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COMPETITIVE ADVANTAGE AND THE BRAZILIAN PHOTOVOLTAIC INDUSTRY

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Thesis presented to Escola de Administração de Empresas de São Paulo of Fundação Getulio Vargas, as a requirement to obtain the title of Master in International Management (MPGI)

Knowledge Field: Gestão e Competitividade em Empresas Globais

Advisor: Prof. Renato João Orsato

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Abstract

The photovoltaic solar energy, as an alternative source of electricity, has developed globally at a fast pace in recent years. Curiously, the favorable conditions for the diffusion of this technology in Brazil, such as high levels of solar irradiation, and one of the most expensive energy tariffs in the world were not sufficient to make the country a leader in this sector. Solar power remains at an infant stage in Brazil. For this reason, this study aims to explore the main factors explaining this situation. I do so by adopting Porter's diamond framework for the analysis of the sector. Based on the analysis of the five aspects of the model, it was possible to conclude that Brazil already has a strong foundation for the development of the photovoltaic industry, such as a favorable regulation, geographical location and financial incentives. However, to become a leader in solar energy, the national photovoltaic industry must be competitive internationally. Furthermore, attractive financing lines in addition to industrial policies and gains of scale are essential.

KEY WORDS: solar power, photovoltaic systems, Porter's diamond model, Brazilian industry.

Resumo

A energia solar fotovoltaica, como fonte alternativa de eletricidade, se desenvolveu globalmente em ritmo acelerado nos últimos anos. Curiosamente, as condições favoráveis para a difusão dessa tecnologia no Brasil, como os altos níveis de irradiação solar e uma das tarifas de energia mais caras do mundo, não foram suficientes para tornar o país um líder no setor. A energia solar permanece em um estágio inicial no Brasil. Este trabalho tem como objetivo explorar os principais fatores que explicam esta situação. Eu faço isso adotando a estrutura do diamante de Porter para a análise do setor. Com base na análise dos cinco aspectos do modelo, foi possível concluir que o Brasil já possui uma base sólida para o desenvolvimento da indústria fotovoltaica, como regulação favorável, localização geográfica e incentivos financeiros. No entanto, para se tornar um líder em energia solar, a indústria fotovoltaica nacional precisa ser competitiva em relação à internacional. Além disso, é necessário desenvolver linhas de financiamento atraentes, além de políticas industriais e ganhos de escala.

PALAVRAS CHAVE: energia solar, sistemas fotovoltaicos, diamante de Porter, indústria Brasileira.

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1. INTRODUCTION

The photovoltaic (PV) solar energy as an alternative source of electrical power has developed at an accelerated pace worldwide in recent years. Being a clean source of energy has fostered the investment in this technology, especially given the increasing awareness of climate change. The concern regarding the climate change was consolidated in the Paris Climate Agreement, the first legally binding agreement where countries compromised to targets aiming to reduce global warming. (Council of the European Union, 2017)

Although the shift towards renewable energy, especially solar power, is already significant in countries such as Germany, United States of America and even China, this source of energy is still marginal in the Brazilian energy matrix. Even though the number of kilowatts produced by photovoltaic systems in Brazil grew 95% from 2017 to 2018, the total capacity installed is a little over 1 GW (ANEEL, 2018). As a comparison, in 2017, China, the leading country accumulated 78 GWs, followed by Germany with 41GWs, Japan with 13 GWs and the United States with 12GWs (EPIA 2017).

This scenario is intriguing, considering Brazil's favorable conditions. The potential for the development of solar power in Brazil is straightforward. Brazil's average solar irradiation varies from 1.500 to 2.500 Wh/m^2. In Germany, it ranges from 900 to 1.250 Wh/m^2 (Pereira et al., 2006). Thus, on average, a system installed in Brazil is capable of producing three times more energy than those in Germany. Furthermore, Brazil has one of the world's highest energy tariffs, which aligned with a favorable regulation, contributes to the financial viability of photovoltaic systems as an alternative energy source. Thus, PV systems should be more viable in Brazil than in most of the leading countries in terms of solar power installed.

Based on this data, this study aims at answering the following research question:

Why does the solar energy industry remain marginal in Brazil?

The study aims to explore the reasons behind this scenario and identify which factors could accelerate the diffusion of solar energy projects in Brazil. In other words, the objective of the study is to identify factors which are of importance to the sector's development and growth in Brazil. Renewable energy is a global trend, and its expansion in Brazil carries many business opportunities for both consolidated firms and entrepreneurs. Hence, this study tries to uncover both the reasons why the PV generation is not more representative in Brazil and aspects that could corroborate to its expansion. By doing so, the study contributes to the literature, entrepreneurs acting on the sector and policymaking.

The study is organized in five chapters. Chapter two contextualizes the solar industry in the world and Brazil. This chapter contains an applied research with the purpose of providing a professional perspective to this study's research object. The literature review is presented in section three with the methodological approach as it is combined in the review of the analytical approach applied in this study. Section four presents the results of the study, in which the analytical approach is applied, and the main conclusions are extracted. Finally, chapter five reinforces the main findings of this study and the applicability of this study in different fields.

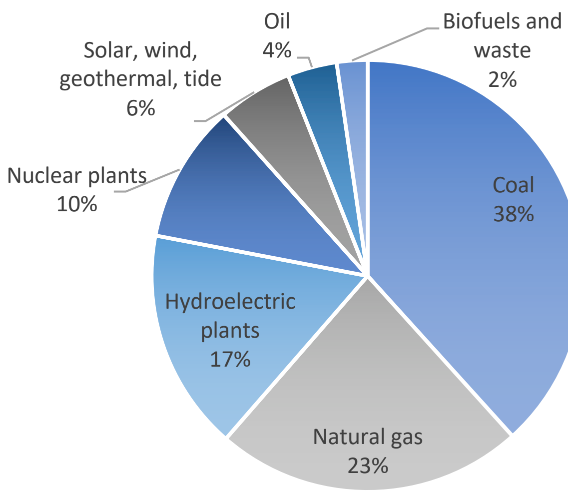
2. INDUSTRY OVERVIEW

This chapter aims to provide a better understanding of photovoltaic systems and their role in the energy matrix worldwide and in Brazil.

The growing importance of electricity for society is unquestionable. The total electricity generation is expected to increase by 69% until 2040 (U.S. Energy Information Administration, 2017). However, the world's energy matrix has not changed much since the 1970s, as 67,3% of the electricity is still generated from combustible fuels, compared to 75,3% in 1974 (International Energy Agency, 2018a).

This is demonstrated in Figure 1, which provides a detailed view of 2016's world gross electricity production by source. As the graph illustrates, traditional energy sources such as coal, natural gas and hydroelectrical are still responsible for over 75% of electricity production.

Figure 1: World gross electricity production by source in 2016



Source: International Energy Agency, 2018a, p.4

Nevertheless, it is important to note that renewable sources such as solar, wind and biofuels are increasing their share in the energy matrix. As appointed by Tanti (2018), today 25% of the world's electricity is produced by renewable energy, hydroelectric plants are responsible for 17% and solar, wind and geothermal for 6 percent. Even though the share of renewables is still small, it is already 10% higher than in 2015, indicating a positive trend.

The renewable energy trend is fostered by the ongoing concerns about climate change and unknown political changes, as renewables are seen by countries as a way to become more independent from energy imports (Weitemeyer et al., 2014). At the same time, renewable energy minimizes environmental impacts and produces minimum secondary wastes, as it excludes energy resources derived from waste products from fossil sources, inorganic sources and fossil fuels (Ellabban, Abu-Rub and Blaabjerg, 2014).

Within the renewable energy sources, this study will focus on photovoltaic power. Thus, a brief explanation of the technology will be presented, followed by an overview of the development of this power worldwide and more specifically in Brazil.

2.1 PV Power – How it works

In the photovoltaic power, the electricity derives from the sunlight. As explained by NASA (2002, p.1), "photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, the resultant electric current can be used as electricity."

The photovoltaic modules are responsible for capturing the sunlight and producing direct current (DC) of electricity. In a photovoltaic system, the electricity is conducted to the inverter, which is the equipment responsible for converting the direct current into the alternating current (AC). The resulting electricity can be then used to supply all kinds of electrical devices.

Photovoltaic systems can be connected to the national grid (on-grid) or as independent installations (off-grid). Off-grid systems usually work with a battery to guarantee that the energy can be stored and used at a different moment than its generation. On-grid systems are connected to the national electrical network, and the electricity that was produced and not consumed are directed to the national grid. Usually, the provider receives a reward, either financial or in electricity. (Kaudinya et al., 2009)

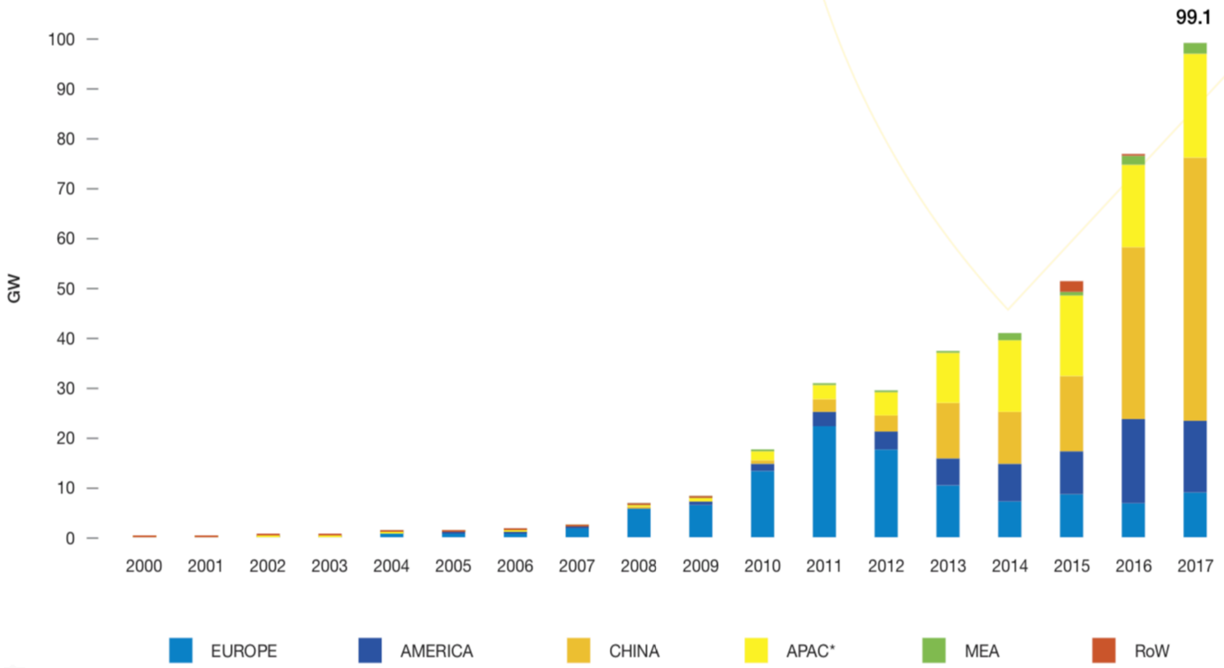
2.2 PV Power - Worldwide Panorama

Aligned with the growing trend of renewable energies and fostered by the lower prices, each year PV power is becoming stronger and more relevant for the world's energy matrix. In 2017, solar was the fastest growing power generation source. In 2018, more PV capacity was installed

globally than any other power generation technology, representing a 30% year-on-year growth, leading to a total global power capacity of over 400GW. (Solar Power Europe, 2018).

As shown in Figure 2, since 2007, the annual global PV power installed capacity has been growing expressively. From 2007 to 2011, Europe led the first wave of significant growth. The second wave started in 2013 due to the rapid development of PV in China and Asia – Pacific (APAC) which compensated the sharp drop of installations in Europe. In 2013, China became the top PV market in the world, installing 11,8GW in one year followed by Japan with 6.9 GW and the United States of America with 4.8GW (EPIA, 2014). Even though solar energy in the Middle East Region (MEA) and the rest of the world (RoW) is still marginal, compared to other regions, it is also growing.

Figure 2: Evolution of global annual solar PV installed capacity



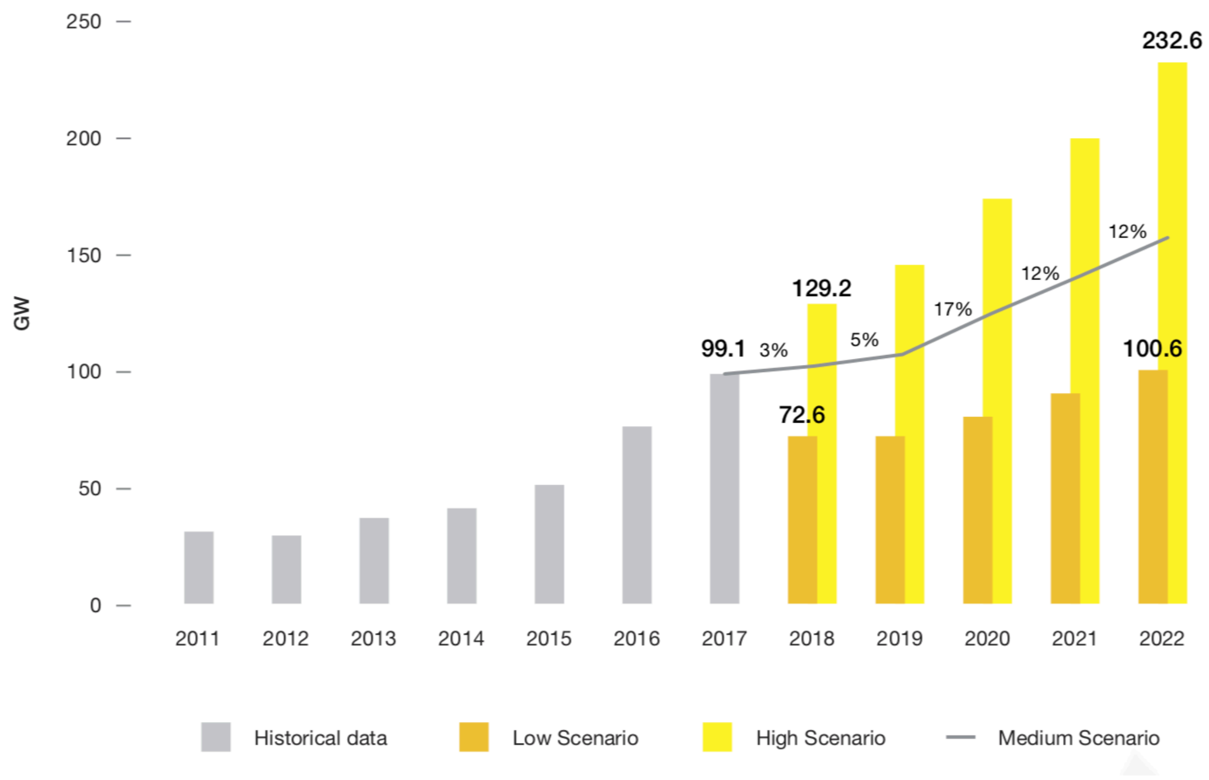
Source: Solar Power Europe, 2018, p.10

China continued to secure its leading position in PV power installed capacity, dominating the global solar market demand. In 2017, China was responsible for 53,3% of the world's solar

volume installed, with 52,8 GW in newly added capacity. USA was the world's second largest PV market with 10,6 GW installed in 2017, closely followed by India, with 9,6 GW added capacity in the same year.

Figure 3 indicates the PV prospect for the next five years in three scenarios, high, medium and low. Both in the high and medium scenario, the PV market is expected to grow. However, it is important to note that the growth is likely to be at a slower rate than 2017 since China's National Energy Administration (NEA) announced significant subsidy cuts in the domestic solar demand.

Figure 3: World annual solar PV market scenarios 2018 – 2022



Source: Solar Power Europe, 2018, p.15

Although China is leading the demand for solar power, price elasticity could take up some capacity initially destined for China, as other countries could accelerate their projects, triggered by the anticipated price drop caused by NEA's decision. (Solar Power Europe, 2018). The

growth projected for the next five years also reflects the recognition that the sector still has a long way to go to unfold its potential.

2.3 PV Power - Brazilian Panorama

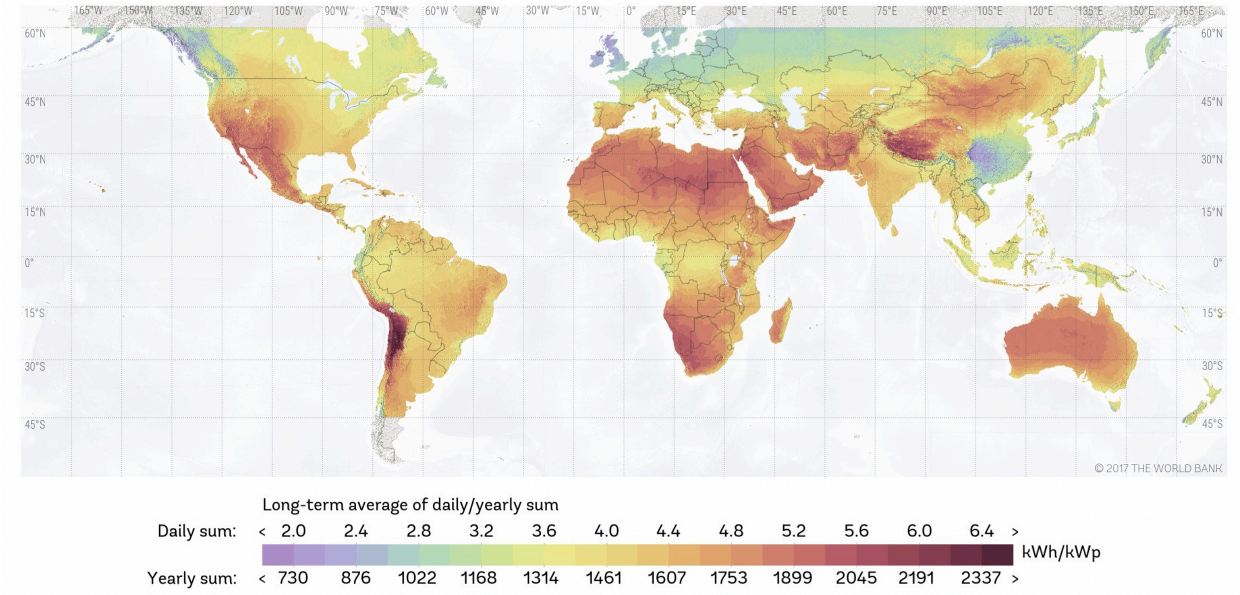
The Brazilian energy matrix is particular and understanding its structure will be of significant relevance to this study. Thus, this session provides more information on the development of PV power in Brazil.

Firstly, it is important to mention that the Brazilian electric matrix is not very diversified and includes a strong presence of renewable sources, mainly hydropower and sugarcane (Miret, 2014). In fact, 71,77% of the Brazilian electricity is derived from renewable sources, in which hydropower counts for 82% of it. (Atlas Brasileiro de Energia Solar, 2017; MarketLine, 2018).

The reliance on the hydropower makes the energetic infrastructure very vulnerable to droughts. The energy crisis in 2001, due to low rainfall, led the country to seek alternatives to reduce its dependence on hydropower. Thus, fossil fuels and other energy sources, such as wind and PV power were incentivized in recent years (Miret, 2014).

The PV power market has been identified as promising, attracting the interest of investors. One of the reasons relates to Brazil's favorable geographical position, as demonstrated in Figure 4, which shows the performance of photovoltaic systems across the globe (The World Bank, 2017).

Figure 4: Performance of photovoltaic systems across the globe



Source: The World Bank, 2017

Figueiredo and Pascal (2016) assert that Brazil's market size positions the country not only as a leader in the Latin America region but also as a potential supply hub for neighboring countries. Brazil stood out as a growing market in 2017, reaching almost 1 GW of solar power, mostly from systems awarded in auctions (Solar Power Europe, 2018).

However, in comparison to other countries the PV power industry is still in its infancy and has a great potential to grow. Rodrigo Sauaia, president of ABSOLAR (Diniz, 2018), highlights that Brazil is more than 15 years behind in the use of photovoltaic solar energy. He emphasizes the need for a structured national program to accelerate the development of photovoltaic solar power to fulfil the country's potential.

3. METHODOLOGY

In order to answer the research question, the present study was structured according to the research procedures suggested by Creswell (2014). As the author highlights, research approaches, research design and research methods are three key terms to construct a study.

There are three possibilities for a research approach: qualitative, quantitative and mixed methods. “Often the distinction between qualitative research and quantitative is framed in terms of using words (qualitative) rather than numbers (quantitative) or using closed-ended questions rather than open-ended questions.” (Creswell, 2014, p. 32). Within the exploratory nature of the research question, the qualitative research was chosen as the most appropriated approach for this study. This decision is in line with Creswell (2014, p.50) recommendation “if the problem calls for the identification of factors that influence an outcome (…), then a quantitative approach is best”, which is precisely the case of this study. To answer the research question, it is essential to study and analyze the solar energy industry, to identify factors that could explain why the solar energy industry remains marginal in Brazil. Thus, exploratory research, with the open-ended question is aligned to this study’s purpose.

Besides selecting the research approach, Creswell mentions that it is also necessary to decide the research design, which means choosing the type of inquiry. Within the qualitative research, Creswell (2014) suggests five types of research design: (a) narrative research which focuses on the stories about the life of individuals; (b) phenomenological research: in which the researcher describes experiences of individuals related to a phenomenon; (c) grounded theory: the researcher derives a general theory of a process, action or interaction grounded in the views of participants; (d) ethnography: in which shared patterns of behaviors, language and actions of a cultural group are studied; (e) case study: the researcher develops an in-depth analysis of a case. The case study was well defined by Yin (2009, p.16) as “an empirical inquiry that investigates a contemporary phenomenon (the ‘case’) in depth and within its real-world context”. Yin’s definition reflects the propose of this study, which is to conduct an industry analysis of the Brazilian solar energy industry to identify factors that might explain why this industry remains marginal in the country. Thus, the case study was selected as the research design for this work, considering the coherence between the case study as a research design and this work’s purpose.

The third element of Croswell's framework is the research method, which involves the forms of data collection, analysis and interpretation of the studies. Croswell emphasizes the importance of considering the full range of data collection before defining which ones are more appropriate for the study. The next session will explain the data collection process, and it will be followed by a session dedicated to the explanation of the data analysis and interpretation procedure.

3.1 Data Collection

The data collection process was divided into two steps as suggested by Croswell (2014, p. 239) "setting the boundaries for the study, collecting information through unstructured or semi-structured observations and interviews, documents and visual materials."

Thus, the first step taken was to set the boundaries of the content to be addressed considering the research question and the research design. Miles and Huberman (1994) identified four aspects that should be considered when setting the boundaries of the study: The first aspect is where the research will take place. Given the scope of the analysis, the research focused on the Brazilian market, however, other countries were mentioned as best practices examples. The second step was to define who would be interviewed. Experts of solar energy with experience in the Brazilian market were selected. To increase the variety of views, consultants, representatives of solar panels and inverters suppliers, as well as companies installing solar systems were approached. The third aspect considered was the events, which was defined as the analysis of the solar energy market in Brazil. The fourth factor analyzed was linked to the previous one, as it referred to the evolving nature of the events, meaning the development of the solar energy in Brazil.

The second step of the data collection process was the collection of information, which was achieved by three sources. The first source of information was observation; the author

participated in the event “solarmente capaz” on December 12th, 2018. The event invited suppliers of the different levels of the solar energy supply chain: Fronius for inverters; BYD for solar panel and batteries; Romagnole for metal structure; Victron for the off-grid and hybrid integration and Aldo, an online platform supplying photovoltaic kits. The purpose of the meeting was to gather suppliers of different levels of the value chain to discuss market trends and to present the equipment’s innovation.

The second source of information was semi-structured interviews. During the execution of the study, nine people were approached by the author. The selected people had broad experience with solar energy and represented different links of the value chain: suppliers of solar power equipment, such as solar panels and inverters; a consultant acting on the renewable energy sector; a representative of a concessionary responsible for the distribution of electricity; and representatives of companies working directly with photovoltaic electricity. From the selection, three interviews were successfully conducted; the profiles are presented below.

Cyro Vicent Boccuzzi worked for 25 years at AES Eletropaulo, the largest Distribution Company of Brazil. He was AES’s vice president from 2001 to 2007. After leaving AES, Boccuzzi founded ECOEE, a Strategic Enterprise Consulting Company working with Management, Technology and Sustainability / Energy Efficiency for the Energy Sector. He also founded and is the President in charge of the Latin America Smart Grid Forum. (Linkedin, 2019)

Marcel Rocha works as the project development specialist at CPFL Renováveis and as a consultant in renewable energies for Watthora Energia. Rocha has 12 years of experience in electrical energy systems, recently he is working directly on renewable energy, mainly photovoltaic solar power.

Luis Fernando Zechi works for Frisokar SA and NG Solar. Zechi has worked as a technician for CESP, Companhia Energética de São Paulo which is the largest producer of electricity in the state of São Paulo. He has experience in the free market for electricity. Currently, Zechi works in the solar energy sector with the implementation of photovoltaic systems.

Table 1 presented below introduces to the semi-structured questionnaire used as the basis for the interview as well as the objective of each question. As the interviews were semi-structured, the survey was not rigid, thus, the questions were adjusted during the interview in order to obtain more information and to keep the conversation flowing.

Table 1: Semi-structured interview questionnaire

	Topic	**Interview question**
1	Overview of the Brazilian solar energy market	How was the development of photovoltaic solar energy in Brazil in recent years? What do you consider to be central to this process?
2	Factor conditions	Which factors would you cite as conditioning factors for the spread of solar energy in Brazil?
3	Demand conditions	Which aspects of the demand would you relate to the performance of solar energy in Brazil?
4	Demand conditions	Which factors influence consumers to implement photovoltaic systems?
5	Related supporting industries	Which elements of the solar energy value chain do you see as strengths in the Brazilian market and which ones do you believe would need to develop further?
6	Related supporting industries	Do you identify any supporting industry or service as essential for the diffusion of solar energy in Brazil?
7	Firm strategy, structure and rivalry	How do you see the development and the role of the national industry for the photovoltaic system's main equipment (ex. panels and inverters)?
8	Government	How has the Brazilian government positioned itself in relation to solar energy? Would you suggest any change?
9	Perspective for the future	Which are your expectations for photovoltaic energy in the coming years?
10	Additional information	Would you like to add any information?

Source: own illustration

Finally, the third source of information was the collection of documents which could be considered of high reliability. More specifically, the focus was on official reports, national studies of the sector, laws and regulations. In the second moment, already developed the analysis of the energy sector were considered in the evaluation of the industry's trends and challenges for the market. Lastly, independent research was conducted so as to provide clarity on the photovoltaic sector in Brazil.

3.2 Data Analysis and Interpretation: Porter's Diamond

As for the data analysis and interpretation, the theoretical foundation for developing an industry analysis is abundant. Many frameworks and perspectives can be used to analyze a sector. However, it is essential to choose a model that can address the research question within a specific industry. As mentioned by Porter (1991, p.97) "no one model embodies or even approaches embodying all the variables of interest, and hence the applicability of any model's findings is almost inevitably restricted to a small subgroup of firms or industries whose characteristics fit the model's assumptions." Thus, some frameworks were considered as options to analyze the solar industry sector so as to identify the best fit.

The competitive forces framework developed by Porter (1989), is one of the most known frameworks for strategic decisions. By analyzing the five forces: customers; suppliers; new entrants; substitute offerings and rivalry within the market, the framework provides a structured way to capture the complexity of competition in a specific market. By understanding how the five forces influence a particular industry, a company can become more competitive by positioning itself where the forces are weakest, exploiting changes in the forces or reshaping the forces in their favor (Porter, 1989).

The competitive forces framework is useful for shaping and guiding the competitive strategy of companies within an industry. However, photovoltaic is still an infant industry in Brazil.

Additionally, the focus of this study is not on the competitiveness of a firm in a specific market, but on the development of the industry in a particular country. Hence, analyzing the competitive forces would not be the most comprehensive framework to understand the reasons why this technology did not develop further in Brazil.

As an alternative framework, the ecological modernization of organizational fields framework developed by Orsato (2004) was considered. Orsato's framework aims to provide a systematic way to analyze the ecological modernization in a specific industry, by focusing on the factors fostering or inhibiting the greening of an entire industrial sector.

Although Orsato's framework might be adequate to explain the factors driving the growth of photovoltaic systems in European countries, such as Germany, it was questionable if it would be the most appropriate method to describe the factors that prevent its expansion in Brazil. According to Cohen (1997) "ecological modernization presupposes the intensification of: (1) organization internalization of ecological responsibility; (2) the implementation of anticipatory planning practices; (3) the implementation of strict governmental regulation; (4) dissemination of hyper-industrialization" (Orsato's, 2004, p. 272).

As it will become evident in the sector analysis presented at a later stage in this study, the assumptions behind the ecological modernization are not clearly identified in Brazil. This can relate to the fact that 71,7% of the country's energetic matrix is already based on renewable sources, mainly hydropower (Atlas Brasileiro de Energia Solar, 2017), while in the rest of the world, 67,3% of the electrical energy is still produced by combustible fuels (International Energy Agency, 2018a). Thus, the greening of the electric sector is not as relevant in Brazil as it is in other parts of the world.

Hence, another framework was considered to provide a better understanding of the sector and identify possible constraining factors for the industry's development: The Porter's Diamond

Model for the Competitive Advantage of Nation's. Porter acknowledges that in a world with increasing competition, nations have become essential, in a sense that nations succeed in particular industries because their home environment is the most forward-looking, dynamic and challenging one (Porter, 1990). In this context, the diamond model was conceptualized to explain the attributes of a nation that enables them to overcome the barriers to change and innovation.

Academicians have applied Porter's diamond in diverse fields and countries in determining the factors a nation has which contributes to an industry success both at local and international level. Liu and Song (1997) implemented Porter's diamond framework to explain the situation and development of the global competitiveness of mainland China's manufacturing sector. Karácsony (2008) applied the framework to showcase the production situation and competitiveness of wheat in Hungary. On the same industry, Al-Hiary, Al-Zu'bi and Jabarin (2010) used Porter's model to explore the competitiveness of the Jordanian agricultural sector, especially in horticultural production. Öz (2000) applied Porter's diamond to shed some light on the competitive structure of the Turkish industry; the study comprehended five industries: glass, construction, leather clothes, automobiles and flat steel. Those are some examples to demonstrate that Porter's diamond model has been widely recognized as a framework to assess the competitive advantage of a national industry or enterprise.

It is important to note that the applicability of Porter's Diamond in the renewable energy industry has also been successfully tested. Dögl and Holtbrügge (2010) analyze the competitive advantage of German renewable energy firms in Russia. The authors based their study on Porter's diamond to examine the demand for renewable energy in Russia and German firms' ability to meet this demand. A few years later, Dögl, Holtbrügge and Schuster (2012) conducted a similar study analyzing the demand for renewable energies in China and India. Still, on the renewable energy field, Liargovas and Apostolopoulos (2014) applied Porter's diamond model

to highlight the significant role of regional parameters when analyzing the competitive advantage of renewable energy enterprises in Greece. Specific to the solar energy industry, Zhao, Zhang and Zuo (2011) developed an interesting study about the photovoltaic power industry in China. Porter's diamond model was adopted in their study with the purpose of identifying and analyzing factors that have significant impacts on the development of China's photovoltaic power industry. Given the similarity between the objectives of this study and Zhao, Zhang and Zuo's work, their study was taken as a reference for this analysis.

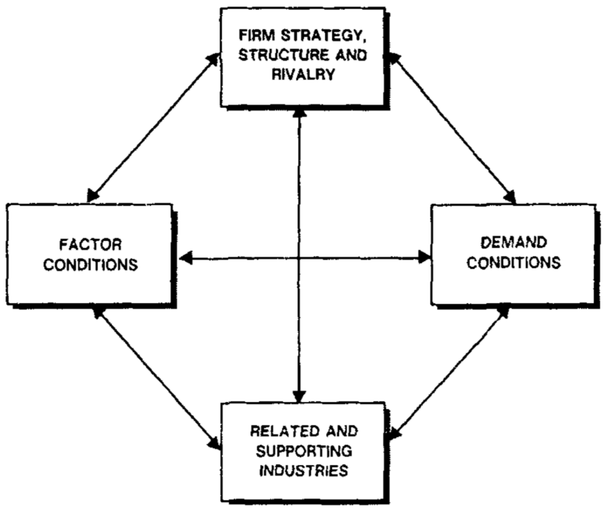
Thus, Porter's diamond framework was considered as the best choice to shed some light in the current constraints of the solar power industry in Brazil. Besides, the focus on the national level of the diamond model is particularly interesting for this analysis, as it permits to compare the Brazilian context to other countries, where solar power is already a representative source. However, it is important to mention that instead of analyzing the factors that make an industry competitive, the framework will be used in the solar energy context to understand why the industry has not developed in Brazil in the same pace as in other countries.

According to Porter (1990, p.73), "companies gain advantage against the world's best competitors because of pressure and challenge. They benefit from having strong domestic rivals, aggressive home base suppliers, and demanding local customers." Porter's study across the industries of ten important trading countries indicated the ultimately, the only way to sustain a competitive advantage is to upgrade it, moving to more sophisticated types. The author emphasizes the tendency among governments to experiment with various policies intended to promote national competitiveness, such as new measures to manage trade and policies to relay antitrust. However, these approaches in Porter's perception are flawed, as they fundamentally misperceive the true sources of competitive advantage.

Thus, Porter (1990) proposed a new approach to the analysis of competitiveness, focusing on the aspects that enable the companies to overcome the barriers to innovation. The author

introduced four main determinants which constitute the diamond model. According to the author, the framework is a dynamic system in which the determinants interact and reinforce each other. Figure 5 illustrates the four factors of the model: (i) factor conditions; (ii) demand conditions; (iii) related and supporting industries; (iv) firm strategy, structure and rivalry. "These attributes, which I collectively term the diamond, shape the information firms have available to perceive opportunities, the pool of inputs, skills and knowledge they can draw on, the goals that condition investment, and the pressures on firms to act." (Porter, 1991, p.111).

Figure 5: Determinants of National Competitive



Source: Porter, 1991, p. 111

Besides the four main determinants presented above, Porter (1991) acknowledges two exogenous factors that although are not determinants themselves, can influence the environment for competitive advantage: government and chance.

Porter (1990, p. 84) acknowledges that indirectly, the government's role in transmitting and amplifying the forces of the diamond is a powerful one. Chance is also included as an indirect determinant in some analysis. On the topic, Porter (1991, p. 112) recognizes that "there is a role for true chance events and historical accidents in the process by which competitive advantage is created".

In Brazil, specifically, the role of *government* is especially important due to the particularities of the electricity sector. For most of its history, the Brazilian electric power system was run as a public monopoly. The threat of electricity shortages from a lack of investment triggered the reform of the sector in 1993, which partially opened the industry for competition (Mendonça and Dahl,1999). However, even though reduced, the government still plays a crucial role in the electricity sector, thus it is a critical factor for this analysis. Furthermore, the influence of *chance* cannot be neglected in Brazil, especially given the high dependence of the country in one source of electricity and the potential impact of changes in the regulation. The six components will be presented in more detail below.

The first determinant of the model is *factor conditions*, which are considered specialized factors of production, for example, skilled labor, capital and infrastructure. Porter (1990, p. 78) emphasizes that "the most important factors of production are those that involve sustained and heavy investment and are specialized. Basic factors, such as a pool of labor, or a local raw-material source do not constitute an advantage in knowledge-intensive industries." Thus, given the specificity of the solar power industry, the factor conditions considered were: potential solar resources; generation costs; on-grid power price; and technology availability and specialized workforce.

The second determinant in Porter's framework is *demand conditions*, which includes customer analysis and different market segments. Porter (1990, p. 79) supports that the nature of the domestic market is more significant for the creation of competitive advantage in the industry than the size of the home demand. "A nation's companies gain a competitive advantage if domestic buyers are the world's most sophisticated and demanding buyers for the product or service. (…) Demand conditions provide advantages by forcing companies to respond to tough challenges". Following Porter's concept, the demand conditions analysis for the PV power industry will address the overall nature of the domestic market and the potential market.

The third attribute of the model is *related and supporting industries*, which in this analysis refers to the industries related to the solar energy that promotes the exchange of information and fosters the innovation in the segment. As mentioned by Porter (1990), internationally competitive home-based suppliers create advantages in downstream industries such as providing the most cost-effective inputs in an efficient and early way. Furthermore, the related industries contribute to the industry by delivering innovation, and a close relationship between suppliers is positive for addressing consumer's needs as well as accelerating the pace of innovation. Based on that, the analysis of supporting industries will discuss the impact of financial institutions in the solar power market. Given the high value aggregated of PV power, the availability of financing lines is essential for the propagation of photovoltaic energy and provides means for its innovation.

The fourth determinant of the model is *firm strategy, structure and rivalry*, which relates to the analysis of direct competition in the sector, identifying main players and the drivers to increase productivity and innovation. Related to this aspect, Porter (1990) mentions that "competitiveness in a specific industry results from the convergence of the management practices and organizational modes favored in the country and the sources of competitive advantage in the industry". Overall, Porter sees the rivalry in an industry as positive for its development since it can be a stimulus to innovation and creation of competitive advantages.

As mentioned before, the role of the *government* will also be considered in this study. According to Porter (1990, p. 84), "the role of the government as a catalyst and challenger, is to encourage – or even push companies – to raise their aspirations and move to higher levels of competitive performance". Porter also recognizes that governments at all levels can improve or obstruct the national advantage through its investments in factor creation. Given the strategic importance of the energy industry for a country, the government is vigorously active and linked to the development of the solar energy sector. Legislation and taxation will be analyzed to

provide a better understanding of the current role of government in the photovoltaic power industry.

The last factor to be analyzed is *chance*. As explained by Öz (2000, p. 510), "chance events are by definition beyond the control of firms but may create forces that reshape the industry structure, allowing shifts in competitive position". By analyzing chance within the context of the Brazilian electric power system, two factors were identified as capable of reshaping the solar energy industry: climate change and governmental uncertainty. The six factors mentioned above will be analyzed in the next chapter.

4. RESULTS

Chapter 2 introduced the PV power technology and provided an overview of its development around the world and, more specifically, in Brazil. Based on that, it is evident that there is still a long path until this technology becomes of relevance to the Brazilian electric matrix. Hence, this session aims at answering the research question proposed in this study: *why does the solar energy remain marginal in Brazil*? In order to do so, this section will use Porter's diamond model to identify the factors that are currently constraining the development and growth of PV power in Brazil, thence to identify how to foster the industry.

4.1 Factor conditions

Concerning factor conditions, Porter mentioned that nations succeed in industries which are particularly good at factor creation. It does not necessarily mean that a nation needs to be abundant in those specific factors since many nations succeed in converting factors disadvantages into a competitive advantage. However, according to Porter (1990), this adaptation is not common as it is only possible under specific conditions.

The analysis of the relevant factor condition for PV power in Brazil, presented in the following session, comprehends the potential of generation, generation cost, the on-grid power price and the availability of technology and specialized workforce.

4.1.1 Potential as an electrical source

The potential of generation is directly related to the solar irradiation and land availability. As it was presented in the industry overview, Brazil has a privileged geographical position with a high level of solar irradiation. The solar irradiation, the direction and the inclination of the PV system have a direct effect on its performance, consequently on the size of the system, meaning that the investment can be reduced when the conditions are favorable.

The direction and inclination of the photovoltaic system can be adjusted during the installation or by trackers, a mechanism that changes the position of the panels following the movement of the sun. The solar irradiation, on the other hand, depends exclusively on the geographic positioning and meteorology of the area. In this case, Brazil is privileged by having comparatively good levels of irradiation across the year. "Measurements of solar radiation indicate that Brazil receives more than enough sunlight to meet the nation's projected energy demand through the use of PV power." (Assunção and Schutze, 2017, p.1)

Although natural resources are favorable for the development of solar energy, they are also extremally advantageous for hydroelectricity. Zechi mentions that there is a strong hydroelectric culture in Brazil which contributed to the delay in the development of alternative sources of electricity, such as solar power.

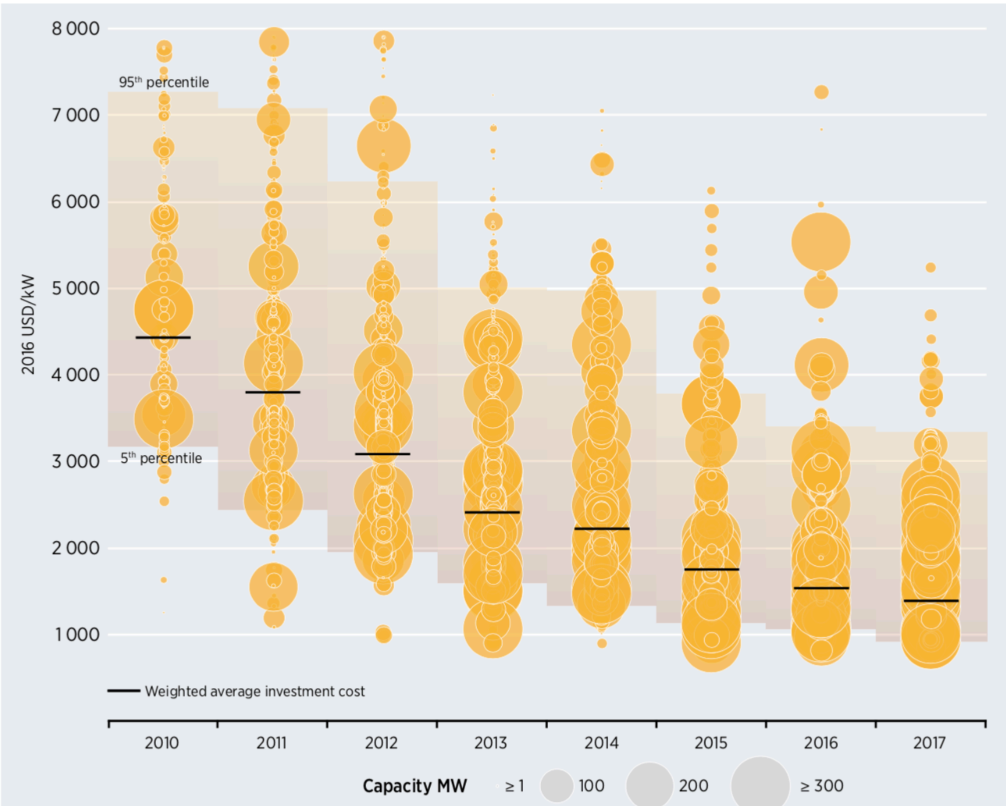
> "For a long time, there was no discussion regarding alternative sources of electricity, Brazil has high availability of water and extensive knowledge in hydropower, additionally, it is a cheap source of electricity. After the hydroelectric power plant is built the cost of generation is marginal. Thus, there was no need to seek alternative sources of electricity generation."

By now, there is already awareness about the importance to diversify the country's electricity matrix, which fosters the development of alternative sources such as solar power. Brazil is privileged in terms of natural resources, which can be considered as a basis for the development of this technology in the country. The potential for solar energy has already been acknowledged by the photovoltaic industry. During the event "solarmente capaz" all companies participating in the event reinforced their belief in the solar energy in Brazil while presenting their plans for 2019. The fact that they are all investing in the country by increasing the portfolio, bringing innovations and increasing their sales force corroborates their words.

4.1.2 Generation costs

The second factor condition to be considered is the generation cost. The cost per kWh produced with PV power is decreasing across the world. Figure 6 illustrates this trend. While the average kW installed of solar cost around US$ 4400 in 2010, in 2017 it decreased to U$ 1400. Additionally, Figure 6 shows that the distribution of the cost of PV power is equalizing across

Figure 6: Total installed cost for utility- scale solar PV project



Source: IRENA, 2018, p. 70

countries. By 2010, the cost of photovoltaic projects in markets where solar energy was not developed yet was at par, and sometimes even cheaper than the average in mature markets. (IRENA, 2018).

According to Boccuzzi, global economies of scale was central to the development of solar energy. The increase of demand and supply across the world lead to a cut on prices. Although the cost of PV generation is also reducing in Brazil, it still is more expensive than in most countries. This is seen by the fact that even though the average solar module price in Brazil decreased 25% between 2015 and 2016, the cost of the solar panel was still the third highest in the world, being lower only than the United States of America (California), Japan and Mexico (IRENA, 2018). Thus, although Brazil is also benefiting from the global reduction of PV power cost, this technology is significantly more expansive in Brazil than in countries that are leading on the installed capacity, for example, a panel costs 20% more in Brazil than in China. The *firm strategy, structure and rivalry* analysis will provide some insights into the drivers of the higher cost in Brazil.

Zechi mentions that the cost of photovoltaic systems in Brazil inhibits its development, “many consumers already believe in the idea, but they are resistant to invest on the technology because they believe it is too expensive and prefer to wait for the price to drop.”

Thus, it is possible to conclude that a reduction in the generation cost of photovoltaic power in Brazil would likely lead to the spreading of this technology in the country. At a lower price, the technology would reach a share of the market that cannot afford it or is hesitant to invest at the moment.

4.1.3 On-grid power price

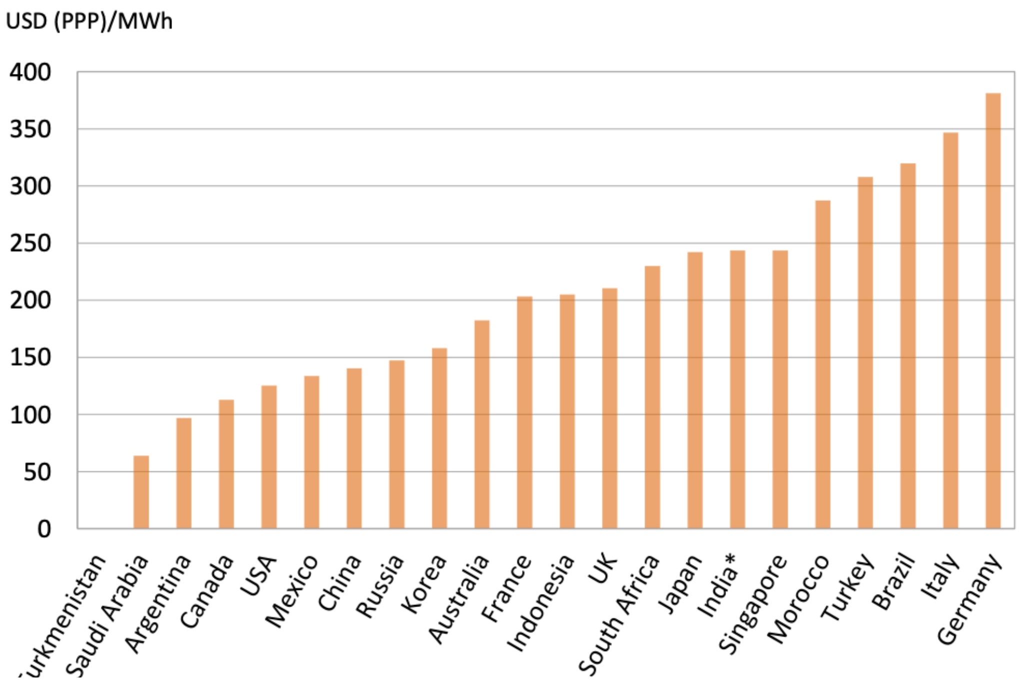
Another factor condition to be considered is the on-grid power price. The high prices of electricity in association with the net-metering system is considered one of the main incentives

of the distributed solar generation in Brazil. According to Boccuzzi, the ANEEL Normative Resolution 482/2012 (REN 482) which created the net- metering system, can be considered the biggest propeller of solar energy in Brazil.

As it will be presented in more details in the regulation section, owners of a PV system only pay the connection fee for the concessionary and eventual exceeding consumption. As explained by Carvalho et al. (2017), ANEEL Normative Resolution n. 482/2012 created an energy offset mechanism that calculates monthly the balance between the energy consumed and produced. If more energy is produced than consumed, the exceeding amount enters the distribution company's system and can be offset in future energy bills, within 60 months.

It is important to emphasize that the Brazilian offset mechanism was designed differently than the method applied in most countries, in the sense that the compensation is not financial, but in credits of energy measured in kW. The compensation is based on a one per one scale, meaning that one kW of exceeding energy will be computed as one kW available to be consumed within

Figure 7: Residential energy prices in selected economies, PPP adjusted -2016



Source: International Energy Agency, 2018b, p.7

60 months. While in Germany, for example, the excess of energy is sold to the concessionary for a lower price than it is bought, in Brazil there is no monetary transaction involved, however, the one per one scale is highly attractive. Although no monetary transaction is involved, the on-grid price is of relevance to calculate the viability of installing a PV system. The on-grid price is the price captive consumers pay for the electricity offered by the local concessionary. As demonstrated in *Figure 7* Brazil has the 3rd highest energy tariff in the world, considering the purchase power parity. (International Energy Agency, 2018b).

The higher the price of the energy purchased from the concessionary, the fastest the return on the investment of photovoltaic systems since consumers who install their system will no longer pay for the electricity they generate to the concessionary. On the topic, Zechi mentioned that the readjustment of prices in 2018 which was in average 15% across the country impacted the solar energy market positively “companies and even residential consumers are realizing that photovoltaic systems can be seen as an investment, with a high return. By adopting solar energy technology, consumers are saving on the energy bill, and it is as if their system would valorize every year since the energy bill increases in average 8 percent per year”.

Boccuzzi provides a comprehensive overview of the context of the abrupt price adjustment in 2015:

> “In 2012, due to a presidential decree, the electricity concessionaries were forced to reduce the energy prices by 20%. This generated a mismatch in the sector, with less money to follow the investments, it was necessary to resort to the national treasury. The side effects are being felt to this day. In 2014, there were no federal funds left to support the price reduction. Thus, since 2015 we are facing the “tariff realism”, which is an abrupt increase of the tariffs. This price increase incentivized the migration to solar energy.”

Thus, the offset mechanism in combination with the extremely high cost per MWh in Brazil provides a financial incentive for the propagation of the PV distributed generation. Even though

the cost of the equipment is higher than in other countries, the payback is calculated between three and six years depending on the geographical location and on the contract with the local concessionary. Hence, the high on-grid power prices incentivize the spreading of solar energy, as it is an economically advantageous solution compared to the alternative of purchasing energy from the local concessionary.

4.1.4 Availability of technology and specialized workforce

Another factor condition that should be considered is the availability of technology and specialized workforce. In relation to the technology availability, Table 2 presented below provides a comprehensive overview of the main components of a PV system, the cost representativeness and the availability in the national industry.

Table 2: Equipment of the PV chain in Brazil

Equipment		% in total cost of PV system equipment	Manufacturing in Brazil
Solar panel	Solar panel	40% - 50%	Yes
Inverter	Inverter	10% - 30%	Yes
Balance of system	Metal structure	20% - 50%	Yes
	Tracker		Yes
	String Box		Yes
	Offset meter		Yes
	Storage		Yes
	Charge controller		Yes
	Smart meter		Yes

Source: SEBRAE, 2017, p. 148

As can be seen, the availability of technology is not a barrier to the development of the industry. Boccuzzi emphasis that even before the regulation, private players were already working towards enabling the solar energy in Brazil, following the solar energy's global trend. "I monitor this technology here in Brazil since 2009. By 2012, when the REN 482 was published, there were already more than 2000 companies working in Brazil with people who went abroad

to develop their competencies and to look for partnerships in order to bring to Brazil the solar energy".

Concerning services and specializes workforce, the scenario in Brazil is quite positive. The main activities necessary for the development of the PV power industry can be found in the country, as represented in Table 3. These activities comprehend the advertising, dissemination of information, financial and insurers support, as well as consultancy, maintenance, which are complementary to the traditional sector related to the installation.

Table 3: Services of the PV chain in Brazil

Companies		Available in Brazil
Publishing	Publishing on the segment	Yes
Supporting Institutions	Associations	Yes
	Teaching and Research Institutions	Yes
	ONGs	Yes
Financing agents	Public and private financial institutions	Yes
	Development agencies	Yes
	Exporting agencies	Yes
	Investors / Private Equity Funds and Venture Capital	Yes
Insurers	Insurers	Yes
	Insurance brokers	Yes
Consulting	Environmental licensing	Yes
	Solar resource assessment	Yes
	Technical Consulting / Engineering / Training	Yes
	Project Finance	Yes
Equipment distributors	Sale of equipment and solar kits	Yes
Project Developers	Development of centralized generation projects	Yes
Systems Integrators	Installation / Systems Integration	Yes
EPC Suppliers	Design, engineering, procurement and construction	Yes
O&M	Operation and maintenance	Yes
Power Generators	Power generation	Yes

Source: SEBRAE, 2017, p. 149

Thus, the availability of technology and specialized workforce should not be considered as a blockage for the development of the PV power in Brazil. The industry has the necessary basis

for its growth; it has the structure to provide the necessary equipment and service to expand further.

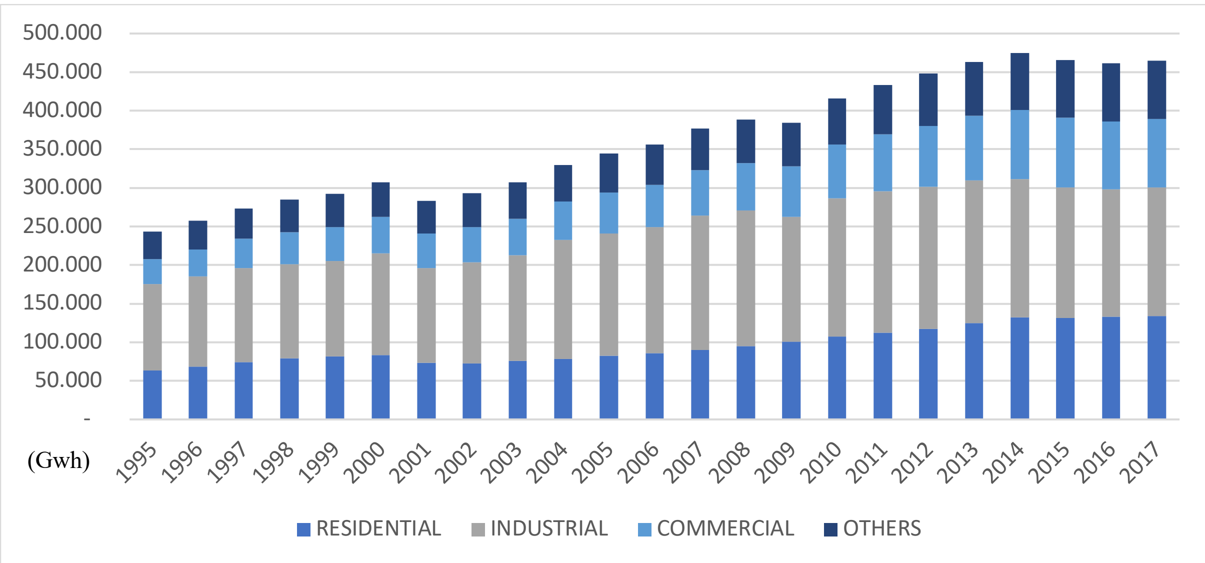
4.2 Demand conditions

The demand conditions analysis for the PV power industry will address the overall nature of the domestic market and assess the potential market. In order to understand the nature of the domestic market, it is of major importance to evaluate the role of PV power in the energetic matrix.

4.2.1 Nature of domestic market

The annual electricity consumption in Brazil grew 27,5% in the last ten years, according to EPE, the state energy research company (EPE, 2018a). The increase was not higher due to the economic crisis in 2015, which lead to a small reduction in the overall consumption, as shown in Figure 8.

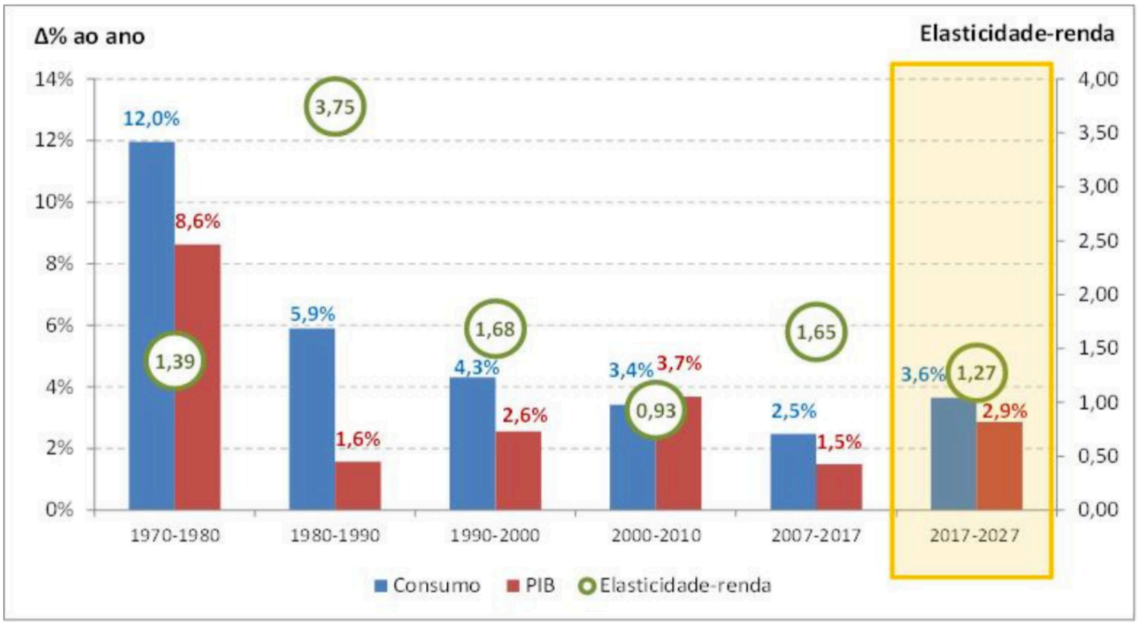
Figure 8: Annual consumption of electricity by class (Gwh) - 1995-2017



Source: own illustration according to EPE, 2018a

The trend for the next ten-year period is towards the increase of electrification of the economy. The total consumption of electricity is expected to grow 0,8p.p more than the economy between 2017 and 2018, given the estimated income elasticity of 1,27. Based on that, the consumption of electricity is estimated to grow 3,6% per year until 2027, as shown in Figure 9. (EPE, 2018b).

Figure 9: Income elasticity of electricity demand: historical x projection



Source: EPE, 2018b, p.40

The increase of demand will require an adjustment on the supply capacity in order to attend the consumers. Boccuzzi mentions that the movements of lack of electricity will be cyclical and each time more frequent in Brazil. Although Brazil is increasing the participation of thermoelectricity in its energetic matrix as an alternative electricity source, thermoelectricity is more expensive energy, which will reflect on the tariffs.

Investments in reduced capacity hydroelectric power plants are also being conducted to increase the supply of electricity. Rocha mentioned that the government in the last twenty years has incentivized the development of the wind power in Brazil by introducing yearly public auctions of wind power, which fostered the development of the industry in the country.

> "In 2014, the government started to incentivize the solar energy market; it was when the first auction for solar power plant took place. In 2015, two solar auctions happened. In 2016, the auction that was planned for December was cancelled days before it was scheduled to happen. It affected a lot the sector, an immature sector needs direction and predictability. In 2017 and 2018 there was one auction per year."

Besides the central generation, it is essential to consider the self- production in the analysis of electricity demand. It refers to the electricity generated to supply its own consumption. This model has faced an accelerated growth in the past ten years, and it has great potential to expand. According to the Energy research company, in 2016, almost 11% of the energy consumed was produced by consumers with their electricity generator, and it is expected to grow by 3,1% per year (EPE, 2017).

Currently, the potential market for cogeneration consists primarily of industrial segments that use large amounts of steam and electricity in the industrial process itself. However, other sources are becoming more relevant. As new sources of electricity become available, the cogeneration is no longer dependent on the steam.

In this context, PV power and other sources of distributed generation are becoming strategic to the electricity's national interconnected system, as they will be able to absorb part of the increase of electricity demand without requiring an additional investment in infrastructure from the government and minimalizing the environmental impact. As mentioned by Assunção and Schutze (2017) by moving away from large, centralized plants, the country could reduce the costs, complexity, interdependencies, and inefficiencies associated with the transportation of electricity.

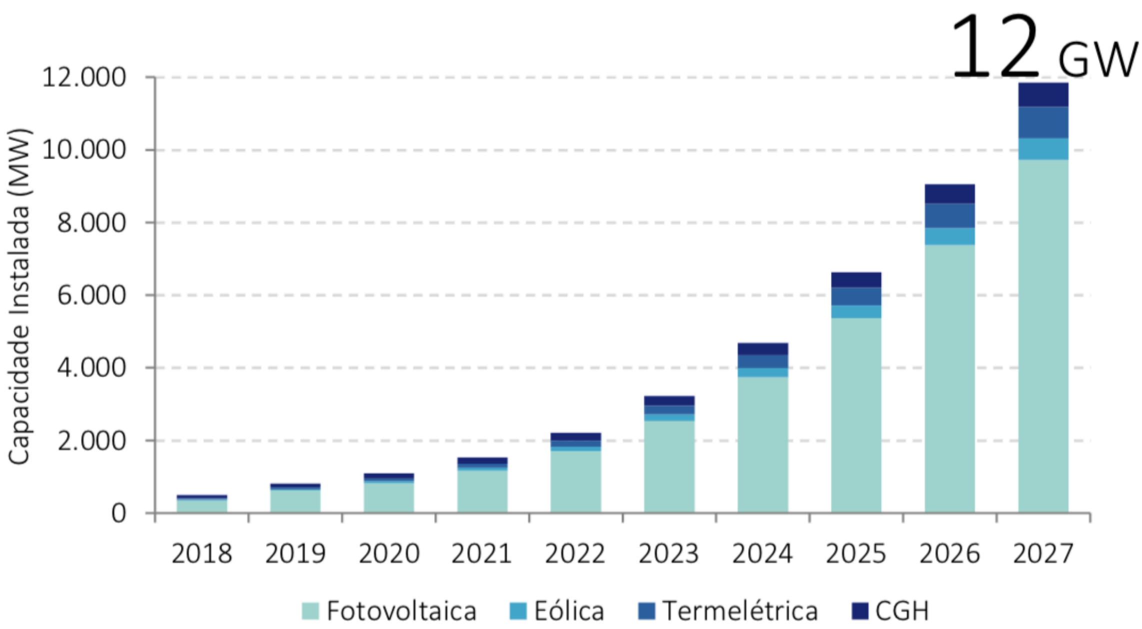
The potential market of PV power outstands from other sources of distributed generation. As indicated by the projection of the Energy research company, PV power is expected to provide 55% of the electricity produced by distributed micro and mini generation; followed by

thermoelectric with 22%; reduced capacity hydroelectric power station with 13% and wind power with 10% (EPE, 2018c)

4.2.2 Potential market

The projection mentioned above for PV power generation provides an insight into the potential market size. The PV power is expected to grow exponentially in the following years, as shown in Figure 10. By 2027, the total capacity of distributed generation is expected to be of 12 GW. PV power is expected to lead it, corresponding to almost 80% of the total distributed generation.

Figure 10: Power and Energy by source in 2027 in the reference scenario



Source: EPE, 2018c, p.210

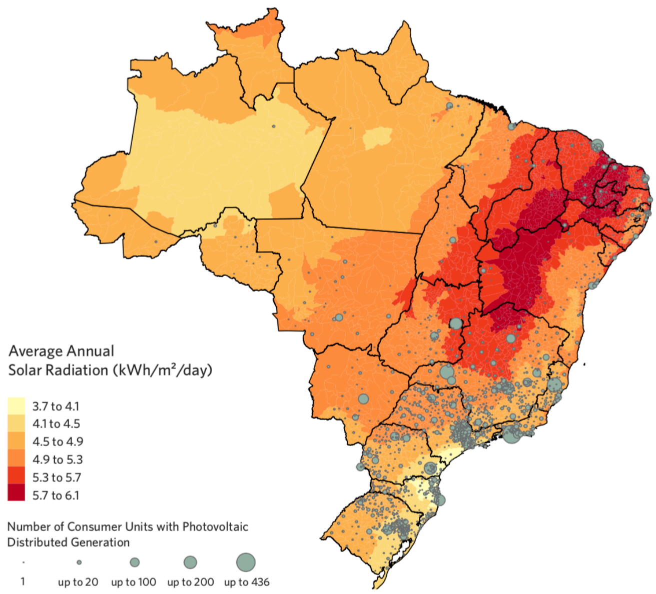
Figure 10 also reinforces the message that solar energy is expected to grow exponentially in the following years in order to reach the above-mentioned projection for 2027, as the current basis is smaller than 1GW. However, one should notice that decentralized solar generation already makes up almost 70% of the decentralized supply and almost all of the installed consumer units at 99%. “This level of consumer interest in decentralized solar energy suggests a great potential for the growth of this renewable source.” (Assunção and Schutze, 2017, p. 3). Boccuzzi

highlights three components that contribute to the attractiveness of solar energy as decentralized generation:

> "There is the environmental component, the economic factor and the independence from the grid. The last one is still going to evolve as today we still do not have efficient ways to store the electricity, however, storage is one of the technological bets, receiving a massive investment worldwide".

The components appointed by Boccuzzi is corroborated by Figure 11 which provides interesting insights into the current distribution of PV power in Brazil. The major concentration of installations is not where the solar irradiation is highest.

Figure 11: Average annual solar radiation and consumer units with photovoltaic distributed generation per municipality in Brazil



Source: Assunção and Schutze, 2017, p. 4

CPI researchers acknowledged that demand-side factors, such as gross domestic product (GDP), population size, and the electricity tariffs, influence where distributed generation is found throughout the country. They were able to identify a positive correlation between the number of PV installations and a) electricity tariff, b) the number of inhabitants and c) income,

given that these factors provide a greater incentive for the population to invest in acquiring their photovoltaic system. (Assunção and Schutze, 2017).

As it was presented, there is a significant potential market for PV power in Brazil, which is expected to grow exponentially due to current favorable demand-side factors and the strategic importance of this technology as a cheaper alternative to grow and diversify the national energetic matrix.

4.3 Related supporting industries

The third determinant of the diamond model consists of relating supporting industries. Given the high aggregated value of PV power systems, financing lines are crucial for the development of the industry. Thus, the role of financial institutions will be assessed in the relating supporting industries analysis.

4.3.1 Financial institutions

Financial institutions have a central role in the development of PV power in Brazil. Due to the high aggregated value of the system, most projects depend on a financing line in order to be executed. To better understand the financing alternatives in Brazil, it is essential to distinguish between public and private financial institutions.

Brazilian Development Bank (BNDES) is the largest financier of the Brazilian renewable energy segment. It has dedicated resources for the financing of renewable energy projects, such as Fundo Clima and Finame: energia renovável. Those lines offer favorable conditions, such as extended terms and low interest rate, which are between 1 and 1,4% per year, to this number, one must add the financial intermediary remuneration which is up to 3% per year. (BNDES 2018a; BNDES 2018b).

The main criteria of the BNDES operational policy is the local content requirement, in order to encourage the Brazilian industry, it requires that at least 60% of national content. In 2014, considering that the solar photovoltaic segment was still very incipient, the BNDES developed a Progressive Nationalization Plan (PNP) specific to the solar photovoltaic chain in order to foster its development. This plan alleviated the rule by implementing a progressive nationalization over time to specific components and processes of the photovoltaic system. (SEBRAE, 2017)

Regional development banks also play an important role in the financing of PV power, offering attractive alternatives similar to BNDES in order to foster the development of renewable energies in their region. Among the regional banks, it is worth mentioning the Southern Regional Development Bank (BRDE), São Paulo's development agency (Desenvolve SP), Northeast Bank and Central West Fund (FCO). The interest rate offered by the regional banks is between 4% and 8% per year.

Although the terms and interest rates of the national and regional banks are attractive, one cannot say the same about the financing process. The banks require extensive documentation to approve the financing request, which makes it exhausting and slow. Once the documents are collected, and the request is submitted, the minimum time required by the banks to analyze the operation is of three months. As additional documents are usually required, the process takes up to a year to be approved.

Private and public commercial banks such as Banco do Brasil, Caixa Economica Federal, Santander, Bradesco, Itaú and BV Financeira offer an agile financing alternative. However, the financing term and interest rate are not as attractive as of the public ones. The interest rate varies from 8% per year to 22% per year, depending on the applicant's risk profile.

In order to foster the PV power industry in Brazil, it is necessary to improve the financing lines options. For national banks, it would be necessary to develop a standardized and agile credit analysis in order to accelerate the evaluation process. Commercial banks should look for attractive conditions. Due to the saving on the electricity bill, part of the risk is already mitigated, as depending on the financing term, the financial resource that is currently used to pay the energy bill can be directed to paying the loan.

4.4 Firm strategy, structure and rivalry

Regarding the analysis of firm strategy, structure and rivalry, Porter mentions that national circumstances and context influence the way companies are organized and managed and determines the traits of the domestic rivalry (Porter, 1990).

This becomes evident when analyzing the strategy, structure and rivalry in the Brazilian photovoltaic industry. In order to conduct this analysis, it is important to distinguish between the two key players: the manufacturing industry of components and the distribution and the installation of photovoltaic systems.

4.4.1 Manufacturers of solar panels and inverters

It is of relevance to mention that a national photovoltaic industry is structuring itself in Brazil. There are currently eight photovoltaic module assemblers, one of them also manufactures the photovoltaic cells, about eleven companies manufacture the interactive inverters and another four hundred firms manufacture other equipment and components of the systems in Brazil. (SEBRAE, 2017)

However, as in the rest of the world, the majority of solar panels and inverters sold in Brazil are imported from China or Europe. This is linked to the higher prices of the modules assembled in Brazil, which are a result of three factors: (i) the lack of fiscal isonomy between imported

and local products; (ii) the lack of scale in the Brazilian market; (iii) the low cost and decreasing prices from the Chinese manufacturing plants. (SEBRAE, 2017).

The president of the Brazilian Association of Photovoltaic Solar Energy, Rodrigo Sauaia explains that "the industry has faced an unfavorable situation due to high taxes, which reach up to 50% on the raw material. This is detrimental to the competitiveness in relation to imported equipment." (Casarin, 2018)

The high taxation of raw materials impacts the competitiveness of the national manufacturing of solar panels and inverters directly. As a consequence, there is no financial incentive fostering the development of the national industry. It was possible to observe that the national manufacturing plants in the country focus on assembling the products in order to attend the requirement of national content of the Brazilian Development Bank (BNDES). The favorable condition of this credit line is the main incentive for developing a national industry.

About the scale, Zechi mentions that "hardly the Brazilian solar panel industry will be as competitive as the international one, mainly due to lack of scale. It is hard to compete with global players". Regarding solar inverters, Zechi mentions that the national industry is competitive, however, there is still a doubt about the equipment's reliability and quality. "Maybe when the national industry of inverters completes ten years, the quality will not be an issue anymore, however, currently there is no data to assess the durability of the national equipment".

Boccuzzi also highlights the lack of scale in the national market. "National manufacturers criticize the pulverization of the distribution of solar power in Brazil. Solar systems are usually small, installed by even smaller companies. The pulverization prevents gains of scale in the sector and reduces the demand predictability, which inhibits its competitiveness".

Thus, although there is a national industry already established in the country, the current scenario does not foster the development of PV power supply chain in Brazil. Rocha suggests that the predictability on the centralized generation of solar electricity, through regular public auctions could increase its competitiveness. It is a common criticism across manufacturers that the Brazilian government is not promoting auctions for solar power plants, which would lead to gains of scale in the sector. For example, Canadian Solar and BYD installed a manufacturing plant of solar panels in Brazil aiming to attend the governmental actions, which did not take place as often as they expected.

Rocha defends the importance of having stability on governmental auctions related to solar power, in terms of consistency and predictability. According to Rocha, the central generation plays a significant role in fostering the market, as it guarantees a minimum demand for the industry, which leads to a gain of scale and the development of new technologies.

> "It is important to have predictability on public auctions to guarantee a minimum demand for the photovoltaic power in Brazil. ABSOLAR estimates that 1GW per year would be healthy. Last minute changes such as the solar auction which was canceled only ten days before the estimated date in 2016 are extremally prejudicial for the sector as it inhibits investments in the industry in Brazil."

Gil, a sales representative of BYD mentioned that the company's decision to install a manufacturing plant in Brazil aimed at attending public auctions. However, the company was forced to change its strategy and attend the distributed generation market, which is more pulverized in order to survive. Boccuzzi also commented that Canadian Solar is asking for support from ABSOLAR, the Brazilian association of solar energy, arguing that without governmental auctions and large-scale projects it will not be able to sustain the production of panels in Brazil for long.

As a consequence of the instability on the solar power market, the photovoltaic power is highly dependent on the international industry. This context does not foster the specialization, differentiation and technological innovation of national manufactures.

4.4.2 Installation and distribution of photovoltaic systems

The scenario is different when considering the installation and distribution of photovoltaic systems. The territorial extension and regionality of Brazil promote the development of local players responsible for installing photovoltaic systems. In this segment, local network and mouth to mouth recommendation play an important role in the expansion of PV power, especially within the distributed generation.

Thus, the circumstance contributes to a pulverized market, characterized by local players. As a reference, Portal Solar, an online platform already has 862 companies registered as distributors or installers of photovoltaic systems. The rivalry between the installers has a positive influence on the propagation of information, which contributes to the dissemination of this technology.

Most of the installers, acquire the photovoltaic system from national distributors, which are responsible for acquiring national or imported products, assembling the photovoltaic kits and delivering to the installers or final consumers. As the market matures, there is an increasing concentration in the distribution of photovoltaic materials. The rivalry between distributors pushed them to develop an efficient logistics system, granting fast deliver, at lower prices accompanied by efficient after-sales support.

Furthermore, the economic context of the Brazilian energetic matrix contributed to the emergence of new business models surrounding the solar energy. Boccuzzi mentioned large scale companies with multi locations, as banks and telecommunications, which cannot migrate to the free market started to look at solar energy as a possibility to save money. “With the REN 482/12 and REN 687/15, it is possible to group the consumers and contract someone offering

electricity at a discount from the concessionary. An investor raises a solar plant of, for example, 5MW and compensates the electricity consumed at different addresses, charging a little less than the concessionary."

The business model mentioned above is particularly interesting as it does not require high investment from the final consumer. This model offers the alternative of a private contract with a discount on the electricity tariff in exchange for the regular contract with the concessionary. Thus, the context of installation and distribution of solar systems is also fostering the development of new business models which is contributing to spreading the solar energy in Brazil.

4.5 Government.

The role of the government in the development of the Brazilian photovoltaic industry cannot be ignored. As mentioned, given the strategic importance of the electricity industry for a country, the government is strongly active, through legislation and taxation. Thus, it is capable of promoting or blocking the development of an industry.

4.5.1 Legislation

Until 2012, the Brazilian government acted as a challenger for the development of PV power in Brazil. By being inert and not regulating the sector, the uncertainty towards photovoltaic energy was so high that investments in the sector were too risky. Anybody willing to invest in the technology would not be certain if the photovoltaic system would be authorized to function and it would not be compensated for the exceeding energy. Thus, until 2012, PV power was only an alternative for off-grid installations, which were disconnected from the national grid.

This scenario changed in 2012 when ANEEL, the Brazilian Electricity Regulatory Agency published the regulation 482 (REN 482). As summarized by SEBRAE (2017), the regulation establishes the general conditions for the access of micro and mini generation to the electric

energy distribution systems and creates the possibility of compensation between the electricity injected by the PV unit and the one consumed from the distribution network in which it is connected.

In order to better understand the energy compensation system, it is necessary to comprehend the structure of the electricity tariff. The electricity bill covers, in a simplified way, two dimensions: (i) energy per se (TE) and (ii) "wire" (TUSD), which remunerates the network responsible for transmitting the electricity. By the current net-metering system, the electricity compensation occurs not only in the TE but also in the portion that remunerates the use of the transmission and distribution networks, TUSD. (Nascimento, 2017).

In addition to the regular tariff, tariff flags are also compensated. Tariff flags signal consumers to the real price of electricity in the country and the supply conditions of the system at a given month. As the generation cost of thermoelectric power in Brazil is higher, there is an additional charge when they are activated. The yellow flag signals that R$ 1,00 will be added to each 100 kWh consumed. Red flag stage one adds R$3,00 and red flag stage two R$5,00 per 100 kWh of consumption. (CPFL Energia, 2019)

REN 482 was a milestone for the PV power in Brazil, as it provided certainty. If a photovoltaic system is installed according to the norms, the local distribution network cannot refuse the photovoltaic installation. Furthermore, it was defined that the electricity generated and not used would be sent to the grid in exchange for credits, solving the issue of the exceeding electricity. (ANEEL, 2012).

The net-metering system also helped to make the investment on a self-consumption photovoltaic installation financially attractive. Instead of paying for the energy to the local distributor, there was the option to produce its own energy and pay only the minimum fee to

stay connected to the network. Thus, PV power was able to provide up to 95% of savings in the energy bill.

In 2015, ANEEL published the regulation 687 (REN 687) which updated the REN 482. This norm introduced new business models: the remote self-consumption, condominiums and shared generation. The remote self-consumption permits the compensation of electricity credits in an address different than the one where the energy was produced, as long as the addresses are linked to the same concessionary. Within the condominium, the electricity generated can be credited to each consumer participating in the agreement; the distribution is proportional to its share in the condominium. Hence, the shared generation allows the creation of a consortium or cooperative among several consumers to benefit from distributed generation. (ANEEL, 2015).

According to SEBRAE (2017) the framework introduced by REN 687, made the Brazilian net metering system one of the most advanced in the world. Thus, the actual regulatory framework is already set to promote the establishment and growth of the photovoltaic segment in the country, both in the distributed generation segment and in the centralized generation.

4.5.2 Taxation

The government is also capable of influencing the development of the PV power market through taxation. In relation to the PV power, the Brazilian government introduced a couple of measures which differentiates the taxation of solar electricity and the photovoltaic system equipment.

The Agreement CONFAZ 101/1997 exempts from the ICMS, which is the value-added tax on sales and services, the operations involving equipment destined to the generation of electricity by photovoltaic systems. This agreement includes solar panels and kits for photovoltaic systems, but it does not comprehend solar inverters and other equipment outside the photovoltaic kit.

The program of support for the technological development of the semiconductor industry (PADIS), grants the exemption of certain federal taxes levied on the industrial implantation, production and commercialization of semiconductor devices and displays, which includes solar cells and solar panels. The program reduces to zero the rates of imported tax and PIS/PASEP and COFINS, which are social taxes. (SEBRAE, 2017).

The electric energy generated by photovoltaic technology also has tax benefits. The ICMS Agreement no. 16/2015 authorizes Brazilian States to exempt ICMS on electricity generated from photovoltaic systems. Apart from Paraná and Santa Catarina all other States adhered to the agreement, meaning that the photovoltaic electricity produced in these States is exempt from ICMS. According to Nascimento (2017), the collection of ICMS on gross consumption increases the average cost of solar generation by approximately 20%. Furthermore, federal law 13.169/15 exempts the photovoltaic electric energy from PIS/ PASEP and COFINS.

The energy produced by a central photovoltaic generation commercialized in the free market also contains tax incentives, such as 80% of exemption on the TUSD and TUST, the tariff for the use of the distribution system, as defined in the law 10.762/03. The discount is reduced to 50% for systems installed after 2017. (SEBRAE, 2017)

As a way to incentivize the investment on the photovoltaic central generation, the government grants an income tax exemption for natural persons on the earnings of debentures emitted to raise funds for the implementation of projects in the area of infrastructure. For legal entities, the income tax on the earnings is defined at 15%.

As demonstrated above, the Brazilian government has taken active measures intending to incentivize the PV power industry in Brazil. By regularizing the photovoltaic generation, the government created a positive framework for investments in this technology. The Federal and State Governments provided important tax incentives for the photovoltaic energy and its

components. However, the tax incentives for components do not comprehend the full value chain; for an instance, inverters and structure outside the system are not included.

4.6 Chance

The analysis of the factor chance includes aspects mainly external to the sector that are not well predicted, but that have the potential to impact the development of the industry (Hosein Rezazadeh Mehrizi and Pakneiat, M. 2008). These aspects are of particular relevance when considering an industry that is not yet consolidated as the solar power in Brazil. Thus, variations in the climate and political view can impact the viability and the potential for the development of the solar industry in Brazil directly, both positively or negatively.

4.6.1 Climate change

As mentioned in chapter one, the Brazilian electricity matrix is extremally dependent in one source, 59% of the country's electricity is generated from hydroelectric power plants (Ministério de Minas e Energia, 2018). Thus, the potential of generation of electricity in Brazil is directly linked to the climate, more specifically to the precipitation, since Brazilian rivers are predominantly sustained by rainwater (Climatic Research Unit, 2015). This is so that the government's monthly report monitoring the Brazilian electrical system dedicates a session to the evaluation of the month's precipitation anomalies (Ministério de Minas e Energia, 2018b).

The impact of irregular rain in the Brazilian electricity generation was already demonstrated in 2001. The below average precipitation level lead to a reduction in the electricity supply, threating forced blackouts. This event was named as the blackout crisis. A forced cut on the electricity supply at specific hours of the day was avoided by a successful campaign which promoted a voluntary reduction in the consumption of electricity. Although specialists (Tolmasquim, 2000; Sauer, Vieira and Kirchner, 2001; Souza, Rodrigues e Reis, 2004) argue that the origin of the energy crisis is related to the lack of investments in the generation and

transmission network, one cannot deny that the precipitation below 85% of the yearly average was a catalyzer.

The electricity crisis returned in 2014, another year in which the precipitation was below the historical average. This time, the crisis was not as intense as in 2001, as the demand was already reduced due to the economic recession and new power plants were already active. However, once more the country experienced the impact of a reduction in the precipitation in the supply of electricity.

Variations on the precipitation are by definition an external event, however, it is capable of affecting the generation of electricity in Brazil. Besides the threat of shortages in the supply of electricity, variations on the precipitation influences directly the settlement price for differences (PLD), which is the price used to value the amounts of electricity settled in the short-term market. (ABRACEEL, 2019a). The PLD is defined weekly by the Electric Energy Trading Chamber (CCEE). Although the PLD's direct effect is on the electricity liquidated on the short-term market, it is also the basis for the definition of the monthly tariff flags and the annual price review conducted by the concessionaires. (ANEEL, 2019a, 2019b)

Hence, a reduction on the precipitation is likely to foster the development for alternative sources of electricity including PV power. The diversification both in the centralized generation and distributed generation is helpful to balance the electric matrix, which would contribute to preventing the shortages on the electricity supply. Furthermore, the lack of rain leads to an increase in electricity prices, which makes the investment in photovoltaic technology more viable. Thus, climate change is an external factor that can foster solar energy in Brazil, especially in a scenario of low precipitation.

4.6.2 Governmental uncertainty

As demonstrated previously, the government has the potential to influence the development of the photovoltaic industry, through regulation and taxation. However, the result of the elections can be considered as chance. Hence, the sector is subject to the uncertainty of a change in the political view, which can impact the guidelines for the sector directly.

The change of the government can influence directly an industry or a sector, especially in a country where the president plays a significant role as in Brazil. The electricity sector is particularly subject to the political view of government given its strategic relevance for the development of a country. The impact of political policies on the sector was demonstrated in 2012 when the government decided to reduce the electricity tariffs.

On the topic, Boccuzzi mentioned that independence is a factor that motivates consumers to opt for photovoltaic technology. Although it is still unfeasible to be completely independent of the grid, since the storage technology is still not as advanced, the partial exemption from the concessionary is already seen as attractive, as consumers are not subject to abrupt changes on the electricity tariffs.

Furthermore, lobby from certain players can lead to a disruption on the policy and change the course of an industry. As mentioned previously, the electric power industry was a monopoly until the1990s. During this period, Eletrobrás was responsible for the generation, transmission and distribution of the electricity. Following the opening of the sector, the competition was introduced to the generation and partially to the distribution of electricity. The transmission is still considered a natural monopoly (Mendonça and Dahl, 1999). Consumers with more than 500MW of contracted demand can opt to participate in the electricity's free market, which allows them to choose their electricity supplier and the terms of the contract. (ABRACEEL, 2019b). Consumers that do not qualify for the free market, known as captive consumers, are linked to the concessionary that acts in their region.

The electricity concessionaries responsible for the distribution of electricity in a region, have historically pressured the government to attend their demands. Recently, ANEEL opened a public consultation to discuss the revision of the REN 482, attending the request of entities representing the distributors of electricity.

According to Koloszuk, president of the board of directors of the Brazilian Association of Photovoltaic Solar Energy and Sauaia, CEO of the Brazilian Photovoltaic Solar Energy Association (ABSOLAR) (2018), “the lobby's intention is to change the rules so that consumers with distributed generation pay more for distribution networks, on the grounds that the tariff impact of alleged cross subsidies would be 0.1% for every 50,000 consumer units”. In other words, the revision of REN 482 intents to increase the amount paid by owners of a photovoltaic system to the concessionary for the distribution of electricity.

However, based on the current regulation, every consumer with distributed generation already pays the cost of availability to be linked to the distribution network, this fee intends to contribute to the maintenance of the infrastructure. Furthermore, the electricity concessionary also benefits from the excess of electricity that is injected in their system as it will help to supply the immediate demand. Thus, an increase in the cost of electricity for owners of a photovoltaic system would reduce the financial attractiveness of the business. Besides, it has the potential to make the remote generation and the condominium model financially unfeasible.

On the topic, Rocha mentioned that as the solar industry is still insignificant for the electricity matrix, he sees the concessionary’s request to change the regulation as a demand for a trigger, in which the concessionaires would already guarantee a way to charge more from consumers with solar systems even if in the future.

The change on the regulation due to the lobby of players of an industry is capable of impacting the development of its industry in two ways: by blocking the development of new business

models and through uncertainty. Changes on the legislation pass the message that rules can change at any moment. Consequently, the risk is higher, which might lead to the reduction of investments in the sector, both from consumers and investors. Thus, an industry that is still immature, as the photovoltaic power in Brazil, might not be able to consolidate itself due to external factors, such as political uncertainty.

5. CONCLUSION

Driven by the purpose to assess why solar energy remains marginal in Brazil, this study was organized in five chapters. Chapter one introduced this study's topic. Chapter two presented the concept of photovoltaic systems and the overview of this technology in the world and more specifically in Brazil. Chapter three presented the theoretical and methodological foundations for this study. Based on Creswell's guidelines, the qualitative research approach was chosen, combined with the case study as the research design. As for the research method, the data collection was based on three sources: observation; semi-structured interviews and secondary data. Finally, the data analysis was guided by Porter's diamond model theoretical framework. Thus, six main determinants of the industry were analyzed: (i) factor conditions; (ii) demand conditions; (iii) related, supporting industries; (iv) firm strategy, structure and rivalry; (v) government and (iv) chance.

The analysis of each determinant considered factors specific to the solar industry. *Factor conditions* analyzed the potential of solar energy as an electrical source in Brazil, generation costs, on grid power price and availability of technology and specialized workforce. *Demand conditions* investigated the nature of the domestic market and the potential market. The *related supporting industries* session evaluated the influence of financial institutions. The *firm strategy, structure and rivalry* chapter focused on the solar panels and inverters manufacturing and installation and distribution of photovoltaic systems. The role of *government* was

investigated through an analysis of legislation and taxation. Finally, the factor *chance* was included by evaluating the impact of climate change and governmental uncertainty.

Based on the analysis of the six determinants, it was possible to observe that although photovoltaic systems are becoming more common in Brazil, there is an immense potential to explore in the country. The analysis of the factor condition demonstrated that Brazil has a favorable potential of generation, which is positive for the technology's expansion. Furthermore, PV power is growing across the world, which contributes to the overall reduction of prices. However, photovoltaic power is still more expansive in Brazil than in other countries. The higher price constrains the dissemination of the technology, as it only reaches a segment of the society that can afford it. Regularity in public auctions of solar energy would lead to gains of scale would likely reduce prices, making the technology accessible for a new range of consumers. Once the consumers respond to the reduced price, gains of scale could lead to a further price decrease, making the photovoltaic solution accessible for even more consumers and maybe even independent from public auctions.

Furthermore, it was possible to observe that the combination of the high on-grid prices with the net-metering system implemented in Brazil helps to promote the financial viability of the system. Brazilian on-grid prices are among the highest in the world and the compensation system of 1 kWh of electricity in excess for 1 kWh of credit grants a relatively short payback. Furthermore, it was also shown that Brazil already has access to photovoltaic technology and a settled supporting industry. Thus, access to technology is not a barrier to the development of the industry.

The analysis of the demand condition appointed that the demand for electricity is expected to increase. Thus, the diversification of the electricity matrix will be necessary. In this context, photovoltaic power can be seen as a strategic source of electricity, both for centralized and distributed generation. The distributed generation is particularly interesting as it is less

investment-intensive than the central generation. Thus, it is seen as an attractive alternative to increase the supply of electricity. In this context, solar energy is expected to grow, moreover, it is already financially attractive for consumers. Thus, industrial policies to the development of the photovoltaic technology should be implemented to accelerate the development of the industry.

Furthermore, it was demonstrated that financial institutions play a significant role in the viability of photovoltaic systems in Brazil. However, financing is still appointed as a hindrance, especially in the distributed generation. The issue of financing is not related to the availability of credit, but on the process, in particular when considering regional and development banks. Hence, in order to promote PV power, it is essential that national and regional banks simplify and accelerate the process. As for commercial banks, more attractive financing lines would be necessary.

In the firm strategy, structure and rivalry analysis, it was indicated that although there is already an established national industry, it is not competitive with the international one. In order to circumvent it, taxation of raw materials must be reduced. Additionally, the regularity of public auctions has the potential to attract investments and to contribute to the reduction of prices of national products, due to gains of scale. These measures have the potential to strengthen the national industry, promoting its competitiveness, specialization and innovation.

The pulverization of installation and distribution of photovoltaic systems promotes the awareness of the technology. This also has the potential to foster new business models, such as to acquire solar energy with a discount, when compared to the concessionary.

The analysis of the legislation and taxation indicated that, although the government was late in regularizing the photovoltaic generation, the legal framework is advanced and positive for solar power. The tax incentives over the photovoltaic energy and solar panels or photovoltaic kits are

also favorable for the PV power. However, it would be positive for the development of the other links of the supply chain to extend the tax exemptions to the remaining components of the system.

Finally, the analysis of chance indicated that variations on the climate such as precipitation have the potential to foster the photovoltaic market, due to the increase in price and the threat of electricity shortage. Furthermore, governmental uncertainty has a substantial impact on the electricity market, changes implemented on the sector due to variations on the political view or lobby can either foster or dismantle the industry, especially at an early stage as the solar industry.

Overall, it is possible to conclude that the potential for the propagation of the PV power in Brazil is positive. However, the analysis of the Brazilian photovoltaic industry also demonstrated that the national industry is still much dependent on the importation of equipment. There is no policy fostering the development of the production of solar cells in Brazil, for example. Thus, it shows that the country lacks the dynamics and challenges that according to Porter challenges the barriers to the innovation and drives to the competitiveness of the industry. Thus, based on Porter's framework, more important than having a national market, it is essential to have a challenging and innovative domestic industry. This might explain why although many factors favor solar the propagation of solar energy in Brazil, the country still is not a leader in the sector.

5.1 Implications for entrepreneurs and government policy

This study has practical implications for entrepreneurs acting on the solar energy industry and may guide the development of public policies in the sector.

Based on the conclusions of this study, entrepreneurs of the photovoltaic industry can focus on the strengths of the sector and introduce measures to overcome the barriers which were

identified. The firms should enhance positive factors such as the geographical, location, legislation and financial viability of the solar energy in order to foster the technology. Moreover, entrepreneurs should focus on the opportunities for new business models within the solar energy industry. The solar industry also presents a potential for business for banks, since consumers usually seek financing lines. The optimization of financing lines and processes would likely accelerate solar power in Brazil.

The findings of this study can also help the development of public policies. As presented above, the solar power has great potential to diversify the Brazilian electricity matrix and to foster the distributed generation, a less investment-intensive way to increase the supply of electricity in the country. Thus, changes in the current regulation should be avoided, as the current net-metering system is central to the development of the solar industry in Brazil. Modifications on the regulation at this early stage could inhibit the consolidation of the industry. On the other hand, regular solar energy public auctions have the potential to foment the industry, since it would provide a fundamental demand which would attract investments and promote gains of scale in the national industry.

Finally, this study can be used as a basis for future researchers focusing on specific topics of the solar energy industry in Brazil. The reasons the Brazilian government has been less active in public auctions for solar power when compared to wind power actions, could be the object of study. Finally, smart grids and its impact on the Brazilian electricity matrix could lead to an interesting research of its own.

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