MBA – MASTER IN BUSINESS ADMINISTRATION

Business Plan for an isolated photovoltaic systems enterprise

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Executive Summary / abstract

Worldwide, around 733 million people lacked access to electricity in 2020, of which 87% live in rural areas (United Nations, 2022). By providing electricity to this population, significant benefits can be gained in terms of advancing human development. There is a genuine chance in the foreseeable future to address this issue using private sector options for renewable energy that are off-grid, such as solar mini-grids or solar home systems (SHS).

This opportunity is being driven by three major trends. Firstly, there are ongoing reductions in hardware costs for solar modules, batteries, and energy-efficient appliances. Moreover, in recent years there has been an improvement in the efficiency of both electricity generating and consuming equipment, which makes it possible to offer, for the same energy level, a higher and more durable level of service. Secondly, a digital revolution is taking place, which includes mobile communication technology that enables payments and monitoring, as well as new fintech solutions like end-user credit assessment. Finally, innovation in business models, such as pay-as-you-go (PAYG) and third-party ownership for solar home systems, enables to provide energy as a service and eliminate previously high upfront costs for low-income households.

However, a remaining challenge exists which is the high initial investment needed to provide these services. If universal electrification is to be achieved by 2030, it is estimated that USD 52 billion in annual investment will need to be made.

With this in mind, what guidelines should a company that wants to provide these services follow? What are the business models that are being successfully implemented?

This paper will try to answer these questions and provide a guide to develop a business model for a company that wants to commercialize off-grid photovoltaic systems in regions not served by electricity grids.

Preface / acknowledgements

I would like to thank and acknowledge the contributions of the following persons and organisations.

First of all, I would like to thank Miguel Arjona, my supervisor on this project, and Julio Eisman, my co-supervisor, who have accompanied me during all the year and given me many valuable advice.

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1. Introduction

1.1. Context

Today, the percentage of people living without electricity around the world is surprisingly high. Specifically, in 2020, the global electrification rate was 91%, which means that 733 million people did not have access to this resource (United Nations, 2022).

Most of the people who live without electricity reside in rural communities that are in remote areas and present difficulties to access, and whose incomes are often low. This makes it difficult for large companies to be interested in electrifying them, as in many cases the costs of reaching them cannot be covered.

Territorially, the Sub-Saharan Africa region accounts for the largest share of people living without access to electricity, 77%. If current trends continue, by 2030 there will be 670 million people without service, which means an electrification rate of only 92%. As can be seen in the picture below, there are many regions where the electrification rate is close to 100%, but efforts are still required to reach the entire population:

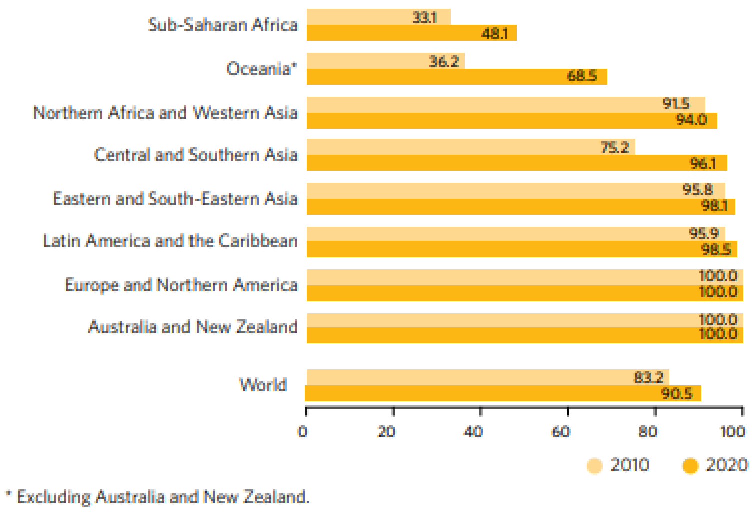

Figure 1. Percentage of population with access to electricity, 2010 and 2020 (UN, 2022)

The intention of aiming to achieve this global coverage is reflected in United Nations goal number 7. This goal covers the energy issue by promoting access to affordable, secure, sustainable and modern energy for all.

The fulfilment of this goal is closely linked to many of the other Sustainable Development Goals. The links between SDG7 and other SDGs are essential to maximise the development cobenefits. The 2030 Agenda recognises that "interlinkages and the integrated nature of the Sustainable Development Goals are of crucial importance in ensuring that the purpose of the new Agenda is realised" (IRENA, 2017).

Figure 2. Linkages between SDG7 and other SDGs (IRENA, 2017)

In particular, energy production and consumption have an important contribution to climate change (SDG 13). Renewable energies offer, for example, a chance for the world to keep the global energy increase below 2°C. They also play a key role in the transition to sustainable urban energy (SDG 11) and can avoid the negative effects of energy production and consumption on ecosystems and biodiversity (SDG 15). On the other hand, they contribute to human development and well-being. They reduce diseases attributed to indoor air pollution from cooking with traditional biomass and inefficient cookers, improve health services and reduce the time women and girls spend collecting fuelwood (SDGs 3, 4 and 5).

In order to achieve the global goal of full electrification by 2030, energy efficiency progress needs to accelerate from the current rate of annual improvement in energy intensity of 1,9% to 3,2%. The target is achievable, but only with significant investment in cost-effective energy efficiency improvements. So far, only East and South-East Asia has reached the target with an average annual rate of 2,7% in the period 2010 to 2019 (United Nations, 2022).

1.2. Strategic goals

With these aspects in mind, it has been born the need to seek solutions that will allow the electrification rate to reach 100% worldwide, and therefore permit all people to have access to this resource.

The main objective of the present work will be to develop a **business plan** for an enterprise whose objective is to **electrify last mile regions using off-grid photovoltaic systems**. What are off-grid photovoltaic systems and what are the characteristics of last mile regions?

On one hand, off-grid photovoltaic systems are electricity generation systems that operate autonomously and independently of the conventional electricity grid. These systems use solar panels to convert solar energy into electricity, which is stored in batteries for later use. The fact that they are not connected to the public electricity grid allows them to be used in remote areas where there is no access to the grid, such as in rural areas or on islands.

On the other hand, last mile regions can be characterized by:

- Geographical isolation, which makes access to energy through grid extension.
- Common socio-economic characteristics, determined by low-income levels. This means that they do not have the economic resources to implement the technological advances that would be necessary for their well-being and development.
- Exclusion or neglect by the authorities responsible for the provision of services.
- Lack of infrastructure for water supply, sanitation, energy and telecommunications, together with low levels of health care, education and culture.

All these characteristics mean that the companies or governments in charge of grid extension do not find it profitable to provide access to the inhabitants of these regions. The business plan to be developed aims to demonstrate that the commercialisation of these systems in these regions is profitable and sustainable in the long term.

Specifically, the aim of the work will be to develop a business plan that will serve as an example for any company that wants to start offering this service. In other words, a plan will not be developed for a specific region, but rather the most relevant aspects and guidelines to be followed in order to provide the service will be established. In this way, the company providing the service would have a model on which to start developing its own plan for a specific region, knowing in advance the factors that have proved to be successful in previous similar projects.

However, the development of the financial model will be done on the basis of a specific region, because in this way it is possible to quantify the costs and revenues that demonstrate the economic viability of the project.

1.3. Project Methodology

The project will be mainly divided into three parts.

Firstly, the project will include an external analysis and a market quantification. As mentioned above, this work is intended to serve as a guide for a company that would like to start providing SHSs in any region of the last mile. That is why the external analysis will be carried out in a generalised way, considering the dimensions taken into account in the PESTLE tool, but without giving specific data of a specific territory. It will give those characteristics that are common to all last mile regions, as well as some tools that can be useful to analyse a specific region. Moreover, the market quantification will demonstrate which countries may present a market with greater or lesser demand potential.

The external analysis will conclude with a SWOT analysis. This external analysis will assess the strategic feasibility of the proposal, that is, it will characterise and try to quantify the potential demand.

Secondly, a presentation of the business model will be made, supported by the use of the Lean Canvas model. This tool allows to design, analyse and develop business models in an agile and efficient way.

Finally, a financial model will be carried out to demonstrate the economic viability of the project and define its profitability.

These three blocks constitute the development of the business plan.

2. External analysis

2.1. PESTLE Analysis

The objective of developing a PESTLE in the external analysis will be to identify and analyze the various external factors that can impact ¡the organization's operations and performance. PESTLE is an acronym for Political, Economic, Sociocultural, Technological, Legal, and Environmental factors. This analysis can help the organization make informed decisions and develop effective strategies that take into account the external factors that could influence its success.

As mentioned before, each of the dimensions will be analysed from a general perspective, mentioning the most important aspects that can influence the start-up of the company providing the PV systems. The economic and socio-cultural dimensions will be analysed together since both characteristics are closely related in the inhabitants of last mile communities.

2.1.1. Public policies for universal energy access

Universal energy access will not be possible without state support. An unequivocal political commitment is required to ensure that the various state bodies support rural electrification programmes in a coordinated manner. The political power must take the leadership role that cannot be assumed by any other actor. Companies currently operating in the market have identified barriers arising from a lack of clear policies as one of the main obstacles to accelerating the distribution of SHSs (Lighting Africa, 2011). The following will discuss and propose a number of measures that the state can take to create an enabling environment for the development of the off-grid PV market.

- **Define energy access as a human right**

Just as access to safe, affordable and reliable drinking water and sanitation services are basic human rights recognised by the United Nations, access to energy is not currently considered a fundamental right by this organisation (United Nations, 2023). However, there are some countries where access to electricity is recognised as a right for all inhabitants, which has proved to be an essential first major step in the political support for the promotion of the SHS market. Some examples of countries where such a declaration exists are:

- Colombia

The Political Constitution of Colombia, enacted in 1991, establishes access to energy as a right for all inhabitants of the country. Article 365 states that:

> Public services are inherent to the social purpose of the State. It is the duty of the State to ensure their efficient provision to all inhabitants of the national territory. Public services shall be subject to the legal regime established by law, and may be provided by the state, directly or indirectly, by organised communities, or by private individuals. In any case, the State shall maintain the regulation, control and supervision of such services. If, for reasons of sovereignty or social interest, the State, by means of a law approved by a majority of the members of either chamber, at the initiative of the Government, decides to reserve certain strategic activities or public services for itself, it shall previously and fully compensate those persons who, by virtue of said law, are deprived of the exercise of a lawful activity (JUSTIA, 2023).

- Bolivia

The Political Constitution of the Bolivian State, promulgated in 2009, establishes in its sixth chapter, article 378 that:

> The different forms of energy and its sources constitute a strategic resource, its access is a fundamental and essential right for the integral and social development of the country, and shall be governed by the principles of efficiency, continuity, adaptability and preservation of the environment (CPE, 2009).

➢ **Promotion and creation of energy policies**

It is important that governments promote and create energy policies that ensure that there is long-term continuity in the development of the off-grid market, in other words, that development continues regardless of whether the government remains the same or not.

These policies can take the form of projects and laws such as those presented below:

- Brazil

Efforts to reach isolated rural communities intensified in 2002, when **Law 10.438** was passed, which among other things approved the reduction of tariffs for low-income consumers and created a national fund, the CDE (Energy Development Account), to promote universal access and use of innovative energy sources. In 2003, the **Light for All** programme was launched with the aim of providing electricity to all inhabitants, especially those living in rural areas. The political commitment of the federal government has proven to be fundamental to the success of this programme, through the involvement of different state agencies and bodies (Iorio&Sanin, 2019).

- **Mitigating barriers to off-grid market development**

Once the off-grid market has been boosted, governments must ensure that they make the most appropriate decisions to mitigate the barriers that may arise in its development. A study carried out by ODI, GOGLA, Practical Action and SolarAid shows the main regulatory challenges facing the SFA market and the main policy strategies that can help reduce them. The study highlights the importance of calibrating and coordinating any regulatory changes with all stakeholders, and in particular the private sector. Although there is no universal set of regulations that can be applied in all cases, analysis of the local context is conducive to better decision-making. Some of the most relevant findings of this study are summarised below (Diecker et al, 2016):

- Regulatory uncertainty: regulatory uncertainty occurs if there is a lack of well-defined responsibilities and objectives at the national level. It can be avoided if off-grid electrification is included as an integral part of national electrification strategies, policies, regulations and action plans.
- Access to finance: currently, the main barrier to the development of the SHS market is the lack of access to finance for service providers. For this market to grow, the government's contribution is key to create an environment conducive to investment.
- Improving the efficiency of supply chains: this can enable products to reach the end customer faster and at lower cost. Efficiency gains can be achieved through the removal or modification of tax and import barriers that hinder the development of supply chains.
- Reducing subsidies for alternative energy: subsidies for energy products such as paraffin and diesel make these products appear to be a cheaper option than they really are. They also delay the development of the SFA market.
- Local value creation: governments must empower local communities so that they are part of the energy development of their region. They should encourage the training of their citizens so that they are qualified to perform the various tasks required. This will make the market sustainable in the long term.

2.1.2. Economy and Society

Last mile regions are typically characterized by a number of challenges due to their remote and isolated location. For example, they present a low population density, which can make it difficult to justify investments in infrastructure and services. As an example, the following is a map of the Valiente Peninsula of Panama, a last mile region. This example is provided because although the external analysis of the work is done in a general way, for the development of the financial model it has been necessary to select a specific region for which to estimate the costs and benefits. The region selected has been the Valiente peninsula of Panama. It is accessible only by boat, as the Panamanian road network does not reach it. It is also sparsely populated.

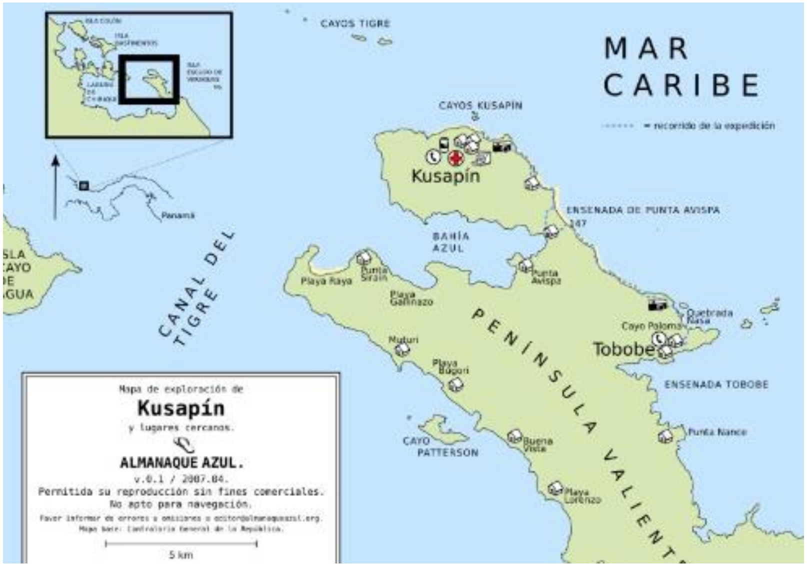

Figure 3. Valiente Peninsula, Panamá (Bahia, 2011)

Given their isolated location and low population, they may have limited road networks, telecommunication systems, and other critical infrastructure. This leads to a lack of basic services such as healthcare, education, and sanitation. In general, these communities end up relying on natural resources for their livelihoods, such as agriculture, forestry, or fishing. They typically have limited economic opportunities, particularly in terms of formal employment, which can lead to high rates of poverty, unemployment, and migration to urban areas.

Understanding these characteristics is important for developing effective strategies in those markets, but what are the key economic and social aspects that a company should consider before starting to provide SHS in these areas?[1]

- Economic growth potential: the company should consider the region's potential to support the demand for SHS.
- Cost of energy alternatives: addressing the costs of energy alternatives like kerosene, candles or diesel generators will be necessary to determine the competitiveness of SHS.
- Supply chain logistics: address the challenges of delivering and installing SHS in the region.
- Financing options: it will be important to consider the financing options available to customers in the region, such as microfinance or pay-as-you-go models[2].
- Cultural considerations: prior to offering the service, the company should ensure that SHS are culturally appropriate and acceptable, which is typically done through interviews and surveys.
- Awareness: develop proper strategies to increase the local awareness of the benefits of SHS.
- Social impact: analyze the impacts of introducing SHS in these communities, such as improving access to electricity, reducing poverty and enhancing education and employment opportunities.

Figure 4. Social impacts of SHS in last mile communities

[1] The following key points have been summarized from the Off-Grid Solar Market Trends Report 2022, developed by the World Bank, which can be found in: https://documents1.worldbank.org/curated/en/099235110062231022/pdf/P175150063801e0860928f00e7131b132de.pdf

[2] PAYG model allows customers to pay for a product or service incrementally over time, rather than paying the full cost upfront.

To sum up, three main topics can be highlighted form these conclusions. **Affordability** is a critical consideration when developing energy access programs, as many low-income consumers may not have the financial means to purchase energy products and services.

Willingness to pay is another important factor to consider. Consumers may be willing to pay for energy products and services if they perceive them as valuable. However, there may be challenges in convincing consumers of the benefits of energy access and in building trust in the products and services being offered. Finally, **consumer behaviour** is also a critical consideration as they may have a variety of reasons for adopting or rejecting energy products and services, including cultural beliefs, social norms, and perceptions of risk and reliability. Understanding these factors can help to adapt the offer to better meet consumer needs and preferences.

2.1.3. Technology

The following section will analyze the technologies which have been historically used to have access to electricity in last mile regions and the ones which can replace them.

Alternative energy sources

In last mile communities, where access to the grid is limited or nonexistent, non-renewable energy sources such as paraffin or candles are often used for lighting and cooking. Other non-renewable energy sources that may be used in these communities include diesel generators (often used for lighting, refrigeration, and other needs), kerosene stoves and charcoal (commonly used for cooking in areas where electricity or gas is limited).

Figure 5. Kerosene candles

Even in regions where the grid is present, many blackouts occur during the year, which implies the need for back-up solutions. Although the most common grid back-up solutions are generators powered by fossil fuels, off-grid solar products, particularly SHS, offer a clean and high-quality alternative for back-up power.

The use of fossil fuel generators and the alternative energy sources previously mentioned have various negative impacts. For example, the use of fossil fuel generators is costly for users and results in significant expenditure on fuel. In West Africa, the IFC[3] has estimated that the total amount spent on generator fuel is $7 billion, which is one billion dollars more than what is spent on the grid (IFC, 2019). Moreover, generators emit pollutants that can have adverse effects on both health and the environment.

Which technology can replace them?

There are three modes of electrification: grid extension, mini-grids and Solar Home Systems (SHS), which are used according to the most appropriate for each territory.

Grid extension is the traditional mode of electrification, which generally has a lower cost than the other alternatives. This mode of electrification becomes a challenge when (Ortiz et al., 2020):

- There are long distances to remote and sparsely populated communities.
- The quality of grid service supply is low, resulting in frequent power outages and load reductions.
- Tariffs for end-consumers are low, which is why utility business models are affected.

Taking into account the characteristics of last-mile communities, this mode of electrification becomes a challenge. The amount of users which would benefit from the grid wouldn't be enough to pay for the cost that the extension requires, and consequently the project wouldn't be sustainable at the long-term.

For this reason, mini-grids and SHS need to be considered as more appropriate modes of electrification for these specific regions.

A **mini-grid** is a decentralized electricity generation and distribution system that serves a small, localized community or group of consumers. It typically includes a combination of renewable energy sources, such as solar, wind, or hydro power, along with energy storage and distribution infrastructure. Mini-grids are designed to provide electricity to communities that are not connected to the main electricity grid, or where the grid is unreliable or insufficient to meet local energy demands. They can be owned and operated by a community or by private companies, and can provide a range of energy services, from basic lighting and mobile phone charging to powering small businesses and productive uses. In addition, they can be scaled up as demand increases, and ultimately connected to a main transmission and distribution grid.

[3] IFC: International Finance Corporation.

A **Solar Home System** is a stand-alone solar-powered electrical system designed to provide electricity to a household or small business. Their initial cost can be a critical barrier for most users, so the availability of financing for deployment and the design of a suitable business plan are important factors to consider when entering this market (IEA, 2020). Its advantages over mini-grids include:

- SHS are less expensive to install and to maintain. This makes them a more cost-effective option for households that require a small amount of electricity.
- They can be easily scaled or decreased in size depending on user's energy needs.
- SHS require less trained technicians to repair and maintain, which is especially important in remote areas where the access is difficult.
- SHS give households independence form the grid, which useful when the grid is unreliable or nonexistent.

Figure 6. SHS in rural communities

Will this transition be beneficiary for users?

Even if the benefits of SHS may seem obvious, there might be those who can argue that the transition to SHS as a primary energy source can have negative consequences for users. However, results show that as long as it has been applied, the consequences have been extremely positive. A research conducted by GOGLA[4] (GOGLA, 2019) revealed the following conclusions regarding the introduction of SHS products:

➢ In 51% of households, solar home systems (SHS) have replaced torches[5] or kerosene lamps as the primary source of light. This transition to SHS has allowed these

[4] Research conducted in Ghana, Côte d'Ivoire, Nigeria and Togo involving 1.678 customers who purchased a SHS product in the first half of 2019.
[5] Portable battery-powered electric lamp.

households to have access to high-quality lighting and additional energy services within their homes, possibly for the first time.

- Of the households surveyed, 26% had previously relied on the grid or generators as their main energy source. For these customers, solar home systems (SHS) serve as a back-up for unreliable electricity access.
- 20% of the customers already had access to solar products (which may include solar products used only for lighting). For those users, purchasing a SHS allowed them to scale up in the energy staircase, gaining access to higher quality products or broader energy services.

Third generation SHS

SHSs have evolved over the years, becoming increasingly efficient and economical. Currently, the equipment on the market is called third generation SHS, which appeared between 2005 and 2015. The following image shows the evolution, between 2009 and 2014, of the average price of a SHS:

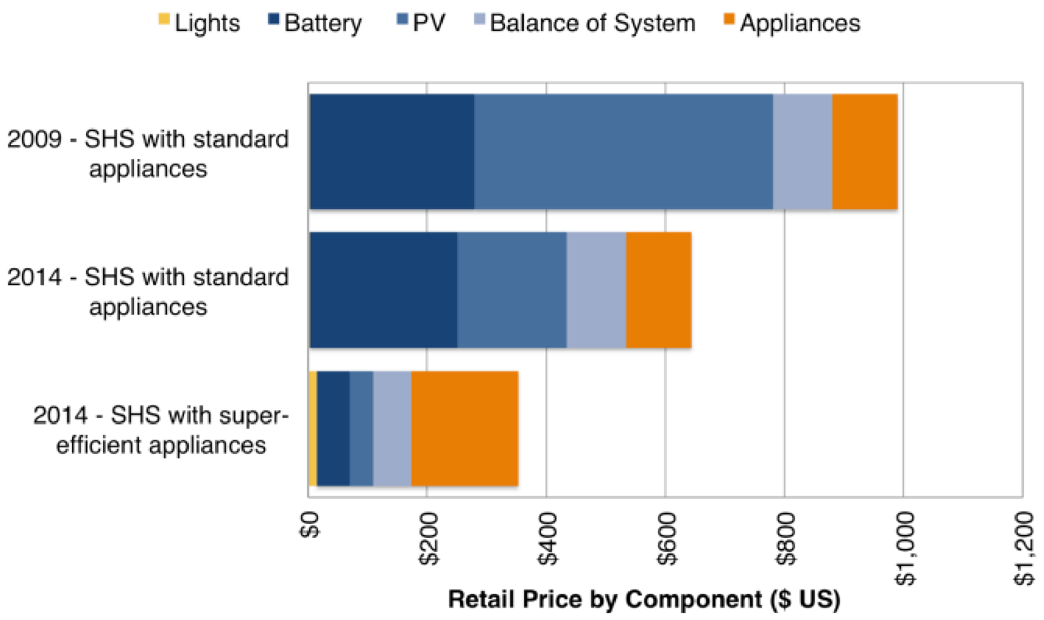

Figure 7. SHS price evolution (Phadke et al, 2015)

As it can be seen, the evolution of technology allows the same level of energy service to be offered at a much lower price.

The main advantages of a third generation SHS that allow a reduction of its price are:

- Use of lithium batteries, which have a longer lifetime than other batteries.

- Use of LED lamps. These lamps provide more light output for the same power consumption. They therefore represent a clear acceleration in universal access to lighting.
- Easy-to-install design with no need for electrical connections (plug and play). In addition, the weight of the equipment is lower, which facilitates installation.
- They require less maintenance, given the increased useful life of their components.

2.1.4. Legal – SHS Regulation

The development of regulation for off-grid PV systems is very different around the world. As previously mentioned, the participation of states plays a key role in the creation of policies that favour the development of the off-grid market. A comparison of these regulations can be made thanks to the RISE[6] platform. This platform is a World Bank-led initiative that aims to measure and assess the regulatory environment for sustainable energy worldwide (RISE, 2022). The platform measures 27 indicators in 111 countries, representing 96% of the world's population.

The platform provides a comparative assessment of countries' regulatory frameworks for sustainable energy, including renewable energy, energy efficiency and energy access. A wide range of topics are covered through a series of indicators including:

- Energy access: indicators assess the quality and accessibility of energy services in different countries, including electricity and cooking fuel.
- Energy efficiency: indicators measure the effectiveness of policies and regulations in promoting energy efficiency in different sectors, such as industry, transport and buildings.
- Renewable energy: indicators assess the quality and effectiveness of policies and regulations to promote renewable energy, such as feed-in tariffs, tax incentives and energy system planning.
- Regulatory framework: indicators measure the quality and transparency of the regulatory framework for sustainable energy, including the effectiveness of regulatory authorities and the clarity of laws and regulations.

By comparing these indicators across countries, the platform allows for the identification of the strengths and weaknesses of each country's regulatory framework for sustainable energy.

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[6] RISE: Regulatory Indicators for Sustainable Energy.

The platform allows to access to information for a specific country or compare different countries among the world, in order to know which ones have further developed regulatory frameworks.

For example, the following illustrations show the results obtained for Panama in relation to the legal frameworks and the attributes for financial and regulatory incentives:

1 Legal framework for renewable energy 100

Sub Indicators	Yes/No	Feedback
Legal framework for renewable energy		
Does the legal framework allow private sector ownership of renewable energy generation?	✓	
Does an official renewable energy target exist?	✓	
Is the target legally in binding?	✗	
Is the RE target linked to international commitments (e.g. NDC or regional commitment)?	✓	
Is there a renewable energy action plan or strategy to attain the target?	✓	

Figure 8. Legal framework for renewable energy Panama (RISE, 2022)

4 Attributes of financial and regulatory incentives 65

Sub Indicators	Yes/No	Feedback
Auctions		
Is competition used to ensure large scale RE generation (projects>10MW) is cost competitive (e.g. through auctions for PPA's)? If so,		
Is there a schedule for future bids/auctions available for investors?	✗	
Is there a pre-qualification process to select bidders?	✓	
Are tariffs indexed (in part or in whole) to an international currency or to inflation?	✓	
Are there provisions to ensure full and timely project completion (e.g. bid-bonds, project milestones)?	✗	
Are projects awarded through auctions/bids online/on track to be online on stated date?	✗	
Have auctions/bids met stated target for installations?	✗	
Fixed tariffs for small producers		
Can small producers (residential, commercial rooftop PV,etc) connect to the grid?	✓	
Are contracts with fixed tariffs available for such producers?	✗	
Is there a schedule or clear rules (e.g. capacity based limits) for adjusting the tariff level over time?	✓	
Are different tariffs available for different technologies and siges of the generation plant?	✗	
Is there a mechanism to control the capacity built under each tariff?	✗	
Are tariffs indexed (in part of in whole) to an international currency or to inflation?	✓	

Figure 9. Attributes for financial and regulatory incentives Panama (RISE, 2022)

The results indicate that the country has proper legal framework for renewable energies whereas the regulatory one is still incipient, with a lack of specific fiscal incentives and the need for greater clarity on the rate of payment in tariff schemes. However, the existence of targets and planning for renewable energy in the country is recognised, which may be an indicator of a greater commitment to future renewable energy development in Panama.

Similarly, the same research can be done for any of the other available countries. Thanks to all the indicators, the platform allows to easily understand the legal and regulatory situation of the researched region.

2.1.5. Environmental Consequences

As mentioned in previous sections, the use of alternative energy sources has some environmental impacts. For example, diesel generators harmful pollutants, including carbon monoxide, nitrogen oxides, and particulate matter, which can contribute to air pollution and respiratory illnesses. Moreover, the transportation and storage of diesel fuel poses environmental risks, such as fuel spills and leaks. Kerosene stoves also emit harmful pollutants. In fact, the World Health Organization estimates that each year, 3.2 million people die prematurely from illnesses attributable to the household air pollution caused by the incomplete combustion of solid fuels and kerosene used for cooking (WHO, 2022).

Similarly, the burning of paraffin and candles can also release harmful pollutants including benzene and formaldehyde. Furthermore, the production of charcoal often involves cutting down trees, which can contribute to deforestation and habitat destruction.

2.2. Market size analysis

Once identified the key external trends it is important to consider which is the size of the market. This will help to determine if the decision to enter the sector could be profitable or not.

As already stated, in 2020 approximately 733 million people were living without electricity, and over 80% of them un rural areas. For 55% of those living without energy, it is estimated that off-grid solar products are the most cost-effective and feasible solution to electrify them. These numbers clearly show that the potential number of customers of the service proposed in this work is high (Lighting Global, 2022).

But among the last mile markets, are there any of them where the technology is more developed than others? As it happens with many other products and services, most off-grid solar sales are into relatively mature markets, while much of the remaining need is concentrated in markets where the off-grid solar sector is nascent or still emerging.

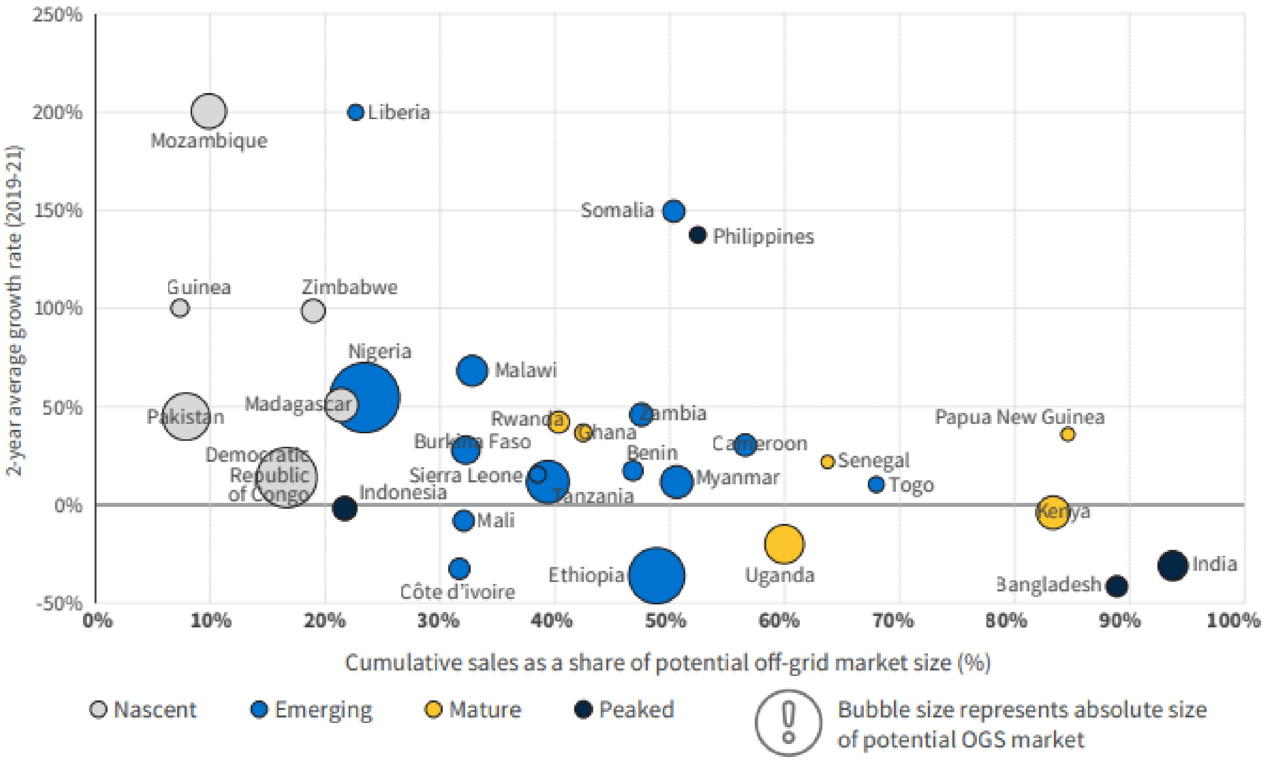

Figure 10. Market Classification[7] (Lighting Global, 2022)

Nascent markets represent those where a high access gap still exists (representing 5% of the population), with minimal sales volumes (less than 10% of the market potential). These markets don't seem specially interesting for the project, as often show slow growth rates.

On the contrary, emerging markets seem much more interesting, as the energy access gap still remains significant (at least 5% of the population), and their growth is considerable (sales reach at least 10% of the potential market and growing).

Finally, mature and peaked markets don't appear to be attractive due to the fact that sales have reached a high share of the potential market and the barriers to enter them are high.

In conclusion, when deciding which country to enter first, the decision could be focused on one of the markets identified as emerging in the precious figure.

305 million people in these markets still don't have access to electricity, which is a huge figure (Lighting global, 2022).

[7] Both the average growth rate and the cumulative sales are based on GOGLA's sales. The bubble sizes are based on the absolute market size of the remaining electricity access gap. Countries included in the classification exclude those with high level of electricity access and the ones where there is no previous record of OGS sales (it comprises around 710 million people of the total 733 million which don't have access to electricity).

Those markets include countries such as Benin, Cambodia, Malawi, Nigeria, Somalia or Tanzania. Most of them are characterized by a degree of stability that enables market expansion.

For example, in Nigeria, with a population of 200 million people and an electrification gap of 45%, the government is aiming to reach 100% electrification by 2040, with 5% of this electrification coming from OGS. However, the weak grid infrastructure in the country only allows 25% of grid-connected consumers to receive up to four hours of power daily, making OGS a viable option for bridging the gap until grid or mini-grid developments can be achieved. The Rural Electrification Agency's programs suggest that OGS will play a larger role in Nigeria's electrification than the 5% target (Lighting Global, 2022).

However, potential demand data for the Valiente peninsula will be provided below as it will be necessary for the further development of the financial model. Considering that it is a difficult to access and developing region, there is no specific census data available, so it has been necessary to estimate the potential demand.

The Kusapín region, the most populated region of the peninsula, had 4,260 people in 2020 (INEC, 2020). As will be discussed later in section *3.1. Customer Segments*, if each household in the last mile is considered to be home to approximately 8 people, the region would have 530 households. Taking into account the estimates of Lighting Global, as previously mentioned, this organisation estimates that for 55% of the people without access to electricity, the best way for them to have access to electricity is through SHS. This percentage represents approximately 300 households in the Kusapin region. This estimate has been reduced to 250 households, taking into account that there will be households that will reject the proposal.

Figure 11. Kusapin region

2.3. SWOT

It has been decided to carry out a SWOT analysis showing the key internal and external factors that may affect the success of the business, which is presented in the following figure:

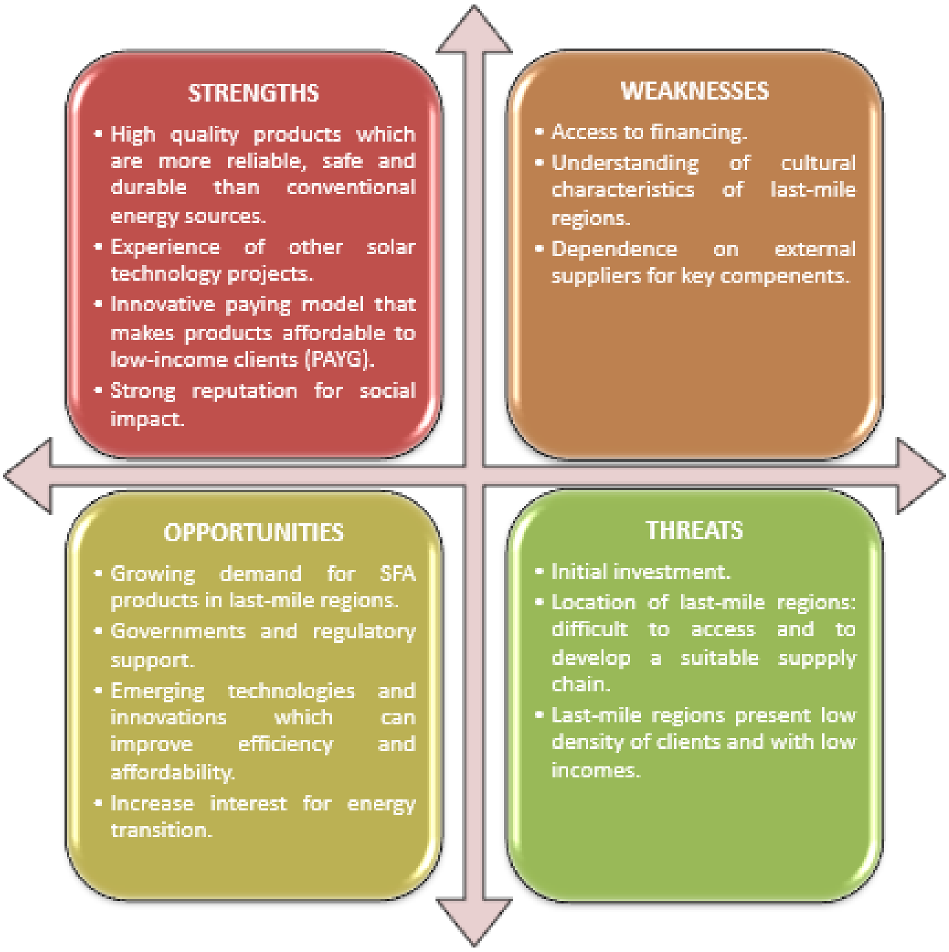

Figure 12. SWOT analysis

After conducting this SWOT, it can be concluded that SHS products are a real necessity in the last mile regions. People need to have access to electricity in a safe way, and these products are the best way to do so. However, given the socio-economic characteristics of the inhabitants of these areas, it is necessary to find a way to deliver them at an affordable price. To this end, new payment methods, such as PAYG, can bring great advantages and allow the market to expand into regions where it was previously considered financially unsustainable.

3. Business Model

Once the problem has been identified and analyzed in a macro-economic way, this section will provide a better insight about the solution proposed to solve it. By using the different elements of the Business Model Canvas tool, the idea will be accurately explained. This tool helps to analyze, structure, and evolve a business while always keeping the bigger picture front of mind.

3.1. Customer Segments

This block will help to understand who is the most important customer for the company. No company can exist without customers, which makes this block extremely important.

The main characteristics of the customer profile to whom the service is expected to be delivered to are:

Location: customer living in a rural area of a country where the access to electricity is high but doesn't reach the 100%.

Household size and composition: rural households tend to have 8 members. 70% of them are children. However, the service will be purchased by the adults, and most commonly by males. Although one of the goals of electrification projects is to involve women in the process of purchasing and installing these products, the reality nowadays shows that females don't usually take part in it.

Figure 13. Customer Profile

Income level: low. Studies and surveys suggest that the income level of actual purchasers of SHS is below $5.50 per day (GOGLA, 2019) (Lighting Africa, 2011). As previously mentioned, affordability will play a key role in the development of the business plan. The user may have some limited savings and a seasonal fluctuation income, as their occupation is usually agricultural. They normally will have a primary education.

Motivation: purchase the SHS for his children to grow up in a home with light and power. Also, they may be willing to reach a higher level of service and be able to own more appliances. They might be also not satisfied with their current way of living. For example, they can be paying expense kerosene as their lighting source, which can also result in a danger of open flames and low levels of illumination.

3.2. Value Proposition

This section will be dedicated to specifying the product that the company will provide to its users in order for them to have access to electricity.

On a trajectory to achieve universal access to electricity by 2030, high-level analysis indicates that off-grid solar technologies are expected to be the least-cost solution for 41% of new household connections between 2020 and 2030 (Lighting Global, 2022).

To have a real impact on households, electricity supply must be adequate in quantity, available when needed, of good quality, affordable, legal, fit for purpose, healthy, and safe. With this in mind, how should systems be sized so that the amount of energy available to the user is adequate?

Currently, the undisputed method for quantifying the level of access to electricity is known as the Multi-Tier Framework, MTF. This method establishes levels ranging from 0 to 5 and refers to the services that electricity provides. The value proposition has been based on meeting what the International Energy Agency (IEA) establishes as a minimum service. The IEA defines a basic energy service package as a package containing, at a minimum, several light bulbs, telephone charging, a radio and potentially a fan or a television (IEA, 2020).

Improvements in equipment efficiency mean that, for the same installed PV system, it is increasingly possible to offer the user a higher level of service.

Although the level of service that can be offered depends on the region where the systems are installed (as the level of insolation is not the same everywhere), the following table can be used as an example to get an idea of the modules that the service provider could offer:

Component/module	120-PRE	240-PRE
Solar Panel	**120 Wp**	**240 Wp**
Energy box	**Charge Controller and 25Ah LiFePO4 lithium battery**	**Charge Controller and 50Ah LiFePO4 lithium battery**
Possible accessories that could be connected by the user	3 LED lamps functioning 5h per day of 1W each (minimum 300 lumens in total), 1 mobile phone charge per day, 1 fan connected 6h per day, 1 radio	3 LED lamps functioning 5h per day of 1W each (minimum 300 lumens in total), 2 mobile phone charges per day, 1 fan connected 6h per day, 1 radio,1 TV functioning 4h per day and an efficient freezer

Table 1. Modules proposal

The following image shows a simple schematic of the equipment provided, as well as the equipment connected by the user. The schematic shows the solar panel and the battery system with integrated charge regulation and protection.

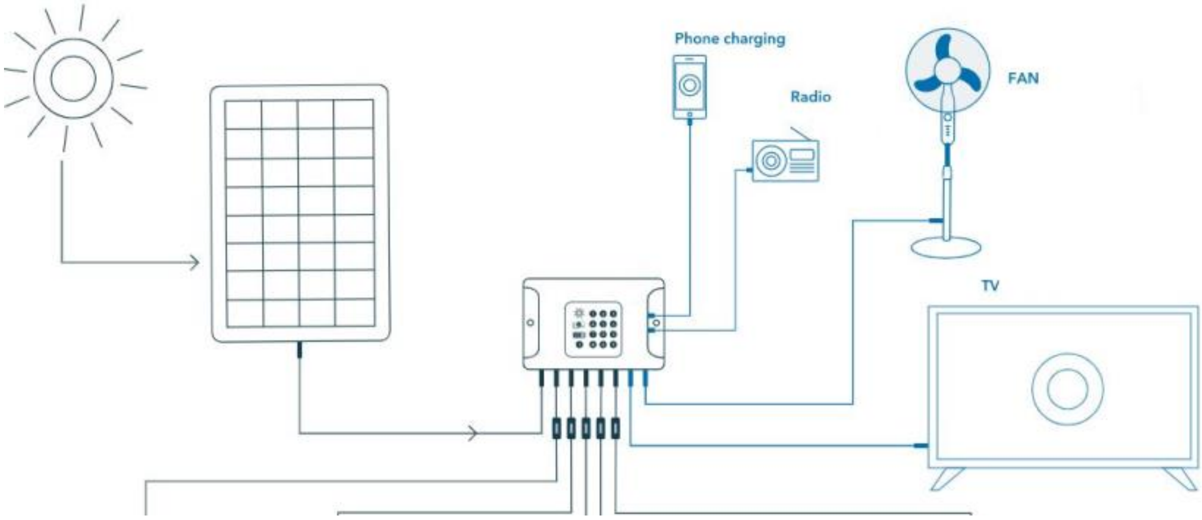

Figure 14. SHS scheme

3.3. Channels and customer relationships

In the following, how the users will be reached and how those relationships will be grown will be discussed.

Considering that users live in isolated regions and often do not have access to conventional means of communication, these dimensions of the Lean Canvas model are of little importance in the definition of the business plan. Users are motivated by the need to purchase the systems and their loyalty is based on imposing a tariff they can afford to pay.

However, some channels could be identified to access future customers such as:

- Print advertising: advertisements in local newspapers and magazines can be an effective way to reach users in remote areas.
- Local associations: it is important to identify if there are local associations in the region where the company wants to start providing the service. Working with these organisations can help to promote the use of PV systems and identify potential new customers.

  The empowerment of local communities has proven to be a key to the success of electrification programmes in isolated communities. Among other things, their participation allows the voices of local residents to be heard. This can help ensure that proposed solutions are culturally appropriate and socially acceptable. In addition, training community residents so that they are able to acquire certain skills related to the installation and operation of the systems is also very important to ensure the long-term sustainability of the project.

- Community visits: talking directly to the residents of these communities is a very effective way to understand their needs and better tailor the proposed service.
- Client referrals: existing clients can help to increase the network. This can be achieved by offering customers incentives for each new sale they generate.

Figure 15. Local visits

3.4. Revenue Streams

The total revenue received by the provider must be sufficient to cover their expenses and provide them with a return on the initial investment. The fact that users' deposits are not guaranteed, due to the difficulties they often have in making payments, shows the importance of defining a good business plan from the outset, which is viable in the short, medium and long term. This payment difficulty means that the service provider's income is divided into two items:

1. Tariff: this is what the user who receives the service pays. In a competitive market, such as the Spanish market, this fee is sufficient to cover the provider's costs. However, in the SHS market, this fee does not fully cover all the provider's costs, as it has to be adapted to the users' payment possibilities.
2. Subsidy: complements the tariff and allows providers to cover the costs of offering their service. Countries with a significant lack of access to electricity often face a major challenge: the tariff paid by the consumer may be set below the real cost. This results in a revenue shortfall for the companies providing the service, which can have disastrous consequences for the quality of service and the ability to make new

investments. For this reason, the application of subsidies is often unavoidable. In order to ensure that the provider is competitive, the subsidy should be kept to a minimum.

And how will the tariffs be received? The payment method used will be the PAYG[8]. The PAYG model is based on a small upfront payment by the consumer (affordable for a large part of the population), and thereafter they pay a monthly fee that allows them to enjoy the device. The monthly fee payable will depend on the module offered to the customer. The ownership of the equipment will remain with the service provider. It may become the user's if the fee paid by the user is increased over a long period of time.

If the user has telephone coverage, payment can be made over the telephone. However, if this is not available, the user can pay physically at local offices.

In the latter case, the payment model to be followed will be as follows:

- The user will have to pay physically at the centre destined for that function.
- When the payment is made, a code will be generated that must be entered by the user in his photovoltaic system, thanks to a web application intended for this purpose.
- The fee paid by the user will determine the level of service he/she will be able to access.
- There will be a local staff member who will be in charge of receiving payments from customers, entering them into the dedicated web application and providing users with the activation code for their system. This person is recommended to be someone who has their own business, and who will be paid for the hours he/she will spend dealing with the SHSs users.

[8] PAYG: Pay-As-You-Go

The payment model can be summarised in the following scheme:

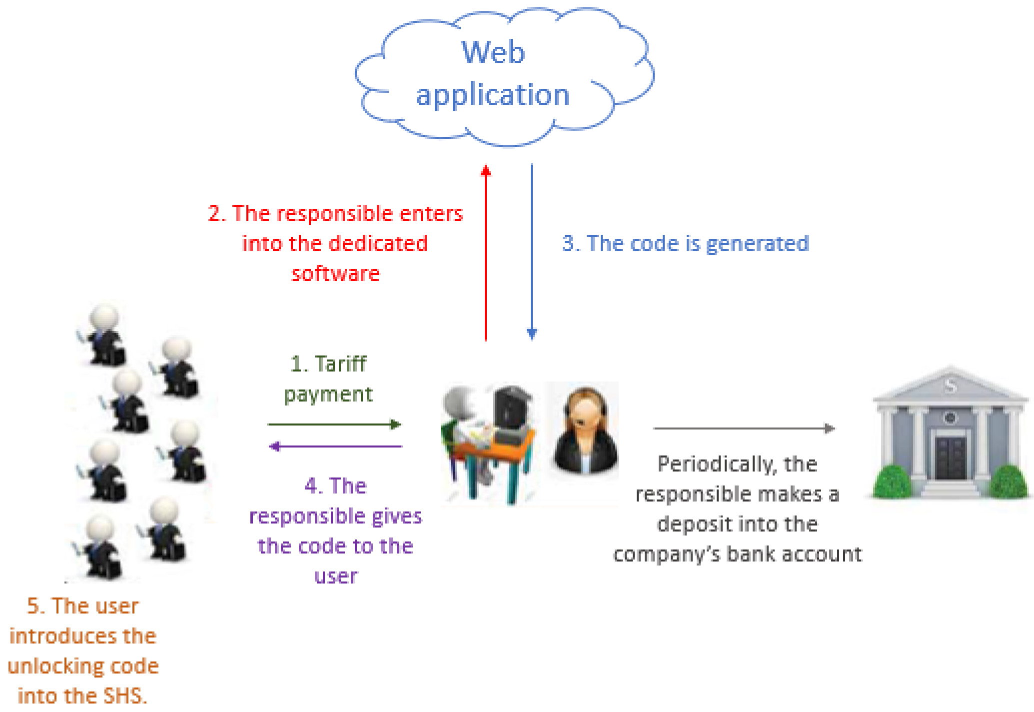

Figure 16. Payment model for SHS users

As can be seen, it is important that the local staff member in charge of receiving payments has access to the Internet in his or her establishment, so that he/she can make use of the web application without any problem.

3.5. Key Resources

Having defined the offer of the company, the following sections will be dedicated to describing what is needed internally to deliver the value to customers. The key resources will be divided in physical holdings, finances and human capital. Given that this work is intended to provide a guideline that any company wishing to start providing this service could follow, the resources that will be proposed should be taken as an example, to be adapted to the market where the service will be offered. The following are, therefore, recommendations on which to start building the company.

Physical holdings

The service provider should have the necessary stock to be able to install the systems for the users who require them. In addition, it should have a small warehouse from which to distribute this stock to users, and to have the replacement parts needed in case of equipment failure. The basic materials needed for each module are:

<table>
<tr><td rowspan="4">Module 120Wp</td><td>Solar Panel 120Wp</td><td rowspan="4"></td></tr>
<tr><td>25Ah battery with charge controller</td></tr>
<tr><td>120Wp panel support module</td></tr>
<tr><td>Installation kit (cables, etc)</td></tr>
<tr><td rowspan="4">Module 240Wp</td><td>2 x Solar Panel 120Wp</td><td rowspan="4"></td></tr>
<tr><td>50Ah battery with charge controller</td></tr>
<tr><td>2x120Wp panel support module</td></tr>
<tr><td>Installation kit (cables, etc)</td></tr>
</table>

Table 2. Physical holdings resources

As previously mentioned, the company should have a warehouse in order to be able to carry out the necessary installations and repairs. The warehouse should be located in a place that is accessible by road, so that materials can be easily transported from the supplier's delivery point.

On the other hand, it should have the most appropriate transport to access its users. This should be considered on a case-by-case basis, as depending on the location, users may only be accessible by boat. It will need to be considered whether it is more cost-effective for the company to have its own vehicles or to rent them on a daily basis.

Finally, the company may need to have a local office, or a shared space, where one person can work and coordinate all the tasks performed by the company. In addition, this person will need at least one computer and mobile coverage.

Finances

As mentioned throughout the paper, the initial cost of the equipment is one of the biggest barriers to the expansion of the off-grid market. In order for users to be able to pay for the service, it is necessary that the payments they make are affordable for them, and they cannot pay the full upfront cost of the equipment. For this reason, the company will need to have sufficient initial cash flow to finance the systems and recover the investment over time. An example will be exposed in the financial model to provide a benchmark for the amount required.

Human capital

The human capital that the service provider would need to have can be summarised as follows:

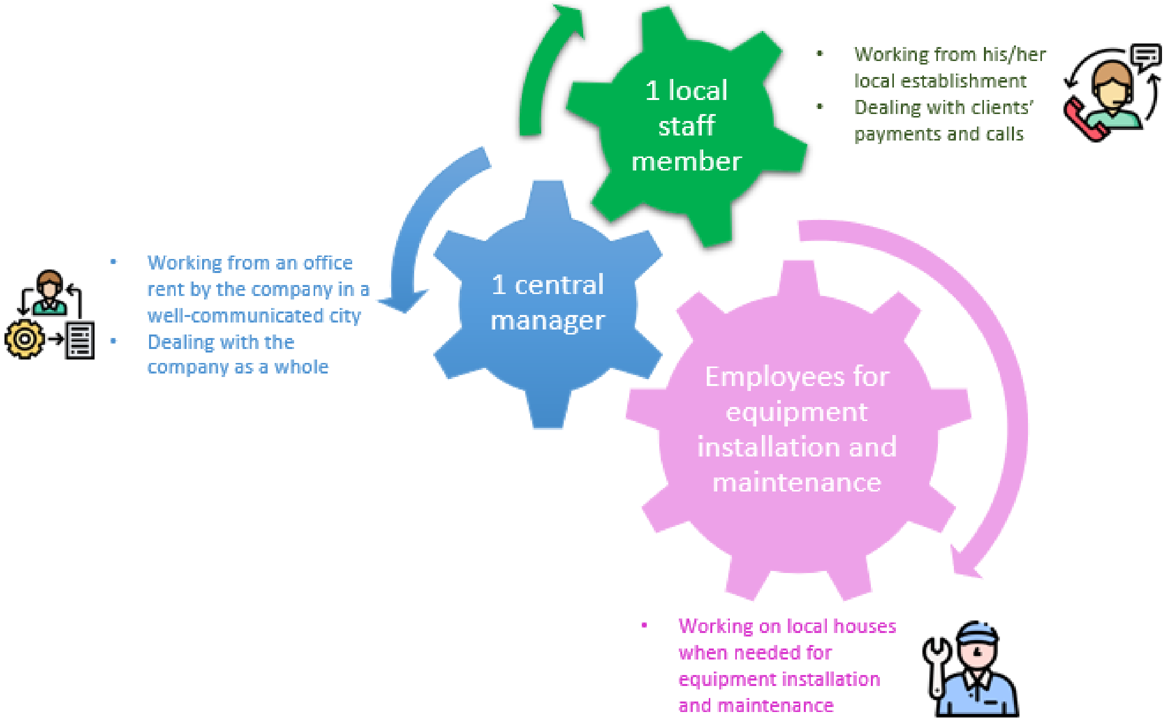

Figure 17. Human capital structure

What work would each of the workers do?

1. Employees for equipment installation and maintenance

The company will need to have a team of people responsible for the installation, maintenance and replacement of the equipment when necessary. It is proposed that these workers should be paid on the basis of the hours they will spend doing tasks for the service provider. Some workers will need to be more specialised than others. Below, four ranges of workers are proposed that the company could have depending on its needs (number of equipment to be installed and difficulty of installation):

Foreman: worker with experience in the management of work teams, who is responsible for supervising and coordinating the tasks of a group of officials and operators in the installation of isolated photovoltaic systems.

Figure 18. Human Capital

Official: has a technical background in the field and has the ability to carry out the most complex tasks within the installation process. He/she is usually in charge of coordinating the work of the team and ensuring that safety and quality procedures are followed.

Operator: can perform various tasks within the installation process, such as attaching solar panels, connecting batteries, performing functional tests, among others.

Labourer: performs manual and physical tasks within the installation process of last mile off-grid PV systems. In general, their role is to assist the operator and the official in tasks that require physical strength or are not technically complex.

2. Central manager

The company should have a person in charge of coordinating all the work carried out (ordering of parts in case of necessary repairs, organisation of the workers dedicated to the maintenance of the equipment...). This person would work from an office located close to the regions where the equipment will be installed, but with mobile phone coverage and easy access to the collection point of the equipment sent by the supplier.

3. Local staff member

As mentioned before, the company should consider having a person in charge of handling payments. It is recommended that this person is someone who has a small business located close to the regions where the equipment will be installed, and who can dedicate part of his/her time to perform the tasks required by the service provider. The tasks of this person could be divided mainly into:

- Collection of payments made by clients. Users could come to the worker's establishment to pay in advance for the service that will be available to them. The local employee will be responsible for collecting these payments and giving users an activation code that, once entered into their equipment, will put it into operation.

- Answering calls from users when they detect an incident. Those users who have a mobile phone could inform this person of any anomaly they detect in their systems, so that a technician can come to carry out the necessary maintenance. If they do not have a mobile phone, they could also physically go to this worker's establishment to report it.

This local worker will be paid for the hours spent performing both services.

3.6. Key Activities

Which areas does the company need to be good at to create value for its customers?

Since the company will generally not face competitors in the region where it markets its products, the key activities it will carry out are as follows:

- Receipt of materials and transport to the warehouse.
- Distribution and installation of equipment.
- Preventive and corrective maintenance of equipment.
- Management of payments and withdrawal of equipment in the event of non-payment.
- Replacement of the equipment after the end of its useful life. This usually happens after 10 years, as this is the useful life of the battery (the component with the shortest useful life). Therefore, this is the component that should be replaced after 10 years of the installation moment.

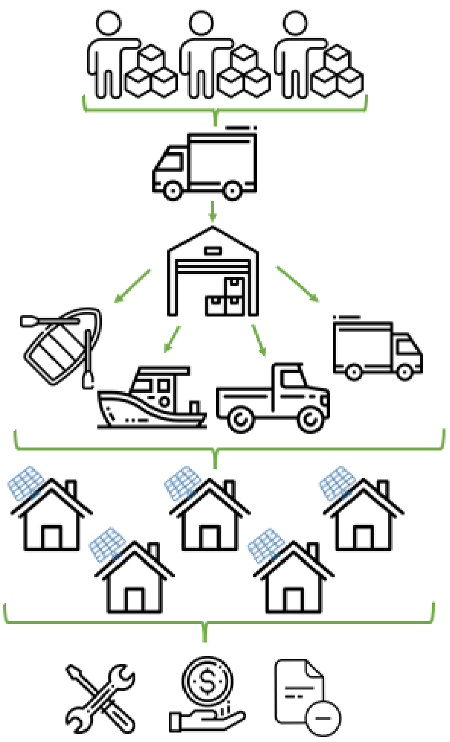

Figure 19. Key Activities Scheme

3.7. Key Partners

The company's main partners will be its suppliers. It will be necessary to find suppliers that sell products adapted to isolated rural communities and that are available in the desired region.

The following are recommended suppliers that have efficient systems and equipment designed for use in isolated rural communities:

1. VeraSol[9]

It offers a wide range of solar kits as well as efficient equipment that can be used with these kits. All the products presented are verified by Lighting Global[10]. The equipment that can be found are the most used by the inhabitants of the last mile: TVs, Electric Pressure Cookers, Fans, Refrigerators and Solar Water Pumps.

2. Zimpertec[11]

The company offers complete photovoltaic systems for private homes as well as its components. In addition, it offers SHS that can be used in schools, companies or for pumping water.

3. Fosera[12]

Like Zimpertec, offers complete solar systems as well as components and energy-saving equipment suitable for use with the systems.

Another important partnership which may be considered is related with the method of payment that will be applied. An agreement with a PAYG-enabled application will be necessary, which allows users to pay through their phones or the local staff member to access the users' activation codes. A recommended one is Angaza[13]. Making use of the PAYG service. This platform enables companies to offer affordable products and services in remote regions through a pay-as-you-go model. Angaza focuses on solar energy, agricultural technology and consumer products, and allows customers to pay via prepaid cards or mobile micropayments.

3.8. Cost structure

The costs will be divided into different blocks and will be considered from the point of view of the service provider. A way for the service provider to structure its costs will be proposed.

[9] https://verasol.org/

[10] Lighting Global is an initiative of the World's Bank Group to rapidly increase access to off-grid solar energy for the hundreds of millions of people living without electricity world-wide. It is managed by the Energy Sector Management Assistance Program (ESMAP).

[11] https://www.zimpertec.com/

[12] https://fosera.com/

[13] https://www.angaza.com/services/#mobile-money-integrations

The proposed cost structure, together with the major costs for each item, is as follows:

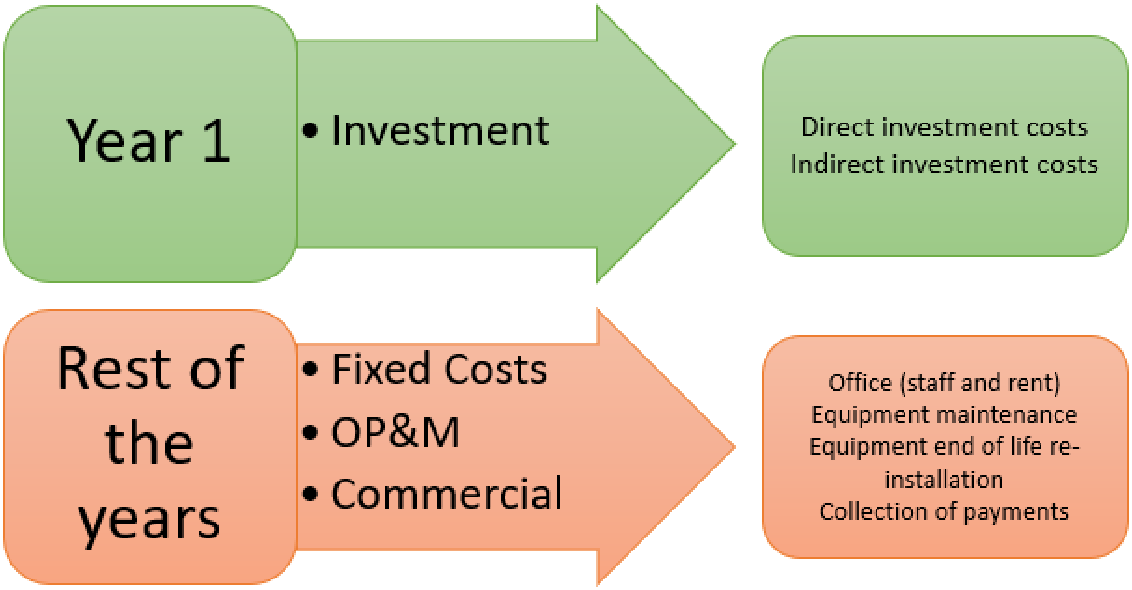

Figure 20. Cost structure

- **Investment costs**

Investment costs would be incurred in the first year, during which all equipment would be installed.

The investment costs would include the direct costs of all materials needed to install the equipment, the labor required and the transport of the equipment. In addition, it is recommended to include the cost of storing the systems from the time they are received from the supplier until they are installed. This cost would be called stock cost, and can be set as a percentage of the cost of materials.

In addition, indirect investment costs would be included, which would be made up of the following:

- Engineering and Reception: corresponds to the indirect costs of engineering, supervision and reception of works of the project. It will be estimated as a percentage of the direct investment costs.
- General expenses: this represents administrative and tax expenses, training for users of the photovoltaic systems and local technicians, and those related to the execution of the installations. It will also be estimated as a percentage of the direct investment costs.

Taking all the details presented into account, the structure of the investment costs will be therefore the following:

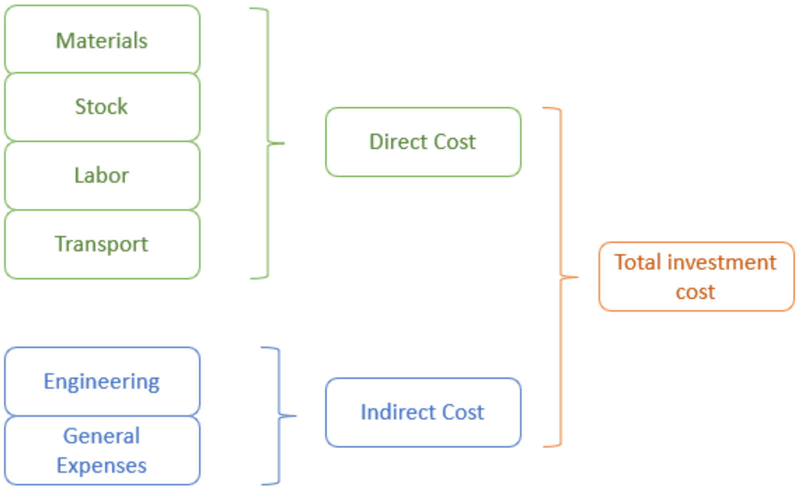

Figure 21. Structure Investment Costs

- **Fixed costs**

As mentioned above, it is recommended that an office be rented in a medium-sized city close to the regions where the equipment will be installed. This office will allow one person to work from there, carrying out all coordination tasks and ensuring that the systems keep its functionality in order.

The fixed costs would therefore include the cost of renting this office, as well as the labor costs of the manager who will work there. In addition, the service provider could include as a fixed cost the equipment and resources needed for the office and the maintenance of the office.

- **O&M**

These costs derive from the use of the equipment. It is proposed to include the costs of equipment maintenance, both preventive and corrective, as well as those that may be incurred due to the depletion of the useful life of the equipment components.

Preventive maintenance refers to maintenance that is performed regularly on the systems with the objective of preventing failures and ensuring their correct operation in the long term. On the contrary, corrective maintenance is performed after a failure or problem has occurred. The objective of corrective maintenance is to restore the equipment to its normal operating state, either by repairing or replacing defective parts or components.

Currently, the component with the shortest lifetime in an off-grid PV system is the battery. Lithium-ion batteries, which are currently used in SFAs, have a lifetime of 10 years. In contrast, the panel can have a lifetime of 20 to 25 years. Therefore, if the supplier plans to offer the service for more than 10 years, the cost structure should include the cost of reinstalling these batteries.

- **Commercial**

This cost represents the commercial cost of receiving payments from customers.

The commercial cost would mainly consist of two parts:

- Labor cost of the local official who spends part of his time receiving payments from customers and answering their calls in the event of an incident.
- The cost of using the app to generate the activation codes that users must enter into their systems once they have made the payment.

4. Financial plan

For the financial model, the tariff calculation model developed by Osinergmin[14] in Peru will be used as an example. Thanks to this report, it has been possible to estimate the labor and transport costs, as well as to access the prices of the equipment needed.

The model will be developed for the Valiente peninsula (Panama), taking as a reference the costs established for the jungle region of Peru. The peninsula is part of the Ngäbe-Buglé region, and in particular, of the Kusapin region.

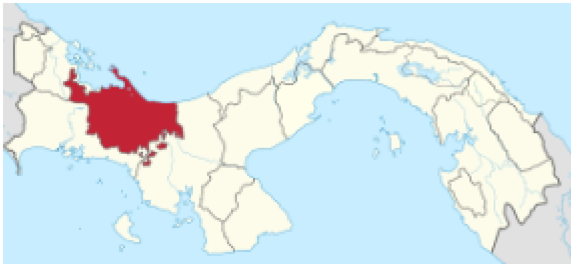

Figure 22. Ngäbe-Buglé region

Figure 23. Kusapin region

[14] The report detailing the procedure for calculating the tariff can be found at the following link: https://www.osinergmin.gob.pe/seccion/institucional/regulacion-tarifaria/procesos-regulatorios/electricidad/tarifa-electrica-rural-sistemas-fotovoltaicos

The objective of this financial model is to demonstrate that the implementation of the service is economically viable for a company, provided that a subsidy is available to cover a percentage of the monthly fee. The plan will be developed for a time period of 20 years.

The model will be developed to provide photovoltaic systems of both 120Wp and 240Wp. Electrification will be carried out with third generation photovoltaic systems (SFV 3G). These are prepaid systems.

In addition, the equipment provided will include a 3W LED that can supply 420lm. In this way, the enterprise providing the service will be able to ensure that users have at least a minimum of light in their homes. The other equipment available to them will depend on their financial ability to purchase it.

The model will be developed considering that payment by users will be made physically.

4.1. Revenues

The financial plan will initially assume the installation of 250 photovoltaic modules (200 of 120Wp and 50 of 240Wp). This is supposed because the region of Kusapin has 250 households. The total fee that the company will receive per month will be US$ 15 for 120Wp modules and US$ 20 for 240Wp modules. It is assumed that 70% of this fee will be subsidised, so end users will have to pay US$ 4.5 per month and US$ 6 per month respectively. A small part of this income will be subtracted from these revenues, which refers to people who, despite having purchased the service, cannot afford to pay and stop paying. These people will be considered to be 2% of the total number of customers, who stop paying for 6 months of the year.

This information can be summarised in the following table:

Monthly charge module 120Wp (US$)	15,0
Monthly module charge 240Wp (US$)	20,0
% Subsidy	70%
Anual unpaid %	2%
Monthly charge to users (module 120Wp)	4,5
Monthly charge to users (module 240Wp)	6,0

Figure 24. Revenue summary

4.2. Costs

4.2.1. Investment

As mentioned before, these include investments in materials and resources (everything necessary for the assembly and installation of the photovoltaic systems).

Materials

It includes the cost of the elements that make up the photovoltaic systems. The following table shows the elements of 3G PV systems chosen for the model, as well as their supplier and unit cost:

Description of equipment	Price (US$)	Supplier
Photovoltaic panel - 12Vdc 120Wp	62,89	Zimpertec
Support module for 120Wp photovoltaic panel	28,73	SolarModul
Support module for photovoltaic panel 2x120Wp	30,59	Polmarg EIRL
Batteries 25Ah, 320Wh with regulation system	170,00	Zimpertec
Batteries 50Ah, 640Wh with regulation system	293,11	Zimpertec
Installation kit	32,40	Zimpertec

Table 3. Materials' cost

Stock

It represents the cost of storage of materials (warehouse, insurance and personnel).

For this example, it has been considered that there will be a warehouse in the city of David, from where the distribution and storage of the equipment will take place.

Following the Osinergmin model in Peru, the cost of stock will be calculated as a percentage of the cost of materials. The cost will include the fixed asset investment (warehouse), as well as the costs of its operation and maintenance (personnel, services, immobilized stock...).

The percentage of stock cost selected is 6.81%, in accordance with the value that has been used by Osinergmin to calculate the Rural Photovoltaic tariff in Peru.

Labor

It corresponds to the labor costs necessary to develop the different activities that allow the installation of photovoltaic systems. The costs used have been based on those presented by Osinergmin in the technical report of the Rural Photovoltaic tariff for the period 2022-2026.

The following table shows man-hour costs by category:

LABOR COSTS	
Category	**Man-hour cost (US$/h-h)**
Foreman	5,33
Operator	4,85
Officer	4,67
Laborer	3,57

Table 4. Labor salaries

As previously explained, each of the different categories corresponds to the level of expertise of the workers. These base salaries will be used throughout the work to estimate the labor cost of the different tasks to be performed, depending on the expertise needed in each case. It has been decided that for the installation of the modules a laborer and an officer will be needed. They will work 8 hours per day, and each day they will install 4 systems. Therefore, the total labor cost for one day of equipment installation will be:

LABOR COST FOR INSTALLATION				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Officer	h-h	4,67	8	37,36
Laborer	h-h	3,57	8	28,56
TOTAL				**65,92**

Table 5. Labor costs for equipment installation

Transport

It corresponds to the cost of transportation and equipment to develop the different activities. Following Osinergmin's model, the costs used have been those defined by the Information System for Standard Investment Costs of Electrical Distribution Facilities (SICODI)[15]. As with the labor salaries, these costs will be used as a base in order to calculate the specific transport cost for each activity, depending on the category and the hours needed to be used. The machine-hour costs by category are presented below:

Category	Cost (US$/h-m)
Truck 10Tn	14,27
Truck 4Tn	12,10
Truck	9,94
Motorcycle	1,87
Boat	23,30
Small boat	6,77

Table 6. Transport costs

The transport cost will vary depending on the route and type of activity. For the case of transport costs in the investment, two routes have been established:

- Material's transport from supplier's reception to warehouse. This route corresponds to the transport of the materials from Panama City to David, where the warehouse would be located. The route would be done in a 10Tn truck, in order to transport all

[15] Set of tools and procedures used for the calculation and management of investment costs in electrical distribution facilities.

the equipment in a single trip. The route would take approximately 6 hours and would be as follows:

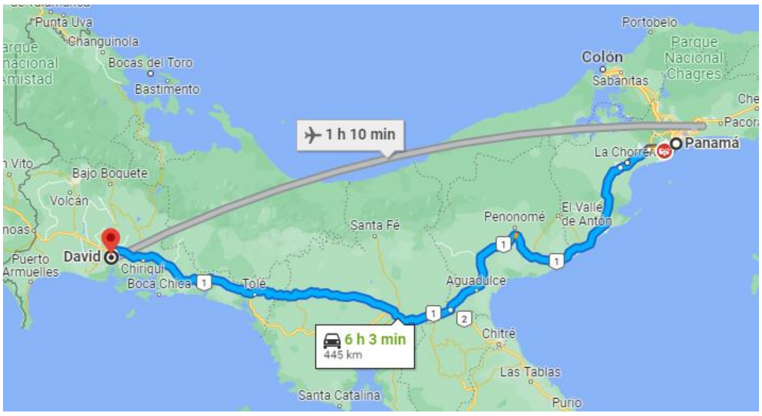

Figure 25. Route Panama City - David

- Transport for the installation of the equipment. This cost corresponds to the transport of the equipment from David to the users' homes. Since the Valiente peninsula is only accessible by sea, it has been considered that the equipment will be transported by truck from David to Miramar, the closest coastal town to the peninsula that is accessible by road. From there, the Valiente peninsula will be accessed by boat. The journey time by truck is 2 hours, including the return trip to the warehouse, which would be 4 hours. It has been estimated that the boat trip would take an average of 1 hour, depending on the exact location of the users. The route would be the following:

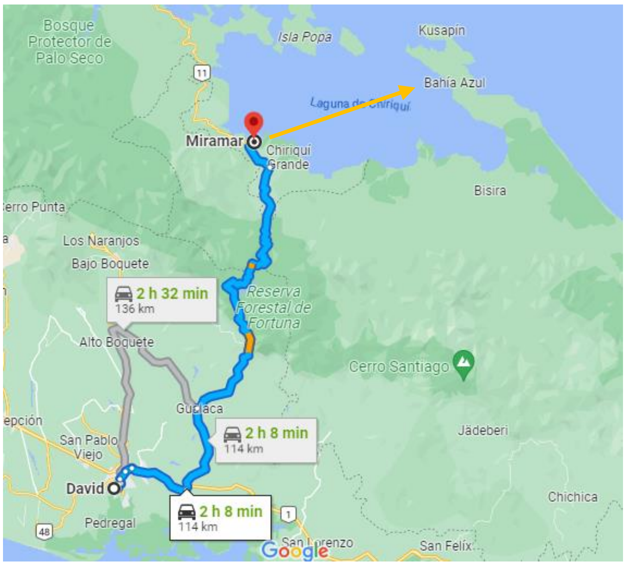

Figure 26. Route David-users' houses

TRANSPORT PANAMA CITY - DAVID				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Truck 10Tn	h-m	14,27	6	85,62

Table 7. Transport cost Panama City - David

TRANSPORT COSTS FOR INSTALLATION				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Boat	h-m	23,3	1	23,3
Truck	h-m	9,94	4	39,76
TOTAL				**63,06**

Table 8. Transport cost for 1 day of installations

<u>Engineering and Reception</u>

Corresponds to the indirect costs of engineering, supervision and reception of works of the project. It will be calculated as 11% of the work cost (materials, stock and labor and transportation resources), as established by Osinergmin in the calculation of Peru's tariff.

<u>General expenses</u>

This represents administrative and tax expenses, training for users of the photovoltaic systems and local technicians, and those related to the execution of the installations. It will be established as 6% of the construction costs, again following Osinergmin's guidelines.

To establish the unit investment cost for each of the modules, the material costs were added together and the previously calculated labor and transport costs per day were divided by 4, as this is the number of units that could be installed in one day. The transport from Panama City to David has been divided by total modules installed (250). The unit investment costs are therefore as follows:

Cost description	US$	Unit cost (US$)
Transport for 1 day	63,06	15,765
Labor for 1 day	65,92	16,48
Transport Panama City - David	85,62	0,34248

Table 9. Unit transport and labor investment costs

	SUMMARY UNITARY COSTS (US$)	
	120Wp module	**240Wp module**
Materials Cost	302,43	490,29
Stock Cost	20,595483	33,388749
Labor Cost	16,48	16,48
Transport for installation	15,765	15,765
Transport Panama City - David	0,34248	0,34248
Total construction costs	*355,612963*	*556,266229*
General costs	21,33677778	33,37597374
Engineering costs	39,11742593	61,18928519
Total unitary investment cost	***416,0671667***	***650,8314879***

Table 10. Summary unit investment cost

As it can be seen, the 120Wp module will have an investment cost of **US$ 416** approximately and the 240Wp one **US$ 651** approximately.

4.2.2. Fixed costs

As explained in the *Cost Structure* section, the fixed costs will represent those derived from having a person in charge of coordinating all the tasks carried out, and in some way being the "representative" of the company in the region in which it operates. These costs have been based on those established in the Luz en Casa project[16], adapted to the country of Panama. The summary of these costs is presented in the following table:

Fixed cost / US$ per month	
Office rent+Light+Water	300
Telephone Service + Internet	20
Staff (manager)	480
Fiscal and tax consultancy service	10
Office maintenance (cleaning)	28
Mail forwarding	10
Office supplies	50
Cleaning supplies	5
Printing	20
Local mobility	37,4
Travel coordination Panama City	10

Table 11. Fixed costs summary

The office would be rented in David. In order to have a price reference, a search has been carried out and the following office has been found that fits the necessary conditions of this project:

Figure 27. Office to rent in David[17]

[16] Project carried out by Acciona in Peru, where a large number of homes have been supplied with electricity since 2009 through SHS. Find out more in: https://safundacionmicro.blob.core.windows.net/media/2738/201407-itdupm-bid-caso-luz-en-casa-es.pdf

[17] https://www.compreoalquile.com/propiedades/clasificado/alclocin-oficinas-economicas-en-edificio-recien-remodelado-60559626.html

Taking into account the labor costs of the equipment installers, it has been estimated that the person working in this office would receive a salary of US$ 6 per hour, which is higher than that of the workers because a higher level of expertise is required. It has been assumed that he/she would work half a day, 4 hours.

For the local mobility, it has been estimated a cost of 1h per day using a motorcycle. For the coordination trips to Panama City, it has been considered that perhaps is needed that this persona travels once per year to the capital by plane, supposing a cost of US$ 120, which would be US$ 10 per month.

All these costs will increase with inflation of 1%.

4.2.3. Operations and maintenance

In this section, the corrective and preventive maintenance costs will be considered, as well as the cost from replacing batteries due to its end life.

Preventive maintenance

The tasks associated with the preventive maintenance are the following:

Component	Activity	Frequency	Workers
Photovoltaic Panel	Thorough panel inspection	Annual	Officer
Battery	Thorough inspection of the battery	Annual	Officer
Photovoltaic Panel	Cleaning and visual inspection of the panel	Quarterly	Operator

Table 12. Preventive maintenance activities

The labor and transport costs for one day of preventive maintenance will be the following. The transport will consider the cost of moving from David to the users' households by boat and motorcycle, as no equipment needs to be transported.

Labor cost officer/day (8h) (US$)	37,36
Labor cost operator/day (8h) (US$)	38,8
Transport cost/day (US$)	30,78

The thorough panel and battery inspection are supposed to be done simultaneously. Six units could be thorough inspected per day, and 16 panels could be visually inspected per day. Considering this information, the unit preventive costs will be the following:

	SUMMARY ANNUAL UNIT COSTS (US$)		
Activity	**Labor cost**	**Transport cost**	**Total**
Thorough panel inspection	6,226666667	5,13	11,35666667
Thorough inspection of the battery			
Cleaning and visual inspection of the panel	4,85	3,8475	8,6975
	Total Preventive unit cost		**20,05416667**

Table 13. Preventive unit cost

Corrective maintenance

The corrective maintenance cost will be calculated estimating a percentage of equipment failure per year. This percentage will be of the 5%. Each reparation will suppose on average a cost of 15% of the material's investment. The workforce needed to develop the corrective maintenance would the formed by an officer and an operator. The transport will consider the cost of moving from David to the users' households by boat and truck, in case some equipment components need to be transported. All this information is summarised in the following tables:

Annual equipment failure rate	5%
Cost of repair of materials over investment	15%
No. of repairs per day	1
Workers	Officer + Operator

Table 14. Corrective maintenance costs

Labor cost officer+operator/day (8h) (US$)	76,16
Transport cost/day (US$)	63,06

Table 15. Labor and transport costs for corrective maintenance

Battery end of life

Taking into account that the model is developed for 20 years, after 10 years it will be necessary to replace the batteries of the installed systems. This cost will include the cost of the 250 batteries to be replaced plus the labor and transport costs necessary for their reinstallation. In this case it will be considered that 6 batteries per day can be reinstalled.

4.2.4. Commercial

As mentioned above, there are two parts to this cost:

- Labor cost of the local employee who spends part of his time answering users' calls in case of an incident in the systems and receiving payments. To estimate this cost, it has been assumed that the employee will spend 15 minutes per caller and 15 minutes per person who comes to pay. The percentage of callers will be 1% per day of the total installed equipment. This information is summarised in the following table:

Salary staff member (US$/h)	4,5
Time/paying user (mins)	15
% calls per incident (daily)	1%
Time spent/call (mins)	15

Table 16. Local staff commercial cost

- Software cost: the cost of using the software which allows to make use of the PAYG technology will be of US$ 4,5 per module installed and per year. It has been decided to consider that this cost will increase with inflation of 1%.

4.3. DCF Calculation

In order to estimate the value of the investment a DCF Calculation has been carried out.

The total investment for the project will be of US$ 115.755. The OP&M will be considered as COGS, as it represents the costs of the materials and labor needed to carry out the activities of the company.

The fixed and commercial costs will be considered as SG&A costs.

The time horizon for the depreciation will be 20 years, and no salvage value will be considered. This is due to the fact that after 20 years, the batteries and the panels would need to be replaced, as it would have ended its useful life.

The company will pay taxes of 25%, as this is the percentage paid by corporations in Panama (Kraemer & Kraemer, 2023).

In order to calculate de net working capital, it has been considered that the average days in inventory will be 10, as after the installation pieces would only need to be in the warehouse in case of equipment failure. The collection period will be of zero days, as the model is based on a pre-payment service. The company doesn't need to wait for its clients to pay, on the contrary, it is necessary for them to pay in order to access the service. The cash ratio will be of 40% and the days to pay suppliers and accruals 30 on average.

All this information allows to estimate the Free Cash Flow of the project, which is presented in the Appendix I.

To obtain the net present value of the project the WACC has been estimated. For the cost of debt, Panama's nominal interest rate has been taken into account. This interest rate has been calculated by adding the real interest rate with the country's inflation. Panama's real interest rate currently stands at 4,7%[18], while inflation has a value of 1,4%[19]. This makes a value of 6,1% for the nominal interest, which is the one that will be taken into account for the WACC calculation.

The interest required by the shareholders will be estimated at 15%. The company's proportion of debt will be 65%, and thus the equity one 35%.

4.4. Results obtained

Once the calculations have been made, the net present value obtained has been of **US$ 36.644**. The Free Cash Flow has allowed to calculate the IRR of the investment, which is **12,6%**. These results show that the investment is profitable and therefore does not involve economic losses. In addition, the IRR value is considerably high, so it can be said that it is an attractive investment.

[18] 2021 value obtained from: https://datos.bancomundial.org/indicator/FR.INR.RINR?locations=PA

[19] March 2023 value obtained from: https://datosmacro.expansion.com/ipc-paises/panama

5. Conclusions

After carrying out the work, it can be concluded that investment in SHS in last mile communities can be very attractive both for the economic benefits that it could bring to the provider company and for its social and environmental benefits.

On the one hand, it has been shown that it is necessary to accelerate the process of universal electrification, as there is currently a high percentage of people in the world who don't have access to this service. This has major disadvantages for the personal and professional development of these communities. The technology that allows these people to obtain this service exists, and therefore it is necessary to promote it and facilitate the conditions for the off-grid electricity market to evolve.

This leads us to emphasise that universal electrification will not be achieved without the participation of both the public and private sectors. Governments have the power to facilitate the evolution of the SHS market, while private companies have the power to commercialise SHS.

In addition, it is worth noting that the use of SHS also brings benefits for the environment, as it replaces the use of polluting energy alternatives. Thanks to this, more than one SDG is combated at the same time.

Finally, the development of the financial model has made it possible to demonstrate that the commercialisation of this service is profitable in the long term. The emergence on the market of new payment methods such as PAYG has accelerated access to these services for people with low incomes, which is also an advantage for the companies providing the service.

6. References

Amol Phadke, Arne Jacobson, Won Young Park, Ga Rick Lee, Peter Alstone, Amit Khare. (2015). *Powering a Home with Just 25 Watts of Solar PV: Super-Efficient Appliances Can Enable Expanded Off-Grid Energy Service Using Small Solar Power Systems.* https://escholarship.org/content/qt3vv7m0x7/qt3vv7m0x7.pdf?t=p0fuga

Bahia Azul. (2011). *Península Valiente*. http://alcibiades-bahiaazul.blogspot.com/2011/07/peninsula-valiente.html

Constitución Política del Estado de Bolivia (CPE). Capítulo 6. (2009). https://www.oas.org/dil/esp/constitucion_bolivia.pdf

GOGLA. (2019). *Powering Opportunity in West Africa*. https://www.gogla.org/sites/default/files/resource_docs/powering_opportunity_west_africa_eng_0.pdf

IEA, International Energy Agency. (2020). *Defining energy access: 2020 methodology*. https://www.iea.org/articles/defining-energy-access-2020-methodology

IFC, International Finance Corporation. (2019). *The Dirty Footprint of the Broken Grid. The Impacts of Fossil Fuel Back-up Generators in Developing Countries.* https://www.ifc.org/wps/wcm/connect/2cd3d83d-4f00-4d42-9bdc-4afdc2f5dbc7/20190919-Full-Report-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UpXC

Instituto Nacional de Estadística y Censo – Panamá. (2020). https://www.inec.gob.pa/publicaciones/Default3.aspx?ID_PUBLICACION=556&ID_CATEGORIA=3&ID_SUBCATEGORIA=10

IRENA, International Renewable Energy Agency. (2017). *REthinking Energy 2017: Accelerating the global energy transformation.* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_REthinking_Energy_2017.pdf?rev=2e2fb801ea3f497abc02b6d36a65c95e

Johanna Diecker, Susie Wheeldon and Andrew Scott. (2016). *Accelerating access to electricity in Africa with off-grid solar. Policies to expand the market for solar household solutions*. https://cdn.odi.org/media/documents/10231.pdf

JUSTIA. (2023). *Constitución Política de Colombia*. https://colombia.justia.com/nacionales/constitucion-politica-de-colombia/titulo-

xii/capitulo-5/#:~:text=Art%C3%ADculo%20365%20ARTICULO%20365%C2%BA%E2%80%94Los,los%20habitantes%20del%20territorio%20nacional.

Kraemer & Kraemer. (2023). *¿Cómo tributan las corporaciones en Panamá?*. https://kraemerlaw.com/es/articles/como-tributan-las-corporaciones-en-panama/#:~:text=Panam%C3%A1%20tiene%20un%20tipo%20fijo,colectivas%20y%20las%20sociedades%20an%C3%B3nimas.

Lighting Africa. (2011). *The Off-Grid Lighting Market in Sub-Saharan Africa. Market Research Synthesis Report*. https://documents1.worldbank.org/curated/en/176581468209676527/pdf/682810ESMAP0WP0NAL0reduced020110224.pdf

Lighting Global. (2022). *Off-Grid Solar Market Trends Report 2022: State of the Sector*. https://documents1.worldbank.org/curated/en/099235110062231022/pdf/P175150063801e0860928f00e7131b132de.pdf

Ortiz R., Pérez-Arriaga I., Dueñas P., González A., Mejía M., Révolo M. (2020). *Misión de Transformación Energética y Modernización de la Industria Eléctrica: Hoja de Ruta para la Energía del Futuro. Foco No 4. Cierre de brechas, mejora de la calidad y diseño y formulación eficiente de subsidios.* https://www.minenergia.gov.co/documents/7686/Foco_4._Cierre_de_brechas_mejora_de_la_calidad_y_dise%C3%B1o_y_formulacion_eficient_JTF0ADK.pdf

Pablo Iorio, Maria Eugenia Sanin. (2019). *Acceso y asequibilidad a la energía eléctrica en América latina y El Caribe*. https://publications.iadb.org/es/acceso-y-asequibilidad-la-energia-electrica-en-america-latina-y-el-caribe

RISE, Regulatory Indicators for Sustainable Energy. (2022). https://rise.esmap.org/about-us

World Health Organization, WHO. (2022). *Household air pollution.* https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

United Nations. (2022). *The Sustainable Development Goals Report 2022*. https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf

United Nations. (2023). *OHCHER and the rights to water and sanitation*. https://www.ohchr.org/en/water-and-sanitation

Appendix 1. Financial plan

External data – Direct Investment Costs (US$)

COST OF MATERIALS	
Description	**Price (US$)**
Photovoltaic panel - 12Vdc 120Wp	62,89
Support module for 120Wp photovoltaic panel	28,73
Support module for photovoltaic panel 2x120Wp	30,59
Batteries 25Ah, 320Wh with regulation system	170
Batteries 50Ah, 640Wh with regulation system	293,11
Installation kit	32,4
LED 3W 420lm	8,41

Table A 1. Materials' cost

Stock Cost	6,81%

Table A 2. Stock Cost

LABOR COSTS	
Category	**Man-hour cost (US$/h-h)**
Foreman	5,33
Operator	4,85
Officer	4,67
Laborer	3,57

Table A 3. Labor Cost

TRANSPORT COST	
Category	**Cost (US$/h-m)**
Truck 10Tn	14,27
Truck 4Tn	12,1
Truck	9,94
Motorcycle	1,87
Boat	23,3
Small boat	6,77

Table A 4. Transport cost

External Data – Indirect Investment Costs

GENERAL EXPENSES	6%
ENGINEERING	11%

Table A 5. Indirect Investment Costs

Transport Costs (US$)

TRSNPORT COSTS FOR PREVENTIVE MAINTENANCE				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Boat	h-m	23,3	1	23,3
Motorcycle	h-m	1,87	4	7,48
TOTAL				30,78

Table A 6. Preventive maintenance transport cost

TRANSPORT COSTS FOR INSTALLATION AND CORRECTIVE MAINTENANCE				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Boat	h-m	23,3	1	23,3
Truck	h-m	9,94	4	39,76
TOTAL				**63,06**

Table A 7. Investment and corrective maintenance transport cost

TRANSPORT PANAMA CITY - DAVID				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Truck 10Tn	h-m	14,27	6	85,62

Table A 8. Panama City - David transport cost

Revenues (US$)

Monthly charge module 120Wp(US$)	15,0
Monthly module charge 240Wp (US$)	20,0
% Subsidy	70%
Anual unpaid %	2%
Monthly charge to users (module 120Wp)	4,5
Monthly charge to users (module 240Wp)	6,0

Table A 9. Summary revenues tariffs

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Income from user fees	0,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0
Subsidy income	0,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0
Unpaid	0,0	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)
TOTAL ANNUAL REVENUES	0,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0

Table A 10. Projections revenues 1

	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Income from user fees	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0	14.400,0
Subsidy income	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0	33.600,0
Unpaid	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)	(144,0)
TOTAL ANNUAL REVENUES	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0

Table A 11. Projections revenues 2

Investment Unitary Cost (US$)

LABOR COST FOR INSTALLATION				
Description	**Unit**	**Cost (US$/Unit)**	**Hours**	**Subtotal (US$)**
Officer	h-h	4,67	8	37,36
Laborer	h-h	3,57	8	28,56
TOTAL				**65,92**

Table A 12. Investment labor costs

Cost description	US$	Unitary cost
Transport for 1 day	63,06	15,765
Labor for 1 day	65,92	16,48
Transport Panama City - David	85,62	0,34248

Table A 13. Investment labor and transport costs

	SUMMARY UNITARY COSTS (US$)	
	120Wp module	**240Wp module**
Materials Cost	302,43	490,29
Stock Cost	20,595483	33,388749
Labor Cost	16,48	16,48
Transport for installation	15,765	15,765
Transport Panama City - David	0,34248	0,34248
Total construction costs	*355,612963*	*556,266229*
General costs	21,33677778	33,37597374
Engineering costs	39,11742593	61,18928519
Total unitary investment cost	***416,0671667***	***650,8314879***

Table A 14. Unitary Investment costs

Fixed costs (US$)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Staff	0	5760	5817,6	5875,776	5934,53376	5993,8791	6053,81789	6114,35607	6175,49963	6237,25462	6299,62717
Inflation		*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Displacements	0	568,8	574,488	580,23288	586,035209	591,895561	597,814516	603,792662	609,830588	615,928894	622,088183
Inflation		*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Office	0	5316	5369,16	5422,8516	5477,08012	5531,85092	5587,16943	5643,04112	5699,47153	5756,46625	5814,03091
Inflation		*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Total Fixed costs	***0***	***11644,8***	***11761,248***	***11878,8605***	***11997,6491***	***12117,6256***	***12238,8018***	***12361,1898***	***12484,8017***	***12609,6498***	***12735,7463***

Table A 15. Projections fixed costs

	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Staff	6362,62344	6426,24968	6490,51217	6555,4173	6620,97147	6687,18118	6754,05299	6821,59352	6889,80946	6958,70755
Inflation	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Displacements	628,309065	634,592156	640,938077	647,347458	653,820932	660,359142	666,962733	673,632361	680,368684	687,172371
Inflation	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Office	5872,17122	5930,89293	5990,20186	6050,10388	6110,60492	6171,71097	6233,42808	6295,76236	6358,71998	6422,30718
Inflation	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Total Fixed costs	***12863,1037***	***12991,7348***	***13121,6521***	***13252,8686***	***13385,3973***	***13519,2513***	***13654,4438***	***13790,9882***	***13928,8981***	***14068,1871***

Table A 16. Projections Fixed Costs 2

OP&M (US$)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
CORRECTIVE MAINTENANCE COST	Number of failure modules	0	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5
	Matrials cost (both modules)	0,0	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4
	Labor annual cost	0	952	952	952	952	952	952	952	952	952	952
	Transport annual cost	0	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3
	Total corrective maintenance cost	0	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6
PREVENTIVE MAINTENANCE COST	Total preventive maintenance cost	0	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5
END OF BATTERY LIFE	Materials' re-installation cost	0	0	0	0	0	0	0	0	0	0	48655,5
	Labor re-installation cost	0	0	0	0	0	0	0	0	0	0	2746,7
	Transport re-installation cost	0	0	0	0	0	0	0	0	0	0	2627,5
	Total re-installation cost	0	0	0	0	0	0	0	0	0	0	54029,7
	TOTAL OP&M	***0***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***62269,8***

Table A 17. Projections OP&M 1

		2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
CORRECTIVE MAINTENANCE COST	Number of failure modules	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5
	Matrials cost (both modules)	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4	1486,4
	Labor annual cost	952	952	952	952	952	952	952	952	952	952
	Transport annual cost	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3	788,3
	Total corrective maintenance cost	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6	3226,6
PREVENTIVE MAINTENANCE COST	Total preventive maintenance cost	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5	5013,5
END OF BATTERY LIFE	Materials' re-installation cost	0	0	0	0	0	0	0	0	0	0
	Labor re-installation cost	0	0	0	0	0	0	0	0	0	0
	Transport re-installation cost	0	0	0	0	0	0	0	0	0	0
	Total re-installation cost	0	0	0	0	0	0	0	0	0	0
	TOTAL OP&M	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***	***8240,1***

Table A 18. Projections OP&M 2

Commercial Costs (US$)

Staff member (US$/h)	4,5
Time/paying user (mins)	15
% calls per incident (daily)	1%
Time spent/call (mins)	15

SOFTWARE COST	
Cost per module (US$/kit/year)	4,5

Table A 19. Summary Commercial costs

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Software cost	0	1125	1136,25	1147,6125	1159,08863	1170,67951	1182,38631	1194,21017	1206,15227	1218,21379	1230,39593
Inflation		*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Time spent collecting payments/year (h)	0	750	750	750	750	750	750	750	750	750	750
Time spent handling incident calls/year (h)	0	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125
Staff member + software cost	***0***	***5526,5625***	***5537,8125***	***5549,175***	***5560,65113***	***5572,24201***	***5583,94881***	***5595,77267***	***5607,71477***	***5619,77629***	***5631,95843***

Table A 20. Projections Commercial costs 1

	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Software cost	1242,69989	1255,12689	1267,67816	1280,35494	1293,15849	1306,09007	1319,15098	1332,34249	1345,66591	1359,12257
Inflation	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Time spent collecting payments/year (h)	750	750	750	750	750	750	750	750	750	750
Time spent handling incident calls/year (h)	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125	228,125
Staff member + software cost	***5644,26239***	***5656,68939***	***5669,24066***	***5681,91744***	***5694,72099***	***5707,65257***	***5720,71348***	***5733,90499***	***5747,22841***	***5760,68507***

Table A 21. Projections Commercial costs 2

Summary Revenues and Costs (US$)

		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Revenues												
	TOTAL ANNUAL REVENUES	0,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0
Investment												
	120 Wp modules	(83.213,4)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	240 Wp modules	(32.541,6)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	TOTAL ANNUAL INVESTMENT	*(115.755,0)*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*
Fixed costs												
	Staff	0,0	(5.760,0)	(5.817,6)	(5.875,8)	(5.934,5)	(5.993,9)	(6.053,8)	(6.114,4)	(6.175,5)	(6.237,3)	(6.299,6)
	Displacements	0,0	(568,8)	(574,5)	(580,2)	(586,0)	(591,9)	(597,8)	(603,8)	(609,8)	(615,9)	(622,1)
	Office	0,0	(5.316,0)	(5.369,2)	(5.422,9)	(5.477,1)	(5.531,9)	(5.587,2)	(5.643,0)	(5.699,5)	(5.756,5)	(5.814,0)
	TOTAL FIXED COSTS	*0,0*	*(11.644,8)*	*(11.761,2)*	*(11.878,9)*	*(11.997,6)*	*(12.117,6)*	*(12.238,8)*	*(12.361,2)*	*(12.484,8)*	*(12.609,6)*	*(12.735,7)*
OP&M												
	Corrective maintenance	0,0	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)
	Preventive maintenance	0,0	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)
	End of battery life	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	(54.029,7)
	TOTAL ANNUAL OP&M	*0,0*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(62.269,8)*
Commercial												
	TOTAL COMMERCIAL	*0,0*	*(5.526,6)*	*(5.537,8)*	*(5.549,2)*	*(5.560,7)*	*(5.572,2)*	*(5.583,9)*	*(5.595,8)*	*(5.607,7)*	*(5.619,8)*	*(5.632,0)*

Table A 22. Projections summary Revenues and costs 1

		2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Revenues											
	TOTAL ANNUAL REVENUES	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*	*47.856,0*
Investment											
	120 Wp modules	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	240 Wp modules	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	TOTAL ANNUAL INVESTMENT	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*
Fixed costs											
	Staff	(6.362,6)	(6.426,2)	(6.490,5)	(6.555,4)	(6.621,0)	(6.687,2)	(6.754,1)	(6.821,6)	(6.889,8)	(6.958,7)
	Displacements	(628,3)	(634,6)	(640,9)	(647,3)	(653,8)	(660,4)	(667,0)	(673,6)	(680,4)	(687,2)
	Office	(5.872,2)	(5.930,9)	(5.990,2)	(6.050,1)	(6.110,6)	(6.171,7)	(6.233,4)	(6.295,8)	(6.358,7)	(6.422,3)
	TOTAL FIXED COSTS	*(12.863,1)*	*(12.991,7)*	*(13.121,7)*	*(13.252,9)*	*(13.385,4)*	*(13.519,3)*	*(13.654,4)*	*(13.791,0)*	*(13.928,9)*	*(14.068,2)*
OP&M											
	Corrective maintenance	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)	(3.226,6)
	Preventive maintenance	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)	(5.013,5)
	End of battery life	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	TOTAL ANNUAL OP&M	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*	*(8.240,1)*
Commercial											
	TOTAL COMMERCIAL	*(5.644,3)*	*(5.656,7)*	*(5.669,2)*	*(5.681,9)*	*(5.694,7)*	*(5.707,7)*	*(5.720,7)*	*(5.733,9)*	*(5.747,2)*	*(5.760,7)*

Table A 23. Projections summary Revenues and costs 2

P&L and DCF results (US$)

			2023	2024	2025	2026	2027	2028
Investment:	115.755,0							
Time Horizon:	20 years							
		Revenues	0,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0
		- COGS	0,0	8.240,1	8.240,1	8.240,1	8.240,1	8.240,1
		- SG&A	0,0	17.171,4	17.299,1	17.428,0	17.558,3	17.689,9
		EBITDA	***0,0***	***22.444,5***	***22.316,8***	***22.187,8***	***22.057,6***	***21.926,0***
Depreciation:	20 years	- Depreciation	0,0	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8
Salvage Value:	0%	***EBIT***	***0,0***	***16.656,7***	***16.529,0***	***16.400,1***	***16.269,8***	***16.138,2***
Taxes:	25%	- Taxes	0,0	4.164,2	4.132,3	4.100,0	4.067,5	4.034,6
		NOPAT	***0,0***	***12.492,6***	***12.396,8***	***12.300,1***	***12.202,4***	***12.103,7***
		- Capex	(115.755,0)					
Days in inventory:	10 days	Inventory	0,0	225,8	225,8	225,8	225,8	225,8
Collection Period:	0	Acc. Receivable	0,0	0,0	0,0	0,0	0,0	0,0
Cash Ratio:	40%	Cash	0,0	835,4	839,6	843,9	848,2	852,5
Payables Due:	30 days	Payables	0,0	677,3	677,3	677,3	677,3	677,3
Accrued Due:	30 days	Accrued	0,0	1.411,3	1.421,8	1.432,4	1.443,1	1.454,0
		- NWC		1.027,4	1.033,7	1.040,1	1.046,5	1.053,0
		- ΔNWC		1.027,4	6,3	6,4	6,4	6,5
		OCF	0,0	18.280,3	18.184,5	18.087,8	17.990,1	17.891,4
		CAPEX	(115.755,0)	0,0	0,0	0,0	0,0	0,0
		ΔNWC	0,0	1.027,4	6,3	6,4	6,4	6,5
		Free Cash Flow	***(115.755,0)***	***19.307,7***	***18.190,8***	***18.094,2***	***17.996,5***	***17.897,9***

Table A 24. P&L and DCF 1

	2029	2030	2031	2032	2033	2034	2035	2036
Revenues	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0
- COGS	8.240,1	8.240,1	8.240,1	8.240,1	62.269,8	8.240,1	8.240,1	8.240,1
- SG&A	17.822,8	17.957,0	18.092,5	18.229,4	18.367,7	18.507,4	18.648,4	18.790,9
EBITDA	***21.793,1***	***21.658,9***	***21.523,3***	***21.386,4***	***(32.781,5)***	***21.108,5***	***20.967,4***	***20.825,0***
- Depreciation	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8
EBIT	***16.005,4***	***15.871,1***	***15.735,6***	***15.598,7***	***(38.569,3)***	***15.320,7***	***15.179,7***	***15.037,2***
- Taxes	4.001,3	3.967,8	3.933,9	3.899,7	(9.642,3)	3.830,2	3.794,9	3.759,3
NOPAT	***12.004,0***	***11.903,4***	***11.801,7***	***11.699,0***	***(28.926,9)***	***11.490,6***	***11.384,8***	***11.277,9***
- Capex								
Inventory	225,8	225,8	225,8	225,8	1.706,0	225,8	225,8	225,8
Acc. Receivable	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cash	856,9	861,3	865,7	870,2	2.651,1	879,4	884,0	888,7
Payables	677,3	677,3	677,3	677,3	5.118,1	677,3	677,3	677,3
Accrued	1.464,9	1.475,9	1.487,1	1.498,3	1.509,7	1.521,2	1.532,7	1.544,5
- NWC	1.059,5	1.066,2	1.072,8	1.079,6	2.270,6	1.093,3	1.100,3	1.107,3
- ΔNWC	6,6	6,6	6,7	6,8	1.191,0	(1.177,3)	7,0	7,0
OCF	17.791,8	17.691,1	17.589,4	17.486,8	(23.139,2)	17.278,3	17.172,5	17.065,7
CAPEX	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
ΔNWC	6,6	6,6	6,7	6,8	1.191,0	(1.177,3)	7,0	7,0
Free Cash Flow	***17.798,3***	***17.697,7***	***17.596,1***	***17.493,5***	***(21.948,2)***	***16.101,0***	***17.179,5***	***17.072,7***

Table A 25. P&L and DCF 2

	2037	2038	2039	2040	2041	2042	2043
Revenues	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0	47.856,0
- COGS	8.240,1	8.240,1	8.240,1	8.240,1	8.240,1	8.240,1	8.240,1
- SG&A	18.934,8	19.080,1	19.226,9	19.375,2	19.524,9	19.676,1	19.828,9
EBITDA	***20.681,1***	***20.535,7***	***20.389,0***	***20.240,7***	***20.091,0***	***19.939,7***	***19.787,0***
- Depreciation	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8	5.787,8
EBIT	***14.893,3***	***14.748,0***	***14.601,2***	***14.453,0***	***14.303,2***	***14.152,0***	***13.999,2***
- Taxes	3.723,3	3.687,0	3.650,3	3.613,2	3.575,8	3.538,0	3.499,8
NOPAT	***11.170,0***	***11.061,0***	***10.950,9***	***10.839,7***	***10.727,4***	***10.614,0***	***10.499,4***
- Capex							
Inventory	225,8	225,8	225,8	225,8	225,8	225,8	225,8
Acc. Receivable	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cash	893,4	898,2	903,0	907,9	912,8	917,8	922,8
Payables	677,3	677,3	677,3	677,3	677,3	677,3	677,3
Accrued	1.556,3	1.568,2	1.580,3	1.592,5	1.604,8	1.617,2	1.629,8
- NWC	1.114,4	1.121,5	1.128,8	1.136,1	1.143,5	1.150,9	1.158,5
- ΔNWC	7,1	7,2	7,2	7,3	7,4	7,5	7,5
OCF	16.957,7	16.848,7	16.738,7	16.627,5	16.515,2	16.401,7	16.287,2
CAPEX	0,0	0,0	0,0	0,0	0,0	0,0	0,0
ΔNWC	7,1	7,2	7,2	7,3	7,4	7,5	7,5
Free Cash Flow	***16.964,8***	***16.855,9***	***16.745,9***	***16.634,8***	***16.522,5***	***16.409,2***	***16.294,7***

Table A 26. P&L and DCF 3

Valuation Results

rd	6,1%
rs	15%
wd	65%
ws	35%

Table A 27. WACC calculation values

PV	US$ 152.399,4
WACC	8%
NPV	US$ 36.644,4
IRR	12,6%

Table A 28. Valuation results