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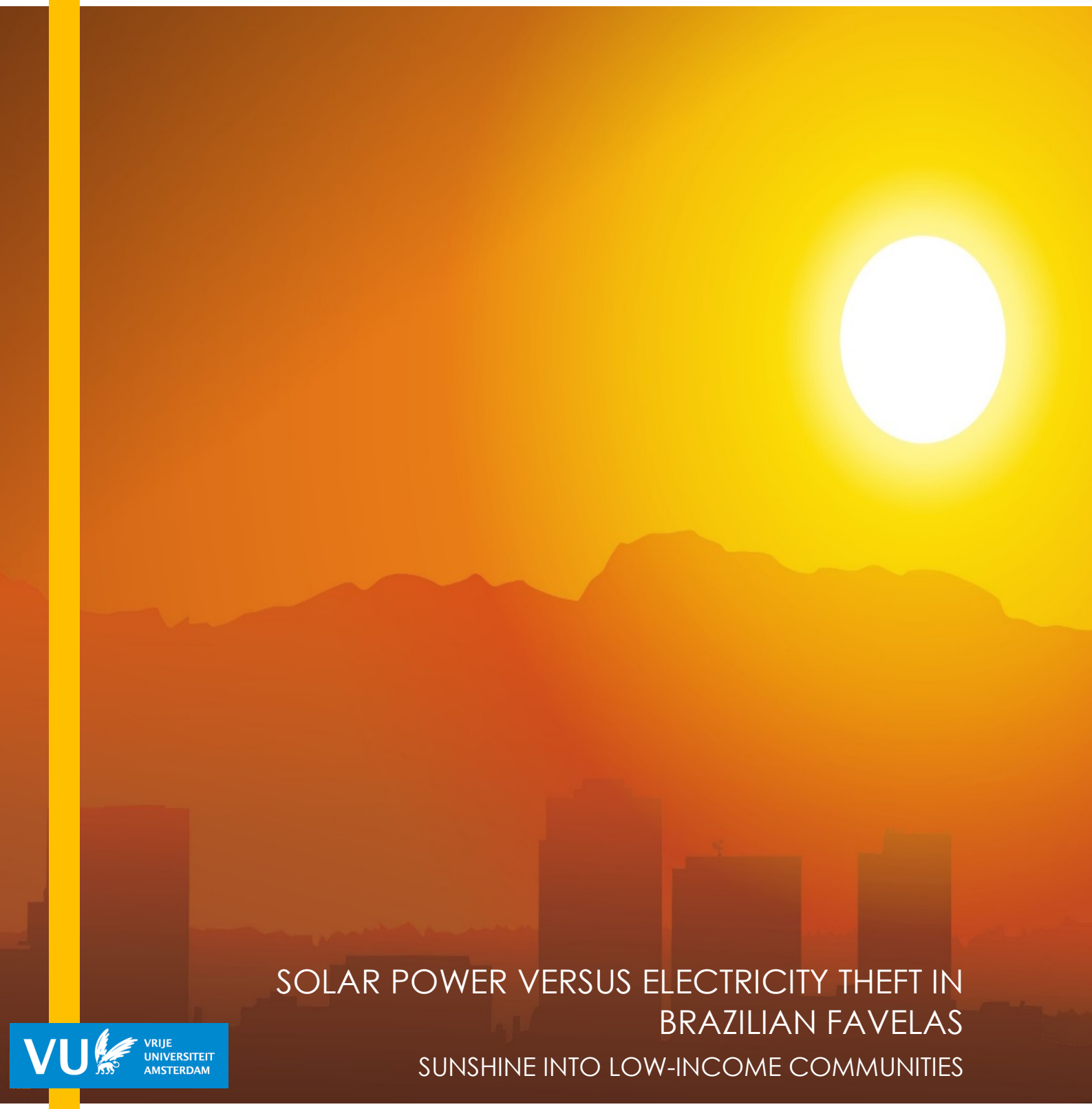

SOLAR POWER VERSUS ELECTRICITY THEFT IN BRAZILIAN FAVELAS

SUNSHINE INTO LOW-INCOME COMMUNITIES

VRIJE UNIVERSITEIT AMSTERDAM

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DIEGO DA SILVA COSTA LIMA

MSC ENVIRONMENT AND RESOURCE MANAGEMENT - RESEARCH PROJECT

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To Eva, the woman who has the key of my paradise.

Ao meu avô com carinho

ABSTRACT

Energy theft is a serious problem for most of utility companies, especially in developed countries causing huge financial losses. In favelas (slums), the illegal connections are not an exception but a rule. Corruption, socio-economic conditions and lack of technological investments are the main reasons pointed for this issue. The lack of government actions and the presence of drug traffic make it difficult for the local distributor company acts to tackle the problem. In order to diminish the theft rates, and to provide clean and safe access to energy for those communities this study assess the potential of solar power and its related technologies. This paper looks into the many ways that solar energy can contribute to alleviate energy poverty in poor areas. To conclude, the main solar solutions in the market are economically assessed, as well business models to provide a different way to approach the electricity theft problem, and contribute to the inclusiveness of slums communities into society and help the utility company to sustainably secure their revenues.

Keywords: Electricity theft, solar power, *favela*, inclusive business models.

LIST OF ABBREVIATIONS

BoP – Base of Pyramid

IBGE – Brazilian Institute of Geography and Statistics

NGO – Non-governmental Organization

PV – Photovoltaic

SE – Social Entrepreneurship

SWH – Solar Water Heaters

ToC – Theory of Change

UN – United Nations

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BACKGROUND

Lack of access to electricity is a problem that approximately 1.3 billion people face on daily-basis around the world (IEA, 2014). This problem is not exclusively of rural areas of sub-Saharan Africa or South-East Asia, in mega-cities of most developing countries the urban poor struggles to obtain access to affordable and clean energy services (Singh et al, 2014).

In 2007, for the first time in history, the global urban population exceeded the global rural population (SEEJPH, 2015). According to the UN, 54 per cent of the world's population is living in urban areas in 2014. This trend is expected to continuous and by 2050 we will reach a percentage of 66 per cent of urbanisation. The urban population has grown fast since 1950, from around 750 million to nearly 4 billion people in 2014 (UN, 2014).

Latin America and the Caribbean is the second most urbanized region in the world with 80 per cent of its population living in urban areas, losing only to Northern America with 82 per cent (UN, 2014). However, higher urbanisation rates is not translated into development. Even though Latin America is more urbanized than Europe, its GDP per capita is three times lower than the European Union, mainly due to the chronic inequalities, mass poverty, lack of infrastructure and urban planning, poor public services, poor governance and weak institutions (Habitat, 2013).

In this context, with rapidly world population growth and urbanisation, the *favelas* proliferated in the last years. In 1990, the number of people on developing areas living in *favelas* was 650 million, however this number increased to 863 million in 2012 (Habitat, 2013). In only 22 years, the number expanded more than 30 per cent. In Latin America, despite the proportion of urban population living in slum dropped from nearly 34 per cent in 1990 to 23,5 per cent in 2012, the number of urban slum population has risen 8 per cent, reaching approximately 113 million people (Habitat, 2013).

The favelas are characterized by lack of basic services and therefore inclusiveness by governments and society itself. The dwellers within have to deal with violent environment, lack of educational systems, decent transportation connections and poor or inexistent sanitation facilities. As well as absence of waste collection systems, rainwater drainage, low or inexistent minimum building standards, high density with low space per person and lack of security of tenure. Last but no least; no access to affordable and clean electricity (UN-Habitat, 2004); with fewer legal options to obtain it. So therefore illegal connections become an attractive way to have access to electricity.

The use of this illegal practice can bring more costs than benefits. Imminent risk of fires, financial losses and law prosecution are common difficulties faced by not only the dweller in the favelas, but also effects the whole society. Often, this practice encourage wasteful habits (Silva, 2003) and increase environmental damages.

It is estimated that worldwide utility companies suffer massive loss more than 25 billion/USD every year owed to electricity theft (Depuru, Wang, & Devabhaktuni, 2011). Moreover, stealing energy causes several problems to the society as a whole. (1)The dwellers have no guarantee of supply and face risks as fires and financial losses due to the overload. (2)The utility companies face huge financial losses. (3)Local government losses income from unpaid taxes associated to electricity consumption. Finally, (4)

consumers (households and companies) have to pay more for electricity to compensate the losses (Smith, 2004).

Therefore, with this presented panorama of poverty and financial losses (electricity theft) i*n what extend could solar power be used in order to help alleviate both?* In the 80's, Dr. Gerhard Knies, a German researcher, in response to the Chernobyl nuclear accident, was the first to estimate how much sun energy was necessary to attend the world's demand for electricity. He reached the conclusion that in just six hours, the world's deserts receive more energy from the sun than humans consume in a year (The Guardian, 2011). Moreover, this paper will investigate the different solar power technologies and how it could be applied to low-income markets to fight poverty and reduce electricity theft.

This research thesis is organized into seven chapters. In the present chapter, the introduction to problem and the purpose of the study are presented. Next chapter presents the analytical framework where the research is framed, providing the literature review found on the same field and the definitions of concepts used throughout the study. The next chapter points out the methodology used to refer the research questions. Chapter four, presents the analysis of the stakeholders and solar technologies. Finally, in chapter five, the results obtained from interviews and evaluation of solar technologies are presented. In chapter six and seven, discussion, and recommendations and conclusion on how solar energy can contribute to alleviate the problem, are provided. In that part, the results are linked to the research questions in order to contribute with insights into the potential of solar energy to empower poor people.

PURPOSE AND SIGNIFICANCE OF THE STUDY

The purpose of this paper is to investigate the role of solar power and its technologies in order to tackle electricity theft. The thesis will provide enough information to utility companies and governments to invest on new alternatives to decrease the rates of electricity theft and raise the inclusiveness of the favela's dwellers.

Electricity theft has been seen as crime for a long time. The government achieved almost nothing to diminish the rate of electricity theft and to enhance the access to electricity to people in the slums.

Adding to that, the adoption of new solar technologies aligned with social interactions in all parts of its implementation could enhance the impacts on the dweller's living conditions, and at the same time, on the utility companies' revenue, on the government's efficiency and on the environment.

Finally, by involving all stakeholders to become part of the solution, it could raise the chances to steer the favelas towards economically, socially and environmentally better future, consequently changing behaviour of electricity theft by raising the social inclusiveness of favelas.

RESEARCH QUESTIONS

In what extend solar energy services can help to diminish electricity theft in the Brazilian *favelas*?

SUB-QUESTIONS

1. What is the size of electricity theft?
2. What are the main social factors that triggers/cause favelas' formation?
3. What is the correlation between electricity theft and energy poverty?
4. Which solar technologies could be useful to tackle electricity theft?
5. What are the main barriers for solar technologies adoption into the slums?
6. How can such barriers be overcome?

ANALITICAL FRAMEWORK

KEY CONCEPTS DEFINITIONS

In this section, the concepts and variables associated with the research project will be defines as precisely as possible.

INDEPENDENT VARIABLE

Firstly, it is necessary to define what the independent variable ´**solar energy services**´ in the context of this research is. In this case, any technology that uses solar to provide electricity or heating to work as substitute of grid connection. It will be taken into account the wide range of technologies: photovoltaic systems, solar thermal, concentrated solar power and solar tubes. However, these technologies need to have a large/medium diffusion in the market and be affordable by low-income population followed by the Base of Pyramid (BoP) concept.

DEPENDENT VARIABLE

The next concept to be defined is **electricity theft**. According to Smith (2004) in his paper about electricity theft, he defines it in four categories: *fraud, billing irregularities, unpaid bills and stealing through connecting lines bypassing the meter*. The latter definition will be used for electricity theft in the research paper as the common way used by favelas' dwellers (Yaccoub, 2010).

In Brazil, this type of illegal connection is known as "*gato*". Translating into English, this means cat. Furthermore, in the next section is shown how the variables will be operationalized.

VARIABLES OPERATIONALIZATION

The variables identified for this project and its operationalization are listed below:

Independent Variable	1st Level	2nd Level	Unit
Solar Energy Services	Technologies	Infrastructure necessary	Price per KWh
			Kwh produced
	Investments	Initial capital necessary	€ necessary for implementation
			Business models
	Environment		CO_2 emissions (avoided)

Table 1: Independent variable according to the Research Question

Dependent Variable	1st Level	2nd Level	3rd Level	Unit
Energy Theft	Grid Infrastructure	Utility Companies	# energy stolen	Non-technical loss / MWh
			# financial losses	€ / year
	Socio-economic conditions	Governance	policy output - towards renewable energy & (poor) inclusiveness	number of policies in the last 10 yrs
		Access to public services		# of HH w/ access to sanitation
				Level of education
				Income of household

Table 2: Dependent variable according to the Research Question

The theory used to guide this paper is the Theory of Change (ToC). "A theory of change is the empirical basis underlying any social intervention", says Brest (2010) *on his article The Power of Theories of Change*. Thus, in the perspective of this research there is the belief that solar technologies adoption in the favelas in Brazil can reduce electricity theft at the same time, ameliorate the life of poor people in these settlements, focusing on social interventions.

WHAT IT IS?

The Theory of Change has its origins in the 1960's when there was a need for more reflection on theories of development regarding to social change and participatory approaches (Vogel, 2012). In the 1990's, it emerged from the field of program theory and program evaluation as a new approach to analyse the programs and initiatives that promote social and political change (Weiss, 1995).

Nevertheless, what is exactly the ToC? Vogel (2012), define it as an "outcomes-based approach which applies critical thinking to the design, implementation and evaluation of initiatives and programmes intended to support change in their contexts". According to Clark & Taplin (2012), ToC is a participatory process where groups and stakeholders articulate long-term goals and identify the conditions they believe are necessary in order to achieve the established goals. Then, these conditions are modelled as *outcomes*, organized graphically in a *causal framework*. Moreover, the ToC will describe which interventions are necessary to bring about the outcomes.

Therefore, for all outcomes there should be identified indicators and ways of gauging that can be used to measure the impacts ensuring that the theory can be tested (James, 2011). Likewise, rationales, assumptions and narratives are indispensable in this approach. Where rationales are used to explain the connections between the outcomes and why one outcome is necessary to accomplish another. Assumptions supports the contextual ground of the theory. Both rationales and assumptions are grounded by research, in order to strength the theory and the likelihood that the stated goals can be reached (Clark & Taplin, 2012).

Continuing with Clark and Taplin (2012), parallel to the assumptions and rationales, the narrative is vital to explain the pathways of change, highlights the major assumptions, rationales and interventions. It will assist this paper to be better understand related to how the elements will work as a whole to meet the main goal.

To conclude, ToC adds rigour, transparency and clarity to the project logic and helps to highlight assumptions that needs to be tested (Ober, 2012).

Vogel (2012), on her review of ToC, points out a consensus regarding to the basic elements that comprise the ToC approach:

- **Context** for the initiative, including social, political and environmental conditions, the current state of the problem the project is seeking to influence and other actors that influence change.
- **Long-term** goal that the initiative seeks to support and who will be benefited.
- **A well-defined sequence/process** of change anticipated to meet the desired long-term outcome.

- **Assumptions** about how these changes might happen, as a way on whether the activities and outputs are appropriate for influencing change in the right direction.
- **Diagram and narrative** that captures the essence of the discussion. Examples of diagrams can be seen in the appendix 1.

WHY USE IT?

Firstly, the theory of change is a participatory process. This approach will help achieve one of the goals of this paper that is the capture of the different points of views from different stakeholders and what they think is necessary to happen in order to start/make a (social) change.

It enhances community participation, as one of the main requirements for the success of slums upgrading programs (Bremner & Park, 2010)). By enabling bottom-up approaches to complex problems, ToC emphasizes the importance of decentralization of influence. For example, the entrance of new actors can influence a change in electricity theft behaviour.

Furthermore, ToC way of thinking can be effectively and simple (Vogel (2012), encouraging to express statements about change like: '*If we take x action, then y change will result, because…*' (Ober, 2012).

This feature will allow testing the hypothesis:

The more solar power technologies for low-income areas are adopt, the less the electricity theft's rate will be.

To conclude, ToC is not a silver bullet for the problems addressed in this paper. However, allows the problem to be viewed from a logical pathway perspective. Its flexibility, gives opportunity to review, adjust or improve the plan when necessary.

LITERATURE REVIEW

ELECTRICITY THEFT AND ENERGY POVERTY

Electricity theft is a problem faced by both poles of the world (North and South) (Smith, 2004). Depuru et al. (2010), points that the overall T&D losses worldwide are more than the total generation capacity of Germany, UK and France. Leading to financial losses and costing to environment around 9 million tons of CO_2. In Brazil, electricity theft is responsible for an annual loss to the country around US $ 2,5 billion (including taxes), according to the National Electric Energy Agency – ($ANEEL_1$, 2011). This represents in power approximately 27,000 GWh or 8 per cent of all electricity consumed.

Many authors have pointed conventional and technology oriented measures to counter electricity theft, i.e. improving meter systems (Depuru et al (2010), Smith (2004), Ghajar at al. (2003)). However, not much has been written about electricity theft as a social degradation causality and the relation between utility companies and low-income customers. Winter (2012) wrote an interesting article about electricity theft as a relational issue. The article demonstrates the relationship between customers and companies in Zanzibar, Tanzania and India. It shows that people's degree of compliance is associated with their impressions of the electricity supplier company.

In favelas of Rio de Janeiro, electricity theft can reach more than 70 per cent of all electricity consumed (Light₂, 2015). These high numbers can be easily associated with socio-economic factors like trust, informal social norms such as corruption and bribery, awareness and electricity pricing effect (Never, 2015). Furthermore, in Brazil, the address proof is associated with the utility bill. Consequently illegal connections leads to increased social exclusion among favelas' dwellers. In addition, Silva (2003) points out that energy consumption in the favelas appears inefficient not only for the clandestinely which encourages wasteful habits, but also by irregular supply altering the voltage. The latter besides damaging equipment, it poses a risk of life for dwellers.

Halff et al (2014), starts the book *Energy Poverty – Global Challenges and Local Solutions* with an interesting observation on how developed the access to electricity is in Western countries that is easy to forget how recent it really is. The chapter continues with an interesting observation on Paris from 1960's. The author draws attention to the fact that 20 per cent of Parisian lacked access to electricity by the time. It is true that a lot has been done since then regarding to energy poverty. However, access to modern energy services remains a distant dream for a lot people. Until recently, the subject got more attention and the United Nations identified universal energy access as an important policy goal that can support the achievement of the Millennium Development Goals (Energy, U. N. 2005).

Energy poverty is not an issue exclusive of rural and isolated areas. Slums located in urban areas also experience the lack of access to electricity (Melo & Lins, 2010). Many utility companies do not invest in expensive grid expansion in such areas due to the risks, and low return investments rates (Lipu et al. 2013). Problems associated with land tenure and its burrocracy to regularize an illegal settlement enhance the social exclusion of favela's dwellers, especially in peri-urban areas where utility companies do not provide coverage and they remain un-served (Rojas at al., 2007). Thus, having been neglected for so long, favelas' dwellers find their own solutions to improve their communities and electricity theft is one of them (Nwangwu, 1998).

Electricity theft as a social issue still need more attention and research due to the limitations that traditional technology-based approaches have been showing so far. According to UN-Habitat, "Rapid urbanization, one of the greatest socio-economic changes during the last five decades or so, has caused the burgeoning of new kinds of slums". It is this particular and degrading way of living, which is characterized by lack of public services that electricity theft often happens.

URBANIZATION

In the last 60 years, the world's population faced a huge change regarding to urbanization. For the first time in history there are more people living in urban areas than in rural areas. In 2014, about 54 per cent of the world's population is now residing in urban areas and is projected to reach 66 per cent by 2050 (UN Economic Division, 2014).

According to the UN report World urbanization prospects (2014), the global urban population has risen from 746 million in 1950 to 3.9 billion in 2014, in other words the world's urban population had a growth of more than 420 per cent in the last half century. Currently, Latin America and the Caribbean is the second most urbanized region in the world (80 per cent residing in urban areas) 'losing' only to Northern America region (82

per cent). Brazil, the subject of this study has a rate of urbanization around 85 per cent (IBGE, 2010).

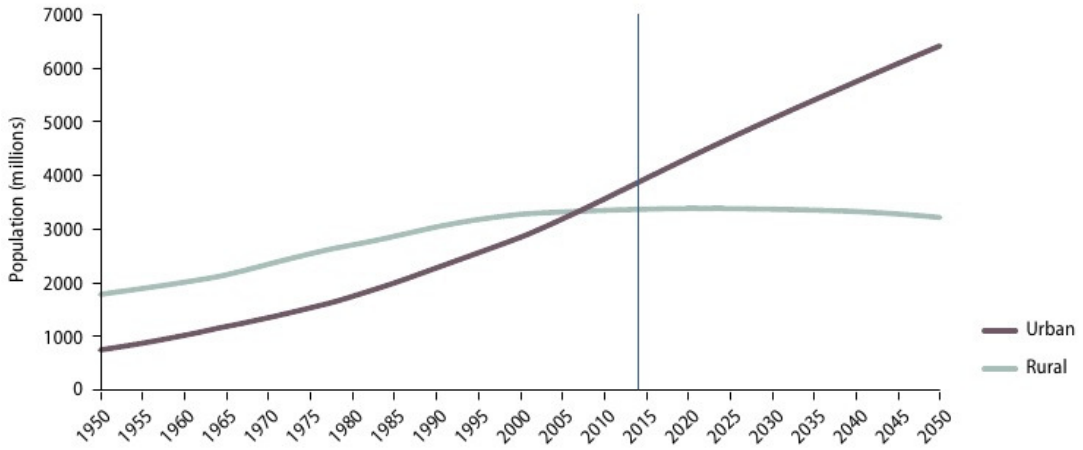

Figure 1 Urban and rural population of the world, 1950 - 2050 Source: United Nations, 2014

The causes for the rapidly urbanization in the last six decades are associated with economic and social transformations (Fay & Opal, 2000). Historically, cities in urban areas are linked with better access to public services as health and education as well more cultural activities and political participation. Leading people to migrate from rural to urban areas seeking for better opportunities and conditions. However, rapid and unplanned growth in urban areas are not sustainable. Lack of necessary infrastructure or police's attention fail to ensure that the benefits of living in urban life are equally shared among its dwellers (Fay & Opal, 2000). This leads to more inequality, pollution, and environmental degradation along with distorted social behaviours.

INEQUALITY

One important economic aspect that affects favelas' formation is inequality. Favelas result from a combination of poverty with disturbances in the housing provision system (UN-Habitat, 2003). Economic inequality works as cause and effect for this problem. Figure 2 describes the situation.

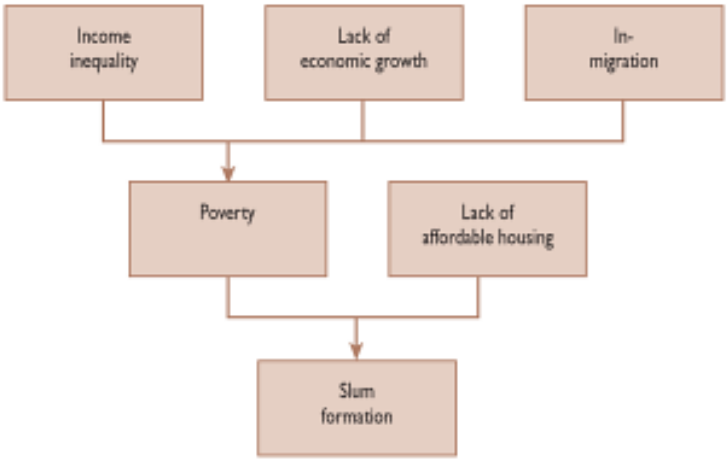

Figure 2: Inequality, poverty and slum formation (source: UN-Habitat, 2003)

Furthermore, solar power can help to diminish income inequality and therefore, alleviate poverty. As pointed by some interviewees, low-income families could benefit from the savings generated by less consumption on electricity bills.

The Gini index measures the distribution of income and consumption among individuals and households in a country (zero being perfect equality and 100 perfect inequality). Brazil, according to the World Bank (2012), has a Gini index of 52.7, being one of the highest inequalities of the world. Furthermore, in Brazil the richer 20 per cent of the population have around 57 per cent share on income or consumption and the poorest 20 per cent have only 3,4 per cent.

To conclude, a study made by Da Matta et al (2007), revealed that in Brazil (from 1980 to 2000) an increase in 1 per cent in inequality, resulted in an increase of 1,6 per cent in dwellers in the favelas. Therefore, cities with higher inequalities are those with the largest number of slums.

FAVELAS' FORMATION

According to the definition given by UN-Habitat, a slum is the term for areas that are home to substandard housing, devoid of regulation and public services (clean water, sewage, schools, health centers, etc.).

In addition, rapidly urbanization growth exceed the capacity of local and national governments to provide safe, healthy and affordable infrastructure in developing countries. Added to this panorama, authorities have been neglected the lack of infrastructure and focusing more on economic growth and as a consequence slums formation rise as housing solution (Ooi & Phua, 2007).

This inability of city authorities to plan and provide affordable housing to low-income population push the people to find their own solution. As Ooi et al criticizes economic development as a way that will provide all basic needs (house, environment and health infrastructures) to urban population. However, the private sector is interested in providing housing and services to middle and high-income market.

> "Biases in investment standards, pricing policy, and administrative procedures, more often than not, skew services in favour of the rich, denying the poor shelter, safe water, acceptable sanitation, minimal nutrition, and basic education." (Yeung, 1991)

According to the UN Habitat, in the world the absolute number of people living in slums have raised from 650 million in 1990 to 863 million in 2013, most due to rapid and unplanned urbanization. The police attention is zero in these areas and they suffer from lack of infrastructure, public facilities and basic services. In this context, urban expansion is seen as poverty and not as affluence. Commonly in the slums, the way to obtain access to electricity is through illegal connections to the grid (GNESD, 2009).

These unhealthy and unfair living conditions affects the capacity to generate income and therefore increases poverty. As poverty being the cause and consequence of slum conditions, thus creating barriers to human and social development. Moreover, this panorama increases the social exclusion usually recognized to have high levels of crime and violence (UN-Habitat, 2004), leading to lager gap between social classes.

THE HISTORIC VIEW OF FAVELAS' FORMATION IN BRAZIL

In Brazil, more specific in Rio de Janeiro, the formation of favelas has its origin by the end of 19th century and the beginning of 20th century. This specific time was marked by economic, social, political, cultural and spatial changes (Vaz, 1994). Is important to highlight the transition from slavery work to wage labour with the abolition of slavery in 1888.

The article of Lilian Fessler Vaz (1994) about housing in Rio de Janeiro gives a good perception on how the favelas started there. Rapidly population growth, resulted in the formation of "*cortiços*", poor collective house with no sanitation, clean water and with high density of people. Rio de Janeiro was passing by a huge transformation and the private sector by time put a massive pressure in the government to end with *cortiços* and start to build new places for who could pay for it. As a result, the local authorities expelled the *cortiços*' dwellers to free the area for the new business, consequently the dwellers moved to the hills of the city and started building their own homes.

The term "favela" comes from a prickly plant and extremely resistant, common in the Northeast of Brazil. The name was first used by soldiers that fought "Canudos War" in the Northeast. They marched back to Rio de Janeiro hoping to receive their pay for their services, while waiting they built their homes in the hills of the city. However, the payment never happened and they never left the 'new homes', naming them 'favela' in reference to the war zone. In addition, a few years earlier (May 1988) the slaves had their freedom and they headed to Rio de Janeiro to seek for better conditions and opportunities. However, the recent Republic installed in Brazil did not provide any aid to these people. Instead, the Federal Government focused on expel the settlements away from the centre and rich neighbourhoods. In response, the favelas went deeper in the outskirts of the city and only increased throughout years of abandonment from local authorities (Ferreira, 2009)

Since then the favelas' dwellers face the neglect of public power and the speculation of private sector to meet their most basic needs.

FAVELA IN NUMBERS

First, there are differences regarding to the definition of favelas between the Brazilian Institute of Geography and Statistics (IBGE) and UN-Habitat. Thus, those differences have an impact on the absolute numbers of the favelas.

Therefore, the numbers presented by IBGE in the last census (2010) are: 11,4 million people living in favelas, representing 6 per cent of Brazilian population, distributed in more than 6 thousands favelas in 323 municipals. UN-Habitat presents a number of 45,4 million people living in favelas, representing 28 per cent of Brazilian population. Table 1 gives an overview of the definition differences between IBGE and UN.

Criteria and defining characteristic of subnormal agglomerate (IBGE) and informal settlements (UN)

Criteria	Defining characteristics	
	IBGE	UN-Habitat
Land Tenure	Illegal occupation of land, i.e. construction in a foreign land ownership (public or	It constitutes a community of individuals living on land

	private), at present or in the recent period (obtaining the land title for ten years or less).	without right or ownership certificate.
Urbanization	Urbanization outside the current standards - reflected by narrow traffic lanes and irregular alignment, lot are unequal in sizes and forms, and buildings not regulated by government agencies.	Households in unsuitable areas from the point of view of natural or industrial hazards and near heavy traffic routes
Urban services	Precariousness in at least two (2) of essential public services: water, sewer and **lighting**.	Precariousness in at least one (1) of essential public services: water, sanitation.
Building material	-	Households in temporary and / or dilapidated structures; precariousness of building material (ex.: material used for walls, floor and roof); Disagreeing with local building codes, standards and laws.
Minimum number of households	51 households	-

Table 3: Criteria and defining characteristic of slums **Adapted from Costa et al. 2005**

According to IBGE, favela is defined as *subnormal agglomerate* as a set of households with at least 51 units that occupy in a disorderly and dense way, on other people's property of land (public or private) and without access to essential public services. The definition adopted by the UN sought internationally standardize the definition of slums, because the differences between the various criteria adopted by the countries did not allow a quantification of the total number of people living in slums in the world. In 2002, the UN adopted a definition, which states that a slum is an area with the following characteristics: inadequate access to clean water; inadequate access to basic sanitation infrastructure and other facilities; low quality of residential units; high density and insecurity about the status of the property (UN-Habitat, 2003).

Currently, the several criteria used by different organs of the Brazilian government to define favela originates hurdles, which may delay the implementation of public policies to tackle the problem (Leite, 2010).

TECHNOLOGY PARADOX

Technology is present every day in our life. Its comprehensiveness is immense and a good example is the smartphone. Nowadays, a 'basic item', independent of which social class everyone has. Many people that lives in deplorable conditions can have access to modern phones at the same time they lack access to basic needs like water, sanitation or electricity.

What if politics could progress at the pace of technology? This question was posed by Start Up Cities Institute, a project from University Francisco Marroquín in Guatemala. They advocate that traditional approaches to political reform increase the risk that reforms will not succeeded. Therefore, Start Up Cities defends that is necessary to innovative ways to test public policies.

The definition of technology is to program nature, directs it to some kind of purpose (Merriam Webster, 2015). Thus, 'social technology' would be a way to structure human behaviour for a social goal. Mainly, it is to bring the spirit of entrepreneurship into politics.

This interesting point of view of public policies is essential to build a theory of change in electricity theft by increasing inclusiveness in the favelas. As advocate by Start Up Cities, social problems are complex and there is no silver bullets for solve them, therefore it is necessary to recognize politics as technology and be humble about the solutions to be tested.

SOLAR ENERGY MARKET OPPORTUNITIES

Only 90 minutes of sunlight striking the earth is necessary to provide the entire planet's energy needs for one year (IEA, 2011), however solar energy represents a small fraction of the world's energy mix. In the last few years, the power and heating sector could see the increase of installed capacity of solar photovoltaic (PV), concentrated solar power (CSP) and solar heating systems. Only in 2013, PV had a 39 per cent growth rate (139 GW) in installed capacity; this was the largest growth rate among renewable energy technologies (RNE21, 2014). Figure 3 shows the average annual growth rates (2013) of renewable energy capacity and biofuels production.

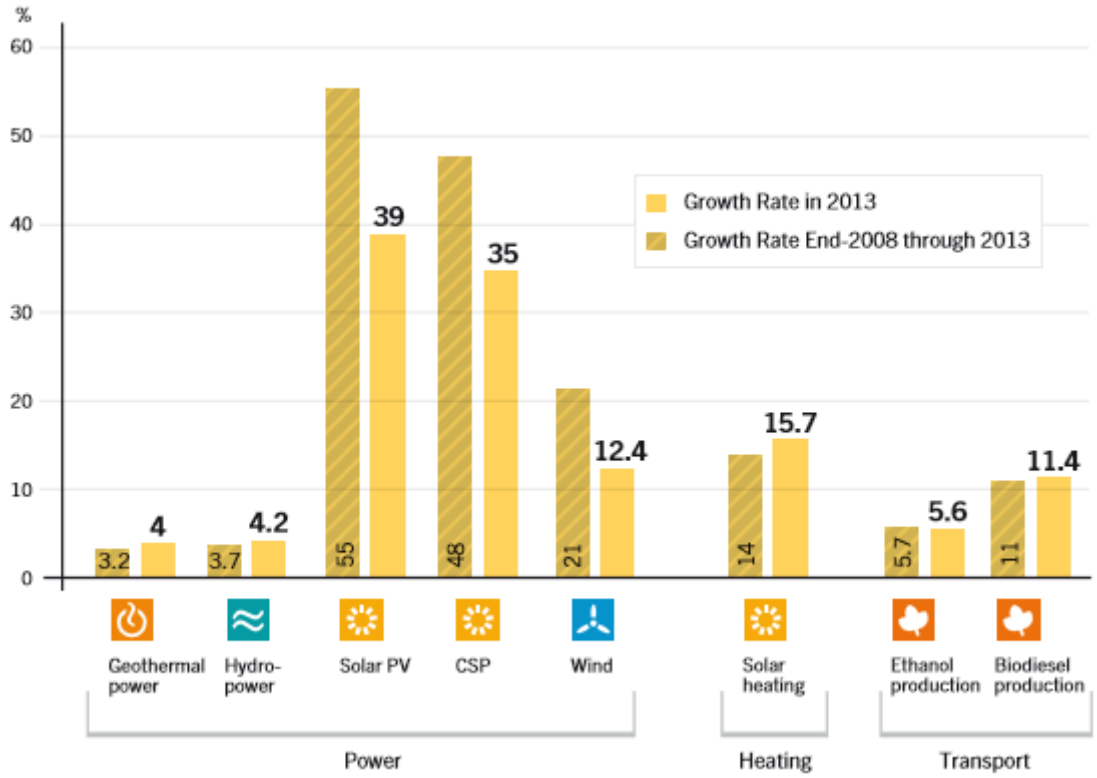

Figure 3: Average annual growth rate **(source: REN21, 2014)**

Lower costs of solar systems, technology improvement and political support are opening new markets in developing countries (REN21, 2014). For instance, in 2012 Brazil regulated a net metering system for distributed generation (DG) allowing homes and companies to invest in renewable electricity generation (ANEEL$_2$, 2012).

Moreover, solar heating systems in Brazil are experiencing fast growth in the last few years. Worldwide, Brazil occupies the fifth position in cumulated installed capacity with more than 5,700 MWth collectors until 2012 (Mauthner & Weiss 2014). The Brazilian government adopted solar heating system in its housing program, representing almost 20 per cent of total sales in 2013 (Dasol, 2014). This is helping the industry to grow and low-income people to have access to solar heaters.

Furthermore, solar (solar PV, CSP and solar heating) is the renewable energy responsible for creating around 2,3 million jobs direct and indirectly worldwide (REN 21, 2014). Thus, this is a great opportunity to create jobs to low-income people to work on installation and maintenance.

Another important feature is solar radiation. It is essential information in order to design a solar system. Brazil has privilege by the abundant solar radiation, where the sun rises on average 280 days a year (Cabral et al, 2013). According to Salamoni & Rüther (2007), yearly the region of Brazil that receives less sunlight is around 1642 kWh/m², which are above the values in the area of greatest sunlight of Germany, which receives about 1300 kWh/m². In addition, Brazil has one of the largest silicon reserves in the world, an important material used to produce solar PV panels (Cabral et al, 2013).

It is worth to mention that in Brazil, the expenditures in the favelas in 2014 were around 68,6 billion reais (approximately USD 21,3 billion) (Valor, 2015). Thus, it is a possible 'new' market for solar companies.

To conclude, Brazil is facing an energy crisis. Most of its electricity generation relies on hydro (see energy matrix in appendix 5). The drop in the average rain in the last few years had a great impact in the hydroeletric's reservoirs. Forcing the government to use thermoelectric (gas, coal and oil) to attend the demand. These alternatives are expensive than hydro, increasing the final prices of kWh. Solar energy is an option to alleviate the panorama and increase energy security.

FINANCING SOLAR POWER TO POOR PEOPLE - NEW BUSINESS MODELS

The very basic needs of vast portion of favelas' population remain unmet. Business-as-usual failed to provide access to poor people, quality and affordability to public services. According to the World Bank (2003), public spending fails to reach the poor, and if it does, service is often inefficient and/or of poor quality.

Lately, social entrepreneurship (SE) appears as an option to overcome the complexities to offer to poor people basic services such as (affordable) access to electricity. New resources and competencies have been putted together to create new business models, an essential tool in order to provide sustainability to the business and to increase social development. A growing number of business models is defying the obstacles that prevented the poor access to clean and affordable energy (Seelos & Mair, 2005).

Innovative and inclusive business models are essential part regarding to the theory of change that supports this thesis. Figure 4 gives an overview of on how poor people should be seen in inclusive business models (Hahn, 2012).

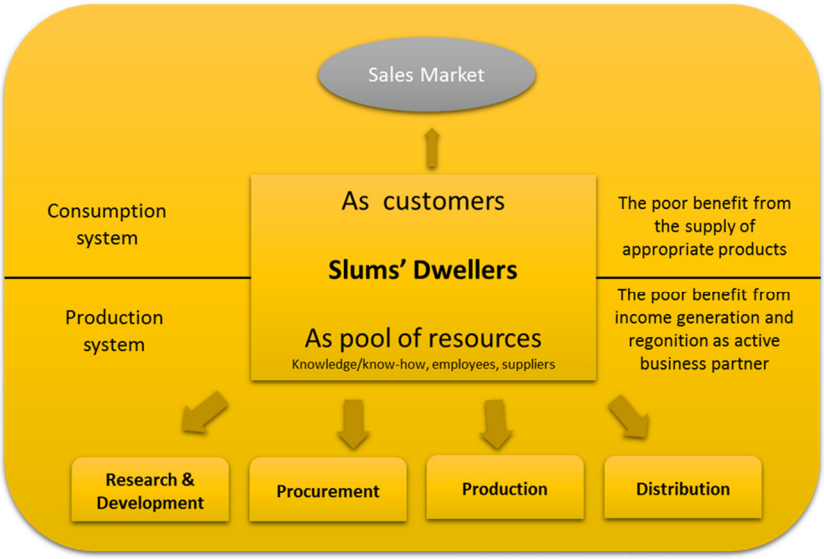

Figure 4: Modes of impact in inclusive business approaches **source: Hahn, 2012**

SE is using new resources and ways to create value. Today, the solar energy market is focused on a Base of Pyramid (BoP) and has several innovative business models. For example, Arc Finance, a global non-profit organization focuses on bring together funders, pro-poor enterprises and end-users to develop solutions to finance access to clean energy and water.

Besides, keeping the price at an affordable level, the main challenges to overcome are high up-front payment for equipment, lack of access to credit for poor people and payment flexibility, taking to account that poor people have unpredictable income variation (Seelos & Mair, 2005).

One of the alternatives is using the cell phone penetration. The concept of Pay-AS-You-Go (PAYG) is common to the majority of people in the developed and developing world. PAYG can sell kWh in the form of scratch cards or electronic top up in existing retail networks. It helps to lower operating costs and risks for companies and allows unbanked people to have access to other forms of payment. After a certain amount of top ups or scratch cards the ownership is transferred to the customer transforming an energy expenditure into an asset purchase (ARC Finance, 2012).

Furthermore, asset finance is another alternative to provide solar energy to poor people. Asset finance is a loan to purchase equipment. According to Arc Finance (2014), asset finance can take the form of either a hire purchase or leasing arrangement. First, the customer pays an initial deposit and the remaining balance paid over a period in regular instalments. After completing the payments, the ownership is then transferred to the customer. In the latter, the leasing company buys and owns the asset. The customer pays a rent over fixed time. At the end of the contract, the customer has a choice of extending, buying or just returning it.

This business model provides an alternative to conventional bank loans. However, a successful asset financing requires that customer satisfaction must last the whole length of the credit term. Thus, product features, performance and after-sales support requires close attention.

Another innovative business model is using the savings generated by solar energy. The customer pass through a complete credit analysis. After that, the customer can choose the amount of initial payment for the system and the remaining balance is paid by monthly installment according to the potential savings that solar energy will generate (Arc Finance, 2014).

Social business are still on early stage in Brazil, however is proven that they have been achieving good results and shows a way to utility companies and governments to seek for other alternatives to deal with electricity theft in the favelas. In the case of access to electricity, the renewable energies are transforming the electric power sector by allowing customers to produce their own energy. Therefore, the utility companies will face new challenges in the way of doing business (Richter, 2011).

Next section, is about the challenges that utility companies will face with the deployment of renewable energies into the electric power sector.

BARRIERS TO ELECTRICITY ACCESS IN THE FAVELAS

Why traditional electricity services do not reach the favelas' dwellers? Lipu, Jamal, & Miah (2013) and Schaengold (2006) identified many barriers where urban poor face problems in accessing legal electricity service.

1. Sociological barriers

The "culture of non-payment", which means that favelas' dwellers are not accustomed to pay for electricity or pay only when they are able, also they can resist to pay when asked. This can be attributed due to relational issues with utility company and dwellers (Winther, 2012).

2. Physical barriers

The favelas are characterized by crowed areas with narrow streets making vehicular access impossible to install power cables.

3. Illegal settlement

Favelas' dwellers often have no legal status. This legal recognition of the land is a pre-requisite for a household to obtain access to legal electricity service. Therefore, dwellers are automatically excluded from form electricity services.

4. Economic barriers

Schaengold (2006) points some important economic reasons why traditional electricity is a barrier. The first is that favelas' dwellers are often extremely poor and any additional bill have a great impact in their finance. Second, their structure of income makes the traditional bill payment arduous. Informality is a reality for most of the dwellers in the favelas. This variation in the income difficult monthly payment for electricity. Finally, the per capita demand in slums is much smaller than in regular areas. To reach the houses in the slums require a large amount of investment to expand the grid, however the payoff is quite small.

5. Awareness barrier

Most of the dwellers in the favelas are uneducated. The low level of education limits their awareness on how electricity is generated, its costs and what are the implications of electricity theft (Lipu et al. 2013). Moreover, the limited awareness plus the energy-for-free idea unable dwellers to use electricity in an efficient way, perpetuating waste habits (Silva, 2003).

6. Violence barrier

In Brazil, especially in Rio de Janeiro, the drug dealers or the militias [1] control the favelas (r). The control comprehends not only the territory, but also all the services within. Electricity, water, LPG distribution and even cable TV are controlled by the drug lords or the militias (Cunha et al., 2011). Thus, preventing the formal services to enter in these areas.

Next section describe the importance of human rights in order to trigger a change in the favelas.

GUARANTEED HUMAN RIGHTS

Human rights are validity everywhere and anytime. Independent from gender, colour, place of residence, or any other status. Its scope is very broad - economic, social, cultural, civil and political rights. However, the fundamental assumption is that all humans are moral and rational beings who deserve to be treated with dignity (United for Human Rights, 2015). Therefore, the right to have a safe and healthy environment that provides to dwellers in the favelas choices and opportunities to ameliorate their conditions and their behaviour related to electricity theft.

> "The ideal of free human beings enjoying civil and political freedom and freedom from fear and want can only be achieved if conditions are created whereby everyone may enjoy his civil and political rights, as well as his social, economic and cultural rights."
>
> —International Covenant on Civil and Political Rights and the International Covenant on Economic Social and Cultural Rights, 1966

In the case of this theory of change, the State is responsible to provide access to health, education and safety, in order to have a positive impact in the lives of favelas' dwellers. Unfortunately, the reality is very different, where the lack of access to public services and violence is a constant in the daily life in favelas (UN Habitat).

[1] Militais are formed by police officers, firefighters, security guards, prison guards and military, off duty or on active duty. Many militia members are residents of the communities and rely on support from local politicians and community leaders (Folha, 2014).

METHODOLOGY

This thesis is divided in two parts. The first part is all about constructing a theory of change to decrease electricity theft in the favelas and increase social inclusion of dwellers by solar power adoption. In order to draw a causal pathway (diagram) to meet the goals of this research, it was carried out 13 qualitative interviews with the main stakeholders and actors. Followed by a stakeholder's analysis. The insights from NGO's, academic staff, civil society groups, utility companies and solar companies were essential to build a solid theory for social change.

The second part consists about evaluate different solar devices available in the market regarding to lightning, water heaters and electricity production. An evaluation method is used to explore which solar devices would be more suitable according to the criteria and insights defined by the interviews.

ANALYSIS

STAKEHOLDERS ANALYSIS

The power and interest of stakeholders was analyzed. This is graphically represented in Figure 5 and elaborated below.

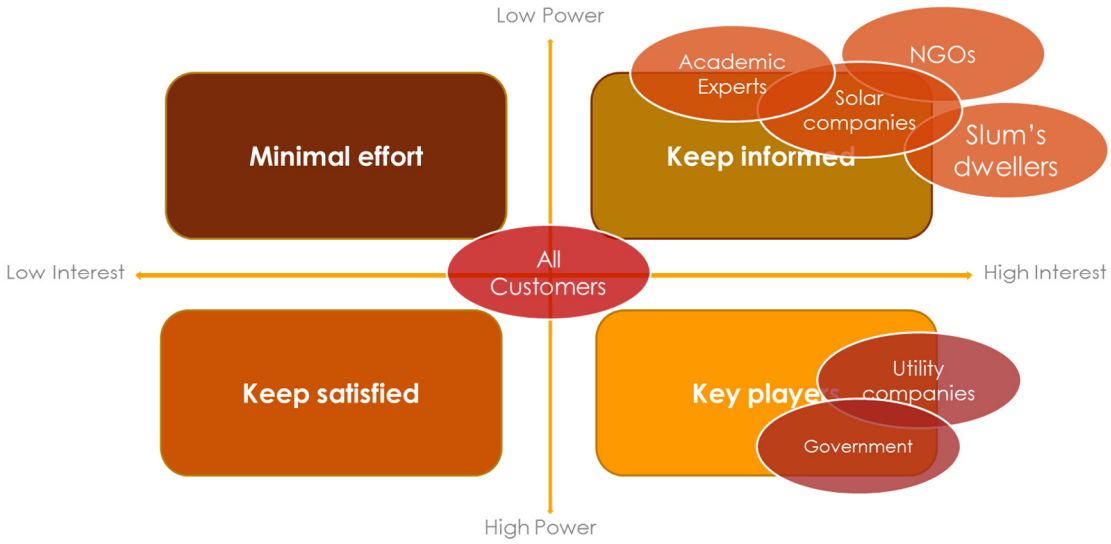

Figure 5: Power and interest matrix **source: adapted from Mendelow, 1991**

(1) All customers is positioned in the centre, because the nature of problem impacts financially everyone connected to the grid (Smith, 2004).
(2) The utilities are key players in this thesis' scenario. They are considered to have high power and high interest due to their core business, providing the necessary infrastructure and finding the most economically feasible way of doing it. Although, they have to follow the policies formulated by the government.
(3) The Brazilian government is seen as key player as well. The loss on tax revenue affects the ability to improve citizens' conditions. In addition, the government has the power to set policies to strengthen renewable energy into the electricity matrix.
(4) Slums' dwellers despite of being directly affected, have little power to change the situation in a long-term.
(5) Solar companies has high interest due to their expertise in the technology and also their interest in the market that can be created. Nevertheless, they are considered to

have low power because the industry does not have much influence in the decision-making process.

(6) NGO's have low power because they are not involved in government and utilities' decision process in poor areas, however they can help to raise awareness among citizens to the problem. At the same time, they have high interest because solar energy could bring improvements to poor people.

(7) Academic experts is believed to have high interest due to their knowledge on the subject and they also provide a good way to promote the electric technology. Nevertheless, they have low power to influence the decision-making of this magnitude.

EVALUATION OF SOLAR TECHNOLOGIES

An evaluation is undertaken to make a comparative assessment between solar devices with different purposes (electricity production, water heating and lightning). It offers the flexibility to assess the alternatives and helps to identify the best compromise solution.

The objectives are (1) decrease in electricity theft rate and help to (2) boost social inclusion in the Brazilian favelas. Based on market development, literature review and interviews with experts and stakeholders, three (3) alternatives are considered, and the features of each solar alternative are described below.

ALTERNATIVES - SOLAR TECHNOLOGIES

Solar energy can be utilized in two forms, (1) passive and (2) active. In the passive form, the most common way is by solar architecture using light tubes. In the active form, solar energy is then converted into electricity or cooling/heating. Figure 6, shows an overview of practical application of solar energy.

Light tubes are structures used to transport or distribute natural light with the purpose of illumination. In other words, uses the daylight to illuminate a household, therefore diminishing its energy use. The assumption regarding to its energy output is around 36 kWh/month. This is the average monthly energy consumption by four inefficient lamps (60 W).

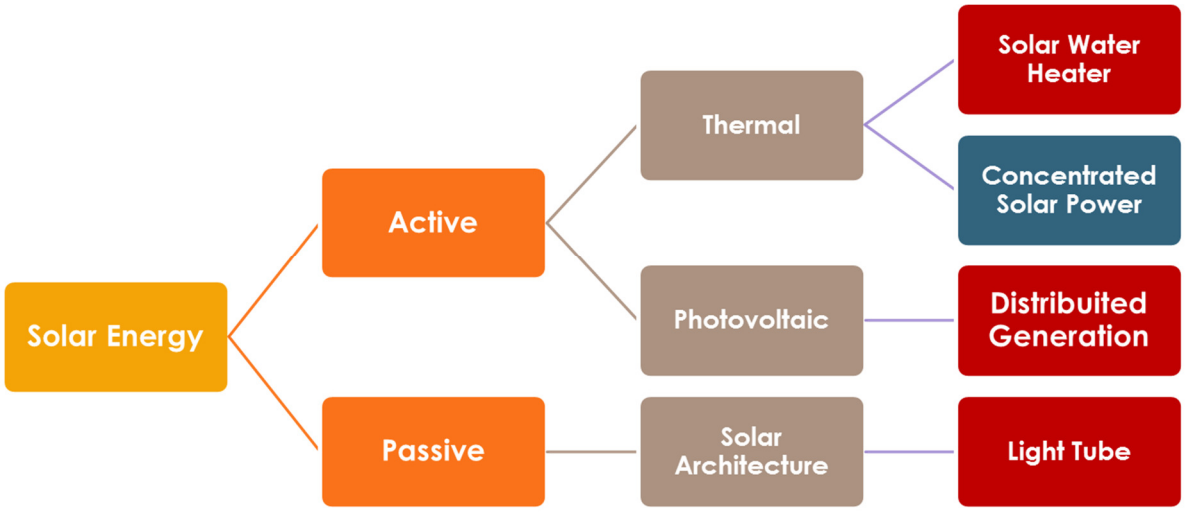

Figure 6: Flowchart of application of solar energy **source: adapted from Tolmasquim, 2003.**

One of the ways of using solar thermal is by solar water heaters (SWH) devices used in households to provide hot water for showers. The main relevance of choosing SWH is that in Brazil, around 72 per cent of households use electric shower. In the winter, it is responsible for around 40 per cent of electricity consumption (Procel, 2013). The assumption regarding to its energy output is around 160 kWh/month for a 200 litres system. This is the average kWh generated by SWH companies in Brazil (Inmetro, 2015).

Finally, the last alternative considerate regards to electricity production is distributed generation. A photovoltaic (PV) system is a well-known technology that converts sunlight into electricity. In the last few years, PV is in a growing market expansion, its efficiency is increasing and its costs are dropping. In addition, PV system can be a solution for households in the favela that are not yet connected to the grid.

To conclude, concentrated solar power was excluded for this study due to its technologic characteristics. It is necessary considerable area and massive maintenance if compared to the other technologies. Its implementation seems not feasible in dense populated areas like favelas.

CRITERIA DEFINITION

The evaluation of solar alternatives can be performed according to different aspects. Three aspects of evaluation criteria are considered in this thesis: economic, social and technological. In order to evaluate the alternatives, four criteria are established, as follow:

1. Costs: This criterion represents the initial investment cost.

2. Contribution to local development: This criterion is based on social and economic effects associated with the technology adoption and its business models i.e. job creation in the area, the importance of dwellers' participation in the business models (production and consumption side).

3. Representation of energy usage: the percentage of which category represents (lightning, water heater and electricity) in energy consumption in a household.

4. Area requirement: area needed for the solar technology.

5. Market uptake: The situation of market penetration for each solar technology in Brazil.

CRITERIA WEIGHTS

In order to assess the criteria weights, assumptions based on literature review was used. As well, stakeholders were asked to weight different categories in pursuance of a change in electricity theft behaviour and an increase in social inclusion in the favelas. The values of weights are presented in Figure 7.

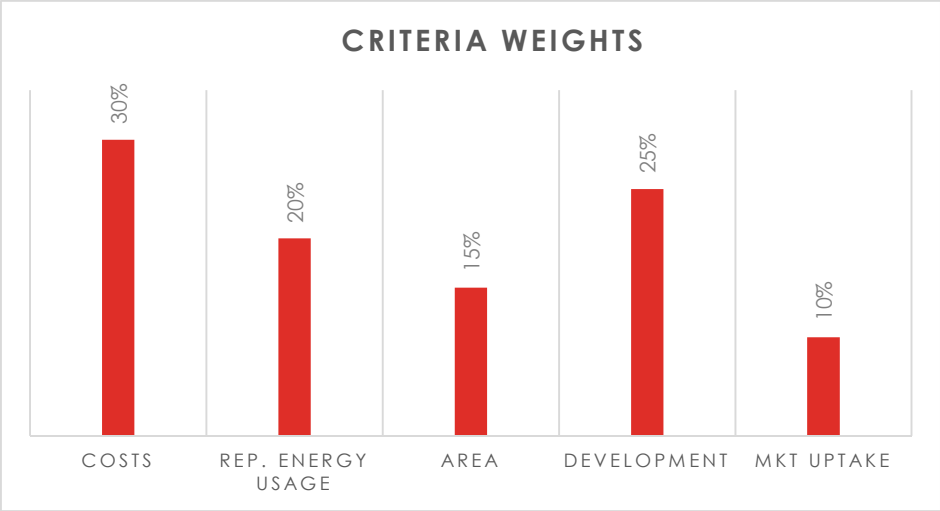

Figure 7: Criteria weights

The graph above shows that the investment costs are the most important aspect, followed close by contribution to local development. As third, appears the representation of which technology has in the energy usage in a household. Then, is followed by area required for the system and for last market uptake.

MATRIX

The matrix presented below indicates the scores of each alternative on each criteria. These scores are based in a regular household in a favela of Brazil with maximum consumption of 300 kWh/month.

Alternatives / Criteria	*Unit*	*Light Tube w/ LED system*	*Solar Water Heater*	*PV System*
Initial Investment Cost	USD	1,200	630	4,750
Representation of energy usage in HH	%	15	40	75
Area required	m2	0,1	2	14
Contribution to local development	---/+++	-/+	--	+++
Market uptake	---/+++	---	++	-/+

Table 1: Evaluation matrix solar alternatives

The scores were based on products` specifications available in the market:

- Light Tube (Solatube - http://www.solatube.com);
- Solar Water Heaters (http://www.dasolabrava.org.br) and;
- PV systems (Insolar – http://insolar.com.br/).

In order to standardize all the scores the pairwise comparison method is used (Saaty, 1990). Therefore, the results are presented in the results of the research.

RESULTS

This study aims to identify the main factors determining the feasibility of solar energy in slums in order to counter electricity theft and improve social inclusion of favelas` dwellers. In a first step, the theoretical framework is applied to all interviews to check which factors are relevant for each stakeholder. Subsequently, the data obtained in the interviews is used to build a Theory of Change regarding to electricity theft behaviour in the slums. For last, an evaluation is made of three solar products available in the market.

INTERVIEWS

Firstly, the interview was composed of nine standard questions. The questions captured the main aspects of the problem, the perception of theft, the barriers for solar in slums and what would be necessary to be done to overcome them. Details of all the interview participants can be found in Appendix 2, with details of each interview in Appendix 4.

THE PROBLEM AND ITS IMPACT

The first question was in what extent electricity theft in slums is a problem. Ten of 13 interviewees stated that electricity theft is a social problem rather than economic or criminal problem. The NGO Teto and the utility companies emphasized that electricity theft is a safety issue, causing fires and therefore becoming a risk to dwellers' lives. Greenpeace also added the view that the lack of government presence in favelas and its incapacity increases access to such essential service.

Furthermore, utility companies also pointed that electricity theft is an economic problem, affecting in its revenue. The financial loss was also mentioned by dwellers as a problem caused by theft. They told that home appliances were lost by the electricity's oscillation. In addition, dwellers mentioned the feeling of been guilty for doing something wrong. However, this was the only way to obtain electricity in their neighbourhoods. It was said as well, that electricity theft enhances social exclusion and poverty of favelas' dwellers.

To conclude, most of the interviews stated that electricity theft is a problem for all society and every person is affected by it, especially in the economic aspect.

COULD SOLAR POWER HELP?

Then, was asked if solar energy could alleviate the currently situation, and if so, how it could help. Therefore, 12 of 13 interviewees declared that solar power could help to diminish electricity theft. The one against mentioned that solar power would be just another way to generate electricity and therefore, it will not contribute to decrease theft wherever it would be implemented.

Subsequently, it was asked how solar power could help to ameliorate the situation. Under the circumstances, five interviewees declared that solar power could help to reduce monthly costs in a low-income household, helping to increase their savings. Likewise, the energy would be consumed where is generated, reducing the need for theft and diminishing future investments in infrastructure (transmission and distribution). In addition, utility companies believe that solar power would be helpful only for households (recently) connected to the grid.

It was also mentioned that solar power could create local jobs, improve the awareness of favelas' dwellers and empower the community.

FUNDAMENTAL CONDITIONS FOR SOLAR IMPLEMENTATION

For this thesis, it was important to know what the indispensable requisites for solar implementation in favelas are. Thus, utility companies, NGOs and solar companies answered that community participation from the conception to the project's execution is essential. They also mentioned the importance of making clear the pros and cons of such implementation to dwellers.

Create value that community can perceive and be connected to grid, were also mentioned by solar companies. In addition, Eletrobrás Amazonas mentioned that the energy output from solar devices would need to match the household demand to be effective.

Finally, dwellers declared that the affordability of solar devices is crucial. Utility companies, NGOs and solar companies share this view.

BARRIERS

Subsequently, it was also asked what the main barriers are for solar power implementation in favelas.

Not surprisingly, most of the interviewees mentioned financial aspects as a barrier. Lack of access to credit, affordability and high up-front payment as the main issues. Further, cultural obstacles were cited, such as inserting a technology with which the dwellers are not used and that will bring changes in their daily lives (such as the issue of having to deal with a utility bill).

Figure 8: Overview of barriers cited by interviewees

In addition, was cited their disbelieve in projects' impacts, the non-payment culture, the short-term way of thinking, low awareness and the high turnover of dwellers in some favelas. The dwellers stated that the imposition of projects with ready solutions, with no flexibility and dialogue is also an obstacle for implementation.

The interviewees also mentioned social barriers such as social inequality, corruption and even lack of political will to deploy solar power in Brazil. Utility and solar companies cited

other impediments like infrastructural and technological. Such as poor housing infrastructure, the need to use batteries, and more robustness and safety of solar home systems.

PUSHING THE BARRIERS AWAY

What is necessary to be done to overcome the previous barriers? The answers presented by stakeholders are presented bellow.

1. Community participation and value creation

There was a consensus among the interviewees that allowing and enhancing community engagement is one of the main alternatives to overcome cultural and social obstacles. In addition, empowering dwellers was also mentioned as a solution to help to run-over financial and social barriers.

2. Compact, mobile and robust solar systems

Solar companies expressed that is necessary to use materials with no commercial value (i.e. no copper for SWH) with attention to the safety of the systems. As well, the importance of mobility, taking into account that dwellers modify their houses constantly or even just move to another place.

3. Social Programs and flexibility

Utility companies mentioned the importance of social programs focused on income generation in favelas. Further, more flexibility and more ideas exchange between projects' leaders and dwellers are valuable to overcome impositions of projects.

4. Investments

Utility companies declared that following the national rule to invest 0,5 per cent of their operational revenue on energy efficiency in poor areas that the connection to the grid have been recently regularized, is one way to ameliorate the situation.

5. Government incentives for solar energy

NGOs and academic experts attempt that the Brazilian government should create more incentives for solar adoption. According to them, this could be done by raising awareness for the solution and removing financial obstacles like taxation in solar electricity generation.

6. Focusing on places with social importance

It was mentioned by solar companies and academic experts the importance of implementing solar devices first in places where its social relevance is high. For example, churches, community centres, schools or sport centres.

CHANGE ON ELECTRICITY THEFT BEHAVIOUR

Furthermore, it was requested to state the importance of the following categories in order to result a change on electricity theft behaviour: (1) access to education and (2) guaranteed human rights. Then, (3) the importance of a sustainable environment, (4) affordability of solar solutions, (5) the relevance of better governance (government and

utility company) and (6) possibility to generate income due to solar implementation. Thus, table 5 demonstrates the results below.

		Access to education	Guaranteed Human Rights	Sustainable environment	Affordability of solar technology	Better governance (government and utility company)	Possibility to generate income due to the adoption of solar energy
NGOs	Teto Brasil	4	5	2	5	3	2
	Greenpeace Brasil	5	5	3	4	2	3
	The African Solar Cooperative	1	3	1	4	4	2
		3,33	4,33	2,00	4,33	3,00	2,33
Academic Expert	Hilaine Yaccoub (Social)	5	5	5	5	5	5
	Prof. Dr.Ing. João Tavares Pinho	5	3	3	4	4	5
		5,00	4,00	4,00	4,50	4,50	5,00
Dwellers	São Paulo	5	3	5	5	5	5
	Rio de Janeiro	4	4	4	5	5	4
		4,50	3,50	4,50	5,00	5,00	4,50
Utility Companies	Eletrobrás Amazonas Energia	5	4	5	5	5	5
	AES Eletropaulo	5	5	4	5	4	5
	Coelba	2	2	2	5	3	4
		4,00	3,67	3,67	5,00	4,00	4,67
Solar Companies	E2Solar	1	2	5	5	2	3
	Insolar	5	5	5	5	4	5
	Devergy	1	4	1	4	3	5
		2,33	3,67	3,67	4,67	3,00	4,33
	Overall	3,69	3,85	3,46	4,69	3,77	4,08

Table 5: Importance of categories in order to change electricity theft behaviour

The results were obtained by asking the interviewees to give a number to each category being 1 less important and 5 the most important feature. This data was used to (1) assist in the formulation of ToC and (2) try to capture the main aspect(s) that can result in a change to favelas` dwellers.

OUTCOMES PATHWAY – THEORY OF CHANGE

The hypothesis defended by this ToC is: *the more solar power technologies in low-income areas are adopted, the less the electricity theft's rate will be*. Thus, the key assumptions underlying the theory of change for this study are as follows:

1. That the adoption of solar power in poor households/areas will increase utility companies' revenue and dwellers savings.
2. That business models are harmonised and aligned with favelas' dwellers situation and needs.
3. That enhanced community participation will lead to increased awareness of the problem and the solutions within.

4. That provision of training to favelas' dwellers will result in job opportunities.
5. That ensure human rights to dwellers will have a positive impact on the relationship between dwellers, utilities and government.

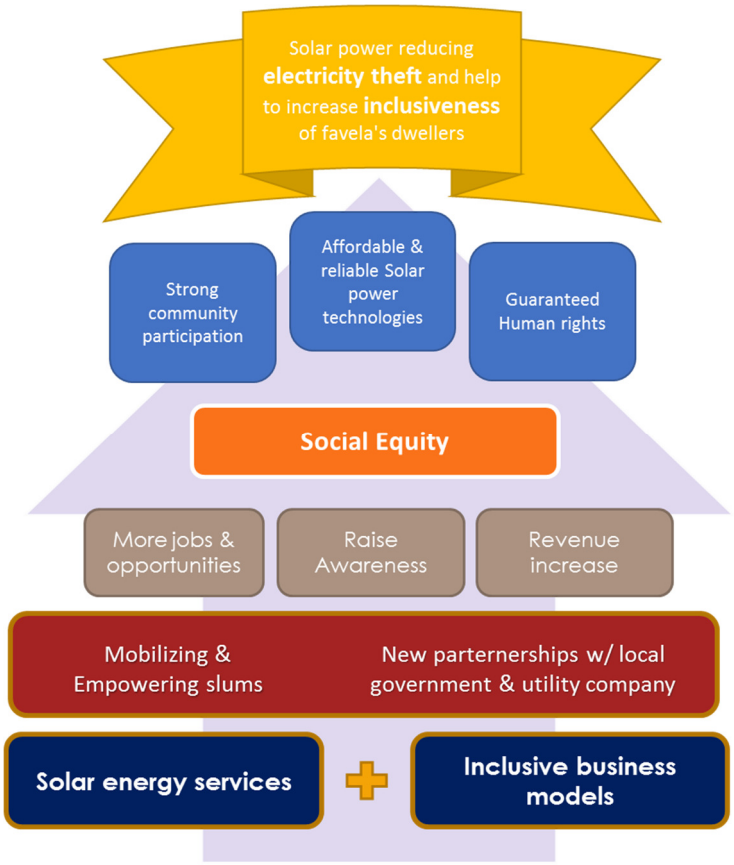

Figure 9: Diagram of change towards less electricity theft and more social inclusion

What is necessary to be done in order to achieve the long-term goals? Solar power comes as a solution to this issue by enabling poor households to increase their savings and utility companies their revenues. In the households' perspective, solar power will protect them from electricity prices oscillation throughout time and will lower their electricity bills when connected to the grid. For the ones not connected to the grid, solar and/or utility companies could use solar devices as a new way to approach dwellers to regularize their situation.

However, only solar technologies itself will not be able to accomplish the desired goals of this ToC. Firstly, solar and/or utility companies necessarily need to adopt inclusive business models. Such models will allow poor people to be able to afford equipment, overcoming the financial barriers such as high upfront payment and lack of access to credit. For example, this can be done by adopting the PAY-AS-YOU-GO system, asset finance or any other system that fits the needs and capacity of dwellers.

In addition, these 'new' business models should as well incorporate dwellers into their production side system. It is necessary to perceive the favela's dwellers as potential employees or suppliers in the production and/or distribution chain. This can be achieved by providing proper training and enhancing community participation since project's

conception to its execution. Thus, dwellers will be able to benefit from income generation and by having access to quality services.

Such empowerment aligned with new partnerships with utility companies, local governments and private sector will results in new ways to increase dweller's social inclusion. In Brazil, your address proof is associated with the electricity bill, therefore the lack of such document results in more exclusion for those living in areas that are not attended by any utility company, but still has access to electricity by theft. This situation can be alleviated by new partnerships between such institutions.

Therefore, these actions will have a positive impact on social equity for favela's dwellers by increasing job opportunities, raise their awareness towards the problem and definitely, it will assist utility companies to increase their revenue.

To conclude, the goals in the favelas will be achieved based on affordable and reliable solar power devices with strong community participation enabling growth in human rights within the favelas.

EVALUATION OF SOLAR TECHNOLOGIES

This section demonstrates the scores obtained after an assessment on multi-criteria`s premise of the chosen solar devices for this study (light tube, solar water heater and PV systems). The scores were obtained by using the software M-Macbeth beta version 3.0.0 (www.m-macbeth.com).

Alternatives	***Total***	*Costs*	*Representation*	*Area*	*Development*	*Mkt uptake*
Light Tube	**43,22**	51,70	21,87	100	33,33	0
SWH	**59,97**	100	58,31	68,70	0	80,0
PV	**52,26**	4,20	100	0	100	60,0

Table 6: Scores of solar devices alternatives

The results demonstrate that light tube is the last feasible device to be implemented in a favela's household. Most due to its high costs compared to SWH, its low market penetration and its capacity to attend only the household lightning.

In the other hand, solar water heater is the most suitable alternative for a household to invest. This is most due to its costs much lower than PV system and Light tube. In addition, SWH requires much less space than PV to be implemented.

However, PV systems has as advantage a well-defined business models that incorporates slum dwellers into its production and consumption system. Taking into the account that its business models can lower costs to the household and improve the community with program training, etc. PV system is an interesting alternative to be explored.

To conclude, this evaluation demonstrates the importance that a business model has into the implementation of any solar alternative in a poor area like a favela.

DISCUSSION AND RECOMMENDATIONS

This chapter reflects on the findings reported in the last chapter with respect to relevant literature and their implications for solar energy implementation in the Brazilian favelas. The objective of this research was to explore in what extent solar energy could help to diminish electricity theft and assist favelas' dwellers to increase their inclusiveness in the Brazilian society.

According to the results obtained in the interviews, it is clear that electricity theft in low-income areas is a social problem more than criminal. Poor people experience variations in their income from time to time (Schreiner & Sherraden, 2007), thus transforming monthly utility bills into a challenge to be overcome. In addition, most favelas are located in areas not recognized by local government, thus such 'neighbourhoods' are not perceived by utility companies. Consequently, leaving dwellers without a formal and legal way to obtain electricity into their homes.

As well, in favelas ruled by organized crime, the common way to obtain access to electricity is by theft (popular known as "*gato*"). Dwellers have to pay high amounts of money to criminal organizations for such "services" and are left with no other choice. Either by lack of knowledge on other alternatives, either by violent repression by such organizations.

INTRODUCING SOLAR POWER FOR FAVELAS' DWELLERS

Taking into account such background, the main point is: how to operationalize the ideas given in the last chapter? First, solar power itself will not solve any of the problems described in this study. The results demonstrate that allowing community participation since the conception of the project to its implementation, most of the social-cultural barriers tend to be overcome (Mathbor, 1997). By presenting in a clear way to dwellers that the benefits will be higher than the costs, the chance of success become much higher. However, there is no prescription on how community participation should be planned in such a complex environment.

In order to ensure favela community's participation and reduce the risks of project's implementation, first it is essential to check the level of organization within the community and how the problem is affecting them. Then, begin with presenting too many dwellers as possible about solutions and changes that will happen within. This would result in exchanging ideas where it is possible to analyze dwellers' feedback and their willingness to participate.

Furthermore, by using the insights of dwellers it will be possible to define which solar technology will be more appropriate to implement. This study focused on solar water heaters, PV systems and light tubes. The analysis showed that solar water heaters are the most feasible to be implemented in the favelas for its low costs and its capacity to substitute electricity to heat showers. However it does not allow dwellers to use solar energy for other purposes i.e. watch TV or listen to the radio.

The PV systems despite its high price, demonstrates great potential to be implemented in in the favelas. The results from the interviews suggests that the best way to introduce it to dwellers is focusing first on places with high social importance like churches, community

centers, day care centers, etc. Then, it could be carried out to the households within the neighbourhood.

Light tubes showed to be not so interesting to counter the issue. Its application is limited only for lightning that does not represent much of the electricity consumption within a regular household. In addition, it requires more intervention in the houses and its technology is still not yet mature compared with the other alternatives. Nonetheless, it could be useful in schools and churches within the community where the need for lightning is more representative than in a normal household.

To conclude, despite of the results showing that SWH, followed by PV are the best options to achieve the goal, it is necessary to take into account the limitations of this study regarding to in-depth fieldwork. It is wise to do a detailed assessment into the community's characteristics as socio-economic situation, level of safety and electricity consumption profile in order to choose the best solar alternative.

MONEY WAS A PROBLEM

Another important aspect of solar power implementation in favelas are the costs associated to it. There is almost a unanimity among the interviewees that affordability can dictate the success of solar power in favelas. The price per Kwh needs to be cheaper or at least utility companies should charge the same price. Offering a solution with affordable prices to favelas' dwellers is a challenge that requires innovative business models.

In the last years, such business models are popping up in developing countries, especially in the Sub-Saharan Africa. Similar ideas can be implemented in favelas of Brazil. For example, the PAY-AS-YOU-GO systems with recharges made by scratch cards, or by mobile phones can help overcome the income variation common among low-income people. New forms to finance solar devices are already been used in the renewable energy sector throughout the world. Asset finance, for instance, is a form of financing frequently used by larger commercial companies, but still relatively new in the small-scale solar sector. In long-term operations, dwellers could pay for their solar home system in monthly basis with the savings generated by solar power in their utility bills.

This study is aware of the risks associated in a long-term operation as financing PV systems up to 12 months for low-income customers. A case in point is that selling with credit is different. Most of sales complete on delivery, however sales with credit ends when the last payment is made. Therefore, all benefits, terms and obligations should be crystal clear to the customers. A further reason is that such an operation will involve credit assessment and there is the possibility that some of the dwellers will not be selected, thus a way to conduct the rejection becomes important. A second reason is that customer satisfaction needs to last the whole length of the credit term. Then, close attention is necessary to product's performance and after-sales support.

Nonetheless, in order to define a suitable business model to act within a favela it is necessary to know the social-economic conditions of the area and try to merge the expertise and expectations from utility companies, solar companies and community leaders. Utility companies could give the financial support to solar companies to operate in such communities. Community centers would work as a hub to incorporate the dwellers participation as much as possible in the process of change.

Furthermore, the essential part of the ToC presented in this study is to enable dwellers' participation into the supplier side (Hahn, 2012). Use their expertise whenever is possible. A good example is to provide them training on how to install and maintain solar systems. This will increase their job opportunities and their knowledge towards the situation. By empowering community, the chances to ensure a sustainable future to the business and trigger a change in electricity theft behavior are increased.

Furthermore, in order to build a sustainable future for the inclusive business models it is advisable to stipulate a counterpart from the dwellers for the training provided. Such counterpart does not necessarily needs to be financial. It can be symbolic. For instance, dwellers will have to pass the knowledge acquired to at least another dweller, thereby strengthening the proposal of change.

To conclude, it is highly recommended that utility companies participate actively in the solar adoption together with solar companies in the favelas. They still invest heavily in tampering proof and smart meters, however in poor areas electricity theft is a result of a social distortion (Smith, 2004; Depuru et al. 2011). This could be seen as an investment alternative for utility companies to tackle electricity theft and an opportunity to break relationship barriers with dwellers in low-income areas.

BENEFITS TO GO SOLAR

The stakeholders contributed with insights on how solar power could help to ameliorate the situation. Then, this study is able to provide some strong reasons why solar can be beneficial to utility companies, low-income people within, and outside the favelas and to solar companies.

The most important reason is that solar power can help to lower electricity bills and therefore reduce the need for theft. The majority of dwellers do not feel satisfied with the quality and the problems associated with electricity theft. However, by connecting them to the grid they will feel the burden of having another bill to pay. This is where solar could assist the dwellers to have a bill according to their income and ensure revenue to utility companies.

Moreover, solar power can diminish future investments on transmission and distribution. The main reason is that the power would be consumed where it is generated, making such investments in a long-term less necessary. It can also reduce technical losses increasing efficiency of the whole energy system.

Finally, the usage of solar power in favelas can help to alleviate poverty by not only increasing dwellers' savings with reduced monthly bills, but also by opening a new market where solar companies can act. More jobs and opportunities for dwellers can be created with the empowerment provided by inclusive business models.

NEW PARTNERSHIPS

The ToC designed for this study enhances the establishment of new partnerships among stakeholders and other actors. Innovation in cooperation using solar energy between utility companies, local governments and dwellers can lead to new opportunities for all sides. For example, utility companies can benefit from innovation in their business model in order to (1) raise their revenues in areas where the theft rate is high, (2) in long-term

adequate their business model to commercialize small-scale consumer-side renewable energy (Richter, 2013).

A good example is the project "Light Recycle" launched by Light, a utility company from Rio de Janeiro, that provides discount on electricity bills and in exchange get recyclable waste in Santa Marta (Ost & Fleury, 2013). Moreover, utility companies could provide for dwellers using solar power proof of residence. This is important for the individual's citizenship status (Ost & Fleury, 2013).

Finally, with government's incentives solar and utility companies can help to democratize solar power in the country. By that, Brazil can decrease its dependence on rain for hydropower and fossil fuels for thermoelectric plants. Local government will also benefit from increase in tax revenue, since tax load on electricity bill is 45 per cent (Klein et al, 2012).

VICIOUS CIRCLE AND POVERTY CRIMINALIZATION

The interviews results show a correlation between electricity theft and energy poverty. Dwellers from Rio de Janeiro and São Paulo declared that in the past (two to three years ago) the only way to access electricity was by theft. Therefore, without the availability of formal electricity, favela dwellers often had to take the initiative in acquiring them. This situation aligned with high prices for electricity, shows a vicious circle in urban areas between being energy poor and electricity theft. Somebody steals electricity because he/she has no access to electricity or because this person cannot afford it.

Solar energy can break this vicious circle of low incomes preventing access to modern energy services. The problem is to overcome the high costs of solar technologies, thus it determines again the importance of innovative and inclusive business models to attend favela dwellers.

To conclude, for years government and utility companies focused in criminalizing electricity theft without distinguishing between urbanized areas and favelas. In areas where theft is the only 'solution' to access electricity, with such no distinction, is evident poverty criminalization. In one hand, it is necessary to have punishment for those who steals power. However, in the other hand, a different approach is necessary by authorities to tackle the problem, because only putting poor people in jail will not solve it.

CONCLUSION

Overall, the aim of this study has been to explore in what extend solar energy services could help favelas' dwellers to have access to clean, quality and affordable electricity. At the same time, provide utility companies and authorities information on how solar can be used as an alternative to counter electricity theft and enhance people' lives in the favelas.

A further reason, is the price of electricity in Brazil. It is increasingly expensive, this year (2015) the price is expected to raise more than 40 per cent. As consequence, the rising of payment defaults of low-income people can be substantial. However, it can be contained with the deployment of solar energy in such poor areas. Thereby, raising the quality of life and democratization clean energy to all citizens.

This research project shows the high relevance of innovative and inclusive business models to overcome financial hurdles presented in an environment where poverty is the rule and money talks louder. As well, it makes evident the importance of community cooperation in all parts of solar project implementation. By empowering people within the favelas through training and considering them into the supplier side the impact of such project can be higher and consistent. By such project implementation, new perspectives should rise in the favelas and help to shape behaviour towards a sustainable use of electricity and its impacts. One of the strong reasons for this thought is that poor people would feel the benefits and impact much more than people in areas already urbanized.

The ToC supporting this study is not a magic bullet and requires constantly reviews and improvements. The interviews tried to comprehend all the stakeholders involved in the issue, however due to financial constraints the study could not count with fieldwork, and thus, could not provide in-depth results towards solar technologies.

Regarding to future researches, more studies attesting the feasibility and impacts of solar power in low-income households outside the favelas is beneficial for democratization of renewables and acceleration towards energy transition. As well, the ToC framework and business models presented in this dissertation could be extended to lower income households in developed countries in order to expand the range of renewables.

In conclusion, solar power has the potential to bring social equity into the favelas not only in Brazil, but also throughout the world. Solar power aligned with inclusive business models enable a new market to be explored by solar companies. As well, it enables independence towards power generation and can be at the same time a threat or an opportunity to utility companies. It depends on how they look at it. Brazil has privileged solar irradiation on its territory and should use it clever to provide development and sustainability to its citizens.

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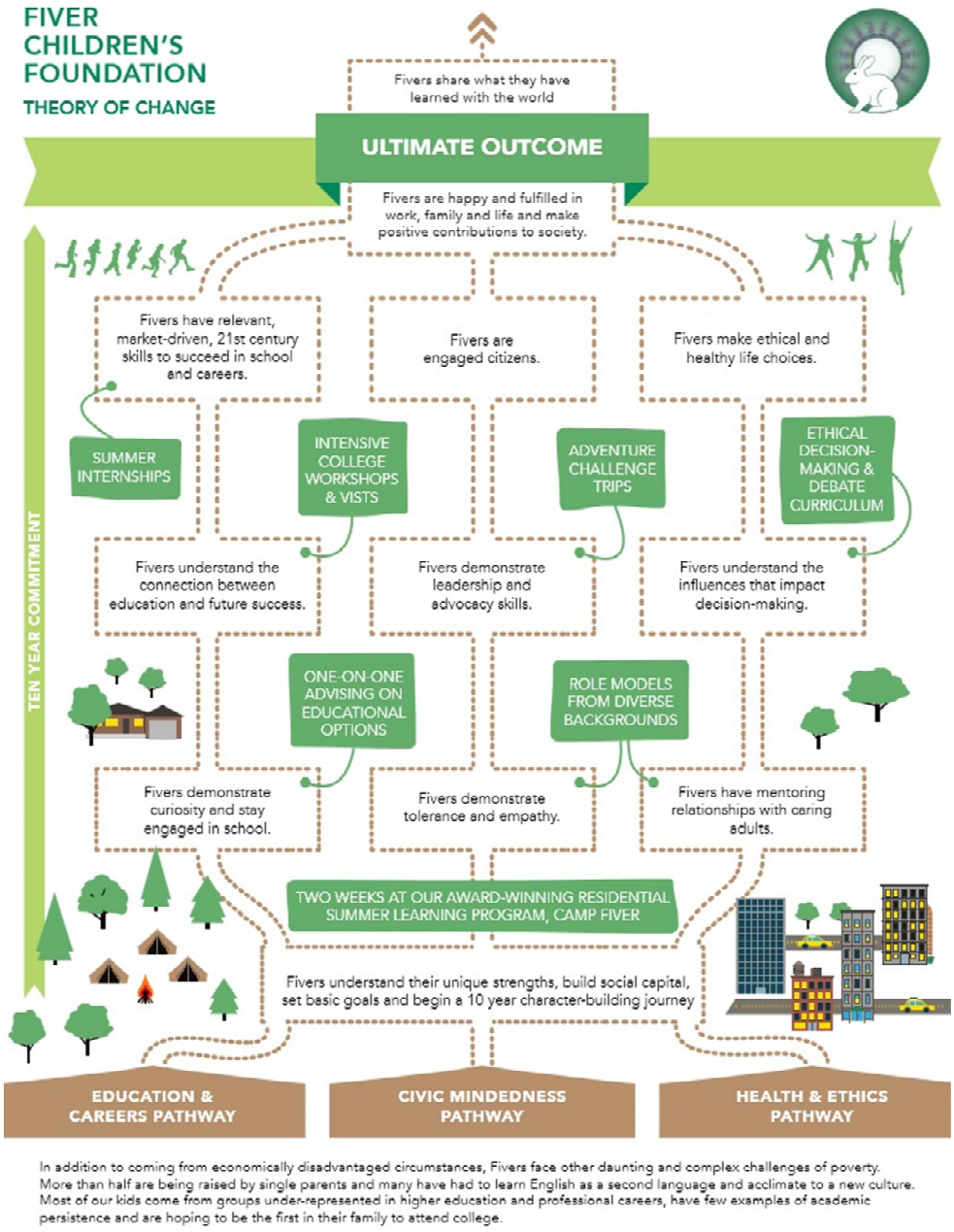
APPENDIX 1 – EXAMPLES OF TOC

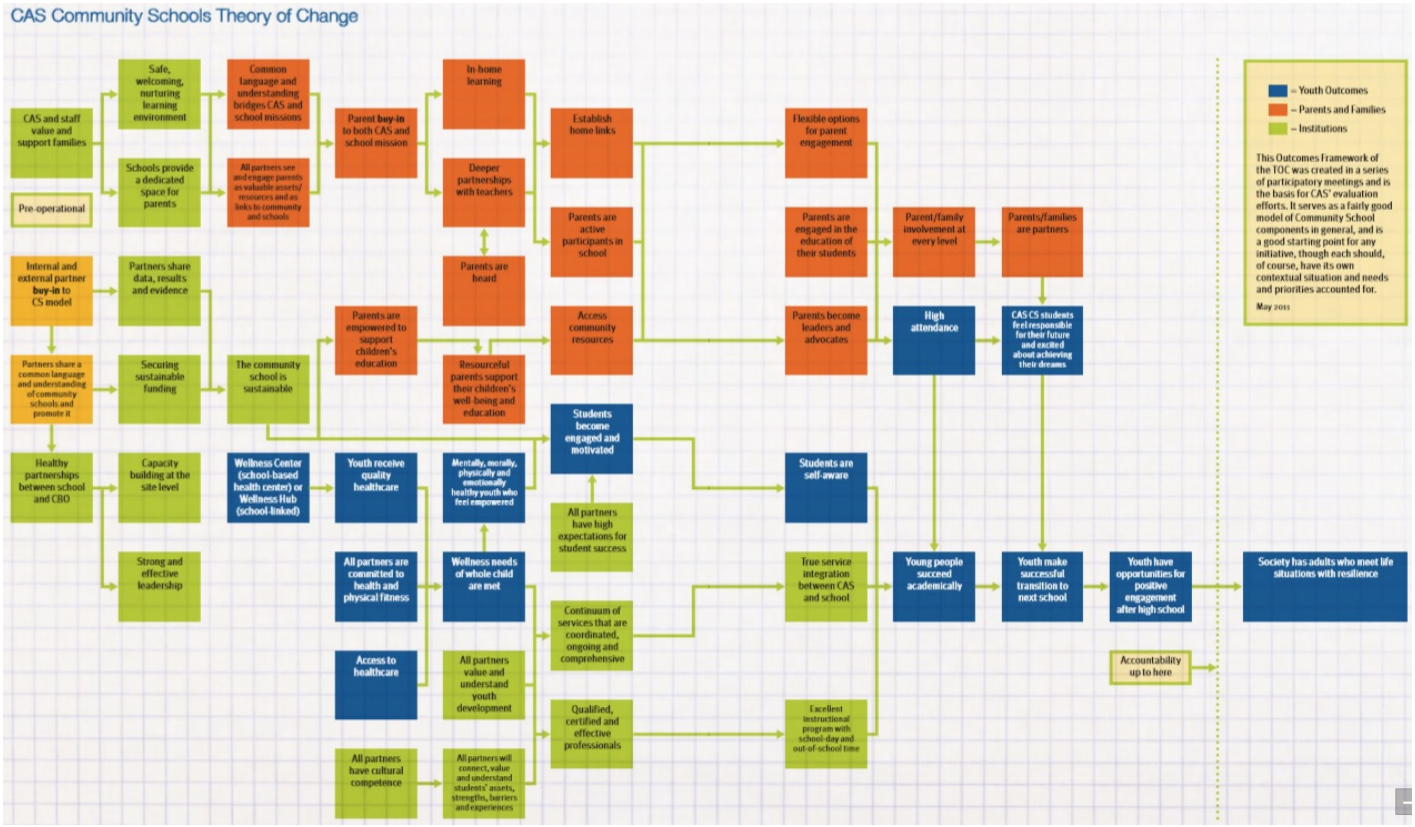
Below are presented, few examples of theories of change around the world regarding to different subjects.

Fiver Children's Foudantion Project – Theory of change developed by Fiver Children's Foundation with ActKnowledge, which provide a key foundation for evaluation, communication, planning, organization and staff development.

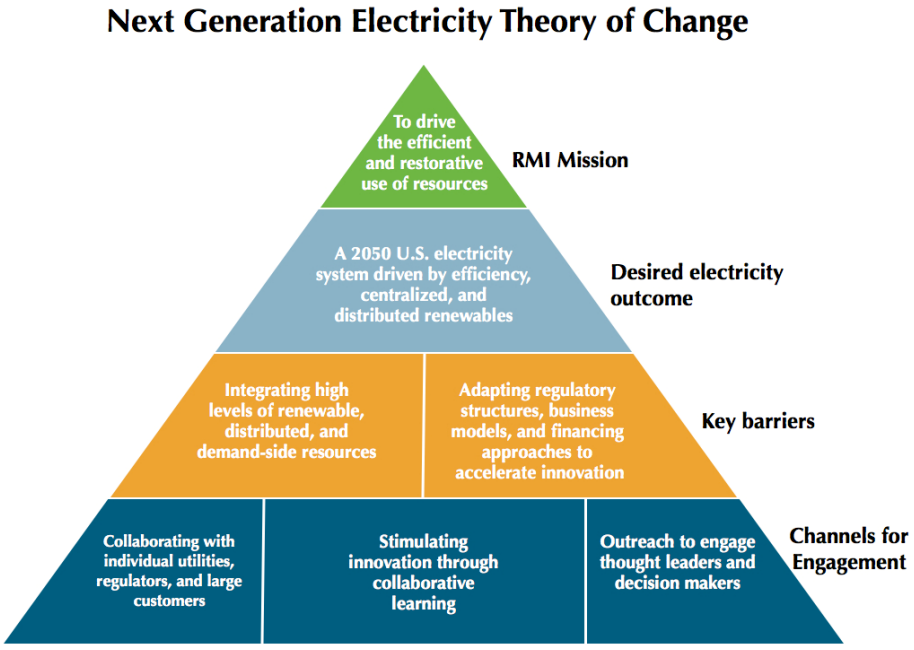


In addition to coming from economically disadvantaged circumstances, Fivers face other daunting and complex challenges of poverty. More than half are being raised by single parents and many have had to learn English as a second language and acclimate to a new culture. Most of our kids come from groups under-represented in higher education and professional careers, have few examples of academic persistence and are hoping to be the first in their family to attend college.

National Center for Community Schools – Building Community Schools: A Guide for action (2011). Theory of change guide on building and sustaining community schools.



Rock Mountain Institute – Theory of change on accelerating the transition to a more renewable electricity system in the U.S. by collaborating with industry leaders.



APPENDIX 2 – LIST OF INTERVIWEES

#	NAME	INSTITUTION	CLUSTER
1	Sacha Senger	Teto Brasil	NGO
2	Hilaine Yaccoub	Universidade Federal Fluminense	Academic expert
3	Maria de Lourdes Andrade Souza		Slum dweller
4	Sustainability department	AES Eletropaulo	Utility company
5	Barbara Rubim	Greenpeace Brasil	NGO
6	Prof. Dr.-Ing. João Tavares Pinho	Universidade Federal do Pará	Academic expert
7	Robson Bastos	Eletrobrás Amazonas Energia	Utility company
8	Bruno Batista	E2Solar	Social enterprise (solar)
9	Henrique Drumond	Insolar	Solar company
10	Monique Rocha		Slum dweller
11	Fabio de Pascale	Devergy	Solar company
12	David Boyd	The African Solar Cooperative	Social enterprise (solar)
13	Credit recovery department	Coelba	Utility company

APPENDIX 3 – INTERVIEWS QUESTIONS

1. In what extent, do you see electricity theft in slums as a problem? If not, why?
2. Do you believe that solar power could help to diminish electricity theft in poor areas? Please explain your answer.
3. According to your point view, what are the main barriers to implementing solar energy in poor communities (perspectives: social, economic, technical, etc.)? Please explain your answer.
4. In your opinion, what are the basic requirements for implementation of solar projects in poor communities?
5. It is possible to implement a project in slum with high crime rate?
6. What is the importance of the following categories, in order to result a change on electricity theft behaviour for slums' dwellers? (being 1 less important and 5 most important.)

	1	2	3	4	5	N/A
Access to education						
Guaranteed Human Rights						
Sustainable environment						
Affordability of new technology						
Better governance (government and utility company)						
Possibility to generate income due to the adoption of solar energy						

7. According to his point of view, how the deployment of solar energy can contribute to the development of slums?

APPENDIX 4 – INTERVIEWS

NAME	JOB TITLE	INSTITUTION	DATE
SACHA SENGER	Director of Diagnostic	Teto Brasil	6/5/15

Background:
Teto is a NGO focused on poverty alleviation in Latin America and Caribbean. The organization works in favelas rebuilding houses with volunteer work (more than 25 thousand volunteers). Present on more than 90 poor areas in Brazil.

- In their perspective electricity theft is a risk for the lives of the dwellers due to fires caused by system overload.
- Electricity theft is also a problem to legalize the land that is situated the settlement. Areas with no formal connection of electricity hinders the settlement process of the communities. It impedes the dwellers to have an address proof without this document they are not allowed to open bank account, have access to credit or having an ID. It enhance the social exclusion.
- In her point of view, solar energy could help to diminish electricity theft only if the solution would be affordable or for free. It also depends on which level of poverty the dwellers are, for extreme poverty this is not the solution.
- Another barrier is the turnover of residents. Heavy flow of sale and purchase of houses.
- According to Teto, the best way to introduce solar power into a favela is getting in touch with the community leaders[2] to explain the benefits and the hurdles of the project. Better if a NGO is already working with the area. Areas that already have a level of organization structured.

NAME	JOB TITLE	INSTITUTION	DATE
HILAINE YACCOUB	**Antropologist Consultant**	**Universidade Federal Fluminense**	7/5/15

Background:
Hilane holds an MSc and PhD in Anthropology from Universidade Federal Fluminense and is an expert in consumer behaviour. She lived almost a year in a favela in Rio de Janeiro to study the behaviour of electricity theft. Ampla Energia, the utility company responsible to provide electricity to the state of Rio de Janeiro, sponsored the project. In 2010, she wrote her Master's thesis addressing the problem of electricity theft by making a profile of the favela's dwellers. Hilaine is a professor at Escola Superior de Propaganda e Marketing (ESPM) and Instituto Europeu de Design (IED).

- In Hilaine's point of view, electricity theft has its roots in the history of the favelas. When the government denied its existence and pushed the favelas far from the

[2] Is common each favela to have an community centre where they try to find they own solutions for their problems and a way to organize themselves to pressure the local authorities for improvements.

city limits. She pointed that the migration of people from the rural areas to the big cities also have an impact to the problem. The areas have no attention from the utility companies due to the lack of safety and the low electricity demand. The regularization is expensive for such a low demand.

- Was also mentioned the pressure that the drug dealers puts on the regularization, for them is better to have streets with no lights and sometimes they control the illegal connection scheme.
- The corruption from the employees of the utility company also help to enhance the problem. They offer the dwellers the illegal connections for a fee.
- She believes that solar energy can help to diminish electricity theft in the favelas. A good way of doing it is giving the dwellers the power to control their own bill with a metering not in kwh, but in money. Showing them how much they are spending.
- The main barriers to implement solar energy in the favelas mentioned by Hilaine is the lack of presence of the government. The discontinuity of the government's programs in these areas generate discredit among the dwellers for any other new proposition presented to them.
- The basic requirements for the success of solar energy in the favelas, according to her, is based on dialogue with the community, proof that the solution works, understand the culture and values of the favela. Brake down prejudice towards the favela and its people.
- She mentioned that the social tariff (the subsidy for the electricity bill) does not reflect with the dwellers' reality. The dwellers' salary is still not enough to cover the new bill even with the social tariff.
- One important aspect mentioned by her is that electricity theft is not entirely related to social condition, but also how the population sees the government. The idea that "is not ok to steal from the neighbour but is ok to steal from the government" is large disseminated in the favelas that Hilaine lived.

NAME	JOB TITLE	INSTITUTION	DATE
MARIA DE LOURDES ANDRADE SOUZA (LIA)	Community Leader	Vila Nova Esperança – São Paulo	14/5/15

Background:
Lia is a community leader in the 'Vila Nova Esperança', an area with 600 households (approx.. 3000 people) in São Paulo. The first dwellers settled in the 1960's. Until 2013, the only to obtain electricity was by illegal connection. This year, the Vila Nova Esperança had its connections regularized by AES Eletropaulo, however there are still households relying on illegal connection.
The dwellers have a basic knowledge on solar energy and its benefits. AES Eletropaulo is studying to implement solar water heaters in the houses to diminish the consumption of electricity used in the showers. She mentioned that the area is safe with no presence of the drug dealers or militia in the area.

- She mentioned that human rights is a luxury in her area. The policy is seen as threat. She continues, "First they beat then they ask".
- The problems brought by electricity theft were:
    - The feeling of theft, having something that is not yours by right.

    - Quality of electricity, a lot of oscillation. One could not turn the TV and other device at the same time.
    - Financial loss, most of house appliances lost due to poor quality of electricity.
    - Social inclusion: they could not have a proof of address, thus there was not possible to have a bank account, access to credit or even having specific documents.
- She believes that solar power can help to the community to save money with lower bills to pay and they can have an increase in electricity quality.
- Money is the most important aspect related to the implementation of solar in poor areas. Is necessary to be cheap.

NAME	JOB TITLE	INSTITUTION	DATE
AES ELETROPAULO	Sustainability sector	AES Eletropaulo – Utility company	14/5/15

Background:
AES Eletropaulo is a utility company that integrates the AES Group Brasil and serves 24 municipalities in the metropolitan region of São Paulo - including the state capital, a key economic and financial centre of Brazil and the world.
Considered the largest utility company in Brazil in terms of energy distributed, the company operates in a concession area with high population density, which has the largest GDP in Brazil.
More than 20 million people served, responsible for more than 46.000 GWh, representing almost 10% of the electricity consumed in Brazil.

- The company believes that electricity theft, apart being a problem that generates financial loss, also requires special attention in the poor areas due to their precariousness that could cause serious accidents and fires.
- They recognized the fact that the only option to obtain electricity in not regularized areas is by illegal tapping (*gato*), causing problems in the whole system.
- Since 2004, the company has a program with the objective to regularize illegal connections in favelas. The company says that the customers are interested in joining the program most to preserve their well-being, their property and belongings.
- The regularization of electricity connections also stimulates a safe and efficient way of using electricity by the new customers.
- According to the company, the program reached 1.579 poor communities, affecting more than 668 thousand families, around 2.7 million people in the period of 2004 to 2015.
- Parallel to that the company have an energy efficiency program that replaced 59 thousand old fridges by more efficient one and replaced around 2 million incandescent light bulbs for fluorescent bulbs.
- The total amount spent in both programs are around R$ 559 million reais.
- The company believes that solar power can help to diminish electricity theft in two ways by generating electricity or heating the waters used in the showers, however only in regularized" areas. In areas that are not yet regularized the company believes that solar energy is not the best alternative for its intermittent feature, requiring batteries to ensure the supply at night, a fact that makes much more expensive the system.

- The company installed around 5.000 solar water heating system in Cidade Tiradentes (São Paulo), an area with estimated population of 220 thousand people with good results.
- They believe that "distributed generation, including solar energy through photovoltaic panels, has advantages over centralized generation because it postpones the need for investments in expansion of transmission and distribution systems. Reduces the charging networks, encourages better use of local renewable energy resources, increases efficiency by cogeneration (electricity generation combined with heat recovery), diversify the energy matrix, while minimizing the system's technical losses caused by Joule effect, improving the stability and reliability of the service of electricity distribution. All these factors contribute directly to the final cost of electricity."
- They mentioned that in the beginning solar energy was seen as competitor, however nowadays they see as one way to mitigate losses and risks. They are studying to make a PPP with local authorities to install solar PV in schools in a near future.
- The company believe that the best way to introduce solar energy in the favelas is by a national law that obligates utility companies to invest 0,5% of their net operational revenue in actions that aim to combat the waste and increase efficiency in low-income areas. Besides that, educational and local public awareness actions should be provided for these projects in order to familiarize residents with the new technology and warn of the importance of the conscious use of energy.
- According to their point of view, the main barriers to implement solar in the favelas are the are the lack of information on this source and its benefits, and the high cost of such equipment in Brazil. Since, this technology is not yet widespread in the country and many other system items need to be imported. In addition, solar energy is not yet widely used in Brazil, regardless of social class; there is still disbelief as to its reliability compared to the usual sources of power generation.

NAME	JOB TITLE	INSTITUTION	DATE
BARBARA RUBIM	Coordinator	Greenpeace Brasil	15/5/15

Background: Barbara is the coordinator of Greenpeace in Brazil. In 2013, the NGO was responsible for the implementation of solar power in community centre in Rio de Janeiro (Vila Isabel).

- She declared that electricity theft is a social problem rather than economic. It shows the government's absence and its inability to provide access to essential public services to all citizens.
- Barbara stated that solar power can help to diminish theft in favelas, because its generation reduces the need for theft.
- The basic requirements for solar adoption in favelas pointed by her were: strong community participation and make sure they are aware of pros and cons. The establishment of some kind of community counterpart, so that they understand the value of the system. The counterpart does not need not be monetary. It is a symbolic requirement and be sure that favela community is pacified.

- According to her, the main barriers are: (1) affordability and access to credit, (2) cultural.
- In order to overcome such barriers, she declared that it is easily solved with the involvement of the community and their training.

NAME	JOB TITLE	INSTITUTION	DATE
PROF. DR.-ING. JOÃO TAVARES PINHO	Professor and Director of Science and Technology	Federal University of Pará and Pará Government Secretary	21/5/15

Background: Professor at the Universidade Federal do Pará with large experience in renewable energy sector.

- He stated that electricity theft is an issue that affects the whole society and he does not believe that solar power could help to diminish theft in slums, because solar power is only another way to generate electricity and therefore, it will not contribute to solve the issue.
- He believes that the only way to counter electricity theft in favelas is through education of the masses; not only to formal school education (education), but the moral, civic education and enlightenment that everyone will have a good quality of life, when will be awareness of what life in society is and that respect for persons and property is exercised.
- The main barriers are: lack of awareness about solar power potential, costs are still high and lack of political will.

NAME	JOB TITLE	INSTITUTION	DATE
ROBSON BASTOS	State Coordinator of Light for All Program for Amazonas state	Eletrobrás Amazonas Energia	22/05/15

Background: Amazônia region is on the top of electricity theft ranking in Brazil. Approximately, 38% of all the electricity generated is lost (2013). Between 2010 and 2013, Eletrobrás Amazonas Energia had losses around R$ 1,5 billion reais (around €443 million)[3]. The company is stated-owned and is responsible to delivery electricity to more than 825 thousand clients. Amazônia is quite an atypical region, which makes the task to delivery electricity a challenge. In the region, the only access to these villages is by boat.

Robson Bastos is engineer responsible to coordinate the actions of Light for All Program – Luz para Todos (LPT) – a government program which aims to bring electrification to all Brazilian citizens. In more than ten years, the program could reach 15,3 million people.

- Mr. Bastos states that the electricity theft in Amazônia is difficult to combat due to the characteristics of the region and the high costs involved. Some communities are located in remote areas (6 or more hours from Manaus – the

[3] 1 euro = 3,3823 – Central Bank of Brazil (23/5/15).

main city) and its electricity consumption is too low. Thus, sending a team to monitor and enforce the laws is too expensive and do not cover all the costs.

- It was informed that Amazonas Energia installed 6 solar power plants in the Amazônia state with a pre-paid system (scratch cards). However, the theft still happens due to the income variability of the dwellers.
- He points that solar energy faces stability problems due the lack of information of the population. Many appliances (like freezers) have been used without concerning to its energy consumption causing an overload to system.
- He mentioned that electricity theft is a problem of lack of income. The subsistence economy is a reality for most of the population living in poor areas in Amazônia.
- According to Mr. Bastos, to solve the electricity theft is necessary create programs to generate income to poor people. Job creation is the best option in his point of view. He pointed that only access to electricity have not brought development to many of the communities attended by the LPT program.
- The best way to introduce solar energy in low income areas is to invest on infrastructure and provide employees in the areas that solar system are located, however this involve high costs and the company do not have the money enough. In the past, the company wanted to invest in the formation of community electrician to support the solar systems, but was putted away due to the possibility of employment bond between the company and the volunteer. The company could face risks of employment costs and safety.
- It was pointed that solar energy can be a solution for electricity theft if can meet the consumption rate of the household.
- He mentioned that the increase of the price per kWh can have a significant impact on electricity theft in low-income areas.
- In order to contribute to the development of the low-income area, the solar energy generation needs to follow the dwellers' consumption. Most of the utility companies do not think about it.
- He points that private utility companies do not invest in low-income areas due to the low return and high risks.

NAME	JOB TITLE	INSTITUTION	DATE
BRUNO G. BATISTA	Director of Operations	E2Solar (Solar Water Heaters)	22/05/15

Background: Bruno is responsible for the operations of E2Solar, company specialized in solar water heaters. In 2008, they installed SWH systems in Paraisópolis (favela with more than 40 thousand people) together with AES Eletropaulo, utility company responsible to provide electricity to São Paulo. In the last years, E2Solar provided SWH systems to the government housing program *Minha Casa Minha Vida* – My House My Life.

- According to Bruno, the program of 2008 had an interest feature. It gave the favela dwellers a possibility of having a proof of address, facilitating their access to credit, formal job and social inclusion - In Brazil, in order to proof your address is used the electricity bill – this was provided by the utility company.
- He believes that solar energy can help to diminish electricity theft, however is not the only solution. It is necessary more actions to tackle the problem.

- According to his part experience, the best way to introduce solar energy into poor areas is to use compact and mobile system using materials with no commercial value and encourage community participation.
- Related to community participation, it was mentioned the importance of training the dwellers (installers, maintenance) to be part of the solution and generate jobs inside the community. Unfortunately, this practice was not used in the project in Paraisópolis.
- In order to create value to the dwellers was important that they could perceive the benefits, otherwise their perception towards the project would be negative.
- One of the main barriers to implement solar energy in poor areas are the price and lack of access to credit faced by poor people.
- The way that solar energy could help to bring development into a favela is by empowering people through access to information about the solution and environment, training programs and income generation.
- He believes the increase on the electricity price influences the electricity theft and solar energy could help to diminish the monthly costs, therefore assisting the utility companies to increase their revenues.
- He mentioned is possible to work in poor areas with high rate of violence using non-commercial value and hiring people within the area.
- In his point of view is crucial that the new (solar) technology creates value (social gain) to the dwellers higher than the price to obtain it. Example used was the possibility to have address proof.

NAME	JOB TITLE	INSTITUTION	DATE
HENRIQUE DRUMOND	Director and founder	Insolar – Solar Company	25/05/15

Background: The Insolar is a social business dedicated to democratizing access to solar energy in Brazil, through the economic feasibility of installing photovoltaic panels initially in pacified communities of Rio de Janeiro. The company is advised by Yunus Negócios Social Brasil is connected to Yunus Social Business Global Initiatives, they invest and provide consultancy to business focused on social development.

- Electricity theft is seem by him as a lost for all society.
- His perception is that the households visited in the favelas (Rio de Janeiro) are willing to pay for good quality electricity that enable them to be part of the society.
- He believes that solar energy could help to diminish electricity theft with well-planned project for the household. The project is only feasible if the household is connected to the grid due to the net metering scheme in Brazil.
- The average time to have a solar system operating in the Brazilian grid is **around 3 months.**
- The best to implement solar in the favelas is to focus on community participation. Starting to install the system in churches, dwellers association, and cooperatives then to households.
- Main barriers: electric infrastructure in the area, cultural barrier towards the new, financial – lack of access to credit and low-income. Security of PV panels is a point to be attended to, however, installing them in locations as church,

association, cooperatives, and the community tends to protect and monitor the equipment.
- Another interesting barrier pointed by Henrique is the discontinuity of social projects. They are viewed with distrust by dwellers.
- Insolar needs to be very careful when address to the favela not to sound like a NGO, but as (social) company that seeks for profit, therefore avoid generating distrust among the dwellers.
- He believes that (high) price has a direct correlation with electricity theft. Solar energy can contribute to lower the bills.
- He believes that solar energy projects could be deployed in favelas with high rate of criminality. He mentioned that criminality is not tackle only by the police but also with job creation and empowering programs. Solar energy could help to increase jobs and opportunities to dwellers in these areas.

NAME	INSTITUTION	DATE
MONIQUE ROCHA	**Dweller at Babilônia – Rio de Janeiro**	31/05/15

Background: Babilônia is a poor community within Rio de Janeiro with around 2,4 thousand inhabitants. The area was pacified in 2009. This permitted the population to have access to public services, before that the only way to obtain electricity was by illegal tapping (*gato*). Monique lives in this area for more than 20 years, she also works with social projects in Rio.

- Monique stated that a few years ago the only way to access electricity in her neighbourhood was by theft. She continues explaining that such practice was not reliable and caused several problems for her like home appliances loss and regular breakouts in her community.
- In her point of view, solar power could help to diminish her electricity bill.
- She declared that community participation is the fundamental requisite for solar adoption in favelas.
- The major barrier pointed by her is the imposition of social projects with ready-made solutions regardless the situation and particularities of the area and people that live in.
- An alternative to push such barrier away is by enabling ideas exchange between dwellers and practitioners. This will lead to increased knowledge for all parts.

NAME	JOB TITLE	INSTITUTION	DATE
FABIO DE PASCALE	Director and founder	Devergy – Solar Company	03/06/2015

Background: Fabio is associate of Devergy an energy services company, providing electricity service to low-income people in developing countries.

- He declared that electricity theft is not a problem for him, mainly because he is focused on off-grid communities.

- In his point of view, solar power could help low-income communities by raising their awareness.
- For him, the fundamental requisite for the success of solar power is resumed in money. People need to have money in order to buy solar systems.

NAME	JOB TITLE	INSTITUTION	DATE
DAVID BOYD	Director	The African Solar Cooperative	03/06/2015

Background: David is manager of The African Solar Cooperative, a social energy provider of solar power to urban slum communities in Ghana.

- Mr. Boyd states that electricity theft in slums stems from exclusion. He believes electricity is essential as education or access to healthcare. He continues, "For if an individual is denied access to electricity, and they choose not to obtain it illegally, they will be at such a severe disadvantage to the rest of the population that they will almost inevitably be stuck in poverty.
- He believes solar is a long-term solution to the issue. Been electricity theft in favelas a poverty's problem. Solar can enable families to develop themselves by increasing their savings and their quality of life.
- The main barriers pointed by him are corruption, short-term thinking 'To ensure people can thrive in the long-term, they need to think long-term', social inequality and solar technology itself. It necessary more development of home batteries in order to people achieve energy independence, however this improvement is recent and it will take time for these products to become cheaper and more efficient; when this happens, there is a real possibility that electricity could become universally accessible.
- The basic requirements for implementation of solar projects in favelas are: People that you can trust are important part. Capital is essential, costs are incurred and if the requisite capital has not been obtained the project will stall, and the stakeholders on the ground will lose faith and confidence.
- Local development by solar in favelas can only occur with the consent of both slum communities and governments. "The consent of slum communities is necessary because these are the individuals that you wish to influence, the people that currently steal electricity because they have no alternative. The consent of the government is necessary because there has been a complete obfuscation of duty towards citizens of developing countries for decades. If governments can be convinced to support solar, whether financially or in principle, then the people that they represent will be more convinced of solar as a sustainable solution."
- He stated that solar in the developing world should be a social not a commercial effort. It is necessary to wait several year before the technology is affordable to the urban poor and is needed a change on this panorama.

NAME	AREA	INSTITUTION	DATE
COELBA	Department of credit recovery	**Coelba – Utility Company**	08/06/2015

Background: Coelba is a utility company that provide electricity to Bahia. It is the third largest electricity distributor in the country in number of customers and the sixth in the volume of energy provided. Coelba serves more than 14 million people in a 563 km2 concession area. Today the company has over 5.5 million customers, 88% of these residential customers. The manager of the company's credit recovery department provided the answers.

- The company declared that theft in the favelas leads to problems regarding to security of population, The quality of power supply. Financial losses for utilities as well as for the population as the government fails to collect ICMS for example, this tax can be applied to the population's quality of life improvements.
- Coelba stated that theft is closely linked to cultural and financial issues. If the solar energy could be provided at low values per kWh, it can help to solve the issue.
- According to them, the primary step to introduce solar energy in favelas is awareness, demonstrate the benefits of solar energy for people in the community.
- The main barriers for solar adoption are: lack of robustness, and security of solar equipment and price for the installation as well as the tariff per kWh has to be accessible to people from the favelas.
- They believe that solar energy could counter payment defaults only if the tariff is cheaper than utilities.
- The company stated that is possible to work in areas with high level of violence if previously agreed with community leaders.

APPENDIX 5 – BRAZILIAN ELECTRIC MATRIX AND PRICE KWH

Bellow one can find the Brazilian electric matrix in 2015.

Source	# Power Plants	Installed Capacity (KW)	%
Biomass	508	12.627,089	8,69%
Wind	277	6.138,549	4,22%
Fossil Fuels	2109	26.298,852	18,09%
Hidric	1176	90.135,529	62,00%
Nuclear	2	1.990,000	1,37%
Solar	317	15,179	0,01%
Import	-	8.170,000	5,62%
Total	4.389	145.375,198	100%

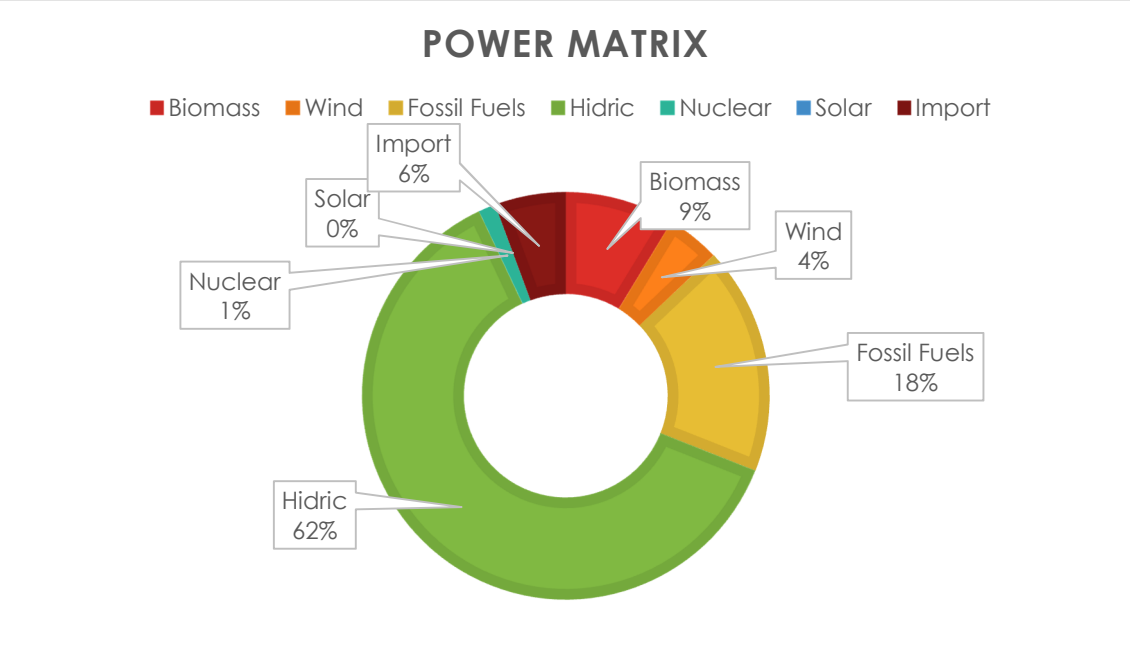


Figure: electricity matrix Brazil Source: Aneel, 2015

Initials	Utility Company	Residential (BRL/kWh)[i]
UHENPAL	Usina Hidroelétrica Nova Palma Ltda.	0,58908
CHESP	Companhia Hidroelétrica São Patrício	0,56166
ELETROCAR	Centrais Elétricas de Carazinho S/A.	0,54651
HIDROPAN	Hidroelétrica Panambi S/A.	0,53739
COOPERALIANÇA	Cooperativa Aliança	0,52441
CEMIG-D	CEMIG Distribuição S.A	0,50974
AMPLA	Ampla Energia e Serviços S/A	0,50692
ELEKTRO	Elektro Eletricidade e Serviços S/A.	0,50616
DEMEI	Departamento Municipal de Energia de Ijuí	0,50359
ELFSM	Empresa Luz e Força Santa Maria S/A.	0,50333
CELPA	Centrais Elétricas do Pará S/A.	0,49425
EFLJC	Empresa Força e Luz João Cesa Ltda	0,49046
MUXENERGIA	Muxfeldt Marin & Cia. Ltda	0,49027

EMG	Energisa Minas Gerais - Distribuidora de Energia S.A.	0,48899
CFLO	Companhia Força e Luz do Oeste	0,48453
EEB	Empresa Elétrica Bragantina S/A.	0,48437
CPFL Santa Cruz	Companhia Luz e Força Santa Cruz	0,48139
EFLUL	Empresa Força e Luz Urussanga Ltda	0,48102
AES-SUL	AES SUL Distribuidora Gaúcha de Energia S/A.	0,48035
FORCEL	Força e Luz Coronel Vivida Ltda	0,47498
CPFL Mococa	Companhia Luz e Força de Mococa	0,47219
LIGHT	Light Serviços de Eletricidade S/A.	0,46858
RGE	Rio Grande Energia S/A.	0,46649
CEMAT	Centrais Elétricas Matogrossenses S/A.	0,46520
ENF	Energisa Nova Friburgo - Distribuidora de Energia S.A.	0,45944
SULGIPE	Companhia Sul Sergipana de Eletricidade	0,45774
CEEE-D	Companhia Estadual de Distribuição de Energia Elétrica	0,45662
ESCELSA	Espírito Santo Centrais Elétricas S/A.	0,45312
EDEVP	Empresa de Distribuição de Energia Vale Paranapanema S/A	0,45160
CAIUÁ-D	Caiuá Distribuição de Energia S/A	0,44736
CELG-D	Celg Distribuição S.A.	0,43831
CERON	Centrais Elétricas de Rondônia S/A.	0,43732
ETO	ENERGISA TOCANTINS - DISTRIBUIDORA DE ENERGIA S.A.	0,43728
CPFL Sul Paulista	Companhia Sul Paulista de Energia	0,43346
BANDEIRANTE	Bandeirante Energia S/A.	0,43341
CEMAR	Companhia Energética do Maranhão	0,43104
COPEL-DIS	Copel Distribuição S/A	0,43037
CELESC-DIS	Celesc Distribuição S.A.	0,42881
CPFL Leste Paulista	Companhia Leste Paulista de Energia	0,42561
EBO	Energisa Borborema ? Distribuidora de Energia S.A.	0,42520
ELETROACRE	Companhia de Eletricidade do Acre	0,42514
CNEE	Companhia Nacional de Energia Elétrica	0,42402
CPFL-Paulista	Companhia Paulista de Força e Luz	0,41964
CEPISA	Companhia Energética do Piauí	0,41803
COELCE	Companhia Energética do Ceará	0,41796
CEAL	Companhia Energética de Alagoas	0,41402
DMED	DME Distribuição S.A	0,41055
ESE	Energisa Sergipe - Distribuidora de Energia S.A.	0,40935
CELPE	Companhia Energética de Pernambuco	0,39524
CPFL Jaguari	Companhia Jaguari de Energia	0,39497
IENERGIA	Iguaçu Distribuidora de Energia Elétrica Ltda	0,39352
COELBA	Companhia de Eletricidade do Estado da Bahia	0,38836
EPB	Energisa Paraíba - Distribuidora de Energia	0,37956
COSERN	Companhia Energética do Rio Grande do Norte	0,37590
ELETROPAULO	Eletropaulo Metropolitana Eletricidade de São Paulo S/A	0,37182
JARI	Jari Celulose, Papel e Embalagens S.A.	0,37079
CEB-DIS	CEB Distribuição S.A	0,36931
CPFL- Piratininga	Companhia Piratininga de Força e Luz	0,36233
CERR	Companhia Energética de Roraima	0,35264
COCEL	Companhia Campolarguense de Energia	0,34574
AmE	Amazonas Distribuidora de Energia S.A	0,32081
CEA	Companhia de Eletricidade do Amapá	0,30111
Boa Vista	Boa Vista Energia S/A	0,28978

[i] Prices without taxes and duties. The aliquot (%) vary from state to state.