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Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? — Source link

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Diffusion of Solar PV in East Africa: What can be learned from private sector delivery models?

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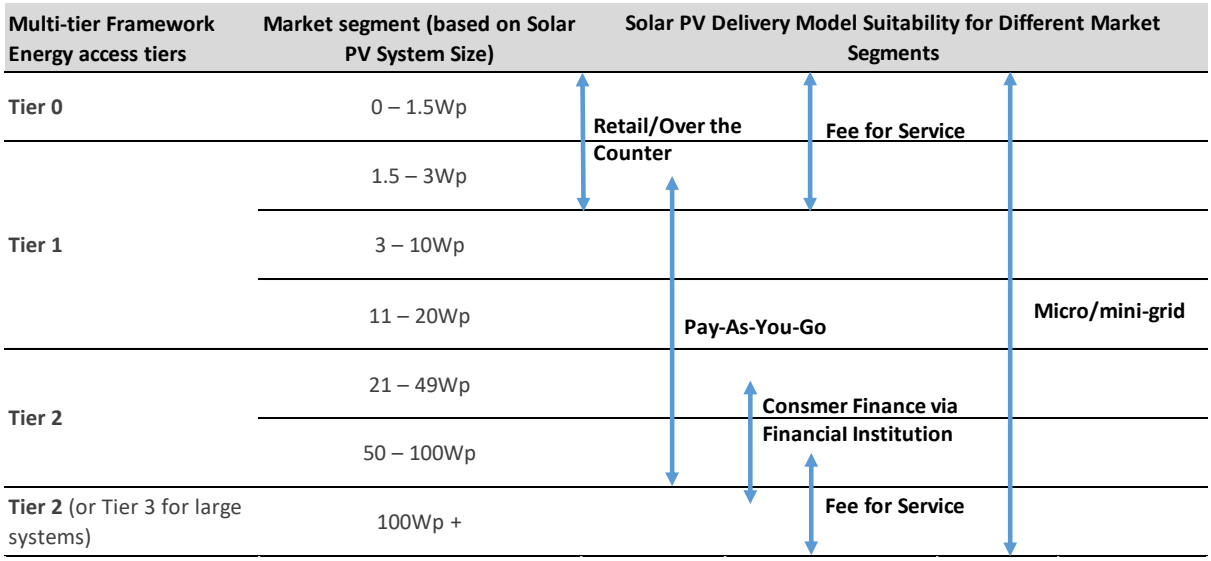
Abstract

Solar PV will play the leading role in addressing off-grid electricity access; it can be applied almost anywhere and used in a wide range of applications for households, businesses, institutions and communities. However, to fully exploit this opportunity, off-grid markets that need these solutions need to be effectively penetrated. This article focuses on delivery models for off-grid solar PV solutions and how they address barriers such as awareness, acceptance, access and affordability.

It is based on a survey of 13 solar PV businesses in East Africa, supported by the Energy and Environment Partnership Programme* and implementing the following delivery models: Retail, Pay-As-You-Go (PAYG), Consumer financing, Mini-grid and Fee-for-service. The survey is complemented by supporting literature and incorporates experiences from a University of Oslo research project on a village scale energy access model in Kenya and case studies of solar PV mini-grids in Senegal and India.

Experiences from implementation of the different models are analyzed and generic descriptions provided. The models are compared to illustrate their suitability and effectiveness for delivering different levels of energy access. Retail and PAYG models are identified as effective at reaching scale, while the mini-grid and fee-for-service models demonstrate good potential to affordably and sustainably deliver a wider range of electricity access. The limitations of conventional rural electrification strategies are also discussed and the potential to incorporate some delivery models into electrification programs assessed.

Graphical/Visual Abstract and Caption



A comparison of the suitability of different solar PV delivery models in delivering different levels of energy access (as defined by the Sustainable Energy for All Multi-tier Framework). Suitability is based on which models currently deliver different sizes of solar PV systems most affordably.

* A challenge fund that provides grant funding to support pilot testing, demonstration and scale up of off-grid renewable energy business models

Introduction

Despite government electrification programmes, the number of people in sub-Saharan Africa without access to electricity increased from 586 million in 2009 to 620 million in 2014 [1, 2]. This, because the rate of electrification was unable to meet the electrification deficit while keeping up with population growth [2]. The table below illustrates this challenge in Kenya, Tanzania and Uganda by comparing the national household electrification rates and new household electricity connection rates with household population statistics.

Table 1: Comparing household population statistics in Kenya, Uganda and Tanzania [3] with national electrification rates [4, 5, 6] and average (2-year) annual rates of new household electricity connections

	# of Households, Millions (2016)	# of Domestic Customer Connections (Millions)	Household Electrification Deficit (Millions)	National Household Electrification Rate	Household Growth rate (Millions/year)	Electricity Connection Rate (Millions/year)
Kenya	10.7	4.56	6.19 (2016)	42.4% (2016)	0.31	1.25
Uganda	7.8	0.93	6.87 (2016)	12.6% (2016)	0.24	0.2
Tanzania	10.4	1.48	8.63 (2015)	15.9% (2015)	0.28	0.2

The International Energy Agency's (IEA) assessment is that, 70% of the World's population without access to electricity are better suited to either mini-grids (52.5%) or stand-alone systems (17.5%) because, due to high costs and technical losses, grid extension is not suitable for sparsely populated, remote or mountainous areas [1]. Sub-Saharan countries are expected to have greater dependency on mini-grids and stand-alone systems as nearly 80% of those lacking access are in rural areas.

IEA's New Policies Scenario projects that by 2040 solar PV will contribute the largest share (47%) of the technology mix for mini-grid and off-grid power generation in sub-Saharan Africa [2]. The exponential increase in solar PV system sales between 2011 and 2016, for the household and small/micro-business market in sub-Saharan Africa, demonstrates that there is truth in some of IEA's projections. However, plenty of work is still required for mini-grids to reach their anticipated potential. There has been a ten-fold growth in sales of solar powered off-grid lighting products in sub-Saharan Africa, from 400,000 units in 2011 [7] to 4.18 million units between July 2015 and June 2016 [8, 9]. The majority of these sales (69%) are in East Africa (Kenya, Tanzania, Ethiopia, Uganda and Rwanda) while most of these systems (81%) are pico-solar (up to 3Wp).

A combination of factors are responsible for this growth:

- Price reduction in solar PV modules and balance of system components, as well as technological advancements in LED lighting, Li-Ion battery technology and efficient appliances [7], which enabled the development of high performance low cost off-grid solutions (e.g. pico-solar products (0.5-3Wp solar powered LED lanterns) and solar home and business systems (3 – >100Wp)). The new range of pico-solar products provide a competitive alternative to kerosene for lighting, while pre-designed plug and play systems (often sold with lights and appliances) address challenges related to appropriate sizing of systems and installation (historically responsible for high solar PV system failure rates [10]. These challenges resulted from a long-established component based approach to selling solar PV systems [11].

- The development and uptake of mobile money transfer systems, which facilitated solar PV end-user finance models by bringing down the cost and complexity of debt recovery and making it possible to centrally manage a large pool of dispersed consumers [12]. Mobile money makes it easier for consumers to make repayments for their systems wherever they can access a phone signal and make smaller payments more frequently. Furthermore, these electronic payments are linked to remote monitoring and control systems, enabling providers to monitor recovery rates in real time and remotely disable systems of defaulting or delinquent customers.
- The regional off-grid lighting market development program developed by IFC/World Bank [13], which demonstrated the business opportunities presented by off-grid markets in sub-Saharan Africa to manufacturers, distributors and retailers. In 2010 Lighting Africa market intelligence studies projected that the market potential by 2015 would be made up of 120 million off-grid households, 10 million off-grid small businesses and 20 million "under-electrified" households (on-grid customers with intermittent and low quality of grid supply). The studies also estimated that African bottom of the pyramid households spent >$5 billion annually on kerosene for lighting [14].
- Renewable Energy business support programs such as the Renewable Energy and Adaptation to Climate Technology challenge fund (REACT) [15] and the Energy and Environment Partnership Programme (EEP) [16], which supported pilot testing, demonstration and scale up of off-grid business models, as well as social enterprise investors who provide early stage equity for these businesses.
- The development of effective delivery models for solar PV products and services, which were necessary to access and serve off-grid consumers who are often dispersed, remote and have limited discretionary income

This article's focus is delivery models for solar PV products and services (including mini-grids). It looks at distribution in a wider context; beyond physically getting the product or service to the final consumer, beyond making it accessible. It looks at how delivery models address other key barriers to uptake such as awareness, acceptance and affordability.

There have been detailed studies undertaken on solar PV markets and delivery models in East Africa. However, most tend to focus on providing analysis on specific models or market segments rather than a comparison of different models.

In his 2005 working paper A. Jacobson [17] provides a historical profile of the Kenya Solar Market from the late 1970's to 2003, briefly describing the solar home system market supply chain (primarily based on the retail/over the counter delivery model) and showing the annual growth in module sales from 1987 to 2001. A more recent analysis of the historical development and structure of the solar PV market in Kenya (covering the period up to 2010) is also undertaken by J. Ondraczek [18] who, in addition, provides a similar analysis for Tanzania and compares the two markets.

The Energypedia website [19] presents the basic concepts of Fee-for-Service and PAYG models, the financial implications associated with implementing these models as well as detailed information on major companies implementing PAYG and Fee-for-Service models in East Africa and other parts of the world.

J. Winiecki et al [12] present a report which focuses on businesses deploying PAYG solar photovoltaic products. The report covers the segmentation of PAYG solar energy technology, experiences with digital payments and off-grid solar energy, segmentation of PAYG solar business models, financing and pricing models used by PAYG solar providers, sales and distribution channels for reaching off-grid consumers, and analysis of trends and the future of PAYG solar. S. Sanyal et al [20] have prepared an issue brief to assess how international development finance institutions (DFIs) can support the PAYG energy access sector in Kenya and Tanzania. The brief is based on a review of existing literature and interviews with senior management of six PAYG solar home system companies active in Kenya and Tanzania, and provides detailed information on the PAYG providers and their product offerings.

J. Kabutha et al [21] document the opportunities, challenges, costs and effects of integrating energy products into a microfinance institution's (MFI) product mix from an in depth examination of two MFIs in Kenya with different approaches to offering loans to their clients for energy services and products.

X. Lemaire [22] discusses the practical experience with fee-for-service from South Africa's ambitious off-grid solar electrification programme, which was based on fee-for-service concessions. His paper focuses on operational and design issues as well as the benefits and difficulties linked to the fee-for-service model and its potential for replication. He also undertakes a case study on fee-for-service companies in Zambia [23] which demonstrates that, even with limitations, a well-articulated public–private partnership can deliver a cost-effective energy service in rural areas.

In a WIREs advanced review, M. B. Pedersen [24] undertakes a detailed review of past, on-going and planned mini-grids in East Africa, providing examples of different mini-grid types and models in Kenya, Uganda and Tanzania.

Method

Solar PV projects have the largest share of the EEP project portfolio for Eastern and Southern Africa; they represent 33% of all projects financed (68 projects). These 68 solar PV projects are spread across 12 countries with the majority (50) in East Africa. A wealth of knowledge has been created through the implementation of different solar PV delivery models by businesses supported by EEP. This makes EEP an ideal avenue through which to learn about the different models.

A study was undertaken to analyze and synthesize the experiences and lessons learnt from the implementation of different solar PV delivery models. It focused on solar PV businesses in East Africa supported by EEP that had demonstrated success (i.e. had achieved scale and/or showed good potential for replication). Thirteen solar PV businesses were selected using this 'success' criteria.

These selected businesses implemented one (or more) of five solar PV delivery models: (1) the Retail/over the counter; (2) Pay-As-You-Go (PAYG); (3) Consumer financing (via a partner financial institution (FI)); (4) Mini-grid and (5) Fee-for-service models.

The split by country and models applied by the surveyed businesses is as follows:

- By country: Tanzania - 4, Rwanda - 4, Kenya - 3, Uganda - 1, and 1 regional (Kenya & Tanzania)
- By delivery model: Retail/Over the Counter - 2, PAYG - 3, Consumer Finance (via FI) - 1, Mini-grid - 6, and Fee-for-service - 3, (NB: 2 businesses implemented more than one model)

The findings presented in this article are based on experiences from the implementation of these 5 solar PV delivery models by the 13 solar PV businesses surveyed. These findings have been presented as an in-depth study report [25] available on the EEP website.

To further enrich the article, lessons from a University of Oslo (UiO) led action research project on a village scale energy access delivery model implemented in Kenya [26], and case studies of solar PV mini-grid models implemented in Senegal and Chhattisgarh, India [27] are also incorporated.

Since it is important to understand the delivery models in the context of the target market, market segmentation is done on the basis of the products or services delivered through the different models. The market segmentation methodology is borrowed from the format applied by the Global Off-Grid Lighting Association (GOGLA) [9] to report sales and impact data, and correlated with the multi-tier framework (MTF) [28]. This segmentation is illustrated in Table 2 below with disaggregated annual sales figures from GOGLA for July 2015 – June 2016 also provided for comparison.

Table 2: Product based market segmentation methodology applied in this article (for reference, the corresponding MTF energy access tier is indicated for each segment as well as sales volumes per segment for July 2015-June2016 [8, 9]

Market segment (Solar PV Capacity)	Service Provided	Corresponding Mtf energy access tier	Volume of Products Sold in sub-Saharan Africa (July 2015 –June 2016)
0 – 1.5Wp	Single light only	**Tier 0**	2,178,836 (53%)
1.5 – 3Wp	Single light + phone charging	**Tier 1** – Task lighting AND Phone charging	1,161,280 (28%)
3 – 10Wp	Multiple lights + phone charging		513,435 (12%)
11 – 20Wp	Entry level standalone solar system (3 – 4 lights, phone charging and low power appliances (e.g. radio, fan))		100,463 (2%)
21 – 49Wp	Basic capacity standalone solar system (above plus power for TV & extended capacity)	**Tier 2** – General lighting AND Phone Charging AND Television AND Fan (if needed)	64,296 (2%)
50 – 100Wp	Medium capacity standalone solar system (above but with extended capacity)		64,328 (2%)
100Wp +	Higher capacity standalone solar system (above but with extended capacity)	**Tier 2** (Large systems could qualify for Tier 3)	44,163 (1%)

Measuring Energy Access using the Multi-tier Framework

To achieve the Sustainable Energy for All (SE4All) target of "Universal access to modern energy by 2030" requires a wide range of interventions. The success of these interventions depends on the ability to assess the level of access to energy for planning and investment, and, later, for tracking progress. The multi-tier framework was therefore introduced as an approach for measuring energy access.

As illustrated below, the multi-tier framework for measuring access to electricity uses five successive tiers categorized on the basis of their electricity supply attributes e.g. the ability to use certain appliances (or access certain energy service). Other supply attributes that are considered (although not presented here) are the power/energy capacity, number of hours per day electricity is available and other aspects which mostly apply to Tiers 3-5 such as reliability, quality, affordability, legality and health and safety.

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Tier criteria		Task lighting AND Phone charging	General lighting AND Phone Charging AND Television AND Fan (if needed)	Tier 2 AND Any medium-power appliances	Tier 3 AND Any high-power appliances	Tier 2 AND Any very high-power appliances
Supported Appliances		Lighting (1,000 lumen hour/day), phone charging, radio	Multipoint general lighting, television, computer, printer and fan	Air cooler, refrigerator/ freezer, food processor, water pump, rice cooker	Washing machine, iron, hair dryer, toaster, microwave	Air conditioner, space heater, vacuum cleaner, water heater, electric cooker
Typical supply technology		Solar lantern	Rechargeable battery, standalone solar system	Medium standalone solar system, fuel generator, mini-gird	Large standalone solar system, fuel generator, mini-grid, central grid	Large fuel generator, central grid

Description and Analysis of Solar PV Delivery Models

The model descriptions below are from a synthesis of information gathered on the different models from the 13 businesses surveyed and results from the UiO research projects on a village scale energy access and mini-grid models. References are provided where external information is used to supplement the model descriptions or validate and support findings from the study.

To avoid disclosing proprietary business information the models are presented in a generic way, with no direct references made to the businesses implementing these models or details provided on how a specific business applies a certain model.

Retail/Over the Counter Model

Over the counter sales is the oldest approach to selling solar PV in East Africa. However, in the past, few businesses were dedicated to marketing only solar PV products. Solar PV was typically sold as an additional product, with revenues from sale of solar products and services only representing <10% of the total business turnover [17]. In recent times, however, a large number of dedicated solar equipment suppliers (for whom solar sales represent >90% of their business) have emerged. Their success has been based on the development and implementation of effective marketing, supply and distribution models.

The retail model is implemented through a multi-level supply chain comprising importer/supplier, distributors, retailers and field sales staff and/or commission based sales agents. A country wide network of distributors and retailers is required to make sure the products are easily accessible to customers across the country. Transactions along the supply chain are mostly cash based, although some suppliers do offer short term credit (up to 30-days) to their distributors.

The retail model is the most common delivery model for single light and single light + phone charging products. The surveyed business showed that it is an especially effective model for the single light product market segment (products in the 6-10$ price range). Product sales are typically in the range of tens of thousands to hundreds of thousands of single lights per supplier per year (single light + phone charging products represent only a small percentage of these).

As products typically have a 2-3 year life span, with only a few having a battery replacement option, customers have to purchase a replacement light every 2-3 years. It is therefore likely that repeat customers contribute significantly to product sales. This was confirmed by a 2016 Lighting Africa survey [29] which interviewed 450 solar PV retailers in Kenya, 77% of whom stated that they get repeat business from their solar customers, most of whom want the same type of product.

Intense below the line marketing (face-to-face) is required when a product is initially introduced and a large rural sales force is required during this time. Experiences of solar businesses indicates that sales personnel should preferably be from the area they are marketing in; to be effective, they need to know the area, speak the local language, understand the customs and attitudes and be able to elicit trust. However, it is difficult to find experienced or qualified sales personnel in rural areas and this results in high costs for recruitment, training and deployment and a high staff turnover. The alternative of using non-local staff is equally difficult as they often struggle to adapt to the new and challenging local working conditions.

Considering the 6-10$ product price, it is difficult to have a supply chain dependent on purely commission based sales agents. The value of the commission would be too low for the effort required. The most common pay package for sales agents used in this model consists of a retainer, a target based incentive and an amount to cover field related costs. Although these sales agents make direct sales, this is not their primary function. Sales agents deployed under this model mainly focus on marketing (i.e. increasing the visibility and awareness of the product and brand) and recruiting and supporting distributors and retail outlets to ensure that the products are always available and accessible to customers. Marketing is typically focused on central gatherings (e.g. market days, religious meetings, village meetings, and co-operative / member group meetings). From the survey of the EEP supported projects it was found that businesses struggled to find a suitable balance between retainer and incentive.

Supply chain costs can make up 30 - 50% of the product price and this cost has to be built into the product price for the model to be effective. However, due to the challenges associated with developing and sustaining a rural sales force, businesses find it difficult to accurately predict the cost of recruiting, training, deploying and maintaining a rural sales force.

After an optimum volume and spread of sales, and a positive customer experience, word of mouth usually takes over. Customers then actively look for the product at retail and distributor outlets. Product quality and timely honoring of warranty claims is necessary to build and maintain this positive experience.

Some key challenges identified by the surveyed business implementing this model are:

- Undercutting at the retail level: When retailers/distributors opt for lower margins to increase inventory turnover, this results in a different price for the same product across different retailers (even in the same town). This often results in consumers distrusting retailers since they don't know who is offering the product at the recommended retail price.
- Counterfeit products: Counterfeiters reap where they have not sown, taking advantage of the work done to create market awareness and trust in a given product, by manufacturing and selling a similar looking product of lower quality (often through the same retail networks used for the authentic products)
- Poor quality products create market spoilage especially when introduced to a new market (they make it more difficult to sell good quality products).

Most East African countries have counterfeiting agencies and mandatory solar PV standards to address issues of counterfeiting and standards, but enforcement is challenging and some form of additional industry self-regulation is required.

Pay-As-You-Go (PAYG) Consumer Financing Model

This is a consumer financing model for solar PV systems that takes advantage of mobile money transfer systems as well as remote monitoring and control of solar systems (i.e. technology that enables remote disconnection of systems). Under the PAYG consumer financing model, the supplier of the solar product also provides consumer finance for the product. The model offers a broad range of customers, especially those without access to traditional financial services, easy access to consumer financing. PAYG provides customers with a flexible way to make repayments (i.e. they can opt for daily, weekly or monthly repayments) while enabling solar businesses easily and effectively

manage a large portfolio of dispersed borrowers by reducing the cost and complexity of collecting large numbers of small repayment amounts.

PAYG is the most common delivery model for 3Wp – 100Wp plus, multiple light + phone charging + appliance systems (Tier 1 and Tier 2). More recently (2016), through innovative PAYG technology partners [30], businesses have also introduced PAYG for 1.5Wp – 3Wp single light and single light + phone charging products (Tier 1 and below) with daily fees in the range of 0.3$/day for 6 months. The PAYG model has demonstrated greatest success with Tier 1 products where the repayment fee is around 0.5$/day for 12 months. PAYG sales in this range are in the hundreds of thousands of systems per supplier per year. For Tier 2 products, repayment fees are in 0.8 – 1.2$/day range for up to 3 years. PAYG sales for this category are in the tens of thousands of systems per supplier per year.

The repayment fee is dependent on the cost of the system and repayment duration; for more expensive systems, the repayment duration would need to be longer for the repayment fee to be lower. The effectiveness of the PAYG model is dependent on the amount of daily/weekly/monthly repayment fee charged i.e. the extent to which this fee can be covered by the discretionary income of the target market segment (the lower the fee, the larger the potential market). The 2014 IEA Africa Energy Outlook indicates that Kenyan households spend 3-5% of their income on electricity; with poor households spending the larger percentage [2]. This would suggest that the PAYG model is currently serving households in the 6 - 40$/day income range, who would not typically be considered as 'bottom of the pyramid' (BoP).

The PAYG model also seeks to reduce the entry barrier by reducing the amount of deposit required. However, this approach could be considered counter intuitive as a customer's ability to put down a large deposit is also a good indicator of their ability to meet their subsequent repayment commitments. The reduction or removal of this filter therefore significantly increases default risk.

Since PAYG customers make their payments directly to the supplier via mobile money, a distribution model based purely on depots can be used. These depots, owned and managed by the solar business, would hold stock and parts and make them accessible to sales agents or installation/maintenance technicians. A supply chain structure similar to the one used in the retail model can also be deployed. As the price of 8 - 100Wp+ systems are in 150 – 1,000$ range, decent commission payments can be made to sales personnel. It is therefore possible to have purely commission based sales agents deployed for this model. To ensure that sales agents target customers who are able to pay, part of the commission is linked to customer repayment rates. The marketing approach for PAYG is similar to that used under the retail model. However, in addition to marketing at central gatherings, supplementary door-to-door marketing is also required. Therefore, in addition to commissions, it may be necessary to consider some travel allowance. Truly off-grid markets are often difficult to access.

For larger PAYG systems, installation support is required. Therefore an additional network of local technicians, to provide installation and maintenance/troubleshooting services, has to be established. With the transition to digital TV in East Africa, solar PV system installers also have to become accomplished TV decoder and antenna/satellite installers. TV is one of the main drivers of solar PV system sales and they are incorporated in the system package, therefore even though the solar business is not directly responsible for TV signals, customers consider a working TV as one which clearly receives a certain number of desired TV channels.

The PAYG model requires a responsive customer service system to register customers, address technical challenges, coordinate and deploy technicians and follow up on defaulters (customers tend not to make repayments when their system is not working). For smaller PAYG systems, the cost of repossession can be significant and it may not be possible to resell/reuse the system. Some PAYG companies instead try to offer defaulters a financial incentive (e.g. reimbursement of their deposit) to voluntarily return the system to a depot or distributer.

PAYG is inherently risky as it is based on providing consumer finance to customers for whom there is little or no credit history or income information. PAYG businesses assess risk by analyzing the payment patterns and customer characteristics of their existing portfolio and using this to quantify (and cost) the default risk for the future portfolio. To cover this default risk, high 'interest' rates have to be charged to PAYG customers. Though risky, this approach simplifies the sales process by eliminating the credit assessment process that traditional financial institutions apply, thus enabling PAYG products to be rolled out quickly and widely.

Since PAYG repayment durations range from 6 months - 3 years, this creates a significant cash flow burden for PAYG businesses; the more expensive the system being offered and the longer the repayment period, the greater the cash flow burden. However, PAYG companies have found innovative ways to address this by converting PAYG loans into securities and selling them on to investors [31, 32]. PAYG businesses mobilizing foreign currency investment also have to account for forex exchange fluctuation risks, because equipment is typically procured in US dollars but repayments are made in local currency. The longer the repayment duration, the greater the associated forex risk.

Consumer Financing (via Partner Financial Institutions) Model

This consumer financing model is based on a partnership between a solar PV supplier and a financial institution (e.g. Commercial Banks, Microfinance institutions, Savings & Credit Cooperatives or Companies/Agricultural Estates/Rural Based Industries willing to extend credit to their staff); the solar PV supplier provides products and associated services while the financial institution (FI) provides the consumer financing and collects repayments. The main difference between the PAYG model and consumer financing via a partner financial institution is this separation of roles.

Since the supplier is paid by the FI upon delivery and installation of the system, this model alleviates the cash flow burden associated with the PAYG model. The default risk is also significantly reduced with this model because FIs have the financial history of their customers and are experienced in vetting loan applications and using different types of collateral instruments. This lower risk profile implies that FIs can offer financing at lower interest rates for longer tenure than PAYG companies. This model is suited for 21Wp – 100Wp+ systems (Tier 2) since traditional consumer financing is more affordable than PAYG when repayment fees exceed the 0.5$/day range and repayment durations are above 18 months.

The marketing costs for this model are low compared to other models since FIs already have a regular and structured way of engaging with their customers. PV suppliers can therefore simply have their sales agents use this existing structure and process for marketing. FI branches can also be used as temporary depots to hold systems until they are picked up by customers or installers, which reduces supplier distribution costs. As with the PAYG model, the supplier requires a responsive

customer service system. When systems fail customers are often unwilling to make repayments which represents a financial and reputational risk for the FI.

FIs prefer to standardize their product offering across all their branches, therefore when a partnership is established, the PV supplier needs to be able to deploy sufficient sales and installation personnel to serve all FI partner branches. If the FI has a large and dispersed countrywide network of branches this can represent both a challenge and opportunity for the solar PV supplier.

This model was previously tried in East Africa in the early 2000s with little success [33, 34]. However, with standardized high quality plug and play solar PV systems, and larger dedicated solar PV suppliers, this potential is being re-explored. Sales through this model are currently in the thousands of systems per supplier per year.

Mini-grid Model

Mini-grids are typically in the 10kW-10MW capacity range while micro-grids are in the 1-10kW range [35] (those below 1kW can be considered pico-grids). Grids can either supply AC or DC electricity; DC grids are usually in the micro/pico-grid range. In East Africa, private solar micro-grids typically serve 20 – 400 customers. These grid systems are technically most effective when a large number of customers can be connected within a 1km radius. However a mix of mini, micro and pico-grids can be used for sparsely populated clusters of customers. Since the technical aspects are not the key focus, for simplicity the word 'mini-grid' is used in this article to collectively refer to mini, micro and pico-grids.

Most of the mini-grids visited during the study provided up to Tier 2 level of service. Some of the mini-grids could technically provide up to Tier 3 but not optimally. The main advantage of grid systems over stand-alone solar systems is that they enable customers to increase their power and energy consumption without having to invest in additional capacity. The entry barrier is also relatively low (connection/joining fees in the range of 0.1-40$).

Solar PV based mini-grids have a high capital cost; installed solar PV mini-grid costs for systems below 40kW, range from 6,000 – 13,000$/kW [36]. However, application of technologies for remote system monitoring and control, pre-paid metering and mobile money transactions have made it possible to manage grids with little or no on-site staff, thereby significantly reducing on site operational costs. Since most mini-grid sites are remote, there are still unavoidably high costs associated with site visits especially when it is not possible to develop an optimum cluster of mini-grids within a given radius.

Electricity tariffs are designed to recover capital costs, cover operational costs and generate a margin. Different strategies are used, but ideally it would be a combination of fixed fee to recover capital expenditure (capex) and an electricity consumption based fee charged to cover operational costs and generate a margin. However, this tariff model is difficult to implement when the fixed fee exceeds the fee for electricity consumption, since customers soon realize that they are paying a high tariff even when their consumption is low. On the private grids surveyed, household monthly electricity expenditure was 3-8$ while that for small businesses was 10-16$. Mini-grid developers indicated that they need a minimum of 6$/customer per month to be viable. However on most of grids surveyed, the average revenue per user (ARPU) is lower than this due to a high percentage of

small, inconsistent or dormant users. Seasonality of income was found to be a significant contributor to inconsistent electricity use.

Mini-grids need a large number of medium to large electricity users per site to be viable. Although users of refrigerators, freezers, electrical machinery and tools (e.g. for grinding, cutting, drilling, welding and milling) are ideal customers, mini-grid developers still need to determine whether it is worth the additional capex to increase the grid's generation and distribution capacity to serve these customers. Highly efficient appliances have a key role as they can reduce the capex required to provide a defined level of service. However, since efficient appliances are often more expensive than standard appliances, financing is required to enable consumers to purchase efficient appliances.

Electricity tariffs also need to be simply packaged and well communicated. If not, it is easy to create a perception amongst users that they are being cheated since most customers struggle to track and manage the units/kWh they consume. Tariff bundles based on typical appliances use seem to work well (e.g. a TV bundle that would allow a user up to 4 hours of TV and a couple of lights and the ability to charge 2 phones). This is because consumers then have the assurance of getting a clearly defined level of service when they make a payment. For this to be implemented effectively, standardization of appliances is required (i.e. it would be difficult to implement if different consumers were using different rated appliances). The mini-grid operator would therefore have a role is providing standardized and efficient appliances. To ensure a large number of early adopters when the grid is being set up and to properly communicate the available tariffs, sales personnel are also required in the mini-grid model to undertake door to door marketing.

The mini-grid developers surveyed indicated that simple pay back periods for mini-grids can be relatively long, between 3 – 7 years, depending on the generation capacity, number of customers and ARPU. Due to inverter costs and additional costs foe reticulation (i.e. to meet grid code standards and prevent electrocution), AC grids are typically more expensive than DC grids and have longer pay back periods. These long pay back periods make it difficult for developers to mobilize commercial finance. In addition, to be a commercially interesting venture, a mini-grid business needs tens to hundreds of thousands of customers (about 30 – 500 sites) to sustainably cover their overhead costs. Considering the challenges that private mini-grids developers are currently facing with accessing finance and identifying suitable sites for commercially viable grids, it will be difficult for them to scale.

Mini-grids are expected to have a key role in expanding energy access to rural and peri-urban areas. In recent years there has been a lot of investment from development partners [37, 38, 39] and the private sector in East Africa to develop commercially viable mini-gird models and an enabling policy and regulatory environment.

Fee-for-service Model

The fee-for-service model is similar to the mini-grid model, with the difference being that electricity services are provided through stand-alone systems as opposed to a distribution network. The model is well suited to providing electricity to dispersed communities, where large distances between customers make mini-grids unviable. It is not a new model, it was famously applied in 1999 as rural electrification model in South Africa using 50Wp solar systems [22]. In its most basic form it can be also applied as a rental model for solar lanterns or rechargeable batteries, where customers pay a recharging or usage fee.

In the fee-for-service model ownership of the systems is not transferred to the customer and the business/project is entirely responsible for maintenance and replacement of the systems. To be sustainable, the model requires large clusters of customers in a given area of operation. A significant upfront cost has to be borne by the business/project and the businesses surveyed indicate that simple payback periods may be as long as 7 years (unless the capex is subsidized). For this reason, it has yet to be successfully implemented as a fully commercial model in East Africa. However, once capex costs for an optimum number of systems are covered, sufficient revenues can be collected from regular service fees charged to existing customers to sustainably finance operations and expansion.

The model is suited for:

- Low income customers i.e. those for whom a Tier 0 –1 energy access level would suffice but are unable or unwilling to purchase a task lighting solution
- Provision of Tier 2 – 3 electricity services in areas where customers are sparsely populated (i.e. not suited for mini-grids) and are unable or unwilling to purchase medium to large solar systems.

Experiences of one of the businesses surveyed showed that for Tier 1 – 2, especially where fee-for-service payments are comparable to PAYG repayments, customers are more inclined to go for the PAYG option since their payments contribute to owning the system.

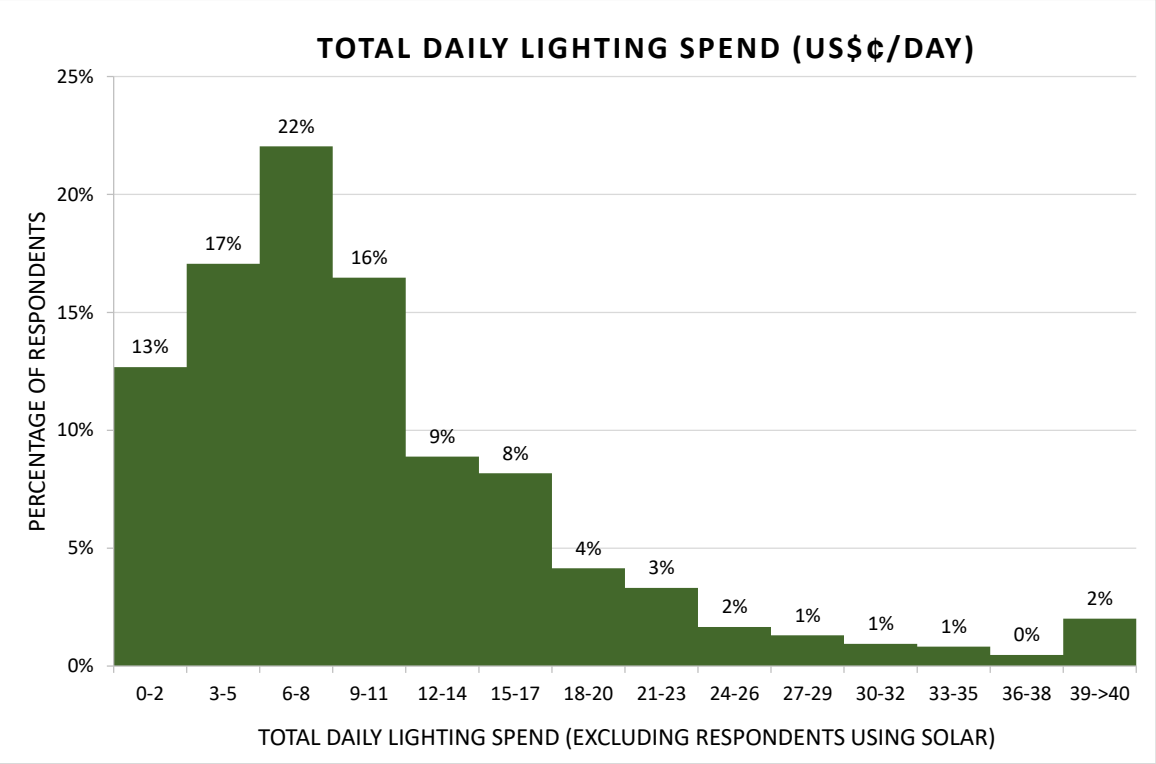
With some East African governments (e.g. Rwanda and Kenya) now considering solar home/business systems as a rural electrification option [40, 41], fee-for-service could prove to be a suitably effective and sustainable implementation model for areas where grid extension or mini-grids are not technically or economically viable.

Case Study: Solar Lantern Rental Model for Low Income Consumers

The Solar Transitions action research project [26] (implemented through the University of Oslo's Department of Sociology and Human Geography) developed an energy centre model [42] in Ikisaya, a semi-arid area in Kitui County, Kenya. The energy centre model, operationalized in March 2012, is based on a 2 kW solar PV system which provides energy for a range of services i.e. lantern charging and renting, phone charging, IT-services (typing, printing and copying) and TV shows. Fees charged for the provision of these services cover operation and maintenance costs. To make the services more accessible, lantern renting evolved from being offered centrally to being offered through agents in neighbouring villages (up to 11 agents within a 30km radius) [43].

The lantern renting services were offered at 10$¢/day and considered competitive with kerosene, which was sold at 50$¢ for a minimum volume of 300ml. However, as the uptake of lantern rental service was lower than expected, the project interviewed 1,189 respondents from the 11 villages to understand why consumers still opted to use kerosene for lighting when the lantern rental services appeared to be a better and cheaper alternative.

The survey found that the majority of respondents (46%) used kerosene as their main lighting source, followed by 18% who used torches. Only 14% used the solar lantern rental services, while 12% owned their own solar lighting system. The majority of respondents (32%) indicated that cost was the main reason for not using the lantern rental services. As illustrated below daily expenditure on lighting (kerosene and/or torch batteries) was found to be much lower than expected; 53% of those surveyed spent 0 – 8$¢/day, with 22% (the highest frequency) spending 6 – 8$¢/day.



Case Study: Solar Lantern Rental Model for Low Income Consumers (Cont.)

Due in part to the seasonal nature of agricultural income in the area, between harvest seasons households have to make difficult expenditure choices and kerosene is preferred because a 50$¢ purchase can be stretched as much as possible by limiting the daily consumption. In contrast, since lantern rental services are charged per day of use, there is no financial advantage to consumers for reducing their daily use.

It is possible to change the lantern rental pricing model to introduce a similar level of flexibility (e.g. consumers paying per lantern charge instead of per day of use). However, although it would benefit consumers, it would also significantly reduce the revenues generated (since consumers would have an incentive to minimize their lighting use and lantern rental expenditure) and subsequently result in a commercially unsustainable model.

Crucially, the survey does suggest that in areas with low economic activity expenditure on lighting will be far below the national average and only solar PV delivery models that can provide Tier 1 electricity services for around 3US¢/day will result in any tangible increase in electricity access for consumers at the bottom of the pyramid.

Discussion

Comparing the Delivery Models

Although it is inevitable that the different business models will be compared against each other (e.g. to determine which is the most effective in achieving access), it is important to also consider that the different models each have a unique role to play in the market. Table 2 below provides a summary of the models discussed highlighting their salient features and pointing out their key strengths and weaknesses.

The off-grid market cannot be served by a single model. Results from the study indicate that each model is particularly effective for a certain market segment and a combination of models is therefore required to serve the off-grid market. However, since the size of the different market segments will vary within and between countries, it is inevitable that some models will have a larger overall market share than others.

Table 3: Overview of delivery models, highlighting their salient features, strengths and weaknesses

Model	Salient Features	Strengths	Weaknesses
Retail/Over the counter	Markets off-the-shelf solar products on cash basis through a network of distributors and retailers	▪ Uses existing distribution channels, enabling easy access. ▪ Most successful model to date in terms of number of units sold	▪ Has only demonstrated success for low cost, entry level products ▪ Requires a large (permanent) rural based sales force to support distributors and retailers and undertake below the line marketing, which presents staff recruitment and retention challenges
PAYG	Leverages the mobile money transaction platform to offer easily accessible consumer financing solutions	▪ Facilitates a blanket approach to providing consumer financing, making it possible to quickly and broadly access a wide range of potential customers ▪ Can use existing distribution channels or an exclusive low cost depot based channel. ▪ Most effective model for delivering solar home systems (that can power multiple lighting points and appliances) ▪ Significant job creation potential i.e. for commission based sales agents, customer service agents and system installers	▪ Significantly high risk of default as it adopts a broad approach to assessing default risk ▪ Model creates a significant cash flow burden for PAYG businesses ▪ Cost of finance to the consumer higher than from conventional FIs due to the model's inherent risks ▪ Mostly serving households in the 6-40$/day income range, who are not representative of the BoP
Consumer Financing (via FI)	Traditional consumer financing model built on partnerships between FIs and solar PV suppliers	▪ Incorporates credit assessment and therefore less risky than the PAYG model ▪ Relatively low marketing costs as FIs are targeting existing customer base ▪ Can potentially deliver consumer finance at lower rates and longer tenures than PAYG	▪ Limited to consumers who have access to conventional financial services ▪ PV supplier needs to have sufficient capacity to serve a potentially large and dispersed number of customers spread across the FI's network
Mini-grid	Centralized approach to providing energy services	▪ Low entry requirement for consumers (i.e. connection fees) ▪ Can provide the spectrum of electricity services at a lower cost than most of the delivery models and allows consumers to climb up the energy access tier levels for little to no cost	▪ Technically and economically best suited to areas with a high population density ▪ Have relatively long pay back periods and mini-grid developers require very large numbers of customers to be commercially viable
Fee for Service	Decentralized approach to providing energy services	▪ Low entry requirement for consumers (i.e. connection fee) ▪ Greater flexibility than mini-grids; can be applied in both densely and sparsely populated areas. ▪ With some government's considering the use of solar home systems for rural electrification, this model could be an effective and sustainable means to implement this.	▪ Significantly high capex requirements and long payback period ▪ Yet to be implemented as a fully commercial model in East Africa

To demonstrate the suitability of the different delivery models for different market segments Table 4 below compares the price of the products or services delivered through different delivery models. The retail model is based on a retail price for an outright purchase, the PAYG model on a down payment and daily repayment amount, the consumer finance (via FI) model on a down payment and monthly repayment amount, and the fee-for-service model on a one-off joining fee and monthly service fee for electricity services provided.

Table 4: Comparison of solar PV delivery models of the surveyed businesses by market segment and consumer prices

Energy access tier	Market segment	Delivery Model	Retail Price	Down payment or Fee-for-service joining fee	Daily PAYG repayment amount	Fee-for-service monthly fee or Monthly repayment for consumer finance
Tier 0	0 – 1.5Wp	Retail	5.5 – 10$			
		Fee-for-service		0 – 1.2$		0.3$
		PAYG			0.3$	
Tier 1	1.5 – 3Wp	Retail	30 – 40$			
		Fee-for-service		4$	0.07 – 0.1$	
	3 – 10Wp	Retail	20 – 170$			
		PAYG		25 – 35$	0.4 – 0.5$	
		Fee-for-service		6 – 9$		4.5 – 6.7$
	11 – 20Wp	PAYG		19 – 80$	0.2 – 1.25$	
Tier 2	21 – 49Wp	Consumer Finance (FI)				25 – 30$
	50 – 100Wp	PAYG		18 – 62$	0.6 – 0.8$	
		Fee-for-service		55$		6.5$
Tier 2 (or Tier 3 for large systems)	100Wp +	PAYG (200Wp)		25$	1.2$	
		Fee-for-service (160 – 320Wp)		64 – 100$		9.5 – 20$

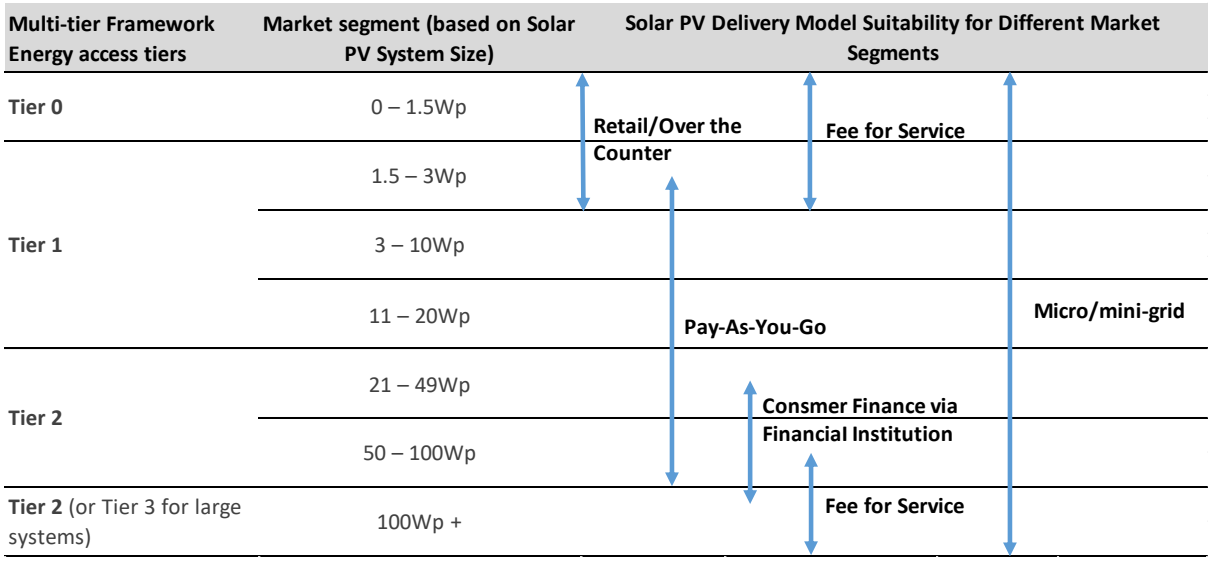
The mini-grids surveyed as part of the study can provide 5 – 100Wp per customer on average. The one-off connection/joining fees for mini-grid customers would range from 0.1 – 40$, while household customers (who typically consume less than 50Wp) would pay 3 – 8$ per month for electricity services and small businesses 10 – 16$ per month. These monthly fees are lower than PAYG system costs for a similar level of service.

As comparison of the different delivery models on the basis of product/service pricing is illustrated in Figure 1 below:

- The retail model is best suited for single light products (Tier 0);
- The PAYG and consumer financing models are suited for multiple light and mobile charging systems as well as basic and medium capacity solar home or business systems. PAYG suits the 3 – 100Wp systems (Tier 1 and 2), while the Consumer Financing model suits 50 – 100Wp+ systems (Tier 2);
- The fee-for-service model is suited for single light (Tier 0) especially where income levels as very low and customers cannot afford to make an outright purchase. It is also well suited for higher capacity solar home/business systems (100Wp+ (Tier 3)) when PAYG becomes too expensive for large solar PV systems

- Mini-grids can provide the spectrum of electricity services at a lower cost than most of the other delivery models. However, the mini-grid projects surveyed were non-commercial which significantly limits the scalability of this model (i.e. although the mini-grids are commercially run they are primarily financed through grants). The next section therefore considers how private mini-grid models can be incorporated into national rural electrification programs under a public private partnership framework

Figure 1: Model comparison – suitability of models (price based suitability)



As shown in Table 5 below, the retail and PAYG models are delivering relatively large volumes of pico-solar and solar PV systems to the market. Both models also create a good number of sales, customer service and technical jobs (mostly for rural youth) as well additional income generating opportunities for rural distributors and retailers along the supply chain.

Table 5: Comparison of solar PV delivery models by annual unit sales/number of customers and jobs created (Source: Surveyed EEP supported companies)

Delivery Model	Units Sold/ Customers per business	Full-time jobs created per business	Other jobs
Retail	50,000 – 300,000	40 - 50	40 – 50 distributors 500 – 3,000 retailers
PAYG	30,000 – 100,000	1,000	1,000 commission based agents and technicians
Consumer Financing (via FI)	2,000	30	30 part time technicians
Mini-grid	500	10 - 50	10 – 20 Point of sale agents and local technicians
Fee-for-service	1,000	40	10 part time technicians

PAYG companies have charted a path for the solar home system lighting market in Africa and demonstrated the role of consumer financing in significantly increasing uptake of off-grid solar PV solutions. The risk appetite for PAYG businesses is relatively high, as illustrated by the fact that they

have much lighter handed customer vetting processes than traditional financial institutions. As PAYG customer delinquency and default rate information is not publicly available, it is difficult to determine how long these companies will continue to have such a high risk appetite.

Although solar PV sales through consumer financing (via financial institutions) are currently low, there are indications that this could change. Most financing institutions have already adopted mobile money transaction systems and the success with PAYG could see them venturing in a bigger way into what they consider as their area of specialization. Mobile money transaction systems significantly reduce the transaction costs associated with processing and recovering loans, which would make it viable for FIs to also provide consumer financing for the lowest priced Tier 1 products. This, combined with the lower risk profile associated with customers of Financial Institutions, indicates the potential for an increased role for the Consumer Finance (via FI) delivery model. Furthermore, with the increasing availability of high quality products and dedicated solar companies (competing with each other for markets), financing institutions don't have to worry as much as they did before about non-performing systems resulting in defaulters and damaging relationships with their customers.

Why the Policy and Regulatory Framework for Rural Electrification Should Be Reconsidered

The archetypal public rural electrification model consists of a capital investment on infrastructure (mostly grid based) to reach off-grid customers, who are then handed over to the public electricity utility. The capital expenditure costs are financed using government budgets, levies on connected electricity consumers and/or grants or loans from development agencies. Although it is widely assumed that this is the most effective model for rural electrification, it has some notable short comings:

- Conventional rural grid connection costs are in the range of 580-4,500$/connection for 5-100 connections per km (costs per connection being lower, the higher the number of connections) [44]. Considering that these customers will spend 3 – 16$/month on electricity (as indicated by the private mini-grids surveyed), more affordable electrification options need to be applied and/or ways found to leverage private sector investment to bridge the funding gap
- Although the public model increases the public utility's customer and revenue base (with little or no investment on its part), it also translates to higher operations and maintenance (O&M) costs for the utility, as new customers become more remote and difficult to serve. One possible effect of this is curtailed demand caused by shortcomings or failures of the electricity network. The 2016 Kenya Power Generation and Transmission Master Planning Study [45] estimated an unserved demand of 836GWh (in 2014) as a result of this (NB: the report mentions that this is a vague estimate and detailed studies on this are required)
- Additional domestic consumers don't translate into a proportional increase in revenue for the utility; while the number of domestic electricity consumers on the Kenyan grid increased by 200% between 2010 and 2016, the revenue generated only increased by 53% [46]. Conversely, during the same period, there was a proportional increase between the number of new small and large commercial customers and the additional revenue generated. Further comparison between the annual revenue from domestic, small and large commercial customers indicates that, on average, a small commercial customer is equivalent to 10 domestic customers while a large commercial customer is equivalent to 13,800 domestic customers. Utilities therefore have little commercial incentive to serve small rural consumers

In light of the success demonstrated by commercial solar PV delivery models (i.e. the retail, PAYG and consumer financing (via FI) models) and the potential of currently non-commercial models (i.e. solar PV mini-grids and fee-for-service) provide low cost electricity services sustainably, there is sufficient justification to consider and develop alternative rural electrification models. These alternative models would, in principle, try to leverage private sector support to help governments' reach their rural electrification targets.

Government support for the solar PV private sector in East Africa has mostly been in the form of exemptions on import duty and value added tax on solar PV modules and balance of system components. Only recently (2016) have some governments (Kenya and Rwanda) started considering how to use standalone systems for rural electrification. This is a significantly positive development since a major shortcoming of most national rural electrification strategies is that they have historically neglected households and small/micro businesses in sparsely populated areas, where grid extension or mini-grids are not technically or economically viable. In such areas, households and small/micro businesses have been expected to find their own solutions with little or no support provided by rural electrification programs.

However, the use of standalone solar PV systems by national rural electrification programs to electrify households and businesses does raise some fundamental policy challenges:

- How will electrification through a standalone solar PV system be reconciled with the conventional grid associated definition of electrification? The conventional grid associated definition is currently the basis on which national electrification budgets are allocated and results measured
- How will solar system based rural electrification programs be designed to ensure that the electricity services accessed are equivalent to those that would be provided by a grid based electrification program?

One key advantage of a grid connection is that it enables a household or business, when ready, to seamlessly graduate along the energy access tiers, with little or no additional cost. While the rural electrification strategies for Kenya and Rwanda are keen to support entry level solar systems that provide Tier 1 and 2 levels of service, they do not explicitly describe how they plan to enable households and businesses to graduate to higher levels of energy access.

When it comes to implementing mini-grids, the public and private sectors have different and complementary strengths. The government/electrification authorities can mobilize large amounts of public funding to implement mini-grids at scale (both in terms of number of systems and size of systems). In addition, this type of public investment is considered a social investment; governments are not looking for a financial return on investment. On the other hand, the private sector's strength lies in speed, efficiency, cost effectiveness and the ability and flexibility to innovate (i.e. quickly adopt or adapt new technologies as they emerge). One could therefore expect that the most effective mini-grid models would be based on well-designed public-private partnerships.

The implementation of solar PV mini-grids in 1,439 villages in Chhattisgarh, India between 2001 and 2014 is an example of a complimentary partnership between the public and private sector, where the government used its resources to finance rural electrification[47]. The program was developed and implemented by the Chhattisgarh Renewable Energy Development Agency (CREDA) and served

57,000 households in 2014. The mini-grids were financed by the national and state government to the tune of US$30 million, most of which was raised through levies charged on conventional electricity. CREDA was responsible for community engagement, village survey for the network design, system design, development of technical specifications and procurement, while private sector was responsible for supply of materials and equipment, installation and provision of day to day O&M services for the mini-grids.

Where government needs to encourage or leverage private sector investment for mini-grids, approaches that enable private sector to secure their investment have to be considered e.g.:

- Allowing private mini-grids to interconnect when the national grid arrives. This way private developers can continue to serve customers on their grid (with cheaper main grid power) and the additional option of selling power to the national grid operator. As private mini-grid developers cannot compete with electricity prices offered by the national grid, the extension of the national grid is currently considered a business risk rather than an opportunity.
- Compensating private mini-grid developers when the grid is extended or when the government decides to implement a mini-grid to serve the same customers
- Developing an off-grid (mini-grid) power purchase agreement model; where private sector focuses on generation while the national utility (which can manage and extend electricity cross-subsidies) focuses on distribution. This way the private investors are guaranteed a return on investment while mini-grid customers can benefit from electricity cross-subsidies.
- Developing effective coordination mechanisms for implementation of mini-grids between government and private sector. This would include, inter alia, a national study to identify all potential mini-grid sites, a clear allocation of sites for government and for private sector, and an accurate government schedule for extending the national grid to mini-grid sites allocated to private sector.

These approaches have to address a fundamental challenge arising from government desire to have standardized electricity tariffs nationally, while the reality is that small private mini-grid developers cannot charge the same tariffs as national electricity distribution utilities (who have the advantage of economies of scale). The Senegal mini-grid case study also demonstrates that government preference for nationally standardized electricity tariffs is not unique to Kenya. In March 2016, the Senegal government was considering how to address this tariff difference through provision of subsidies to private mini-grid developers.

A mini-grid model is a utility model, and for any utility model to be commercially viable it has to be based on an optimum (often large) customer base. This raises a key question for private sector; are there sufficient mini-grid sites in their target region or country for them to reach the optimum customer base needed to operate a commercially viable mini-grid business?

As mentioned above, considering the additional burden that connected rural electrification customers on the periphery of the grid represent for national electricity utilities, government should also consider how to concession these customers to private mini-grid businesses (who would serve them through a sub-distribution model). This could be one possible way to help private mini-grid developers reach an optimum customer base. Mini-grid developers should also consider combining

the mini-grid model with the fee-for-service model to serve customers that they would be unable to reach through the mini-grid, further growing their customer base.

Conclusion

Solar PV delivery models can be considered the final component to delivering electricity access through solar PV based solutions. They complete a circuit whose other key components include technology and finance.

Based on private sector experience with solar PV delivery models in East Africa, this review indicates that:

- The retail model and the PAYG model are currently the most effective (at reaching scale) and commercially viable,
- The consumer financing model (via FI) is a very promising commercial model and
- The mini-grid and fee-for-service models are unlikely to be commercially viable in the short to medium term.

The success of the retail and PAYG models, however, must be tempered by the realization that these models have been limited to delivering the lowest level of energy access (Tier 0 – 1). Although PAYG is providing solutions for Tier 2 – 3, these are only affordable for high income consumers. The gaps that need to be addressed are therefore: 1) how to affordably provide higher levels of energy access across all income brackets and 2) how to deliver the most basic access to 'true' bottom of the pyramid consumers.

The consumer financing model (via FI) has potential to partly address the first gap; and there are good indications are that the mini-grid and the fee-for-service models can address both gaps. However, while mini-grid and fee-for-service models currently show potential for operational sustainability, it seems unlikely that purely privately funded, commercially viable versions of these models will be implemented in the short to medium term. But, considering the limited success of conventional (grid based) rural electrification programs and the public funds available for this, there is the opportunity to consider how innovative mini-grid and fee-for-service models based on public-private partnerships can be applied as rural electrification strategies.

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