sector, including the global leaders MTN, TIGO and M-Pesa. They are all commonly used by off-grid solar companies to receive payments. However, integration into their internal platforms has been slightly more complicated than in neighbouring Tanzania and Kenya.

Senegal Several distributors offer PAYG options to buyers of their products, either off their own balance sheets or via a third-party financier. Caurie provides credit for Bonergie products, for example. MicroCred is a micro-finance organisation, primarily for entrepreneurs, but it is widening its focus to individuals. MicroCred launched a pay-as-you-go pilot for its SunKing solar home system. Mobile money has been used in Senegal for several years, to pay electricity bills to the national power company, Senelec. It remains to be seen how quickly these proposed systems will spread to pre-paid small power systems in remote areas

Sierra Leone There is no clear evidence of PAYG platforms operating at scale. The big brands Azuri and BBOXX have their distribution network here, but they never tried to penetrate the difficult rural market. However, one early stage company - Easy Solar - is looking to use Angaza - a 3rd party PAYG platform, and another company - Veriown - is looking to launch its own proprietary PAYG platform targeting the very bottom of the income pyramid rather than the middle-income households. According to Easy Solar, the lack of mobile money use is the biggest challenge in Sierra Leone.

Tanzania There are many PAYG providers active in Tanzania. The Angaza Energy Hub is a web interface that enables companies to manage their PAYG distribution operations.

Uganda There are several companies in Uganda retailing PAYG solar systems, ranging from pico-systems to kW size for commercial customers. Most of these companies use their own PAYG platform and sell their own products.

Zambia There is some availability of pay-as-you-go, but it is much more limited than other countries. Airtel and MTN are the main mobile money operators. VITALITE received in October 2018 a grant from the GSMA Mobile for Development (M4D) to deliver 500 cookstoves across rural Zambia.

Zimbabwe Solar Access, a division of TeleAccess Zimbabwe, offers PAYG access for Azuri Technologies solar products.

Huge potential market. Roughly 602 million people don't have access to electricity in SSA, being all potential customers for off-grid solar companies. Secondly, an estimated 200-250 million people who currently experience unreliable supply (see 2.2.2) may want to purchase a SHS as a backup system. Furthermore, there is also a potential market for those households who already own a device willing to 1) upgrade the system; 2) buy appliances; 3) access financing services to buy other products or services.

Solar panels, LEDs and batteries are getting cheaper. Prices of the three main SHS's hardware components are falling quickly. If this trend continue, companies will be able to offer more powerful products at a lower price.

Security. PAYG reduces logistic problems and risk related to collecting / transporting cash in rural villages; fewer circulating cash reflects in less attacks and robberies to vulnerable field agents.

Remote monitoring. M2M communication allow to keep monitored:1) the user behaviours, consumption patterns in order to anticipate their increasing service needs; 2) the operating parameters, so that faults / malfunctions / improper use can be easily detected and corrected. Moreover, "data that provides an understanding of customers' behaviour builds confidence in the financial sector", making easier for companies to get funded (World Bank, 2015).

3.3 Weaknesses and Threats: end-user perspective

Limited level of service compared to alternatives. Solar home systems don't provide the same level of energy access of alternatives like diesel generators, mini-grids and grid connection, especially the smaller ones. This is mainly due to the limited power capacity, daily availability, and the constraint on connecting only DC appliances; here it raises the need for a complementary market of super-efficient DC appliances to unlock the productive use of energy.

Quality of products. Many poor-quality products are being sold in SSA, even though a series of quality standards are available and continuously updated by the Lighting Global Framework. Companies selling cheap products might focus on pushing sales rather than establish a sustainable market for the product; those products are less likely to last long time before they break, and this may cause a general loss of trust on renewable energy systems.

The typically Western consumerist model would not work in a market like the Sub-Saharan one, where the principles of "no-waste" and the need for re-using are already intrinsically present in the local cultural matrices. An industry that is still in its infancy, but with great growth potential, could be the perfect breeding ground to put into practice an economy that can self-regenerate, applied right in the region where most of the materials come from. If the sector's sales follow the projections, there will be a problem of repairing and recovering materials such as photovoltaic modules, solar cables

and lithium batteries; given the inaccessibility of the villages, it arises the double need to regulate the recycling of components with high residual value and to adopt quality standards so that the products are long lasting, easily disassembled and recyclable.
Quality standards adopted in different countries were extracted by a detailed analysis made by Climatescope in 2017, and reported in Table 4 with minimum updates.

Table 4: Existing quality standards in selected countries - Source: Climatescope (2017)

Quality standards for off-grid solar products
Botswana. The Botswana Bureau of Standards (BOBS) is the national body governing standards in the country. Whilst a number of standards exist in their catalogue relating to solar water heating systems and some relating to solar power systems, there is no mention of standards for small, portable solar products such as solar lanterns. Furthermore, solar standards that do exist are voluntary, which makes adherence by suppliers open to abuse. An influx of substandard products, particularly from Asia, have impacted the reputation of the market among end users. However, the SIAB is advocating for mandatory standards.
Cameroon. Any standards are effectively set by Eneo as it controls connection. National standards are under development with Eneo's guidance.
Cote d'Ivoire. There are no standards targeting pico-solar specifically, although Cote d'Ivoire has a certification agency that covers a number of individual electronic components. In general, there is very little control over the quality of the products imported, and the use of makeshift and dangerous power systems in rural areas is common.
Ethiopia. Ethiopia's Standards Agency (ESA) adopted International Electrochemical Commission (IEC) standards for pico-solar in 2013 as a voluntary measure. This had little effect as low-quality generics are still flooding into the market. ESA also announced in 2018 the introduction of quality standards for small-scale SHS, as 60% of the products imported in the nation had been identified to be poor-quality (ESI Africa, 2018).
Ghana. There do not appear to be any regulations on quality standards.
Kenya. Kenya does not apply its own quality standards. The World Bank's Lighting Global program has quality standards and is very active in Kenya. Distributors of quality-verified solar kits say that generic products are commonly available and counterfeits are a problem.
Liberia. There are no quality standards in place for pico-solar.
Malawi. No quality standards have been implemented. Most NGOs reference standards used by Lighting Africa, a joint initiative of the International Finance Corporation and the World
Mozambique. There are no quality standards in place for pico-solar products. As a result, the market is flooded with cheap Chinese imports.
Nigeria. Nigeria does not have its own standards codes. Instead, it uses international standard codes. More information on standards can be found on the SON website http://son.gov.ng/frequently-asked-questions/.
Rwanda. Solar product retailers are only subject to general electronic goods standards, as established by the Rwanda Bureau of Standards and enforced by Switzerland's Société Générale de Surveillance, a global leader in the sector. The sector is dominated by high-quality brands (for example, Mobisol, Azuri and Ignite Power) as a consequence of the USD 13.4m in donor funding awarded to the sector to date.

Senegal. Lighting Africa is a continent-wide project that introduces quality standards and testing procedures for small solar home products. Although some manufacturers are certified, it is not a legally-enforced measure, as many products being sold do not have the certification. Gaining accreditation is expensive and a company must have a large-enough manufacturing capacity to make the amounts required for assessment. There is a difficult dichotomy between solar products sold on the black market that do not pay VAT and import fees and better-quality items sold by formal distributors.

Sierra Leone. Only products with IEC certification are eligible for the import duty and goods and services tax (GST). An approved list of products is provided to all ports and country entry points.

Tanzania. Since 2007, Tanzania has set requirements for PV systems, including how the product and its components work. But these only apply to traditional home solar arrays. As a result, the government may consider setting standards on pico-solar products based on the 'Lighting Global' standard. Low quality solar products have tarnished citizens' view of the technology. In recent years, Tanzania saw a wave of low quality and fake products enter the country, prompting the Bureau of Standards to undertake a market surveillance exercise in 2015. On the supply side, a customs official verifies products at the point of origin before a container is shipped to Dar es Salaam. Still, poor products are being imported. There are standards in place for solar and pre-verification of shipments.

Uganda. Solar products must comply with standards laid out by the Uganda National Bureau of Standards which stipulates both compulsory and voluntary standards. It is not clear how effectively these are enforced but some vendors reported that they ensured compliance.

Zambia. The Zambia Bureau of Standards is developing standards for solar panels, but these are still in draft stages.

Exclusion from the electrification programs. Off-grid solar solutions like SHSs have been at the heart of the electrification strategy of some African governments in order to extend electricity access to the most inaccessible areas, especially in countries like Mali and Burkina Faso, where standout results have been achieved thanks to donors and results-based financing. Nevertheless, in South Africa households do not want to be included in SHS programs for fear of being classified as electrified, thereby risking exclusion from future introductions of more efficient technologies or expansion of the grid (Azimoh et al., 2015).

Pure entertainment use over a sustainable economic development. Two main concerns related to the already large diffusion of mobile phones in rural villages are:

- Risk of increased dependency on smartphones that could lead to potentially negative effects on rural communities. In fact, GOGLA declares that 89% of East African households report they use their phone more since using their SHS (GOGLA, 2018c).
- Companies may easily induce desire on unsustainable and unnecessary consumer goods bringing behavioural modifications to the social structure; entertainment may become increasingly more important than satisfying the economic development needs. Experiences in the field reveal that many customers may change their priorities and desires from using solar home systems. Introducing those systems in rural communities may induce people to use the little amount of energy available to for entertainment (e.g. TV football matches, social networks, video games, etc.) rather than activities useful for their sustainable, “healthy” development.

These are important social effects which are often undervalued, even if they are not directly related to the particular solution adopted to bring them energy. There is a need to address policies for a thoughtful choice about the appliances provided by companies, giving preference to productive-use machines as opposed to profit-making ones. Solar Home Systems' introduction should be accompanied by training and actions aimed at promoting their rational use, towards an improved social and economic development.

High price due to high costs of financing. The costs of consumer financing via PAYG is still too high, accounting for 20-40% on the final price (Lighting Global, 2018a) and it is going to fall only whether the business model reaches the economy of scale and gain the confidence of investors. It is due to 1) the mobile money transaction fees and 2) PAYG providers' costs to sustain their credit and finance capability. As companies reach scale they will be able to externalize the customer financing management in order to reduce this cost. It is also possible to lower the transaction fees by extending the partnerships network between off-grid companies, MNOs and technology providers: a better integration would make possible to access discounts on SMS, data, and mobile money transactions, other than improve the overall process and economic efficiency.
A web-based pricing study – whose results are reported in Figure 35 - reveals that the financing cost is extremely variable depending on the financing period; it can even triple the cash-sold retail price in case of 10 years-long payment plans.

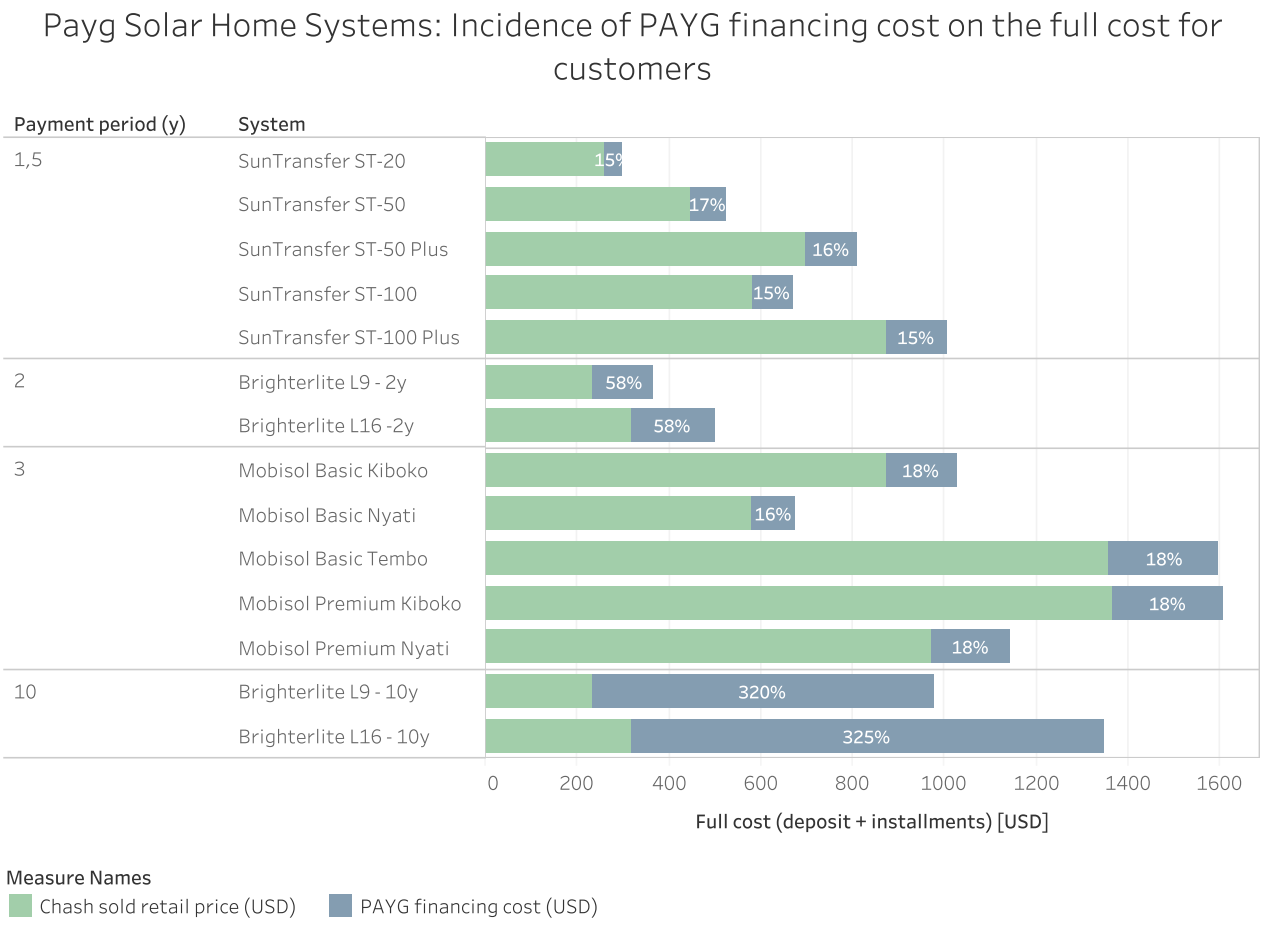


Figure 35: Financing cost of PAYG solar home systems is highly related to the financing period - Author's elaboration on a web-based pricing study

Lack of digital literacy. A lesson learned by SVN from their introduction of PAYG solar lamps in Benin is that - although there was a real need for them - some people were almost completely illiterate: of course, they could not read text messages reminding them to pay or communicating the unlocking code to enter into the device (Edouard Fagnon, 2017).

Need to own a mobile phone, or to live near a local agent. All the three main types of PAYG business models need at least one a mobile phone or, alternatively, an authorized retail shop nearby where to buy scratch-cards (Energypedia, 2018). This could be an issue in areas where there is still a low mobile phone-penetration and a weak PAYG off-grid solar distribution network.

Companies might tend to "follow the money". Most of the players tend to expand their business in densely populated areas to reduce O&M costs. Rural and isolated households who would benefit most from SHS, may not be reached because of it.

SHS may become obsolete when the grid comes. SHS may become obsolete when reached by a mini-grid or the main grid, unless it is used as backup system. Another possible solution to the problem is the Swarm Electrification approach, which consists of linking together more isolated solar home systems to increase storage capacity and stability (less power cuts); these "swarm grids" can be connected to 1) another swarm grid; 2) a micro-grid; 3) the national grid.

3.4 Weaknesses and Threats: business perspective

After the first wave of investments, PAYG companies have slowed down their initially auspicious growth, for many reasons. Some of them are explained below.

Slow expansion process of distribution networks. On the grounds that Kenyan, Ugandan and Tanzanian markets are becoming more and more competitive, companies are now trying to enter emerging markets, which are also among the most difficult places in the world to make a business. Such a move is also due to the attractiveness of countries such as Congo and Nigeria, where most of the off-grid population is concentrated. The experience of Shell Foundation with PAYG companies suggests that "reaching customers who have never been reached by any other consumer service/finance [...], developing the culture of sound buying on credit and maintaining long-term relationships involves many people, is difficult to organise and does not scale like a typical tech business" (Persistent and Shell Foundation, 2018). Gathering data on customers to elaborate sales strategies, is a slow trial and error process requiring testing time.

Sub-Saharan households are comfortable with stop paying and go without electricity. Early pioneering companies belonging to the "first wave" made their financial planning expecting that – once experienced solar lighting – customers would have wanted to keep paying in order to have a regular energy supply. They were wrong: many users take advantage of the flexibility offered by the PAYG payment plans either because they have seasonal earnings, unpredicted expenses, or simply because they are open to refrain from electricity. This unexpected behavior led to lower collection rates and subsequent increase of the financing and operation costs (Persistent and Shell Foundation, 2018).

High capital expenditure and management costs. Complex software development, hardware designing and large data-storage resulted more expensive than expected for first PAYG companies, since the concept was still unexplored and they had to build everything they needed in-house. High management costs were a problem too, being the first managers – young expats from US and Europe – more expensive than local employees (Persistent and Shell Foundation, 2018). As a result, investors saw relatively low profit per customer accompanied by companies' delay in the development and uncontrolled capital expenditure, partially loosing trust.

Funding availability. Availability of finance – especially debt financing – is constantly the main issue for early-stage technology-based businesses. First movers were lucky enough to capitalize on an investors' momentum, but new entrants struggle to get funded. Shell Foundation – which have been tracking several PAYG emerging companies – warns that "slow investor processes have caused almost every second wave company in the sector to run out of working capital at one time or another, idling its sales force from stock outs and losing momentum. These actions take a serious toll on the development of a young business".

Small PAYG providers cannot compete with big players. In some countries (e.g. Kenya) a lot of competition between different PAYG companies: while "the biggest PAYG players have the ability and resources to command the attention of mobile operators and aggregators in these markets, smaller players still struggle to integrate with them and fall below the required threshold to attract their interest. Eventually, this leads to a less diverse PAYG industry and limited choices for the end user, as well as additional charges placed on the nascent PAYG industry as a result of having an aggregator" (GSMA, 2018b).

Low-margin business. The profit margin of PAYG solar home systems are actually not really low (they range between 30% and 50%) but the total profit is generally low because they are low-price products (Persistent and Shell Foundation, 2018). Moreover, the development costs are still very high since at this stage.

Mobile money regulation. While more than a hundred companies are trying to pave the way for a digital revolution using a market-based approach, "regulatory progress to support the digital financial services (DFS) market remains stalled, and PAYG off-grid solar companies struggle to innovate in order to survive in the midst of a highly fragmented DFS provider network" (USAID, 2018).

Solar off-grid market regulation and governmental policies. There are different ways to provide subsidies to the sector:

- The *tax concession scheme* provides for tax exemptions and subsi dies in specified territories. An example of concession model subsidy is the Programmes Prioritaires d'Electrification Rurale (PPER): "In Senegal, providers can bid for subsidies and receive tax exemptions to deploy renewable-energy solutions within specified concession areas. As of early 2017, however, only three of the ten designated concessions were operating, and the program was not meeting electrification targets. Companies also reported difficulties with product technical requirements" (McKinsey&Company, 2018).

- *Start-up subsidies* ease access to financing for startups, successfully adopted by the Tanzanian government by providing access to a financing facility for start-up costs for small-scale lighting and basic electricity-supply technologies (McKinsey&Company, 2018).

- *Tax preferences* on solar home system kits, components, and appliances reduce or exempt from VAT and excise duty imports. This measure can really make the difference in fostering a better affordability for the poorest households, especially those living still off-grid. In fact, the company M-KOPA states that the only way to scale is to exempt solar products from duties and VAT, and GOGLA recommend to governments to "follow the model of prudent national governments such as Kenya and Tanzania, and adopt a long term zero VAT and tariff policy for solar products and their component parts" (GOGLA, 2015). Exemptions implemented across East-Africa were a key reason for the rapid growth of the sector in the region (ODI, 2016), but even in countries where solar products are exempt from duties and VAT, there is a controversial issue about batteries, being generally not exempted. Current reductions in Sub-Saharan countries are reported in Table 5.

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Table 5: VAT and duty reductions in selected countries - Source: Climatescope (2017), expanded and updated by the author

VAT and duty import reductions or exemptions
Benin. The government announced in 2017 to provide a tax exemption on the products imported under the project Bright Lights for Benin led by SVN, whose goal was to bring the PAYG model to the country.
Botswana. The standard VAT rate of 12% is applicable to off-grid pico-solar products, as confirmed via the newly-launched Botswana Trade Portal. And, whilst these products are exempt from import duties, so is all equipment and machinery used in the manufacturing sector, according to the broadly applicable Customs and Excise Duty Act.
Cameroon. There is a VAT exemption on all solar equipment. This is the only form of 'subsidy' afforded to solar products in Cameroon. There is no import tariff waiver for solar products, but the government does allow for tariffs to be waived for specific projects, subject to negotiation. This is likely to apply to large projects involving foreign money and equipment, rather than small players.
Democratic Republic of Congo. There are no VAT reductions. Generally, importers and distributors of products such as solar lamps, panels and so on must pay a 10% import tax. However, it is likely that the government will extend decree n15/009 to off-grid solar products, which would exempt these products from import duties and any VAT levied at time of import. It is unclear when this would be implemented.
Cote d'Ivoire. Solar PV products generally benefit from a reduced VAT rate - 9% against the normal 18% applied to most goods and services - and a reduced import duty of nil to 1%. However, securing such discounts is cumbersome, from both customs (for the duty exemption) and from the Ministry of Finance for the VAT reduction. Delays at customs can be costly as importers need to pay for warehouse space in the harbour. These problems have led to considerable contraband imports from neighbouring Burkina Faso, where exemptions cover a wider set of components and are easier to access.
Ethiopia. Products can receive exemptions from import duty. Import duties for solar lanterns are set at 0%.
Ghana. A zero-rate import duty applies to solar cells and panels and wind power equipment.

Kenya. An amendment to the VAT code in 2014 specifies that "specialised solar equipment and accessories, including solar water heaters and deep cycle-sealed batteries, which exclusively store solar power," are VAT-exempt. Power generation equipment is exempt from import tariffs, as is PV equipment. Applications running on their own source of power, such as solar lanterns, are subject to a 10% import tariff.

Liberia. There are no reductions in VAT, and no reductions in import duties compared with other products.

Malawi. Pico solar products do not enjoy any VAT reductions compared with other products. Pico solar products are import duty-free, which according to the majority of licensed retailers, has encouraged a flood of low-quality products.

Mozambique. Off-grid pico-solar products are not differentiated from general consumer goods, and are thus subject to the general tax rate of 17%. Off-grid pico-solar products are technically classified as "intermediate beneficial goods" under Mozambique's import laws, which means they qualify for a tariff of 7.5%. This is lower than most consumer goods.

Nigeria. PV panels and modules are exempt from paying the 5% VAT rate, whereas entire PV systems are not. However, as most solar systems are shipped 'bundled', it can be hard to get 0% duty on the panels. Some small and medium-sized enterprises import solar equipment through neighbouring Benin's duty-free port at Cotonou, then transport the solar equipment overland to Niger and from there into Nigeria.

Rwanda. VAT exemption for energy products in Rwanda was extended in 2015 to include solar water heating systems, solar-powered pumping stations, solar appliances (including TV, radios and fridges) as well as renewable power generation equipment, including solar panels, batteries, inverters, trackers and wind generation equipment. Rwanda is part of East Africa's customs union and as such applies the full exemption of import duty to all solar products, including storage and DC appliances.

Senegal. Solar panels are exempt from paying VAT (it can be claimed back), but other electronic parts like batteries and lanterns must pay VAT. The VAT rate is 18% and other taxes at customs amount to about 25%. MicroCredit says that total import duties (see below) amounting to about 45% are a big setback for its business. It is looking to set up shop in other nearby countries where the tariffs are lower and says it wants to work with partners to pressurise the government to reduce tariffs. Solar products benefit from a reduction in import duties, but solar lanterns and batteries pay import taxes of 20% as they are classed as electronic products.

Sierra Leone. Quality-assured products, adhering to IEC standard, will be exempt from GST (goods and services tax), which is the VAT equivalent. The Ministry of Energy, along with the Renewable Energy Association, will compile and present the list of qualifying products to customs. There is some scepticism amongst importers as to whether this will be effectively implemented at the ports.

Tanzania. The following are exempt from VAT: solar panels, modules, solar charge controllers, solar inverter, solar lights, vacuum tube solar collectors and solar batteries. Otherwise, the standard VAT rate of 18% applies.

Uganda. The standard VAT rate in Uganda is 18%. Off-grid solar products are import tariff exempt. This extends to the whole of the solar system including the cables inverter and battery if shipped together. However, suppliers have reported difficulties with import exemption when shipping components such as cables and batteries separately to solar panels.

Zimbabwe. Solar products receive import duty exemptions, although stakeholders feel the laws are outdated and importers don't receive full benefit.

4 Discussion

4.1 Policy recommendations

Better design the electrification programmes. Policymakers shall consider Solar Home Systems an effective electrification solution as a first step in the energy ladder, where the all the other solutions are too expensive or impossible to implement. A good electrification programme should identify the best technological option in every location, in order to avoid, for example, companies to electrify with SHSs where a mini-grid or the grid extension would be more suitable. Geospatial Electrification Models are certainly helpful tool which should be used by planners as a decision support system. The Energy Modelling Platform for Africa holds intensive hands-on training sessions specifically designed for building capacity inside the African governmental authorities, companies and academia. It is also necessary to share public, clear information on where, how and when the main grid is planned to be extended.

Solar Home Systems are often undervalued as they may be confused with pico-solar products and labelled as providers of a "second-class" energy. Two successful examples are Philippines and Bangladesh, where governments prioritized SHSs over the grid in areas difficult to reach by the grid extension, giving rise to a massive, quick uptake. In order to do this, governments shall not measure the electrification rate just on the basis of the connections to the national grid. A large amount of detailed data on the number of households electrified by off-grid solutions are in the hands of companies, and could be used as additional input for better designing the national electrification strategies. Off-grid solar firms are also able to monitor their customers energy consumption pattern, which is an extremely important information for energy planners.

Governments should strengthen the dialogue with the private sector promoting the exchange of information, bringing the double advantage: authorities would improve significantly the quality and effectiveness of the electrification planning; companies would take advantage of the synergy with the authorities to unlock new business opportunities.

Adjust the off-grid regulations. All governments shall reduce or exempt import duties and taxation on off-grid solar products, digital platforms, and selected appliances which would enable the sustainable development; remove limitations on mobile money transactions and foster its adoption among the population; implement national or global product standards (such as the Lighting Global Quality Standards) to ensure only good-quality systems reach the market (McKinsey&Company, 2018). There is also a need for more commitment of governments on running PAYG mini-grid and PAYG clean cooking pilot projects.

Business environment. A good business environment means lean bureaucracy on licensing and favourable labour market regulations: companies need to hire nimbly local agents, maintenance workers, and enter into multiple partnerships with distributors. Low levels of corruption are crucial for companies which need to ship valuable equipment, as well as a stable local currency. In fact, they are usually financed in foreign currency like dollars or euros while the revenues are in local currencies. Weak currencies reflect also in higher cost of importing equipment and components (Climatescope, 2018c). Therefore, to promote a fully sustainable development of the sector

policymakers should facilitate access to local currency financing, in particular, long-term debt financing (McKinsey&Company, 2018).

Unlock distribution channels. The high cost of this technology is due to the difficult distribution, since users that would benefit most from it are located in remote and sparsely populated regions. Security of freight transport and good road network are not ensured in rural SSA; thus, it is crucial that companies could easily establish partnerships and cooperation with local distributors of any kind: successful experiences were possible thanks to a wide distribution and marketing network consisting of local shops, retailers, banking agents, gasoline stations, and telecommunication kiosks. Public infrastructures, such as post offices and police stations could be made available by governments as storage in isolated areas (McKinsey&Company, 2018).

Mobile money regulation. The PAYG off-grid business opportunity need an enabling mobile money environment in order to gain a foothold. Digital service providers could promote financial inclusion and foster the access to electricity, but there are still countries where they are not allowed to provide mobile money services (USAID, 2018). For example, in Nigeria there is a big and fast-growing penetration of mobile phones, however, "the country has limited mobile money penetration (about 1 percent of mobile subscribers)due to the Central Bank of Nigeria's (CBN) regulation which limits MNO-driven mobile money provision"(Agbaegbu and Malo, 2018).

4.2 Conclusions

This work demonstrates that PAYG off-grid renewable systems provide a first step in the energy ladder, able to fulfil in part the important gaps in centralized infrastructure development and provide access to financial services at the same time. The accessibility provided by digital technology-based delivery models is playing a key role in fostering the universal access in the continent by 2030. Recent digital innovations such as Internet of Things, GSM connectivity, Software platforms and mobile money have paved the way for countless application in a continent which is fast-moving. Delivery of utility services on a pay-as-you-go basis integrated with mobile payments is a successful example of it, as many start-ups have developed their concept in the last five years. With an impactful potential in their hands, they struggle to get funded and crash into countries' adverse regulatory frameworks. For this reason, there is a big need to elaborate policy recommendations tailor-made for individual African countries and to give a bigger weight to these innovative solutions when designing national electrification strategies. One of the biggest problems about PAYG solar home systems is a misleading perception of this technology: the distorted view that DC systems provide a "second-class energy" is largely spread among the policy-makers. These systems are now able to power fridges, air conditioning, and other productive-use appliances, in some cases even with more continuity than unreliable national grids. Most of the rural communities don't mind the way they get the access – whether it is by a mini-grid, the national grid, or SHSs – because they just need an easy and affordable way to improve their quality of life, save money, and improve their business activities to generate more incomes.

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