IIIEE Theses 2017:30

Innovative Business Models for Distributed PV in Brazil

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, September 2017

iiiee THE INTERNATIONAL INSTITUTE FOR INDUSTRIAL ENVIRONMENTAL ECONOMICS

Published in 2015 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
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ISSN 1401-9191

Acknowledgements

First, I would like to thank the International Institute for Industrial Environmental Economics (IIIEE) at Lund University for making the Environmental Management and Policy program such a great experience.

Second, I would like to thank my wife for her continuous and unconditional support and care during the whole period of the program.

Third, I would like to thank my supervisor Lars Strupeit for his support, sharp comments, and valuable guidance in the extensive and often technical literature on the subject of solar PV.

Fourth,I would like to thank all the interviewees, for accepting to spend time and energy in sharing their views on the developments of business models for distributed PV.

Finally, I would like to express my gratefulness to those rainy days in Argentina which made me buy a ticket to and discover the wonderful country of Brazil, a country which is so similar and so different at the same time from my home country. I would like to thank all the Brazilians I met during the last two years for being friendly, easy going and helpful. Also, I send special thanks to all the Brazilian musicians for creating such a wonderful ocean of music, which was a great inspiration during the thesis writing.

Abstract

Most of the increase in world electricity demand until 2030 is expected to come from developing countries (IRENA, 2016) and transition to carbon free energy production technologies offers the opportunity to reduce the negative effects of this increase. With majority of the low and middle income countries located in the areas of favourable solar radiation, PV technology is likely to become a key source of energy in these countries.

Brazil is one of the middle income countries with very high solar potential and has much to benefit from the rapid deployment of PV. However, the development is impeded by various economic, institutional and social barriers.Innovative business models can be helpful in overcoming these barriers and accelerate the market adoption of PV. By looking at the case of Brazil, this study investigates how innovative business models for distributed solar PV can help to overcome the deployment barriers.

Business models of Third Party Ownership, Community Solar, Crowd-funding and Peer-to-Peer Energy Trading are analysed through the business model canvas framework of Osterwalder and Pigneur (2010). The results show that all four models can have unique contributions to help increase the deployment of distributed PV in Brazil by effectively addressing the fundamental barrier of financing, by offering complementary value propositions, by increasing the potential user base and by increasing awareness among general public, through peer effect or community bonds. With its findings the study contributes to the limited research on PV business models in urban context in middle income countries. Policy recommendations include regulatory adjustments to prepare for a future energy system with distributed generation and disruptive business models with advanced digital technology like crowd-funding and P2P, opening ways for the electricity distribution companies to align their interest with solar businesses and cooperate, and providing low cost credit lines aimed at smaller solar companies

Keywords: PV, Brazil, business models, distributed generation, crowd-funding, peer-to-peer

Executive Summary

According to International Energy Agency (2010), developing economies will be responsible for most of the economic growth, increase in energy demand and resulting greenhouse gas (GHG) emissions in the near future. Solar PV is likely to become a key source in those countries. However, the pathway to increase solar PV deployment in developing countries is not yet clear and may be slowed down due to a number of barriers.

Without right models for commercialization, the diffusion of technological innovations might be slow or even not happen. Businesses and their business models also play a central role in market adoption of distributed PV (WEF, 2017). However, the research on business models for solar PV in middle income developing countries and urban context is rather limited.

Brazil is one of the largest developing countries with a high solar energy potential but still relatively low PV deployment rate. By taking Brazil as the case country, the study presents four innovative business models of solar energy around the world and investigate how these business models can help Brazil increase the deployment of distributed PV.

Measures to support distributed PV systems exist in the Brazilian regulation. Most important of these is the net metering system which allows PV owners to reduce their electricity bills by obtaining electricity credits for the surplus energy that is fed into the grid. There are also a number of barriers to the development of distributed PV in Brazil. These are the high initial costs of PV systems and difficulties in financing, the lack of economic incentive to install systems with higher capacity than needed for self-consumption, the lack of incentive for distribution companies to cooperate with solar companies, and the lack of awareness among the public.

A business model is "the rationale of how an organization creates, delivers, and captures value" (Osterwalder and Pigneur 2010), and the ability of each business model to address the identified barriers stems from its combination of customer segments, value propositions, channels, customer relationships, revenue streams, resources, key activities, key partners and cost structure.Innovative business models for distributed solar PV selected for the analysis in this study are (A) third party ownership, (B) community solar, (C) crowd funding, and (D) peer-to-peer energy trading.

(A) In the **Third Party Ownership (TPO)** model, the solar company deploys solar PV systems at the consumer's premises, in return of leasing contracts or electricity purchase agreements. The model can effectively address the financing problem by relieving the consumers of the burden of high initial investment cost and provide access to solar energy with immediate reduction in energy costs. Moreover the model offers long term stable energy costs, which is valuable especially in Brazil where rapid electricity price increases are experienced.

(B) **Community Solar** model offers individual customers to buy or rent a solar lot in a large scale solar facility off-site. The community solar model is similar to TPO model by addressing the barrier of high initial investment. However, community solar is advantageous over TPO model since it targets a much larger customer segment, including consumers who resides in apartments.This is possible due to the virtual net-metering regulation.

(C) **Crowd-funding** businesses acts as a matchmaker between the individual investors, who wish to support solar PV deployment and the independent solar projects looking for funding. Crowd-funding can provide an alternative financing option to solar companies with TPO or

community solar models. Through crowd-funding low cost (5%-6%) financing can be secured for projects, and financing cost reduction will potentially lead to reductions in lease prices.

(D) In the **Peer-to-peer energy trading** (P2P) model, solar PV owners sell excess electricity directly to other consumers through a digital platform. Although the regulation does not allow trades of electricity credits, it does allow trading of the PV assets. Accelerated trading of PV assets through secure online contracts could in effect lead to commercialization surplus energy, which could increase the profitability of the PV systems.

The results of the study show that all four models can have unique contributions to help increase the deployment of distributed PV in Brazil by effectively addressing the fundamental barrier of financing, by offering complementary value propositions, by increasing the potential user base and by increasing awareness among general public, through peer effect or community bonds.

None of the models can directly address the issue of the lack of incentive of the distribution companies towards distributed solar power. However, regulatory adjustments can change this picture, and a cooperation model between innovative solar businesses and distribution companies could be developed.

Policy recommendations include regulatory adjustments to prepare for a future energy system with distributed generation and disruptive business models with advanced digital technology like crowd-funding and P2P, opening ways for the electricity distribution companies to align their interest with solar businesses and cooperate, and providing low cost credit lines aimed at smaller solar companies

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Abbreviations

ABRACEEL Association of Brazilian Energy Traders
ABRADEE Association of Brazilian Electricity Distributors
ANEEL National Agency of Electricity
BNDES Brazilian Development Bank
EPE Energy Research Company
ICT Information and Communication Technologies
GHG Greenhouse gas
NGO Non-Governmental Organisation
P2P Peer-to-Peer
PPA Power Purchase Agreement
PROINFA Programme to Incentivize Alternative Electricity Sources
PV Photovoltaic
TPO Third Party Ownership

1 Introduction

According to Intergovernmental Panel on Climate Change (IPCC), 56,6% of the anthropogenic greenhouse gas (GHG) emissions in 2004 resulted from the combustion of fossil fuels (2007). Transition to carbon free energy production is increasingly becoming one of the most important ways for the reduction of GHG emissions and thus climate change mitigation. Renewable energy technologies offer enormous opportunities on the way to this transition. Specifically, harnessing the energy of sun through photovoltaic (PV) technology proved to have high potential in pioneering countries, such as Germany, Italy, Japan and the U.S.(EIA, 2016b).

On the other hand, according to International Energy Agency (2010), developing economies will be responsible for most of the future economic growth, energy demand and greenhouse gas (GHG) emissions. IRENA (2016) predicts world electricity demand to grow more than 50% until 2030, and 95% of this growth will come from developing countries. Solar PV is likely to become a key source in those countries (ibid). However there are various challenges for the widespread deployment of solar energy in developing countries, ranging from political instability and inadequate infrastructure, to problems of financing the relatively high upfront cost of PV. Overcoming these and many other challenges requires a collaborative approach by different actors involved in energy sector.

Being one of these actors, businesses can play an important role in the efforts to increase the share of solar PV in developing countries. Interest in the role of businesses in sustainable development has increased recently, as more academicians and professionals emphasized the need for business-based, economically sustainable approaches (Kolk&Buuse, 2013). Through innovative business models, solar companies may become the key for unlocking the solutions to some of the challenges PV technology is facing in developing countries.

Despite all the challenges, the majority of the low and middle income countries are in the areas of favourable solar radiation, thus have high potential for energy production through PV. Brazil is one of those countries with high solar potential but relatively low PV deployment rate, due to various challenges.

This study is concerned in general about energy production through PV, and in particular about the potential of innovative business models in Brazil for increasing the deployment of this technology. By taking Brazil as the case country, the study aims to identify the emerging business models of solar energy around the world and investigate if and how these business models can help Brazil increase the share of solar energy.

1.1 Background

Transformation of energy production away from fossil fuels is a necessity to overcome not only the challenges of climate change, but also of sustainable development, and of even global security, if one considers the international conflicts arising for the control of fossil based energy sources. Energy systems need to be based on low carbon technologies and PV is one of these low carbon technologies, and even though the technology has been around for quite some time, due to its high cost its use was limited to demonstration projects until recently. Especially in the last years, PV is increasingly being deployed around the world and is on its way to become a key source in electricity sector in many countries (IEA, 2017).

Global PV market can be divided in two main segments: large scale (utility) segment and small scale (distributed) segment. Distributed PV can be on-grid or off-grid. Although the distributed segment has been the main type of PV deployment for long time, most of the recent global growth is driven by utility scale projects. The most widely used method for deploying utility scale PV has been through competitive call for tenders, or auctions, to grant long term power purchase agreements (PPAs). Although auctions are not a support mechanism by themselves, they are a design element aimed to setting the support level, as opposed to administratively set support, such as feed in tariff (del Rio et al., 2015). The deployment of distributed PV, on the other hand, is mostly driven through support schemes such as feed-in-tariffs/premiums or net metering.

Another noteworthy development in the global PV market is the recent rapid price decrease which is pushing energy policy makers of many countries to include PV in energy development plans (IEA, 2017). Not only the cost of solar modules have seen a remarkable decrease in the last years (SEIA, 2017), but also some of the recent utility scale tenders resulted in historic low power purchase agreement (PPA) prices. For example in 2016, Chile, Abu-Dhabi and Dubai awarded utility solar PPAs with costs below 0,03 USD/kWh, which points to a 85% decrease since 2009 (Lazard, 2016), and is a price level that can compete with most new fossil and nuclear based projects (Lazard, 2016; IEA, 2017).

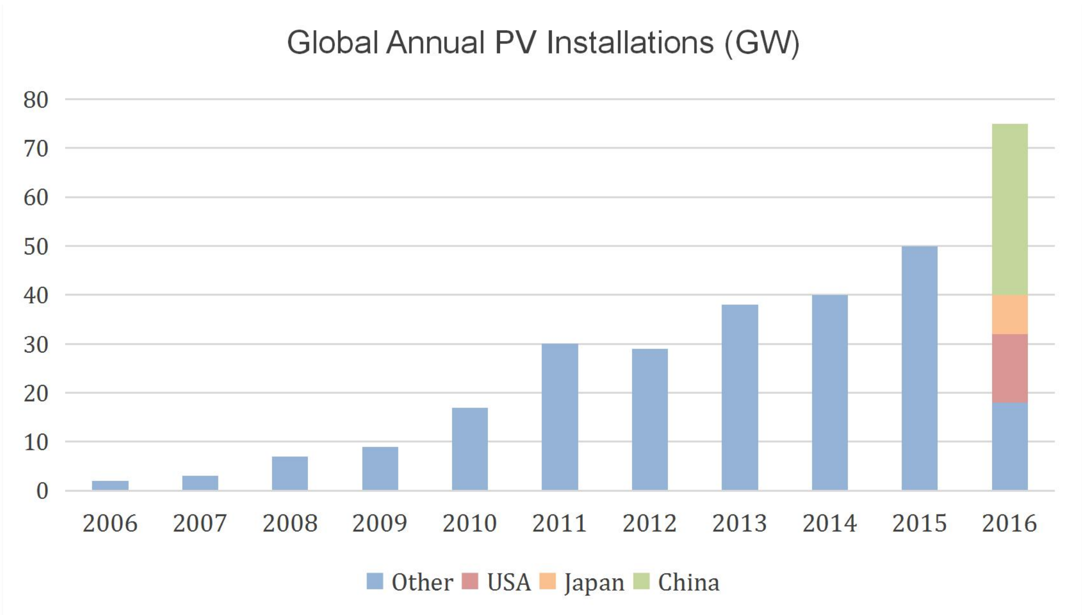

Figure 1 : Global PV installations 2000-2016

Source: IEA,2017

The global market for PV has grown remarkably between 2000 to 2016, with worldwide installed capacity rising from 0.8 GW to 303 GW by the end of 2016 (IEA, 2017). In 2015, 50 GW, and in 2016 75 GW capacity was added (REN21, 2016; IEAb, 2016). With all these added capacities, global PV capacity was multiplied by four in just five years (IEA,2017). It is estimated that over the next five years global installed capacity will be doubled (GTM,2017).

Through its support policies, Germany has long been the driving force behind global PV expansion, and the leader in installed capacity. However, recently this has changed, with China and Japan reaching higher capacities than Germany, and the U.S. catching up (EIA, 2017). The following table shows the capacity added in 2016 and cumulative capacity of leading countries.

Capacity installed in 2016 (GW)		
1	China	34,5
2	USA	14,7
3	Japan	8,6
4	India	4
5	UK	2
6	Germany	1,5
7	Korea	0,9
8	Australia	0,8
9	Philippines	0,8
10	Chile	0,7

Cumulative installed capacity (GW)		
1	China	78,1
2	Japan	42,8
3	Germany	41,2
4	USA	40,3
5	Italy	19,3
6	UK	11,6
7	India	9
8	France	7,1
9	Australia	5,9
10	Spain	5,5

Table 1: Installed PV capacity by country
Source : IEA (2017)

By installing 34,5 GW in 2016, which is a capacity close to total installed capacity of Germany (41,2 GW), China is now the leader in PV capacity. With the recent PV investments of China and Japan, Asia/Pacific region hosts 48% of global installed capacity, whereas Europe has 34% and Americas has 16% (EIA, 2017).

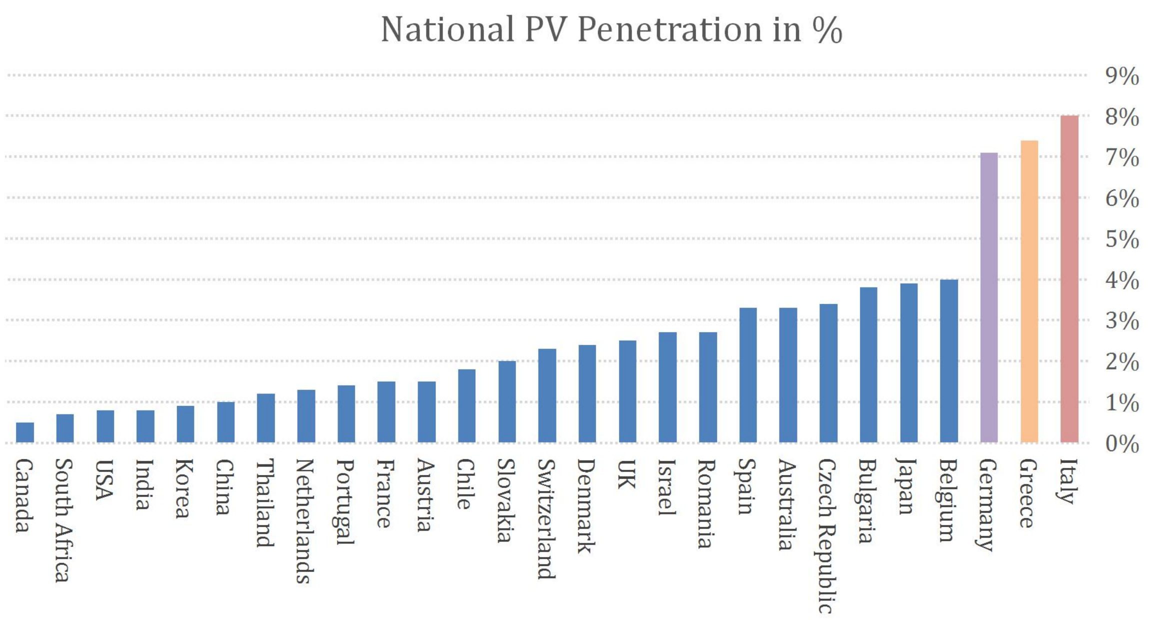

Figure 2: National PV penetration in % of electricity demand based on 2015 demand
Source: IEA (2016b)

However, when measured by the installed capacity per capita, the picture is slightly different: Germany still leads the list, followed by Italy, Belgium and Japan (Solar Super State Association, 2016). Moreover, according to IEA (2016b), Italy, Greece, Germany are the top three countries for solar PV penetration ratio to national electricity demand (Figure 2).

Although more than 60% of the global PV capacity is deployed in the top 5 countries, some developing countries started to appear in the picture: In 2016, India doubled its installation level by adding 4 GW, Chile, Thailand and Philippines added over 700 MW, while Turkey and South Africa added over 500 MW each. However, most of the low and middle income countries, especially Latin American countries, apart from Chile, are following with a slower pace (IRENA, 2016). In general, the growth of solar PV has, so far, missed most of the areas with favourable solar radiation (IEA, 2016). And even though global PV deployment is experiencing high growth rates, it is important to put this growth in perspective. PV still covers less than 2% of global electricity demand (IEA, 2017), and even in the countries with the highest national penetration rates it is still less than 10%. Thus, there is a long way and many challenges ahead for PV to cover a substantial part of the world's electricity demand.

Solar PV in Brazil

One of the countries with very high solar energy potential but relatively low PV penetration so far is Brazil. Brazil is the largest country in South America, and one of the largest and most populous countries in the world, with 200 million inhabitants and land size larger than European continent. It is the 7th largest economy in the world by purchasing power parity (IMF, 2016), and the 7th most energy consuming country, comparable to Germany (Enerdata, 2016).

Most of Brazil's electricity demand is covered by hydropower. By 2017, the country have total installed capacity of 153 GW, and hydro makes up over 60% of the total capacity (Förster&Amazo, 2016; ANEEL, 2017). Figure 3 shows the electricity mix of Brazil by fuel type. Though increased rapidly over the last couple of years, the solar capacity of Brazil is still very low. The cumulative installed solar power capacity in Brazil has reached 279 MW by August 2017, of which 172 MW is utility scale and 107 MW is distributed PV (ANEEL, 2017).

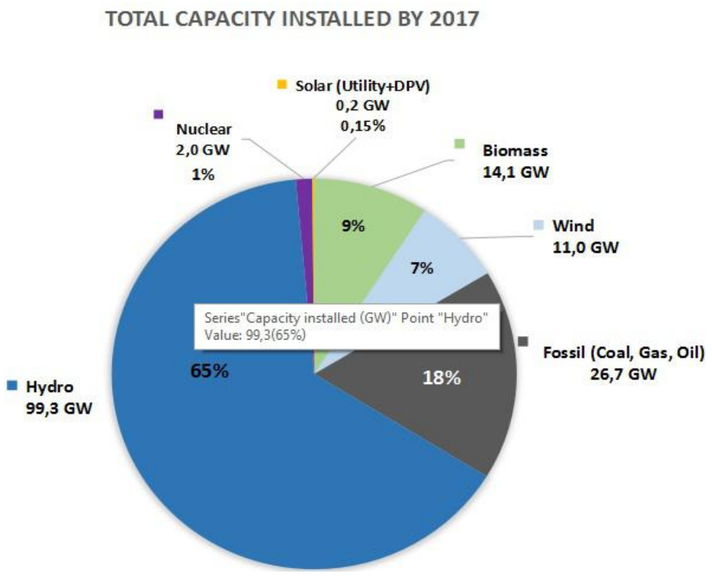

Figure 3: Electricity matrix of Brazil
Source: ANEEL (2017)

This high dependency on hydro power poses several problems. First of all, the potential locations for additional hydro investments are increasingly in areas where negative environmental and social impacts are very high, such as the Amazonian basin (Souza&Cavalcante, 2016). One example of this was the environmental damage that Belo Monte dam in the state of Para caused, and the strong public opposition to the project, especially by the indigenous communities. A second problem is the increased energy security risk, showing itself in the form of large scale electricity shortages, especially in the years of drought (Gouveia, 2012). High dependency of energy production on hydro exposes the electricity prices to rainfall variations.

Due to such problems Brazil needs to diversify its energy mix. However an emerging risk in the process of this diversification is the rapid increase of fossil based sources, especially natural gas. The dangerous trend of increasing the share of natural gas in electricity mix is reflected in GHG emissions. Between 2005 and 2015 CO_2 emission related to electricity production by natural gas has increased almost 5 folds (SEEG, 2017). It is increasingly important to find ways to counter the trend of growing share of fossil based energy resources. One way to avoid the problems of high dependency on hydro without increasing GHG emissions is to diversify the energy mix of Brazil through other forms of renewables, such as wind and solar.

This need of diversification is indeed reflected in the energy policies of Brazil. Brazil has set targets for renewable energy in its latest ten-year energy expansion plan (PDE 2026) and aimed for adding 13 GW of PV capacity by 2026, of which around 9.5 GW is utility scale and 3.5 GW is distributed generation (EPE, 2016). The government institutions responsible from development and application of energy policies and regulations are as follows: Ministry of Energy and Mines (Ministério de Minas e Energia) is responsible for the energy policy of Brazil, Energy Research Company (EPE) is the body responsible to support the Ministry in policy making and the National Agency of Electricity (ANEEL) is the regulating body responsible from power market.

The solar PV market in Brazil can be divided to two main segments: distributed generation and large scale utility projects. The main instrument of supporting distributed generation is the net metering scheme. ANEEL established the net metering system by Resolution 482 in 2012, which was revised and improved in 2015 with Resolution 687.

For the utility scale solar PV deployment, auctions have been the main instrument of promotion. Brazil launched the Programme to Incentivise Alternative Electricity Sources (PROINFA) in 2002, which was initially based on a feed-in tariff scheme with administratively set variable tariffs but revisions in 2004 and 2007 provided the bases for renewable technologies procurement with auction scheme (IRENA, 2015; EIA, 2016a). First auction was held in 2008, for biomass, which was followed by several auctions for non-hydro renewable energy sources every year until 2015 (IEA, 2016a). Typically, the contracts for solar auctions were awarded for 20 years and the winning bidders signed a PPA directly with the distribution companies and are required to deliver electricity in 3 or 5 years, depending on the auction (Förster&Amazo, 2016).

According to the U.S. National Renewable Energy Laboratory (2017) Brazil has the 5th highest solar energy potential in the world, thanks to its geographical position. Latitude is an important factor for the economics of solar PV, and due to their location, annual yield is up to three times higher in developing countries than in developed countries (IRENA, 2016). Despite its very high potential, Brazil has been following behind the other countries in the case of PV deployment. This situation is arguably created by the initial lack of policy incentives for solar PV (Souza&Cavalcante, 2016).

However, recent policy changes have already accelerated the investments and deployment of both the utility scale and distributed generation. On the utility segment, so far there has been four auctions exclusively for solar energy that awarded in total around 3,3 GW solar PV contracts (ABSolar, 2016). Some of the projects are expected to start operation in 2017 (Souza&Cavalcante, 2016). However a big portion of the projects that were contracted have not yet started to be constructed and recently the government initialized a de-contracting process (GTM, 2017). The solar energy auction planned for 2016 was cancelled twice, however the new government has recently announced an auction to be held in December, 2017.

On the other hand, supported by the net metering scheme, the number of distributed PV installations has also increased considerably from only 3 in 2012 to over 14 000 by the end of September/2017, and the installed capacity has reached over 115 MW (ANEEL, 2017). Moreover, Brazilian government installed off-grid PV systems to remote areas during early 2000s, as part of the rural electrification program "the National Program for the Universalization of Access and Use of Electricity - Luz Para Todos (Light for All)" which started in 2003, and it is estimated that around 30 MW of off-grid solar systems are still operational (Souza, 2016).

More supportive policies, in the form of draft bills, are in the pipeline of legislative process. One of these draft bills is about the import taxes on solar equipment, with a proposal to lift the import duty for the equipment which is not locally produced. The other draft bill envisions the distribution companies to be able to invest in solar energy generation projects. The draft bill proposes that the distribution companies are able to even install solar panels on the roofs of customers with low-tariff, which is a reduced tariff applied to customers with very low consumption, aiming to economically support lower income households. The low-tariff customers, according to the proposal, will not be able to object the installation of PV system, if they want to continue benefiting this reduced tariff.

In fact, Brazil is named as one of the upcoming PV markets until 2020 by a recent reports (IEA, 2017). In 2015 the Ministry of Mines and Energy of Brazil announced a development plan for distributed generation (2015), and in 2017 National Electrical Energy Agency (ANEEL) estimated that by 2024 Brazil will have close to 900.000 units installed, reaching a total capacity of 3,2 GW (2017). This acceleration in deployment, the sheer size of its energy consumption, but above all the very high solar potential make Brazil an important case to study for the deployment of photovoltaics.

1.2 Problem Definition

Developing countries could highly benefit from rapid deployment of solar power. However, the development is impeded by various barriers, including economical and infrastructural barriers, and barriers related to several types of deployment knowledge. We need to find various ways to overcome these barriers to be able to increase the deployment of solar energy in developing countries. Brazil is one of these developing countries with very high solar potential but low level of PV deployment due to several barriers.

Businesses and their business models play a central role in market adoption of distributed PV (WEF, 2017). Business can be helpful in overcoming the barriers and accelerate the market adoption of PV through carefully arranging their value propositions. Without right models for commercialization, the diffusion of technological innovations might take very long time or might even not happen. Many technologies developed so far, that could have been beneficial for developing countries, could not achieve commercial viability, or remained as part of charity work by NGOs (Kalk&Buuse, 2013).Some scholars even argued that the business model is as important for large-scale adoption of new technologies as the technology itself (Teece, 2010; Gordijin&Akkermans, 2007).

On the other hand, recently several innovative business models are emerging in the area of solar energy around the world. These innovative business models are offering services ranging from facilitation of peer-to-peer (P2P) trading of the excess electricity produced by distributed solar PV, to financing the solar investment cost through crowd-funding. Whether it is P2P solar energy trading with decentralized technology of blockchain or crowd-funding, these new models could potentially change the whole system of energy economics (Butenko, 2016). Most of the change is anticipated to happen through decentralization and cost reduction, both of which could have tremendous influence, especially for developing countries (German Energy Agency, 2016).

Brazil, and many other developing countries, have unreliable energy networks which stretch thousands of kilometres with poor maintenance and high losses; remote communities with no or low quality grid connection; high solar potential but low possibilities to cover the initial solar investment costs; high electricity costs relative to income... all of which innovative business models solar energy can have potential impact on. However, it is not yet clear which business models will be successful for the deployment of PV in Brazil.

As Chapter 2 of this study demonstrates, most of the current knowledge on business models of PV is either from countries with more developed PV markets or from low income countries which are trying to utilize PV technology for rural electrification. The number of studies focusing on PV business models in middle income countries are very limited.

Traditionally business models have been seen as constructions of internal values, strategies and resources of the companies, which overlooks the role of external conditions (Provance et al., 2011). Scholars stressed the importance of local context for the emergence and development of new business models (Birkin et al.,2009; Provance et al., 2011; Strupeit&Palm, 2016), thus models emerged in developed or low-income country contexts might not be directly transferable to Brazilian context. It is, therefore, important to find out how these innovative business models of PV would perform in the local conditions of Brazil.

1.3 Objective and Research Question

Taking these views as departure point, the objective of the study is to look at how innovative forms of business models can help overcome barriers and increase the deployment of PV, in the case of one of the largest energy consuming developing countries, Brazil.

In line with this objective, this study tries to answer the following research question:

RQ: How can innovative business models help increasing the deployment of distributed PV in Brazil?

1.4 Scope

This study focuses on business models for deployment of distributed PV in Brazil. The study analyses four selected business models that have innovative character and that were not utilized in Brazil. The selection of the models are based on previous research. Although the study does not limit itself with a specific PV system size, utility scale applications which are established to supply electricity to distribution companies and which are awarded long term PPAs through governmental energy auctions in Brazil are out of the scope of this study. The reason for this focus is that the utility scale is already a business model based on energy procurement auctions.

The geographical focus of the study is grid connected urban areas all around Brazil. There are two main reasons for this focus: Firstly, practical limitations of time and size forced the study to choose between on-grid and off-grid models, as there are also several innovative business models based on rural off-grid electrification. Secondly, over the last 15 years successful rural electrification programs applied by Brazilian government significantly reduced the portion of population without access to electricity and reached 99,65% electrification rate (World Bank, 2017).

1.5 Audience

Completed as a part of the Environmental Management and Policy Master Program at International Institute for Industrial Environmental Economics, the principle audience of this study is academia. Studying the potential of up-and-coming business models for solar in a developing country context could enhance the knowledge on the topic by addressing a gap in the literature, which has so far mostly focused developed countries. The study can be beneficial for identifying the potential benefits of these models for Brazil and possibly for the other developing countries with similar conditions.

The area of solar PV and areas related to business models based on ICT are developing rapidly. Thus, by studying the novel area of solar business in a developing country context at an early stage, this study can be helpful for the solar businesses which would like to operate in Brazil with innovative business models; for the national and international investors who would like to familiarize themselves with the market conditions and suitable business models to overcome barriers, and for policy makers in Brazil and countries with similar conditions to design informed policies and adapt necessary regulations early on, which could help them leapfrog developed countries on solar energy; and lastly for citizens who would like to install solar energy to find out about innovative business models which can offer them better conditions on financing or help them reduce their energy costs.

By broadening our understanding of the potentials of business models in increasing the deployment of PV, this study can help researchers to find more effective ways for renewable technologies to diffuse, businesses to deploy renewable energy in a more cost-efficient way by shortening their learning process and the policy makers to design more effective policies to support the renewable energy and reach their GHG emission reduction targets .

1.6 Ethical Considerations

The study utilized interviews as primary data source. During the interviews interviewees were clearly informed about purpose of the research and oral permissions obtained to use their views in the study. In one case where there could arise possible conflict with the views expressed by the interviewee and the employer of the interviewee, the interviewee was contacted to confirm that those views can be used in the study. Potentially sensitive information provided by the interviewees, such as business details and personal privacy, is not included the study unless it is explicitly stated by the interviewee that the information can be used in the study.

1.7 Disposition

The study is structured as follows:

In Chapter 1, the problem addressed in the study and the specific research question are presented against the background of the solar PV in general and its state in Brazil in particular.

In Chapter 2, the state of scientific research in the field of study is outlined; research on emerging solar business models in developed and developing market contexts are presented.

Chapter 3 presents the analytical framework used for data analysis, the research design and the methods used in the study.

Chapter 4 presents the Brazilian distributed PV market in detail, looking at the regulatory framework and business landscape that solar companies operate in.The chapter further investigates the barriers for development of PV in Brazil.

Chapter 5 presents the analysis of the business models of Third Party Ownership, Community Solar, Crowd-funding and Peer-to-Peer Energy Trading through the analytical framework of business model canvas and investigates how they can help overcome barriers under Brazilian context.

In Chapter 6, a discussion is presented, where major findings of the study and their relevance to similar studies are explained, the limitations of the study and suggestions for future research are discussed.

In Chapter 7, research question is answered based on the findings of the study and policy recommendations are presented.

2 Business Models for PV: The State of Research

Solar energy, together with a broad selection of renewable energy technologies, is seen as the most important instrument to diminish the negative effects of energy production by leading to significant overall reduction of GHG and in that way mitigate climate change (IPCC, 2007). The necessary large scale deployment of renewable energy technologies requires altering the way energy business has functioned so far and brings structural changes to the energy sector (Klose&Kofluk, 2012). So far, the main way of conducting business in the energy sector has been through a linear chain of companies, carrying electricity from centralized power plants to the end consumer (Richter, 2012). Even the electricity grid is designed for this unidirectional model (Wainstein & Bumpus, 2016). However, this model is being challenged now and the biggest challenge comes from renewable technologies allowing for a distributed small scale generation which creates producers from the consumers (Valocchi et al., 2016; Richter, 2012).

Figure 4: Traditional electricity value chain
Source: Richter (2012)

The WEF report (2017) on the future of energy argues that there are three main trends in electricity system which are working in a vicious circle and reinforcing each other:

-**Electrification** of large sectors such as transportation,

-**Decentralization** of energy production by distributed energy resources, such as PV,

-**Digitalization** of the grid by smart meters, but also beyond,e.g. in areas of production and interaction with consumers.

The report argues, however, that the system faces a great risk of value destruction if it fails to capture the benefits of distributed energy resources (WEF, 2017). This is especially the case for utility companies, as increased share of renewables is seen as a direct threat to established business models of utilities, which is based on revenues from energy sales (Frantzis et al., 2008; Richter, 2013; Duthu et al., 2014). Less energy demand from consumers with PV systems would lead to lower revenues for utility companies. In return, lower revenues would push utility companies to increase the electricity tariffs to compensate, which can make PV even more attractive. This systemic diffusion model based on feedback loops for distributed PV, known as the "Death Spiral", has recently received attention of scholars (Felder&Athawale; 2014; Castro, 2016).

World Economic Forum (2017) suggests four essential points for the successful integration of new technologies: the regulatory paradigm should be reformed to better accommodate the diffusion of distributed generation; the necessary infrastructure that allows the development of new business models should be deployed; the role of the consumer, embedded in a digital and interactive electrical system, should be redefined; and lastly, new business models for innovative retail distribution and commercialization activities should be incorporated. The authors of the report envisions a future electricity system in which consumers equipped with distributed generation and storage technologies will produce, consumer, store and sell electricity (ibid.).

These trends and the challenges they pose motivated some researcher to investigate new business models for PV, with a focus on how utility companies can overcome this challenge by increased share of renewables (Frantzis et al., 2008; Richter, 2012; Richter, 2013; Lehr, 2013; Tayal, 2017).

Richer (2012) expects the most important changes to occur in the beginning and end stage of electricity value chain, generation and consumption, and based on that he separates the business models in two broad categories: customer-side business models and utility-side business models. In customer-side business models a smaller PV system, typically from a couple of kW up to 1 MW, is located on the property of the customer. In utility-side models the energy is produced in larger amounts, typically some hundred MW, on a site located elsewhere and distributed to the consumers through traditional grid-lines.

Some scholars argue that the interests of utilities with solar companies and customers need to be aligned, to be able to create a sustainable long-term market for distributed PV. Richter (2012) contributes to this discussion by analysing the two categories of business models, and finds that utility companies would benefit more from utility-side models. This could mean that they might be more willing to cooperate with other solar businesses in this area.

Third Party Ownership Models

Frantzis et al. (2008) conceptualized generations of PV business models in the U.S. as being Zero generation, First generation and Second generation. According to this conceptualization, Zero Generation business models are when customer finances and owns the PV system, First Generation is when a third party finances, owns and operates the PV system, and Second Generation is when there are more variations in terms of ownership, operation and control of PV systems (Frantzis et al., 2008; Richter, 2012; Överholm, 2015).

In Third Party Ownership (TPO) model, the solar energy is offered as a service to the customer by the solar company, either through leasing the PV system or through selling the electricity produced by the PV system with a 15-20 years contract, which is referred as solar PPA (SEIA, 2015; Wainstein & Bumpus, 2016). Although in both of the options, there is a monthly payment by the customer, the main practical difference is that, in leasing the typically monthly payments are fixed, while in PPA the payment varies with the amount of energy consumed (Zhang, 2016). The TPO model is designed to overcome the difficulties of customers to finance the initial cost of PV system (Strupeit&Palm, 2015), while at the same time reducing the transaction costs such as obtaining licenses and permits (Hobbs et al., 2013). Arguably the most successful example of TPO model is SolarCity Corporation, the largest company in the U.S. PV market which was acquired by Tesla Motors Inc. in the end of 2016 (Wainstein & Bumpus, 2016; SolarCity, 2016). Before its acquisition by Tesla, the company had more than 300.000 customers and had installed capacity of 2.45 GW, with having the full solar value chain under its roof (Wainstein & Bumpus, 2016; SolarCity, 2016).

Frantzis et al. (2008) argued that the PV market has moved from Zero generation to First generation in the US, and TPO models represents more than 60% of the distributed solar market in the U.S. (Litvak, 2014). Frantzis et al. (2008) envisioned that the market will move ahead to Second generation models, which will allow flexibility in terms of different combinations of financing and ownership.

Strupeit and Palm (2016) conducted a comparative study on organizational configurations of business models residential PV in the U.S., Germany and Japan, and found that the models dominating each of these markets were different, depending on the local conditions of not only supportive policies for PV, but also of other industries. For example, in Germany, unlike in the U.S., customer owned model dominated the market, in which the solar companies marketed the PV as a better investment option then others, and offered the value of financial gains through existing feed-in tariff policy (Strupeit&Palm, 2016). On the other hand in Japan, the main driving model for PV adoption has been through inclusion of PV system in pre-fabricated homes. In this way, the cost of PV system is added to the total mortgage value of the homes, which provides an attractive financing option (ibid).

Community Solar

There are several business models aiming to overcome the financing barrier for PV through pooling of contributions of a large number of people. A such business model group identified in literature is community solar model, in which individual customers can purchase electricity, receive credits on their bills or rent PV panels from a large scale solar facility that is built off-site (Asmus, 2008; Zhang, 2016). Community solar model is well established in the U.S. market. According to variations in arrangements, this model can take alternative names such as solar condominium, as it is often referred as in Brazil, in which participants can buy or rent a solar lot in a large scale solar facility operated by a managing company (Castro et al., 2016).

Community solar model offers several advantages, such as reaching cost efficiency due to larger scale, and allowing energy cost reductions for the customers who lives in multiple floor buildings, who does not have the proper space or orientation for PV, or who lacks ownership of the houses/flats they live in (Huijben and Verbong, 2013; Zhang, 2016). Only a small portion of the rooftops are suitable for PV applications: according to the U.S. National Renewable Energy Laboratory (2008), ratio of suitable rooftops in the U.S. is between 22% and 27%, depending on the state.

A corresponding model in Europe, especially in Germany, is solar cooperative model (Yıldız, 2014). Solar cooperatives model is based on energy or financial gains in return of equity shares, and it mostly relied on the feed-in tariff scheme (ibid.). The two shapes that this model took in the U.S. and in Germany also illustrates the influence of local policy schemes on business model development. One important difference of solar cooperative model is that equity owners in cooperatives have a say in the strategic management of the project, which may not be the case for community solar/solar condominium. Apart from solar cooperatives, Yıldız (2014) also identified projects realized through financial participation of a large number of investors in Germany, which are called "closed-end funds".

Crowd-funding

Recent developments in Information and Communication Technologies (ICT) expanded the possibilities of pooling financial resources, and allowed emerging business models. One of these new models is Peer-to-Peer Lending or Crowd-Funding, which can be a model on its own or can function as the financing component for other business models. In this model, the necessary funding is raised through the relatively small contributions of large number of individuals (the crowd), through an online platform without the facilitation of traditional financial institutions. P2P lending and crowd-funding are very similar models, and in fact the two concepts are often used interchangeably. Typically in P2P lending each individual investor receives an interest for the investment and is paid back in a certain number of years;

whereas in crowd-funding the investor acquires an equity for the investment he/she made (Branker et al., 2011; Tongsopit et al., 2016). Owning a part of the PV system, the investors then, for example, sell the energy produced by their share to the beneficiary.

This alternative financing model is claimed to have the potential to radically alter existing production and consumption pattern, with internet being the enabler (Bocken et al., 2014). Some scholars argued that crowd-funding for renewable energy, apart from tapping into the otherwise unused financial resources, can also increase social support for renewable technologies by engaging a large number of citizens actively (Vasileiadou et al., 2016; Fleiß et al., 2017). Moreover, through crowd-funding, network of potential investors can be expanded geographically (Algawal et al., 2011), for example by receiving online investments from other countries. Crowd-funding initiatives can also expand the investor base. In their research about citizen participation initiatives for PV in Austria, Fleiß et al., (2017) state that in such initiatives often a minimum investment option is offered, around €50, which provides a "low entry threshold option" for investing, which a majority of the citizens can afford.

The literature provides several real life examples of crowd based financing model for PV. For example, a study by Meier et al. (2014) identified a case business in the U.S., called Mosaic, which is financing rooftop solar projects through P2P lending. The study also identified a model based on crowd owning a utility scale solar project, where the company called SunEdison manages the solar park, and investors own a part of the solar park and use the power produced by that.

The questions about economical viability of alternative financing models has received the attention of scholars. Branker et al (2011) looked at the financial performance of major online P2P lending platforms, such as LendingClub and Prosper, for funding a PV system in Ontario, Canada. They calculated that all of the platforms are able to fund rooftop PV with favourable financial returns to lenders, thanks to the feed-in-tariff policy. They argue that the major advantage of this model of funding over traditional financial institutions is the opportunity it offers for low income borrowers, who otherwise could not get loans, to access the funding (Branker et al., 2011). On the other hand, some scholars pointed at the potential risks that crowd funding can pose, and the pressure it puts on tightly regulated securities market, by often operating outside such regulations (Turan, 2015). Moreover Branket et al. (2011) points at the risk that in global P2P lending platforms, the investment could go to places where the return is highest, which could be richer countries with feed-in-tariffs, instead of developing countries.

Peer-to-Peer Trading

The developments in distributed solar market, such as consumers turning into prosumers, are opening doors to new business models, with ICTs being the enabler. An emerging business model which has recently received attention of scholars, is P2P energy trading. P2P energy trading is based on the idea that prosumers can sell the surplus energy of their PV systems to other consumers, or prosumers who need more than what their system produces (Long et al., 2017). This trading can be done through an online platform operated by a facilitating company.

Studies show that P2P energy trading bring various benefits. Lou et al. (2014) analysed a prosumer to prosumer trading scheme within grid connected microgrids and concluded that through trading between prosumers considerable economic gains can be achieved. Moret and Pinson (2017) showed that when prosumers were allowed to share energy at community level, the overall electricity procurement of the community is reduced. Gustavo et al. (2015) simulated a P2P trading scheme within a microgrid in Brazil, which included both PV system owners and at least equal number of consumers without PV system. Their simulation for Brazil also revealed that P2P trading among consumers increased economic feasibility of the system, and economic gains were higher in the scenario with more consumers without PV system. This is possible as P2P trading increases the efficiency by distributing the surplus energy production within the microgrid, and thus reduces the need for individual members to buy energy from the grid.

Long et al.(2017) argues that due to the hierarchical nature of the distribution networks, P2P trading will have to be carried out in three levels: 1)within microgrid where each prosumer is a peer, 2) among microgrids within a cell composed of many microgrids, 3) among cells. In similar lines as Lou et al (2014), the authors argue that in such a structure the efficiency, flexibility and responsiveness of each level is increased. However, according to Long et al. (2017) these technical arrangements for P2P trading have to be supported with effective business models.

One important question about P2P energy trading is if it is possible within current regulatory framework for energy. Butenko (2016) looked at the compatibility of P2P business models for solar PV with the current regulatory framework in Netherlands, and suggested that what is happening is not only a technological change but also a change in norms and values about the role of energy consumers, and thus a regulatory reform is needed to accommodate these changes.

P2P energy trading can be facilitated by a centralized platform, in the same way eBay organizes the trade of consumer products. On the other hand, the recent developments of blockchain technology can eliminate the need of a central platform, and instead the trading can occur through a decentralized platform. Blockchain is the digital technology behind BitCoin and allows decentralized and secure P2P trading, which offers possibilities for solar prosumers to trade surplus energy with their neighbours securely and automatically, through digital contracts (Long et al., 2017). German Energy Agency (DENA) is one of the first to study the potential impacts of blockchain technology on energy (2016). The study concludes that, Blockchain based P2P energy trading has the potential to reduce grid and metering costs, and add customer value through more transparent information about energy origin (DENA, 2016). The study also suggests that offering an alternative to unreliable services of utility companies, P2P energy trading might get more appeal in developing countries where the distrust to established institutions are higher (ibid.).

Despite their potential and disruptive character in other industries, P2P based models are yet to reach a level of disruption in distributed PV market, and according to Wainstein and Bumpus (2016) this can be due to the heavily regulated nature of energy markets and the resistance of existing actors for the incorporation of a more participative business model.

PV Business Models in Developing Country Context

In the context of developing countries, most of the research on solar business models has focused on off-grid solutions for rural electrification in the low-income markets, such as sub-Saharan Africa and India (Pode, 2013; Ramcahndran, 2016). In these countries, extending the grid to remote and rural areas is often financially, technically and organizationally infeasible, and although PV stands out as a viable solution, high initial capital costs limit the wider deployment of this technology (Kolk, A. & van den Buuse, D., 2013). Thus, the business models in low income countries try to offer solutions to financing of these systems, and focus on small PV systems designed for producing enough energy for lighting and mobile phone recharging in places where power grid does not exists (Pode, 2013; Anand&Rao, 2015). The research pays particular attention on fee-for-service model, which is a TPO model where a small fee is paid by the customer for a solar home system (Pode, 2013; Friebe et al. 2013; Scott, 2017).

Pode (2013) found that while fee-for-service model is popular in sub-Saharan Africa, in Asia customers prefer permanent ownership through micro-credit. Friebe et al. (2013) conducted a research on Solar Home System (SHS) markets in Africa and Asia, and found that the battery based off-grid system design makes it difficult for companies to offer long term service contracts, as replacement of batteries is expensive. Moreover a comparison of pre and post paid fee-for-service business models in India revealed that although pre-paid model is preferred by the customers, it results in too low consumption level and thus economically not feasible (D'Agostino et al., 2016). The authors suggest that business models should try to focus on solutions that would result in higher consumption, to be able to reach economic feasibility (ibid.)

Studies on rural electrification through PV showed that, apart from the financing, two most important factors that influence the success of business models in low income countries are raising awareness among customers through partnerships with local communities and capacity building for technical personnel on the field (Anand&Rao, 2015; Scott, 2017).

In one of the few studies on middle income countries, Tongospit et al.(2016) identified that, in the context of urban Thailand, TPO models are emerging rapidly together with community solar model. However, most of these models rely on existing feed-in-tariff policy in Thailand, and the uncertain future of this support policy limits the market expansion. Zhang's (2016) study on Chinese rooftop PV market revealed similar results. He identified the TPO model, in the form of solar energy management service companies, and crowd-funding model to be two growing business models in China. According to the study, there are two different crowd-funding models in China: equity crowd-funding and lease-out model. Equity model was successfully applied in 2014, in Qjanhai, Shenzhen, to raise capital for world's first megawatt level distributed PV project (Zhang, 2016). Lease-out model is developed by SolarBao company, and in this model the lenders of crowd-funding authorizes SolarBao to install and lease out the PV system to customers on behalf of themselves. In the end of commitment period the investor can keep the panels or sell it to SolarBao (Zhang, 2016).

The literature review conducted as a part of this study reveals that most of the research on business models for solar PV focused on pioneering countries, and the research that focus on developing countries is mostly focusing on business models for rural electrification through off-grid PV systems. The studies focusing on middle income countries and rural context is rather limited, and there were no studies found that focused on Brazil. Thus, there is a gap in the PV business models literature focusing on urban context in Brazil, which is a gap this study aims to address.

3 Theoretical Approach and Methodology

3.1 Theoretical Approach: Business Model Analysis

Scholars argued that business models are as important as the technology itself when it comes to the diffusion of clean technologies (Teece, 2010), and actually innovative business models can overcome several barriers and in that way help the diffusion of solar technologies (Tongsopit et al., 2016).

The concept of business model has increasingly received attention of scholars since 1990s (Huijben and Verbong, 2013). Although there are several different definitions of the concept of business model (Teece, 2010; Osterwalder & Pigneur, 2010), what is common in these definitions is the reference to how a company creates, delivers and captures value.

For the purpose of this study the definition of Osterwalder and Pigneur (2010) is chosen: Business models is "the rationale of how an organization creates, delivers, and captures value". Thus, in its simplest form a business model is the blueprint of how a company does business (Osterwalder et al.,2005).The business model serves as a building plan that allows designing and realizing the business structure and systems that constitute the company's operational and physical form (ibid.).

In this study, innovative business models for PV is analysed through the theoretical framework suggested by Osterwalder and Pigneur (2010). The authors suggest a business model framework which consists of different elements, or so-called "building blocks", both for comprehensive analysis of and for creating the business models. Their framework defines a business model in terms of the nine building blocks. Represented in the frame of a canvas, these blocks are customer segments, value propositions, channels, customer relationships, revenue streams, resources, key activities, key partners and cost structure. Below are short descriptions of each building block according to Osterwalder and Pigneur (2010).

Customer Segments are the different groups of customers that a company aims to serve. A business may choose to serve one or several different segments of customers, which should be defined in the business model, as each segment may require different offers, ways to reach them, types of relationships, and may have different profitabilities and willingness to pay. A company, for example, can choose to serve mass markets, niche markets or diversified.

Value Propositions are a bundle of products and services that create value for a certain customer segment, in other words they satisfy customer needs and they are the reason why customers choose a company over another one. Some examples of value propositions can be price, design, brand or simply convenience.

Channels are how a company communicates with and reach the customer to deliver the value propositions.The channels can be direct, such as in-house sale, or indirect, such as retail stores. Moreover channels can be owned by the company, such as a website, or by partners, such as an online marketplace. Owned channels have higher profit margins compared to partner channels, however, partner channels allow companies to widen their reach.

Customer Relationships refers to the type of relationship a company establishes with the target customer segment. These relationships can be motivated by customer acquisition, customer retention or boosting sales. Types of relationships can range from direct personal assistance, which is often used in banking, to fully automated services, or even co-creation, as in the case of youtube.com.

Revenue streams represents how a company generates revenues from a customer segment. There are two types of revenue streams: one-time payment transaction revenues or recurring payments. Most common ways to generate revenue streams are asset sales (such as one time sale of PV system), subscription fees (such as gym membership), usage fees (such as electricity from utility), lending/renting/leasing (such as car rentals), licensing (such as in media industry), brokerage fees (such as real estate agents) and advertising revenues (such as many websites). Revenue streams can have two main types of pricing mechanism: fixed or dynamic.Fixed pricing is based on static variables, such as quality, volume or customer segment. Dynamic pricing is based on market conditions, such the inventory situation (often used by airline companies), demand, outcome of bidding (auction) or bargaining.

Key Resources describes the most important assets required to make a business model work. Key resources can be physical (such as a production facility), intellectual (such as brands or patents), human or financial.

Key Activities describes the most important activities required to make a business model work. In the framework, these activities are categorized as production (such as manufacturing), problem solving (such as consulting or hospitals) and platform management (such as online marketplace).

Key Partnerships refers to the network of partners a company relies on to make a business plan work. There are four different kind of partnerships: strategic alliances between non-competitors, "coopetition" which refers to partnerships of competitors, joint ventures and buyer-supplier relationships.

And lastly, **Cost Structure** refers to the most important costs incurred while a company is operating. A company could be cost driven, meaning that it can try to minimize costs to offer the lowest price, or value driven, in which company focus less on costs but more on the high quality of its offerings. Many companies fall somewhere in between these two categories. The costs can be fixed or variable, and can benefit from economies of scale and scope.

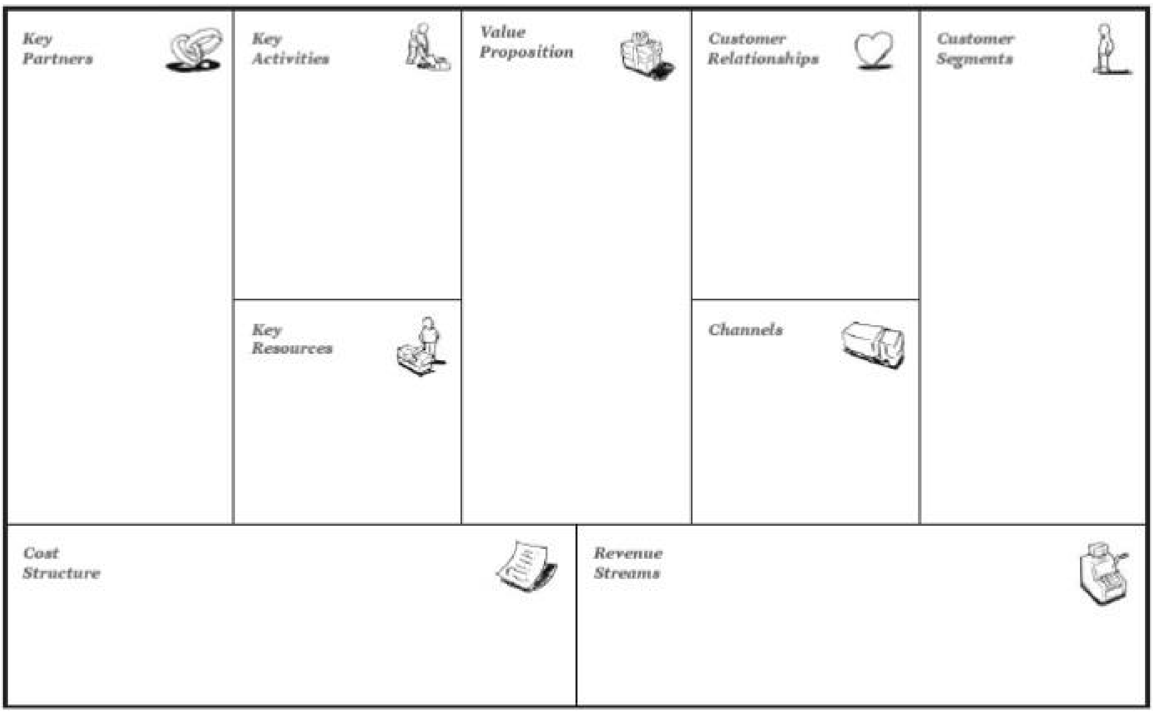

Figure 5. Business Model Canvas
Source: Osterwalder and Pigneur (2010)

The theoretical framework of business canvas (Osterwalder&Pigneur, 2010) is chosen for this study because the canvas framework is intuitive yet comprehensive. The framework is also flexible, since it is not industry or country specific. Through the building blocks, the framework allowed comprehensive and structured analysis of the potential and suitability of innovative solar business models in Brazil. Another reason of choosing the business canvas framework is that it has been successfully applied in the area of solar energy by many researchers (Boehnke & Wüstenhagen, 2007; Richter, 2013; Huijben and Verbong, 2013; Tongsopit et al, 2016).

3.2 Research Design and Methodology

In this study, qualitative case study approach was adapted. A case study explores a specific phenomenon, thus the "case", in its real world context (Yin, 2010). The study was conducted in three stages: First, a comprehensive literature review is carried out in order to map out the existing knowledge about PV business models around the world and the barriers for the development of PV in Brazil. This was followed by 10 semi-structured interviews that were conducted with PV companies in Brazil and other countries, regulatory bodies in Brazil, researchers and consumers. Majority of the interviews were carried out in Brazil, mainly in Rio de Janeiro. In the last stage, selected business models were analysed through the theoretical framework of the business model canvas and their suitability to Brazilian context and potential for overcoming the barriers was discussed.

The research process initially began with a dive-in approach, collecting information on PV companies with innovative business models around the world and the PV market and regulatory framework in Brazil. The initial process was useful during the literature review in terms of both providing real-life examples of models described by scholars and helping to identify more keywords to search for literature. Moreover this process also supported the interviewee selection to a great extent. The initial research was followed by analysis of the academic knowledge on PV business models. Through the analysis a gap in the academic knowledge was identified, the study scope was narrowed down and a research question was formulated.

PV business models were identified through the initial research and literature review, and this gave rise to the question of which models should be included in the study. This study focuses on business models that can be categorised as innovative. Although some models are relatively mature (at least in some countries - such as TPO model in the U.S.), and some are still at the start-up stage (such as P2P energy trading), the decision for which models to include in the study was based on the criteria of lack of substantial presence in the Brazilian PV market.This selection criteria resulted in inclusion of all the models, except the self-ownership of PV systems. There can be several variations of each model, though fundamental blocks of the models remain. For this reason business models were approached in the broad sense, and the analysis were in most of the cases broadly based on the models of successful companies around the world.

The thesis rests on two main data sources: secondary data collected through desktop research and primary data collected through semi-structured interviews. Acquired through desktop research, the first group of data source is academic and grey literature, consisting of reports by industry organizations, governments agencies, consulting companies and websites of businesses.

In the case of statistical data, particular effort was put into to reaching the most up to date data from the original source. National Agency for Electricity (ANEEL) of Brazil transparently publishes all the data related to the net metering system, including a list of each single system owner, on its website. Thus, all the data used in this study related to the net metering system in Brazil is taken directly from the website of ANEEL.

The second data source, the 10 semi-structured interviews, were conducted with the representatives of Brazilian and foreign solar companies, related government bodies, energy professionals, researchers and consumers in urban and rural areas. The interviews were conducted face-to-face, mostly on site but in some cases online. Most of the face-to-face interviews lasted between 60 to 90 minutes, though the duration was shorter for the interviews with consumers. Notes were taken during the interviews. The interviews typically conducted around a small set of open ended questions, of which the content slightly changed according to the interviewee group. While business model related questions informed by the theoretical framework were in focus for companies, for government agencies more policy related questions, and for consumers questions about practicalities of electricity consumption and awareness about PV were asked.

The main method of choosing interviewees was purposeful sampling, thus the selection was not statistically representative. Relevant stakeholders that could help answering the research question were identified through initial research and the findings of literature, and for each interviewee group several potential interviewees were approached through the means of e-mail or the social media platform LinkedIn. Maximum variation was attempted in sampling, thus for each analysed model a company working with that model was interviewed. In some cases, such as consumers, the interviewees were chosen through convenience sampling. Table 2 below shows a list of interviewees, according to the interview date (see Appendix A for detailed information on the interviewees).

Organization / Locality	Interviewee
Endless AB	Eduardo Rechden (CEO)
Danish Technical University	Prof. Pierre Pinson (Researcher)
LO3 - Brooklyn Microgrid	Sasha Santiago (Marketing Director)
Jamaraqua Community	Solannge Laryce (Consumer)
Rio de Janeiro	Ricardo F.Goes (Consumer)
COSOL Energia	Csaba Sulyok (CEO)
Energy Research Company (EPE)	Gabriel Konzen (Analyst)
Rio de Janiero	Cecelo Frony (Consumer)
Axis Renovaveis	Luiz Pacheco (CEO)
Trine AB	Hanna Lindquist (Communication Manager)

Table 2: List of interviewees

In the analysis part of the study, potential of selected business models for overcoming barriers for the increased deployment of PV in Brazil are investigated. Primary and secondary empirical data collected on selected business models were categorized and then analysed through the business canvas framework of Osterwalder and Pigneur (2010). The analysis of important building blocks of the business models, such as how they create value for customers, in turn provided bases for determining if and how they could be of help in overcoming specific barriers for distributed PV in Brazil.

There were certain practical constraints placed on the research. Firstly, the researcher does not speak Portuguese. Although thanks to the international nature of the PV sector in Brazil (Souza et al., 2016) there was a large body of documents available online in English, certain relevant and important documents, which could possibly enhance the reliability of the study, could not be reached due to this language barrier. Moreover, language barrier also limited the research often to secondary sources, especially in relation to the policy documents and market regulations. Another practical limiting factor for the study was that number of interviewees in each group were limited, which was related to the availability of resources for the research.

Validity is a key quality measure of a study and refers to the proper collection and and interpretation of the data (Yin,2010). In this study, validity was tried to be increased through including a varied set of data, resting on literature on one side and interviews with different stakeholder groups on the other, which also gave the possibility of triangulation.

Qualitative research is particularistic by nature (Yin, 2010), and especially findings from a case study has limited generalizability. Moreover, how business model shape themselves is very much related to the context of the specific country, thus models cannot directly be transferred to another country. However, the findings of a qualitative study can be analytically generalized (Yin, 2010), which means that findings of this study can have important implications for other countries, especially with similar conditions.

4 Distributed PV in Brazil: Market Conditions and Barriers

This section will take a closer look at the Brazilian distributed PV market and first analyse the regulatory framework and the business landscape that the solar businesses operate in, and then identify barriers for wider deployment based on previous studies. This chapter constitutes a base for the following chapter, where the implications of the market conditions for each business model are discussed.

4.1 Regulatory Framework

Brazil is supporting the distributed PV deployment mainly through a net metering system. Under the net metering scheme of Regulation 482/2012, the owners of the PV systems up to 5MW consume the electricity produced by the system directly and inject the surplus production into the grid. In return, they receive energy credits (in kWh) from the distribution company that are equal to the amount they have injected, which is then deducted from their future bills; in case of higher consumption than production. This could be, for example, in cases of higher consumption levels in summer seasons due to cooling. The electricity credits are personal for each consumer and they cannot be sold or transferred. Thus the regulation prevents the commercialization of surplus electricity from PV systems. However, what can be commercialized is the asset itself, so PV systems can be sold or rented out to other consumers.

The regulation underwent a revision in 2015, which introduced virtual net metering with remote generation, and community solar/solar condominium options with shared generation. Virtual net metering opened up the possibility of owning solar panels in a different location than consumer's premise and receiving electricity credits, which can be saved for 5 years (Vieira, 2016). Community solar option allowed users to share PV installations, on or off-site, and receive separate credits from one system. The revision updated the maximum power for being included in the net metering system from the initial 1MW to 5MW (IDEAL, 2016). The revision also shortened the time limits for distributors to secure connection of distributed PV systems to the grid. This revision is in force since March 2016. Moreover, so far 16 states in Brazil adopted the exemption of the ICSM sales tax for the excess energy injected into the grid, as a measure to further support PV deployment (Castro et al., 2016; IDEAL, 2016). Without the exemption, both the injected and the received amount of energy is subject to taxation which severely limits the economic viability of the system .

In Brazil, the regulation divides the electricity market into two: one section is composed of 'free consumers', which constitutes around 20% of the overall consumption (ABRADEE, 2016) and the other section of 'captive consumers'. Only 'free consumers', those who have electricity demand equal or higher than 500 kW, have the right to sign PPAs and purchase electricity directly from generators (ABRACEEL, 2017). These would typically be commercial and industrial consumers with high demand. Thus, the existing legislation does not allow solar companies to sell electricity directly to regular residential consumers.

Brazilian electricity sector was unbundled in 1995, thus activities of generation, transmission and distribution are separated, and the legislation brought certain restrictions on the distribution companies. Brazilian legislation forbids the distributor companies in engaging power production activities or take part in any other company, which limits the options of distribution companies in terms of solar (Gallo&Lobianco, 2015)[1]. There is a draft bill[2] under process in Brazilian Senate which involves provisions to allow distribution companies to generate power only if it is based on solar energy, and install PV on the roofs of the social tariff[3] consumers. If the bill is approved, it can encourage distribution companies to cooperate with solar businesses and accelerate the PV deployment, however, according to EPE analyst Gabriel Konzen, the draft bill has important flaws and the approval process might take rather long, if the fact that it was submitted back in 2015 is taken into consideration (personal communication, August 4, 2017).

Since net metering system relies on the savings from energy costs for the consumer, the cost of energy directly influences the economic feasibility and thus the adoption rate of PV. In the recent years electricity prices Brazil have seen significant increases, reaching 50% (Morais&Yaneva,2017). According to ANEEL (2017), average basic price of electricity without taxes and charges in Brazil is €0,12/kWh[4], though there are substantial price differences among distribution companies, with the highest price being €0,19/kWh. Currently average household electricity price with taxes added in Brazil is higher than countries with similar GDP per capita[5], such as Turkey, comparable to prices in the E.U. countries. Figure 6 shows the average Brazilian electricity price including taxes and charges compared to selected European countries.

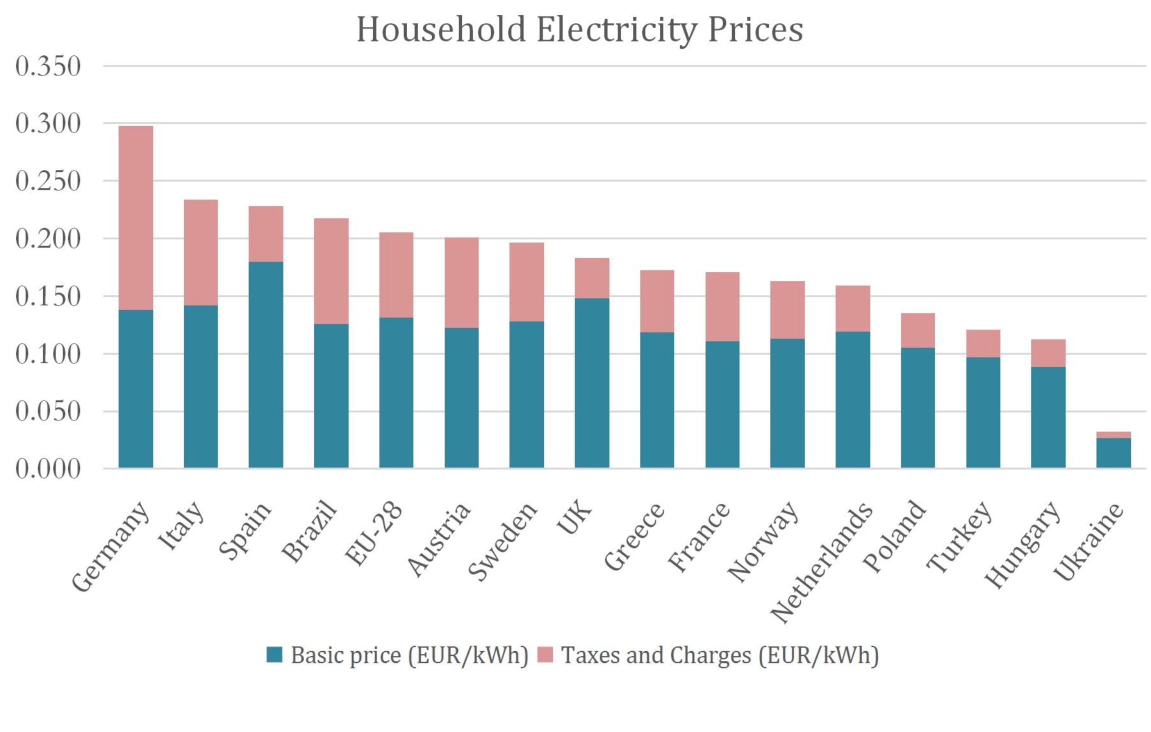

Figure 6: Household electricity prices in selected countries

Source: ANEEL(2017), ABRADEE (2016), Eurostat (2017)

[1] That being said, a holding company with activities in both generation and distribution sectors, CPFL, is reported to establish solar company (Reuters, May 3, 2017).

[2] Draft bill PLS 277/2015 by senator Wilder Morais.

[3] A discounted tariff for consumers with low consumption.

[4] BRL 0,47/kWh

[5] $8.650 as of 2016 with current US$ (World Bank, 2017)

According to the Association of Brazilian Electricity Distributors (2016) the high price of electricity is the result of high burden of taxes and charges: with more than 40% of the final electricity price in Brazil being taxes and charges, Brazil has the second highest ratio of taxes and charges among members of International Energy Agency.

An important development related to the regulatory framework is the proposed reform of electricity sector. With the change of cabinet in 2016, Ministry of Mines and Energy started the process of public consultations[6] for regulatory changes in electricity sector that aims to provide "long term sustainability for the sector" (MME, 2017), and the consultation process finished in August, 2017. If approved by the Senate, the changes will take effect in 2018 (GS, 2017).

One of the most important changes that the proposed reform includes is the introduction of the binomial electric tariff (ibid.). As of today, the electricity tariff for low voltage consumers in Brazil is composed of generation, transmission and distribution costs, grid losses (technical losses and thefts) and several taxes and charges.The tariff imposes volumetric charges for the transmission and distribution costs (see Appendix-B). However, these costs are composed of variable and fixed costs, and a reduction in electricity consumption by PV system owners brings the reduction to variable costs of distribution companies, but not to their fixed costs (Castro et al., 2016). Thus in the current tariff structure, where both the fixed and the variable costs are charged based on volume, distribution companies cannot recover the fixed costs from PV owners. Although at first the loss can be carried by the distribution company, it might slowly reflect this loss on other consumers by increasing the price, a situation in which an unfair shift of the cost burden to consumers without PV systems occurs (Castro et al., 2016). In the binomial tariff, fixed distribution network costs are charged separately from the volume of energy, where the former is charged by a fixed rate and the latter by a volumetric rate (ibid.). However, a shift to the binomial tariff structure would bring an economic disadvantage to distributed PV by reducing the amount of savings on electricity bills. The negative influence for the economic feasibility of PV systems can result in the pay-back time for the investment in PV systems to double, which clearly would slow down the PV adoption (Konzen G., personal communication, August 4, 2017).

All in all, the net metering system in Brazil, especially after its revision, and the relatively high price of electricity offer a fertile ground for the development of PV market. On the other hand, certain limitations that the regulatory framework imposes, such as banning the commercialization of energy credits, the high consumption criteria for consumers to be free to sign PPAs and restrictions on the activities of distribution companies hinders the development of the distributed PV market. Moreover, there are several proposed changes that can alter the regulatory framework, however, the uncertainty around the changes can influence the market negatively.

4.2 Business Landscape

With the net metering regulation distributed PV started to pick up and in 3 years reached over 115 MW installed capacity (ANEEL, 2017). The revision of the system in 2015, which introduced more favourable conditions and options, came into force in 2016. The positive influence of this revision seems to have resulted in further acceleration of deployment, and so far more than 14 000 systems have been registered to the net metering scheme.

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[6] Public consultation #33/2017 (MME, 2017)

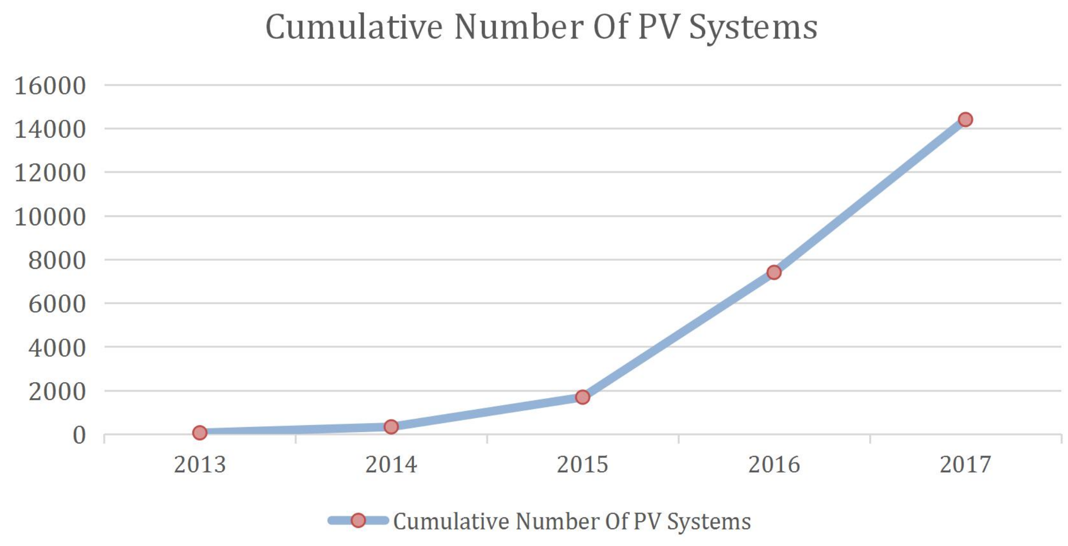

Figure 7: Cumulative number of distributed PV systems in Brazil

Source: ANEEL (2017)

As the Brazilian net metering system allowed sharing of systems, over 16 000 individual customers are receiving credits from the installed 14 450 systems. The states with the highest number of distributed PV installations were in Minas Gerais (3118), Sao Paulo (2946), Rio Grande del Sur (1643) and Rio de Janeiro (1268) (ANEEL, 2017).

In terms of the type of installations in Brazil, residential installations constitute the majority by the number and by the capacity. As shown in Figure 8 below, 79% of the PV systems are installed on residential buildings, while 15% of them are installed on commercial buildings (ANEEL, 2017). In terms of capacity the ratios are similar: 72% of the installed capacity is residential and 16% is commercial (Castro, 2016 in IDEAL, 2016).

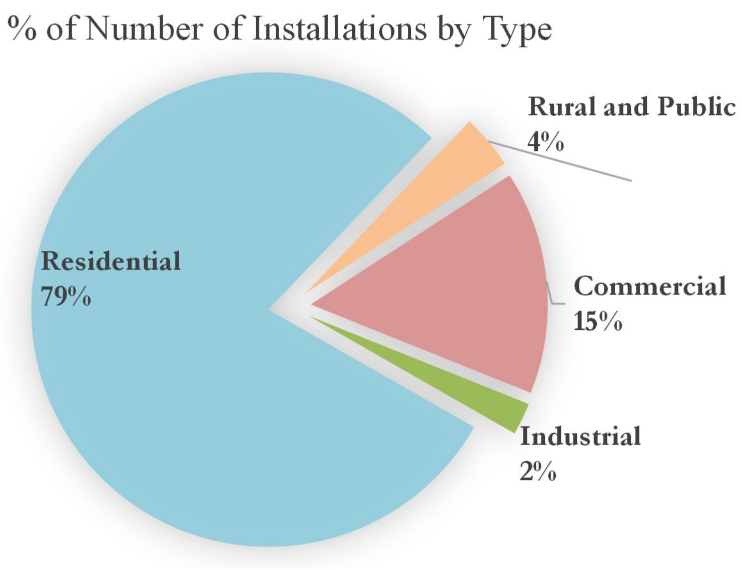

Figure 8: % of Number of PV installations by type

Source : ANEEL (2017)

Looking at the profiles of the PV companies operating in the market, what catches the eye is that almost all of the solar companies in Brazil are small installation companies, thus the market is dominated by self-ownership model. According to a recent survey, the majority of the solar companies have five or less employees (Greener, 2017). Typically, these companies buy solar system kits from the distributor company and install the system to customers' premises. Over 70% of the companies responded to the survey installed only one system per month. The survey further reveals that the PV market in Brazil is newly emerging, as almost 75% of the solar companies in Brazil are less than 2 years old (Greener, 2017).

Following the global trend, the PV system prices in Brazil are decreasing. According to the survey conducted among the companies, the average price for PV systems in January 2017 was €2.22/W[7] for 2 kW systems and €2.02/W for 4 kW systems, which was 10% and 12% lower respectively than the year before (Greener, 2017). For comparison, the price of utility scale applications with capacity above 1MW is 40% lower at around €1.35/W.

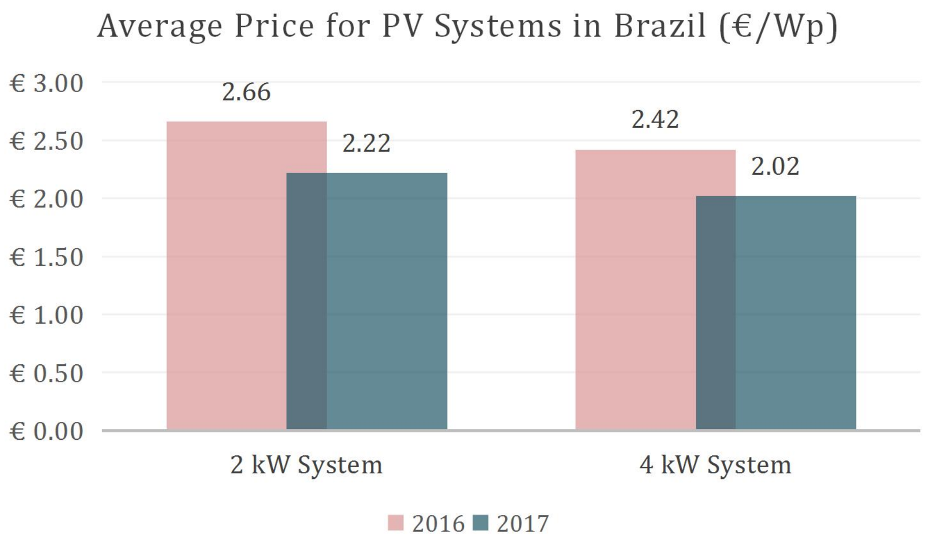

Figure 9 : Average Price for PV systems in Brazil

Source: Greener (2017)

In some countries that lead PV deployment, the ratio of hardware costs constitute a minority of the total system cost. For example in the U.S., the hardware costs, or so-called the "soft-costs" are only 36% of the total cost (Friedman et al.,2013). However the cost composition in Brazil seem to be different. Soft costs related to project development and installation constitute only 17% of the total cost, while 83% of the PV system costs are related to the hardware cost, with the PV panels being the biggest component (IDEAL, 2016). This cost structure has some implications for the business models, which are discussed in the next section.

Alternative financing mechanisms have not yet been developed in Brazil, and in most cases customers bear the upfront cost. According to the survey conducted among the solar businesses, in 43% of the PV projects the costs were paid in cash by the customer, and in 25% of the project through loans from commercial banks, which often have unfavourable interest rates (Greener, 2017). Majority of the companies surveyed (59%) sees the problem of

[7] As of 01.09.2017, 1 Brazilian Real = €0,27

financing as the biggest barrier in the development of PV market. Thus some installation companies try to ease the upfront cost for the customer and offer the possibility of payment through instalments, which constitute the payment method for 18% of the installations. Although in very recently Brazilian Development Bank (BNDES) has announced that the procedures for the financing of PV installations are simplified, and the participation of BNDES is increased, the effect of these changes are yet to be seen (2017).

All in all, there is a growing distributed PV market in Brazil and the net metering system is an important support for it. The market, however, is at its infancy and can be identified as Zero Generation (Frantzis et al., 2008), which is dominated by residential systems, installed by small companies, owned by the customer and often paid in cash or through high interest loans.

4.3 Barriers to PV in Brazil

This section presents a review of the research about barriers to increased deployment of PV in Brazil and similar developing countries, with the purpose of identifying those barriers which business models could possibly help overcome.

The literature on barriers to PV deployment is well established (Timilsina et al., 2012) and although the barriers vary among countries, there are several common barriers (Karakaya & Sriwannawit, 2015). These barriers can roughly be classified as technical, economical and institutional (Timilsina et al., 2012).

In general, technical barriers refer to PV efficiency limitations, performance constraints of batteries and raw material limitations (Timilsina et al., 2012). Economical barriers are mostly related to high initial system costs and difficulties in financing these costs (Timilsina et al., 2012; Echegaray, 2014; Strupeit, 2017). Institutional barriers are mainly about inadequate policies and regulations (Faria et al., 2017).

The research on barriers to PV specifically in Brazil is rather limited. However, similar to other countries, most authors point to the high initial costs as being the main barrier in Brazil (Echegaray, 2014; Faria et al., 2017; Martins, 2015 in Castro et al., 2016). Faria et al. (2017) stresses the barrier of financing, especially the high interest rates in Brazil and the difficulties of accessing low cost loans. Moreover, the authors of the study argues that the high taxes on energy constitutes another barrier, even though some individual states decided to cease charging some taxes.On the other hand, Ferraz and Bicalho (2015) show that in several regions of Brazil grid parity, i.e. the situation where cost of electricity from distributed PV and from local utilities are equal, has already been attained. Thus, they argue that the main barriers are not economical but instead related to institutional aspects, such as inadequate policy design and industry risks.

One of these regulatory barriers some scholars have identified is the existing net metering regulation. According to the regulation, the amount of surplus energy fed into the grid is credited to the consumers account. However the regulation does not envision any commercialization of those credits, thus there is no economical incentive to install equipment that produces more energy than what is needed for self-consumption (Faria et al., 2017). Guerreiro (2016 in Castro et al.,2016) emphasizes that, by preventing the commercialization, the existing regulation makes different alternative business models infeasible, and points out the liberalization of commercialization as a key factor for the development of distributed PV in Brazil.

Several scholars raised the potential problems that utility companies can face with higher rates of distributed PV and stressed the need for having these companies on board (Frantzis et al., 2008; Richter, 2012). In Brazil, Castro et al.(2016) point out the regulatory barriers that are specific for distribution companies, to positively participate in the diffusion process of distributed PV. They suggest that distribution companies have several doubts about the development of distributed PV, such as grid instability, increased administrative procedures and most importantly financial losses due to lower energy sales (Castro et al., 2016). A study showed that in the case of widespread distributed PV deployment, Brazilian distribution companies might loose 30% of their revenues (Andrade, 2016 in Castro et al.2016).

Moreover, the electricity tariff in Brazil does not differentiate grid costs and energy costs, and it is argued that as more consumers switch to PV they will not be paying for the cost of grid. This will result in lower revenues for distribution companies initially, and to cover the loss they are likely to pass on the loss to other consumers as higher tariffs, which also points to a problem of reversed income distribution and social injustice (Castro et al., 2016). Although a simulation study by ANEEL (2017) recognizes this effect, it argues that the impact on the tariff is rather limited, around 1% accumulated over the next 7 years.

A study conducted among the Brazilian PV system installers demonstrates the important role, in this case a negative one, distribution companies can play. According to the study, almost 90% of the installers claimed that their projects were delayed several months because of the bureaucratic problems with distribution companies at the grid connection stage, and that distribution companies were reluctant to comply with the deadlines stated by the regulation and unwilling to cooperate in several technical issues (IDEAL, 2016). It can be argued that, this reluctance of distribution companies partly results from the federal legislation that bans distribution companies from power generation, and participation in other companies, or developing any activity beyond distribution company's purpose (Gallo&Lobianco, 2015).

A research conducted in Brazil about the views of end-customers and company managers reveals that lack of awareness and misconceptions about the PV is a quite common phenomenon (Echegaray, 2014). Although private consumers value the environmental benefits of PV technology, they have several misconceptions such as confusing PV panels with solar water heating panels, or believing that energy can't be harvested on cloudy days, or the energy from PV would not be enough to cover the demand. On the other hand, company managers have less misconceptions about the technology, and they think that sourcing the energy need of their company from PV can increase the company reputation, however they believe this increased reputation would not attract more customers. Moreover, the high upfront cost of PV systems makes it difficult for the managers to legitimize such an investment to shareholders, who often are interested in short-term gains (Echegaray, 2014).

All in all, the previous studies show that the main barriers for distributed PV in Brazil are the high initial costs and difficulties in financing the installations, the lack of economic incentive to install higher capacity systems than self consumption due to the net metering regulation and the lack of interest or even negative attitude of distribution companies. Moreover there is a lack of awareness among the public, which further limits the market development.

5 Analysis

In this section the suitability of four business models for Brazil and the potential of the models to address the identified barriers for PV in Brazil are analysed through the business model canvas framework. The analysed models are third party ownership, community solar, crowd-funding and P2P trading.

5.1 Third Party Ownership Model

In the TPO model, instead of the end-consumer buying, having it installed and owning the residential PV system, a solar service company installs the system on the consumer's premises, owns and takes care of the maintenance. In return, the end-consumers buys the electricity produced by the system through a long term power purchase agreement. In cases where direct electricity sales are not legally possible, the solar service company can lease the system, and in that case the end-user pays for using the system.

Third Party Ownership Model Canvas

<table>
<tr>
<td rowspan="2">Key Partners
Hardware suppliers
Financial institutions
Distribution companies
Governmental bodies
Insurance companies</td>
<td>Key Activities
PV system installing
Customer acquisition</td>
<td rowspan="2">Value
No upfront costs
Immediate reduction of electricity costs
Long term stable electricity price
No transaction costs for consumer
Property value increase</td>
<td>Relationships
Long term financial (PPA/lease)</td>
<td rowspan="2">Customer Segments
Low voltage consumers with roof space
Companies with high demand
Above average consumption in areas with high electricity prices</td>
</tr>
<tr>
<td>Key Resources
Skilled personnel
Marketing channels
System monitoring platform</td>
<td>Channels
Door-to-door sales
Offices
Show cases
Partnerships
Website</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Initial investment for PV system
Customer acquisition activities
Transaction costs (licences, permits etc.)
Cost of financing</td>
<td colspan="2">Revenue Streams
Monthly renting fees for residential
Monthly energy sale payments for commercial</td>
</tr>
</table>

Table 3: TPO Model Canvas

The customer segments that the TPO model targets are mainly consumers who owns appropriate roof space for the PV system, possibly living in single family detached houses, industries with roof space, companies such as supermarkets and large stores, or public bodies such as schools.

In the case of Brazil high voltage industrial customers are already subject to a lower electricity tariff, thus have less economic incentive to install PV systems. For this reason, industrial customers would be less of a priority for TPO companies in Brazil. Moreover as lowering electricity costs is possibly one of the most important incentives for customers, it is more appropriate to target the customers who have above average energy consumption and who live in states where the electricity tariffs are the highest. These customers would typically be high demand commercial consumers. For example, one of the interviewed companies which operates with the TPO model in Brazil, Luiz Pacheco from Axis Renovaveis, defines their main target customer segment as commercial customers which would like to reduce their energy costs, and the company has completed a project and signed a PPA with a drug store chain with 11 stores in the state of Minas Gerais (personal communication, August 28, 2017).

According to the net metering regulation in Brazil, free-consumers can sign PPAs and buy electricity from any source they wish, but captive consumers are not allowed to sign solar contracts based on the amount of energy generated. Since PPA is not legally available for this kind of customers, renting[8] stands out as the only available option that TPO companies can offer for captive customers in Brazil.

A customer segment that is identified to be a potential target segment for TPO model is the rural communities that are connected to national grid, especially the remote communities in the states of Amazonia and Para. Although several of these communities were connected to the national grid in the last 15 years, the supply quality can be very low. For example, Solange Laryce from the community of Jamaraqua located in remote area of Para state mentioned that the electricity supply is extremely unstable, cut-offs are very often (personal communication, July 23, 2017). The unstable electricity supply often cause the light bulbs to explode and household equipments to be harmed, which result in a heavy economic burden for the community members.

The most important value proposition of the TPO model is that the model allows the customers to reach solar energy and immediately reduce their electricity costs, without having to pay for a high initial investment cost for the system. The model offers a long term predictable energy or renting pricing, thus eliminating the risk of future increase in energy prices. Moreover, the model also proposes the values of eliminating transaction costs that occurs in the process of securing financing from the bank; eliminating various risks, such as technical problems, and costs related to maintenance.

The main value proposition of the TPO model clearly addresses the barrier of financing the high initial cost of PV systems, which is a fundamental barrier in Brazil. Immediate reduction of energy costs and long term predictable electricity pricing address the needs of commercial customers, who are often interested in immediate economic gains to satisfy the shareholders.The already high electricity prices coupled with high dependency on hydro, point towards future risk of even higher prices, especially if issues such as ongoing deforestation in Amazon region and climate change are taken into consideration. Although under such risks long term predictability would normally be expected to appeal to commercial customers, the interviews reveal that this potential appeal runs against a socio-cultural feature. Long term contracts are not very common in Brazil, since planning 10-20 years ahead is difficult for Brazilians, considering the rapid changes in developing countries in general. Interviewees claim that this cultural point makes the potential customers reluctant to sign under a 20 year contract. According to Csaba Sulyok, one way to solve this problem is

[8] Although the terms "leasing" and "renting" are used interchangeably in this study, in Brazil "leasing" has a special legal status, thus in Brazilian context the term "renting" corresponds to the business activity described here.

to increase the duration of contracts progressively, and adjust the rent accordingly, as people need to get used to the system (personal communication August 1, 2017).

The channels for TPO model to reach the customers to deliver the proposed value can be door to door sales teams, neighbourhood offices, advertising in the form of show cases, ambassador programs, partnerships and online platforms. Ambassador programs as channels to reach customers can be effective in Brazil. Earlier studies have shown the importance of peer-effect (Palm, 2017). Several interviewees mentioned the importances of peer-effect in Brazil. Gabriel Konzen from EPE explained this as follows:

> "Solar is also a social process, people need to see it working in their neighbour"
> (personal communication, August 4, 2017)

Lack of widespread knowledge can lead to suspicion towards solar systems which is one of the barriers for Brazilian distributed PV market. For example, one of the interviewees, Cecelo Frony illustrates this barrier by expressing that he would not consider to install PV system to his two floor house even if it comes with 10%-15% reduction, as for him the reduction is not big enough to go through all the hassle and "have your roof destroyed" for something he is not even sure if it works (personal communication, August 11, 2017). There could be many potential customers thinking in similar way and an ambassador program and strong awareness campaigns organized by the industry organizations could help.

There are two types of revenue streams for TPO model, depending on whether the customer is a PPA customer or leasing/renting customer. As mentioned earlier, in Brazil, only consumers with high demand can commence a PPA directly with an energy generator, thus the PPA option for TPO is only available to these high demand consumers. For these customers the revenue stream is monthly energy sale payments. For regular consumers the model offers renting option, thus for this type of customers the revenues would come from monthly rental fees. In some countries, such as the U.S., tax credits are also part of revenue streams of the TPO model. However in Brazil there are no such extra incentives that can bring additional revenues, which limits the revenues of TPO companies in Brazil to monthly fees. One of the financial resources of TPO companies is the funds, which they create by packaging several projects and sell to investors (Hobbs et al., 2013). However, in the current economical recession in Brazil, this could be difficult. Thus financing options could be more limited in Brazil for this model than, for example the U.S., which require higher reliance on the company capital. The case Axis Renovaveis illustrates this issue, as the company so far realized 20 projects amounting to 3,5 MW capacity, and all of them were financed by the company's own capital (L.Pacheco, 2017).

TPO model relies heavily on key partners: suppliers of PV panels and inverters, various types of investors and financial institutions for securing low cost financing, insurance companies, governmental bodies for permits, and especially distribution companies as net metering requires grid connection and thus coordination with the distribution companies. High levels of bureaucratic red-tape and the negative attitudes of distribution companies are recognized by the several interviewees: as it is a widespread idea that distribution companies have nothing to gain from higher rates of distributed PV deployment. Unless a ground for cooperation is found, the current situation where negative attitudes of distribution companies slow the project completion for TPO companies is expected to continue. In the case of renting, the customers might be unwilling to start the payments before the project is operational, which can pose a financial risk, especially if combined with higher reliance on equity as financing source.

TPO companies have mostly fixed costs in the form of initial investment for the purchase and installation of the PV system. They often benefit from economies of scale, for example they can acquire equipment cheaper in wholesale market. As shown in the previous chapter, the prices for solar systems are falling in Brazil, similar to global trends, and there are substantial price reductions (up to 40%) for systems above 1MW capacity (Greener, 2017). Moreover one of the important costs for TPO model is the "soft costs", such costs associated with customer acquisition. However these costs constitute a small portion of the system costs in Brazil (IDEAL, 2016), possibly due to relatively lower labour costs in Brazil compared to pioneer countries. Thus the TPO model in Brazil can benefit from hardware cost reductions due to economies of scale and experience relatively lower soft costs.

5.2 Community Solar

The community solar model is based on a large-scale solar facility built off-site and the energy produced by this facility is shared by the members. The revised net metering regulation in Brazil allows remote and shared generation, thus opens the way to develop community solar projects in the form of solar condominium, where members of the condominium can buy or rent solar lots comprised of a certain amount of panels. The virtual net metering system, then, allows the consumer to receive energy credits for their bills.

Community Solar Model Canvas

Key Partners	Key Activities	Value	Relationships	Customer Segments
Hardware suppliers Financial institutions Distribution companies Governmental bodies Condo managements Insurance companies	PV system installing Customer acquisition Maintenance Billing **Key Resources** Financing Skilled personnel Marketing channels Online platform	No or less upfront costs Immediate reduction of electricity costs Long term stable electricity price No transaction costs for consumer Hassle free Community feel	Long term financial (rent/own) Distant **Channels** Website Partnerships Direct	Low voltage consumers in apartments Home owners Commercial

Cost Structure	Revenue Streams
Initial investment for PV system Customer acquisition activities Transaction costs (licences, permits etc.) Cost of financing Land	Monthly renting fees Monthly management fees Solar lot sales

Table 4: Community Solar Model Canvas

The target customer segment for this model in Brazil are low-voltage consumers, residing in apartment buildings who does not have the opportunity to have PV on their roofs, detached home owners who either does not have roofs suitable for installing PV or prefer not to have PV system on their roofs, or commercial customers. The innovative feature of this business model in terms of customer segments is that it allows consumers living in apartments, which is a large segment[9] that usually does not have available roof space, to own solar panels or use solar energy. Even if the building has available rooftop, some apartments occupied by renters who lacks the rights for such an installation.The community solar model targets this customer group, who otherwise do not have access to solar energy.

Moreover, some detached house owners might not have the available roof space, due to the water tanks placed on their roof, something not uncommon in Brazil. Another reason for Brazilian home owners to prefer not having the PV system on their roof is the security concerns. PV systems are quite valuable and especially in some cities where the criminal activity is high, risk of theft can deter home owners from installing PV systems on their roofs.

Another customer segment that this model targets is low voltage businesses which do not have available roof space. A large number of businesses in urban areas falls under this category, such as company offices, supermarket chains, banks or pharmacies.

Although virtual net metering allows remote and shared generation, there is a geographical limit for the community solar projects in Brazil. According to the revised net metering regulation, remote generation can only be remunerated when the generative system and the owner of the system are located within the borders of the same distribution company.

The value proposition by community solar model includes, similar to TPO, the opportunity to access solar energy without high initial investment and experience immediate reduction of electricity costs. The initial investment costs can fully be avoided in cases of renting a solar lot or it can be significantly reduced in case of buying a solar lot, as lower unit costs related to economies of scale would bring down the costs. Higher energy yield compared to rooftop PV, due to optimal location and tilting, reduces the initial investment cost for the developer and increases the savings of the consumer. Savings can further be increased by solar tracking, as tracking increases the efficiency of the system around 30% (Huang et al., 2013). The energy produced by the system is credited to the account of the consumer by the distribution company according to the net metering regulation in Brazil.

Another value proposition of this model is to enable the renters living in apartments to access solar energy and reduce their electricity costs. Moreover, community solar model eliminates the risks such as technical failures or roof damage, and the issue of maintenance. As shown by previous studies and interviews with the consumers before, certain misconceptions among the consumers about PV systems is one of the barriers for market development. Community solar model can effectively overcome this barrier, not by raising awareness but by offering a problem free option. In fact, Clean Energy Collective, which is one of the largest community solar developers in the U.S. uses this 'hassle free' feature of community solar on their website with the saying "out of sight, out of mind" (CEC, 2017).

Collectively owning the power production facility, and the community feeling this can induce, can also be a value proposition of this model, especially if the project members live in

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[9] Around 4 million households, 10% of total households in Brazil (Statistical and Geographical Institute of Brazil,2017)

vicinity. The solar energy cooperative, Revolusolar, which is established in Babilonia community in Rio de Janeiro, claims that the solar energy offers the community members energy independence and economic savings, in that way it allows the community itself to take a collective step towards tackling the issue of social inequality (Dhuyvetter, 2017). According to Prof.Pierre Pinson from Danish Technical University, collective renewable energy projects brings out the commitment in consumers (personal communication, July 15, 2017).This is important as, commitment brings awareness about renewables which can spread to friends and families of community solar members and help higher rates of deployment and political support.

Community solar projects can reach their customers through their online platform, local partnerships or direct marketing. Main point of contact is usually the website of the project developer, where the customer can find information about the project and submit interest. Community solar model requires very little physical encounter with the customers, since the project is developed off-site, not on the premises of customers. Partnerships with local administrations or residential building management companies (condos) could open a channel to reach the customers more effectively and also an opportunity to utilize publicly owned spaces for the project. For example, by offering solar energy and energy cost reduction, local administrations can improve their reputation and public support, while community solar company can have access to large base of customers.

Similar to the TPO model, community solar model establishes long term relationship with the customers through solar lot ownership or rental agreement. The relationship could even be a fully automated one, which requires no physical contact. In the case of renting a solar lot, on the bases of the proposed value of being 'hassle free', the customers can actually 'sign-up and forget', and only reap the financial benefits. As mentioned in TPO model, securing long term agreements with the customers can be challenging in Brazil, which calls for employing tactics to gain the trust of the customers. On the other hand, the model could be based on collective ownership, which requires more engagement from the project members, and which can foster community type of relationship with environmental consciousness.

Revenues of the community solar models in Brazil can be rental fees or revenues from sales of solar lots and the monthly fees for the management of the solar facility. Similar to the TPO model, due to the regulatory restrictions sale of energy to captive consumers is not possible, however renting a solar lot is legal and it practically gives access to the energy produced. According to Csaba Sulyok, the cost of renting the solar lot is typically 10%-20% less than the usual cost of electricity for the consumer (2017).

The key resources required for community solar models are mainly financing, marketing channels, skilled personnel for project management, online platform, previous projects and existing customers. The organization developing a community solar project firstly and most importantly needs to secure necessary financing for the project. A website for informing customers and an online platform involving system monitoring and personalized accounts for customers another key resource. Lastly, previous projects and existing customers can be seen as key resource to activate peer-effects to overcome the barrier of misconceptions and lack of awareness.

The model moves the burden of financing from the customer to project developer. The costs are reduced due to economies of scale, but also due to efficiency increases resulting from optimal location and tracking systems. However it is found that it could be a challenge to secure initial funding, since rather large amounts of funds are needed. According to Csaba

Sulyok, even though Brazilian banks recently opened special credit lines for solar with relatively favourable interest rates of 7%-8%, it is still difficult to access these funds in Brazil (2017). One of the problems is the large collateral that the banks ask for these loans. This limits the entry of new and small companies to the market. However according to the report of Ideal Institute (2016) most of the solar companies on the market are fairly new and small.

Initial system installation costs are relatively low for community solar model, due to economies of scale. Per watt prices of solar systems are considerably lower for systems with capacity higher than 1MW. On the other hand, suitable land is one of the costs that community solar developers have to bear, compared to TPO model. Unless, door-to-door marketing is employed, community solar model does not require a larger number of human resource, which reduces the soft costs for this model.

5.3 Crowd-funding

A Crowd-funding model is often a stand-alone online platform which acts as a matchmaker and aggregator between the investors and the independent solar projects looking for funding. However it can also be an integral part of TPO model, used for raising funds.

In this model, large number of investors invest in solar panels or even cells of a solar project developed by a local solar company, then the solar company installs the panels either on the premise of the customer or as off-site plant and the system is rented out to customers on behalf of the investors. Investors receive monthly rent on their panels from the customers, the solar company is paid its installing costs, and the crowd-funding company takes a commission. This model could be used in places where access to low cost financing is difficult even for third party organizations. Since this is precisely the situation in Brazil, crowd-funding can offer a low-cost funding for PV projects.

In Brazil crowd-funding platforms started to operate in 2011 and in 2015 there were 24 active crowd-funding platforms (Alves, 2015).

Crowd-funding Model Canvas

Key Partners	Key Activities	Value	Relationships	Customer Segments
PV installation companies Fintech companies Governmental bodies	Crowd-funding platform development and management Customer acquisition Project evaluation Management of capital	Access to alternative funding No upfront costs Immediate reduction of electricity costs Long term stable electricity price Financial returns (for investors) Being part of the change(for investors)	Long term project support for customers Fully automated for investors	Crowd investors Low voltage consumers Companies
	Key Resources		**Channels**	
	Crowd-funding platform Marketing and project evaluation personnel		Crowd-funding platform Social media/blogs Online community	

Cost Structure	Revenue Streams
Crowd-funding platform development and management Investor and customer acquisition activities Transaction costs	Commissions

Table 5: Crowd-funding Model Canvas

The customer segments that is targeted by solar crowd-funding model belong to two categories: investors and consumers. To avoid misunderstandings it is necessary to point out that investors are considered as customers in this model as they do not invest in the crowd-funding company, instead they use the services of the company. Crowd investors are any individual who wishes to invest in solar projects. It was found that the primary investor segment for solar crowd-funding companies are individuals living in high-income countries. There are two main reasons for this: economy and environmental/social concerns (H.Lindquist, personal communication, September 6, 2017).

Economically, investors from high income countries have relatively more disposable income for saving however investment options in those countries for small investors are with low returns. Hanna Lindquist from Trine mentioned that , for instance, the interest rates for savings accounts in Sweden are close to zero, especially for amounts that are small (2017). On the other hand, these investor can receive 5%-6% return on their solar investments through Trine's platform. Higher rates of environmental and social concerns among individuals from high-income countries constitute the second reason for targeting this group.According to Harju-Autti (2014) Austria and North European countries showed highest rates environmental awareness in the world.

Domestic investor can also be among the targeted customer segment. Especially individuals who lives in regions with relatively less solar radiation might wish to invest in solar project in states with higher solar potential, and in that way try to increase financial returns. The key challenge here is the high interest rate that Brazilian investors can receive for their savings from the banks. If the return from the solar projects in Brazil cannot match the interest rate on savings from the banks, it would be challenging to convince Brazilian crowd investors to invest in solar projects. Another challenge voiced by Csaba Sulyok is related to high levels of income difference in Brazil:

> "Capital is very much concentrated in the hands of the top few percent of the population. And who take investment decisions on their behalf are elite investment bankers. Aiming at the middle class to collect small investment is a difficult venture, especially in the developing world where this class is virtually non-existent." (personal communication, August 1, 2017)

The other customer segment category is consumers that are the beneficiary of the solar project. Depending on the type of beneficiary project being roof-top or community solar, the customer segment can slightly change. For roof top projects the customers are low voltage residential or commercial consumers with roof space. For community solar projects funded by the crowd, the customer segments are the same as community solar model: the consumers living in condos, low voltage commercial consumers or home owners who prefer not to have panels on their roofs.

The main value proposition of the crowd-funding model is the access to low cost financing for customers. Moreover, the analysis of TPO and community solar models revealed that, access to low cost financing for initial investment is difficult not only for individual consumers who wish to install PV system, but also for TPO and community solar model businesses. The solar companies in either model finds it challenging to secure low cost loans from commercial banks, as most of solar companies in Brazil are small. Through crowd-funding, TPO or community solar companies can get access to low cost financing, which can also reflect on reductions in lease prices, or compensate for lack of tax credits. The case of Trine illustrates this value proposition. H. Lindquist explained that in the countries that Trine operates, such as Kenya or Zambia, the yearly interest rate on loans for solar investments are around 20%, however through crowd-funding Trine can offer financing to the solar project developers for nearly half that cost (September 6, 2017).

On the other side of the coin, the value propositions of crowd-funding model for investors are the financial returns and the feeling of being a part of positive social and environmental change. Financial returns from the rented PV systems in Brazil can be relatively high for the investors living in high income countries with low interest rates. If communicated effectively, the value of being part of a positive social and environmental change can resonate with investors from countries with high environmental awareness, such as North European countries. "Impact investment", which is a type of investment motivated not only by financial returns but also by positive social and environmental impact, is already a growing area (Morata, 2017) and impact investors globally invested over $20 billion in 2016, with 9% of these going to Latin American markets (GIIN, 2017). Economic gains were also strong, as impact investment funds that are smaller than $100 million have outperformed other funds and returned a net IRR of 9.5% to investors, and those focused on Africa have performed especially well with 9.7% IRR (GIIN, 2015). Moreover, energy cost savings archived by solar can be a significant contribution for disadvantaged groups and result in improved social conditions.

Online crowd-funding platform is the main channel that crowd-funding model is utilizing to deliver the value to its customers. The project owners can submit their projects and after a screening the project details appear on the platform. The project details typically include a presentation of the beneficiary and the project, financial conditions such as price per solar panel and pay back period, legal conditions for the project returns, risk assessment of the project and the current state of the crowd-funding campaign. In line with the social and environmental motivations of the target customer segment, how the project will result in environmental and social improvement is also mentioned. For example, in the platform of Trine, the number of people that will be provided electricity and the amount of CO_2 emissions that will be reduced by the project is presented on top of each project presentation

The crowd-funding platform can be self developed or alternatively customizable platforms provided by professional crowd-funding platform developers[10] can be purchased. There are also open-source platforms available for companies with limited resources.

The revenues of solar crowd-funding model comes from the commissions and fees charged. There could be several arrangements for how the commission is charged. It can be in the form of percentage charges from the investment or the return, or it can be in the form of a share on the interest rate. Trine, for instance, offers 5% return for the investors while the interest rate offered for the project developer is usually around 10%. According to H.Lindquist this creates a win-win-win situation, where investors can receive higher than average returns, the project developer can access to lower interest rate loan than they could find in their country, and the crowd-funding platform secures financial sustainability (September 6, 2017).

There are several risks associated with this model. For example, fluctuations of the value of local currency, in our case Brazilian Real, stands out as a risk for international investors. Since the lease payments will be in local currency, in case of decrease in the value of Brazilian Real, the investors will be faced a lot lower returns on their investment, which can be a

[10] For an example see www.katipult.com/

deterrent factor for international investors. Moreover since these investments are beyond the coverage of guarantees that applies to conventional investment options, such as in bank savings or bonds, in case of failure of the project or bankruptcy of crowd-funding platform, the investors might loose the principle and the interest (Berger, 2014). According to C.Sulyok, most small investors can't evaluate the risks properly, which brings out the need for a trustworthy institution to do it for them, thus small investors tend to trust more to an established financial institution than an crowd-funding website (August 1, 2017). Gaining the thrust of crowd investors stands out as an important challenge, and H.Lindquist draws attention to the fact that they have realized that being a Swedish company was an advantage for gaining the trust of potential investors (September 6, 2017)

Another challenge is related to the financial regulatory framework. There are strict limitations on loans between individuals imposed by Brazilian Central Bank, which makes it difficult to establish crowd-lending platforms that coordinates direct lending between individual investors to project owners (Alves, 2015). A sightly different arrangement is found to operate in the international market, which is based on individual investors owning PV panels and leasing out to project beneficiaries. The legal statue lease-out model in Brazilian financial regulation needs to be further investigated, which is out of the scope of this study.

One of the important costs in this model is the financial transaction costs, especially if the crowd-funding platform is an international one. The cost of financial transaction fees can be up to 5% of the transferred amount (SunExchange, 2017). Depending on the arrangement, the burden of financial transaction can be on the investor or the crowd-funding company[11], though in any case transaction costs influence the operations of the company. One strategy that is employed by some solar crowd-funding companies is accepting digital currencies, such as Bitcoin, for the payments. The investors can invest and then receive their returns in Bitcoin, and in that way avoid transaction costs.

5.4 P2P Energy Trading

PV systems allows the traditional energy consumers to also become producers, so called prosumers. In times of surplus production, prosumers have the option of (1) storing the energy in batteries, (2) feeding it into the grid and either receive energy credits or payment in return. Recently being developed around the world, innovative P2P energy trading can offer a third alternative, by allowing to flexible energy trading of surplus energy from distributed energy resources among peers (Long, 2017).

Although under development, this model is expected to be effective in the future. There are several projects around the world, mostly under development, such as Brooklyn Microgrid in the U.S., Vandebron in Netherlands, SonnenCommunity in Germany and Powerledger in Australia (DENA, 2016; Zhang, 2017).

This analysis is based on a model that is being developed by Brooklyn Microgrid, which envisions grid-connected prosumers within a physically defined community to exchange surplus energy. Smart meters are installed at the premisses of the prosumers and a digital trading platform provided by the P2P company. With the help of a mobile application the

[11] This depends on if the investors have to send investment directly to an account that is located in the project country, or if the crowd-funding company or payment service aggregates the funds and transfer them to project country. Sun Exchange can be an example for a company using the first method, while Trine uses a payment service located in France.

prosumers can decide on the conditions of the trade, such as minimum price or time period. Through the trading system, the energy allocation is coordinated.

Since different versions of the P2P model are still under development, there are uncertainties about the details of the building blocks, which necessitates that the analysis is partly based on assumptions and envisions on how the model could be set up under Brazilian conditions.

P2P Model Canvas

Key Partners	Key Activities	Value	Relationships	Customer Segments
Smart meter suppliers Fintech companies Distribution companies	Trading platform Installation and maintenance of smart meters Customer acquisition Community management	Access to solar energy (for consumer) Reduced energy costs(for consumer) Financial gains (for prosumers) Increased efficiency Community feel Increased resilience	Fully automated Community building	PV system owners Consumers
	Key Resources Trading platform Marketing channels Personnel		**Channels** Online platform/app Community meetings	

Cost Structure	Revenue Streams
Initial investment for smart meters Customer acquisition activities Management of trading platform	Trading platform fees Commissions

Table 6: P2P Model Canvas

Although the net metering regulation in Brazil does not allow commercialization of the energy credits, it does allow shared generation and commercialization of the PV assets. Thus, secure online contracts offered by blockchain based trading platform can potentially allow trading of the PV assets, in the form of short term renting. The energy credits received during the renting period would be registered in the account of the renter, and the rental fee is billed to the renter.

It is often the idea that P2P trading requires large deployment of rooftop PV system. However P2P model could potentially spread quickly in Brazil, if it is bundled with other business models which allow acquisition of PV systems, such as TPO or community solar. The owners of each solar lot in a community solar project or renters of TPO financed rooftop systems can rent out their extra capacity for a certain period of time to either another solar lot owner or a consumer without PV systems. The community solar management, for example, would digitally keep track of the rent-outs through the trading platform records, and periodically reports the trading balance to distribution company to register the energy credits.

There are two groups of customers targeted by this model. The first group is the customers who own a PV system, either as rooftop or in a community solar project. These are either residential or commercial prosumers. The second group is the customers, residential or commercial who do not or cannot own a PV system, such as renters living in apartments, but would like to use solar energy and reduce their electricity bills.

The value proposition of this model differs according to the role a peer assumes. When a prosumer sells surplus energy to another peer, the value is the financial gains from renting PV system, which eventually leads to shorter payback times for the initial investment of PV. With the net metering regulation, the prosumers do not have the incentive to install PV capacity higher than their own consumption, as extra energy credits will accumulate and be wasted. However, P2P trading allows the prosumers to rent out their extra capacity in an effective way.For the buyer of energy the value proposition is access to solar energy and the reduction in energy bill, as the buyer can set up the maximum price he/she would like to pay, and for example only rent PV capacity from other peers if the expected cost of electricity generated by the system is lower than the grid price.

According to Sasha Santiago from Brooklyn Microgrid, the price can also be higher than the grid tariff, since solar energy sourced from your neighbour can be considered as a premium product by the community members (personal communication, July 4, 2017). Thus, financial gain is not the only value proposition. Contributing to the local community through greening the energy used locally, helping the economical benefits to stay within the community and increasing local energy resilience are other value propositions of this model.

The main channel for the P2P model is the online energy trading platform and a mobile phone application.Due to the community emphasis of the model, the P2P trading company reaches out to customers through community information meetings, locally distributed marketing materials and locally placed office.

The revenues for this model comes from P2P trading platform managements fees and commissions from each P2P trading. To be able to take part in the platform prosumers need to have smart meters installed, and the cost of this smart meters is charged through management fees. The main resource for this model is the P2P trading platform. Besides that, highly skilled technical personnel for the development and management of blockchain based platform is another key resource. Since the model has a strong community focus, local partnerships and relationships can be considered as another key resource.

Members of the P2P trading community, prosumers, can be considered as key partners as well as customers. Producers of smart meter systems are another key partner. The digital trading platform needs to be in communication with the distribution company for technical reasons, which is done through the smart metering system. Moreover the PV systems participating in the P2P trading are assumed to be within net metering system. This means that, in Brazil, the energy trade would take place within the net metering systems, through energy credits, thus all these make the distribution company a key partner. On the other end of the trade, money is received in return of PV capacity rental, and the required financial transaction points at the financial institutions, especially fin-tech companies as another key partner.

As mentioned, P2P trading can be offered as a service within other innovative business models. This suggests that the P2P trading can be incorporated into the other solar models, but also suggests that P2P trading companies can partner with TPO or community solar companies. Thus existing solar companies can also be key partners in P2P model.

In this model the company installs smart meters to the premises of the members, and supplying and installing these systems constitutes a cost. Moreover, the development and management of the P2P trading platform and mobile application is another important cost.

6 Discussion

The Third Party Ownership model can effectively address the financing problem by relieving the consumers of the burden of high initial investment cost, and provide access to solar energy with immediate reduction in energy costs. Moreover the model offers long term stable energy costs, which is valuable especially in Brazil where rapid electricity price increases are experienced. The findings suggest that due to regulatory restrictions in Brazil the TPO model needs to be modified. Energy sales through long term PPAs needs to limited to free consumers which are often commercial consumers, while for residential consumers renting option can be offered.

There are also some challenges for TPO model to function in Brazil. The first challenge is accessing the financing for the initial investment of PV systems. It was found that, currently low cost financing options are limited for small companies, which is the size of most of the solar companies in Brazil. One consequence of this situation is that it can put larger players with easy access to national or international financing in an advantageous position in the market. The second challenge for TPO model is related to distribution companies and concerns the project delays that are caused by the grid connection process. Under current conditions, distribution companies continue to see distributed PV generation as a threat, thus have little motivation to assign resources to accelerate the connection processes. However this challenge can turn into an advantage, if the regulatory changes allow distribution companies to explore the benefits of distributed generation. In such a situation, distribution companies can partner with solar businesses in deploying PV systems, which would give them the incentive for smoother connection of the PV systems.

The Community Solar model is found to have the potential to ease or overcome the barrier of financing by reducing or eliminating the initial investment for PV and offering reduction in energy costs. Recent revisions in the net metering regulation opened the way to community solar model by allowing to receive energy credits from remote and shared generation. The only condition of virtual net metering is to have the system in the same utility company concession area. The model offers 'hassle-free' access to solar energy where the customers can sign-up and forget.

The Community Solar model can also foster community feeling and engagement, through which it can address the issue of lack of awareness. Moreover reduced energy cost can bring economic improvements in disadvantaged communities, which can help tacking social inequality.

Regulatory limitations on consumer types have the same modification effect as TPO model for community solar model: low voltage captive consumers can only rent or buy solar panels, while free consumers have the additional option to commence a long term PPA. The model has the advantage of reaching a large customer base of people living in apartments or who would not like to have PV on their roof due to various reason, such as visual, risk of damage or security.

Difficulties about accessing low cost funding in Brazil is also present for community solar model. The collaterals demanded by the financial institutions that offer special credit lines for PV investments create a market barrier for small companies. The situation suggests the need for cooperating with larger companies operating in other industries, which can potentially have easy access to such special credit lines. Although previous research showed that company managers' attitudes towards solar investment is not positive (Echegaray, 2014), immediate financial gains in the form of solar lot sales or rents could appeal to the managers.

All in all, the Community Solar model is similar to the TPO model by addressing the barrier of high initial investment. However, community solar is advantageous over the TPO model since it can target a much larger customer segment and achieve lower costs and thus faster pay-back time due to higher efficiency.

The crowd-funding model is found to have the potential to overcome the financing barrier in an indirect way by enabling the solar businesses reach low cost financing. In that sense crowd-funding model can address the challenges faced by TPO and community solar models and in that way help these models unleash their true potential. With access to low cost financing, TPO and community solar companies can offer better rental rates for the consumers, which in turn would increase the deployment for distributed PV. The regulatory restrictions of individual lending in Brazil requires the model to adjust. The adjustment can be in the form of allowing the investors to buy solar panels to be leased out to consumers, which is a model applied in China and South Africa.

The crowd-funding campaigns can be launched throughout Brazil, and in that way a large investor base can be reached. For example, some investors living in Southern Brazil may prefer to invest in community solar projects located in states with more favourable radiation, then rent out the panels to local consumers and in that way increase the return on investment. The project campaigns can also be launched internationally, in a fashion similar to SunExchange or Trine, and in that case investors from European countries can find the relatively high yields and the return on investment attractive. Moreover social and environmental benefits of the PV projects offers the value of being part of the change, which can appeal to investors from countries with high environmental awareness.

The crowd-funding model has several risks, such as currency rate fluctuations for international campaigns, risk of loosing investment in the case of project failure or bankruptcy. These risks can translate to challenges in gaining customer trust. Although there are several crowd-funding platform successfully operating internationally and in Brazil, there platforms are mostly based on rewards or donations, thus customers might find it more difficult to trust the crowd-funding campaigns that is based on long term financial relationship. On the other hand, since in the crowd-funding model each investment is a relatively small amount, the risks might be seen as less of a problem by investors from higher income countries if the investment motivation can be supported by the motivation related to environmental and social benefits of the investment.

One advantage of the buy-panels-to-lease-out version of crowd-funding model over TPO is that, in cases of delayed projects because of longer than expected grid connection process at distribution companies, the project developer solar company or the crowd-funding company would financially be less effected as the crowd investors would only be paid once the beneficiary consumer who rents the system starts paying.

P2P energy trading model, although still under development, is found to have the potential to enable the prosumers in Brazil to commercialize the surplus energy, and in that way to have the economic incentive to install higher capacity. It is a common idea that for P2P energy trading to take place, large deployment of distributed PV should already be in place. However P2P model could potentially spread quickly, especially if it is bundled with other business models, such as TPO or solar community.

Although the net metering regulation does not allow commercialization of the energy credits, what it does allow is the commercialization of the PV assets. The secure online contracts offered by blockchain technology can potentially allow renting of the PV system, though in a much faster way than today, thus effectively enabling energy trading. However, concerns about the legality of this model are often raised, and without the required adjustments in the regulation regulation, technical preparation and the involvement of distribution companies the fast spread of this model in the near future could lead to several complications.

Considering the rapid development of distributed renewable energy sources, disruptive potential of advanced digital technologies and quick spread of sharing economy models, P2P energy trading is expected to be effective in the near future. Several variations of P2P energy trading model are currently investigated or tested around the world and it is yet to be seen which specific model arrangement will take ground. It is expected to see the P2P energy trading businesses to operate on a commercial scale initially in developed distributed PV markets, such as Germany or the U.S. However experiences from other collaborative consumption models enabled by ICT (e.g. the controversial case of Uber in Brazil) show us that it can take surprisingly less time than expected for these models to spread and arrive in Brazil, and such developments in the area of energy will probably happen while the issues with more basic character are still in place. Therefore, it is important to investigate the potentials and the challenges related to P2P energy trading in Brazil and prepare the energy market for a smooth transition towards a future distributed energy system.

An important finding on the study is the central position that distribution companies take as key partners in each model. In line with previous research (Frantzis et al., 2008; Richter, 2012; Richter, 2013; Lehr, 2013; Tayal, 2017), distribution companies in Brazil are found not to see their interest in the growing distributed PV market, and finding ways to align the interests of solar businesses and distribution companies appears to be a challenge that needs to be addressed. Regulatory restrictions on the activities of distribution companies limit the possibilities for this task. However, although under current regulation distribution companies cannot generate energy, a cooperation model between solar businesses and distribution companies can still be developed. Areas of value creation opportunities based on mutual benefit between solar companies and utility companies, such as managing grid load and avoiding further investments, can be identified, which could especially be relevant in areas where there is urban development and significant increase in energy consumption (RMI, 2014).

7 Conclusion

This qualitative case study explored the potential of innovative business models in Brazil for increasing the deployment of distributed PV. Based on primary and secondary data collected through 10 semi-structured interviews and desktop research, the study first identified the emerging business models of PV around the world and then analysed if and how these business models can help Brazil increase the share of PV through the analytical framework of business model canvas of Osterwalder and Pigneur (2010).

Brazil is a country with very high solar potential and has much to benefit from the rapid deployment of PV, however, the development is impeded by various barriers, including high initial costs and difficulties in financing the installations, the lack of economic incentive to install higher capacity than self consumption, the lack of interest of distribution companies, and lack of awareness among the consumers. It is necessary to investigate various ways to overcome these barriers, to be able to increase the deployment of solar energy. Innovative business models can be helpful in overcoming these barriers and accelerate the market adoption of PV.

Therefore, the objective of the study was to look at how innovative forms of business models can help overcome barriers and increase the deployment of distributed PV in Brazil. Based on this objective, the study tried to answer the following research question:

RQ: How can innovative business models help increasing the deployment of distributed PV in Brazil?

The findings of this study suggest that all four innovative business models can help increase the deployment of distributed PV in Brazil in various ways and overcome several barriers, financing of high upfront cost being the most fundamental. Each business model can bring its unique contribution and improve the deployment of distributed PV by offering often complementary value propositions or addressing different customer segments. The business models can mostly operate under current regulatory framework and market conditions, once certain adjustments are made.

The TPO and the Community Solar models can help by effectively addressing the barrier of high upfront costs.

The Community Solar model can further help the deployment by expanding the potential customer base to residents of apartment buildings, and by reducing the payback time through increased efficiency.

The Crowd-funding model can help by providing the much needed low-cost financing for Brazilian solar companies.

And the P2P Energy Trading model can help by reducing the payback time for the investments by allowing the commercialization of surplus PV generation capacity and thus creating incentive to install higher PV capacity.

The current regulatory framework can pose challenges for crowd-funding and P2P models. Moreover the models alone cannot tackle the problem of the perception of conflicting interests of solar businesses and distribution companies. The policy recommendations, therefore, are as follows: Regulatory and technical adjustments are needed to prepare the market for the future energy system with distributed generation and to ensure the smooth development of disruptive business models with advanced digital technologies, like crowd-funding and P2P. Furthermore, policies are needed to be developed to reduce transaction costs and open ways for the distribution companies and solar businesses to align their interests and cooperate for higher deployment of distributed PV. Complementary to the policies, establishing regional and national solar industry platforms to bring all the stakeholders together and create a long term PV development plan could foster such cooperation. Moreover, Brazilian solar market is mostly comprised of small companies which have difficulties accessing the low cost financing, thus low cost credit lines aimed at smaller solar companies are needed to be developed to help reduce the market entry barriers.

With its findings this study contributes to the limited research on PV business models in urban context in middle income countries. As previous studies documented the emergence of innovative business models to tackle the barrier of financing in middle income countries such as Thailand and China (Tongospit,2016; Zhang,2016), this study found that these models could function in Brazil and have strong potential to address the problem of high up-font cost and help increase the deployment of distributed PV. The findings of this thesis support the previous research arguing that new business models cannot directly be transferred between countries and their development is shaped by local context (Birkin et al.,2009; Provance et al., 2011; Strupeit&Palm, 2016).

On the other hand, the study has several limitations. Firstly, the language barrier potentially prevented the study to utilize important documents published in Portuguese, and also reach out to more interviewees. Secondly, due to limited time and resources, the study does not include detailed legal and financial analysis of each business model. The detailed legal status of crowd-funding and P2P models, and financial feasibility of each four models remain to be analysed. And thirdly, the study has limited number of interviews. Increasing the number of interviewees in each stakeholder group, and especially inclusion of different consumer segments, NGOs and electric distribution companies could enhance the reliability of the study.

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Appendix A - Interviewees

Endless AB
Eduardo Rechden (CEO)
Lund/Sweden - 07.06.2017

Endless AB is a Swedish company which tries to solve the financing problem by helping solar projects in Brazil to meet investors from Northern Europe. The company CEO Eduardo Rechden, a Brazilian himself, shared his extensive knowledge on Brazilian solar market.

http://www.endless-energy.se

Danish Technical University
Prof. Pierre Pinson
Online - 15.06.2017

Pierre Pinson is a Professor at DTU Elektro, Centre for Electric Power and Energy, heading a group focusing on Energy Analytics&Markets. Prof.Pinson was interviewed related to ongoing research of Energy Analytics and Markets groups about new market designs for renewable energy sources , and more specifically energy collectives.

http://pierrepinson.com

LO3 - Brooklyn Microgrid
Sasha Santiago (Marketing Director)
New York/U.S. - 04.07.2017

Brooklyn Microgrid, a project of energy company LO3, is a community microgrid in the neighbourhoods of Gowanus and Park Slope in Brooklyn/NYC. Currently under development, the pioneer project aims to allow prosumers in the community to trade their surplus energy from PV through a blockchain based system.

http://brooklynmicrogrid.com/

Communidade de Jamaraquá
Solannge Laryce (Consumer)
Tapajos Nature Reserve, Para/Brazil - 23.07.2017

Jamaraquá is an Amazonian community that is located in the northern portion of the Tapajós National Forest in the state of Para, by the bank of Tapajós river. Jamaraquá lies 75 km away from the nearest city of Santarém and has 24 households.The community was connected to national electricity grid only eight years ago, however the connection is still unreliable. Laryce family pays around €70(250 BRL)/month for their electricity.

https://jamaraqua.wordpress.com/

Ricardo F.Goes (Consumer)
Rio de Janeiro/Brazil - 27.07.2017

Mr. Goes is a consumer who lives in a three room apartment in Rio de Janeiro.He provided important insights on the consumer end of the electricity value chain. He also provided recent electricity bills (see Appendix B), which provides an example of the consumption patterns and composition of the bill, and the actual cost of energy for a consumer.He consumes around 200kW/month in average, and pays around €45(BRL 160).

COSOL Energia
Csaba Sulyok (CEO)
Online - 01.08.2019

COSOL is an innovative energy start-up in Brazil, developing community solar projects in the form of solar condominiums, in which consumers can rent or buy solar lots and receive the energy credits through net metering system, and save on energy bills. The COE of the company, Csaba Sulyok is an entrepreneur from Hungary, moved to Brazil some years ago and studied PhD on solar energy in the state of Bahia. He provided important information on the Brazilian solar market and community solar business model adapted to Brazilian conditions.

www.cosol.com.br

Empresa de Pesquisa Energetica (EPE)
Gabriel Konzen (Analyst)
Rio de Janeiro/Brazil - 04.08.2017

EPE (Energy Research Company) is a governmental agency in Brazil. The agency is responsible for conducting research in the area of energy policy, and in that way support the decision making process in the Ministry of Mines and Energy. Together with ANEEL, the agency plays a key role in shaping the regulatory framework and support scheme for solar energy. Gabriel Konzen is an analyst in EPE, specialized on the distributed PV.

www.epe.gov.br/

Cecelo Frony (Consumer)
Rio de Janiero/Brazil - 11.08.2017

Cecelo Frony is a professional musician who has his residency and his studio in a two floor detached house in Rio de Janeiro. He does not necessarily represent an average consumer, however he provides a good example of a consumer living and running a small business in a detached house. Mr. Frony pays around €160 (BRL600) for his electricity bill in average, including the consumption of the musical equipment he has.

Axis Renováveis
Luiz Pacheco (CEO)
E-mail - 28.08.2017

Axis is a Brazilian solar energy company that started to apply third party ownership model.They realized an off-site project a project for a drug store chain, which received media coverage, where the drug store company rented the PV system installed and owned by Axis, and in that way reached significant reduction of its electricity costs. Company partner Mr. Pacheco provided insights on their business model through e-mail correspondence.

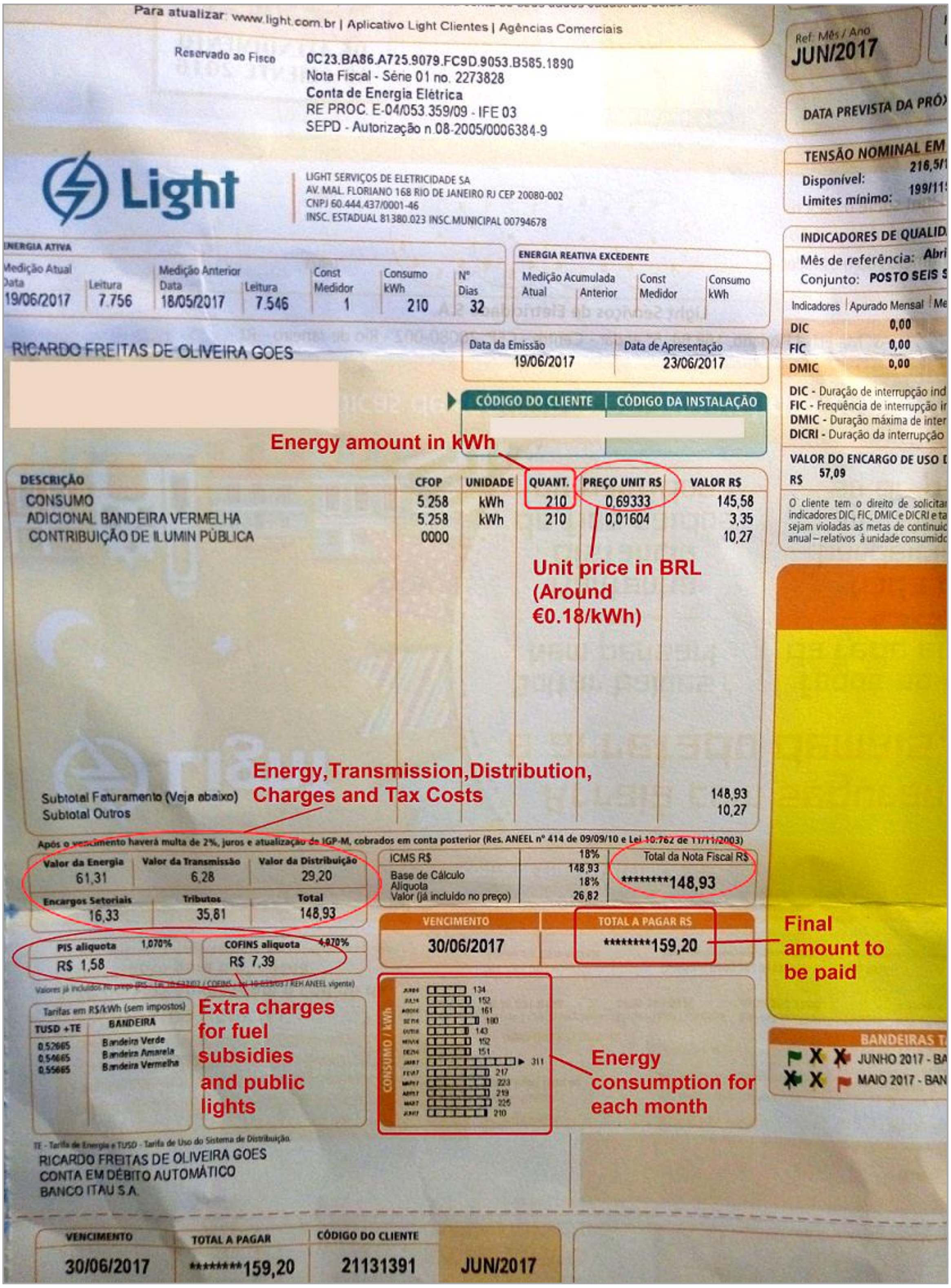
http://axisrenovaveis.com.br/

Trine
Hanna Lindquist (Communications Manager)
Göteborg - 06.09.2017

Trine is a start-up crowd-funding company from Sweden, which funds solar electrification projects in several African countries, such as Kenya and Zambia. So far close to €2 million was invested in solar projects through Trine.The company runs a platform where anyone can invest in these projects with a minimum amount of €25.Interviewing them provided detailed insight on the inner workings of international solar crowd-funding model.

https://www.jointrine.com/

Appendix B - Sample Electricity Bill


Para atualizar: www.light.com.br | Aplicativo Light Clientes | Agências Comerciais

Reservado ao Fisco
0C23.BA86.A725.9079.FC9D.9053.B585.1890
Nota Fiscal - Série 01 no. 2273828
Conta de Energia Elétrica
RE PROC. E-04/053.359/09 - IFE 03
SEPD - Autorização n.08-2005/0006384-9

Light

LIGHT SERVIÇOS DE ELETRICIDADE SA
AV. MAL. FLORIANO 168 RIO DE JANEIRO RJ CEP 20080-002
CNPJ 60.444.437/0001-46
INSC. ESTADUAL 81380.023 INSC. MUNICIPAL 00794678

Ref: Mês / Ano JUN/2017

DATA PREVISTA DA PRÓ

TENSÃO NOMINAL EM
Disponível: 216,5/1
Limites mínimo: 199/11

ENERGIA ATIVA

Medição Atual Data	Leitura	Medição Anterior Data	Leitura	Const Medidor	Consumo kWh	Nº Dias
19/06/2017	7.756	18/05/2017	7.546	1	210	32

ENERGIA REATIVA EXCEDENTE
Medição Acumulada Atual | Anterior | Const Medidor | Consumo kWh

RICARDO FREITAS DE OLIVEIRA GOES

Data da Emissão 19/06/2017
Data de Apresentação 23/06/2017

CÓDIGO DO CLIENTE | CÓDIGO DA INSTALAÇÃO

INDICADORES DE QUALID
Mês de referência: Abri
Conjunto: POSTO SEIS S

Indicadores	Apurado Mensal
DIC	0,00
FIC	0,00
DMIC	0,00

DIC - Duração de interrupção ind
FIC - Frequência de interrupção ir
DMIC - Duração máxima de inter
DICRI - Duração da interrupção

VALOR DO ENCARGO DE USO D
R$ 57,09

O cliente tem o direito de solicitar indicadores DIC, FIC, DMIC e DICRI e ta sejam violadas as metas de continuid anual – relativos à unidade consumido

DESCRIÇÃO	CFOP	UNIDADE	QUANT.	PREÇO UNIT R$	VALOR R$
CONSUMO	5.258	kWh	210	0,69333	145,58
ADICIONAL BANDEIRA VERMELHA	5.258	kWh	210	0,01604	3,35
CONTRIBUIÇÃO DE ILUMIN PÚBLICA	0000				10,27
Subtotal Faturamento (Veja abaixo)					148,93
Subtotal Outros					10,27

Após o vencimento haverá multa de 2%, juros e atualização do IGP-M, cobrados em conta posterior (Res. ANEEL nº 414 de 09/09/10 e Lei 10.762 de 11/11/2003)

Valor da Energia	Valor da Transmissão	Valor da Distribuição
61,31	6,28	29,20
Encargos Setoriais	**Tributos**	**Total**
16,33	35,81	148,93

ICMS R$ 18%
Base de Cálculo 148,93
Alíquota 18%
Valor (já incluído no preço) 26,82
Total da Nota Fiscal R$ ********148,93

PIS alíquota 1,070% R$ 1,58
COFINS alíquota 4,970% R$ 7,39

VENCIMENTO 30/06/2017
TOTAL A PAGAR R$ ********159,20

Tarifas em R$/kWh (sem impostos)

TUSD + TE	BANDEIRA
0,52665	Bandeira Verde
0,54665	Bandeira Amarela
0,55665	Bandeira Vermelha

CONSUMO / kWh: 134, 152, 161, 180, 143, 152, 151, 311, 217, 223, 219, 225, 210

BANDEIRAS T
JUNHO 2017 - BA
MAIO 2017 - BAN

TE - Tarifa de Energia e TUSD - Tarifa de Uso do Sistema de Distribuição

RICARDO FREITAS DE OLIVEIRA GOES
CONTA EM DÉBITO AUTOMÁTICO
BANCO ITAU S.A.

VENCIMENTO	TOTAL A PAGAR	CÓDIGO DO CLIENTE	
30/06/2017	********159,20	21131391	JUN/2017