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The Brazilian Photovoltaic Market

Potential for new Investments?

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Executive Summary

Kick-off in the Brazilian solar power production. With the introduction of a (well-designed) feed-in law and tax incentives, the emerging economy stimulates the electricity generation from renewable energy sources. With solar radiation values ranking among the highest on earth, the potential of photovoltaic electricity production is promising. The inclusion of this technology in the Brazilian power matrix enables opportunities for foreign involvement given the immaturity of the local industry segment, while a growing and dispersed demand predestines the country to grow into a lucrative photovoltaic market. However, tapping new markets is a sensitive matter and requires special attention towards the many aspects influencing market development.

This thesis identifies the relevant variables, relevant for market development, by conducting a comprehensive market analysis. Firstly, it comprises a detailed evaluation of economic competiveness for photovoltaic power production in the different Brazilian regions. Results highlight the importance of conditions for capital acquisition and identify locations where photovoltaic power production is profitable. Due to vast intra-regional differences of electricity prices, favorable production sites are mainly independent from their regional location. Secondly, the research presented in this paper points out further relevant economic, political, social and technological factors highly relevant for understanding market dynamics in the Brazilian photovoltaic sector. The pursuance of a qualitative approach identifies social tendencies in particular, which may negatively affect consumer behavior.

Despite the (not yet) favorable conditions skills and electricity prices, this thesis finds that in some areas, private investment in photovoltaic is profitable today. Given this fact, the study concludes by creating hypotheses based on the assumption that lucrative investment opportunities will be exploited sooner or later.

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Electric Units & Exchange Rate

kW	kW is a unit of power: defines the rate at which energy is used or generated	kWh	kWh is a unit of energy: defines the quantity of energy used or generated
MW	1.000 kW	MWh	1.000 kWh
GW	1.000 MW	GWh	1.000 MWh
TW	1.000 GW	TWh	1.000 GWh

1 €	2,58R$
1 USD	2,0 R$

Abbreviations

Abbreviation	Complete Name
ABINEE	Brazilian Electrical and Electronics Industry Association *Associação Brasileira da Indústria Elétrica e Eletrônica*
ACL	Free Contracting Environment *Ambiente de Contratación Libre*
ACR	Regulated Contracting Environment *Ambiente de Contratación Regulada*
ANEEL	National Agency for Electric Energy *Agência Nacional de Energia Elétrica*
BNDES	Brazilian Development Bank *Banco Nacional do Desenvolvimento Econômico e Social*
CCEE	Electrical Energy Commercialization Chamber *Câmara de Comercialização de Energia Elétrica*
CMSE	Monitoring Commission for the Electricity Sector *Comitê de Monitoramento do Setor Elétrico*
CNPE	National Council for Energy Policies *Conselho Nacional de Política Energética*
EPE	Company for Energy Research *Empresa de Pesquisa Energética*
ICMS	Tax on Services and Circulation of Goods *Imposto sobre Circulação de Mercadorias e Serviços*

IDB	Inter-American Development Bank
INMETRO	Institute for Metrology and Standardization and Industrial Quality *Instituto Nacional de Metrologia, Qualidade e Tecnologia*
IPI	Tax on Industrialized Products *Imposto sobre produtos industrializados*
LPT	Light For Everybody *Luz Para Todos*
MERCOSUR	Common Market of the South
MME	Ministry of Mines and Energy *Ministério de Minas e Energia*

1 Introduction

As emerging economy Brazil is growing quickly, both economically and demographically. The World Bank expects the Brazilian population to grow up to 219 million people until 2030 and names the country one of the fastest developing economies[1] (World Bank 2013). Additionally, rising living standards pressure existing energy provision concepts and make secure and sustainable energy supply one of the most important aspects for the economy. In total an increase of up to 1.245 TWh in electric energy consumption is projected until 2030 (MME/EPE 2007: 213). This constitutes a 90% increase compared to current consumption levels (MME/EPE 2012a: 38). In response the Brazilian government seeks to develop all sectors of power generation. This includes the utilization of the high potential for renewable energies. Brazil's electricity generation is exceptional since over 80% of electricity in generated by hydro power (EIA 2012). Although Brazil is located in a region on Earth where solar radiation is one of the highest in the world, this potential is mainly untapped (Meisen 2010: 29).

The centralized structure of the Brazilian energy system and the great reliance on hydropower are the main challenges of Brazil's power provision. The large distance between power generators and consumers resulted in supply bottlenecks over the last years. In addition, heavy draughts caused serious power outtakes. This led to policy efforts aiming at the diversification and decentralization of the electricity sector. Accordingly, in April 2012, net-metering was introduced in Brazil. The feed-in law allows businesses and residential consumers to feed into the grid the electricity they produce with renewable energy technologies, and to earn credits on their electricity bill. The legislation refers to solar, wind, biomass and hydro power production for micro-generators and mini-generators. Micro-generators cover facilities with an installed capacity of up to 100 kW and mini-generators cover facilities with an installed capacity of up to one MW (Nielsen 2012a).

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[1] I am referring to this time frame because Brazils population is expected to reach a peak by 2030

This approach differs from the European motivation to introduce feed-in laws: in the European Union the promotion of renewable energies is based on the idea of climate protection, competition enhancement and on reducing the dependency on fossil fuel imports (EU 2008). The main driver behind introducing the net-metering regulation in Brazil, in contrast, is to guarantee security of supply.

This regulation is especially promising for solar-based photovoltaic (PV) technologies as small grid-connected roof-top systems can mitigate transmission losses and back up hydro power production cycles by its complementary nature.[2] With 30 MW, accounting for 0.03% of the total installed capacity, photovoltaic is so far negligible in Brazil. (Varella at al. 2012:26). However, the combination of a long-term regulatory environment and high solar radiation paves the way for photovoltaic electricity production. The new regulatory design allows small PV producers to earn credits on their electricity bills, which could kick-start PV production particularly in the residential and the commercial sector. Electricity prices for households rank among highest in the world and within the commercial sector the highest increase in demand is expected. With high power prices, PV installations are more likely to be profitable since own consumption can be covered with self-production.

Foreign companies have shown interest in the emerging PV sector given the growth prospects of this infant industry and the new regulatory incentives for electricity production. (DENA 2012: 11). For potential market entrants, knowledge concerning the economic and political conditions is crucial, especially because they are more volatile than for example in the European Union. The recent 30% drop in electricity prices bears witness to this fact and stresses the uncertainty of the concrete viability for photovoltaic systems in the Brazilian residential and commercial sector (Döhne 2013). Thus a comprehensive market analysis including the financial performance of PV technologies in Brazil shall be conducted here in order to inform companies, which are active within the PV value chain, about the prospects in the Brazilian PV market. The aim of this study is to identify opportunities and obstacles for foreign companies in the Brazilian photovoltaic sector by analyzing economic, political and social conditions.

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[2] Rain vs Sun

2 Purpose of Research

Long-term studies confirm the theoretically high potential of solar energy production in Brazil (Meisen 2010, Pereira et al. 2006). Besides these local conditions, the magnitude of future cost reductions for PV equipment has a significant influence on its competitiveness. The common way to assess the potential of cost reductions in an industry is the application of learning curves. For the PV sector a noteworthy decline in costs is projected for the next decades (ISE 2012: 9). This development improves the possibilities for the utilization of solar energy in Brazil. With regard to the feasibility of PV technologies in Brazil, studies mainly focused on rural electrification, finding that national PV projects are suitable for off-grid electricity production. However, program evaluations criticized weak implementation strategies and stressed the need for continuous project assessments (Kissel 2008: 10). Detailed power price analyses found that inefficient regulation and limited competition in the distribution sector are the main obstacles for an adequate price level (Devienne 2011). Only recently the research started to cover grid-connected PV installations. Studies with regard to the evaluation of suitable policies and selected production sites were conducted (Mitschner/Rüther 2012, Jannuzzi/de Melo 2013). Results suggest that net-metering is an appropriate mechanism for Brazil and that PV installations may be economically feasible in areas with intensive solar radiation and high electricity prices. The latter is not surprising but emphasizes the relevance of policy measures with regard to price changes. This research is driven by the attempt to draw a broad picture of the overall PV potential in the Brazilian residential and commercial sector against the background of the newly introduced net-metering regulation.

3 Methodology

The recent change of the regulatory framework results in a market environment for which performance data and policy evaluations are not yet available. Thus this analysis pursues a qualitative approach (Golafshani 2003: 600). This design aims to generate hypotheses regarding the identification of variables influencing the emerging photovoltaic market in Brazil and as such the potential for a business entering it. This method is commonly used to create some general understanding of a topic (Gerring 2008: 655).

In a first step, I will describe current conditions and policy developments in the Brazilian PV sector. This is includes the identification of the main actors, relevant market characteristics and particularly the new regulatory framework enhancing PV development. Taking into account the special characteristics of the Brazilian power market, I will then explain the factors influencing the likelihood of the emergence of a Brazilian PV market. Based on calculations of Net Present Values (NPV), I will indicate where in Brazil PV systems are currently profitable. NPVs indicate the present value of a long-term investment in a PV installation (Myers/Brealey 2005: 85). Assumed system sizes are the common capacities of 3 kW in the residential and 30 kW in the commercial sector (Abinee 2012: 58). Therefore the scope of this research covers power production from micro-generators. The calculations take into account regions of different solar radiation and the significant variance of electricity prices ranging from 0,20 R$/kWh to 0,41 R$/kWh (ANEEL 2013). Furthermore, three interest rate scenarios are included in order to evaluate the profitability of PV systems with regard to available financing options. Against the background of recent electricity price drops, NPV calculations are crucial to determine the financial performance of PV systems in Brazil. Given the great variety in prices, I attempt to avoid average values in my arithmetic analysis when possible.

The evaluation of expert interviews completes the analytical part. The purpose of the interviews is to incorporate the views of experienced individuals regarding the developments in the Brazilian PV market. In cooperation with the practice institution, enviacon International, experts have been selected and interviewed personally in Rio de Janeiro and via telephone. Results are presented in the so-called PEST framework which outlines key social, technological, economic and political factors in the Brazilian PV market segment (Johnson et al. 2008: 55). The last section will derive future research opportunities in the light of the present study and the correspondent expert opinions by stating hypotheses.[3]

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[3] This study focuses on electricity and does not consider primary energy sources. The use of the term energy in this paper always refers to electric power

4 Electricity Sector Brazil

The following section describes important characteristics and actors in the Brazilian electricity sector.[4] First, I explain the market situation analyzing supply and demand. Second, I cover the transmission and distribution of electrify. Lastly, I will introduce relevant actors as well as the ownership structure in the Brazilian electricity market.

4.1 Supply & Demand

Brazil's electricity supply structure is rather peculiar, given the fact that it has one of the largest hydro power productions in the world. In total, hydropower accounts for more than 80% of the electricity generation and for 67% of the installed capacity in the Brazilian transmission network. Off-grid power production mainly takes place in the northern Amazonas region.[5] The rest of the total 115 GW of installed capacity splits into 14% thermal generation, based mainly on fossil fuels, and into 12% renewable energy, mainly wind and biomass. Solar power plants barely contribute to the volume of the installed capacity. Brazil is a net importer of electricity and as imports from Paraguay account for 5% of the installed capacity. With a share of merely 2% nuclear power covers only a small part of Brazil's electricity supply. Figure 1 portrays the portion of each energy source.

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[4] Within the context of the world cup in 2014, large photovoltaic systems for soccer stadiums are planned; Those prestige projects are not included as they are not covered by the net-metering regulation

[5] In this analysis off-grid power production is not considered as the new regulatory environment is based on feed-in laws

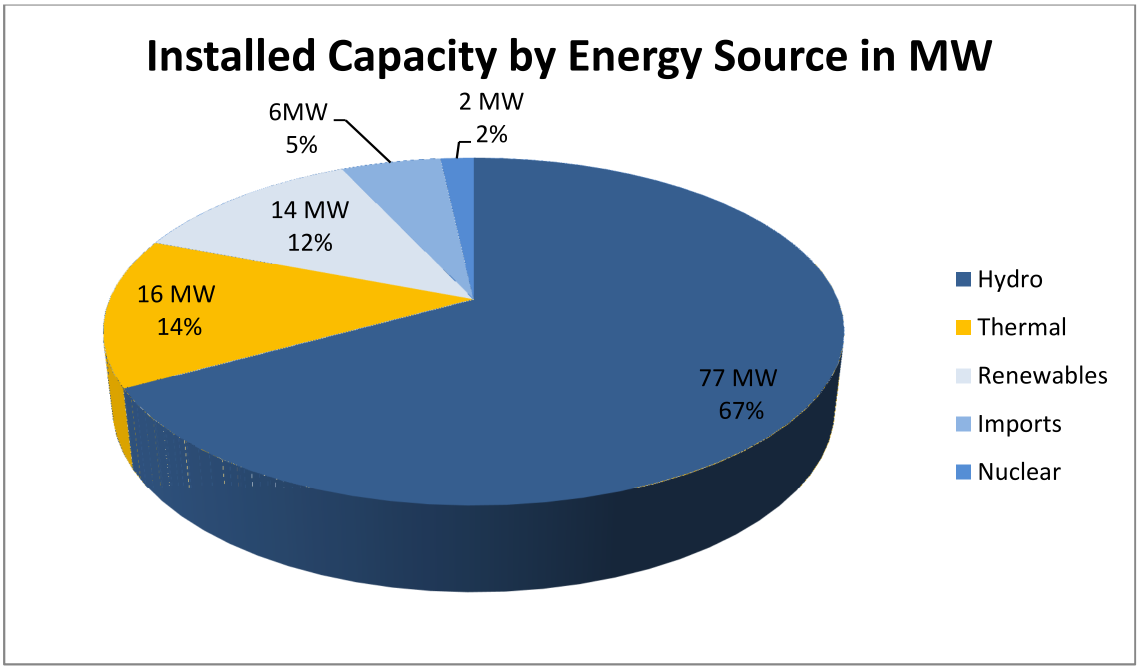

Figure 1: Installed Capacity by Energy Source

(MME/EPE 2012a)

Given the great potential of hydropower, especially in the Amazonas basin, and the mistaken belief of lacking fossil fuel resources,[6] it has been the main source of electricity. It played a key role in Brazil's socio-economic development and is a major and mature industry. Despite concern regarding the overwhelming dependency on hydropower, this source will continue to be the major source of electricity generation in Brazil (IAEA/UNDESA 2006: 63). Unlike wind, biomass, and PV, hydro power has traditionally accounted for a large share of the Brazilian electricity matrix, leading to it being considered a rather conventional energy source. The centralized structure and the reliance on mainly one predominant resource negatively affect the quality of energy security: High transmission and distribution losses and the limited availability of electricity in dry seasons pose serious challenges (EIA 2012).

In order to compensate the rising energy demand in Brazil, the development of 182 GW total generation capacity is planned to cover all energy sources. With 33 GW of the increase being produced with hydro, its significance remains constant and its share of the total installed capacity decreases by only 1%.The contribution of the new renewable energy sources is planned to account for 20% and mainly consists of wind

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[6] In 2007 in Brazil extensive off-shore oilfields were found, followed by new discoveries in 2012 (Blount/Lorenzi 2012)

and minimally on the utilization of solar resources. The remaining increase splits into 14% of conventional thermal and 2% of nuclear power production.

In total 531 TWh of electricity were produced in 2011. Including imports, this number increases to 596 TWh. The total power consumption accounts for 483 TWh (EIA 2011). The significant difference bears witness to the losses resulting from transmission and distribution (MME/EPE 2012a: 92). Consumption varies greatly among different regions. The southern states are the biggest consumers and account for over 40% of the total electricity consumption. This results from greater population density and a higher degree of industrialization in the south and south-east (MME/EPE 2007: 167). Consumption patterns among different sectors are displayed in figure 2.

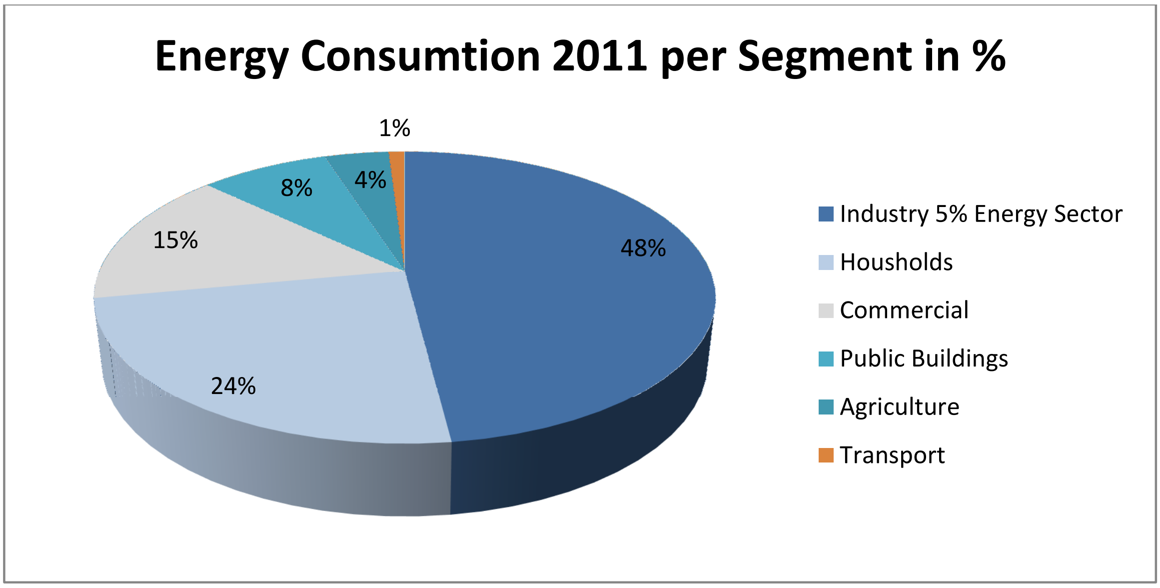

Figure 2: Energy Consumption by Segment

(MME/EPE 2012a)

Brazil’s policy makers announced an estimated total annual growth of electricity demand of 4.6%. The biggest increase is expected in the in the commercial sector, followed by the households (MME/EPE 2012a:38). This indicates the value of power generated with PV rooftop installations allowing for decentralized production by small businesses and households.

4.2 Transmission & Distribution

The extensive Brazilian power grid, the National Interconnected System (SIN), consists of 96.140 km transmission lines and almost completely connects the country from north to south. The rest of the country is covered by isolated systems located mainly in the Amazon region and consuming only about 3% of the total energy produced in Brazil. Today about 96% of the total population has access to the grid. The niches without electricity distribution are directly related to geographic location and economic difficulties for extending the power grid. SIN is divided into five different supply territories: south, south-east, midwest, northeast, and north. The electric power distribution market is serviced by a total of 63 concessionaires (Francisco 2012: 9). Figure 3 reflects the correlation between grid development and population density and degree of industrialization.

The National Interconnected System 2012

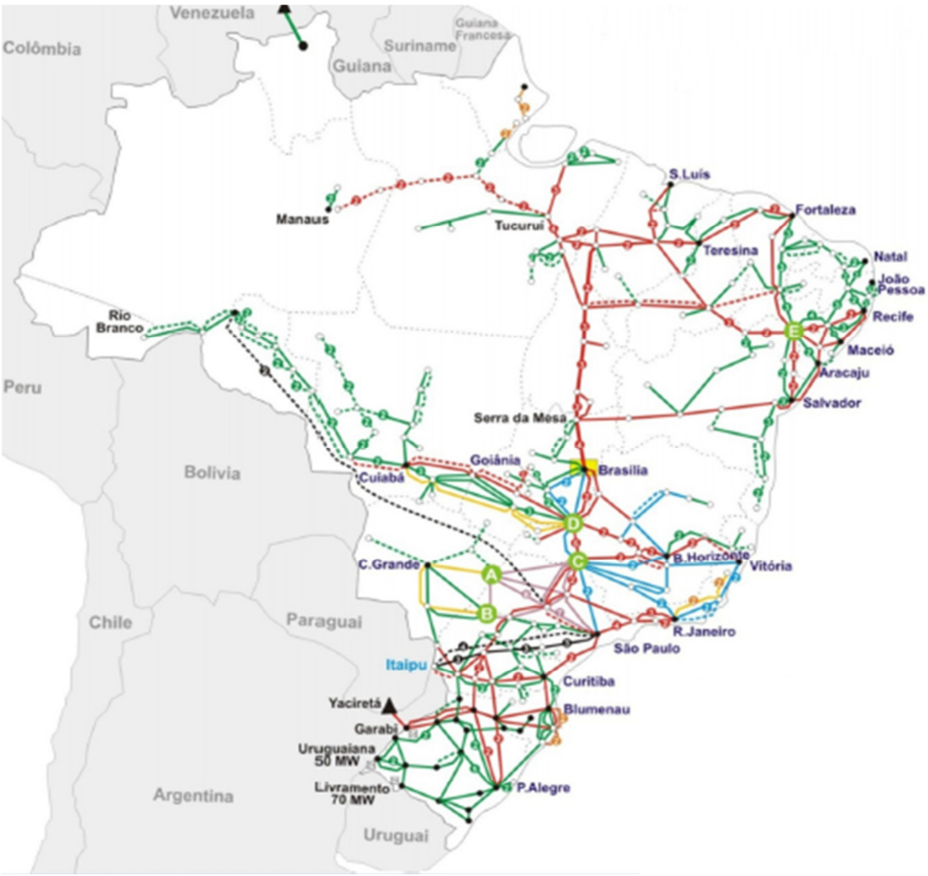

Figure 3: The National Interconnected System

(MME/EPE 2012a)

The grid carries large amounts of electric power from the generation stations to consumption areas over long distances. The centralized, extensive and outmoded structure bears the risk of causing supply bottlenecks (Baker Institute 2004: 25). In 2012, Brazil witnessed three large blackouts lasting for several hours and bringing several industries to a halt (Boadle 2012). Another major problem is the great amount of transmission and distribution losses. In 2012, about 15% of generated power was lost due to technical issues and pilferage. The national ten year energy expansion plan refers to the development of the transmission system not only in terms of generating additional capacities but also includes attempts to make transmission more effective (MME/EPE 2012a: 124). The newly implemented net-metering regulation counters this trend by the attempt to decentralize energy supply and thus to foster energy security.

4.3 Actors & Owner Structure

In 2001, Brazil experienced the most drastic electricity shortage in its recent history, forcing the government to ration power in order to prevent extensive blackouts. In the heavily populated and industrialized southeast region, cutbacks in usage from 15 to 25% were required from the industrial sector at great cost to the economy and the working population. This power crisis set an end to the privatization trend in the power sector, which was proposed in 1996. The administration of the left-wing President Lula da Silva, aimed at creating an environment in which both public and private companies may coexist and expand the sector (Kissel 2008: 52).

The initial aim of privatizing the electricity sector was to fix public finances and increase macroeconomic stability. Electrobrás, the federal generation holding company controls 55% of total installed capacity, while regional state-owned companies hold most of the remainder. Also, most transmission capacities are under public control. However, the 63 distribution companies now consist of 70% private actors (Kissel 2008: 52). As a result of the power crisis in 2001, the institutional reform process, which had begun in 1996, was continued. New regulatory agencies were created that were directed at the establishment of a well-structured power market and encouraging investment.

Already in 1997 the National Agency for Electric Energy (ANEEL) was established with the duties of regulating and inspecting electricity services. ANEEL audits electric energy production, transmission, distribution and retail markets according to guidelines instituted by the Brazilian Federal Government. It promotes the auctions for contracting with both public and private service utilities and grants concessions to utilize the hydroelectric potential. It also regulates tariffs, sets targets for each distribution utility and solves conflicts between agents (Silva 2010: 8).

The independent National Electric System Operator (ONS), founded in 1998, remained responsible for the coordination and control of the generation and transmission installed in the SIN. Its first objective is to optimize the SIN. It contracts and manages the electric power transmission services and defines the operational rules for the basic net transmission installations, which are then approved by ANEEL (Nascimento 2012: 25). Both institutions are subordinated to the Ministry of Mines and Energy (MME). The National Council for Energy Policies (CNPE) is the strategic actor and advising council to the president. It sets guidelines, proposes energy policies for the electric sector and is responsible to secure energy provision in all five Brazilian areas (Nascimento 2012: 25).

In response to the power crisis, in 2003 the Monitoring Commission for the Electricity Sector (CMSE), the Company for Energy Research (EPE) and the Electrical Energy Commercialization Chamber (CCEE) were established. The CMSE has the mission to monitor and assess the security of electricity supply across the country and is directly coordinated by the MME. The EPE is responsible for long-term research and planning in the power sector. Its studies aim at supporting the development of future policies to efficiently expand the power sector. The CCEE is the operator of the commercial market and is in charge of the auction system. The rules and commercialization procedures that regulate CCEE's activities are audited and approved by ANEEL (Silva 2010: 9).

The reforms created two environments in which to trade energy: The Free Contracting Environment (ACL), and the Regulated Contracting Environment (ACR). The ACL is governed by free negotiations between generators, marketers, free consumers, importers, and exporters of power. Participants of the free market negotiate their power purchases and sales through bilateral agreements. With regard to their trading conditions they are not subject to the determinations of the ANEEL. In the ACR distribution companies buy energy in public auctions. They submit five-year demand projections to the EPE. The sum of all demands sets the total market that will be offered in the auctions. In these actions the generators compete with prices and the winners get the concession from the distribution company. The final consumers of the regulated market are households, public institutions, commercial and small industrial actors (Devienne 2011: 4). They cannot participate directly in the power market and make use of their consumer power as they receive power from the distributor in charge. Therefore they are called captive consumers (Linhares 2004:15). This study focuses on the ACR since the net-metering mechanism is tied to set electricity prices from the distribution companies.

5 Photovoltaic in Brazil

This section outlines the technical opportunities for power produced with PV systems in Brazil. Furthermore, it describes the existing use of PV technology and relevant industry characteristics.

5.1 Conditions & Benefits

Brazil is located in a region where solar radiation is among the highest in the world. The daily solar radiation varies from 5,9 kWh/m² in the north-east to 5,2 kWh/m² in the south.[7] The Amazon region belongs to the sunniest areas in Brazil, but is also the worst location for ecological and economic reasons for the energy to be tapped there (Pereira et al. 2006: 48). Figure 4 allows a comparison of the annual average radiation potential of solar energy for each of the Brazilian regions.

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[7] In Germany for example the daily radiation is between 2,5 kWh/m² and 3,4 kWh/m²

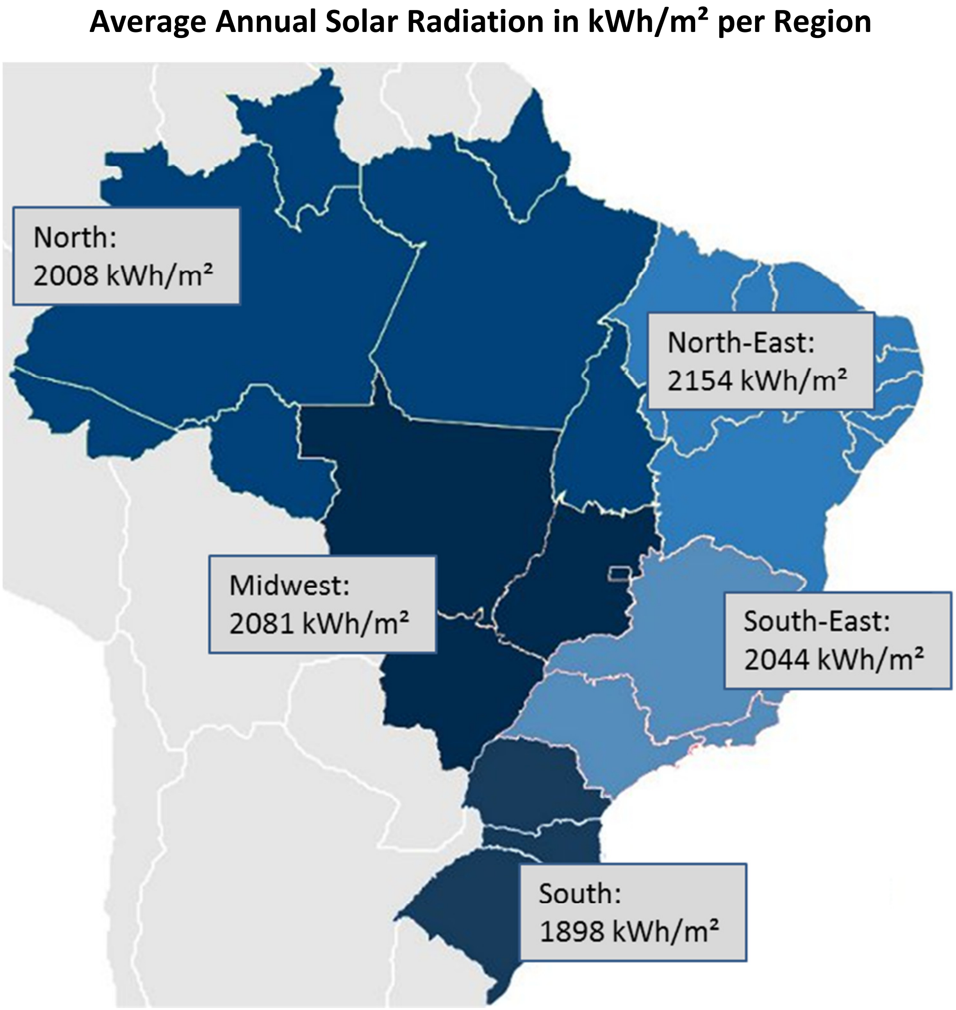

Figure 4: Annual Solar Radiation per Region

(Pereira et al. 2006)

The theoretical potential for grid-connected energy produced with PV technology is enormous. The estimated annual electricity amount to be produced with this source accounts for about 6,897,050 TWh. Comparing this number to the total annual energy consumption of 483 TWh in 2011 indicates the magnitude of available resources (Moner-Girona 2011: 9). PV electricity could further reduce transmission losses as no transport from the generation sites to consumer sites in the large and complex SIN is necessary. Electricity shortages can be avoided because of the complementary nature of hydro and PV generation peaks. However, PV as an alternative energy source to alleviate such problems is still regarded inappropriate by many experts in non-industrialized countries due to the high costs associated with this technology. In the case of Brazil plentiful solar radiation and relatively high electricity tariffs suggest that PV technology might reach economic feasibility for on-grid installations in the near future. When PV power costs equal the retail electricity prices, PV is said to have reached grid parity. The moment of grid parity is often considered as the most important milestone of introducing new technologies aiming at diversifying the energy generation portfolio and signaling economic feasibility (Mitscher/Rüther 2012: 689). Beside local conditions, the reduction of future technology costs has a great influence on PV's competitiveness. Learning curves predict a decline of about 20% with each doubling of the cumulated PV module production (ISE 2012: 9).

Growing environmental concerns and restrictions, both on the national and on the international level, are increasing the costs of new hydro energy projects, such as the controversial Belo Monte power plant in the state of Amazonas (Mitscher/Rüther 2012: 689). Therefore, the expansion of the Brazilian power portfolio is even more important for a secure and sustainable energy provision. Power produced with PV technology causes zero emissions and has no environmental impact on ecosystems. Additionally, the introduction of a new segment into the energy sector will create opportunities on the labor market in the long-run (ABINEE 2012: 36).

5.2 Use & Development

The first initiative to incorporate the use of PV on a national level was the Program for Energy Development of States and Municipalities (PRODEEM). The program was coordinated by the Brazilian Ministry of Mines and Energy and is considered to be one of the largest PV-based rural electrification programs worldwide. PRODEEM was established in 1994 and until 2002 approximately 9000 standalone[8] photovoltaic systems were installed with a total capacity of 5 MW in 26 Brazilian states with a focus on the Northeast and Northern region (Varella et al. 2012: 17). However the program's success remained limited as the Federal Court of Accounts in Brazil (TCU), responsible for the financial assessments of government programs, stated in an evaluation report in 2002. The TCU uncovered flaws with regard to the overall concept and the organizational structure. This resulted in a complete restructuring of the program and strict conditions for installation sites and maintenance procedures (Kissel 2008: 10). PRODEEM was then integrated in the national development program *Light for*

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[8] Stand-alone PV systems are not connected to the grid

Everybody (LPT) aiming at the provision of electricity access to the entire Brazilian rural population until 2008. The stand-alone systems installed in the context of PRODEEM were reutilized and incorporated in LPT. The program provided electricity access to 2,5 million rural families, benefitting around 12 million people (Varella et al. 2012: 18).

The electrification rate in Brazil today is 98,3%. The population in the Amazonas region remains one of the most disadvantaged with regard to electricity access. Moreover the lack of access to electricity is also an urban problem: more than 11 million citizens live in favelas, where 200.000 do not have access to electric power (DENA 2012: 21).

Until recently, no considerable attempts to integrate photovoltaic into the Brazilian energy matrix were conducted. The majority of installations are located in the rural regions, meeting the demands that are distant from the SIN. In 2012, the total PV installed capacity was about 30 MW with an on-grid capacity of 7,6 MW (Varella et al. 2012: 26). The implementation of grid-connected PV power plants started with the development of a one MW project, called Tauá, in the north-eastern state Ceará. It was developed by the Brazilian corporation MPX and partially funded by the Inter-American Development Bank (IDB). Since its finalization in 2011, further capacity expansion is planned (IDB 2011). Several utilities announced the construction of PV power plants in the last year. Newspapers report that ANEEL received requests for the installation of a total 29 photovoltaic plants with a combined capacity of 793 MW (Pekic 2012a).

5.3 Photovoltaic Industrial Sector

In Brazil so far only one PV module manufacturer exists. Tecnometal's annual production is limited to 100 kW although an expansion up to 25 MW is planned. In the past Heliodinamica produced modules, but broke off production in the 1990s due to powerful international competition. Thus, almost all modules are imported. Most imports come from China Japan and the United States. However, the company Brazil Solair is currently planning a module production facility with a 30 MW capacity in the north-eastern state Paraíba. Technology will be supplied by the German Schmid Group (Pekic 2012b). Likewise, the value chain for PV suppliers is not complete: Although

Brazil ranks 6th worldwide with regard to silicon production, no purification processes to solar silicon are available. No PV cells are produced in Brazil (DENA 2012: 69). Estimated additional costs resulting from transport and import regulations raise the price for modules in Brazil by up to 30% compared to international price levels (MME/EPE 2012b:25). However, imported products are still cheaper than Brazilian modules. The national production for inverters is equally dominated by foreign competition.[9]

Within the field of scientific research and development Brazil participates with small PV technology projects (Kissel 2008: 11). Nevertheless the Brazilian education system lacks PV-orientated study programs and professional expertise. The human capital needed to develop the PV sector in Brazil is consequently barely existent. In a long-run this is a major obstacle for the PV market development.

Although the volume of the Brazilian PV market remains low and the import of modules poses legal and financial obstacles, international companies started to take interest in further market developments. They joined the Brazilian Electrical and Electronics Industry Association (ABINEE) in order to obtain PV-relevant information and to build up a network. ABINEE is the Brazilian organization representing the electrical industrial sector with currently 127 local and international signed members in the PV section. In order to enter the Brazilian market, most foreign companies establish a joint-venture with local partners (DENA 2012: 64).

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[9] Inverters convert the power produced into a usable form

6 Net-Metering

In April 2012, the Brazilian energy regulatory body, ANEEL, enacted new rules aiming at enabling distributed power production of renewable energy sources. The net-metering mechanism allows small-scale power generators of up to one MW to offset their electricity bills with credits from the energy they feed into the grid. The legal base for grid connection of distributed renewable energy power producers is the regulation 482 from April 17, 2012. Minor amendments and rectifications were approved December 11, 2012 (ANEEL 2012a).

The first section covers the general grid codes. Qualifying small distributed generators include distributed micro-generators and distributed mini-generators. Micro-generators cover any facility with an installed capacity up to 100 kW. Mini-generators cover facilities with an installed capacity up to one MW. Both types have to utilize an incentivized energy source, such as solar, wind, biomass hydro and cogeneration and be interconnected at the concessionaire's distribution network through consumer-installed systems. Hence, producers generating energy in excess of the amount of power consumed in one month are eligible to receive credits (in kWh) on their electricity bill for the power they generate and feed into the grid. If the generating capacity of one's facility is less than the amount of power consumed, the generator is required to pay for the difference between the energy consumed and the energy generated.

In the second and forth section grid access rules for mini- and micro-generators are indicated. Pursuant to the regulation the distribution concessionaires have 240 days[10] to adjust their billing and operating systems and elaborate or revise technical requirements so that access to net metering can be made available upon request. Adjustments were conducted according to the so-called PRODIST regulation in which technical standards and processes for power distribution are defined. Costs associated with on-site meter adjustments required for net-metering are borne by the small

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[10] The request by distribution concessionaires to extend the amendment period by 180 days has been declined by ANEEL

power producer. The distribution concessionaire is responsible for operation and further maintenance, including technical replacements. Moreover they are required to collect data and to conduct evaluations at no cost to the participating consumer. Qualifying micro- and mini-generators are not required to execute a formal interconnection contract. A less bureaucratic interconnection agreement is sufficient.

The following section elaborates on the billing processes for participating consumer units. For all energy fed into the grid in a given month the owners of generation systems receive credits on their electricity bill. Consumer units are required to pay the difference between the energy consumed and the energy generated. The regulation provides that the credits earned by the micro or mini generators expire after 36 months. Differences in the rate structure resulting from peak and off-peak tariffs are taken into account. Credits earned for excess power produced can be applied to another registered consumption unit serviced by the same concessionaire.

The regulation appears user friendly, avoiding time-consuming paperwork and with adaption costs borne by the distribution concessionaire. However, compared to the feed-in tariff for example in Germany where for 20 years payments for electricity fed into the grid is guaranteed, this mechanism is less market stimulating since added earned credits depend on one’s consumption rather (BMU 2012).

7 Regulatory Framework

Besides the net-metering regulation other policy measures exist with regard to the utilization of renewable energy sources. They are worth mentioning to understand which factors may influence the development of a PV market in Brazil.

7.1 Renewable Energy Policies

In 2002, the renewable energy program, PROINFA, was established to promote alternative energy sources for electricity generation and to integrate produced power in the grid. However, photovoltaic solar energy is not included in PROINFA's renewable energy portfolio because PV policies used to be directed towards off-grid installations for areas that are too far removed from the SIN. Even though PV technology was not specifically included in PROINFA, the LPT program made use of available funds from PROFINA to deploy solar energy with photovoltaic technologies. However, the few photovoltaic projects are insufficient to consider the program itself as supporter of this technology (Varella at al. 2012: 18).

7.2 Taxes

In line with the net-metering regulation, ANEEL approved tax benefits for commercial solar power producers. Solar energy utilities up to 30 MW size are eligible for an 80% discount on Transmission System Use Tariffs (TUST) and Distribution System Use Tariffs (TUSD). According to the regulation, enterprises that enter into commercial operation until 2017 have the discount of 80% applied to the tariffs during the first 10 years of operation. After the tenth year of operation, this discount is reduced to 50 percent. For enterprises which enter into commercial operation after 2017, a 50% discount is available (ANEEL 2012b).

Two other relevant tax incentives exist to promote the use of some photovoltaic equipment: the exemption of both the state-level Tax on Services and Circulation of

Goods (ICMS) and the Tax on Industrialized Products (IPI). Tax exemptions reduce ICMS and IPI to zero for all PV modules. Inverters are not excluded and taxes occur for both national and international products (ABINEE 2012: 58).

Since most PV equipment is imported, national import taxes arise. A rate of 12% occurs for photovoltaic modules and 14% for inverters. Exemptions are made for members of the Common Market of the South (MERCOSUR) (ABINEE 2012: 57).

7.3 Certification

All PV systems and their components need certification from the Brazilian Institute for Metrology and Standardization and Industrial Quality (INMETRO) before being applicable for power production in Brazil. This accounts for both, national and international products. This process is mandatory and other international certifications are not recognized. A special working group as part of the Brazilian Program for Labeling (PBE) establishes the standards for PV systems and their components in order to continuously improve their technical quality and enhance innovation. The regulation 352, July 2012, from INMETRO sets the conditions for the certification process (INMETRO 2012). With submitting all product and company specific paperwork, the product is tested in a laboratory recognized by INMETRO. They are being evaluated regarding efficiency and technical performance, among others. The PV modules get labels presenting their efficiency range from A to E, A being the most efficient. In case of successful testing the product receives the certificate and the import license. They are valid for the entire product line within the same manufacturing process (Galdino et al. 2004: 1). This procedure is time-consuming and cost-intensive. Currently, 35 PV modules from 35 manufactures are certified and obtainable from Brazilian distributors.

7.4 Sources of Finance

The Brazilian Development Bank (BNDES) offers loans below-market rates at 2,5% for renewable energy projects. Loans are tied to a local content regulation. This mechanism requires domestic production of 60% of the value chain aiming at the promotion of domestic manufacturing and creating local jobs (DENA 2012: 130). By contrast to wind technologies, PV was excluded from those conditions since the 60% mark was set too high for a barely existing industry. However, international panel producers are so far not eligible for loans from BNDES due to tightened local content regulations (Nielsen 2012b). Generally, this approach has a better chance of working in large domestic markets, whereas in smaller markets it bears the risk of price increases for renewable energy technologies and creating a domestic industry which is unable to compete in the international supply chain. Requiring domestic production for a large portion of the value chain may also result in losing access to the latest technology and low-cost components for domestic electricity generation (Sivasanker et al. 2012: 8). We observe this trend currently in Brazil where financially feasible components are only available as imports.

As observed until the recent introduction of the net-metering regulation, the initiatives to stimulate the use of PV solar energy have been limited and were not sufficient to promote the intensive use of this energy source, especially considering the country’s high solar potential.

8 Photovoltaic Market Analysis

The financial performance of a PV system is assessed with the calculation of Net Present Values. NPVs indicate the present value of net cash flows generated by a project taking into account inflation and returns. This method is a widespread and reliable measure in capital budgeting because it reflects the time value of money by using discounted cash flows. Moreover a PEST analysis is conducted to draw a complete picture of all relevant variables influencing the PV market in Brazil. It outlines the political, economic, social and technological factors important to assess the market for a business.

8.1 Net Present Value Assumptions

The NPV of an investment is the sum of the present worth of annual net cash flows and revenues, generated over the life time (t) of a project, minus expenses (Myers/Brealey 2005: 85). Positive NPVs suggest financial feasibility of a project. NPV analyses are based on the implicit assumption, that earned revenues can be reinvested with a return which equals the assumed costs of the PV system. Moreover, NPV analysis assumes perfect markets for capital goods (Myers/Brealey 2005: 88). In the following NPV calculations are determined considering all existing electricity prices for the residential and the commercial sector, different irradiation regions and varying interest rate scenarios. All monetary amounts and NPVs are stated in the Brazilian currency Real (R$).

NPVs are calculated with the following standard formula:

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0$$

C_t: Cash flows for any given year

C_0: Initial Investment

r: Interest rate

This analysis assumes an initial debt financed investment of 21.359 R$ for a 3 kw photovoltaic system in the residential sector. In the commercial sector it presumes a debt financed investment of 188.047 R$ for a 30 kW photovoltaic system. This includes all accruing costs such as technical equipment, import taxes[11] and fees. Tax exemptions for ICMS and IPI for PV modules are taken into consideration (ABINEE 2012: 58).

The systems' lifetime are 25 years and have a performance ratio - the portion of the generated power that actually has been produced - of 80%. 1% annual system efficiency losses and 2,5% annual power price increases are included in this calculations (Mitscher/Rüther 2012: 690). The cash flows result from the multiplication of solar irradiation, capacity, capacity factor and electricity prices. Given the 1% system losses but 2,5% electricity price increases, it becomes clear that cash flows constantly grow over the years. Given the recent drop of energy prices up to 30%, conditions for PV profitability have changed since the magnitude of cash flows depends on this parameter.

From the equation it is easy to understand, that the denominator has a strong influence on the result. Conditions for capital acquisition in Brazil are tight with interest rates being among the highest in the world (Mitschner/Rüther 2012: 690). In order to stress the importance of available financing opportunities and the great impact they may have on financial performance, three different interest rates will be taken into account. An interest rate of 2,5% is available from the BNDES for renewable energy projects. This option is so far tied to the 60% local content regulation, resulting in a 30% increase of system costs due to the immaturity of the Brazilian PV sector. Additional costs are considered in the calculations.

The interest rate currently available for a long-term loans offered by Brazilian banks accounts for 7,25% and represents the scenario in which no additional financial support is offered. The current interest rate sets a historic record low and thus the final scenario considers a rate of 16,2% representing the average rate from 1999 until 2013 (Trading Economics 2013).

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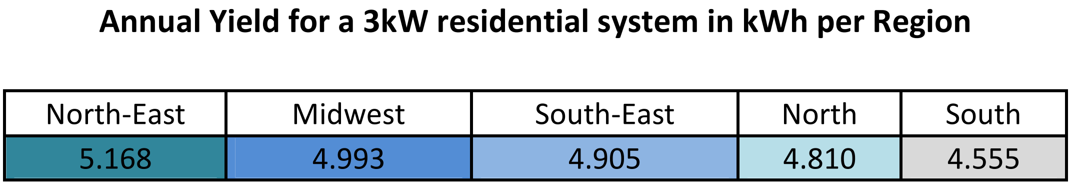
[11] As only one PV system producer exists in Brazil most systems are imported, calculations consider foreign products

8.2 Analysis of Financial Returns Residential Sector

The following section displays and explains the profitability of a 3 kW PV system. Illustrations consider the yield generated by the installation, the three interest rate scenarios and variations of NPVs in different locations.

8.2.1 PV Yield & Overview Regions

Figure 5 shows that in all areas the yield of a 3 kW PV power plant exceeds by far the average residential electricity consumption. Annual household average energy consumption ranges from 1800 kWh in the northern to 2000 kWh in southern regions (MME/EPE 2008: 15).



Annual Yield for a 3kW residential system in kWh per Region

North-East	Midwest	South-East	North	South
5.168	4.993	4.905	4.810	4.555

Figure 5: Annual Yield per Region, Residential Sector

(Own calculations)

In this context it is important to note that consumption varies greatly per region and income class. Nonetheless, those high values indicate the technical potential of PV installations in all Brazilian regions. The dimension of values suggests making use of the option, indicated in the net-metering regulation, to register another consumption unit served by the same concessionaire. Thereby losses of credit earned can be avoided since they are only valid for 36 months.

Irradiation values are the same within one region and therefore less important for the interpretation of results within one region. A comparison of NPVs among regions is illustrated in the figure below. The averages of all calculated NPVs are pictured by varying interest rates for the installation of a 3 kW photovoltaic system in figure 6.

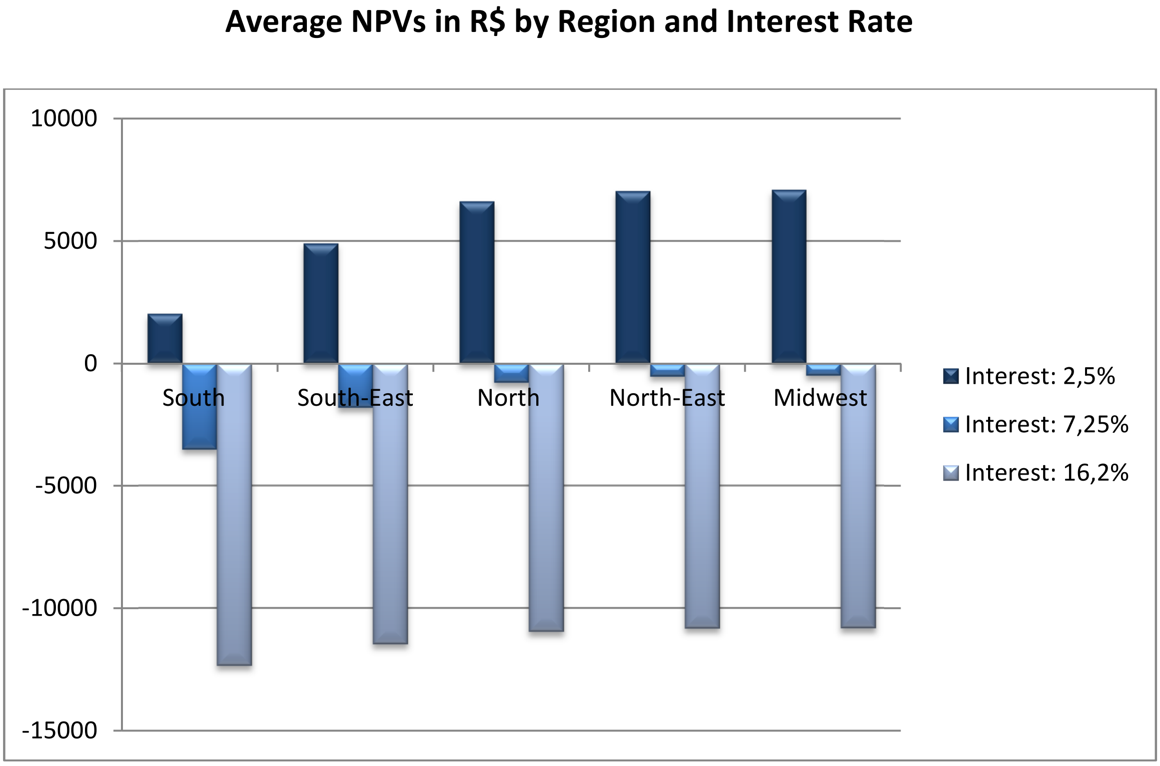


Figure 6: Average NPVs by Region and Interest Rate, Residential Sector

(Own calculations)

Results suggest financial feasibility in all regions for an interest rate of 2,5% percent. The south with an average NPV of 2011 R$ appears to be the least and the midwest with an average NPV of 7.071 R$ the most profitable region. The midwestern, northern and north-eastern region account for an average NPV well above 6.000 R$, whereas in the south-east for roughly 5.000 R$. Considering an interest rate of 7,25% average NPVs reject the economic viability of a PV system in the residential sector in all five regions. Again the southern region with an average NPV of -3.533 R$ appears to be the least profitable region and the midwest with a NPV of -504 R$, followed by the north-east with a NPV of -535 R$. Taking into consideration an interest rate of 16,2% average NPVs reject the profitability of a PV system in all five regions. Just as in the other two scenarios, the south with an average NPV of -12.344 R$ lists the largest negative value whereas the midwest and the north-east show the smallest negative values with -10.813 R$ and -10.829 R$.

8.2.2 Interest Rate Scenarios

In order to provide a more complete illustration of the NPV dispersion the figures 7,8 and 9 show the range of NPVs per region considering each interest rate scenario.

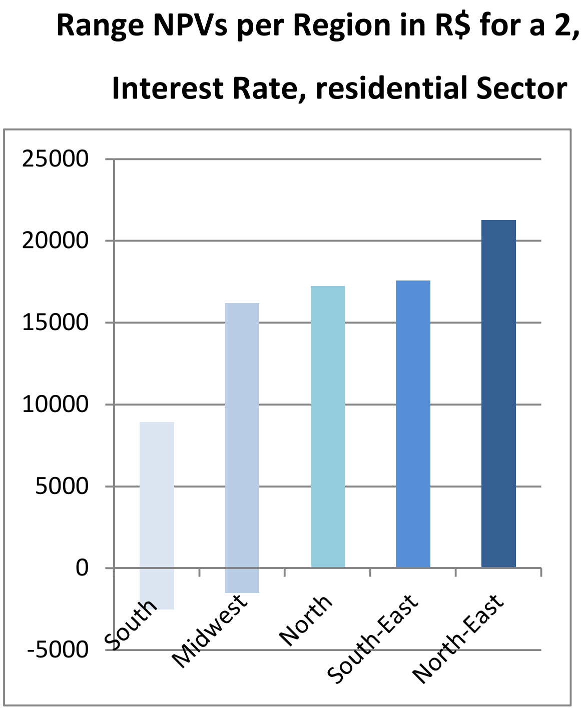

Range NPVs per Region in R$ for a 2,5% Interest Rate, residential Sector

Figure 7: NPV Ranges for a 2,5% Interest Rate, Residential Sector
(Own calculations)

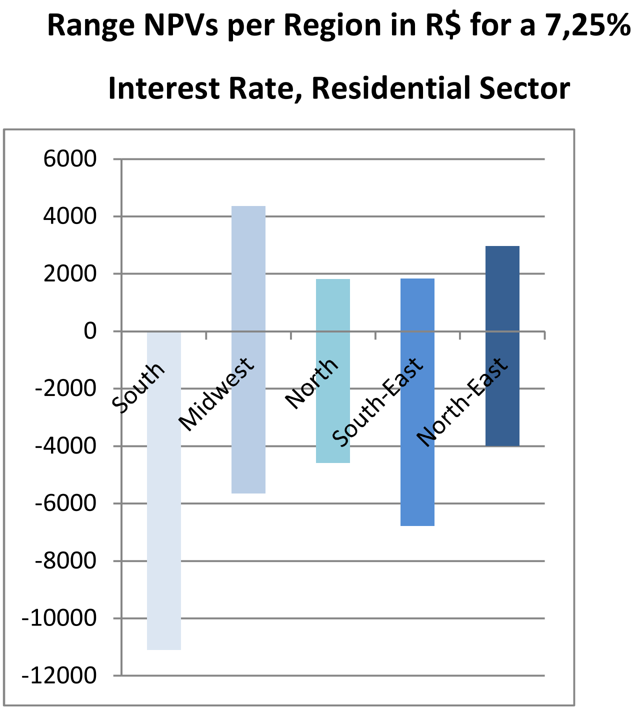

Range NPVs per Region in R$ for a 7,25% Interest Rate, Residential Sector

Figure 8: NPV Ranges for a 7,25% Interest Rate, Residential Sector
(Own calculations)

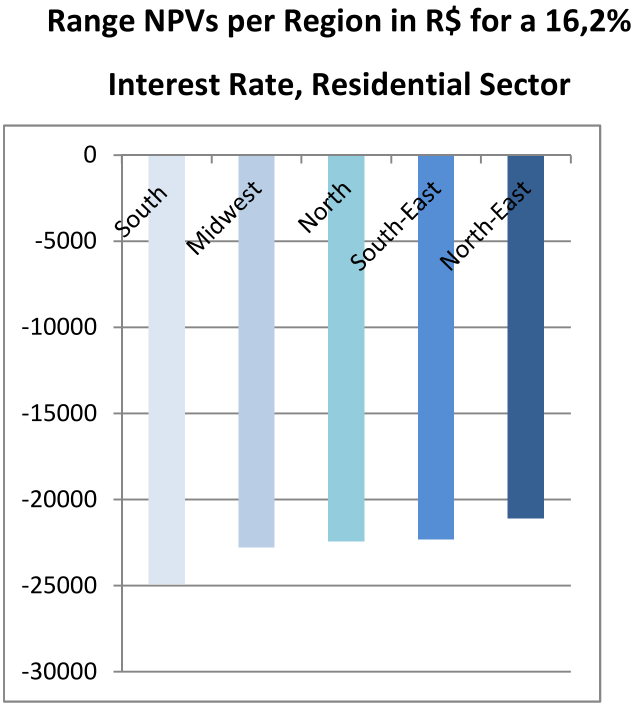

Range NPVs per Region in R$ for a 16,2% Interest Rate, Residential Sector

Figure 9: NPV Ranges for a 16,2% Interest Rate, Residential Sector
(Own calculations)

Figure 7 indicates financial feasibility for all states in the north, north-east and south-east with the north-east being the most profitable region. The highest NPV in the north-east accounts for 12.889 R$. The majority of NPV ranges is positive in the southern and midwestern region and therefore suggests the investment in 3 kW PV installations to be worth it. The lowest value of -2.509 R$ can be observed in the south. It is important to note that this interest rate of 2,5% from the BNDES is tied to a local content regulation of 60%, meaning that 60% of the value chain has to take place in Brazil.

As indicated in chapter four the Brazilian PV industry is far from being fully developed. However, the 30% price increase resulting from extra costs due to a weak local industry does not seem to have a great impact. The loan with an interest of 2,5% equals out the additional costs and suggests financial viability in most areas of all five Brazilian regions.

Figure 8 considers an interest scenario of 7,25%, the current interest rate available for loans from Brazilian banks. In all regions NPVs range negatively rather than positively. Values indicate that nowhere in the South a PV installation in the residential sector is profitable considering the current interest rate and electricity prices. The lowest value in the south equals -6.239 R$. The midwest lists the highest value with 2.361 R$.

Figure 9 portrays that in none of the five Brazilian regions a PV project in the residential sector may be financially viable in an interest scenario of 16,2%. The southern region lists with -13.713 R$ the lowest, and the north-eastern with -9.051 R$ the highest NPV.

The three tables 7,8 and 9 bear witness to the impact magnitude of financing conditions. The access to cheap money changes the financial performance of PV rooftop installations significantly. Moreover the tables indicate the widespread range of NPVs. Therefore, varying electricity prices within regions have to be taken into consideration when assessing the financial performance of PV systems in the residential sector.

8.2.3 Electricity Prices, States & Cities[12]

As indicated in chapter 2, electricity prices vary greatly and range from 0,21 R$/kWh to 0,42 R$/kWh. The presented results are based on energy prices from 24 of the total 27 Brazilian states, including the Federal District, Brasília. States which are not yet connected to the SIN are not considered. As power prices vary among cities in the same state, 40 cities are considered in the illustrations below. In order to facilitate the presentation of results while meantime being as specific as possible, only varying prices among distribution utilities in the same city are summed up to average prices for calculations. The figures 10, 11, 12, 13 and 14 portray all calculated NPVs per state, city and interest rate. Positive NPV results suggest the financial feasibility of a project. Some values might appear rather low given the fact that apart from money also time has to be invested in a PV project. However, the Brazilian Institute on Geography and Statistics estimates the average income of a household being 2.000 R$ (IGBE). Thus already a NPV of 100 accounts for 5% of the monthly income in some Brazilian households.[13]

NPVs by City, State and Interest Rates in the Midwest – Residential Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
Midwest	Braslia	Federal District	-1520	-5647	-13414
	Goiânia	Goias	4335	-2142	-11641
	Ceres	Goias	9444	916	-10095
	Campo Grande	Matto Grosso do Sul	11240	1992	-9551
	Cuiaba	Matto Grosso	11857	2361	-9364

Figure 10: NPVs by City, State, Interest Rates in the Midwest, Residential Sector

(Own calculations)

For an interest rate of 2,5% in the midwest only in Brasilia a 3 kW PV installation would not be profitable. The electricity prices in the Federal District, at 0,2425 R$/kWh among the lowest in the country, explain this outlier. The highest values created are in the states Matto Grosso do Sul and Matto Grosso. The comparison of the NPVs for the

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[12] It is important to note that results should be considered as conservative values as further taxes can be saved by reducing the amount of electricity received from a distribution utility; Consumers being eligible for net-metering only pay taxes on the difference of power generated and power consumed

[13] As indicated in the introduction, interpreting average values deserves special consideration because of the heterogeneous character of the Brazilian society

two cities Ceres and Goiânia indicates the great price variety of power available in the state of Goias. Taking into consideration an interest rate of 7,25% only in three cities we can observe a positive NPV.

NPVs by City, State and Interest Rates in the North-East – Residential Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
North-East	Campina Grande	Paraíba	2986	-2950	-12050
	Aracaju	Sergipe	4722	-1910	-11524
	Recife	Pernambuco	5405	-1501	-11317
	Fortaleza	Ceará	5629	-1367	-11249
	Natal	Rio Grande do Norte	5641	-1360	-11246
	Maceió	Alagoas	6167	-1045	-11087
	João Pessoa	Paraíba	7836	-46	-10581
	Salvador	Bahia	8912	598	-10256
	Estância	Sergipe	9987	1242	-9930
	Teresina	Piauí	12889	2979	-9052

Figure 11: NPVs by City, State, Interest Rates in the North East, Residential Sector

(Own calculations)

For the state of Maranho no data was available and is therefore missing in this illustration. In this north-eastern region, the highest solar irradiation takes place resulting in higher NPVs compared to the other regions. With an available interest rate of 2,5% in all cities the NPVs are significantly high, ranging from 2.986 R$ to 12.889 R$. Again, the great variance between cities in both the state of Sergipe and the state of Paraíba bears witness to the great difference in electricity prices within one state. However, for seven out of ten cities the financial viability is not given in the interest rate scenario of 7,25%. The high results compared to the 2,5% interest rate scenario drop significantly. NPVs for an interest rate of 16,2% are negative for all cities and states in the north-east.

NPVs by City, State and Interest Rates in the North – Residential Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
North	Manaus	Amazonas	566	-4398	-12782
	Belém	Pará	5726	-1309	-11220
	Porto Velho	Rondônia	7595	-190	-10654
	Palmas	Tocantins	8180	160	-10477
	Rio Branco	Acre	10937	1810	-9643

Figure 12: NPVs by City, State, Interest Rates in the North, Residential Sector

(Own calculations)

The northern region is covered least by the national grid. The states Roraima and Amapa are not yet[14] connected to SIN and thus do not appear in this illustration. An interest rate of 2,5% suggests financial profitability in all states and cities ranging highest in the state of Acre with 10.937 R$ and lowest in the state of Amazonas with 566 R$. The latter relatively low value can be explained by the fact that in Manaus electricity prices are up to 0,1 R$ lower than in the other northern cities. A loan based on a 7,25% interest rate only results in positive NPVs in Acre and Tocantins. Those two areas are closest to the SIN. Similar to the other regions, an interest rate of 16,2% does not result in positive NPVs in any locations within the north.

NPVs by City, State and Interest Rates in the South – Residential Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
South	Florianópolis	Santa Catarina	-2509	-6239	-13713
	Campo Largo	Paraná	-2174	-6038	-13612
	Porto Alegre	Rio Grande do Sul	-1660	-5731	-13456
	Guarapuava	Paraná	-762	-5193	-13184
	Xanxerê	Santa Catarina	927	-4182	-12673
	Tapejara	Rio Grande do Sul	1578	-3792	-12476
	Siderópolis	Santa Catarina	1776	-3674	-12416
	Içara	Santa Catarina	3020	-2929	-12039
	Caxias do Sul	Rio Grande do Sul	4412	-2096	-11618
	Carazinho	Rio Grande do Sul	4995	-1747	-11442
	Panambi	Rio Grande do Sul	5242	-1599	-11367
	Ijuí	Rio Grande do Sul	5380	-1516	-11325
	Faxinal do Soturno	Rio Grande do Sul	5923	-1191	-11161

Figure 13: NPVs by City, State, Interest Rates in the South, Residential Sector

(Own calculations)

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[14] The ten year energy expansion plan indicates grid access for those two states by the end of 2014

In the southern region we observe the lowest irradiation among all regions. This may explain the fact that results are relatively low in comparison to the other regions for all interest rate scenarios. The population density and the high degree of industrialization in the south are the reason for the high number of distributors within one state. An interest rate of 2,5% suggests profitability for a 3 kW PV residential roof-top installation in several cities in the state of Rio Grande do Sul and the state of Santa Catarina. The cities in Rio Grande do Sul rank highest because of high electricity prices. By contrast in the state of Paraná only negative NPVs can be observed. These results again indicate the wide range of power tariffs within one state. Neither in the 7,25%, nor in the 16,2% interest scenario, positive NPVs result from the calculations. Apart from the outlier in the Federal District, NPV results in the south are the lowest compared to the other regions.

NPVs by City, State and Interest Rates in the South-East – Residential Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
South-East	Piraju	São Paulo	943	-4172	-12668
	São Paulo	São Paulo	1124	-4064	-12613
	Campinas	São Paulo	1305	-3956	-12559
	Nova Friburgo	Rio de Janeiro	2560	-3205	-12179
	Jaguariúna	São Paulo	3224	-2807	-11978
	Poços de Caldas	Minas Gerais	3559	-2606	-11876
	Rio de Janeiro	Rio de Janeiro	5633	-1365	-11248
	Vitória	Espírito Santo	5728	-1308	-11219
	Colatina	Espírito Santo	6802	-665	-10894
	Belo Horizonte	Minas Gerais	7419	-296	-10708
	Niterói	Rio de Janeiro	9461	927	-10090
	Cataguases	Minas Gerais	10981	1837	-9629

Figure 14: NPVs by City, State, Interest Rates in the South-East, Residential Sector

(Own calculations)

The south-east with its mega cities Sao Paulo and Rio de Janeiro is a large energy consumer. Thus various power distributors exist within each state. For an interest rate of 2,5% positive NPVs occur in all cities. The highest NPV can be observed in Cataguases in the state of Minas Gerais, the lowest in Piraju, the state of São Paulo. Even though results show a variance within the same state, cities in São Paulo tend to low NPVs. Minas Gerais and Espirito Santo list greater values because of higher tariffs.

With an interest rate of 7,25% only the cities Niterói and Cataguases suggest profitability of a PV installation. In none of the southern states positive NPVs occur in the interest scenario of 16,2%.

Although the yield in all areas exceeds the annual consumption of one household by far, financial viability is influenced heavily by electricity prices for any household. The values in the tables 7,8 and 9 show that comparisons among regions are insufficient in order to determine the financial performance of a 3 kW roof-top PV installation in the residential sector. A detailed analysis, which pays credit to the diverse energy price structure within and across states, outlines a more complete picture. Furthermore, the evaluation of different interest rate scenarios shows that financing conditions are essential for the success of PV systems in the residential sector.

8.3 Analysis of Financial Returns Commercial Sector

The following section displays and explains the profitability of a 30 kW PV system. Illustrations consider the yield generated by the installation, the three interest rate scenarios and variations of NPVs in different locations.

8.3.1 PV Yield and Overview Regions

The commercial sector typically consists of everything else that other sectors do not include. Buildings used by businesses or other organizations to provide work space build up this consumption unit. Thus it includes among others shops, stores, offices, hotels and restaurants. Further hospitals, public schools and government facilities belong to the commercial sector.[15] The wide range of buildings in the commercial sector contributes to the complexity of analyzing it. The variety and size of businesses rejects the appropriateness to consider a typical load profile. However, figure 15 indicates the yield obtained from a 30 kW PV installation usable in the commercial sector in order to outline a first overview for the technical potential.

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[15] Although fees and taxes for energy supply are not considered in this thesis, please note that in Brazil public organizations usually pay smaller charges than the consumers within the commercial sector; Thus public energy consumers are typically analyzed separately

Annual Yield for a 30 kW commercial PV system in kWh per Region

North-East	Midwest	South-East	North	South
51.684	49.932	49.056	48.180	45.552

Figure 15: Annual Yield per Region, Commercial Sector

(Own calculations)

Compared to the residential sector no concrete statement can be made with regard to partnering with another consumption unit. The huge difference among agents within the commercial sector results in varying consumption patterns. As indicated in the analysis for the residential sector, average NPV illustrations are less informative than indicating their full range of distribution. Thus average NPVs are not portrayed in this section.

8.3.2 Interest Rate Scenarios

The figures 16,17 and 18 illustrate the range of NPVs per region considering each interest rate scenario in the commercial sector.

Range NPVs per Region in R$ for a 2,5% Interest Rate, Commercial Sector

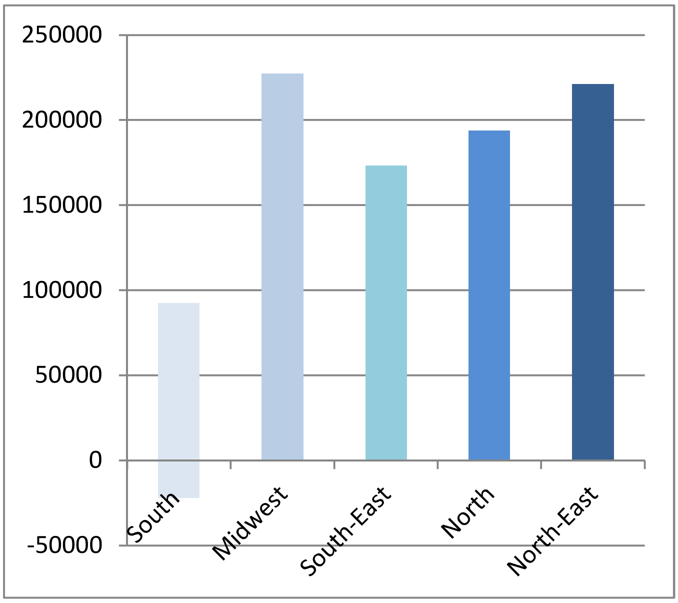

Figure 16: NPV Ranges for a 2,5% Interest Rate, Commercial Sector
(Own calculations)

Range NPVs per Region in R$ for a 7,25% Interest Rate, Commercial Sector

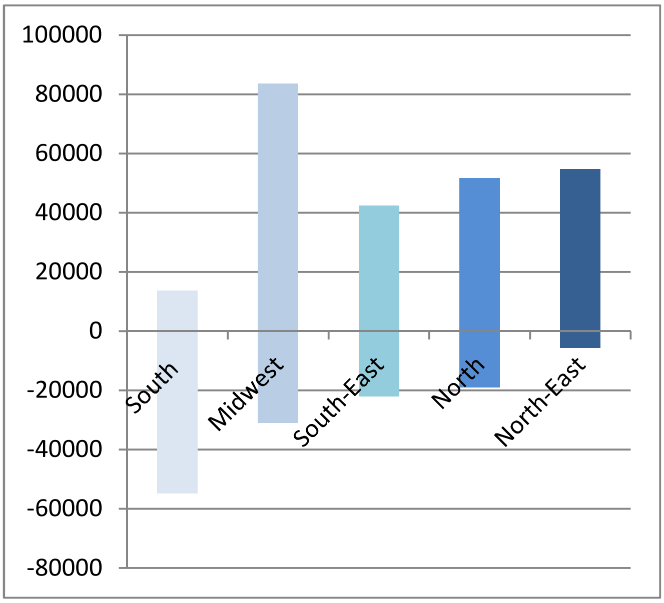

Figure 17: NPV Ranges for a 7,25% Interest Rate, Commercial Sector
(Own calculations)

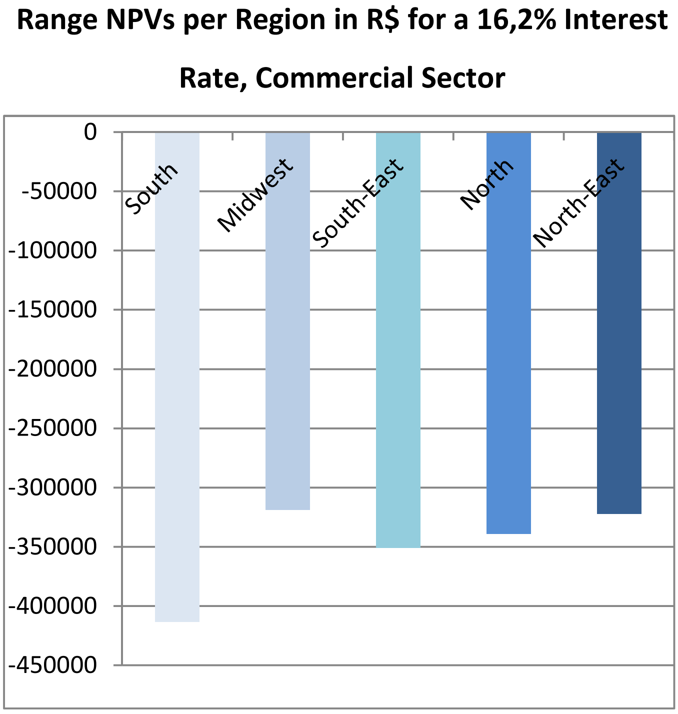

Figure 18: NPV Ranges for a 16,2% Interest Rate, Commercial Sector
(Own calculations)

Figure 16 indicates financial feasibility for all states apart from the south. By contrast to the residential sector four regions suggest financial viability in all states. The midwest ranks highest with a NPV of 209.358 R$ followed by the north-east with 161.200 R$. The south is like in the residential segment by far the least favorable location for PV systems in a 2,5% interest rate scenario. One should keep in mind a 2,5% interest rate is only available if 60% of the value chain creation takes place in Brazil.

Figure 17 displays an overall better financial performance for the 7,25% interest rate scenario than in the residential sector. The midwest lists with 83625 R$ the highest and the south with -54.817 the lowest value. The latter suggests the south being the least profitable production site again.

Just as in the residential consumer segment none of the five regions lists positive NPVs for an interest rate of 16,2%. The states in midwest list with -50.668 R$ the highest and the ones in the south with -120.675 R$ the lowest result. However, relatively higher NPVs originated mainly from greater yields, emphasize greater profitability in the commercial than in the residential sector.

8.2.3 Electricity Prices, States & Cities[16]

In the commercial sector electricity prices range from 0,21 R$/kWh to 0,42 R$/kWh. On average they are only lower by 1% than in the residential sector. As in the residential sector, the illustrations in this section take into account electricity prices from 24 states and 40 cities. Again, only varying prices among distribution utilities in the same city have been summed up in average prices for calculations. The tables below portray all calculated NPVs per state, city and interest rate.

NPVs by City, State and Interest Rates in the Midwest - Commercial Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
Midwest	Braslia	Federal District	18003	-30927	-108595
	Goiânia	Goias	75582	3542	-91165
	Cuiaba	Mato Grosso	108810	23433	-81106
	Campo Grande	Mato Grosso do Sul	141388	42936	-71244
	Ceres	Goias	209358	83625	-50668

Figure 19: NPVs by City, State, Interest Rates in the Midwest, Commercial Sector

(Own calculations)

In the midwest, the city Ceres with a NPV of 209.358 R$ is the most favorable location for 30 kW PV system. Considering all regions this value is the highest observable resulting from highest power prices in the country. The difference to Goiânia of 133.776 R$ in the 2.5% interest rate scenario indicates the difference of power prices within the same state. Brasilia again is the city with the lowest results caused by low energy prices in the capital. They negatively affect the financial performance of PV systems in the 7,25% interest rate scenario.

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[16] Results shall be considered as conservative values for the commercial sector as well because tax savings are not included in NPV calculations; In this sector higher fees and taxes arise

NPVs by City, State and Interest Rates in the North-East - Commercial Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
North-East	Campina Grande	Paraiba	60037	-5764	-95870
	Recife	Pernambuco	77289	4564	-90648
	Aracaju	Sergipe	80426	6442	-89698
	Fortaleza	Ceara	89501	11874	-86951
	Natal	Rio Grande do Norte	89725	12008	-86883
	Maceió	Alagoas	90957	12746	-86510
	João Pessoa	Paraiba	102496	19654	-83017
	Estância	Sergipe	120533	30451	-77557
	Salvador	Bahia	121653	31122	-77218
	Teresina	Piaui	161200	54796	-65247

Figure 20: NPVs by City, State, Interest Rates in the North-East, Commercial Sector

(Own calculations)

For the north-east results portray Teresina with the highest NPVs. With 161.200 R$ this location suggests the greatest financial viability. In the city Campina Grande the low electricity prices reduce the financial viability resulting in a negative NPV in the 7,25% interest rate scenario. By contrast, in the same state the city João Pessoa indicates significant economic profitability. The difference in power prices between Estância and Aracaju in the state of Sergipe does not result in negative NPVs, but emphasizes the magnitude of local concessionaires which individually set their price levels.

NPVs by City, State and Interest Rates in the North - Commercial Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
North	Manaus	Amazonas	37826	-19060	-102594
	Belém	Para	90566	12512	-86629
	Porto Velho	Rondonia	111244	24890	-80369
	Palmas	Tocantins	115004	27141	-79231
	Rio Branco	Acre	155942	51648	-66838

Figure 21: NPVs by City, State, Interest Rates in the North, Commercial Sector

(Own calculations)

In the northern region Acre is the city in which an investment in a PV system creates the highest cash flows. With a result of 155.942 R$ its NPV is four times the results in Manaus in the state of Amazonas. The negative NPV in the 7,25% interest rate scenario originates from low energy prices in Manaus. The cities Palmas and Porto Velho perform similarly.

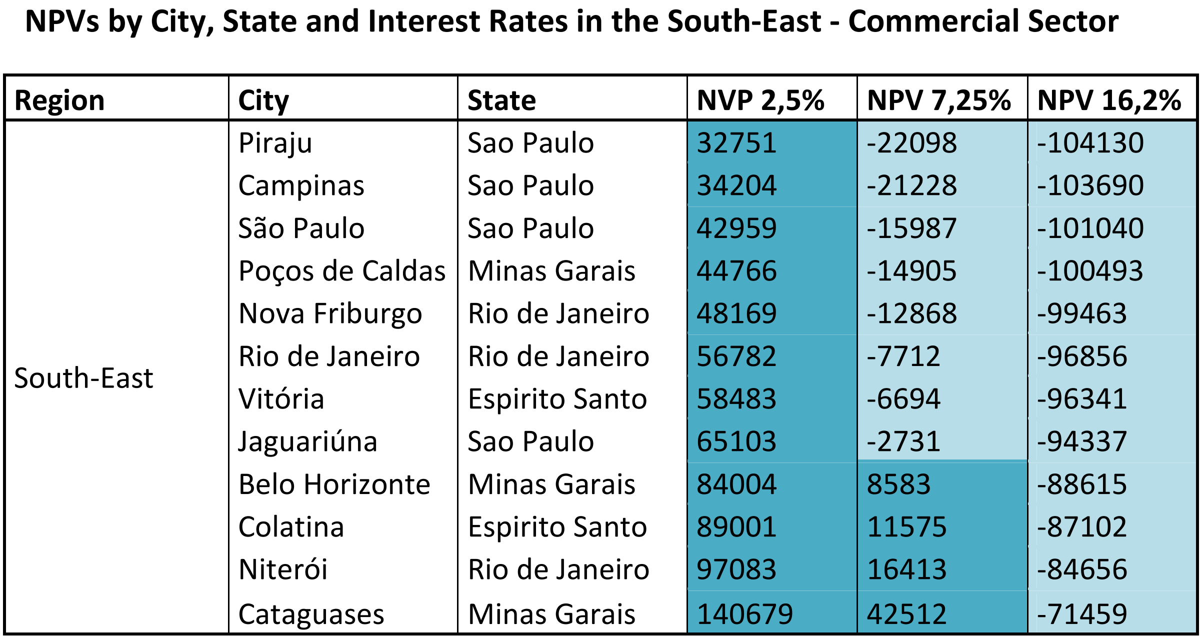
NPVs by City, State and Interest Rates in the South - Commercial Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
South	Florianópolis	Santa Catarina	-21905	-54817	-120675
	Campo Largo	Parana	-19041	-53103	-119809
	Guarapuava	Parana	9099	-36257	-111290
	Siderópolis	Santa Catarina	15517	-32415	-109347
	Porto Alegre	Rio Grande do Sul	16455	-31853	-109063
	Ijuí	Rio Grande do Sul	32303	-22367	-104266
	Xanxerê	Santa Catarina	42473	-16278	-101187
	Panambi	Rio Grande do Sul	43658	-15569	-100829
	Içara	Santa Catarina	47410	-13323	-99693
	Tapejara	Rio Grande do Sul	48594	-12614	-99334
	Carazinho	Rio Grande do Sul	60641	-5403	-95688
	Caxias do Sul	Rio Grande do Sul	80388	6419	-89710
	Faxinal do Soturno	Rio Grande do Sul	92434	13630	-86063

Figure 22: NPVs by City, State, Interest Rates in the South, Commercial Sector

(Own calculations)

All cities in the state Rio Grande do Sul list positive NPVs with an interest rate of 2,5%. Faxinal do Soturno is the most favorable location in both the 2,5% and 7,25% interest rate scenario. The city Florianópolis shows negative NPVs in all scenarios. Compared to the residential sector prices are lower by 0,3 R$ in this city. Significant differences can further be observed among cities in Parana and Santa Catarina. By contrast to the residential sector, the cities Faxinal do Soturno and Caxias do Sul list positive NPVs considering an interest rate of 7,25%.



NPVs by City, State and Interest Rates in the South-East - Commercial Sector

Region	City	State	NVP 2,5%	NPV 7,25%	NPV 16,2%
South-East	Piraju	Sao Paulo	32751	-22098	-104130
	Campinas	Sao Paulo	34204	-21228	-103690
	São Paulo	Sao Paulo	42959	-15987	-101040
	Poços de Caldas	Minas Garais	44766	-14905	-100493
	Nova Friburgo	Rio de Janeiro	48169	-12868	-99463
	Rio de Janeiro	Rio de Janeiro	56782	-7712	-96856
	Vitória	Espirito Santo	58483	-6694	-96341
	Jaguariúna	Sao Paulo	65103	-2731	-94337
	Belo Horizonte	Minas Garais	84004	8583	-88615
	Colatina	Espirito Santo	89001	11575	-87102
	Niterói	Rio de Janeiro	97083	16413	-84656
	Cataguases	Minas Garais	140679	42512	-71459

Figure 23: NPVs by City, State, Interest Rates in the South-East, Commercial Sector

(Own calculations)

Such as in the residential sector in all cities positive NPVs occur considering an interest rate of 2,5%. The city Cataguases ranks highest with 140.679 R$ and Piraju lowest with 32.751 R$. Compared to residential consumers Belo Horizonte and Colatina list positive NPVs in the 7,25% interest rate scenario. Differences of financial performance for a 30 kW PV system can be observed in all states considered in this illustration.

Given that in the residential a 3 kW and in the commercial sector a 30 kW system is considered, the latter generates a yield ten times greater than in the household segment. However, the diverse nature of the commercial sector makes general statements with regard to sufficiency of produced power and moreover partnering with other consumers served by the same concessionaire difficult. The overall financial performance in the commercial segment is better than in the residential sector. NPVs show that higher module costs for greater PV systems are equaled out by the amount of energy they produce for which credits can be earned on the monthly electricity bill. Such as in the residential consumer segment, varying power prices within states result in significant differences of financial performance.

8.4 PEST - Analysis

The PEST analysis is a tool to understand market growth or decline and as such the potential for a business in the market of interest. PEST stands for the Political, Economic, Social, Technological, Legal and Environmental factors. In this case they characterize the status quo of the PV market and provide a framework for companies trying to understand the new environment, which originated from the introduction of net-metering in Brazil. The information gathered in these four perspectives is used to understand and present market characteristics and to guide strategic decision-making. The factors within and across the four categories are interdependent and nor perfectly separable (Johnson et al. 2008: 56). When making use of the information presented in the PEST, special attention should be paid to the fact that overall conditions may change quickly (Gillespie 2007). The expert interviews conducted in Rio de Janeiro in January 2013, contribute relevant social tendencies influencing the many aspects of the PEST framework in particular. Information obtained from interviews is marked with the following symbol: 💬

The *new* Brazilian Photovoltaic Market

Political

- Tightening of environmental regulations for conventional energy sources expected on a global scale
- ➲ Overall promotion of renewables

- Feed-in law: Net-Metering regulation No. 482 ANEEL since April 2012
- ➲ Support of solar energy production power production up to one MW

- Tax incentives regulation No. 481 ANEEL, since April 2012
- ➲ 50 - 80% tax breaks on TUST and TUSD for solar energy utilities up to 30 MW

- Expansion of electricity production mainly directed towards hydro power generation; Renewable energy policies prioritize wind
- ➲ Reduction of potential market growth

- Energy Prices used as a tool for economic and social policies and for political interests
- ➲ Risk of political instability

- BNDES grants for renewable energy power production tied to 60% local content regulation
- ➲ High costs for local investors
- ➲ Ineligibility of international investors

Economic

- Tax exemption for national and international PV equipment of ICMS and IPI
- ➲ Cost reductions

- Great variance of financial performance for PV systems within regions **AND** states
- ➲ Individual site assessments necessary

- Lack of specific private and public financing products
- ➲ Risk of reducing demand for all PV related products
- ➲ Slow market development

- PV industry and PV supplies are **so far** barely developed in Brazil; **BUT**: national attempts to foster a local production chain
- ➲ Current need for imports
- ➲ Tightening of import regulations with local industry consolidation

- Arise of import tariffs: 12% for PV modules and 14% for inverters
- ➲ Cost increases

- Recent drop of electricity prices, February 2013
- ➲ Counteracts Net-Metering incentive
- ➲ Financial losses for power utilities

Social

- Population growth by 2.4% until 2030, economic development and rising living standards
- ➲ Overall increase of electricity demand

- Portuguese language essential for any economic activity
- ➲ Network creation

- Joint-ventures as suitable model for developing a PV project or introducing new products
- ➲ Reputation and trust among potential consumers

- Traditionally high inflation rates
- ➲ Aversion to investment projects with long return periods

- PV as new, revolutionary technology in the off-grid power production
- ➲ Skepticism in the consumer segment

- Comparably low carbon electricity production due to high share of hydropower
- ➲ Tendency to reject the need for further renewable energy development
- ➲

Technological

- On-grid roof-top installations
- ➲ Mitigation of transmission and distribution losses

- Complementary production cycle to hydropower
- ➲ Balancing of energy generation peaks

- Learning curves predict the noteworthy reduction of about 20% with each doubling of the cumulated PV module production
- ➲ Cost reductions

- Immaturity of local PV industry and corresponding public education programs
- ➲ Lack of skilled labor supply
- ➲ Opportunities in education programs

- Limited national research funding
- ➲ Lack of information systems creating awareness for PV power production

- Time and money consuming INMETRO certification process for all national and international PV system components
- ➲ Cost increases

9 Hypotheses Generation

Insights, derived from the present study, comprise the factors influencing the PV market development in Brazil. In the following hypotheses, the outcome of interest i.e. the dependent variable is the development of the Brazilian PV market. The explanatory or independent variables are the factors that are believed to have a causal effect on the outcome. This part is meant to portray starting points for further research opportunities by stating hypotheses to be tested, once more data on the Brazilian PV market is available.

Positive Net Present Value results suggest that already today, some private PV investments promise returns above the current market rate of interest. Both the residential and the commercial sector list positive NPVs in the interest rate scenarios 2.5% and 7.25% in several cities. In spite of the rise in power prices, economic profitability is given in certain locations. Within the NPV logic, this leads to the overall assumption that demand for PV equipment will increase, as investors can be thought to take advantage of lucrative investment opportunities.The following hypotheses are based on this assumption.

Hypothesis 1:

The availability of skilled labor results in higher NPVs for a PV installation in the Brazilian residential and commercial sector.

The increased demand for PV products creates a labor market building up the skills, which are necessary for PV installations (and possible even production). With skilled labor not being a scarce resource anymore, human capital becomes less expensive. By reducing the initial installation costs (C_0), PV systems reach higher financial performance rates and grid parity is likely to be reached earlier on within the context of the net-metering regulation.

Hypothesis 2:

Increased PV development fosters social acceptance of PV technologies.

With the availability of sufficient human capital and therefore lower initial investment costs, the market is assumed to grow. With the dispersion of PV roof-top installations, awareness regarding the technology and its financial opportunities among potential consumers increases. Additionally, financial benefits originating from the net-metering feed-in law will reduce skepticism towards the new technology.

> **Hypothesis 3:**
>
> Pressure from power utilities on politics will increases NPV results in the long-run.

Recent electricity price drops caused significant losses for both private and public utility companies (Reuters 2013). Lower revenues most likely result in cutting investment expenditures and thus in deteriorated service quality. In order to balance losses, the introduction of a regulatory mechanism increasing final consumer prices can be expected in the long-run. With higher tariffs or charges NPVs rise.

10 Conclusion & Outlook

This thesis analyzed investment opportunities in the Brazilian PV market and finds that promising conditions exist. First, I have given a quick overview of the Brazilian electricity market and its most relevant actors and agencies. Second, I have analyzed the current conditions for PV in Brazil showing that prior to the introduction of the recent regulation, ne could not speak of the existence of a significant market. The third section explains the regulatory framework, which is meant to incentivize PV investment by way a feed-in law. This allows PV producers to offset their gross electricity production against their electricity bill. The fourth section examines investment returns under the new framework using Net Present Value calculations under different interest scenarios. Results vary by region and sector. It finds that given current conditions, positive NPVs can be found, indicating that PV investments are likely to occur. The PEST framework sums up my interview findings, portraying difficult, however surmountable, challenges to potential investors. The last section points to further research opportunities.

Some findings deserve special attention. Local energy prices are of utmost importance as they influence the financial performance to a greater extent than difference in solar radiation, since in all Brazilian regions this parameter is one of the highest on earth. High yields produced by distributed generation units in both the residential and the commercial sector, bear witness to the great potential of solar energy. In addition the availability of financing options is highly relevant for the profitability of PV technologies. So far, access to cheap money is tied to a local-content regulation which reduces opportunities for international actors albeit the immature nature of the Brazilian PV industry. Thus, in spite of an expected decline in costs for PV technology, the tight financing conditions and the lack of additional incentives may ease the pace by which the market grows.

Given my findings, I cannot make any claims regarding to regional or state-level financial performance given the fact that electricity prices vary so greatly within the considered locations. However, the PV industry can take advantage of the outstanding solar potential in certain Brazilian cities where PV power plants are economically justifiable due to high power prices although no direct financial support is provided to start the diffusion of this technology. Beyond that, expert know-how points to the fact that social characteristics are highly relevant for the consumer behavior of potential customers. Skepticism towards both the technology and the new supplier can be diminished by cooperating with local organizations. Well-maintained partnerships may provide further benefits when import regulations tighten due to the emergence of a local PV industry. Moreover, the current potential of learning effects given the lack of information and education programs opens up opportunities in the Brazilian PV market. Political developments require special attention as within the electric sector prices have been exploited as policy instruments for economic and social policies.

The introduction of the net-metering regulation marks the starting point of governmental attempts to diversify and decentralize the Brazilian energy matrix. However, the developed hypotheses suggest that the dimension of the PV market development depends on various independent parameters which leaves ample questions for further research.

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Table Expert Interviews

Name	Position	Organization
Andrade, Leonidas	Director Photovoltaic Section	ABINEE, Brazilian Electrical and Electronics Industry Association
Hanh, Philipp	Renewable Energy Associate	German Chambers of Commerce, AHK Rio de Janeiro
Kissel Dr., Johannes	Coordinater Renewable Energies	Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ Rio de Janeiro
Krenz, Peter	Advisor Renewable Energies	Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ Florianopolis
Rauschmayer, Hans	Founder	Solarize, Technology onsultancy Rio de Janeiro
Tinnefeld, Frank	Vice President Sales and Business Development	Schmid Group GmbH
Zeller, Kathrin	Project Coordinaator	Konrad Adenauer Foundation, Rio de Janeiro

Statement of Authorship

I hereby assure that this academic paper is my own and that no other sources or aids than the ones named have been used.

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Eleonora Azzaoui

Berlin April 8, 2013