Off-Grid Solar Systems Enterprises in Rural Areas of Developing Countries: Sustainability.

The Case of Tanzania

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Dissertation written under the supervision of Prof. Susana Frazão Pinheiro

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"Human development is all about human freedom: freedom to realize the full potential of every human life, not just of a few, nor of most, but all lives in every corner of the world – now and in the future."

The 2016 Human development report: Human development for everyone.

Abstract

Title: Off-Grid Solar Systems Enterprises in Rural Areas of Developing Countries: Sustainability

Sub-Title: The Case of Tanzania

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The lack of electricity in rural areas and cities, in developing countries is one of the main causes for the delay in their economic and social development, when compared with developed countries. A recent trend, with a prospect of continue growth, is the use of renewable energies to satisfy populations' energy needs. For developing countries, it can close their development gap, in a sustainable manner, thus surpassing a stage of growth that all the developed countries went through – industrialization.

The present dissertation aims to analyse in which way off-grid solar systems enterprises, that operate in rural regions of developing countries, can create sustainable development. By analysing specific and innovative strategies, and business models tailored to the needs of the markets at the bottom of the pyramid.

The first part, the literature review, has the purpose of analysing the problems of electricity shortage in the world, the role and growth of renewable energy, in particular off-grid solar systems, and the correspondent different dimensions required for its sustainability through innovative business models.

It is then followed by a case study of an enterprise, Off-Grid Electric, operating in Tanzania, where it is analysed how different innovative strategies created and adopted by the company are customised to the market conditions of one of the poorest countries in the world.

Sumário

Título: Empresas de Sistemas Independentes de Energia Solar em Zonas Rurais de Países em Desenvolvimento: Sustentabilidade

Subtítulo: O Caso da Tanzânia

Autor: Laura Vendrell Serrano Duarte

A falta de eletricidade em zonas rurais e em cidades de países em desenvolvimento, é umas das principais causas do atraso no seu progresso económico e social, quando comparados com países desenvolvidos. Uma tendência recente e com perspetiva de continuo crescimento, é a utilização de energias renováveis para satisfazer as necessidades de energia das populações. Poderá traduzir-se num meio para os países em desenvolvimento reduzirem o seu *gap* de desenvolvimento face aos restantes países, de forma sustentável, ultrapassando assim uma fase de crescimento que todos os países desenvolvidos viveram – a industrialização.

A dissertação apresentada pretende analisar de que forma as empresas que operam em zonas rurais de países em desenvolvimento e que providenciam sistemas independentes de energia solar, podem alcançar um desenvolvimento sustentável. Analisando estratégias específicas e inovadoras, bem como modelos de negócio adaptados às necessidades dos mercados na base da pirâmide.

A primeira parte da revisão de literatura tem por objetivo analisar o problema de falta de eletricidade no mundo, o papel e crescimento das energias renováveis, em especifico sistemas independentes de energia solar, e de seguida estudar as diferentes dimensões necessárias para a sua sustentabilidade através de modelos de negócio inovadores.

De seguida é apresentado um caso de estudo de uma empresa, Off-Grid Electric, que opera na Tanzânia. Serão analisadas as estratégias inovadoras por ela utilizadas para se adaptar às condições de mercado num dos países mais pobres do mundo.

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Firstly, I would like to thank my parents for always considering my education a priority, for their support and patience and for always believing in me. My sister, for her encouragement and for showing particular interest in my dissertation.

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List of Acronyms

5 P's	Pro-Poor Public-Private Partnerships
AfDB	African Development Bank
BNEF	Bloomberg New Energy Finance
BOP	Base of the Pyramid
DC	Developing Countries
EUP	Energy Using Products
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOGLA	Global Off-Grid Lighting Association
IEA	International Energy Agency
IRENA	The International Renewable Energy Agency
kWh	Kilowatt-hour
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-operation and Development
OGE	Off-Grid Electric
PPP	Public-Private Partnership
PV	Photovoltaic
RE	Renewable Energy
REA	Rural Energy Agency
SHS	Solar Home Systems
SPS	Solar Pico Systems
UN	United Nations
UNDO	United Nations Development Programme
W	Watts
WBG	World Bank Group

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Introduction

The present dissertation was developed in the scope of Entrepreneurship and Development seminar, as part of the MSc in Management of the Católica-Lisbon School of Business and Economics.

The idea for the topic of this dissertation came from an article on the Economist which is an exposure of the recent trend, in African countries, to invest in off-grid Photovoltaic (PV) systems to bring electricity to rural areas, where grid systems impose high costs of installment (*Economist* 29 of October 2016). The article explains why this new industry is so well suitable for developing countries (DC), especially the African ones. Today, off-grid solar industry powers more than 600 000 households in Africa, and is growing at a fast-tracking pace (*Economist* 29 of October 2016).

The present dissertation aims to emphasize one major research question: how enterprises in DC, that provide off-grid solar systems, can achieve a sustainable development? And what is the role of innovative technologies and business models in the sustainability of enterprises in DC markets?

The present dissertation is organized in four chapters: Literature Review, The Case of Tanzania, Teaching Notes and Conclusions, Limitations and Future Research.

The first - **Literature Review** - is where literature and data are collected, in order to deepen the necessary concepts and tendencies that characterized and impact the off-grid PV systems in rural regions of DC.

Initially, it will be addressed the lack of electricity access around the world, as a constraint for the socio-economic development of countries – once, energy access is widely considered a necessity "though not sufficient condition for improving human developing" (Scott 2017, p.50), and an opportunity for sustainable technologies to have an impact in the way DC can surpass their delay in terms of development.

The next section - *Renewable Energy* – focuses on the major developments felted in the industry. Renewable energy (RE) is a sector that has been growing for the past 13 years. The *Global Trends in Renewable Energy Investment 2016* (2016, p.6) describes: "this year's report demonstrates a solid trend towards increasing investment and capacity, highlighting how far

renewable energy has come from the days when it was all too readily dismissed as a niche sector". Although Africa is not the biggest investor in renewables, it is "one of the most promising markets for renewable energy over the next 10-20 years, with its growing population, urgent need for new generating capacity, lack of electricity access in remote areas, and its natural resources in sunshine, wind, biomass and geothermal" (*Global Trends in Renewable Energy Investment 2016*, 2016, p.28).

The *PV Solar Systems* section will be dedicated to the description of such systems and their advantages.

Attention will also be paid to the business model of enterprises – *Off-Gird Solar Enterprises* - that have as mission to provide off-grid energy to poor communities that do not have access to the grid. The focus will be on the new and innovative business models that are being used by entrepreneurs in these countries to allow their projects to be sustainable.

The last section – *Access Sustainability of Off-Grid PV Systems Projects* – is where a framework for sustainability is constructed to face all the different dimensions that affect sustainability of such projects.

The second chapter of this dissertation – **The Case of Tanzania** – is a case study of a specific enterprise, Off-Grid Electric (OGE), that operates in Tanzania, providing small-scale off-grid solutions to rural and isolated populations. In this chapter, after a small introduction to the country it is given a full description of the enterprise and the different elements that constitute their strategies and business model.

The third chapter of this dissertation - **Teaching Notes** – is where the author explains the learning objectives of this work, followed by the proposed five teaching questions, for analysis in the classroom, and their suggested answers.

The last chapter is devoted to **Conclusions, Limitations and Future Research**.

Literature Review

Energy Access

Throughout the 20th century, the development of nations demanded the expansion of their electricity grid supply. Access to electricity turned time consuming and physically heavy activities into routine or easier tasks. In developed countries, electricity supply lead to the improvement of the well-being of people in all sectors of society (Mandelli *et al.* 2016; Sovacool 2012).

Energy poverty is defined as the "lack of access to electricity and (the) dependence on solid biomass fuels for cooking and heating" (Sovacool 2012, p.9157). Annexe 1 gives the aggregate regional electricity access data across the world. The first learning to take from the table below is that the lack of electricity access is a reality for around 1.2 billion people[1], which means that nearly 20% of the world population does not have access to electricity. The second important understanding is that the majority of the latest is concentrated in the developing world. Furthermore, the figure also demonstrates how the lack of electricity is distributed among the developing word: most of the problems in getting access to electricity come from the rural regions, which account for the lowest levels of electrification rates.

Among the DC, Africa is the continent where the percentage of the population without access to electricity reaches the highest levels. In all Africa, there are 634 million people that live without electricity, which means the transformation that was felt in the developed world, was not a reality for most of the countries in the continent. Moreover, it is in Sub-Saharan Africa where most of the people without electricity access live (electrification rate of 35%). Here, the urban electrification rate, although not as low as in rural areas, only reaches 63% (the lowest percentage in the world), and the rural electrification rate does not exceed 19%. The rates show us that, on those rural regions, communities do not even have access to electricity for meeting their basic needs, such as cooking, lightning, health or even public services (Feron 2016; Mandelli *et al.* 2016; Sovacool 2012; and Urmee & Md 2016).

[1] Source: International Energy Agency (IEA), World Energy Outlook 2016.

In the developing world, policymakers and stakeholders pay more attention to the development of urban regions, whereas the rural ones, due to their characteristics, are left behind. Mandelli *et al.* (2016) define rural regions as scattered populated, geographically remote and of difficult access. These regions are connected by roads, when they exist, and are distant from the major urban centres. This limited accessibility represents a constraint to service providers and to access the regional and national markets. Owing to the lack of industrialized activities, the main sources of income are pastoralism, cattle raising, agriculture, fishing, tourism or forestry. Thus, all the above factors contribute to the non-economical development of these regions, through a vicious cycle, where all these factors are responsible for "high illiteracy rate, gender inequality, lack of access to health care, infrastructures and clean water supply" (Mandelli *et al.* 2016, p.1621).

The characteristics of the rural regions, also make clear why it is so difficult to achieve high electricity rates in those isolated regions due to the risk and the high cost of investing in the extension of the grid. As stated by Mandelli *et al.* (2016), the cost of electricity provided by the grid network in rural regions can reach levels that are ten times higher than the prices in urban regions. Which explains why "Access to electricity, not only for meeting basic needs, but also for productive uses, is a significant challenge faced by policymakers and stakeholders in the developing world" (Shi *et al.* 2016, p.437).

What changed?

In the last couple of years, awareness regarding human development around the world helped improving the lack of access to electricity.

In 2012, the UN announced that year as the "International Year for Sustainable Energy for All". The aim of this proposal is to encourage countries, corporations, and other groups to act in accordance with three goals by 2030: "universal access to modern energy services, reducing global energy intensity by 40%, and increasing renewable energy use globally to 30% of total primary energy supply" (United Nations Foundation 2012).

In 2015, a set of universal Sustainable Development Goals was agreed between the world leaders (Figure 2).

Figure 1: Sustainable Development Goals

Source: United Nations Foundation 2012

The focus of this dissertation is in goal #7 – Affordable and Clean Energy – its aim being to call for secure, affordable, reliable, sustainable and modern energy for all. Nevertheless, it is important to recognize that the development of affordable and clean energy affects the regions of the world without access to electricity, but also can help reducing poverty and, by using sustainable technologies, reduce the impacts of climate change. In turn it will end up influencing many other goals.

In addition, the Paris agreement also deepened the concerns announced by UN in 2012, when195 nations agreed on accomplishing a value below 2ºC on temperature increases.

As is stated by the United Nation Foundation (2012), "the global energy transaction requires a rapid increase in energy productivity, a new generation of institutions to manage our energy systems, an integrated approach to energy that embraces centralized and decentralized[2] sources, and ever increasing share of renewables in the mix". Besides, this transaction indicates a historical economic opportunity for growth and job development.

For DC, these global agreements can be translated into a need to eliminate the lack of access to electricity; however, to accomplish it using clean and sustainable ways of production.

[2] Centralized systems are the ones connected to the grid network, whereas decentralized are off-grid systems.

Renewable Energy

RE are not a recent development, they exist for a long time, however, in the past, not enough attention was paid to these types of clean energy. To that stagnation or lack of development, mainly contributed the lack of interest in the environment shared by the majority of the countries and the high costs associated with the technologies used.

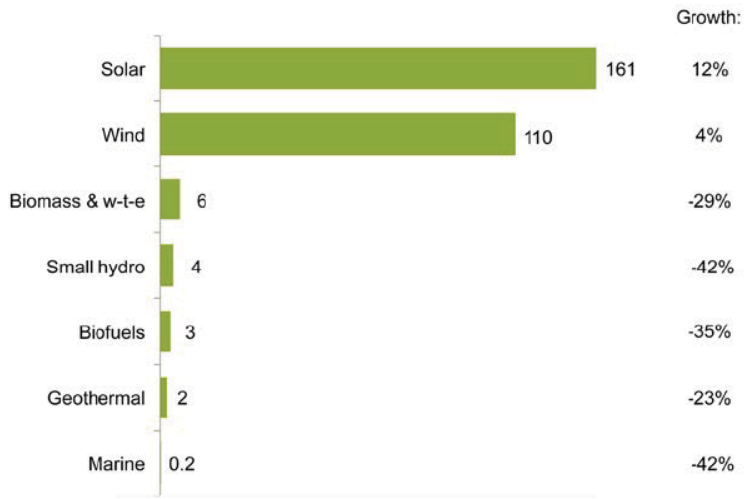
Renewable energy is defined as "energy from renewable non-fossil sources namely wind, solar, geothermal, ocean (wave) energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas" and "to be renewable, the source must be tapped in a sustainable way, e.g. so that availability is not reduced year by year or that the use entails negative social, environmental or economic impacts" (*Sustainable Energy Markets in Tanzania* 2012, p.8).

Market

RE have been gaining ground from fossil energies. For the first time ever, in 2015, the new generating capacity installed coming from renewable sources (excluding large hydro), accounted for 53.6% of the total investment (*Global Trends in Renewable Energy Investment 2016* 2016). Although not as impressive when compared with the global existing power capacity. Nevertheless, the window of opportunity for RE is the ageing process that is still on their beginning compared with coal, gas, nuclear and hydro plants that are established for decades and reaching the end of their lives (*Global Trends in Renewable Energy Investment* 2016). However, action is needed so that investments are made into RE. Besides, the life expectancy of RE is increasing, with a turbine reaching a life time of 20 years and PV systems even a longer period, excluding the option to repower to extend lifetime (*Global Trends in Renewable Energy Investment* 2016). Also, the time of construction of a solar park is from three to six months and a wind farm is of nine months; whereas, a coal or gas plant takes several years to build.

Figure 3 gives data on the global new investment made worldwide. The tendency demonstrated is for solar and wind. Investments in solar accounted for $161 billion dollars in 2015; representing a 12% growth compared with the previous year. Along with, wind accomplished the second highest investment; however, compared with 2014, the growth was not as representative as in the solar sector.

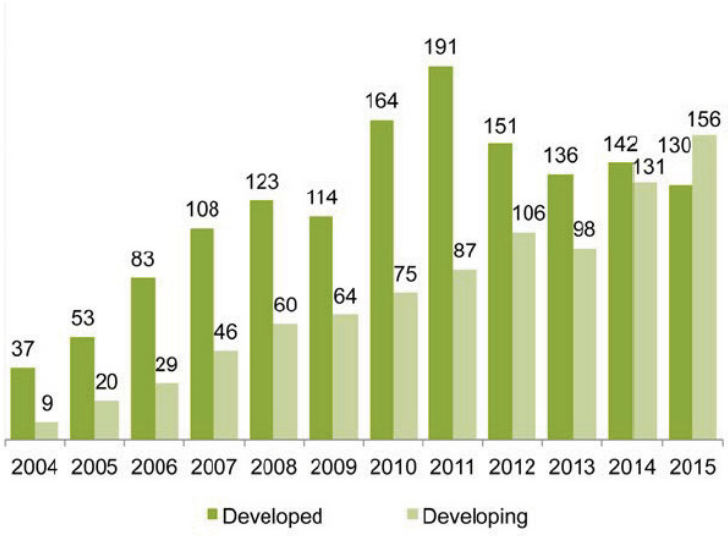
Figure 2: Global New Investment in RE by Sector 2015, and Growth 2014, $BN



Source: *Global Trends in Renewable Energy Investment* 2016, p.15.

Another important input of the RE market indicated by figure 4, is the fact that 2015 brought more investment from DC than developed ones, that accounted for $156 billion dollars of the $286 billion dollars invested globally (*Global Trends in Renewable Energy Investment* 2016), demonstrating to the critics that renewable energy technologies are not a luxury, and can be affordable even for the poorest nations.

Figure 3: Global New Investment in RE of Developed vs Developing Countries, $BN



Source: *Global Trends in Renewable Energy Investment* 2016, p.15.

Recent advances, in technology, policies, and agreements made between nations, are raising the investment in RE.

Off-grid PV systems

IRENA estimates that by 2030 almost 60% of the new power generation capacity, for universal use, will come from off-grid installations. Among the rapid growth of off-grid installations, the solar powered lights have expanded quickly in recent years. Data from the *Off-Grid Solar Market Trends* report (2016) puts the cumulative global sales during the past five years exceeding 8 million units. The huge demand for access to modern lighting has been one of the drivers of this market, as well as the technological improvements and the reduction of manufactures costs.

Developments have occurred asymmetrically in different parts of the world. In the developed world, the U.S. position themselves as leaders on the off-grid market; although it is more a niche market (*Off-Grid Renewable Energy Systems: Status and Methodological Issues* 2015; *Global Trends in Renewable Energy Investment* 2016). In Europe, off-grid PV systems account for less than 1% of the installed PV systems capacity. In Africa, the leading markets are Kenya, Tanzania and Ethiopia, and are mostly related to lack of electrification.

The off-grid solar market is experiencing a rapid growth and evolution. The energy access challenge, encouraged by the Sustainable Development Goal #7, has discovered its place in the international stage. This international awareness created a growing trend of development partners that are pursuing to support this emerging industry. Creating a "pathway in sight to defeat the energy poverty that stunts economic development for much of the world, the development community is looking for ways to accelerate this promising trend" (*Off-Grid Solar Market Trends Report* 2016). The 1.2 billion people that live without access to electricity grid, rely on inefficient and often hazardous alternatives such as kerosene lamps, candles, battery-powered flashlights and car batteries[3]. These alternative sources of off-grid energy impose great risks for human health and are more expensive than grid-powered electrical machines in terms

[3] Source: *Off-Grid Solar Market Trends Report* 2016.

of cost per kWh. Estimates by the World Bank Group (WBG)[4] say that those people spent around $27 billion in 2014 on alternative energy sources (data from Africa and Asia). An opportunity is therefore present to the off-grid solar industry that offers better services at lower costs.

Among the different types of sources and technologies that deliver a green foot print, the focus of this dissertation is to understand the importance of one type of RE - Off-grid PV systems. Those deliver all the right features to be implemented in rural and isolated communities in developing countries (as explained in the following sub-chapter) – where a lack of access to electricity translates into a constraint for their development.

Figure 4: Types of Solar PV Systems

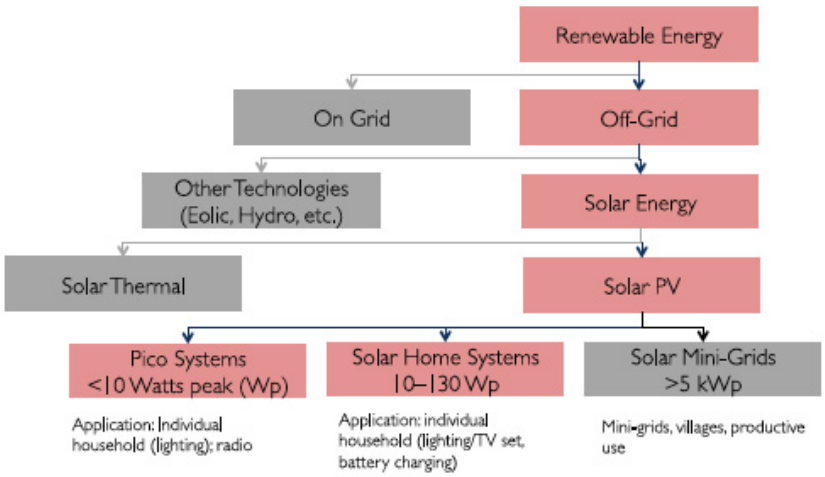


Figure 1. Types of solar PV systems. In this paper, the sustainability of off-grid PV systems is addressed.

Source: Board 2008.

In Figure 5, it is demonstrated how the division of renewable energy is made between grid and off-grid, and the different types of off-grid solar systems that exist, whose differences are related to diverse solutions regarding technology (Feron 2016), explained in Exhibit 4,5 and 6.

4 Source: https://www.gogla.org/sites/default/files/documenten/final_sales-and-impact-report_h22016_full_public.pdf

Off-grid PV systems in remote un-electrified regions

Off-grid RE generation technologies, such as solar, small hydro, geothermal and wind power are more reliable and cost-competitive than fossil fuel-based generation systems in rural and remote areas. Accessibility is therefore one of the most important features of off-grid systems; also, in most of these regions it would be unfeasible, in terms of costs, to extend the main grid. Additionally, the fact that these regions are concentrated in developing countries, where, for example, solar radiation reaches high levels, makes the investment in solar energy in developing economies "the vision of solar PV products as environmentally sustainable solutions that provide brighter, safer, and healthier lighting than traditional resources" (Stojanovski *et al.* 2017, p.33). The installation of off-grid systems, also allows basic electrification that is more reliable, cheaper, and quicker than the national grids or diesel generators.

Mandelli *et al.* (2016) enumerates several features why off-grid systems are so suitable for these rural regions of the planet, dividing them into five dimensions: environmental, economic, technical, political and social (Annexe 7).

Developments

Stand-alone off-grid PV systems can cover from single households to public or commercial buildings, and are user-friendly and cost-effective solutions (Rolland 2011). It affects the environment by reducing the use of dry-cell batteries or diesel generators that run appliances, and replace the usual traditional biomass and kerosene lights that contribute for diverse risk factors such as environmental pollutions and health problems besides the economic and social benefits that such system deliver to the communities.

Solar home system (SHS) are an icon of stand-alone systems, and are already 30 years old, being the most well-known and installed RE system in the world. The photovoltaic industry has been investing in developing new solutions and improving components, such as LED lamps, storage and self-adaptable charges. Regarding energy storage, one important improvement that can be highlighted in the increase of the batteries storage capacity, adjustable both to solar and wind projects, as well as to small-scale PV systems (*Global Trends in Renewable Energy Investment* 2016). Improvements in battery chemistry and manufacturing processes led to more competitive prices, that had a great impact in 2015, and were boosted by the development of lithium-batteries for the electrical vehicles industry. Also, an entrepreneurial effort has been accomplished on the progress of sustainability as a way of development and, therefore,

investments are being made in creating economies of scale as factories get bigger (Exhibit 8,9 and 10).

The systems small investment costs and widely dissemination (also helped by those small costs) allowed the development of real market approaches that do not depend on subsidies – such as Off-Grid Electric.

Challenges

Costs and storage continue being the biggest challenge for RE, although recent improvements (described above) are occurring. In 2015, the R&D investment stayed stable at $9.1 billion dollars (*Global Trends in Renewable Energy Investment* 2016), even with the falling fossil fuel prices. Regarding policies, a change from subsidies to auctions shown a decrease in prices.

Still, this type of projects face challenging financial obstacles that cannot be addressed by current market mechanisms: high initial costs, limited local financial resources and low return rates (Shi *et al.* 2016). Also, the low-income residents may not be able to afford electricity fees and fail to understand or respect the financing agreements and schemes – representing high potential risks to investors. Those communities may underestimate the benefits and, therefore, their willingness to pay is smaller. This poverty-affordability deadlock cannot be tackled without external interventions (Shi *et al.* 2016) - policy intervention and government support are necessary for further development of these projects. Constant innovations in the field of technology and the rise of production - so that prices are competitive - are essential for the sustainable development of such systems.

Also, plants of mini-grid PV systems, that are autonomous from the grid connections, still face some challenges regarding the response to load demand. Those types of systems do not deliver the regular supply immediately compatible to users' needs.

Innovation is another challenge posed to RE. There are two ways in which innovation can boost competitiveness of RE technologies – decreasing their capital cost or increasing their efficiency (*Global Trends in Renewable Energy Investment* 2016).

Off-Grid Solar Enterprises

In DC, Off-Grid enterprises display different features from the ones in developed countries. In this sub-chapter, it is presented an analysis of the main characteristics of the off-grid solar market in developing countries – considering the market itself and the extra challenges presented by their location in DC.

The importance of knowing the markets where the enterprises operate is essential for the development and implementation of a self-sustainable and replicable business model that would originate a successful enterprise. Outlining a business model is also one of the major challenges that the off-grid lightning market faces in DC.

Markets

In order to understand the relevance of drawing new strategies and business models for the establishment and growth of the off-grid solar market in DC, it is important to recognize their particular characteristics.

First of all, it is indispensable to distinguish the two existing markets - the off-grid solar and the base of the pyramid markets (Scott 2017).

As mention above, due to the high costs of extending the electric grid across rural areas of DC, the off-grid solar market turned out to be essential for those populations to have access to energy. As stated by Scott (2017) the potential growth of the off-grid lightning market is expected to follow the tendencies of the cellular phone technologies. In Africa, the subscription of mobile phones has increased 30% in the last ten years, demonstrating the potential of such technologies even for low-income populations.

On the other hand, the BOP markets, originally defined as “the 70% of the world’s population that lives on less than two dollars a day” (Scott 2017, p.51), and “lack of formal institutions and commercial entities” (Scott 2017, p.50), and it is believed that new business opportunities recline in designing and distributing goods and services to those poor areas. Due to the weak consumer purchasing power, it is necessary that unique and individualized strategies and business models are defined. Within this market, the most important challenges to be addressed are the institutions voids, that create gaps in manufacturing, distributing and marketing (Scott

2017). Although, BOPs' markets share common characteristics, there are some specific conditions of each market that should be taken into consideration by enterprises.

The characteristics of both two markets will influence the way entrepreneurs start and grow their businesses. Attention must be paid to the special characteristics of the market they are trying to access, and to do so, the challenges presented in the next sub-chapter should be addressed, so that innovative ideas emerge.

Business models

To overcome the challenges associated with facilitating the understanding of renewable energy transformation in general, it is vital for entrepreneurs to carefully develop their business model (Gabriel & Kirkwood 2016). "It is common to see great technological achievements fail commercially because little, if any, attention has been given to designing a business model to take them to market properly." (Teece 2010, p. 192; Ikejemba *et al.* 2017). Ikejemba *et al.* (2017) present examples of fail projects due to, specially, lack of sustainable management.

A business model follows the logic of value creation: it translates the way in which businesses designs and implements its added value and revenue generation efforts (Gabriel & Kirkwood 2016).

When considering these two markets, there are a few characteristics that are common and very important – community interaction, partnerships, and local capacity building (Scott 2017).

Community interaction

Community interaction is needed because it allows enterprises to gain local trust and political goodwill. Entrepreneurs should have knowledge of the culture, social issues and economic systems of BOP markets. Understanding the community norms and institutions will be an advantage for the companies in interacting, participating and partnering with local rural communities.

Partnership

Owing the institutional voids that are characteristic of BOP markets – manufacturing, distributing and marketing – it is important the creation of cross-sector partnerships. Either with multinational corporations, social enterprises or NGO's. Through these partnerships, firms have

the prospect of "leverage the strengths, including non-market actors, to gain efficiencies or to fill institutional voids (Scott 2017, p.52).

Glasbergen (2007, p.52) states the importance of a tri-sector partnership for firms by joining "the moral authority of NGO's, the market principles of businesses, and the public authority of the state".

Local Capacity Building

Scott (2017, p.53) defines local capacity building as "the sharing of capacity and resources outside the boundaries of the firm to enhance local skills and resources and fill institutional voids". The concept is multifaceted due to the different ways of envisaging local capacity building. Three different heights arise for the entrepreneur: firstly, the lack of distribution network, inherent to BOP markets, may be a concern to the future establishment and growth of the enterprise; Secondly, the nature of rural areas – isolated, populations usually have lack of knowledge regarding solar products and have little or no experience with technology; and lastly, it needs to exist capacity to provide the service and repair products, which means that an after-sale assistance should be developed and maintained.

To overcome such challenges, one of the approaches that is recommended by the literature on BOP markets, is to treat the populations of those rural regions as consumers and producers.

Barriers specific to BOP off-grid solar appliances market

As mentioned above, it is important for enterprises to consider the appropriate pricing system. However, it should also be deliberated how to support consumers in making the initial purchase. These types of problems are not address in developed nations because firms let the financing of the purchase to other institutions. Owing to the informal economy of BOP markets, it is necessary to have a functional strategy to make solar lighting products attractive to families, enabling them to take the risk and do the up-front investment. Different methods to overcome this barrier are used by entrepreneurs – microfinance[5], traditional government subsidies, installment payments, or new innovative models such as pay-as-you-go[6].

[5] Allow low-income individuals to obtain financial support, offering the opportunity for them to become self-sufficient.

[6] "It allows the end-user to pay for the systems in affordable instalments, and it incorporates a technology-enable mechanism to disable the system if a payment is overdue". (*Off-Grid Solar Market Trends Report 2016*, p.26)

Another barrier for the establishment of off-grid lightning enterprises is linked to the lack of knowledge of the populations. Therefore, it is important that enterprises include in their business model a strategy that outlines how to educate local communities about solar products, and to build a relationship of trust in the reliability, quality and effectiveness of the product. Most of the firms do not take into consideration the creation of such relationship because they are not always connected to a direct increase of sales (Scott 2017; Teece 2010; Glasbergen 2007). Enterprises that want to succeed usually use word of mouth, door-to-door campaigns, and product trials to get closer to consumers.

The last barrier concerns the development of a strong distribution network. Off-grid lighting products need technical expertise; such as installation, and maintenance and repair. For that, it is necessary for the sustainability of the establishment and growth of such enterprises to employ different distribution networks. That can be achieved through the training of local entrepreneurs to operate as distributors and marketers, and to install or repair equipment. The use of local entrepreneurs helps, not only in the distribution network, but also the community interaction and the building of local capacity.

All the barriers enumerated above are interconnected. Business models should be approached as holistic (Gabriel & Kirkwood 2016). A concept used by social and human sciences to describe an integral comprehension of phenomes and, not an isolated analysis of their constituents. By integrating all the different factors of both markets that influence off-grid lightning enterprises, it is possible to construct strategies and business models that can adapt to the characteristics of these markets, and therefore contribute to the sustainable development of such enterprises.

Development of new approaches to partnerships

"The issues we face are so big and the targets are so challenging that cannot do it alone. When you look at the issue, such as food poverty or water scarcity, it is very clear that no individual institutions, government or company, can provide the solutions." (Paul Polman, CEO, Unilever). So, if no individual, government or company can provide solutions to some type of problems, such as the lack of electricity access, it is necessary collaboration between different types of organizations (Gray & Stites 2013). This interaction will produce unimaginable solutions and is the key to unravel sustainability. Collaborations, or partnerships, are therefore influenced by the definition of sustainability. Each company will therefore outline their own

vision of sustainability that will influence how they define their orientation for problems and their motivations for such partnership (Gray & Stites 2013). That explains the difficulties to find common ground.

Public-private partnerships have been developed to eliminate problems with conventional approaches that rely on one of the sectors. The concept has been redefined and some innovative approaches have emerged – as pro-poor public-private partnership (Chaurey *et al.* 2016; Scott 2017). As Chaurey *et al.* (2016, p.50) states 5P's "increases access of the poor to basic services by promoting inclusive partnerships between local government, business, community groups, NGO's, Faith Based Organizations and others.".

Access sustainability in off-grid PV systems projects

One definition of sustainability *"stresses the importance of bringing industrial systems into harmony with nature by balancing use and regeneration of resources and striving to preserve the lives of humans, other species and future generations."*

Collaborating for systematic change.

Access to electricity is essential for the growth of economies helping them to meet their basic needs – efficient lightning, heating, cooking, mechanical power, transport and telecommunications services. Therefore, in DC, if investments are made in bigger systems, like the SHS, which supplies more power, advantages can go beyond the basic needs and provide economic welfare through productivity increases – replacing manual work by automated processes, which consequently, leads to a positive virtuous growth cycle.

As supported by the UN, Sustainable Development is not possible without Sustainable Energy.

Development Theory

The Development Theory is a cluster of research and theories on economic and political development[7]. These theories try to define the best way to achieve change in society. This concept appeared in the 1940's in the U.S. Recent developments include the Human Developing Theory, the Sustainable Theory and the Post-Development Theory.

Nevertheless, the Sustainable Theory in the one going to be addressed to analyze the PV systems in rural regions of DC.

Sustainability

Sustainability has been defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Frame *et al.* 2011; Gladwin et al. 1995). Or as in Hong et al. (2015), sustainable development can be translated into the capacity of a specific system to deliver output at an equal or greater level than the historical average.

So, if off-grid projects do have the necessary capacity to deliver at an equal or greater levels than the grid electric systems do, and do meet the needs of the present by reducing the lack of access to electricity; the future is not compromised due to the use of solar energy in the electrification of these regions. Thus, it is possible to understand that this type of systems do seem sustainable; however, for the success and life-long of the project, other dimensions need to be address.

Sustainable Off-Grid PV Systems Development – Dimensions

Indicators of sustainability are complex: different authors divide sustainability of projects into different dimensions. According to Kumar *et al.* (2016) and Frame *et al.* (2011) sustainability can be divided into five dimensions – environmental, institutional, economic, technical and social. A slightly distinctive perspective to the dimensions is given by Feron (2016), who just considerers four dimensions, excluding the technical. Due to the high importance of the technical dimension, the approach taken will considerer the five dimensions of sustainability.

[7] https://www.britannica.com/topic/development-theory

→ Institutional Sustainability

Institutions draw a framework that formulates the rules for interactions between human beings. To assess the dimension five different indicators are going to be used – stability and long-term visions, regulation, standards and enforcement, decentralization, expert know-how, and adaptability (Feron 2016).

The first - stability - indicator has great importance due to the political environment in DC. Stability, is normal in developed countries, where a joint force is put into the different types of regulations and supports the development of certain ideas/projects. However, in the majority of DC there is no political stability and so more constraints to this type of projects are present. Stability is needed in the formal institutions[8]. Disruptive changes of institutions, such as constant changes in the constitution, elimination or creation of ministries and changing regulation, influence stability. Several examples of failed projects due to the lack of stability are offered in Feron (2016).

Connecting stability to the second indicator - regulation, standards and enforcement - is natural. Stability is obtained by a clear delineated path of regulations and standards, that are enforced. However, the characteristics of the countries need the informal institutions [9] for a proper enforcement of regulation and standards. In DC, although not permitted by law, corruption, for e.g., is widely accepted due to norms and attitudes of society (Feron, 2016).

The next indicator, decentralization, is also very important. As stated by Feron (2016) most of the times it is better to have decentralized institutions rather than centralized. "Decentralized is meant to facilitate decision-making, thus enhancing the chances of a technology to meet the needs of the populations" (Feron, 2016, p.6). These local participations are more effective because local users identify best what they need, instead of creating misalignments between institutions. Therefore, the existence of an agency aimed at rural electrification has proved to be positive.

[8] "Refer to laws and regulations that have been legally enacted by actors and that determine the political, economic and enforcement system" (Feron 2016, p.5).

[9] Are not legally enacted but were stablished is an evident place based on moral or religious value (Feron 2016).

Lastly, formal institutions need to be adaptable and understand the changing needs of the population. Having expert know-how[10] on technical features contributes enormously for the preparation of this institutions to the many challenges they can face.

→ Environmental Sustainability

The most important factor for environmental dimension is environmental awareness. As Feron (2016) states the civil society needs to be aware of environmental issues – norms, regulations, and general information about their benefits; therefore, environmental awareness is when human recognize how they impact the environment (Kollmuss *et al.* 2002). Education is crucial, although it is not present in rural regions of DC (Annexe 11). So, it is as necessary for institutions and economic agents to help changing. Feron (2016) gives some examples: institutions should provide policies (such as subsidies on RE) as well as provide proper infrastructures (such as recycling bins).

There is no doubt about the positive impact of PV systems in the environment (pollution reduction, climate change mitigation), nevertheless it also faces some possible negative impacts, that can be translated into challenges if properly addressed. This type o systems, if not accurately used, can harm the environment, for e.g. what to do with battery disposals and PV panels when they reach the end of their lives.

→ Economic Sustainability

Regarding the evaluation of economic sustainability, there are five important points that should be taken into consideration – cost-effectiveness, reliability, initial investment, operations and maintenance, and productive use.

Since financial resources are scarce, especially in DC, for electrical solutions to achieve sustainability they must be cost-effective comparing to other alternatives (Feron 2016). One way to create sustainability through cost-effectiveness is to have the right support from governments, for e.g. with subsidies, to make this type of projects more attractive for investment. However, in DC the bigger percentage of subsidies are allocated into conventional energy sources rather than in RE. An example mentioned in Mills (2014) is Nigeria, where the subsidies for social programs such as security, critical infrastructure, human capital development, and land and food security combined are lower than the kerosene subsidies.

[10] That it is obtained through the investment in education such as universities.

"These policies favor unsuitable energy sources, neglecting the internationalization of external costs caused by environmental damages and, in turn, blocking cost-effective solutions" (Feron 2016, p.8). The initial investment costs of off-grid PV systems are high, whereas the operation and maintenance costs are lower compared to other off-grid solutions, such as diesel generators (Feron 2016). As shown by Rolland (2011), installing a SHS, the most common system, implies high investment costs that are not at reach for most of the users' income in DC (Annexe 12). Using schemes for financing this type of installments, such as microfinance, allows to give less importance to the price and focus on the quality of the systems. As Feron (2016) and Rolland (2011) stated, although sometimes low-income households are not willing to pay to have the system, there is no doubt that over the lifetime the investment will pay-off.

As mention in the chapter before, the operation and maintenance of such systems, particularly the specific components, are very important for their sustainability (Rolland 2011). Feron (2016) gives some examples, where the systems turned out to be unsustainable due to the lack of maintenance. Users' need to be aware and informed of how to maintain and manage such systems by trained professionals – reliability. Another common problem that face is the lack of spare parts for substitution, if needed (Feron 2016).

The productive use of such systems by households is a highly relevant for economic sustainability, and can be later translated into economic development. There is a correlation between energy consumption and income (Amri 2017). Fishbein (2008) puts together real examples of how these types of systems can be used in a productive manner, allowing income to grow in that community. For example, the e-commerce of digital local culture and handcrafts, artisan, rural industry, agriculture uses, solar water heaters and ovens, food processing, etc. However, economic development takes time to achieve. And, to do so, it is important to assist rural populations with education and training; which is easier with the support of the government.

→ Socio-Cultural Sustainability

Solar PV systems can very much improve to rural communities, both in terms of opportunities, living conditions, equality, development, health and education (Feron, 2016). However, they must be accurate in assessing the needs of the community, as a better understanding of their singularities and culture is essential to figure out the right approach for enterprises. Also

connected to accuracy, is social acceptance. Communities, and end users, need to understand the benefits of off-grid solar systems and how to operate and maintain them, eradicating abandonment among users.

→ Technical Sustainability

The last dimension to have in consideration is technical sustainability. When systems are implemented, their needs have to be assessed both in terms of demand for energy, peak load, average daily load, solar resource, daily autonomy, battery technology income and appliances (Frame 2011). The willingness of users to sustain the systems, by showing interest in understanding how the system works, is important for the technical life-long of the projects. Also, with a lot of non-brands entering the market, it is crucial that good publicity is done, so that households do not choose lower installment prices that do not last as much as the accredited ones – such as a global product quality certification system (Nygaard 2016).

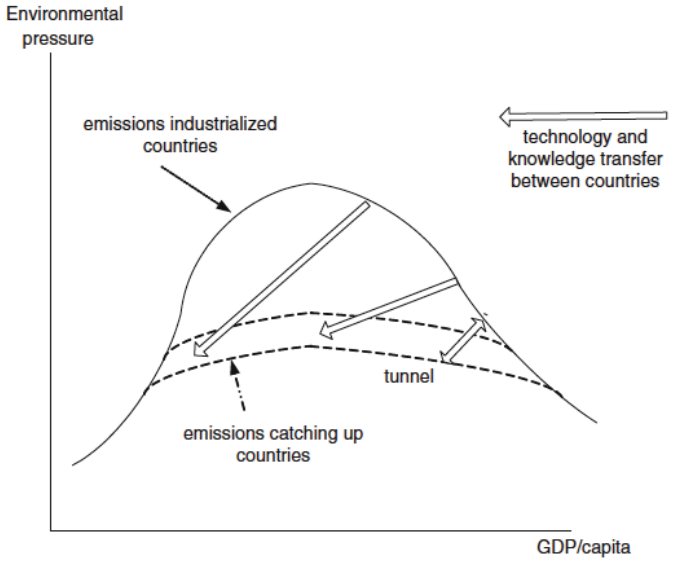
The complexity of such sustainable evaluation demonstrates, not just the major constraints to these projects, but also the major benefits that they can deliver. From the previous analysis, it is possible to understand that all the dimensions are interconnected. The role of policies and governments in the implementation and life-long of such projects is essential. However, and following Hong *et al.* (2015) a separation between the capacity of the system to be sustainable and the capacity of the user to sustain the system throughout time, most also be considered. Data collected across the world, illustrates how the willingness of users to sustain the off-grid solar PV system can display their success or failure (Hong *et al.* 2015).

Leapfrogging

Leapfrogging can be translated into small and incremental innovations that lead the dominant firm to stay in a place. The concept is frequently used for DC. And, can be directly applied to the recent improvements in solar PV systems in rural communities of developing nations. In DC leapfrogging appears in the context of sustainable development as a theory of development that may accelerate development by shipping inferior, less efficient, more expensive or more polluting technologies and industries to move directly to more advanced ones (Walz 2010). The concept of Environmental Kuznets curve (Figure 8) is based on the hypothesis that there are three stages of economic development: in the first stage, environmental pressure grows faster

than income; after a while, environmental pressure still increases but at slower rates than GDP; and after that, environmental pressure declines despite of the continuum income growth (Walz 2010).

Figure 5: Leapfrogging through the Environmental Kuznets Curve



Source: Walz 2010

Nowadays, an alternative exists regarding the way developed nations behaved. Leapfrogging, is therefore, that alternative, allowing DC to reach the peak of the Kuznelts curve at a much minor level of environmental pressure (Walz 2010; Szabó *et al.* 2013).

The challenge that the lack of electricity rates pose to DC, such as African countries, followed the same approach in the last 20 years. To eliminate poverty, they tried traditional approaches such as installing large size power plants and extending the grid (Szabó *et al.* 2013). However, with not much success in the eradication of poverty. In the last couple of years, different approaches have been taking place– sustainability approaches. Continents, like Africa, have great potential in terms of renewable energies; "which could be use in an environmental-friendly way to meet Africa's energy demands several times over" (Szabó *et al.* 2013, p. 501). Although, it is irrefutable the great potential that DC have in terms of renewable energy technologies, it was not a recent discovery. What is changing is the type of innovation connected to RE industry, that is creating a leapfrogging to flexible technologies such as the implementation of decentralized systems in rural areas.

The case of Tanzania

Country profile

Tanzania is an African country with a population of 52.5 million people[11] – the largest in East Africa and the one with the lowest population density (Exhibit 1, 2 and 3). However, its population is rapidly growing, with two-thirds of it being under 25 years old[12] (Exhibit 3).

Tanzania is one of the poorest economies in the world, having one of the lowest per capita income, although having recently reached high growth rates that can be the result of its vast natural resources wealth and tourisms. Between 2009 and 2016, its GDP reached an impressive growth of 6-7% per year[13]. Tanzania has also already accomplished a transaction to a market economy[14], even though the government still owns some telecommunication, banks, mining and energy companies[15].

The economy of the country is mainly based on agriculture, which accounts for one-quarter of its GDP (Exhibit 5). And although the productivity is irregular and low, due to the dependence on rainfall and backward technology, the sector employees 80% of the workforce[16]. Other sectors also have low productivity levels, owing to ineffective mobilization of resources to promote development. An economy which is mainly based in primary production, with no investment in technology, industry and services, makes itself more vulnerable to international market changes and new technologies that use less raw materials. As stated by *Tanzania development vision 2015* (p.10) "development has generally been characterized by a low level of mobilization of domestic natural, human and financial resources to produce wealth and to raise the standards of living of the people".

[11] Data from 2016 estimations by CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html
[12] CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html
[13] Estimations by CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html
[14] Economic system where economic decisions and pricing of goods and services are guided by the aggregate interaction of individuals and business, and there is little government intervention. http://www.investopedia.com/terms/m/marketeconomy.asp
[15] Such as TANESCO – Tanzania Electric Supply Company, totally owned by the government. 59% of the total capacity is supplied by the company; CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html
[16] CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html
[16] Estimations by CIA, https://www.cia.gov/library/publications/the-world-factbook

Energy and RE profile

The energy sector in Tanzania is characterized by its dependency on biomass for domestic uses and low electricity access rates (Exhibit 6). Household consumption relies mostly on biomass fuels - such as wood and charcoal that account for 90% of the total energy use. Data from the IEA (2016) (Exhibit 7) indicates that, in 2014, there were 36 million people living without access to electricity in Tanzania, which means that only 30% of the total population of the country had access to electricity. It also shows that in rural areas of Tanzania the access to electricity only reaches 18% of the rural population. In 2013, the same figure accounted for only 4% of the rural population (Exhibit 8). The boost in electricity consumption is affected by both the fast-growing population, as well as the liberalization of the energy sector. The contribution of the private sector is increasing, and the domestic energy, in rural areas, is being served by NGO's that operate with stand-alone systems. Therefore, the number of connections has been increasing, with escalations of around 7.5% on a yearly basis[17].

The country has a diverse range of RE resources that are not fully exploited, such as hydropower, geothermal, solar, and wind. The main contributor for electricity generation is hydropower, although this industry has been subjected to some challenges, in the last years, due to climate changes. Excluding hydro, other RE account for 4.9% [18] of the generation capacity.

The main constraints of the development of RE are institutional, regulatory and legal, knowledge and capacity, and economic and financial (Renewable Energy in Africa: Tanzania country profile 2015). Exhibit 9 and 10 resume the main challenges and achievements of RE in Tanzania.

Policies

As a response to the growing concern around the world, with the problems of lack of electricity (for e.g. UN Sustainable Development Goals) and the perception from the government of

[17] "Empowering Tanzania: Energy for growth and sustainable development", 2016, report, European Union Delegation to Tanzania and the East African Community.

[18] Estimation by Renewable Energy in Africa: Tanzania Country Profile, 2015, Africa Development Bank Group, www.afdb.org

Tanzania that the policies and strategies being used in the country were not responding to the changing market and technological conditions, the country developed different measures. It adopted long-term strategies that aim to boost the country out of poverty and meet the needs of a fast-growing population. The government designed the New National Development Vision, that aims to "guide economic and social development efforts up to the year 2025"[19]. It is based on five main attributes: high quality livelihood; peace, stability and unity; good governance; a well-educated and learning society; and a competitive economy capable of producing sustainable growth and shared benefits.

To attain these development goals by 2025, the government needs to increase the access to electricity rates – in rural and urban areas. To do so, it expects to connect to the grid all the areas that are within 10km from the main grid connection and that have at least 500 inhabitants[20]. The electricity supply industry strategy in Tanzania anticipates a restructuring of the power utility and a progressive separation of the generation, transmission and distribution segments into separate companies - a job that it undertaken by TANESCO; therefore, boosting competition, which will increase performance and governance to allow a sustainable socio-economic transformation, secured with the participation of the private sector.

However, the government believes that mini-grids and off-grid solutions are more cost-effective to operate half of the rural population[21]. Also, the country is presently part of a pilot program to scale-up RE in low-income countries – that is in line with the strategy of the government and supported by the African Development Bank (AfDB) and the World Bank Group. Additionally, Rural Energy Agency (REA) grants support to mini-grid and stand-alone systems, in collaboration with the innovative Lighting Rural Tanzania project and are working together on the Tanzania Energy Development and Access Project that aims to foster off-grid projects.

[19] Tanzania development vision 2025.

[20] *Empowering Tanzania: Energy for growth and sustainable development* 2016.

[21] *Renewable Energy in Africa: Tanzania Country Profile* 2015.

Example – Off-Grid Electric

Off-Grid Electric is a Tanzania-based company that provides solar services. It was founded in 2011 by three entrepreneurs with diverse backgrounds – Xavier Helgesen (CEO), Erica Mackey (COO) and Joshua Pierce (CTO). Although the company registers and manages sales though Tanzania, it is in the Seychelles that is managed the investment, as well as hardware and software development.

The shared vision[22] of three entrepreneurs was to make solar energy accessible and affordable to everyone - by making it a mass market option instead of a niche product. Knowing the different constraints of such type of enterprises in rural areas of DC – as the initial costs and aftersales services, among others; the business was constructed through innovation. The founders believed in audacious ideas, such as investments in hardware, software, distribution and financing, by creating an innovative business model.

The company offers SHS, that includes the hardware to generate solar energy – solar panel, storage and wires, and the related energy using products. The energy is provided through three different types of services: the entry-level, the second level, and the third level. The first level, provides two LED lights and a phone charger for eight hours per day, further appliances can be added at an additional cost. The second level offers six lights, two phone charges and a radio. The third level, field-tested in 2014 and implemented in 2015, powers also a TV.

Business model and Strategies

Off-Grid Electric offers, to low middle-income consumers in rural Tanzania, SHS based on innovative Business to Customer offer - customer-led business model that focus on the needs and not on the products.

How is it an innovative business customer offer?

Different features among business models translate the focus on consumer needs, rather than on the product itself. Those features include a range of different strategies that focus on specific characteristics of rural communities in DC.

[22] http://offgrid-electric.com/

→ Know your customer

Off-Grid Electric believes that it is important to know the client. Through their database of clients, it is possible to observe that it seems to exist differences in lifestyle and aspiration choices between them. The most important point that differentiates consumers is the individual finances; there is and income bell-curve which assures there will not be one solution for everyone. Therefore, a range of price points and offerings is made available by the company. By offering different prices and different levels of service, that try to match the different characteristics of consumers, it allows to reduce the perception of risk among the future customers.

→ Affordability

Since the company operates in low middle-income contexts in DC, affordability is an important characteristic that should be taken into consideration. The perspective costumers are those who live in the base of the pyramid, which means with less than 2 dollars per day. Therefeore, the different ranges of offers aim not just to adapt to customers' needs, but also to improve affordability of the communities. Off-Grid Electric asks for a deposit of US$6 for the installation of a self-sustaining solar systems including solar panels, lithium batteries, LED lights, and a meter. For the customers to use the energy produced and storaged in the system, they send the company a mobile phone payment and in return receive a passcode they can enter the meter to unlock it and use energy. The daily fee to unlock the systems goes from US$0.18 to US$0.63, depending on the level of service chosen. For about US$5 to US$10, which is less or equal to the values spent on kerosene, households can afford greater power and duration of light, and the possibility to charge a phone or power a television. Therefore, families can access technology, that otherwise, would not be able to afford, by being able to use micropayments or pay-as-you-go strategies. The minimum payment is for one day; however, customers have flexibility and if no payment is done, the energy access is disable but no penalty is charged. Therefore, flexibility and adaptability of the business model to customers' needs allows families with no reliable income, or that earn seasonal income, to manage their payments as best suitable.

→ Mobile Money

Off-Grid Electric covers all transfer charges to the mobile money provider, so there is no penalty for those who make small top-up payments, giving total freedom for families to manage their income, without any pressure of incurring into debt.

For those who do not have access to a mobile phone (which is common in Tanzania), the company offers the possibility of payment in their mobile money kiosks, or even, for those that do not have easy access, can give the money to their agent who then makes the payment for them.

→ Retained ownership of SHS and EUP's

Off-Grid Electric retains ownership of SHS and EUP's which cuts the initial investment and maintenance costs for the consumer. Once more, the costs for customers, and the attention to affordability, are the focus of the business model of the company.

→ Trainings for a network of local dealers for installation and customer support: personal contact with customers is better than surveys

Another important feature of the Off-Grid Electric business model is the importance of the involvement of the communities where the systems are being installed, in all the process of the company. One of the principles defended by them is that the personal contact through visits to homes is more efficient than any survey. Therefore, the organization also dedicates it's time to the creation of a training network of local dealers for installation and customer support. For e.g., the company has already invested in the Off-Grid Academy, for technical training of local dealers. This allows them to focus on customer care, that is not as usual but is very much appreciated and a great advantage to the company and its success. However, training local people to be the agents of the company allows to foster local empowerment and employment. The importance of the involvement of the communities with the project is also one of the major benefits of the framework constructed so that the systems can be sustainable in the long-run.

As a result, Off-Grid Electric focus on local capacity building by incorporating local communities as both producers and consumers. The company is vertically integrated, which means that does not outsource any part of its operations and internally manages and delivers every aspect of its service. The systems are designed in partnership with Fosera, a German solar company, manufactured in Thailand and branded M-Power. The distribution and installation is also made by the company, allowing a faster development and growth of the enterprise, and impact among social, environmental and economic development.

Empowerment and Employment

Off-Grid Electric has a strong focus on developing staff talent. The conditions offered by the company include benefits, hot meals and transportation, when needed. The salary starts at the same as earned by teachers, and there are good prospects of promotion if employers perform well. The number of opportunities that emmerged with the appearance of new regional offices allow an increasing number of opportunities for more experience workers. Off-Grid Electric works on the bases of bonus, therefore being able to promote good customer service and efficiency.

In accordance with many of the energy access projects, the company works through agent-based sales. However, Off-Grid goes a step beyond and also focus on professionalize the role of local-agents with training, equipment, and permanent support. To assure that the customer is well recruited and supported, the company needs to be sure that their employees are exceeding expectations when dealing with the final consumer. So, commissions are earned by employees when new customers are recruited and when the ongoing service provided is good. This fosters the commitment of the sales agent to the company, and throughout the life of the project.

Also, the empowerment of populations is a dimension where the company is having a major impact. It is important for them to offer good customer service, so that their database of clients grows and the sustainability of installations is met. However, when training the employees at a local level, the company acknowledges the importance of empowering the population, if it is well practiced it will help the sustainable development of those populations.

Software and Value of data

Alongside with the vertically integrated structure of the company, there is a very important component that was developed internally and is one of the most important innovative features of the stability of the project – customer relationship management system (CRM), with a mobile enable software platform. The name of the software if SURGE, its functions are to collect data, connect all processes of the company and being the backbone of its operations. In 2014, Off-Grid spent 2:1 on software versus hardware, which is a way of expanding to other geographies.

With SURGE, the company can collect the customer's payments history, demographic information, and exact GPS coordinators.

Although it is recognized the importance of surveys in collecting data on the satisfaction of consumers, the company acknowledges that the one-to-one relationship with customers allows the identification of issues, that the survey would not approach, and to further aggregate them to then work the data.

Yet, the information collected by the software, regarding customer's usage profiles, puts OGE in a strong position to use this data to optimize their operations and performance. Although it is not an easy task, companies need to know what to look for, so that afterwards action in defined to tackle the issue.

Partnerships

Partnerships are important to the scalability and sustainable success of OGE. The company has different partnerships that aim for different benefits among that interactions. A division in five different types of partnerships is going to be adopted, and described below.

→ Mobile money partnerships

As mention above, Off-Grid uses mobile money as a payment method. At the start of the company, M-Pesa was the mobile platform used for customers' payments. This platform belonged to Vodacom Tanzania, an OGE partner. Other alliances were made, as the integration with Airtel for the use of its mobile money offering.

For OGE, such partnership is important, to make the service economically attractive. The company structured a business model that was adaptable to the different needs of consumers, which in Tanzania are very diverse. Therefore, customers' payments tend to occur in small amount, being in the best interest of the company, to be able to pay minimal charges for businesses. For that objective, Off-Grid spent nine months negotiating to reach an agreement on the adjusted rates. So, mobile money platforms provided the payments structure, functionality and accessibility to OFE. On the other hand, OGE could drive mobile money usage and adoption. The company claims to have created a large-scale acceptancy among communities that it serves, driving many people to use mobile money for the first time.

→Technology partnerships

Fosera Solar, a German engineering company, collaborates with OGE on product design and technology manufacturing. The choice of this partner was related to Fosera´s philosophy, which prioritizes durability and longevity on its products. Off-Grid withdraw value from this relationship with long-term, large scale corporate customers.

Off-Grid Electric also gives the opportunity to Fosera to be part of a philanthropic partnership[23]. Fosera, therefore, is charitable giving to human causes on large scale by producing adaptable SHS that are durable (in accordance to the different atmospheric conditions registered in Tanzania) and doing it at a fair price with the aim to sustainably development the communities where OGE offers its services.

→ Donors

OGE has a few donors - namely AECF, USAID, Finnish Government, Power Africa, OPIC, EEP and IFC - whose role is to seed funding to kick start can ultimately self-sustaining business model. The donors, on the other hand, can create a philanthropic sponsorship by advertising the organization through OGE. Donor support has been critical to put the service up to speed and running.

→ Customers

The relationship with customers is also considered a partnership, due to the nature of the business model put into place. The attention payed to the needs of consumers was translated into the business model through the value added by the service provided, which can be translated into the following impacts for the consumers: cost savings, longer light hours, brighter lights, and less pollution. Due to the nature of the business that the founders were trying to implement, the relationship between Off-Grid and the customers can be considered as a partnership. Through most of the strategies adopted by OGE, it is possible to see how the company is trying to transform this relationship into an exchange that seems to deliver the same conditions as a partnership would do. Not a partnership in the sense that profits and liabilities are shared, but where a commitment is maid, where both parties agree on deliver their part for

[23] Effort that an individual or organization undertakes based on an altruistic desire to improve human welfare; http://www.investopedia.com/terms/p/philanthropy.asp

it to work. Therefore, OGE asks for two thinks in return, revenue and feedback for service design and delivery.

→ Financial partnerships

Figure 6: Financial Partnerships of OGE

Date	Value	Investors	Type of Investment
2014	$7 million	Omidyar Network Solar City Vulcan Capital	Equity Financing
2014	$16 million	IFC Venture Capital Group Solar City Vulcan Capital Zouk Capital LLP	Equity Financing
2015	$7 million	The David and Lucile Packyard Foundation USAID	Debt Financing
2015	$25 million	DBL Investors Aster Capital	Equity Financing
2015	$45 million	International Financial Coorperation Cordiant Capital Ceniarth Calvert Foundation	Debt Financing
2016	$10 million	Helios Investment Partner	Equity Financing
2016	$8 million	responsAbility	Debt Financing

Source: https://www.crunchbase.com/organization/off-grid-electric#/entity

Recognitions and future opportunities/challenges

A way of recognizing the success of OGE and the innovation of its business model, is through the many approaches it received to use its platform or take it to another market.

In 2015, the focus of the company was the construction of the ideal service model instead of full expansion, always valuing the partners inside new markets that understand and operate in the local context. Today the focus of Off-Grid Electric is the upgrade of its software and the optimization of the hardware design and supply chain management, with more focus in continuous innovation and relationship with the existing customers, whilst allowing the company to scale quickly.

The customer is experience that reaches the consumer is excellent due to some indispensable factors, such as vertical integration, door-to-door sales and data analysis that can be used to innovate their hardware.

Figure 7: Off-Grid Electric Future Goals

12.000 customers in Rwanda by the end of 2016
150.000 customers in Tanzania
Possibility of geographical expansion to Eastern and Western Africa, engaging in partnerships like Total, EDF, Helios Investment
Expectations of operations growth to one or two additional countries by the end of 2016

Exhibits

Exhibit 1: Map of Tanzania

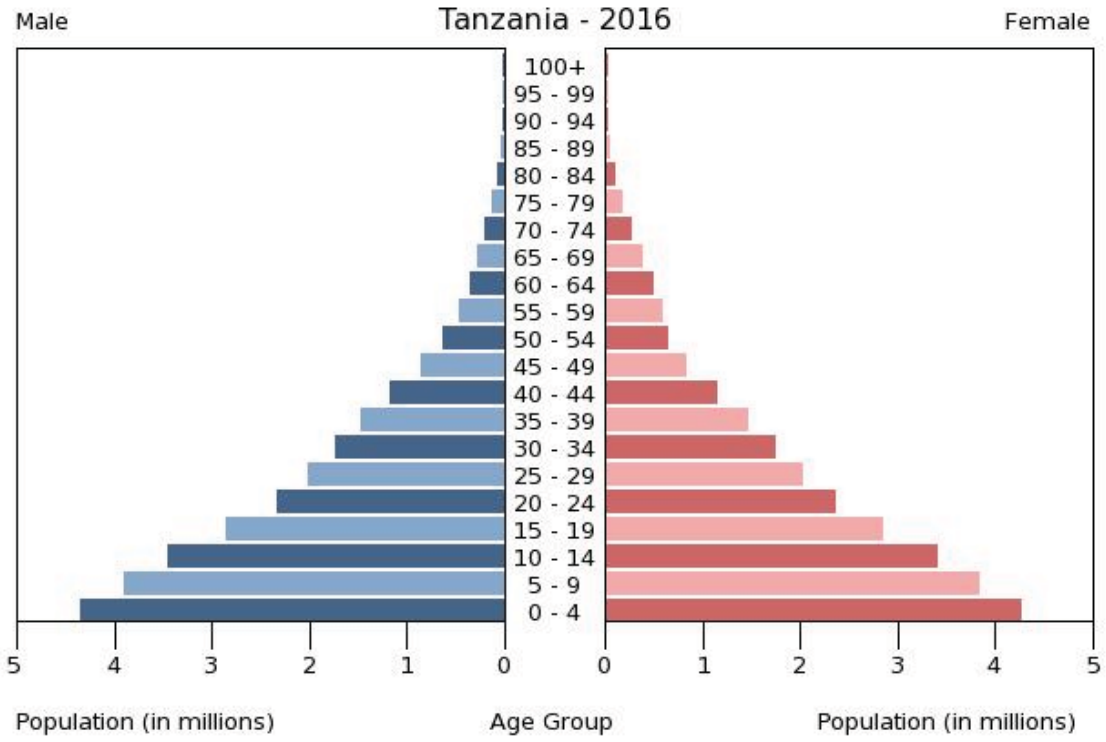
Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 2: Tanzania Geography

Location	Eastern Africa, bordering the Indian Ocean, and between Kenya and Mozambique
Area	947.300 sq km
Natural Resources	Hydropower, tin, phosphates, iron, ore, coal, diamonds, gemstones, gold, natural gas, nichel
Land use	Agriculture land 43.7% (arable land 14.3%; permanent crops 2.3%; permanent pasture 27.1%); Forest 37.3%; Ohter 19%.
Natural Hazards	Flooding on the central plateau during the rain season; and drought.
Environmental Issues	Soil degradation; deflorestation; desertification; destruction of coral reefs threatens main habitats; recent droughts affected marginal agriculture; wildlife threatened by illegal hunting and trade,
International Agreements	Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Wetlands.

Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 3: Tanzania Population Pyramid



Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 4: Tanzania Society

Population	52.5 million (2016 estmations)
Population Growth	2.77%
Urbaization	31.6 of total population (2015 estimations)
Major Urban Areas	Dar Es Salaam (capital) 5.116 million; Mwanza 838.000

Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 5: Tanzania Economy

GDP (per capita)	$3.100 (2016 estimation); $2.900 (2015 estimation)
GDP - composition, by sector of origin	Agriculture 25.1%; Industry 27.6%; Services 47.3% (2016
Agriculture - products	Coffe; sisal; tea; cotton; pyrethrum; cashew nuts; tabacco; cloves; corn; wheat; cassava; bananas; fruits; vegetables; cattle; sheep;
Industries	Agriculture processing (sugar, beer, cigarettes, sisal twine); mining (diamonds, gold, and iron); salt; soda ash; cement; oil refining; shoes; apparel; wood products; fertilizer.
Industrial production grwoth rate	6% (2016 estimation)
Labor force - by occupation	Agriculture 80%; Industry and Services 20% (2002 estimations)
Population below poverty line	67.9 % (2011 estimation)
Exports - commodities	Gold; coffee; cashew nuts; manufactures; cotton.
Exports - partners	India 21.8%; China 8.2%; Japan 5.1%; Kenya 4.6%; Belgium 4.3% (2015 estimations)
Imports - commodities	Consumer goods; machinery and transportation equipment; industrial raw materials; crude oil.
Imports - partners	China 35.2%; India 13.7%; South Africa 4.5%; UAE 4.4%; Kenya 4.1% (2015 estimations)
Exchange rates	Tanzanian shillings (TZS) per US dollar - 2.182 (2016 estimation)

Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 6: Tanzania Energy

Electricity - production	6.1 billion kWh (2014 estimation)
Electricity - cosumption	5 billion kWh 82014 estimation)
Electricy - exports	0 kWh
Electricity - imports	60 million kWh (2014 estimation)
Electricity - installed generating capacity	1.2 million kw (2014 estimation)
Electricity - from fossil fuels	33.5% of total installed capacity (2012 estimation)
Electricity - from hydroelectric plants	66.5% of total installed capacity (2012 estimation)
Electricity - from other renewable sources	

Source: CIA, https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Exhibit 7: Electricity Access in Africa 2014

Region	Population without electricity millions	National electrification rate %	Urban electrification rate %	Rural electrification rate %
Africa	**634**	**45%**	**71%**	**28%**
Sub-Saharan Africa	**632**	**35%**	**63%**	**19%**
Angola	*16*	*33%*	*69%*	*6%*
Benin	*7*	*29%*	*57%*	*9%*
Botswana	*1*	*53%*	*69%*	*32%*
Burkina Faso	*14*	*18%*	*58%*	*1%*
Burundi	*10*	*5%*	*28%*	*2%*
Cameroon	*9*	*62%*	*96%*	*23%*
Cabo Verde	*0*	*96%*	*100%*	*89%*
Central African Republic	*5*	*3%*	*5%*	*1%*
Chad	*13*	*4%*	*13%*	*1%*
Comoros	*0*	*69%*	*89%*	*62%*
Congo	*3*	*42%*	*56%*	*16%*
Côte d'Ivoire	*8*	*62%*	*88%*	*31%*
Democratic Republic of Congo	*62*	*18%*	*42%*	*0%*
Djibouti	*1*	*42%*	*54%*	*1%*
Equatorial Guinea	*0*	*66%*	*93%*	*48%*
Eritrea	*3*	*32%*	*86%*	*17%*
Ethiopia	*73*	*25%*	*85%*	*10%*
Gabon	*0*	*89%*	*97%*	*38%*
Gambia	*1*	*45%*	*66%*	*13%*
Ghana	*8*	*72%*	*91%*	*50%*
Guinea	*9*	*26%*	*53%*	*11%*
Guinea-Bissau	*1*	*21%*	*37%*	*6%*
Kenya	*36*	*20%*	*60%*	*7%*
Lesotho	*2*	*17%*	*43%*	*8%*
Liberia	*4*	*10%*	*8%*	*11%*
Madagascar	*21*	*13%*	*22%*	*8%*
Malawi	*15*	*12%*	*46%*	*5%*
Mali	*13*	*26%*	*53%*	*9%*
Mauritania	*3*	*29%*	*47%*	*2%*
Mauritius	*0*	*100%*	*100%*	*100%*
Mozambique	*16*	*40%*	*67%*	*27%*
Namibia	*2*	*32%*	*50%*	*17%*
Niger	*16*	*15%*	*62%*	*4%*
Nigeria	*98*	*45%*	*55%*	*36%*
Réunion	*0*	*99%*	*100%*	*87%*
Rwanda	*8*	*27%*	*72%*	*9%*
Sao Tome and Principe	*0*	*59%*	*70%*	*40%*
Senegal	*6*	*61%*	*88%*	*40%*
Seychelles	*0*	*98%*	*98%*	*98%*
Sierra Leone	*5*	*14%*	*33%*	*1%*
Somalia	*9*	*15%*	*33%*	*4%*
South Africa	*8*	*86%*	*87%*	*85%*
South Sudan	*12*	*1%*	*4%*	*0%*
Sudan	*24*	*40%*	*67%*	*26%*
Swaziland	*0*	*65%*	*84%*	*60%*
Tanzania	*36*	*30%*	*57%*	*18%*
Togo	*5*	*27%*	*35%*	*21%*
Uganda	*31*	*19%*	*52%*	*12%*
Zambia	*11*	*28%*	*62%*	*5%*
Zimbabwe	*7*	*52%*	*78%*	*40%*
North Africa	**1**	**99%**	**100%**	**99%**
Algeria	*0*	*100%*	*100%*	*100%*
Egypt	*1*	*99%*	*100%*	*99%*
Libya	*0*	*100%*	*100%*	*99%*
Morocco	*0*	*99%*	*100%*	*97%*
Tunisia	*0*	*100%*	*100%*	*100%*

Source: IEA, World Energy Outlook 2016

Exhibit 8: Electricity Access in Africa 2013

Region	Population without electricity millions	National electrification rate %	Urban electrification rate %	Rural electrification rate %
Africa	**635**	**43%**	**68%**	**26%**
Sub-Saharan Africa	**634**	**32%**	**59%**	**17%**
Angola	*15*	*30%*	*46%*	*18%*
Benin	*7*	*29%*	*57%*	*9%*
Botswana	*1*	*66%*	*75%*	*54%*
Burkina Faso	*14*	*17%*	*56%*	*1%*
Burundi	*10*	*5%*	*28%*	*2%*
Cameroon	*10*	*55%*	*88%*	*17%*
Cabo Verde	*0*	*94%*	*100%*	*84%*
Central African Republic	*5*	*3%*	*5%*	*1%*
Chad	*12*	*4%*	*14%*	*1%*
Comoros	*0*	*69%*	*89%*	*62%*
Congo	*3*	*42%*	*62%*	*5%*
Côte d'Ivoire	*15*	*26%*	*42%*	*8%*
Democratic Republic of Congo	*61*	*9%*	*19%*	*2%*
Djibouti	*0*	*50%*	*61%*	*14%*
Equatorial Guinea	*0*	*66%*	*93%*	*48%*
Eritrea	*4*	*32%*	*86%*	*17%*
Ethiopia	*71*	*24%*	*85%*	*10%*
Gabon	*0*	*89%*	*97%*	*38%*
Gambia	*1*	*36%*	*60%*	*2%*
Ghana	*7*	*72%*	*92%*	*50%*
Guinea	*9*	*26%*	*53%*	*11%*
Guinea-Bissau	*1*	*21%*	*37%*	*6%*
Kenya	*35*	*20%*	*60%*	*7%*
Lesotho	*2*	*17%*	*43%*	*8%*
Liberia	*4*	*10%*	*17%*	*3%*
Madagascar	*20*	*15%*	*37%*	*4%*
Malawi	*15*	*9%*	*32%*	*4%*
Mali	*11*	*26%*	*53%*	*9%*
Mauritania	*3*	*28%*	*47%*	*2%*
Mauritius	*0*	*100%*	*100%*	*100%*
Mozambique	*16*	*39%*	*66%*	*27%*
Namibia	*2*	*32%*	*50%*	*17%*
Niger	*15*	*15%*	*62%*	*4%*
Nigeria	*96*	*45%*	*55%*	*37%*
Réunion	*0*	*99%*	*100%*	*87%*
Rwanda	*9*	*21%*	*67%*	*5%*
Sao Tome and Principe	*0*	*59%*	*70%*	*40%*
Senegal	*6*	*55%*	*90%*	*28%*
Seychelles	*0*	*97%*	*97%*	*97%*
Sierra Leone	*6*	*5%*	*11%*	*1%*
Somalia	*9*	*15%*	*33%*	*4%*
South Africa	*8*	*85%*	*90%*	*77%*
South Sudan	*11*	*1%*	*4%*	*0%*
Sudan	*25*	*35%*	*63%*	*21%*
Swaziland	*1*	*27%*	*40%*	*24%*
Tanzania	*37*	*24%*	*71%*	*4%*
Togo	*5*	*27%*	*35%*	*21%*
Uganda	*32*	*15%*	*55%*	*7%*
Zambia	*11*	*26%*	*45%*	*14%*
Zimbabwe	*9*	*40%*	*80%*	*21%*
North Africa	**1**	**99%**	**100%**	**99%**
Algeria	*0*	*99%*	*100%*	*97%*
Egypt	*0*	*100%*	*100%*	*99%*
Libya	*0*	*100%*	*100%*	*99%*
Morocco	*0*	*99%*	*100%*	*97%*
Tunisia	*0*	*100%*	*100%*	*100%*

Source: IEA, World Energy Outlook 2015

Exhibit 9: Renewable Energy Challenges in Tanzania

Increasing electricty demand
Risks of disruption to generation and associated electricity prices shocks due to th increasing unpredictabiity of hydropower
Uncertainty of the credit worthiness of the utility
Low access to reliable energy
The vastness of the country coupled with low population density makes grid extensions too expensive for many difficult to reach areas
Health risks and environmental degradation from household reliance on biomass energy

Source: Renewable Energy in Africa: Tanzania Country Profile, 2015, Africa Development Bank Group, www.afdb.org

Exhibit 10: Renewable Energy Achievements in Tanzania

Policies, legislation and institutional framework	Underlying positve effect through attraction of the prive sector and strategic policies and institutions such as Energy and Water utilities authority act (2001 and 2006), National Energy Policy (2003), Rural Energy (2005), Electricity Act (2008), and
Private sector development partners	Independent power projets contribute to 40% of national grid´s effective generating capacity; various non-governamental organizations (NGO's)
Contribution of development partners	Joint energy sector working group
Environmental and social aspects	MEM and REA; ensure compliance with social and environmental safeguards.
Rural energy access expansion	Outcomes of the off-grid component of World Bank supported Tanzania Energy Development and Access project (TEDAP); REA grant support to mini-grid and stand-alone systems, and the innovative Lighting Rural Tanzania project will

Source: Renewable Energy in Africa: Tanzania Country Profile, 2015, Africa Development Bank Group, www.afdb.org

Teaching Notes

Learning Objectives

The Case of Tanzania – Off-Grid Electric case study can be discussed by management students interested in Strategy, Development, Innovation, Renewable Energy Sources and Technologies, Social Entrepreneurship and Social Innovation.

The authors' proposed learning objectives are mention below:

- Understand Tanzania context as a developing nation by foreseeing the main conditions that affect socio-economic development of the country;
- Comprehend how RE sources and technologies can create an impact in DC, particularly the stand-alone solar systems for rural areas of Tanzania;
- Realize how sustainability of off-grid PV systems in rural areas affect the business models by creating innovative business models and strategies that are adapted to the specific market conditions;
- Understand how partnerships can help to achieve sustainability;
- Recognize the potential of leapfrogging in developing countries;
- Build skills in the analysis of strategies in different conditions than the ones felt in developed nations, be aware of the different environment, and how constraints can be overcome through innovation;
- Comprehend major changes in the thoughts and actions of poor nations, and what can be the future of such nations.

Suggested Teaching Questions

The method of analysis suggested by the author is in the form of a classroom discussion. Therefore, the following teaching questions were design to support and endorse the learning objectives presented above.

TQ1 – Would you considerer Off-Grid Electric mission and core activities appropriated for Tanzania? Would you considerer the enterprise a successful example?

TQ2 – Do you considerer the business model designed by Off-Grid Electric an innovative? Do you think it is adapted to the necessities of the markets where the enterprise operates (BOP and stand-alone PV systems markets)?

TQ3 – What is the role of partnerships in the sustainability of stand-alone systems? How do the partnerships of Off-Grid Electric contribute to the strategy and sustainability of the enterprise?

TQ4 – What does the concept, of leapfrogging' stand for? How can it be applied to the case study? Provide further examples of such phenomenon.

TQ5 – How can the sustainability of stand-alone systems in Tanzania be assessed? Can they promote the socio-economic development of the country? (Open question).

Teaching Questions Discussion

Below the author suggests answers to each of the TQ. These answers are not exhaustive solutions, they are recommendations.

Suggested Answer TQ1: Regarding the first part of TQ1, the purpose is to access if OGE mission and core activities are sustainable for Tanzania. The first step for students is to understand the characteristics of the country – Tanzania. Then to examine the main characteristics of the enterprise presented in the case study. For the second part of the TQ, a deeper discussion may be engaged by the class. The concept of "success" may differ among the students, however the importance goes to understand OGE overall path and achievements.

- Tanzania has 52.5 million inhabitants and its population is growing fast. Through Exhibit 3 is possible to observe the age and gender distribution of the population, in 2016; more than two-thirds of its total population are under 25 years old, with a bit more density for man than women. With such a young and fast growing population, attention must be payed to education and job creation, to allow the young generation opportunities and a sustainable development.
- Tanzania is one of the poorest countries in the world and its government still has a great power over the country, although its economy already turned into a market economy,

which is growing fast (Exhibit 5). Their economy is principally based on Agriculture, and it is there that most part of the workforce is concentrated.

- The energy scenario in Tanzania is also very peculiar. The country has 36 million people living without access to electricity (Exhibit 6), which can be translated into a national electrification rate of a mere 30% of national electrification rate. Today, the lack of access to electricity is considered one of the Sustainable Development Goals by the UN, and if it is addressed, it can help create sustainable development. Furthermore, Tanzania is characterized by extreme low access to electricity among the rural regions of the country, where grid connections are too expensive to be installed. For years, measures to change that situation have been put into place without a great success in changing the situation. A look to Exhibit 7 helps to understand that the rate of electrification in rural areas of Tanzania only reaches 18%.
- As mentioned international attention is being given to such lack of energy and development in DC, and it is possible to observe the change in the behavior of the government, that in partnership with other institutions and organizations, is trying to address such issues. Different policies are being used by the government to boost RE uses and enhance electricity access to rural regions through different mechanisms than the grid connection.
- The mission of Off-Grid Electric is to provide solar energy accessible and affordable to everyone through delivering the best service possible of stand-alone solar systems. In order to do so, OGE focus on design, build, distribution, and monitoring while assuring that it is affordable for rural communities. Therefore, the NGO focus not just in providing the systems but also in maintaining and controlling the service that it is providing.
- As it is important to create sustainability, and so OGE is investing in local capacity building. One of the ways to achieve this purpose in by training local people on how to sustain the solar systems – the company believes that local communities can be treated as consumers and producers. With this, the company is achieving two purposes: assure that there is knowledge among populations to sustain their systems, and by creating training and job opportunities in Tanzania to its young population. Empowerment is also a major objective of OGE, to both their benefit and the community's.
- Therefore, it is possible to observe a match between the profile of the country and the OGE mission and main activities. The way the business was drawn seems to match the

major challenges the country is facing. By providing energy to rural locations that do not have access to the grid connection, they promote the elimination of harmful resources and make people less dependent of domestic activities. By paying attention to the status of the country, where populations do not have stable and high incomes, and at the same time empowering young women and man for a sustainable development. It can be said that Off-Grid Electric is a successful example, due to its high adaptability to the specific market challenges.

SWOT Analysis	
Strengths	**Weakenesses**
Addressing lack of electrcity in rural areas; Vertical integrated; Afforfability; High Adaptability; Empowerment; Local Capacity Building; CRM Software; Microcredit and Pay-as-you-go options.	External financing needed; Community relationship; Policies.
Opportunities	**Threats**
Growing database of customers in Tanzania; Geographical expansion; Private and Public Parnerships.	Less expensive imitation of solar systems gaining ground; Appropriate policies.

Suggested Answer TQ2: For TQ2 the starting point is to analyze the main characteristics of OGE business model, followed by a discussion of their innovative components through a deliberation on the definition of innovative strategies. Finally, the definition of the markets where OGE operates should be discussed, and confronted with the company business model to access the main strategies created to adapt the business to Tanzanian market characteristics.

- OGE business model adopted strategies that focus on the needs of the consumer, rather than on the product. Therefore, by using the Business Model of Canvas (Annexe 15) a guide for the main strategies adopted, the company gave great focus to the customer interface. In the following table are drawn the main characteristics of the business model of the enterprise.

Figure 8: Business Model Analysis

Infrastucture Management	Product	Custumer Interface
Vertically integrated structure SURGE software that works as a customer relationship management system by a mobile platform Technology Partners: Fosera Solar that cooperates in the design and technology manufacturing ↓ Value to OGE by Fosera philosophy that prioritizes durability and longevity Donors: AECF, USAID, Finnish Government, Power Africa, OPIC, EEP and IFC Customers faced as partners Financial Partners: equity investment from Soalr City, Vulcan Capital, among others	Solar energy accesible and affordable for low and middle-income communities in DC ↓ Problem solving: off-grid electricity access for those communities that their own characteristics are far away from the grid connections Different bundles are possible to chose from, depending on the specific needs of each household ↓ Three different levels, that differ in terms of number/types of appliances Also, the compant focus on innovation in design, build distribution and monotoring ↓ All considered the product that OGE offers	Customer segment: low and middle-income communities in isolated regions ↓ Turning a nich market product into a mass market Business model **focus on the consumer needs** rather than on the product Carefully manage the relationship with customers by following some strategies: Know you cusotmer Affordability (pay-as-you-go and microfinance) Mobile phone transfer charges are supported by the enterprise Diferent ways of executing payments adapt to the different Training: **users seen as consumers and producers** Channels: Door-to-door Use local work force to advertise and explain the main benefits to potential consumers Use local work force to to the installations and maintenance
Cost Structure	**Financial Aspects**	Revenue Streams
Value driven business model by focusing on the value creation rather than in the		Pricing: product feature dependent Usage fee

- Deliberate on the definition of innovative strategy, which occurs when a company uses strategies that incite advancements in technologies or services. Off-Grid Electric gives importance to audacious ideas, that can be investments on hardware, software, distribution and financing. Through the table above, it is possible to understand the innovative strategies that the company developed.
- Following Scott (2017) there are three main characteristics that are common to BOP and stand-alone systems markets, that should be addressed: community interaction, partnerships and local capacity building. Creating a relationship with the customer, to gain local trust and political goodwill, is important for enterprises that are establishing themselves in this type of markets. A good knowledge of culture and social issues, as well as economic systems is determinant for the successful implementation of the business. Due to the institutional voids in manufacturing, distributing and marketing that exist in BOP markets, it is necessary a strong cross-sector partnership in order to effective overcome those voids. Lastly, it is important to establish local capacity building to allow the sharing of capacity and resources outside the enterprise, filling institutional voids with better local skills and resources. Also, other characteristics that, also, should be considered are related to the off-grid solar systems markets: financing and distribution network. Due to the high cost of investment in the systems, appropriate mechanism should help households willing to take the initial investment risk, and subsequent fees. Comparing the information regarding the markets where OGE operates, it is understandable that the enterprise had in considerations all the factors mention above when designing its business model. If attention in payed to the table above, different examples of how they adjust their strategies are possible to encounter.

Suggested Answer TQ3: To answer TQ3 a discussion around the role of partnerships should be held, and afterwards attention should be given to specific partnerships made by Off-Grid Electric.

- Partnerships are useful for enterprises when they face complex issues where alone it is not possible to attain success. As Gray (2013) states, there is a need for cooperation between different kinds of organizations when facing problems as poverty, water scarcity or lack of electricity access. By cooperating, firms can reach unimaginable solutions for the challenges that they may face, specially on BOP markets.

- The important thing here is for students to peak some examples of partnerships and explain how do they create value for the enterprise. Some as examples are given, such as Fosera Solar, the technological partnership of OGE, that cooperates with the design and technology manufacturing. OGE gain value with this partnership due to the philosophy that Fosera follows: prioritizes durability and longevity. Whereas, Fosera created a philanthropic partnership.

Suggested Answer TQ4: Start defining leapfrogging, and then a connection is expected between solar stand-alone systems in DC. The discussion should be next oriented to acknowledge where, in the case study, it is possible to observe more examples of leapfrogging. Other examples are then asked, and in conclusion some drawbacks of this strategy can be addressed.

- Leapfrogging is defined by Walz (2010) as the use of more efficient, less expensive and less polluting technologies, skipping older technologies, to boost development.
- OGE operates in providing energy for isolated regions of Tanzania, through stand-alone solar systems. By leapfrogging from grid connection to solar energy supplied by off-grid systems the company is taking advantage of the technological innovations of the systems and implementing them in areas of a developing country where the costs to expand the grid connection would be too high. Therefore, and as discussed in TQ1, one of the reason for the lack of development of those regions is the lack of electricity; that affects not just the production and businesses but also consumes time needed to perform the basic needs of a household.
- Other examples of leapfrogging are possible to be found in the case study. Off-grid electric constructed their business model introducing a variety of leapfrogging strategies, other examples is the use of SURGE, the software that manages the customer relationship management system through a mobile platform. The company is thus using recent and innovative technologies to be able to provide the best service possible, having into consideration the conditions of the market where it operates (discussed in TQ2).
- Further discussion can focus on the innovative financing mechanisms used by OGE. Such as pay-as-you-go systems used to grant access to installation instead of more “traditional” approaches that were common before such type of payments structures.

Also, microfinance is a good example of a recent innovative financing mechanism that is also well suitable to BOP markets.

- Other examples of such phenomenon are the effects in DC countries of the mobile phone adoption. It skipped the fixed-line technology of the 20th century and progressed straight to the mobile technology of the 21st century.
- It is important to acknowledge that leapfrogging is not always possible to accomplish. Sometimes the mid-tech may be needed before jumping to more innovative and modern technologies.

Suggested Answer TQ5: The last question is an open question, where students should focus on the information given in the case study and their own knowledge to formulate an opinion on the future and possible impact of such project for developing countries. The purpose is to create a discussion where different points of view may be given regarding such innovative projects. Some examples are given in the table below.

Figure 9: Sustainability Assessment

Institutional	Environmental	Economic	Soicio-Cultural	Technical
Formal institutions are working to achieve stability through regulation and enforcement ↓ • Government 2025 vision; • Creation of descentralized institutions such as Rural Energy Agency or reducing TANESCO territory	Environmental awareness in the most important factor for thsi assessement	Cost-effectiveness and realibility are of major importance for OFE ↓ • Microfinance; • Partnerships with realible organizations, such as Fosera.		Training of local communties to perform the operations and maintenance
Informal instituions can help the enforcement of such regulations and help formal institutions to gain knowledge of the population needs ↓ • International agreements; • Growing number of informal institutions, since their role is being recognize as an advantage	OGE cares for the relationships with customers and communities where it operates, and invests in training and educating the communities on their benefits and maintenance of	OGE helps with the initial investment by supporting systems as Pay-as-you-go, which facilitates communities to take the risk on the insvetment OGE trains agents from local communties so that proper assistance is given	Focus by OGE on the relationship with consumers and communities	Focus on partnerships that deliver the values that OGE defends, such as Fosera for the desing and manufactor of the systems Investment in software as a way to better reach the needs of the
Although their have been improvements, stability of formal instituions is a major factor for the sustainability, and still faces some challenges	Collaboration between formal institutions is essential for OGE in creating environmental awareness	Assuring produtive uses are the most challenging feature, company could use partnerships to boost the economic development of such communities	OGE assures good envolvement with communities where it operates	OGE giver great importance to leapfrogging technology to reach sustainability

Conclusions, Limitations of the Study and Future Research

The case study emphasizes the importance of enterprises in rural regions of DC providing off-grid solar systems to reach sustainable development. The lack of electricity is a problem on developing nations, mainly in their rural regions, and it is vital to face such constraint to development. NGOs', like Off-Grid Electric, try to address these issues my providing affordable and accessible energy to these communities. However, the market conditions are far from similar to the ones in developed nations market. Therefore, for enterprises to be successful and able to boost development in these areas, they need to adapt and construct new strategies. If they do so, as Off-Grid Electric, it is possible nor just to make the enterprise a sustainable business, but also to empower communities and boost development. Nevertheless, the importance of government' policies and partnerships' is irrefutable, as the problem addressed is too complex for a single organization.

The change in behaviour needs to come from all of us. It is not enough that governments sign agreements. It is necessary that business, investors and cities understand that they also have a role in exercising a change in the behaviour - to a more sustainable one.

While writing this dissertation, some limitations to our study occurred. The major one is the lack of information and data gathered in developing countries. Although, governments and organizations are starting to create institutions to gather this data, most of the times there is no sharing among organizations, which difficult the analysis. Therefore, it is not easy to measure how particular strategies of OGE are impacting communities. For that, a field research is needed.

For future analysis, it would be interesting to study specific impacts that strategies are having on development. That can be done through data collecting in the field. Also, it would also be a good research to evaluate how this type of enterprises are stablishing themselves in different countries, and how they adapt their strategies.

In the long term, it would be noteworthy to study the impacts that the strategies are having in rural communities and the different technologies that are going to be introduce over time.

Annexes

Annexe 1: Electricity Access in 2014 - Regional Aggregates

Region	Population without electricity millions	Electrification rate %	Urban electrification rate %	Rural electrification rate %
Developing countries	**1 185**	**79%**	**92%**	**67%**
Africa	634	45%	71%	28%
North Africa	*1*	*99%*	*100%*	*99%*
Sub-Saharan Africa	*632*	*35%*	*63%*	*19%*
Developing Asia	512	86%	96%	79%
China	*0*	*100%*	*100%*	*100%*
India	*244*	*81%*	*96%*	*74%*
Latin America	22	95%	98%	85%
Middle East	18	92%	98%	78%
Transition economies & OECD	**1**	**100%**	**100%**	**100%**
WORLD	**1 186**	**84%**	**95%**	**71%**

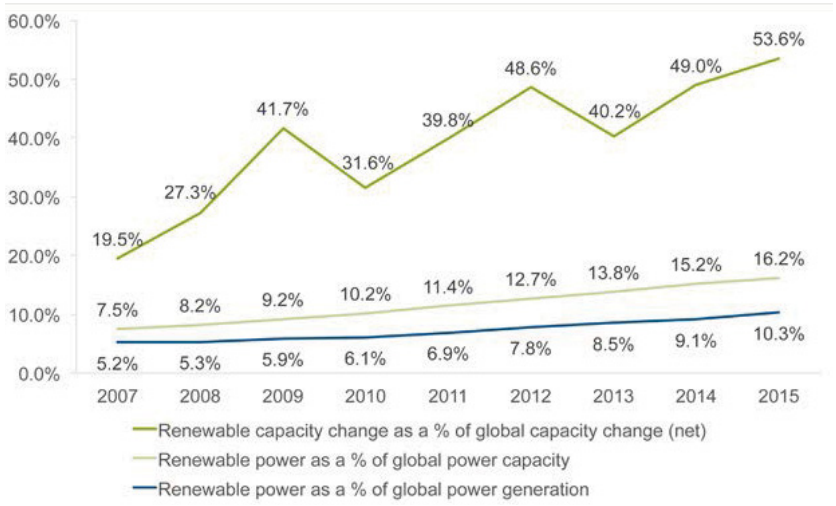
Source: World Energy Outlook 2016, IEA

Annex 2: Electricity Access in 2013 - Regional Aggregates

Region	Population without electricity millions	Electrification rate %	Urban electrification rate %	Rural electrification rate %
Developing countries	**1 200**	**78%**	**92%**	**67%**
Africa	635	43%	68%	26%
North Africa	*1*	*99%*	*100%*	*99%*
Sub-Saharan Africa	*634*	*32%*	*59%*	*17%*
Developing Asia	526	86%	96%	78%
China	*1*	*100%*	*100%*	*100%*
India	*237*	*81%*	*96%*	*74%*
Latin America	22	95%	98%	85%
Middle East	17	92%	98%	79%
Transition economies & OECD	**1**	**100%**	**100%**	**100%**
WORLD	**1 201**	**83%**	**95%**	**70%**

Source: IEA, World Energy Outlook 2015

Annexe 3:Renewable Power Generation and Capacity as a Share of Global Power, 2007-2015



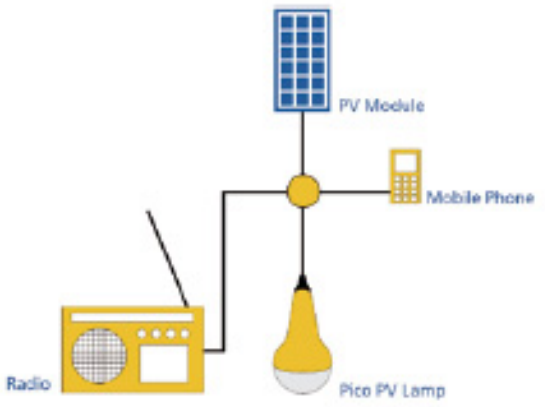
Source: *Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data* 2016, p.30.

Annexe 4: Types of Off-Grid Solar Systems

Solar Pico Systems	Solar Home Systems (SHS)	Solar Mini-Grid
Small SHS	Bigger systems	Usually used for large projects
Power output of 1 to 10W	Power output that can reach 250W peak	E.g.: hospitals or hole communities
Flexible (allow different combinations)	Sinclude several independent components: modules, charge controller, battery and the	Complex systems that require coordination
Possible to install the panel in separate or integrated (such as solar lanterns)	Charge controller is the central component, it manages the distribution of power among the different appliances	
Easy installation	Appliances: LED, radios, TV, fridges,and even Acs	
User friendly application	Price: from 140 to 1600€	
Low investment cost	Mature business models have been developed to hlp when affordability is a problem for rural-users.	
Little maintenance costs	Require trained technicians for installation and maintenance so that they deliver energy for many years	
Price: from 50 to 150€ of one kit including a solar modulo; or from 7€ to smaller systems		

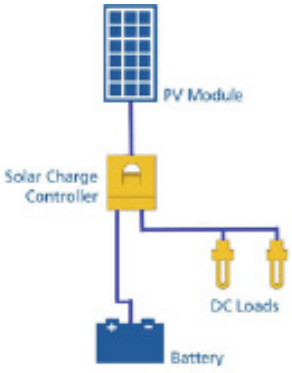
Source: Feron 2016

Annexe 5: Pico System



Source: Rolland 2011.

Annexe 6: Solar Home System



Source: Rolland 2011

Annexe 7: Advantages of Off-Grid Systems in Rural Regions

Environmental	Economic	Technical	Political	Social
Awareness of GHG emissions	Elimination of transmission costs	Advances in:	Take pressure from the centralied systems	Poverty fight
Impacts on electricity indusry	Elimination of distribution costs	performance;	Decrease independence in fossil fuels	Reduce the lack of access to electricity
Decrease independence in fossil fuels	Elimination of risk and costs of investment in large plants	metering;	Increasing primary source diversification	Boost development
		control equipment.		

Source: Mandelli *et al.* 2016.

Annexe 8: PV Generator Assumption

	2020	2030	2040
Technology	C-Si	C-Si	Thin film C-Si
Efficiency (%)	16	20	23
Nominal DC voltage[a] (V)	12/24	12/24	12/24
Lifetime[b] (year)	25	25	25
Performance after 25 years	80%	85%	90%
Manufacturing cost (€/W)	0.4	0.3	0.25
Average consumer price (€/W)	0.86	0.7	0.62
Price up to 200 Wp (€/W)	1	0.8	0.7
Price for 200–500 Wp (€/W)	0.95	0.76	0.67
Price above 500–1000 Wp (€/W)	0.9	0.72	0.63
CO_2 emissions (kg/kWp)	560	340	230

Source: Zubi *et al.* 2016, p.312

Annexe 9: Battery Assumptions

	2020	2030	2040
Technology	Lead–acid, VRLA	Li-ion	Next generation
Lifetime (cycles)[a]	500–1000	1500–2500	2000–3000
Price (€/kWh)[b]	120–140	280–320	180–220
Energy density (Wh/kg)	40	250	300
Power density (W/kg)	30	600	900
Maximum power (W/Wh)	0.75	2.4	3
Roundtrip efficiency (%)	90	95	95
Maximum DoD (%)	80	90	90
Self-discharge (%/M)	3	2	2
Operating temperature (°C)	0–50	−20 to 60	No practical restrictions
CO_2 emissions (kg/kWh)	55	40	20

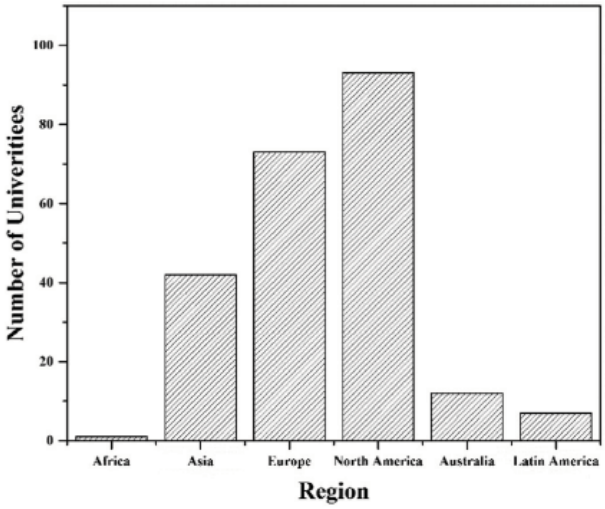
Source: Zubi *et al.* 2016, p.313

Annexe 10: Daily Electricity Demand (Wh/Day)

	2020	2030	2040
C I (LED + electronics)	245	245	245
C II (LED + electronics + fridge)	465	455	450
C III (LED + electronics + cooker)	745	645	645
C IV (LED + electronics + fridge + cooker)	965	855	850

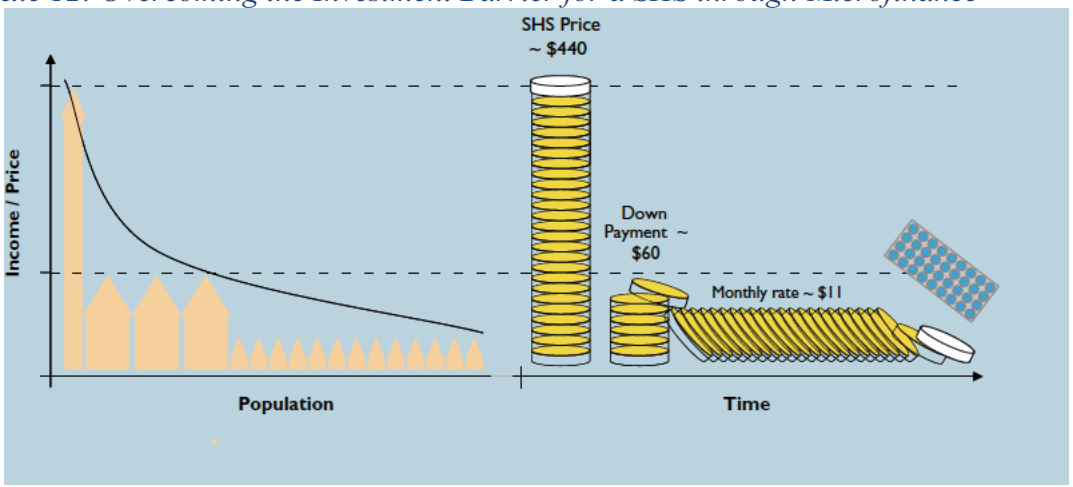
Source: Zubi *et al.* 2016, p.315

Annexe 11: Number of Universities World Statistics



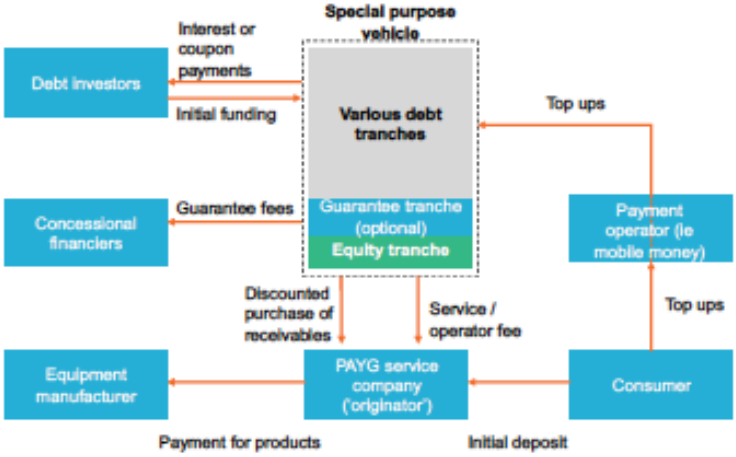
Source: Kumar *et al.* 2016, p.609.

Annexe 12: Overcoming the Investment Barrier for a SHS through Microfinance



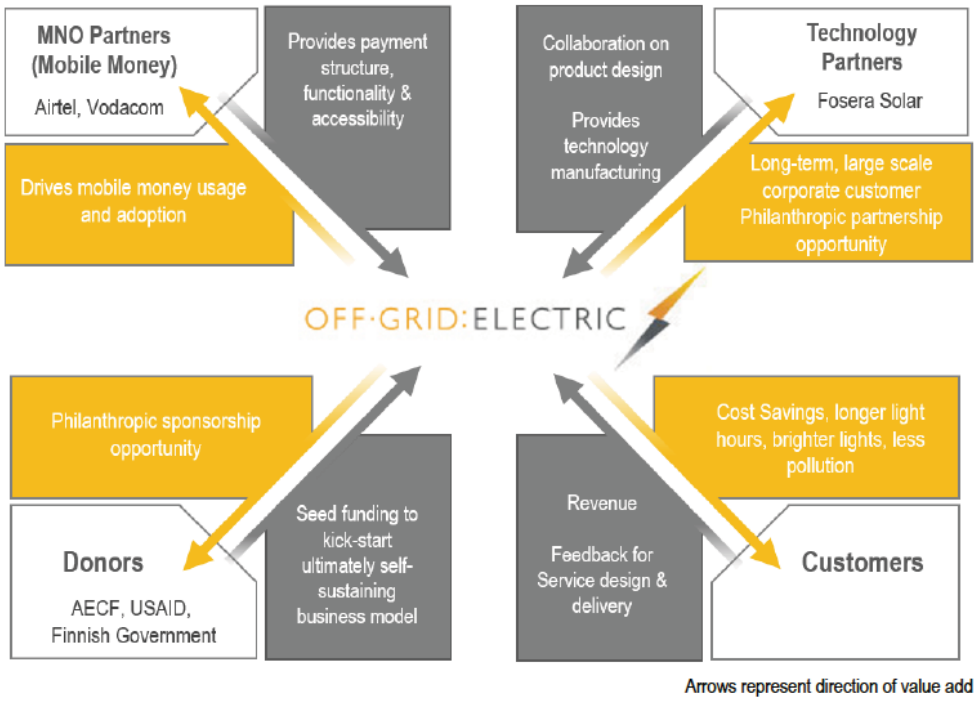
Source: *Rural Electrification with Renewable Energy: Technical, Quality Standards and Business Models* report.

Annexe 13: Cash Flow under a Special Purpose Vehicle Structure to Consumer Finance



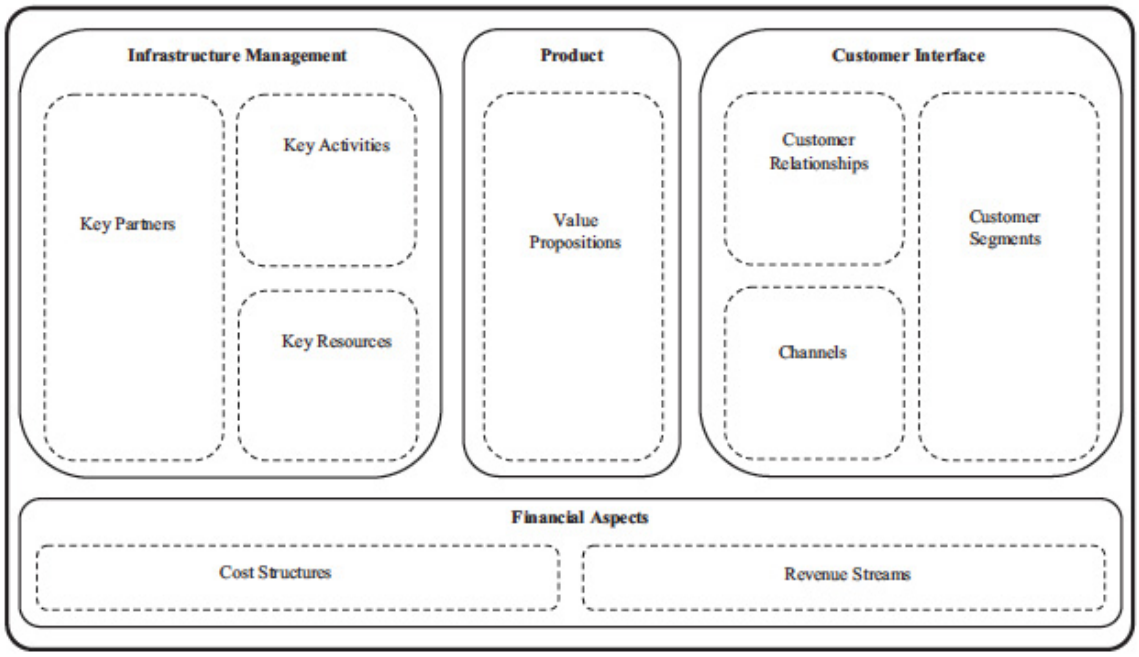
Source: *Off-Grid Solar Market Trends Report 2016* 2016

Annexe 14: Off-Grid Electric Partners



Source: *Mobile for Development Impact: Off-Grid Electric – Bright, Modern Lighting and Electrical Services Affordable to Everyone* 2015

Annexe 15: Canvas Business Model



Source: Gabriel & Kirkwood 2016

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