

Photovoltaic Stand-Alone Systems and the Rural Electrification in Sub-Saharan Africa: The Private Sector Delivery Models and the Challenges of a Base of the Pyramid Market

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ABSTRACT

Concerning the efforts for the universal access to electricity, more attention should be given to rural areas, where the vast majority of people without access to this basic service is located. Within this context, more support should be given to Sub-Saharan Africa (henceforth, SSA), the region of the world with the largest concentration of individuals without access to electricity, which simultaneously has a huge potential for generating it by using photovoltaic systems. Under these circumstances, stand-alone systems can be seen as a good option, as they have capacities that are suitable to the potential low level of consumption of this population, have lower costs when compared to other alternatives and can be implemented in an independent way by the private sector, without the involvement of other stakeholders.

It is not easy to do businesses in these areas, because they comprehend the so-called Base of the Pyramid markets, what implies in a series of challenges for the entrepreneurs. They try to adopt different strategies in order to overcome these challenges and establish profitable businesses in these adverse environments. The present study tries to understand the challenges found in these markets and the successful strategies, in terms of delivery models, adopted in the region by these entrepreneurs. A reflection with the intent to discover if the delivery model choice determines the success of a photovoltaic stand-alone business in rural SSA, as well as to decide which delivery model seems to be the most promising, is made.

Key words: rural electrification, solar pv, stand-alone systems, delivery models, Base of the Pyramid market, Sub-Saharan Africa

1. INTRODUCTION

Access to electrical energy is a fundamental aspect in the efforts to reduce poverty around the world, since it is able to contribute both to the economic development, as well as to the improvement of the quality of life of those living in the planet's poorest areas [1, 2]. SSA, the poorest region in the world, concentrates the largest number of individuals without

access to this basic service. They represent 588 million of the approximately 1 billion people without electricity in the world, inhabitants of rural areas in its vast majority [3]. Therefore, the resolution of the lack of access problem is related to rural electrification, which tends to be more complex and expensive than to provide the access in urban areas, due to different nature aspects [3].

2. LITERATURE REVIEW

According to the International Energy Agency (IEA) and the World Bank, to ensure universal access to electricity by 2030, 60% of new generation resources must come from off-grid solutions [3]. When analysing separately the rural areas without access, this percentage is even higher, around 70% [3]. This is related to the fact that the extension of transmission lines in developing countries is not economically feasible for remote rural areas, due to the high costs associated to it, the low demand for electrical energy in these areas and the transmission losses [1].

The data presented demonstrates the importance of the role that the off-grid systems should play in the context of the expansion of sustainable electrification in rural areas. In this context, the photovoltaic solar power should play an important part. Between the off-grid generation systems that make use of renewable energy sources, solar photovoltaics has advantages.

In the context of SSA, the option for solutions that use the solar resource makes total sense, since the region has excellent potential for this type of generation. In this regard, there are three technology options available: solar micro-grids, pico-photovoltaic systems (PPVS) and solar home systems (SHS). The last two are classified as stand-alone systems.

The microgrids require higher investments than the stand-alone systems, and usually need support from international investors and governments. They also demand a combination of various generation units with a high technological complexity and are appropriate to the contexts in which the dispersion of the community is low and there is a certain level of consumption that justifies these investments [4]. This

is not the case of SSA rural areas without electricity access, where the households' consumption, as well as the small businesses', are usually limited to night lighting and to power small electronic appliances. That results in a too low base load for system which comprises a distribution grid, as the microgrid. **Figure 1** presents the best fitting of grid extension, micro-grids and stand-alone systems in terms of cost of electricity according to community characteristics.

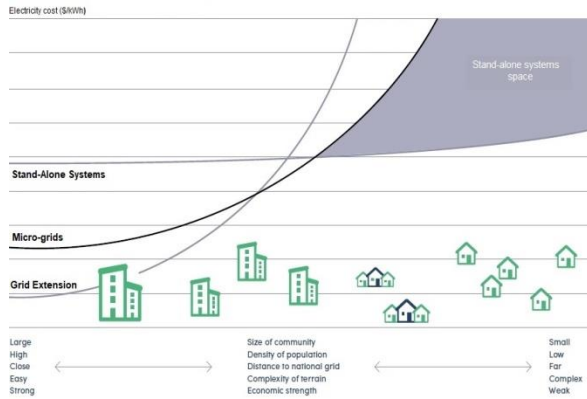


Figure 1: Electricity cost according to local characteristics [5].

In the case SSA rural areas, communities tend to be small, to present low population density, the distances to the main grids tend to be large, the terrain tends to be complex, the economic environment is underdeveloped, the potential demand for electricity is usually low, as well as the investment power of those potential consumers. Within this context, the stand-alone systems take advantage against micro-grids, proving to be more suited to the region. Therefore SHS and PPVS are the technologies considered in the present study.

The main difference between them is related to the rated power. PPVS present lower capacities (below 11Wp) than SHS (above 11Wp). However, they are classified in different segments according to Global Off-Grid Lighting Association (GOGLA), as shown in **Table 1**.

Table 1: GOGLA stand-alone photovoltaic systems segments [6].

Overall Category	Capacity Watt-peak (Wp)	Services provided	Corresponding MTF service level
PPVS < 11Wp	< 1,5Wp	Single light	Enables partial Tier 1 electricity access to a person/household
	1,5 - 3Wp	Single light and mobile charging	Enables full Tier 1 electricity access to at least one person and contribute to a household
	3 - 11Wp	Multiple light and mobile charging	Enables full Tier 1 electricity access to at least one person, up to a household
SHS ≥ 11Wp	11 - 21Wp	SHS entry level (3 to 4 lights, mobile charging, radio, fan etc.)	Enables full Tier 1 electricity access to a household
	21 - 50Wp	SHS basic capacity (as above plus power for TV, additional lights and appliances)	Enables full Tier 2 electricity access to a household when coupled with high-efficiency appliances
	50 - 100 Wp	SHS medium capacity (as above but with extended capacities)	Enables full Tier 2 electricity access to a household even using conventional appliances
	≥ 100Wp	SHS higher capacity (as above but with even higher capacities)	

PPVS are divided according to the service provided. There are three segments: single light (0-1,5Wp), single light & mobile charging (1,5Wp-3Wp), and multiple lighting & mobile charging. While SHS are segmented by rated power: 11-21Wp, 21-50Wp, 50-100Wp, and above 100Wp. They are also related to the level of service they provide through the Multi-Tier Framework, from Energy Sector Management Program (ESMAP). Single lighting PPVS provide at the maximum partial Tier 1, single lighting & mobile charging provide at the maximum full Tier 1, while multiple lighting & mobile charging can provide partial Tier 2. 11-21Wp SHS provide partial Tier 2, 21-50Wp can provide full Tier 2, 50-100Wp can provide partial Tier 3 and above 100Wp can provide full Tier 3.

2.1. BoP market

Although photovoltaic stand-alone systems are more accessible and affordable alternatives than other solutions, there is a huge challenge concerning its marketing for electrification of remote rural areas. It is the fact that a large proportion of individuals who inhabit these places is part of the so-called Base of the Pyramid (BoP) market [1], which imposes several additional restrictions to entrepreneurs who intend to offer this type of solution in these areas. The success of electrification initiatives in these markets is, therefore, not only related to the choice of the technology, but also to the development and adoption of innovative business models, which make possible the establishment of profitable businesses for companies [7], at the same time they make the solutions affordable for the consumers. Although the initial cost for this technology is lower than for other alternatives, it is also the main limiting factor for the spread of these systems, being usually more expensive than the value BoP consumers are able to pay [3].

There are different definitions of BoP market, but the one adopted in this study is that it is composed by the individuals who receive less than USD 8 per day [8]. The BoP consumers are usually located in the least developed countries or in rural areas of developing countries [9], being that the case of SSA rural areas. Therefore, the challenge of rural electrification in SSA cannot be dissociated from the one that is operating in BoP markets. These markets have a high uncertainty level [10, 11], which can be related to diverse common aspects of BoP consumers. They have very limited purchase power, as they usually work in the informal market, in seasonal activities and receive their payments on a daily base, what makes it difficult to save money and make higher investments [12, 13].

The absence of regular cash flows shown in the previous paragraph, with the absence of credit records and their lack of capacity to satisfy loan requirements, limit the access of the BoP consumers to the traditional financing channels and makes it difficult for them to pay for basic services [14, 15]. As a

consequence of these restrictions of revenue and financing, the demands tend to be low in these markets [12]. Consequently, the main challenge to the companies operating in the BoP markets is trying to reduce their costs to the minimum [16].

2.2. Delivery models

In order to reduce their costs for supplying and marketing photovoltaic stand-alone systems in these markets, companies adopt different delivery models. [17] found four delivery models that have had satisfactory results in SSA, through the analysis of projects based on photovoltaic systems, of the *Energy and Environment Partnership* (EEP) portfolio.

Retail model

Retail model is the former delivery model used in the region. The consumer acquires the system through a cash payment, and becomes its owner. There are two different types of this model, “cash & carry” and “cash sales”. In the first, the consumer is responsible for the installation, operation and maintenance of the system, while in the latter, the supplier is responsible for the installation, which increases the cost of the system [18].

This model is implemented through a supply chain that usually comprises an importer/supplier, distributors, retailers and a team for field sales [17, 19]. It also requires a national network of distributors and shops, to ensure that the products are easily accessible. The transactions along the supply chain are based in cash, but there are some vendors who offer short-term credits to their distributors [17].

Pay-As-You-Go (PAYG) model

PAYG model is the most recent model. It is a financing model based on transactions *per* mobile-money, which are increasingly common in SSA, being offered by mobile phone companies through GSM technology. The consumer makes a deposit (of a given value) for the mobile phone service provider, which is converted into mobile-money, and after this he can make transfers through his mobile phone via SMS.

In this model, system supplier provides the financing to consumers. The consumer pays an initial value, and the remaining is paid in instalments by mobile-money on daily, weekly or monthly basis, according to his preference. The products provided through this model have a mechanism of remote control and monitoring, which makes possible for the supplier to block their operation in case of consumer default, and it also serves to collect data about his customers. The payment plans usually have terms between 12 to 36 months, but there are also some longer than that [20]. At the end of this period, the consumer becomes the owner of the system.

From the suppliers' point of view, this model has facilitated their activities, as it reduced the cost and complexity of the supply chain. In physical terms, it just needs warehouses, where retailers and installation and maintenance technician fetch the products or parts

they need [17]. The establishment of partnerships with dealers with national reach, to disseminate more easily the products is a common practice [19].

Consumer financing model (via financial institution)

This model is based on the establishment of a partnership between the supplier of the system and a financial institution (FI), which can be a commercial bank, a microfinance institution, savings and credit cooperatives, among others [17]. It can be divided in two parts: the technological, which involves the system supplier, responsible for its delivery, installation, operation and maintenance; and the financial, which is in charge of the partner institution, responsible for providing credit to the consumer, and collecting their payments [18].

Hence, the supplier is paid by the FI for the delivery and installation of the system, without having its resources committed. The risk of default is reduced, since the FI has records of their clients and experience in analysing credit applications through various instruments. Also they are able to offer financing with lower interest rates and longer terms [17]. After paying the loan, the consumer becomes the owner of the system.

Fee-for-service model

Unlike other models presented here, in the fee-for-service model the consumer does not pay for the product, but for the service, so he does not become the owner of the system at any time. The consumer usually pays the supplier a given value for the installation and then has to pay a monthly fee for using the service, in which are already included the maintenance costs [12]. The supplier is, therefore, responsible for the installation, operation, maintenance and, if necessary, replacement of the system. In this regard, it has to promote periodical technical visits to check if the system is operating properly. In case of constant default of the consumer, the system is removed from his house.

Distribution channels

The distribution channels are important for businesses to maximize the reach of their products or services. Although there are several different models when it comes to distribution channels, [5] presented the five that prevail for the supply of photovoltaic stand-alone systems in SSA.

In the first one, the company has its own distribution channel. A different method is the one where the company sells its products through networks of existing distributors. The third type is based on partnerships with relevant institutions in the area (may be FI, mobile phone companies or local NGOS) and uses its structure. In the franchise model, the company offers packages of franchising to local entrepreneurs who wish to become resellers. In the last model the company hire local entrepreneurs that

become responsible for the rental of the products. This can be only applied to the fee-for-service model.

In order to reach a larger number of costumers, the suppliers usually use more than one type of distribution channel at the same time [5].

3. ANALYSIS OF THE MODELS

The aim of this reflection is to analyse the adequacy of these models to the different categories of photovoltaic stand-alone systems, as well as the strengths and weaknesses of each one of them in the context found in SSA rural areas and the definition of distribution strategies that best fit them.

The final goal is to answer two research questions. The first is if the choice of the delivery model determines the business success, and the second concerns the definition of the most promising delivery model for the region.

Retail model

The acquisition of the system is made through cash payment. From the supplier's point of view it is seen in a positive perspective, once he does not have his capital tied-up in financing, becoming exposed to a very low financial risk [18]. For BoP consumers, such as those found in SSA rural areas, it is difficult to make cash payment for the system given their limited resources. Thus, this model is only suitable for systems with lower costs, presenting limited market potential.

Therefore, this model presents itself as suitable for lower capacities PPVS, the cheapest systems that within the range consumers with daily income below USD 8 can pay. This explains the reason why it is the most widely used model for the single light only (0 – 1.5Wp) and the single & mobile charging (1.5 - 3Wp) segments of PPVS [17]. The first category is priced between USD 7 and USD 11, while the second between USD 18 and USD 35 [22]. This makes the model more effective for the first category [17], since BoP consumers have difficulty in accumulating savings.

The single light systems, best sellers of this model, usually have a useful life of 2 to 3 years [17]. This contributes to the sustainability of the business, once at the end of this period, the consumer ends up acquiring a new solar lamp. If the product has satisfied his needs, it is very likely that he will buy it again from the same supplier, since for BoP consumers it is important to have ensured the reliability of the product in which they are investing [21]. The result is that the annual sales of these products are in the level of tens to hundreds of thousands per supplier [17].

From the consumer's point of view, there are two other negative aspects with regard to the model. As the consumer becomes immediately the owner of the system, he also becomes responsible for its maintenance and eventually replacement of damaged components, when they need to do it they tend to opt for low quality components, as they are cheaper than the ones with superior quality [18], what can result in

system failures. Moreover, with respect to the "cash & carry" model, in which the installation is made by the consumer, it can result in poorly installed systems [18]. In both situations, the consumer access to electricity may be, consequently, compromised.

With respect to distribution channels, there are several possible and interesting options for the model. As the system is sold through cash payment, lower are the expenditures with the supply chain, lower tends to be the final price of the product. In this regard, having his own supply chain can be appropriate, because depending on the site in question, fewer intermediaries may result in lower costs along the distribution channel. The supplier must have his own warehouses, sales' team and installation and maintenance team. The latter just in the case of "cash sales" model, in which the supplier is responsible for the installation and maintenance of the systems.

Another option is the marketing of systems through existing channels of distribution on location through the use of an existing structure, which may be or not specialised in this type of product. It may represent cost reduction, because in certain areas it may be more expensive for the company to maintain its own structure than to pay to intermediaries. Usually there are two hierarchical levels in this distribution channel, a distributor and a reseller. The establishment of an institutional partnership can also be a good option to contribute to expand the business. By establishing a partnership with a local institution (a NGO, i.e.), the company can get easier access to potential consumers, since many inhabitants of the area must have contact with the NGO, which reduces marketing costs.

The franchising model can also be suitable for this type of delivery model. It is quite interesting because the company is not responsible for those costs linked to the maintenance of sales teams and dissemination or technical assistance. It becomes responsible only for providing training and some support in terms of marketing. However, this model depends on the existence of local entrepreneurs interested to become franchisees.

Distribution expenses are among 30% and 50% of the price of the product, in which they have to be included to make the model sustainable [17]. However, forecast them accurately is not a simple task, as they can greatly vary according to the characteristics of the served area. In the case of its own distribution channel, what includes spending on recruitment, training, and maintenance of the sales' team, technical assistance and expenditures with the warehouse. In order to reduce them, an interesting option is to have a sales team that is also able to perform installations and providing technical assistance.

In rural areas of SSA, these costs tend to be higher, as there is usually a lack of transport systems and the distances between the communities are larger, which increases the cost of transporting the team. This is a

challenge faced primarily by new companies, or the ones that are launching new products, and therefore require a sales team that has as main function the dissemination of the product, that is to make it known in the market. Once a product has already become known and provided positive experiences in the community, word of mouth advertising becomes enough in BoP markets and consumers start to go directly to the dealer, or to the warehouse to acquire them [17]. To ensure that the experience of consumers is positive, it is important, therefore, to offer a quality product associated with a warranty.

In relation to sales and marketing team, hiring local work-force is a differential, as they are part of the community, they usually have higher credibility within his friends and neighbours, as well as they do not face challenges in terms of communication. However, the company may have difficulties in finding local workers, since these are areas in which the population has a low educational level and as such the company would have additional expenses training them.

Because it is a model used in the marketing of the simpler PPVS, which have low prices, it is difficult to have a sales team working on a commission basis. Therefore, they usually receive a fixed value, plus a bonus for sales targets and a value to cover the costs in the field.

PAYG model

The PAYG model is the latest among the four addressed in this study, and has contributed to the expansion of sales of SHS [22]. As it is based on the provision of funding for the acquisition of the system by the consumers, it is able to exploit higher stand-alone systems segments than those typically marketed through retail model. From the supplier's point of view, it is interesting to make higher-value products accessible to BoP consumers. On the other hand they require higher initial investment, once the term for financing payment is usually between 12 to 36 months, which may be even higher [20]. During this period the company has its investment power reduced, becoming exposed to a higher risk than in the retail model.

The absence of formal institutions is common in a BoP environment [23], and many of these consumers do not have access to traditional financial services. Through PAYG, these consumers have easy access to financial services. Besides that, it has facilitated the activity of suppliers, once they don't need to physically collect payments from consumers, which can be complex and expensive in the case of SSA rural areas, where the population is scattered.

PAYG model is most often used for PPVS with higher capacities, multiple light & mobile charging (3Wp-11Wp) and all segments of SHS [22]. However, since 2016 it has been used to smaller PPVS, single light & mobile charging (between 1.5Wp and 3Wp), with daily instalments of USD 0.3 over 6 months [17]. The greatest success was obtained with the SHS with

the lowest capacity (11Wp-21Wp), with daily instalments in USD 0.5 over 12 months, while these systems price starts around USD 125 [17, 22]. This resulted in sales at the level of hundreds of thousands of units per supplier annually [17]. For SHS with higher capacities, (above 21Wp), the rates are between USD 0.8 and USD 1.2 per day within a period of 36 months, and the annual sales at the level of the tens of thousands of units per supplier [17].

The success of the PAYG model is related to the fact that it offers three different payment basis (daily, weekly and monthly), as well as with the low value of the instalments that are paid by consumers. This even allows BoP consumers with the most limited incomes to be able to cope with the value of those instalments. Taking into consideration that BoP consumers in SSA spend on average 5% of its revenues with energy [24] and the values of the instalments presented above, it is concluded that this model fits households with daily incomes between USD 6 and USD 24.

The value of the instalments depends on the cost of the system in question, on the value of the initial payment that the consumer was able to make (which tends to be low in order to attract customers), and on the financing term. In order for stand-alone systems with higher capacity, thus more expensive, to have lower value payments accessible to consumers, the number of instalments - and consequently the term - must be higher. The success of the model depends on the value of the rate charged to consumers.

The mechanism for monitoring and control, which enables the company to lock the system in case of default, contributes to the reduction of exposure to risk, since when they have their electricity turned off, consumers tend to make the default payment [17, 20]. Besides that, this mechanism enables the company to collect data about the consumption profile of its customers, as well as on the probability of them becoming defaulters. In this sense, the company takes advantage of the competitors that are entering the market. However, it can be harmful to consumers, who may have its bargaining power reduced [22].

With regard to the distribution channels, there are two strategies that fit better. The first is the company has its own structure, composed of warehouses and sales and installation and maintenance teams, which go directly to the warehouses to fetch the products and parts that they require. Another possibility is the establishment of partnerships with mobile phone companies that have relevance in the local context, since the consumers that this model seeks to achieve are necessarily associated to one of them, once they realize their payments through mobile phones. In this regard, the company can reduce its distribution costs, taking advantage of an existing structure, as well as of the partner's costumers, which may represent an advantage in terms of marketing the product and obtaining the trust of those individuals.

When selling SHS, the sales team can be paid exclusively by commissions, as they are systems of

higher price, starting around USD 125 [22]. A strategy used for the sellers to focus on customers who have conditions to afford the payments, is to associate part of the commission to the instalments [17]. Hiring and training community members for the sales team or installation and maintenance can contribute to the success of the venture, since they tend to have greater credibility in the community, as well as have ease communication with these consumers. However, the population of the rural areas of SSA usually has a low education level, which, in turn, results in higher training costs.

To make the model successful, it is necessary to offer a responsive customer service system, to register customers, face technical challenges, coordinate the installation and maintenance technicians and follow the default clients. Customers tend not to make payments when the system is not working properly [22]. For lower power systems, the cost of reintegration of property of the system by default can be significant to the company, because it may not be possible for it to be resold. Some companies, therefore, offer these customers a financial incentive to voluntarily return the system to a warehouse.

PAYG has evolved and companies have realized they can increase profits by offering new loans to their clients for the acquisition of other products not necessarily related to electrical energy [20]. In this regard, the mechanism of control and remote monitoring continues to be used in case of default, blocking the system, and if the situation persists, both the product purchased and the system have their property reintegrated.

East Africa is the sub-region of the SSA where this model has achieved hugest success, because in general, it offers a consolidated mobile phone network. However, it is expected to expand to other sub-regions, since the number of mobile phone service signatures in the last ten years has had an exponential growth [1], and the coverage of this network is already superior to the one of the power grid [7].

Consumer financing model (via FIs)

Consumer financing model is the model that offers major difficulties in terms of implementation in SSA. It is based on the partnership between the supplier of the technology and a FI acting on the area, while the business environment in the BoP markets in the region is extremely informal [1]. The biggest challenge faced by this model is the difficulty to find a FI for the establishment of the partnership, as there are few who have activity in this kind of area [18].

As mentioned before, in this model the company is responsible for providing the technology, as well as its installation, operation and maintenance, while the FI is responsible for the financing. The great advantage for the supplier is that the one who holds the risk is the FI, once it pays the full value of the system to the supplier as soon as the system is purchased by the consumer, becoming responsible for the collection of the payments. However, FI's is low, once it has credit

records of its customers and experience in the evaluation of credit [17, 18].

This model is most often used with the most simple stand-alone systems, single light PPVS (0-1.5Wp), or single light & mobile charging (1.5Wp-3Wp) [5]. However, it is more appropriate for the dissemination of SHS with capacities above 21Wp, i.e., stand-alone systems with higher levels of service (Tier 2), because this model consists in a more affordable financing option in relation to the PAYG when the instalments to be paid by consumers exceed the value of USD 0.5 per day and these payments will last for more than 18 months [17]. This occurs because FIs are more robust, so they are able to offer more advantageous financing options without being so exposed to risks. As the instalments to be paid on a daily basis have values starting at USD 0.5, this model reaches upper segments of SSA BoP consumers, corresponding to households with daily revenues above USD 10.

With regard to distribution channels, through the establishment of partnership with the FI, the supplier can use its distribution network and, in turn, reduces its costs. The subsidiaries of the FI serve as temporary depots, where the supplier's installers take out the product to be installed. In addition to it, there are also cost reductions associated with the distribution of the products. The supplier takes advantage of the existing structure used by his partner to reach their customers (with whom the FI has credibility and a relationship of trust), once it provides credit to these individuals even having the knowledge of their limited funds.

The supplier should offer an efficient and responsive customer support service, because when the systems fail it is common that consumers no longer make the payments, which, consequently, can be a financial and reputation risk for FI [17]. The choice for local workforce training for installation and maintenance contributes to the responsiveness of the customer service. It not only shortens the displacements, but also this local staff will tend to have a greater concern to ensure the services to their friends and neighbours.

However, as mentioned for the other models, due to the low educational level of the population in the region, the training of locals for both sales and technical support can provide difficulties and raise the business cost.

Another issue that may result in a higher cost to the supplier is the fact that the FI tend to have the standard offers in all the areas where it operates. The supplier of the system must, therefore, have sufficient sales workforce and installation and maintenance technicians to cover all these areas. As this model is more suitable for the delivery of systems of higher power, that involving higher figures, the sales team should get paid based on commissions, as it also works as an incentive to gather more customers.

This model was applied in East Africa in the beginning of the year 2000, and it has achieved some

success. More recently it started to be used again due to the emergence of more standardized SHS and of high quality and specialized suppliers. The sales by this model are at the level of the thousands of systems annually by vendor [17].

Fee-for-service model

Among the models discussed in this study, the fee-for-service model is the only one in which the consumer does not get the ownership of the system at any time. The supplier leases the system to the consumer, who performs an initial payment corresponding to its installation and then pays a monthly fee, in which are already included the supplier maintenance costs. In this model, the supplier is responsible for the installation, operation, monitoring and maintenance of the system, as well as for its replacement in the case of failure [18].

The initial investment made by the company is high, while its payback can take about 7 years, which is a negative aspect of this model. In this regard, the supplier is exposed to a high financial risk. In case the supplier has an optimal number of customers, after the payback the revenue received through the service fees charged to consumers becomes sufficient for the sustainability of the business [17]. In this sense, it is important to have some support for the initial investments in terms of subsidies, so that the supplier becomes less exposed to risk and able to recover his investment more quickly.

An advantage of this model is that it can be applied to all segments of the system. Nevertheless, it presented itself more suitable for BoP consumers with lower revenues, to which a Tier 0 or Tier 1 level of access is sufficient, i.e., the categories of PPVS with lower capacities, single light (0-1.5Wp) and single light & mobile charging (1.5Wp-3Wp), but who do not have conditions or are not willing to acquire a system [17]. As mentioned above, these systems are usually sold through the retail model, through which the consumer acquires it by cash payment, what can be a huge difficulty for a large part of BoP consumers, because of their reduced investment capacities.

To ensure its competitiveness compared to the other models, two aspects are fundamental. The service fee should be low enough so that the consumers would prefer it [18]. When dealing with systems that provide service level Tier 1 or Tier 2 of the MTF, i.e., systems with rated power between 1.5Wp and 100Wp. With the emergence of PAYG, if the service fee charged to consumers presents values similar to those of the instalment to be paid through the PAYG, consumers tend to opt for the PAYG, once they become the owners of the system after finishing the instalments payment [17]. The other aspect is that the technical assistance must have high quality, in order it represents a differential compared to competitors who adopt other delivery models [18].

In relation to the distribution channels, the supplier may be responsible for the installation, operation, monitoring and maintenance of the system, having its

own team of technical assistance and marketing, as well as own depots where the systems and parts for replacement are stored, or he can opt for the recruitment of local entrepreneurs, who are responsible for the marketing and delivery of the products to consumers, as well as for all the other services related. This second type is interesting in the sense that distribution costs and warranty service are under the responsibility of the local entrepreneur. It is also interesting in terms of dissemination of the product, because the local entrepreneur tends to have a greater understanding of these consumers, as well as he tends to have easier access to them. Besides that, if the local entrepreneur has good knowledge of the ground it can result in a more responsive technical assistance.

With the fast growth of the photovoltaic sector and constant emergence of new technologies, coupled with the long terms of this model, it gets risky that the system becomes obsolete in some point of the lease term [18]. In this regard there is the possibility of consumers quitting and opting for a more modern technology.

Therefore, for higher rated power systems, this model shows itself as an interesting option for the supplier only if there are subsidies to support the initial investment. Otherwise, the option for other delivery models is more profitable in the short term.

4. RESULTS

The analysis performed about the four different delivery models is summarized in **Table 2**, where the different distribution channels possible for each model, the different segments of products for which they have already been applied and the level of service they are capable to offer are presented, as well as the their strengths and weaknesses.

The first goal of this study is to answer if the delivery model choice determines the success of photovoltaic stand-alone systems business in rural SSA. The conclusion reached by this investigation is that the choice of the delivery model is important but not capable to determine the success of the business. It is important that the chosen model is appropriate to the segment of stand-alone systems that is intended to sell, and it is possible that different models succeed in supplying the same product. On the other hand, the wrong choice of a model can determine the business failure. For example, if the entrepreneur opts for a retail model to provide SHS of high power in a BoP market, such as those found in the SSA rural areas, that results in a cash payment level that is above the purchase power of these consumers, which, in turn, results in the failure of the business. The segments of systems for which each type of delivery model shows to be more appropriate are detailed below (Table 2).

The retail model, based on the cash payment, is suitable to the simplest and cheapest PPVS segment, single light (up to 1.5Wp), because they represent an investment not so high for BoP consumers, as they have limited resources. The fee-for-service model in

Table 2: Delivery models comparative table

Delivery Model	Distribution channels	Product Segments (by nominal capacity)	MTF level of service	Strengths	Weaknesses
Retail Model	Own; Local distributors and dealers; Institutional partnerships; Franchise	PPVS below 1,5Wp	Tier 0 e Tier 1	<ul style="list-style-type: none"> • Supplier exposed to reduced financial risk • Consumer acquires the system ownership • High probability of new purchase in each 2 to 3 years 	<ul style="list-style-type: none"> • No financing option • Low market expansion potential • Consumer is responsible for maintenance • Consumer may be responsible for the installation
		PPVS from 1,5Wp up to 3Wp			
PAYG Model	Own; Institutional partnerships (mobile phone company)	PPVS from 1,5Wp up to 3Wp	Tier 1 e Tier 2	<ul style="list-style-type: none"> • Easy access to financing for consumers • No need for physical payments collection • Flexible payment basis (daily, weekly or monthly) 	<ul style="list-style-type: none"> • High initial investment for the supplier • Supplier exposed to high financial risk • Bargaining power of consumers can be reduced • Repossession costs can be high
		PPVS from 3Wp up to 11Wp SHS from 11Wp up to 21Wp SHS from 21Wp up to 50Wp SHS from 50Wp up to 100Wp			
Consumer Financing Model via FI	Institutional Partnerships	PPVS below 1,5Wp	Tier 0, Tier 1 e Tier 2	<ul style="list-style-type: none"> • Supplier gets paid for the systems immediately • The financial institution owns the risk • More advantageous financing options for higher costs systems 	<ul style="list-style-type: none"> • Difficulty to find a partner institution • Higher cost systems are affordable only for the BoP consumers higher segments • Supplier must have enough workforce for all the areas where the partner institution is present
		PPVS from 1,5Wp up to 3Wp SHS from 21Wp up to 50Wp SHS from 50Wp up to 100Wp			
Fee-For-Service Model	Own; Local distributors and dealers	PPVS below 1,5Wp PPVS from 3Wp up to 11Wp SHS from 11Wp up to 21Wp SHS from 21Wp up to 50Wp SHS from 50Wp up to 100Wp SHS above 100Wp	Tier 0, Tier 1, Tier 2 e Tier 3	<ul style="list-style-type: none"> • Use of financial institution distribution channels • Credibility of the financial institution with their clients • Supplier is responsible for substituting the system in case of failure 	<ul style="list-style-type: none"> • Consumer never becomes the owner of the system • Supplier exposed to high financial risk • Subsidies are important for the model sustainability • Need for physical collection of the consumers payments • Risk of the system becoming obsolete during the long term of the service

turn is suitable for this same segment of systems, because it presents itself as a more affordable alternative for the lower incomes of BoP consumers, who have difficulties to perform a cash payment as imposed by the retail model. This exemplifies what was mentioned above: that different models can achieve success with the same product segment.

PAYG model is used for various segments of products but it shows better results for the most basic segment of SHS (11Wp-21Wp). However, allowing very flexible payments made by mobile-money and being a relatively recent model leads to the belief that it still has potential to be exploited and should also become the main model for all other product categories with rated capacities between 1,5Wp and 50Wp in SSA BoP markets, as these consumers have irregular flows of income and difficulty to obtain credit. Finally, the financing model through FI is more suitable for the higher segments of SHS with rated powers above 50Wp. In this product segment the FI is able to offer better financing terms than the PAYG model, due to their greater robustness but in the SSA rural areas, there is the challenge of the scarcity of this type of institution.

Apart from the choice of the delivery model that is appropriate to the type of system to be sold, another aspect that contributes to the success of the venture is a detailed study of the environment found in the market where technology will be offered, to ensure that the chosen delivery model is adapted to this context, which enlarges the possibilities of good results.

With regard to the second goal of this research, concerning the most promising model, the PAYG model presents itself as the one. There are several aspects that led to this conclusion. The first is the fact that it is a relatively recent model, which has not yet had all its potential deeply exploited in some of the photovoltaic stand-alone system segments. Another point is its flexible payment plan, through mobile-money, that fits well to the BoP rural context in SSA, where the mobile phone network is more widespread than the electrical grids and consumers have low and variable incomes.

However, the supply of financing to consumers with low purchasing power who live in areas in which FI are scarce and when present usually do not have credit options appropriated to them along with a mechanism for remote monitoring and control that allows the supplier to lock the system in case of default, reduces the risk to which the entrepreneur is exposed and, lastly, with the possibility to use this model for financing other goods and services. This is undoubtedly the main aspect that contributes for the PAYG model to show itself as the most promising one, with a great future perspective.

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