NOVA SCHOOL OF BUSINESS AND ECONOMICS

GERRIT HELD
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# The Dawn of Solar Power in Brazil: Current State and Future Challenges

Dissertation presented to Nova School of Business and Economics, as a condition to obtain the Master of Science in International Management

Field of Knowledge:
Solar Energies, Support Policies

Supervisor: Prof. Luís Brites Pereira

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FUNDAÇÃO GETULIO VARGAS
ESCOLA DE ADMINISTRAÇÃO DE EMPRESAS DE SÃO PAULO

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2017

*“Brazil competes with other opportunities, sun is not only in Brazil, it is everywhere. If we do not create a more competitive, more favourable environment, the resource finds profitability elsewhere and that’s all we do not want at the moment.”*

*Fernando Coelho Filho, Minister of Mines and Energy in Brazil*

### Acknowledgements

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## Abstract

As a sun-soaked South American giant with a population of more than 200 million, Brazil is considered to have some of the best conditions for solar power worldwide. Despite its tremendous potential, the country has so far been rather slow in developing the national solar power market. After a devastating energy crisis in its draught afflicted hydroelectric sector, the dawn of solar power seems on the horizon. With the goal of diversifying its energy mix, Brazil initiated the large-scale deployment of solar power in 2014. Three years after its commercial commencement, the solar energy drive is stalled and policy efforts seem trivial under deteriorating political and economic conditions. As a comprehensive analysis of the industry's state of affairs is currently insufficiently portrayed, this paper attempts to fill this gap by discussing the latest solar market developments and outlining the progress and status of Brazil's solar energy market objectives. While the findings prove a significant discrepancy between the desired and achieved progress, this paper also finds that there is reason to be optimistic that the solar market growth will be unleashed in the future. As such, the analysis focuses on the critical state of the Brazilian solar market in 2017 and showcases the underlying challenges of transforming an energy sector during a recession.

***Keywords:*** Brazil, Solar Energy, Support policies.

## Resumo

Como um gigante sul-americano encharcado de sol com uma população de mais de 200 milhões, o Brasil é considerado como tendo algumas das melhores condições para a energia solar em todo o mundo. Apesar do seu enorme potencial, o país tem sido bastante lento no desenvolvimento do mercado nacional de energia solar. Após uma devastadora crise de energia em seu projeto de setor hidroelétrico, o alvorecer da energia solar aparece no horizonte. Com o objetivo de diversificar seu “mix” de energia, o Brasil iniciou a implantação em larga escala da energia solar em 2014. Três anos após o início comercial, a energia solar está paralisada e os esforços políticos parecem triviais sob deterioração das condições políticas e econômicas. Como uma análise abrangente do estado da situação da indústria está atualmente insuficientemente retratada, este trabalho tenta preencher essa lacuna discutindo os últimos desenvolvimentos do mercado solar e descrevendo o progresso e status dos objetivos do mercado de energia solar no Brasil. Embora os resultados demonstrem uma discrepância significativa entre o progresso desejado e o progresso alcançado, este artigo também descobre que há motivos para ser otimista de que o crescimento do mercado solar será desencadeado no futuro. Como tal, a análise concentra-se no estado crítico do mercado de energia solar brasileiro em 2017 e apresenta os desafios subjacentes de transformar um setor de energia durante uma recessão.

***Palavras-chave*:** Brasil, Energia Solar, Politicas de suporte

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## List of Abbreviations

| | |
|---|---|
| ANEEL | Brazilian Electricity Regulatory Agency |
| ABSOLAR | Brazilian Photovoltaic Solar Energy Association |
| BMWi | German Federal Ministry for Economic Affairs and Energy |
| BNDES | Brazilian Development Bank |
| BNDES Finame | BNDES Financing for Machinery and Equipment |
| BNDES Finem | BNDES Financing for undertakings |
| BNEF | Bloomberg New Energy Finance |
| CCEE | Brazilian Electric Energy Trading Chamber |
| CMSE | Brazilian Electricity Sector Monitoring Committee |
| COD | Commercial Operating Date |
| COP 21 | 21st Conference of the Parties – 2015 Climate Change Conference |
| CNPE | Brazilian National Council for Energy Policy |
| EPE | Brazilian Energy Research Company |
| GDP | Gross Domestic Product |
| GIZ | German Agency for International Development Cooperation |
| GW | Giga Watt |
| GHG | Greenhouse gases |
| GENI | Global Energy Network Institute |
| IRENA | International Renewable Energies Agency |
| IEA | International Energy Agency |
| KfW | German Development Bank |
| kWh | kilo Watt hour |
| KW | Kilo Watt |
| LCR | Local Content Requirement |
| LDCs | Less Developed Countries |
| MW | Megawatt |
| MME | Ministry of Mines and Energy |
| MWh | Mega Watt hours |
| MSMEs | Micro, Small & Medium Enterprises |
| NDC | Nationally Determined Contribution |
| PPA | Purchasing Power Agreement |
| RAPEEL | Monitoring Report of Generation of Electric Power |
| ONS | Brazilian National Grid Operator |
| PV | Photovoltaic |
| RE | Renewable Energies |
| SIB | State Investment Bank |
| SDG | Sustainable Development Goals |
| UNCCC | United Nations Conference on Climate Change |

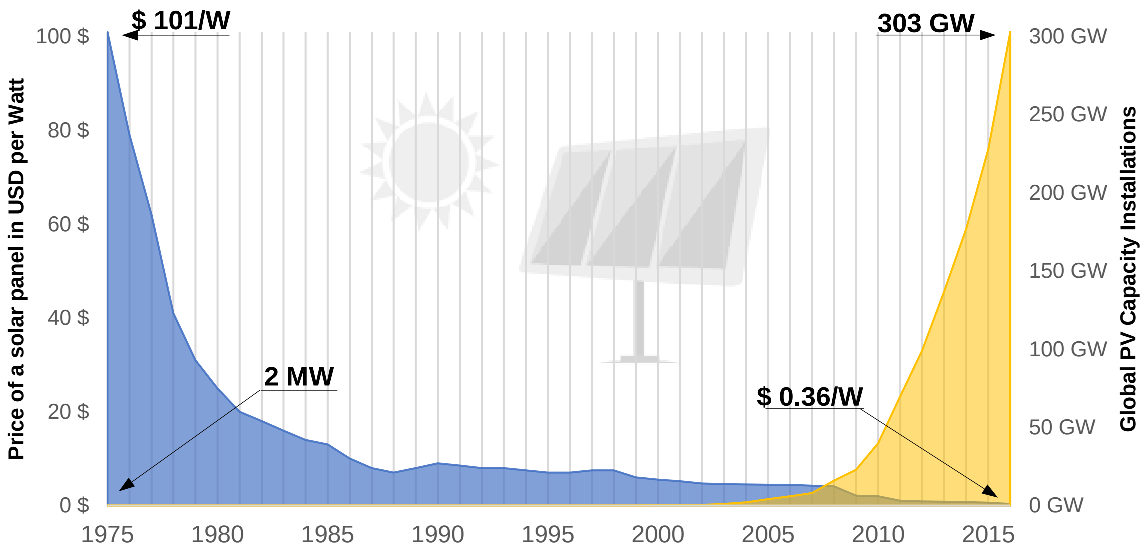
# CHAPTER 1 - INTRODUCTION

## 1.1 Background and Motivation

Concerns over potential **changes to the global climate** have increased noticeably in recent years as advances in scientific understanding have clarified the links between human activities, greenhouse gas (GHG) emissions and changes in the Earth's climate (IPCC, 2007). Urgent actions need to be taken among governments, private sector and civil society to tackle the effects of global warming. The Paris Climate Agreement, concluded in 2016 under the framework of the United Nations Conference on Climate Change (UNCCC), and the Sustainable Development Goals (SDGs), an Agenda 2030 that succeeds the Millennium Development Goals (MDGs), have set forth promising action oriented pathways to a climate resilient development and have shed light on the **importance of renewable energies** in this endeavor (UNFCCC, 2016).

The importance of clean energy stems from the fact that **almost two-thirds of global GHG emissions come from the energy sector** (IEA, 2015). Hence, the deployment of technologies that use less energy or that can produce energy with lower CO2 emissions will be inevitable for reducing anthropogenic emissions. Today, renewables are described as having finally earned a place in the investment landscape as the choice for wind and solar is becoming less an ethical but an economic one (Segers, 2016). Among the renewable energy sources available, solar is considered to have the greatest potential over the next 100 years (Reddy, 2012). Thanks to technological advances, price reductions and adequate governmental support policies, the industry has experienced a phenomenal growth in the last twenty years.

Figure 1 Global solar PV development - Price vs. Capacities - 1975 – 2016




Source: own illustration with data from ren21 (2017) and Bloomberg (2017)

As seen in Figure 1, in 1975, the price of solar PV was near US$ 100 per watt and total installations came to around 2 megawatts (MW). Nevertheless, over the last 41 years' things have changed dramatically, with the lowest price per watt in 2016 being around US$ 0.36, and global installations totaling around 303 Gigawatt (GW). More Photovoltaic (PV) capacities have been installed between 2010 and 2014 than in the previous forty years and financing for solar has been at a record level of US$ 161 billion in 2015, accounting for about half of new total global renewable energy investments (EY, 2016). The beauty of having exponential growth on your side is that very quickly, even the current yellow spike (Figure 1 above) will be comparatively small. The International Renewable Energy Agency (IRENA, 2016a) puts it in a nutshell: **"the age of solar power has arrived"**. While most of today´s solar power capacities are currently installed in developed countries, emerging economies have made significant strides in recent years. China and India are massively scaling up their solar capacities and in countries like Chile or the United Arab Emirates solar power is today already more cost efficient than coal or gas (Bloomberg, 2017).

With plentiful sunlight and a population of more than 200 million, Brazil is considered to have some of the best conditions for solar power worldwide (Brosseau, 2017). Despite its tremendous potential including solar radiation that is, on average, twice as strong as in Germany, one of the world leaders in solar power generation, **Brazil (2016: 84 MW[1]) is way behind fellow emerging economies such as China (112 GW of solar capacity) or India (14,7 GW of solar capacity) in developing the national solar power sector** (EOLA, 2014; Nuoshu, 2017). Faced by the threat of a potential energy crisis in its traditionally strong hydroelectric sector due to drought, Brazil's government only recently undertook first steps towards pushing the solar sector from small pilot projects of kilowatt-scale (solar home systems) to commercially operating power plants.

**In 2014, Brazil committed to expand its grid connected solar capacities from 0,01 % (~ 21 MW) to 3.3 % (7 GW) of the total electricity capacity by 2024** (EPE & MME, 2015). The commitment was followed by Brazil's first national solar capacity auction which resulted in 31 solar parks being awarded with a combined capacity of 889 MW and a commercial operating date (COD) anticipated for August 2017. What no one foresaw at the time was the the **unfolding of a drastic economic and political crisis** in Brazil. The economy contracted by 3.8 % and 3.6 % in 2015 and 2016 respectively and is not expected to recover until 2018 (Bloomberg, 2017). The Brazilian Real depreciated more than 40 % since 2014 reaching as low as US$/R$ 4.1 in January 2016 (it has since fallen back to R$ 3,26). Power consumption fell, creating an oversupplied distribution market and inflation jumped from 6 % in 2014 to 11% in 2016 (BNEF, 2017).

Ultimately, the economics of many projects deteriorated and were in particularly hurt by the fact that solar power delivery contracts were fixed in Brazilian reais as opposed to dollars (BNEF, 2016). Due to the resulting high cost and challenging financing conditions, **the timely expansion of utility scale solar is said to be in jeapardy** (Andreão et al, 2017). While the recent economic and political turmoil undoubtedly overwhelmed investors, Brazil's national development bank[2] Banco Nacional de Desenvolvimento Econômico e Social (BNDES), which, as an intermediary of public money, plays a key role in incentivizing the uptake of new technologies, has come under criticism by various scholars

[1] of which 21 MW are utility scale and 63 MW are off-grid residential solar systems
[2] Throughout this paper, the terms state investment bank (SIB), promotional bank (PB) and development bank (DB) are used interchangeably

for its lackluster funding support and strict lending terms (Transfer LBC, 2015; Ferraz, 2016; BMWi, 2016; Currie, 2017; Andreão et al, 2017).

Andreão et al (2017), being the only scholar to shed light on the most recent challenges to the expansion of solar Photovoltaic in Brazil, sees in particulary the government’s two pronged objective of expanding capacity installations while at the same time achieving a progressive nationalization of a Photovoltaic industry as key problem for the sector. Due to the relevance of the topic and the fact that ongoing struggles in the solar sector are currently insufficiently covered in a comprehensive manner, this research was motivated by the attempt to review the latest solar market developments and outline the progress and status of Brazil’s solar energy market objectives. The basic hypothesis underlying this work is that **Brazil’s promotional strategy for solar must come into question as its tremendous solar potential is currently being wasted** and that **benchmarking the results policy mechanisms have delivered** is cardinal to maintain credibility for the future of the sector.

**The idea for this research was developed during a one-year Master programme at the São Paulo School of Business Administration FGV-EASP in 2016/2017**. The at the time prevailing political and economic crisis significantly impacted my study and living experience in Brazil, thereby helping me to get acquainted with the ongoing challenges and opportunities faced by companies in Brazil. With a personal background in renewable energy engineering and career aspirations in the field of sustainable development, Brazil’s desired transition towards a more diversified energy mix ignited my interest to bring to light the state of the local solar PV market.

Next to my study, **a five-month internship at the Export and Project Finance representative office of the German Development Bank (KfW IPEX Bank) in São Paulo**, from 23.01.2017 to 30.06.2017, gave me the opportunity to confirm the need and relevance for a market study in the solar power sector. My participation in client meetings with BNDES, commercial banks, law firms and infrastructure development companies helped me to gather useful background knowledge on renewable energy financing in South America and allowed me to acquire a good understanding of the challenging financing conditions faced by the solar industry in Brazil. Finally, a personal meeting with Ms. Fernanda Rocha, an expert from the FGV Center for sustainability study (GVces), led to the specific suggestion to review the solar marker development against the background of unstable macroeconomic conditions more closely, an area that according to her has been insufficiently researched to date.

## 1.2 Objective and Scope

With the above given context, **the objective of the thesis is to explore the extent to which solar support mechanism have been effective to date and to outline Brazil’s status and progress towards delivering on the 2024 target of 7 GW new large scale solar generation capacities**.
The research first employs a descriptive approach to capture the contemporary phenomenon of the solar market policy framework in Brazil, following which a brief analysis will review the current state and relevant developments from October 2014 to August 2017. Data collection and evaluation was guided by a mixed-method approach, using both qualitative and quantitative data to provide a complete picture

of both supply and demand activities in the solar sector. Collected data was consolidated, filtered and then analysed.

**A. Qualitative Data**

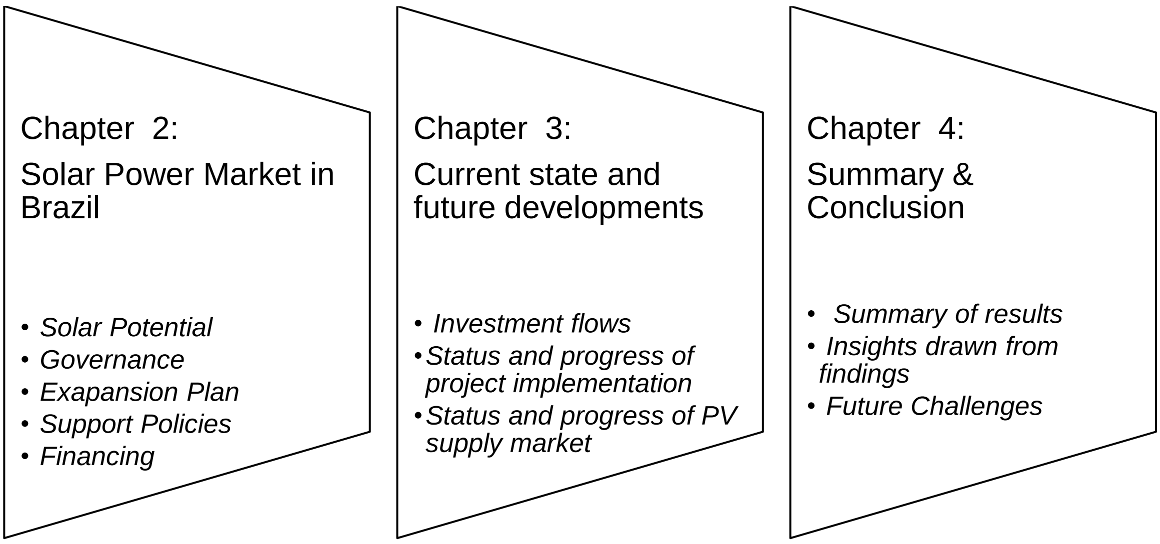
For the first part of the research, a descriptive literature review was undertaken to inform the reader about the state of Brazil's solar market policy landscape. Materials were almost entirely drawn from the International Renewable Energy Agency (IRENA), the Global Energy Network Institute (GENI) and Brazilian Renewable Energy Institutions. In addition, news articles and existing market studies were reviewed through means of Google Scholar and the Nova School of Business and Economics library.

**B. Quantitative Data**

In the second and more analytical part of the research, data was drawn from inspection reports, internal government statistics and periodic publications of the Brazilian Electricity Regulatory Agency (ANEEL), the Energy Research Company (EPE), the Ministry of Mines and Energy (MME) and the Brazilian Development Bank (BNDES). Investment data, tools and analytics carried out at the Bloomberg New Energy Finance (BNEF) terminal at the FGV EASP library (Brazil) and the University of Mannheim (Germany) further complemented the research.

Although residential (distributed) solar power generation is touched upon, **the scope of this thesis primarily deals with support policies for utility-scale solar generation** (also known as centralized generation). The rationale that underpins this decision is the fact that the commercialization of solar only recently emerged as opposed to residential solar home systems that have been in the market for much longer. On top of that, the exclusion of the residential power sector narrows the research scope significantly as the market dynamics for distributed generation are different. The research structure for the remaining part of this paper is as follows:

Figure 2 Research Structure




Source: Own illustration

## 1.3 Relevance

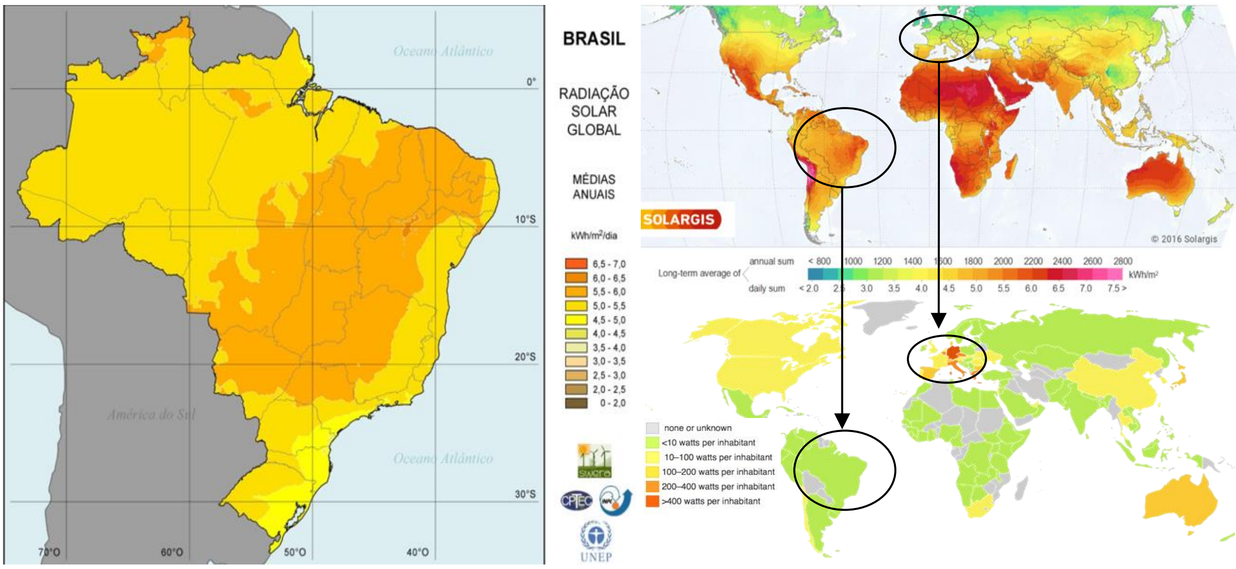
Given the fast-changing policy landscape in Brazil's energy sector and the lack of a detailed preliminary research, the thesis fills a gap in research by responding to the need for discussing the latest solar PV market developments and outlining the progress and status of Brazil's solar energy market objectives. As Andreão's et al (2017) "Financing the Expansion of Photovoltaic Power Generation in Brazil: Challenges of using similar mechanisms for different renewable sources" has delivered one of the very few contributions in English with respect to the examined topic, the thesis aims to add an additional piece of research to the revolving discussion for the international audience. From the point of view of professionals, the author provides an up to date market analysis and thus helps in capturing the current and futurte investment outlook in Brazils solar generation (deman) and manufacturing (supply) sector. Lastly, this work adds to the discussion of Brazil's underlying economic weaknesses and shows why innovation-led growth is such a challenging issue in South Americas largest country. While the focus will be on the current state of affairs, the author also tries to shed light on the future challenges and opportuntiies for practitioners.

# CHAPTER 2 - SOLAR POWER MARKET IN BRAZIL

## 2.1 Potential and Expansion plans

With about **3,000 hours of sunlight a year**, Brazil is considered to have some of the best conditions for solar power worldwide (GENI, 2010). **Estimates for Brazil's technical solar energy potential Brazil vary between 114 GW**, by the Global Energy Network Institute, **and 193 GW**, by the Brazilian Solar Photovoltaic Association (2017). Figure 3 (left) illustrates the solar radiation means throughout Brazil (kWh/m$^2$). The dark orange colors indicate the region where the radiation is most prominent. Daily solar radiation values range from a low of 4.25 kWh/m$^2$ in the State of Santa Catarina – South-East of Brazil - to a high of 6.5 kWh/m$^2$ in the State of Bahia – North-East of Brazil (INPE, 2008). The annual solar irradiation mean on the other hand is measured at 1500-2500 kwh/m$^2$, which is much greater than the levels for most European countries such as Germany (900-1250 kwh/m$^2$), France (900-1650 kwh/m$^2$) or even Spain (1200-1850 kwh/m$^2$). In fact, **solar radiation in the sunniest region of Germany**, one of the leaders in the use of Photovoltaic technology**, is 40 % lower than in the least sunny region of Brazil**. Given the abundance of sunlight, experts think that solar power could potentially be developed in almost every part of Brazil (Martins et al. 2007). The North-East and the Centre region are the best suitable fit.

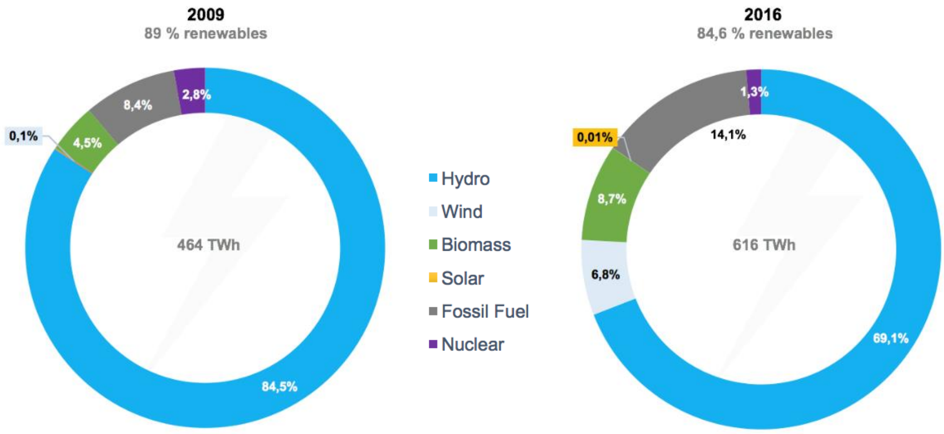
Figure 3 Global Solar Radiation in Brazil vs. worldwide / installed PV capacities in Watts per capita




Source: adapted from the Brazilian Atlas of Solar Energy (Martins et al. 2007), Solargis and EPIA (2014)

Despite the tremendous potential and near perfect conditions, **solar is still a largely unexplored source of energy in Brazil**. According to the Ministry of Mines and Energy (MME, 2016a), the use of solar power sources is so far limited to about 10,000 micro and small scale residential systems with a cumulative capacity of about 63 MW in 2016. Thus, solar power accounts for less than 10 Watts per inhabitant in Brazil (Figure 3, bottom right). In contrast to China's solar capacities of 112 GW or India's 14,7 GW, Brazil's numbers seem ridiculously small. Even when looking at Bangladesh, a much poorer country with less favorable climatic conditions but an impressive number of 1.5 million solar systems, Brazil is outclassed (ren21, 2017). One reason for the slow uptake is that the technology and its benefits are not much known to the country as the government has built a traditional culture of dam building, favoring hydroelectric generation capacities for its energy expansion (WEF, 2015; Currie, 2017). In fact, hydroelectricity composes by far the largest share of Brazil's total electricity supply of 616 terawatt hours (TWh) in 2016 (Figure 4: right site). Unfavorable climate conditions however, lowered its contribution over the years from 84,5 % in 2009 to 69,1 % in 2016 and forced Brazil to diversify its energy mix (IDB, 2014). Initially, the void was largely filled by coal, natural gas and biomass (Transfer LBC, 2015) yet, in the late 2000s, wind power notably gained prominence and is today representing a remarkable 6.8 % of Brazil's electricity supply, up from 0,1 % in 2009 (MME, 2017a, 2017b). **The contribution of solar energy to the domestic electricity supply is with 0,01 % (~ 21 MW) currently unimportant**. [3]

Figure 4 Electricity Matrix: Share of energy sources in Brazil's power production, 2009 vs. 2016




Source: own elaboration with data from MME 2017a, b and EPE & MME (2017)

With a renewable energy share of 84,6 %, Brazil boasts one of cleanest energy matrices in the world (Global Average: 20,3 %). Not surprisingly, Brazil's emissions of 68 g CO2 per kWh are much lower compared to other countries with dirtier electric grids like India (856g CO2/kWh), China (764g CO2/kWh), Russia (437g CO2/kWh) or the United States (503g CO2/kWh) (WEF, 2015). With more than 200 million consumers and a largely unexplored solar energy market, Brazil is an attractive destination for foreign investors (AHK, 2014). **As Brazil's strong dependence on hydropower leaves the country vulnerable to extreme weather events which led to severe electricity shortages in the past, the simple, clean and rapid deployment of solar Photovoltaic is increasingly perceived as an ideal solution to the present challenges** (IRENA, 2016b).[4] According to Bloomberg new Energy Finance (BNEF, 2017), solar power generation can potentially contribute to 20 % of Brazils domestic electricity mix by 2040. In contrast to hydro or wind power, one of the main perceived advantages of solar power generation is that it can provide electricity to remote areas thereby addressing Brazil's challenge of geographical dispersion[5] between electricity generation and consumption (Transfer LBC, 2015).

[3] Figure 22 in the appendix provides a more detailed overview of the electricity flux from generation to consumption.
[4] Significant capital costs and difficult licensing requirements are other disadvantages with hydro.
[5] Brazil is the 5th largest country in the world by geographic size and thus has the challenge to transmit power across long-distances

The rural electrification project *Luz Para Todos* ("Light for All") has until recently been the only initiative to promote the distribution of solar technology in Brazil (ANEEL, 2017e). With the realization that solar is a viable alternative to hydro, the Brazilian government only lately undertook steps to incentivize the large-scale uptake of solar. Today, two distinct technical approaches are being supported (Mattar et al, 2015):

A. **Centralized Solar Generation:**
   - Grid connected solar power systems of utility scale
   - Installation Capacity: 5 MW - 100 MW
   - Aims to feed energy from large power plants to the electric grid;

B. **Distributed Solar Generation:**
   - off-grid solar home systems for self-consumption
   - Installation Capacity: 5 KW - 5 MW
   - Aims to reduce the dependence on the grid through stand-alone residential systems

The medium and long term planning in the Brazilian power sector first revealed in 2004 that there is a real possibility for a diversification of the electricity mix with renewables other than hydro (Pepitone, 2016; Capos Neto, 2016). Despite this early discussion, strategic solar energy targets in terms of installed capacities firstly found appropriate recognition in the **2014 published 10-year Energy Expansion Plan** (PDE 2024), which projected **2,6 GW utility - scale capacities to be installed by 2018** (1,5 % of energy mix) and foresaw a total of **7 GW by 2024** (3,3% of energy mix). Next to the 7 GW anticipated grid connected installations, Brazil`s Energy Research Company (EPE) also projected 1.3 GW from off-grid residential power systems for 2024 (EPE & MME, 2015). Overall, the plan estimated the cumulative capacity (centralized + distributed generation) at 25 GW by 2030 (Table 1).

Table 1 Energy Expansion plan according to the 2004 and 2014 published Targets

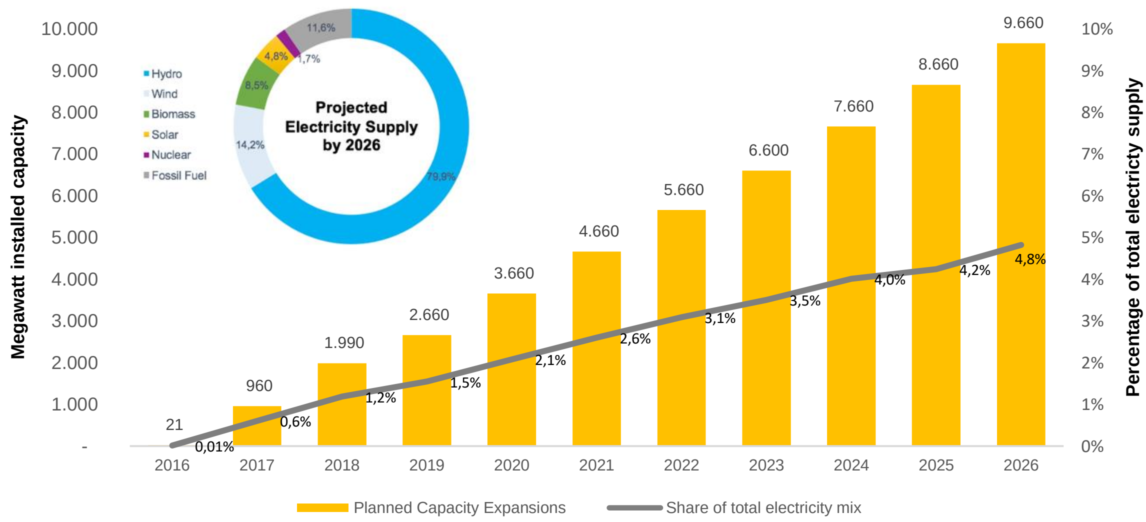
| **Capacity Installed** | **2004** | | **2014** | | **2024** | | **2030** | |
|---|---|---|---|---|---|---|---|---|
| | GW | % | GW | % | GW | % | GW | % |
| Hydro | 71 | 76,5 | 96 | 71,8 | 127 | 61,1 | 139 | 54,2 |
| Natural Gas | 10 | 10,4 | 11 | 8,3 | 21 | 10 | 21 | 8,2 |
| Charcoal | 1 | 1,5 | 3 | 2,4 | 4 | 1,7 | 4 | 1,4 |
| Nuclear | 2 | 2,2 | 2 | 1,5 | 3 | 1,6 | 5 | 2,1 |
| Biomass | 3 | 3,6 | 11 | 8,3 | 21 | 9,9 | 28 | 11,0 |
| Wind | 0 | 0,0 | 5 | 3,7 | 24 | 11,4 | 33 | 12,9 |
| *Utility-Scale Solar* | *0* | *0,0* | *0* | *0,0* | *7* | *3,3* | *17* | *6,8* |
| Other | 5 | 5,8 | 5 | 4,0 | 0 | 4,0 | 0 | 0 |
| **Total** | **93** | **100** | **133** | **100** | **207** | **100** | **247** | **100** |
| *Residential Solar* | *0,0* | *0,0* | *0,0* | *0,0* | *1,3* | *1,5* | *8,2* | *3,2* |
| | | | | **Total Solar** | **8,3** | **4,8** | **25,2** | 10 |

Source: adapted from, EPE & MME (2015)

In 2015, **Brazil reemphasized its commitment** at the landmark Paris Agreement of the UNFCCC by **pledging to increase the use of renewables other than hydro up to 28 % – 33 % by 2030** (Goldenberg & Roberts, 2015). Brazil's current president, Michel Temer, ratified the Agreement of Climate Change in 2016 (Appendix: C. Photos). While not legally binding, the intended Nationally Determined Contributions (NDC) are supposed to guide future energy policies of signatory countries and need to be renewed every five years. The pledge to further diversify the energy mix sent a strong signal to the renewable energy community in Brazil and thus strengthened the government's long-term commitment for the solar sector (GVces, 2016).

The most up to date solar expansion forecasts were presented in the 2017 issued and revised **10-year Energy Expansion plan (PDE 2026**), which projects the country to reach a cumulative solar PV deployment of more than **13 GW in 2026, up from 84 MW in 2016**. Figure 5 outlines the 10-Year solar expansion targets for centralized solar power.[6] **Centralized generation is foreseen at 9,66 GW,** while distributed generation is estimated at 3.5[7] GW (EPE & MME 2017). With almost 10 GW grid connected capacities, solar would account for 4.8 % of Brazil's 2026 domestic electricity supply. Due to reduced electricity demand caused by the ongoing political and economic crisis in Brazil, the new plan however also downward adjusted its previous 2017 target to 960 MW.

Figure 5 EPE 10-Year Solar Expansion Plan, 2016 - 2026




Source: own illustration with data from EPE & MME 2017

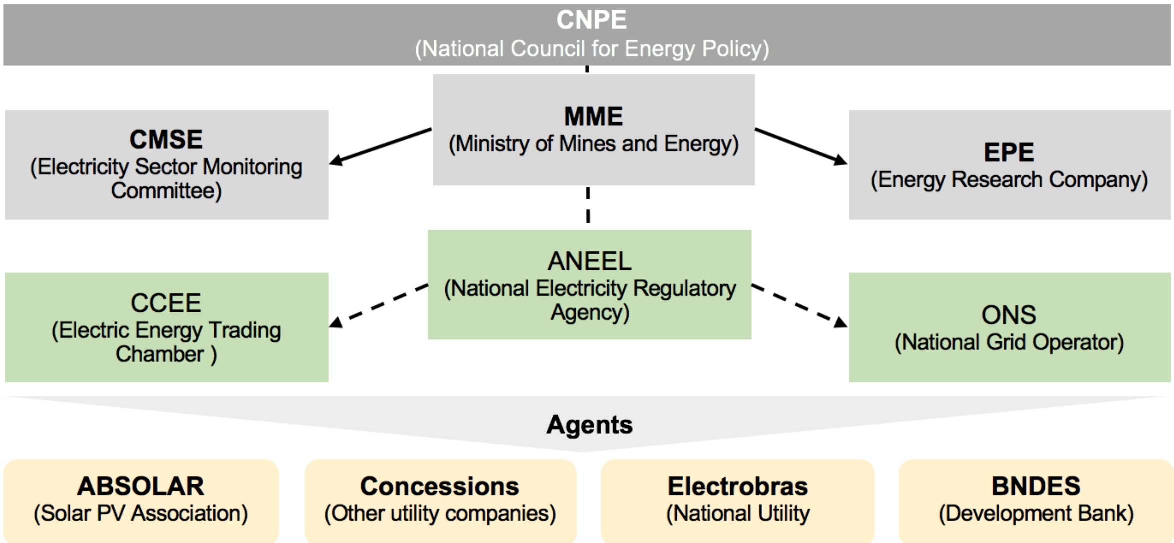
Although the projected timeline for the development of solar is not binding, adhering to its set schedule strengthens the government's credibility and sends the right signal to the sector. The International Renewable Energy Agency (IRENA, 2016b), sees **renewable energy target setting as the key element for a successful solar policy framework** (discussed in Chapter 2.3). Figure 22 in the Appendix shows the 2026 Energy Expansion Plan for all energy sources.

[6] While projected with an expansion of 3.5 GW by 2026, distributed generation is not included in calculations for the domestic electricity supply as its systems are by design only for self-consumption and thus not connected to the grid
[7] Figure 25 in the appendix shows the projected expansion for distributed sola generation up until 2026

## 2.2 Governance and Stakeholders

Brazil's energy sector is the third largest in the Americas, after the United States and Canada (ren21, 2017). The electricity sector was essentially in government's hands until the early 1990s, characterized by centralization of operations and planning as well as vertical integration of the transmission, distribution and generation of the sector. Following years of a state controlled regime, reform changes helped to liberalize the sector and established the institutional framework that is today guiding the energy market policy (IDB, 2014). As Figure 6 illustrates, the National Council for Energy Policy (CNPE[8]) is at the top of the whole sector advising the presidency on overarching policies by focusing on ensuring adequate power supply. The **Ministry of Mines and Energy (MME[9]) is responsible for the overall policy setting**. As supporting arms of the MME, the Energy Research Company (EPE[10]) is responsible for long-term planning of generation and transmission expansion, while the Electricity Sector Monitoring Committee (CMSE[11]) monitors the safety and efficiency of energy supply. The **policies developed for the domestic power market are independently regulated and controlled by the National Electricity Regulatory Agency (ANEEL[12])** through the help of the Electric Energy Trading Chamber (CCEE[13]), which as off-taker coordinates the electricity commercialization (wholesale market clearing house / auctions), and the National Grid Operator (ONS[14]), which controls the generation and transmission of electricity (Enel, 2017). The authorized and regulated activities are then carried out through Brazil's national utility provider Electrobras (holds ca. 40% of capacity), other state owned utility companies and private sector companies that hold distribution concessions. The National Development Bank (BNDES) supports the entire system through adequate funding (Transfer LBC, 2015). Finally, as Solar Photovoltaic Industry Association, **ABSOLAR[15] represents all solar market stakeholders and promotes the uptake of PV electricity in Brazil** (ABSOLAR, 2017).

Figure 6 Institutional structure of the Brazilian Electric Sector




Source: own illustration based on Transfer LBC (2015), Enel (2017a) and ABSOLAR (2017)

[8] Conselho Nacional de Politica Energética (CNPE)
[9] Ministério de Minas e Energia (MME)
[10] Empresa de Pesquisa Energética (EPE)
[11] Comitê de Monitoramento do Setor Elétrico (CMSE)
[12] Agência Nacional de Energia Elétrica (ANEEL)
[13] Câmara de Comercialização de Energia Elétrica (CCEE)
[14] Operador Nacional do Sistema Elétrico (ONS)
[15] Associação Brasileira de Energia Solar Fotovoltaica (ABSOLAR)

## 2.3 Support Policies & Instruments

The legal framework for the solar energy market has had some significant developments in the last few years as Brazil shifted its focus from small scale projects of kilowatt-scale (distributed generation) to utility-scale (centralized generation) solar power plants. Besides the overall objective of energy affordability, quality and security (MME & EPE, 2017), solar specific policies were created to achieve the following strategic objectives (BNDES, 2016b):

i. **Contribute to the diversification of the national electricity mix**
ii. **Promote the progressive establishment of a national solar equipment value chain**
iii. **Enhance the competitiveness of Brazilian companies + foster innovation**

To achieve these strategic objectives, the Brazilian government employs three support mechanisms to mobilize private sector investments and incentivize the deployment of centralized solar generation: A) Auctions, B) financial incentives and C) fiscal incentives.

### a) Auctions

**Auctions are the key instrument to generate demand for all forms of energy developments in Brazil** (Ferraz, 2016). The motivation to use auctions stems from the fact that the government is traditionally favoring large scale power plants (centralized) over distributed (decentralized) power systems (AHK, 2014). According to the renewable energy think tank IRENA (2012), the price competition resulting from an open market auction is best suited for the early market development of a new technology such as solar. **To prevent discontinues market development, auctions need to be scheduled regularly and are usually held on an annual basis**. Ferraz (2016) stressed the importance of a regular and stable demand for solar panels in respect to the development and sophistication of a mature solar supply chain in Brazil. Only companies established in Brazil are eligible to take part in the bidding. The Ministry of Mines and Energy typically specifies the capacity which is up for auction as well as the exact project generation location. ANEEL coordinates and organizes the annual bidding events and sets the initial (ceiling) price, after which project developers can submit a bid for a specific solar power park, pitching their project proposal and outlining the price per unit of electricity at which they can best realize it. **ANEEL** then compares the different offers on the basis of price and other criteria and **signs a 20-year purchasing power agreement (PPA) with the most competive bidders** (Lucas et al, 2013). From the different types of energy supply auctions employed in Brazil, the most common types for solar are the A-3, which happens three years prior to the planned project operation date, and the reserve energy auctions, which is used to contract additional capacity for security of supply (IRENA, 2015). Table 9 in Appendix provides a list of every renewable energy auctions between 2007 and 2015.

### b) Financial incentives

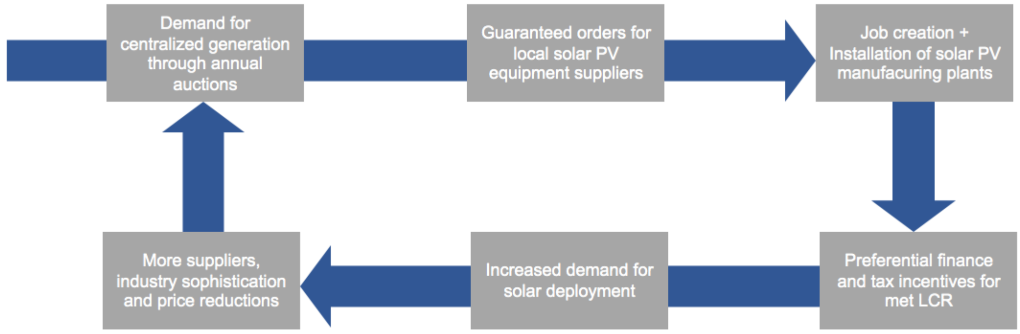
Along with demand generation auctions, financial incentives are essential instruments for the still immature solar industry in Brazil. **Market interest rates are currently not affordable for project developers and thus require subsidies.** Brazil's state owned development bank **BNDES** is the key player for financial incentives. In accordance with its mandate as inductor of economic development for public priority sectors, it allocates subsidized interest loans to renewable energy project developers that fulfil its specific lending requirements (BNDES, 2017, discussed in more detail under 2.4.2). Once an enterprise has been awarded with a generation project at the annual auction, it can apply for the best terms of credit from BNDES.[16] Next to BNDES as the key financier for the renewable energy industry in Brazil, the public banks CAIXA and Banco do Brasil as well as regional development banks, most prominently BRDE (South) and Banco do Nordeste (North-East) provide complementary credit lines and/or serve as extended arm of BNDES (Ortus Engenharia, 2016). Furthermore, pre-investment support is provided by Innova Energia, which provides subsidies of up to 90% for R&D project with specific energy efficiency standards.

#### c) Fiscal incentives

In addition to financial incentives, the Brazilian policy makers also provide fiscal incentives in the form of **import tax exemptions and state tax** (ICMS[17]) **exemption**. The in 2011 issued Decree7660 established for the first time import tax exemptions and set those for solar PV equipment in the range between 2 % to 10 %.[18] The still pending legislation (317/2013) aims to introduce import tax exemptions for solar PV generation equipment where there is no equivalent local production available. State tax (ICMS) or value added tax (VAT) exemption are currently valid until the end of 2021. Furthermore, projects that score particularly well on the environmental impact assessment can obtain additional tax benefits from case to case (IRENA, 2015).

**The Brazilian government pursues a solar PV nationalization plan that foresees a progressive value chain integration of the local equipment supply chain next to expanding the demand of generation capacities** (BNDES, 2017). Essentially, the plan stipulates that a minimum amount of equipment for solar PV projects in Brazil must be sourced from manufacturers based in Brazil. This so called local content rule (LCR)[19] aims to protect the local industry in its infant stage from cheaper and more competitive international imports. Figure 7 illustrates how the combined intervention of government held auctions and fiscal as well as financial incentives is meant to initiate a **virtuous cycle of job creation and industry sophistication** that leads to gradual price reduction of the technology and an improved competitiveness of the Brazilian solar sector (BNDES, 2016b).

Figure 7 The progressive nationalization plan for solar PV in Brazil




Source: BNDES, 2016b

[16] Table 8 in the appendix provides an overview of the interest differentials between BNDES loans and commercial facilities
[17] *In Portuguese: Imposto sobre Circulação de Mercadorias e Serviços (ICMS)*
[18] *As defined in Tax Table for Industrialised products (TIPI Table). Solar PV: 8541.40*
[19] Local Content Requirement and Local content rule is henceforth used interchangeably

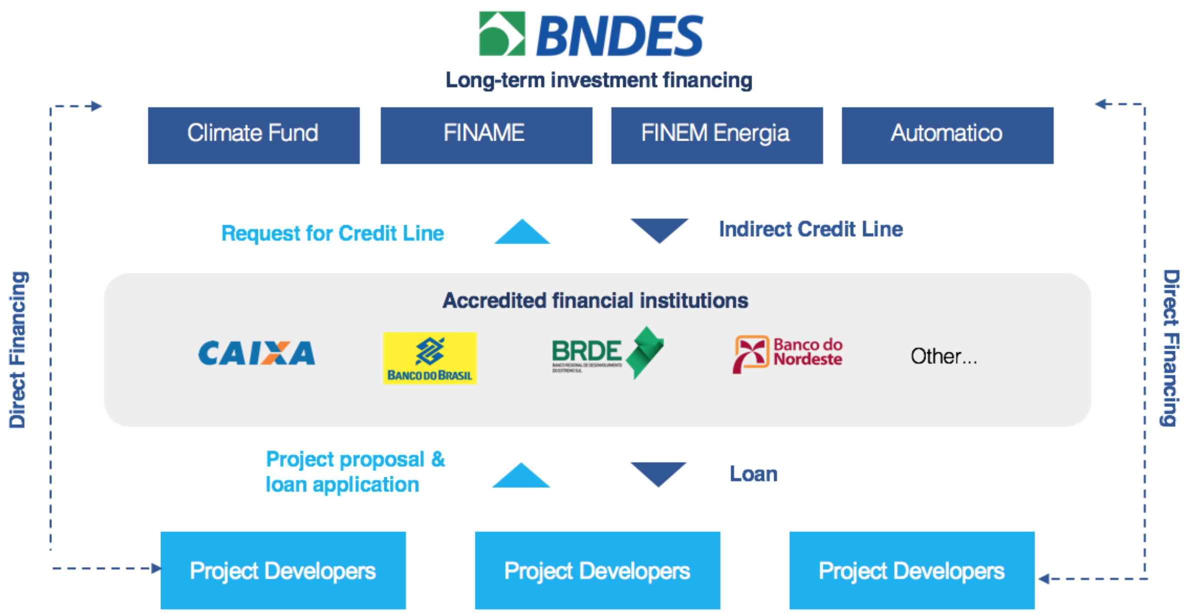
## 2.4 Financing

### *2.4.1 Terms & structure*

Accessing attractive rates of financing is seen by many industry observers as the biggest challenge to solar developers in Brazil (Transfer LBC, 2015; BMWi, 2016; BNEF, 2017; Ferraz, 2016; Andreão et al, 2017). The loss of Brazils investment-grade in 2015 added to the already difficult local funding landscape. High inflation levels allow the central bank to offer interest rates only above 10 %. By the time a typical bank loan is passed on to consumers, a 15 % interest rate[20] is often normal (BMWi, 2016). As solar technology still needs to bridge the funding gap[21] between economic and financial viability, **attractive long-term financing is currently only available through the National Development Bank BNDES or its accredited financial institutions** (Currie, 2017; BNEF, 2017; (Andreão et al, 2017)**.**

As intermediary of public money, BNDES' mission is "to foster sustainable and competitive development in the Brazilian economy, generating employment while reducing social and regional inequalities" (BNDES, 2017b).[22] Put differently, **BNDES is the key financier for channelling long-term credit into less developed financial markets** (Torres & Zeidan, 2016). It acts either directly or indirectly[23] through accredited financial institutions such as the public banks CAIXA and Banco do Brasil as well as regional development banks, most prominently BRDE[24] (South) and Banco do Nordeste (North-East). Figure 8 provides a graphical illustration of the operational structure of BNDES funding support for solar development in Brazil.

Figure 8 Operational structure of BNDES funding support



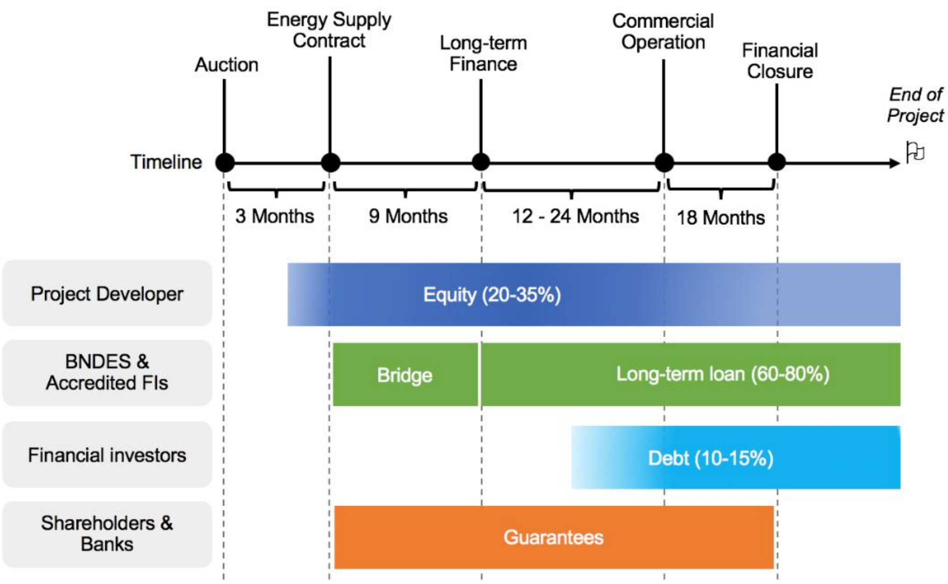

Source: own illustration based on IRENA 2012 and BNDES 2017b

[20] Figure 23 in the Appendix compares commercial and public financing interest rates for renewable enery projects in Brazil
[21] Figure 24 in the appendix provides illustrates the funding gap along the innovation pathway for new technologies such as solar, IRENA (2012)
[22] Table 11 and 12 in the Appendix provide more details about the organizational background and structure of BNDES
[23] *In 2016, direct lending and indirect lending operations comprised 45% and 55% respectively*
[24] *Banco Regional de Desenvolvimento do Extremo Sul*

BNDES receives its funds from the compulsory pension fund for workers (so called FAT)[25], the national treasury as well as international borrowings or capital market operations (BNDES, 2017b; Mazzucato & Penna, 2015). Solar energy supporting facilities include A. the Climate Fund (support for the acquisition of machinery and equipment as well as project implementation related to the reduction of GHG emissions and adaptation to climate change), B. FINAME (financing support for the purchase and sales of energy efficiency machines and equipment), C. FINEM Energia (financing the expansion and modernization of the power generation infrastructure in Brazil), and D. Automático (funding for production capacity expansion of MSMEs). Figure 23 in the Appendix provides a detailed overview of the different funding options in Brazil. **FIMAME is the most important BNDES facility for long-term renewable energy project finance** (BNDES, 2014).

**Long term loans through BNDES' FINAME facility are currently offered with an interest rate between 9.1% and 13.56%** (fixed long term interest rate of 7.5% + BNDES margin + risk spread[26]). Indirect financing comes at a slightly higher cost (fixed long term interest rate of 7.5% + financial intermediation rate + commercial bank spread). The **amortization period** for solar projects varies per loan size[27] and project risks but can be **up to 20 years** (BNDES, 2017b). Furthermore, the bank offers financing of up to 80 % of the total investment value of a given solar project. With a **BNDES participation of up to 80 %**, project developers therefore always need to fund 20 - 40 % of the required capital through a combination of equity and debt instruments from shareholders or other financial investors (BNDES, 2016b). Assuming the development and construction of a new solar park requires capital costs of US$ 150 million, BNDES could contribute a max. of US$ 120 million, while the remaining amount would need to be sources from traditional funding facilities. Figure 9 illustrates the importance of BNDES financing.

Figure 9 Project finance structure for infrastructure projects




Source: BNDES, 2016b

[25] *Public fund for social tax contribution over all Brazilian enterprises net operating revenues*
[26] Margin to cover non-performing loans
[27] a detailed overview of the different financing options per funding facility is provided by Figure 21 in the appendix

### *2.4.2 Local content rule*

Under the progressive nationalization plan for solar, the local content rule is the key eligibility requirement for accessing public funding in Brazil. Essentially, **BNDES specifies local content criteria for PV equipment that project developers who want to gain access to its subsidized loan program must comply with.** BNDES adapted the approach from the successfully applied local content methodology in the wind power sector (BNDES, 2014). Realizing the shortcomings of its weak financing support for the sector, the bank reviewed and revised its lending methodology in 2017 (BNDES, 2017a, c). The following paragraphs discuss the key difference between the old and the new local content rule lending conditions.

***2014 – June 2017: Old Methodology***

From October 2014 to June 2017, BNDES employed a three-phase schedule that accredited the materials and processes required to produce a Photovoltaic module (solar panel) and Photovoltaic system (module + electric components, metal structure, inverter) into basic, optional and premium local content items (Table 2). BNDES differentiated between crystalline silicon solar panels and thin-film panels (see Table 12, Appendix B.). **Basic items** (green), such as the module, had to be assembled or produced in Brazil in order to obtain funding, **optional items** (yellow), such as the Glass or Junction box, could be imported, while **premium items** (red), such as the wafer or silicon, were due to their higher technological sophistication not required to be sourced locally. A so called "**N-Factor**"[28] determined the minimum percentage of local content by aggregating the balanced percentage scores of each component.

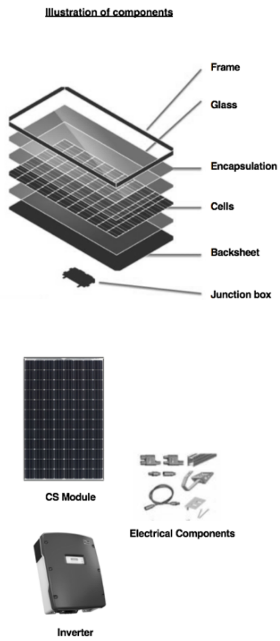
Table 2 Old methodology: local content requirements for crystalline silicon modules and systems

**CRYSTALLINE SILICON (MONO/POLI) PANELS**

| | | Components | Level of Requirement | 2014-Dec/2017 Classification | 2014-Dec/2017 % Adjustment | Jan/2018 - Dec/2019 Classification | Jan/2018 - Dec/2019 % Adjustment | Jan/2020 - Classification | Jan/2020 - % Adjustment |
|---|---|---|---|---|---|---|---|---|---|
| Photovoltaic Module | Materials | Glass, Polycarbonate or Acrylic | Made in Brazil with local content | Optional | 10% | Optional | 10% | Optional | 10% |
| | | Backsheet | Made in Brazil with local content | Optional | 5% | Optional | 5% | Optional | 5% |
| | | Encapsulation (EVA) | Made in Brazil with local content | Optional | 5% | Optional | 5% | Optional | 5% |
| | | Junction box | Made in Brazil with local content | Optional | 5% | Basic | 40% (Junction box + Frame + Module) | Basic | 60% (Junction box + Frame + Module + Cell) |
| | | Frame | Made in Brazil with local content | Basic | 60% (Frame + Module) | Basic | | Basic | |
| | Processes | Module | Module Assembly Process (Connection of cells + overlap of materials + lamination + framing + connection of modules + tests) | Basic | | Basic | | Basic | |
| | | Cell | Process of Cell Production (Chemical treatment + doping + antireflex treatment + Printing contacts + tests | Premium | 30% | Optional | 30% | Basic | |
| | | Wafer | Wafer Manufacturing Process (Slotting) | Premium | 5% | Premium | 5% | Premium | 5% |
| | | Ingot | Ingot Manufacturing Process (Silicon Foundry + Crystallization) | Premium | 5% | Premium | 5% | Premium | 5% |
| | | Silicon solar grade | Manufacturing Process Siemens (electronic grade) or Metallurgical (solar grade) | Premium | 30% | Premium | 30% | Premium | 30% |
| | | | **Minimum Module Nationalization factor - "N Factor" (%) (Only basic items)** | 60% | | 40% | | 60% | |
| Photovoltaic System | A' | | Minimum Module Nationalization factor - "N Factor" (%) (Only basic items) | | 60% | | 40% | | 60% |
| | A' | | Relative participation of the MODULE in the system (%) | | 60% | | 60% | | 60% |
| | A | Module | Basic items defined in Table 1: Photovoltaic Module Crystalline Silicon Technology | Basic | 36% | Basic | 24% | Basic | 36% |
| | B | Electrical Components (String box + Cabling) | Made in Brazil with local content | Basic | 20% (Electrical Components + Metal structure) | Basic | 40% (Electrical Components + Metal structure + Inverter) | Basic | 40% (Electrical Components + Metal structure + Inverter) |
| | B | Metal structure (lift) | Made in Brazil with local content | Basic | | Basic | | Basic | |
| | C | Inverter | Made in Brazil with local content | Optional | 20% | Basic | | Basic | |
| | | | **Minimum Nationalization factor for the System - "N Factor" (%) (Only basic items)** | 56% | | 64% | | 76% | |
| | | | **Minimum Nationalization factor for the system - "N Factor" (%) (basic items + inverter)** | 76% | | 64% | | 76% | |

Optional Items (yellow) | Basic Items (green) | Premium Items (red)

**NOTE:** A 6% adjustment to the "N Factor" will be considered if the PV module used has ENERGY CLASSIFICATION "A" according to ENERGY EFFICIENCY TABLE - PHOTOVOLTAIC ENERGY SYSTEM - MODULES available on the INMETRO website.




Source: adapted, translated and modified from BNDES, 2016b

Under the old methodology, **BNDES stipulated a minimum "N Factor" of 60 % for the PV module up to December 2017**. With respect to the PV system, a progressively increasing BNDES participation

[28] Nationalization Factor

ranging from 56% (up to December 2017) to 76% (January 2020 onwards) was established. **The amount of financing that a project developer could receive from BNDES was derived from its maximum participation percentage (at the time 70%) multiplied by the "N factor"** (See Table 4 below). A higher "N factor" thus results in a higher amount of public funding, which gives the project sponsor the flexibility to decide whether to source a component locally or from abroad. If a project developer, for example, decided to assemble only the module in Brazil (60%) while sourcing everything else from abroad[29], BNDES' funding would be restricted to 42 % of the investment costs (60% x 70% = 42%). If a project developer however would decide to produce also the cells and the glass in Brazil (60%+30%+10%= 100%), BNDES could provide 70% of the total project costs (100% x 70%).

***June 2017 – onwards: New Methodology***

On the 28th of June 2017, BNDES introduced a new local content methodology for the accreditation of PV equipment, a move aimed at "**simplifying the rules, raise the banks participation in financing, increase flexibility, reduce the scope of obligations and extend the deadlines for changing the incentive leve**l" (BNDES, 2017c). The complex old "N factor" formula, which was widely considered to be one of the main obstacles in accessing public funds (Transfer LBC, 2015; Goldenberg & Roberts, 2015; Ferraz, 2016; Andreão et al, 2017), was substituted with a new and simplified accreditation **Factor C** (Table 3).

Table 3 New methodology: local content requirements for PV generation system

| | | Components | Crystalline Silicon | Thin-Film | until Dec/2019 | Jan/2020 - Dez/2022 | 2023 - onwards |
|---|---|---|---|---|---|---|---|
| PV Generation System | C.1 | Module | Glass | Substrate | 5% | 5% | 5% |
| | | | Backsheet or Encapsulant | Cover or Encapsulant | 5% | 5% | 5% |
| | | | Junction box | Junction box | 5% | 5% | 5% |
| | | | Cell | Deposition and definiton of cells | 30% | 30% | 30% |
| | | | Complete assembly + frame | Encapsulation | 60% | 50% | 30% |
| | C.2 | Electrical components (cables CC, combiner/string boxes) | | | 10% | 10% | 10% |
| | C.3 | Metal structures (fixed racks in floor or roof and trackers) | | | 10% | 10% | 10% |
| | C.4 | Inverter | | | 20% | 20% | 20% |
| | | System Factor C - min. items required to allow accreditation | | | 80% | 90% | 70% |

Mandatory items (green) Optional Items (yellow)

Source: adapted and translated from BNDES, 2017c, d

On first sight, the new schedule is much easier to read and only differentiates between mandatory (green) and optional (yellow) accreditation items. The complete **module assembly**, **frame**, **encapsulation**, **electrical components** as well as **metral structures** are now considered **mandatory local content components** and thus must be sourced locally in order to access BNDES financing. All other items (**Glass, Backsheet, Junction box and cell) are optional** and thus will be counted as bonus to the accreditation factor if sourced locally. Furthermore, crystalline silicon and thin-film panel technology are treated equally and have with the exemption of the module assembly the same accreditaton factors. Overall, it becomes clear that the new methodology focuses more strongly on the

[29] Foreign manufacturers of renewable energy and energy efficiency technology must pay a 14% tax surcharge on imports.

assembly for local content and leaves project developers the flexibility to source more technologically demanding processes from abroad. Also, with the minimum **local content of 80%** until December 2019 (Table 3 above), followed by a 90% requirement until December 2022 (Note, that the inverter becomes a mandatory item as well) and 70% thereafter, BNDES significantly raised its funding partcipation. Yet, **the most significant change is the preferential financing for micro, small and medium sized enterprises (MSMEs).** For MSMEs, the new accreditation factor (formerly called N Factor) will no longer be applied and operations shall have 100% of BNDES' new funding participation of 80% (Table 4). For larger companies, the old formula of multiplying the maximum participation percentage (80%) with the respective accreditation factor C remains unchanged.

Table 4 Comparison of funding participation under the old and new methodology

| **Company Size** | **Operational Revenue*** | **Old Methodology** | **NEW Methodology** |
|---|---|---|---|
| Micro | Below **US$ 110** thousand | › Factor N x 70% | › Directly 80% BNDES participation |
| Small | Below **US$ 1.10** million | | |
| Medium | Below **US$ 92** million | | |
| Large | Above **US$ 92** million | | › Factor C x 80% |

* All figures as of 31 Dec 2016 / Exchange rate R$ 1 = US$ 3.26

Source: adapted from BNDES, 2017a and d

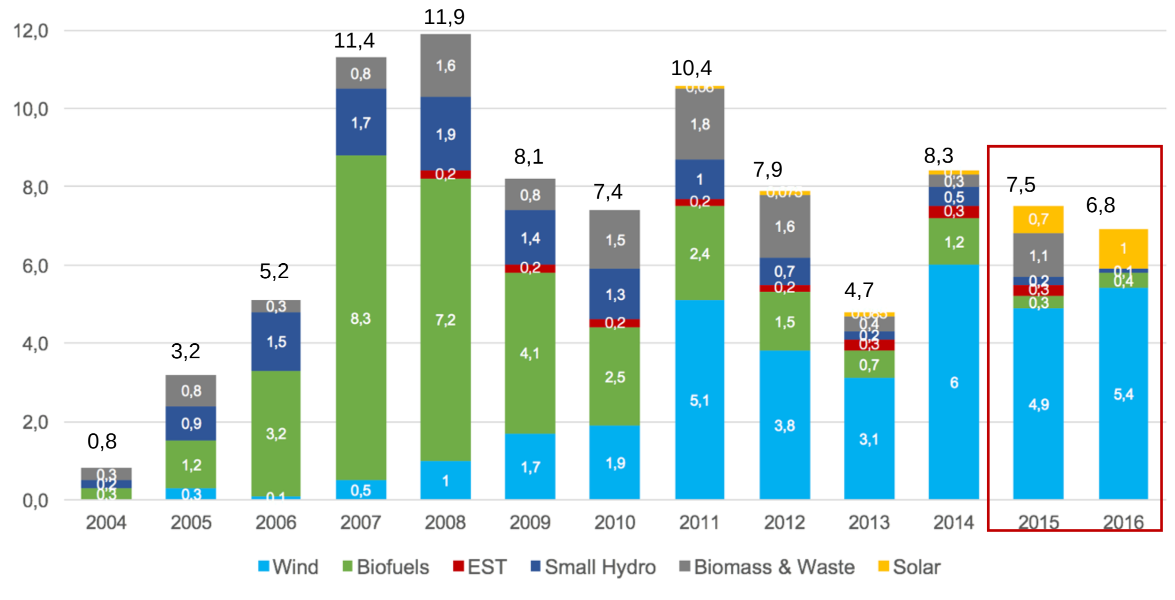
## CHAPTER 3 - CURRENT STATE AND FUTURE DEVELOPMENTS

### 3.1 Investments

#### *3.1.1 Private Sector*

According to Bloomberg New Energy Finance Data (2017), Brazilian renewable energy investments progressed closely in line with recent economic boom and bust cycles between 2004 and 2016 (see Figure 10). Investments increased almost exponentially until 2008 before getting slumped by the effects of the global financial crisis. While 2011 again represented a major growth year, mainly due to the strong contribution of the wind power sector that accounted for 50% of the total investment in that year, the economic downturn in 2014 clearly proved to be a less than ideal backdrop for a fairly stable renewable energy development until then. Despite returning to a decent investment volume of US$ 8,3 billion in 2014, the year 2015 and 2016 witnessed a gradual decline. While wind energy sector investments have seen tremendous growth since 2009, the solar PV sector almost didn't appear in Bloomberg's statistics until 2015. Specifically, investments in solar asset finance grew from US$ 700 million in 2015 to $1 billion in 2016. The growth of 40% is a direct result of the investment uptake from the solar energy auctions held in 2014 and 2015 (in detail discussed under Chapter 3.2.1) from which Brazil anticipates exponential growth in the coming years.

Figure 10 Investments into Renewable Energy in Brazil, 2004 - 2016 (in billion USD)




*Note: EST stands for Energy Smart technologies. Total values include estimates for undisclosed deals. Includes corporate & government R&D and spending for storage projects*

Source: Bloomberg New Energy Finance Data (BNEF, 2017)

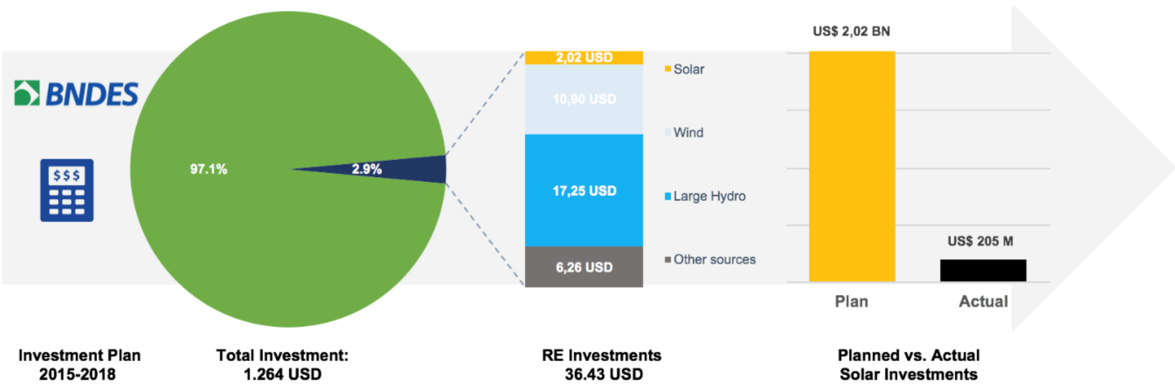
Comparing the actual investments for 2015 and 2016 of US$ 1.7 billion with the investments made during previous years, a significant upward trend is noticeable. In fact, solar is representing the biggest investment share besides the traditionally strong hydro power. The investment uptake can be explained by the recent introduction of the auction mechanism, which provides a platform for international companies to channel big funds of up to US$ 150 million into the solar market.

### *3.1.2 Public sector*

According to the **BNDES investment plan for 2015 to 2018**[30], funds of US$ 36,4 billion (R$ 118.8bn) were allocated for power generation projects in Brazil, of which US$ 17,25 billion were expected to go to hydro, US$ 10,9 billion to wind and approximately **US$ 2.02 billion (R$ 6,6 billion) to solar power development** (see Figure 11). Another US$ 6,26 billion was expected to go towards financing other power generation sources (BNDES, 2014). The public investment figures have a strong practical relevance for the renewable energy sector as BNDES is the main source of long-term debt for large-scale infrastructure projects in Brazil. While the plan is not binding, it has historically had a 91% accuracy rate, according to BNDES (2014). Without sufficient funding, the project construction gets delayed until further notice. In addition, the reason why private companies participated at the annual demand auctions was the belief to receive adequate funding support through state subsidized loans from BNDES (Chapter 2.3 and 2.4 above). Without sufficient funding, project implementation gets delayed or even runs the risk of getting cancelled.

When looking at total BNDES commitments for solar between 2015 and 2018 (Figure 11: right site), **there is a noticeable discrepancy between the planned and actual investment volume**. As of July 2017 (BNDES, 2017c), the bank has only invested R$ 200 million (US$ 61 million) into industry developments (supply site) such as new factories, adjustments or expansions for implementation of new production lines. Its demand site (installations) support is even further behind schedule. **BNDES approved its first financing for a solar power generation project almost three years after the first commercial solar projects were awarded in Brazil**. In May 2017, it extended a credit for 79% of the total investment volume or R$ 529 million (US$ 144 million) for the Pirapora Solar Complex in Minas Gerais (BNDES, 2017e). Considering the finance structure of a typical project (Figure 9 above), this means that most project developers had to rely on equity and commercial debt instruments for funding.

Figure 11 BNDES investment plan 2015 – 2018, Power generation by source (in billion USD)




Note: Exchange rate used – BRL/USD = 3.26

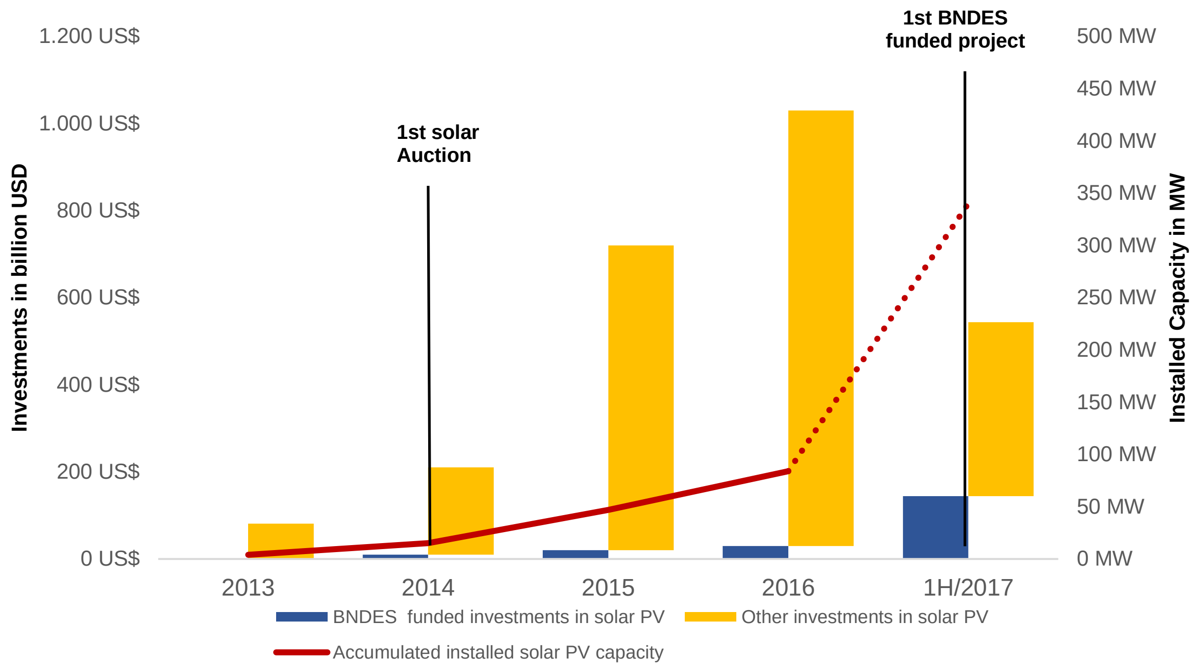
Source: BNDES, 2014, 2017c, 2017e

Aggregating the total supply and demand site support for the solar sector up until May 2017, **BNDES' promotional business accounts for merely 11% (R$ 529 million + R$ 200 million = R$ 729 million)**

[30] The bank publishes the report every three years.

**of the banks projected investments until 2018 of R$ 6,6 billion.** Relative to all solar financing investments in 2015 and 2016 (Figure 10 above), its promotional business represents a similarly low 12,5% of the US$ 1,7 billion total investment. Considering that BNDES will already publish its new investment plan in December 2017 (after the three-year completion), the investment target is far from being achieved. While the failed achievement of the promotional business can be attributed to the detrimental economic and political realties since 2014, BNDES should take part of the blame as well as it is mandated to provide countercyclical support in the event of challenging financing conditions. In either way, **BNDES's current funding is not helping project developers to fulfil their implementation timelines and thus puts in question the adequateness of the strict lending requirements** (Chapter 2.4.2). Despite the upward trend (first financing awarded in May 2017), BNDES is currently not fulling its role as key financier for channelling long-term credit into the less developed solar markets (Figure 12).

Figure 12 Development of investments in Solar PV vs. BNDES contribution




Source: Own elaboration based on data from BNDES (2017c), BNEF (2017) and MME & EPE (2017)

## 3.2 Implementation

### *3.2.1 Deployment of generation plants*

Solar PV was added to the open tendering process of general renewable energy auctions for the first time in 2012. In 2013, while only the second year having solar energy included in the mix, the auctions attracted 400 applications for PV utility development (Andreão et al, 2017). Yet, due to the open competition between the different energy auction sources, wind farms ended up as auction winners. From 2009 until 2016, a total of 509 wind farms were contracted, comprising a total of 13.4 GW of expected capacities (ANEEL, 2016c). While the promotion of wind power since the late 2000's has been extraordinary, solar farms are in a less developed state.

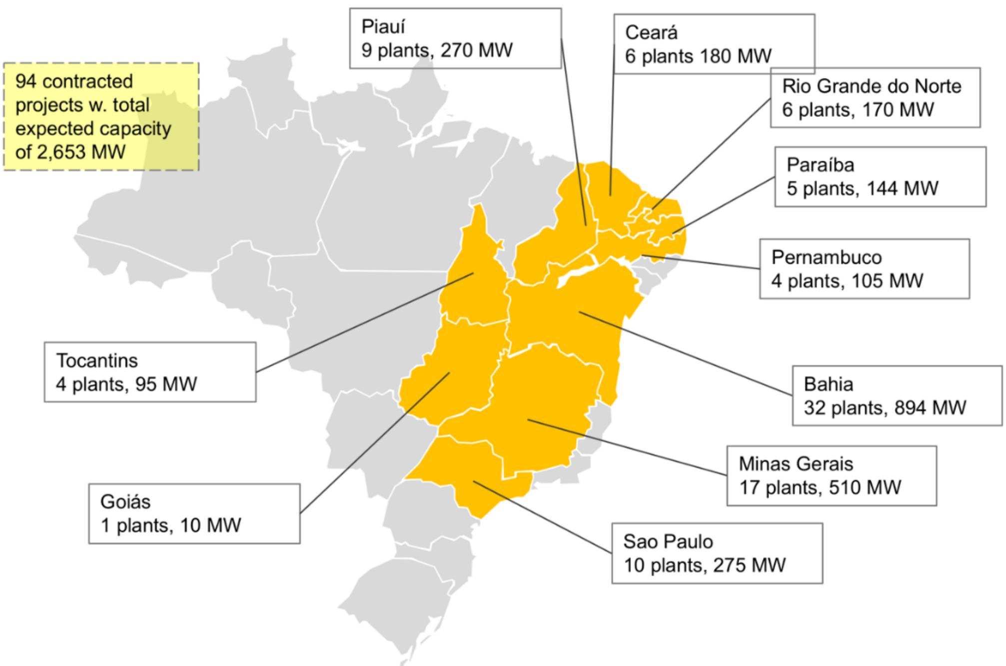
Table 5 Solar Energy Auctions in Brazil 2014 – 2016[31]

| # | Date | Solar Projects awarded | Contracted Capacities (in MW) | Price (US$ / MWh) | Scheduled start of operation | Amount invested (in Mio R$) |
|---|---|---|---|---|---|---|
| *1* | Auction 10/2014 | 31 | 890[32] | 88,2 | 10/2017 | 4.144 |
| *2* | Auction 08/2015 | 30 | 834 | 84,3 | 08/2017 | 4.341 |
| *3* | Auction 11/2015 | 33 | 929 | 78,2 | 11/2018 | 4.396 |
| *4* | Auction 12/2016 | ✘ | ✘ | ✘ | ✘ | ✘ |
| | **Total** | **94** | **2.653** | | | **12.882** |

✘ Cancellation of Auction
Source: own illustration adapted from MME, 2017

As Table 5 outlines, **the first solar only auction for large scale PV projects took place in August 2014** resulting in 31 power plant winners with an average sales price of US$ 88,2/MWh for a 20-year electricity power agreement (MME, 2017). Its commercial operation date (COD) was at the time anticipated for October 2017. The 2014 auction was followed by two more auctions in August and November 2015, contracting 63 purchasing power agreements (PPA) worth 834 MW and 929 MW with a scheduled start of operation for August 2017 and November 2018, respectively. **Reduced electricity demand caused by a worsened macroeconomic outlook led the government to call off its only solar auctions for 2016** (Gaylord, 2016). Overall, the generation capacities contracted amount to a total of 94 power plants with a cumulative capacity of 2,653 MW. Project locations were spread over 10 states with Bahia (894 MW), Minas Gerais (510 MW) and São Paulo (275 MW) receiving most of the installations (Figure 13).

Figure 13 Contracted utility-scale solar power plants in Brazil

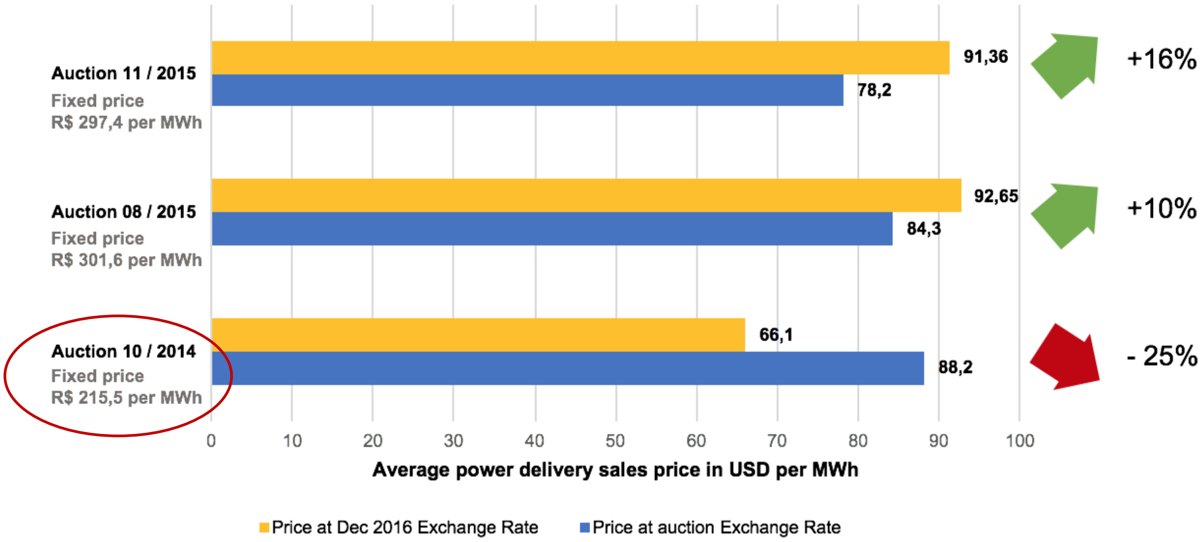



Source: adapted from EPE & MME (2017)

[31] Table 10 in the appendix provides and a more detailed overview of project winners and their plants, capacities and investments
[32] This figure has also been reported at 1048 MW

From the first to the last auction**, the average bidding price fell from 88.2 US$/MWh to 78.2 US$/MWh** (Table 5 above). While the cost reduction trend moved in the right direction, industry analysts (BNEF, 2016, 2017) perceived some of the in 2014 contracted prices as very tight and predicted struggles in the face of the recession.[33] As solar power delivery contracts were fixed in Brazilian reais and not in dollars, **contracts signed in 2014 significantly lost their value due to inflation**. As Figure 14 shows, the 2014 average auction price deteriorated by 25%, yielding US$ 66 in Dec 2016 as opposed to US$ 87 (R$ 215,5) per MWh in October 2014. In contrast, 2015 auction winners saw their power delivery contracts appreciating by 10 % and 16 % respectively as they benefitted from an inflation upwards adjusted reais value.

Figure 14 Solar PV power delivery sales prices in US dollars ($/MWh) vs. Dec. 2016 exchange rate




Note: 2016 exchange rate – 31 Dec 2016: USD 1 = BRL 3.26
Source: own illustration based on data from ANEEL (2017d,f)

In addition, the **unexpected cancellation** of the highly anticipated **2016** auction left many stakeholders “perplexed” and was widely criticized for sending the wrong signal to the Brazilian supply chain (Kenning, 2016). From a strict demand and supply site perspective, overcapacities left the government with no choice. Yet, the fact that the **auction was cancelled on short notice (5 days prior to schedule)** was attributed to poor institutional planning and therefore resulted in a loss of credibility to the government (Gaylord, 2016; Andreão et al, 2017).

With respect to the successful implementation of the 2017 schedule, **ANEEL**’s latest “General Summary of Solar Generation Projects” **registers a total installed grid connected capacity of 148 MW**[34] (Table 6). The capacities belong the Lapa Solar Park in the north-eastern state of Bahia, where the Italian utility group Enel has begun operation with two of its plants in June and August 2017 (see Appendix C. Photos). The current capacity installations account for 5,5% of all awarded projects since 2014 and represent 8.6% of the projects expected to be delivered by August and October 2017 respectively

[33] The levelised cost of electricity (LCOE) for solar in Brazil was at the time estimated much higher at around 95 US$/MWh, BNEF (2017)
[34] 148 MW refers to the new added centralized generation capacity

(Table 5: 1.763 MW). Given the resulting delta of 91,4% not delivered projects (148 MW / 1763 MW), the **progress falls short of the implementation schedule** and puts into question the construction status of the remaining plants.

Table 6 Solar power plants and capacities in commercial operation as of 15th August 2017

| 2017 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Nov | Dec | Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MW Installed** | 0 | 0 | 0 | 0 | 0 | 120 | 0 | 28 | - | - | - | 148 |
| **No. of plants** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | - | - | - | 2 |

Source: adapted from (ANEEL, 2017a)

While Canadian Solar Inc. managed to successfully deliver its project within the August 2017 deadline, 6 out of 8 winners from the 2014 auction requested ANEEL in April 2016 for permission to pospone the scheduled operation date by 2 years from October 2017 to Ocotber 2019 (BNEF, 2016). In response, **ANEEL introduced a so called "de-contraction auction" to allow financially distressed companies to opt out of their contracts from previous solar energy auctions**. The auction was held on the 28th of August 2017 and resulted in **249,66 MW of power contracts being terminated** by 9 project developers (PVM, 2017). This helped project developers who struggled with the financial feasibility of their projects (Figure 14 above) to cancel their contracts officially and thus avoid a potential litigation with the government (Dykes, 2017).

To assess the construction status of the other projects, a closer look at **ANEEL's performance measurement methodology** is required. ANEEL's inspection committee is typically tracking the implementation and expansion of planned solar projects according to four performance indicators: **A. Viability**, **B. Adherence to deployment schedule**, **C. Construction progress**, and **D. Compliance with periodic reporting**. Using the data of ANEEL's (2016a, 2016b, 2016c, 2016d, 2016e, 2017a, 2017b, 2017c, 2017d, ) periodic inspections reports, the current implementation results are analysed in the following:

**A. Viability**

| | |
|---|---|
| **Indicator Definition** | The viability of projects is defined as a parameter to examine the economic feasibility of the project irrespective of the adherence to the foreseen timetable. ANEEL distinguishes between the following three categories: 1) No restriction for entering operation: Plants with environmental license and civil works in progress, 2) Some restriction for entering operation: Plants with works not started or with unfinished environmental licensing, 3) Severe restriction for entering operation: Plants with suspension of the environmental licensing process or declaration of environmental unfeasibility, revocation process under analysis, lawsuits or other serious problems |

**Results** ANEEL's August 2017 review report indicates that **only 38 % of all awarded solar projects are currently considered economically feasible** (Table 7). This accounts for **1083 MW** out of **2830 MW**[35] expected for the next two years (ANEEL, 2017a). In contrast to the originally expected 1763 MW, ANEEL downward adjusted its projection to 683,53 MW for 2017. Given the currently installed 148 MW (Table 6 above), 535,5 MW are still expected to be installed until end of the year. At the same time, 47 % of the projects awarded since 2014 are currently stalled due to "some" (e.g. unfinished environmental licensing) or "severe" (e.g. environmental unfeasibility, lawsuits) restrictions for entering operation. In other words, the economic viability of these projects is put into question. Lastly, 415 MW are due to severe problems not expected to go into operation at all (relates "de-contracting auction" discussed earlier).

Table 7 Projected new solar installations in MW for entry into operation - 2017 to 2024

| Status | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | Without projection | Σ |
|---|---|---|---|---|---|---|---|---|---|---|
| ✓ | 683,53 | 398,88 | - | - | - | - | - | - | - | **1.082,4** |
| ! | 30,00 | 736,62 | 565,84 | - | - | - | - | - | - | **1.332,5** |
| ✗ | - | - | - | - | - | - | - | - | 414,66 | **414,7** |
| | **713,53** | **1.135,50** | **565,84** | - | - | - | - | - | **414,66** | **2.829,5** |

✓ No restriction for entering operation: Plants with environmental license and civil works in progress

! Some restriction for entering operation: Plants with works not started or with unfinished environmental licensing

× Severe restriction for entering operation: Plants with suspension of the environmental licensing process or declaration of environmental unfeasibility, revocation process under analysis, lawsuits or other serious problems

Source: illustration adapted and modified from ANEEL, 2017a

## B. Adherence to deployment schedule

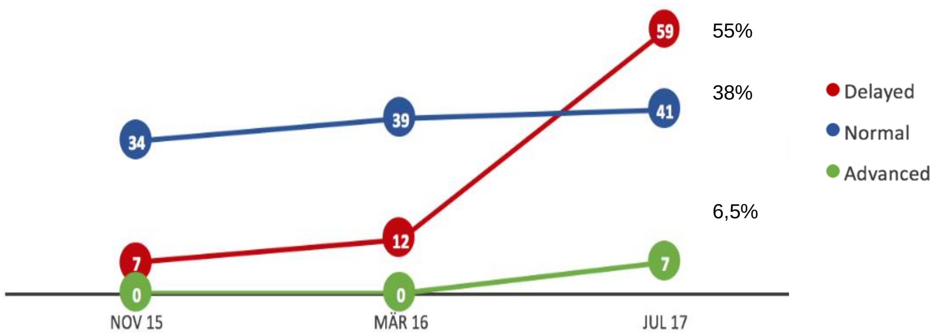
**Indicator Definition** ANEEL also classifies new solar generation projects according to their adherence of the deployment schedule and distinguishes thereby between the following three categories: 1) delayed: The last event of the schedule not performed on the deadline, 2) normal: The last event of the schedule performed on the obligation date, or, events scheduled, even if not performed, are still within the term of obligation and 3) advanced: Last scheduled event held in advance of the scheduled date.

**Results** Analyzing the adherence to schedule of Brazilian solar plants, the numbers show a negative trend: as of July 2017, out of 107 PV[36] power plants analyzed only 6.5 % (7 projects) of all awarded solar plants are in an advanced schedule while 38 % (41 projects) are according to schedule and **55% (59 projects) are delayed** (see Figure 11). It is worth noting that projects with construction delay increased significantly from ANEEL's review in March 2016 to July 2017.

[35] ANNEL's figure for total solar expansions until 2019 of 2829 MW is not in line with the MME auction figure (Table 4). The different measurement is attributed to different

[36] The number of inspected projects by ANEEL of 107 clashes with the figures published by the MME and EPE (94). This is can be attributed to the lacking coherence between regulatory institutions, which sometimes also report 1048 MW of contracted capacities for the 2014 auction

Figure 15 Implementation status of new commercial solar operations




Source: own elaboration based on ANEEL (2015, 2016a, 2017b)

### D. Construction Progress

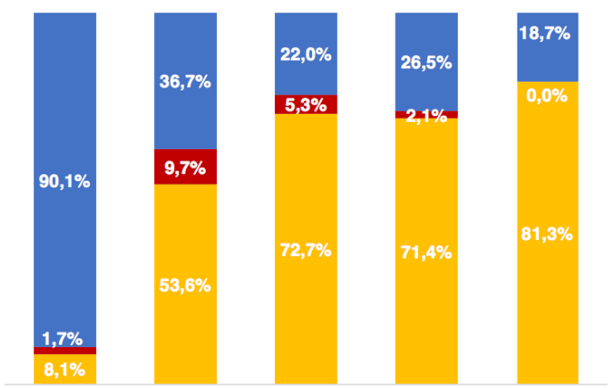
**Indicator Definition**

Lastly, the inspection committee of ANEEL classifies solar projects according to their construction status. This is to verify whether the civil works of the structure has already begun or whether there is a halt of the construction work due to lawsuits, foreclosure or loss of the environmental license. ANEEL classifies the construction progress as either 1) not started: The inspection did not verify the beginning of the civil works of the main structures of the plant, 2). Under construction: the inspection confirmed the beginning of the civil works of the main structures of the plant or 3). construction interrupted: civil works on temporary hold due to lawsuits or other hindrances.

**Results**

Looking at the progress of construction as of April 2017, **only 18.7 % (556 MW) of the solar capacity expansions are currently under construction** (ANEEL, 2017c). In contrast, 36,7 % (2845 MW) of all wind power and 26,5 % (485 MW) of all biomass expansions were under construction (see Figure 16). At the same time, construction has not yet started with 81,3 % (2425 MW) of the solar plants, which seems concerning considering the much lower figures of wind (53,6%) and biomass power plants (71%).

Figure 16 Construction status of new electricity generation projects in Brazil, April 2017




| | Hydro | Wind | Thermal | Biomass | Solar |
|---|---|---|---|---|---|
| Under construction | 10313,79 | 2845,40 | 1495,87 | 484,64 | 556,00 |
| Construction interrupted | 199,90 | 749,00 | 360,20 | 38,77 | 0,00 |
| Construction not started | 932,22 | 4156,96 | 4933,99 | 1306,99 | 2424,52 |

Source: illustration adapted and modified from ANEEL, 2017c

**C. Compliance with periodic reporting**

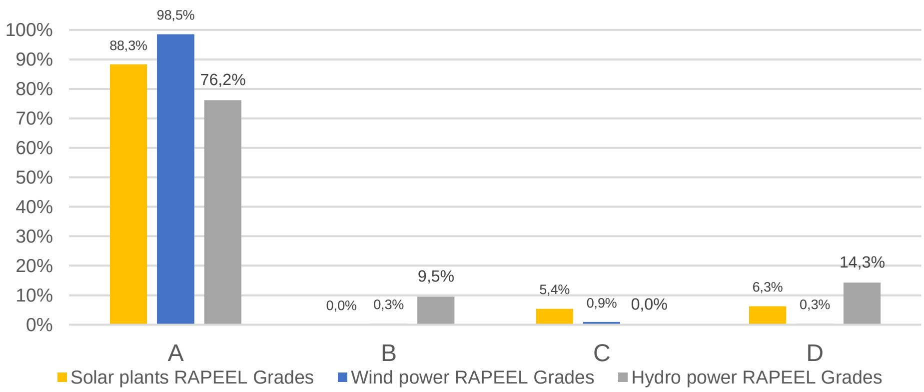
**Indicator Definition**

ANEEL's inspection team also monitors whether the project responsible company is delivering a quarterly project progress report called RAPEEL[37]**.** The compliance with this periodic reporting is graded according to the following four categories: A (higher than 3.75); B (between 2.75 and 3.75); C (between 1.5 and 2.75); and D (lower than 1.5). The grades are the quarterly average of the monthly fulfilment of reporting obligations. A "zero" indicates that the company did not send the report, a "one" indicates that the report was sent out of the tolerance period; a "two" indicates that the report was incomplete, incorrectly answered or answered without standards; a "three" indicates that the report was sent in the tolerance period but delayed; and a "four" indicates that the report was sent on time. Figure 12 summarizes the results of 110 analysed projects.

**Results**

The last publicly available statistics of the RAPEEL tool results date back to July 2017. Comparing the results of solar power projects against those of wind power and hydro (Figure 16) no significantly worrying results are apparent. In fact, **88.3 % of all projects deliver their reports timely** and only 11,7 % either sent the reports after the deadline or incomplete. Interestingly, the performance of all three renewable energy sources seems to be very much alike with respect to reporting. While the other parameters gave more reason for concern (Andreão et al, 2017), this figure proves an upward trend and shows that most solar project companies comply with their reporting requirements.

Figure 17 Weighted RAPEEL grades of new solar and wind power generation projects in Brazil




Source: own elaboration based on data from (ANNEL, 2017d)

### *3.1.2 Establishment of a local supply chain*

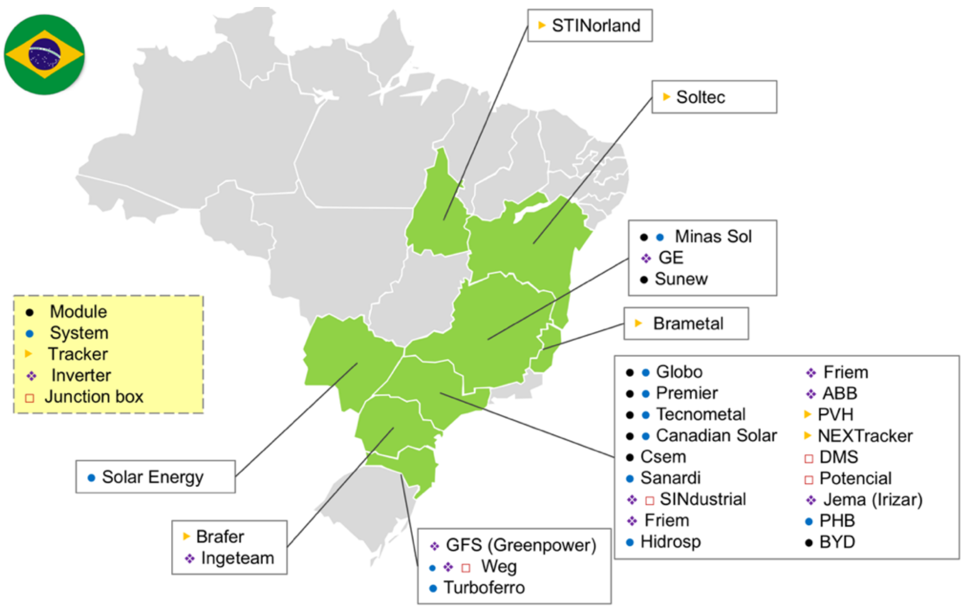
The industrial development of the Brazilian solar market is still considered to be at an early market stage (Nuoshu, 2017; Reuters, 2017; Lopes Sauaia, 2017; Andreão et al, 2017). Like many other industries in Brazil, **the renewable energy industry is heavily protected against low-cost foreign competition through tariffs and financing incentives**. With low competition, supplier margins are fat and cost competitiveness is low. Other structural issues such as high taxes, poor infrastructure and low technical expertise are adding to a challenging market dynamic for investors (Bloomberg, 2017).

[37] Relatório de Acompanhamento de Empreendimentos de Geração de Energia Elétrica (RAOEEL) = Monitoring Report of Generation of Electric Power

The Brazilian government incentivizes investments in the local supply chain by stimulating demand through annual auctions and providing tax as well as financial incentives (2.3 Support Policies & Instruments). **As subsidized funding is linked to a strict local content policy** (section 2.4.2 above), **international solar equipment companies need to set up local production facilities**. Regular demand is crucial to allow the supply chain to mature and compel companies to make the necessary expenditures in training and specialized labor (Andreão et al, 2017).

According to reports (Transfer LBC, 2015), **at least 500 MW solar delivery contracts must be awarded annually to justify investments in new production facilities**. Considering the fact that more than 2,6 GW have been contracted through previous auctions, the criteria has been more than fulfilled to justify supply chain investments. When looking at the local PV manufacturing landscape (Figure 18), almost all technical components required for a solar PV system are currently registered in Brazil. As of February 2017, ABSOLAR **lists 6 companies with respect to module manufacturing, 10 for system assembly, 8 for inverters[38], 6 for trackers[39] and 4 for the Junction box[40].**

Figure 18 Map of solar equipment suppliers in Brazil as of Feb. 2017




Source: adapted and updated from Sauaia (2017)

Most manufacturing locations are in the state of Sao Paulo. All companies are certified local content producers through BNDES's newly established accreditation process (section 2.4.2). As the list of 34 producers includes both active (full capacity) and inactive (not running at capacity) as well as small and large scale producers, it is difficult to judge the actual degree of industry sophistication. Nevertheless, the fact that no local module supplier was available in Brazil three years ago indicates that the supply chain matured tremendously over the years. Tecnometal, for instance, used to be the only large module supplier for a long time (Andreão et al, 2017). With the **inauguration of Brazil's largest module manufacturing facility – 400 MW per annum - in December 2016, another company - Canadian Solar – has joined the crucial supply chain segment**. On top of that, the Chinese renewable energy

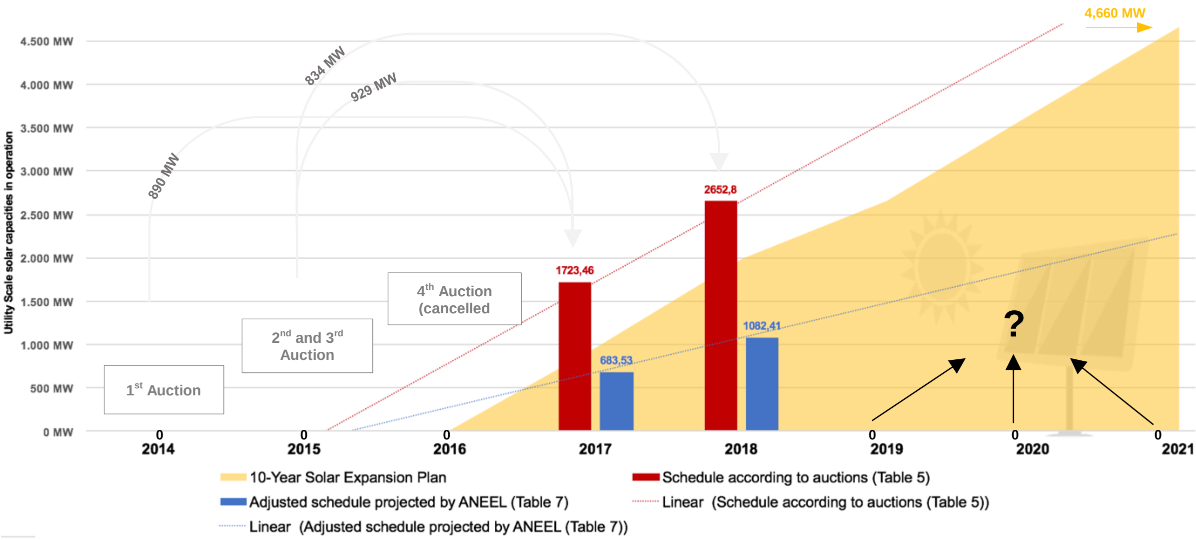
[38] A solar inverter (also converter) is responsible for converting the variable direct current (DC) from a solar panel into a utility frequency alternating current (AC), Wiki (2017)
[39] A tracker is a device that orients (rotates) the solar panel toward the Sun, Wiki (2017)
[40] A junction box is an enclosure on the module where the PV strings are connected and distributed to the inverter, Schneider Electric (2017)

technology company BYD has also opened a solar panel factory in April 2017 (BYD, 2017) with a total production capacity of 200 MW.Considering an expected demand of 1 GW solar PV capacities per year (Figure 5 above), the currently relevant large-scale module manufacturers will not be able to supply the entire market. Globo, Premier, Csem, Minas Sol or Sunew are considered relatively small players (20 – 50 MW) that are positioned to cater mostly to the small scale residential (solar roof top systems) market. **Given the impending market boom, new utility-scale manufacturing facilities with an annual capacity of 200 MW to 400 MW remain highly demanded in the foreseeable future.** Furthermore, as Brazil does not yet have a complete solar supply chain in place, imports of cells, solar grade silicon or other materials are still required (Table 3 above: shows the equipment that BNDES allows to be imported).

Most technology companies that invested in Brazil continue to have sourcing options in countries like China, India or Europe. **Due to Brazil's cost competiveness problem, cheap international imports from China - said to be up to 40 % cheaper** (Reuters, 2017) - pose extreme difficulties for investors. In addition, the cancellation of Brazil's only solar auction in 2016 was very bad news for the industry. With a bleak outlook and a year without new orders, industry analysts (Gaylord, 2016) see companies that are unable to capitalize on more competitive export markets on the verge of bankruptcy. Thus, **despite respectable advancements in maturing the solar PV supply chain, the industry faces much uncertainty after the auction cancellation**.

Figure 19 illustrates the overall dynamic of the current solar market in Brazil. Capacities expected to be delivered in 2017 and 2018 (red = original commercial operation date) are going to be delayed and are according to the latest projections by ANEEL not even fully implemented. ANEEL foresees a total of 1082 MW (blue) to be likely to enter operation over the course of 2017 and 2018 (Table 7 above), while the auction in fact contracted 2653 MW. Thus, under current projections, **the Brazilian solar manufacturing industry faces an uncertain outlook for the years 2019, 2020 and 2021.** Despite these negative trends, the government's announcement to award new solar projects at the December 2017 auction raises hopes again and sends a positive signal to the Brazilian solar market.

Figure 19 Comparison of solar capacity projections according to different sources




Source: own illustration based on data from ANEEL, MME, EPE

## CHAPTER 4 - SUMMARY & CONLUSION

Back in October 2014, Brazil belatedly held its first national solar auction awarding contracts for the construction of 31 solar parks with an expected capacity of 889 MW. It was the dawn of solar power in Brazil, a country desperate to reduce its drought afflicted energy dependence on hydro. Three years and a recession of historical proportions later, **Brazil's plan to unleash its unexploited solar potential is moving much slower than anticipated**. This research paper analysed the extent to which solar support mechanisms have been effective and outlined the status and progress towards delivering on the 2024 target of 7 Gigawatt new large scale solar generation capacities.

The findings show that as of August 2017 **merely 2% (148 MW) of the for 2024 targeted 7GW solar power capacities are currently operational**. Considering that Brazil's 10-year energy expansion plan targets 960 MW of solar PV capacity installations for 2017, the current progress also falls short of the set short term targets. Project developers are crippled by supply deficiencies and challenging financing conditions in the face of a rapidly changing exchange rate landscape. The Brazilian Real depreciated as much as 40% during the **economic downturn** and **eroding electricity demands** stalled the government's drive towards energy diversification, all of which **negatively affected policy effectiveness** (Figure 20: <u>Outcome</u>). As a result, some of the solar parks that were expected to deliver power on 2017-2037 are likely to go into operation with 1 or 2 years' construction delay.

Despite worse than expected outturns and challenging conditions on the short-run, **the medium to long term prospects for solar in South America's largest electricity market remain good**. Brazil is too exposed to its dependence on hydroelectricity to not care about the solar market and government support policies will need more time and adjustments to gain traction. As for the deeper structural problems that affect the sector's competitiveness, a concerted and coherent approach is required to deal with both supply (local industry sophistication) as well supply-site (installation, financing) issues. New demand auctions are scheduled for end of the year and projects with environmental licencing and advanced civil works totalling **1 GW are expected to be operational in the first half of 2018**. With the economy expected to pick up pace again, Brazil's solar promise is inching closer towards realisation.

As for the near future, the government needs to address the sector's underlying weaknesses and find ways to make state interventions more efficient. The following challenges need to be addressed:

› ***Insufficient financial support****:* The only bank with attractive long-term financing, Brazil's development bank BNDES, significantly underachieved its targeted promotional business by distributing only a pitiful 11% of its earmarked budget of R$ 6.6 billion to support the solar deployment in Brazil. In fact, only one financing loan for a solar utility project has so far been approved by BNDES, which raises the question of the adequateness of the current lending policy. As BNDES is eager to ensure that the impending solar boom is rooted in a solid domestic manufacturing industry, funding needs to be designed more intelligently to fit the resources of the sector. So far, only R$ 200 million have been invested in new factories, adjustments or expansions for implementation of new production lines. (Figure 20: <u>Inputs</u>).

- › ***Policy uncertainty**:* The unexpected cancellation of the fourth-generation auction in 2016 due to an electricity market oversupply has severe implications for the solar supply chain in Brazil. A year without orders puts many uncompetitive companies at the brink of bankruptcy. While industry observers understand that the government cannot support solar power during periods of overcapacity, the government's reversal of promised support is likely to discourage companies considering investments in manufacturing capacities in Brazil in the future. In order to regain lost trust and build credibility with investors, the government needs to be more consistent about its solar commitment. Abandoning the solar industry after compelling so many manufacturers to make investments in the market is short lived and keeps the sector in unnecessary uncertainty (Figure 20: Inputs).

- › ***Adequateness of nationalization plan*:** Brazil's protectionist nationalization plan that foresees a progressive value chain integration of the local solar equipment supply chain has so far been a big obstacle for project developers. The notorious "Brazil cost" - thick red tape, impenetrable taxes, high inflation, an unskilled workforce and poor infrastructure - is crippling local suppliers and makes them internationally uncompetitive. According to reports, local solar modules are as much as 40% more expensive than Chinese imports. To qualify for low interest loans from BNDES, projects must commit to source a significant number of components from local suppliers. This severely affects the viability of many projects as the Brazilian solar market is still relying on imports. BNDES' introduction of a new local content rule in June 2017, which focuses more strongly on the assembly and less technological demanding processes, was a good step forward (Figure 20: Output A).

- › ***Slow Project Execution**:* Most of the solar projects awarded since 2014 face serious execution problems and are not likely to be operational any time soon. Out of 107 contracted projects, only 6.5% are currently ahead of schedule while 55% of all projects are running a construction delay. On top of that, only 19 solar power plants have started construction and 47% face difficulties in the projects economic viability as a result of which 250 MW of power contracts signed in the past few years had to be cancelled. Nevertheless, as the first solar park by Italian energy company Enel started operations in June 2017, the market seems to finally gain traction (Figure 20: Output B).

As this research solely gave an overview of the current industry situation, future research should continue to observe the market status and progress towards delivering solar energy targets. Some ideas for future research could be dealing with the following issues:

A. **Extension of the research findings** by means of a more detailed analysis between the distributed and concentrated solar generation markets in Brazil with respect to potential and adequateness of policy design and regulation;
B. **Diversification of the research design** by focusing primarily on exploratory interviews with policy makers and regulatory institutions (e.g. ANEEL, BNDES, EPE, MME), solar project developers (e.g. ENEL, Canadian Solar) or scholars and analysts (e.g. Bloomberg, FGV); and
C. **Market analysis of the emerging PV manufacturing industry** in Brazil with research focus on the long-term perspective and competitiveness in global markets under the background of increasing price competition from China.

Figure 20 Solar Market Radar: Status and Progress towards target delivery

**Solar Market Radar: Status and Progress towards target delivery**

| Objective | Indicator | 2014 | 2015 | 2016 | Jun 17 | Total | Status | Comments |
|---|---|---|---|---|---|---|---|---|
| **Inputs** | | | | | | | | |
| **Public support Mechanims** | **Indicator** | | | | | | | |
| 1.1 Preferential finance through BNDES | Nr. of projects financed | 0 | 0 | 0 | 1 | 1 | | First finance in June 2017 |
| | Total amount of financing approved for solar industry (project developers + local suppliers) | 0 | 0 | 200 M | 529 M | 729 M | | Budgeted funds not disbursed |
| 1.2 Publicly held auctions | Capacity demand generated through auction mechanism | 898 MW | 834 MW | 929 MW | 0 | 2.65* GW | | Successfully attracted demand |
| | Auctions held | 1 | 2 | 0 | - | 3 | | 2016 auction cancelled |
| **Output A** | | | | | | | | |
| **Supply Site Actitivity** | **Indicator** | | | | | | | |
| 2.1 Progressive establishment of a national solar equipment value chain | Cumulative number of equipment suppliers in Brazil | 4 | 10 | 34 | 34 + | 34 + | | Investments made |
| | Number of module suppliers with an annual capacity of more than 100 MW | 0 | 0 | 0 | 2 | 2 | | onlly 2 manufacturer |
| **Output B** | | | | | | | | |
| **Demand Site Activity** | **Indicator** | | | | | | | |
| 3.1 Progressive installation of generation capacities through timely implementation of plan | % of financially viable projects | - | - | 7% | 38% | 38% | | Improvements made |
| | % of projects that adhere to the deployment schedule | - | - | 10% | 38% | 38% | | Improvements made |
| | % of projects under construction | - | - | 9% | 19% | 19% | | Status still concerning |
| | % of projects that comply with periodic reporting | - | - | 74% | 88% | 88% | | ok |
| **Outcome** | | | | | | | | |
| **Long-term objective** | **Indicator** | | | | | | | |
| 4.1 Energy Security is strengthened | Sufficient electricity supply | No | yes | yes | yes | yes | | recessionary effect |
| 4.2 Diversification of the electricity mix through solar | Installed capacity of centralized generation | 0 | 0 | 21 MW | 148 MW | 169 MW | | only 2 plants operational |
| | Installed capacity of distributed generation | 15 MW | 40 MW | 63 MW | 100 MW | 100 MW | | residential growth still low |
| | Total cumulative solar cpacities | 15 MW | 40 MW | 84 MW | 248 MW | 269 MW | | Upward trend, yet insignificant |

* This number is also reported as 2,8 GW and 3,1 GW

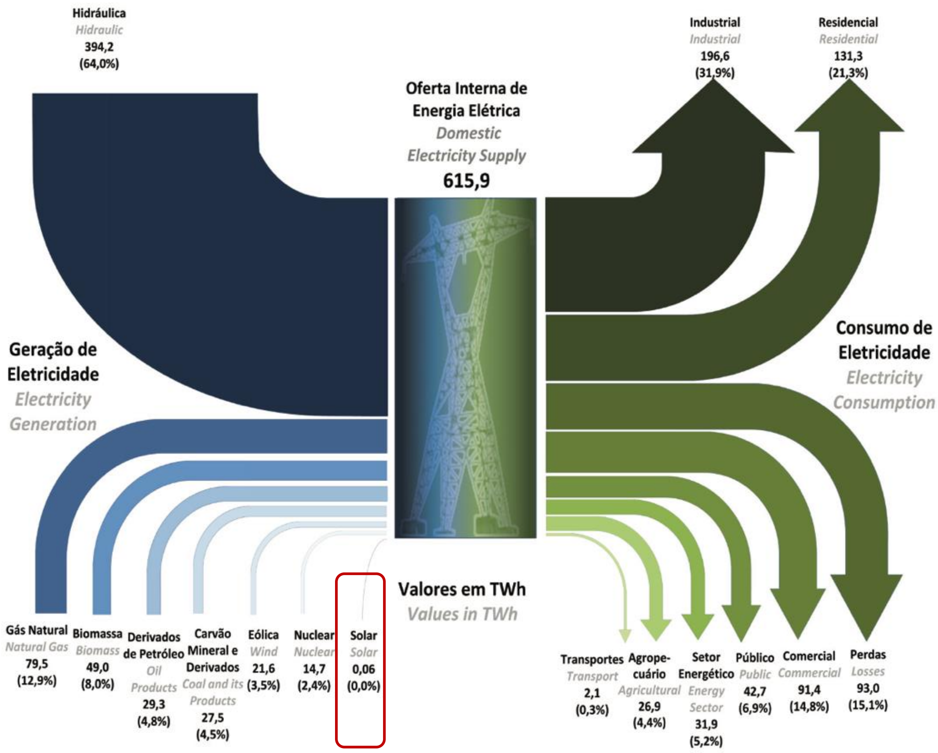
| | |
|---|---|
| | According to plan |
| | Needs attention |
| | Far behind plan |

Source: own elaboration with data from ANEEL, MME, BNEF (2017)

## APPENDICES

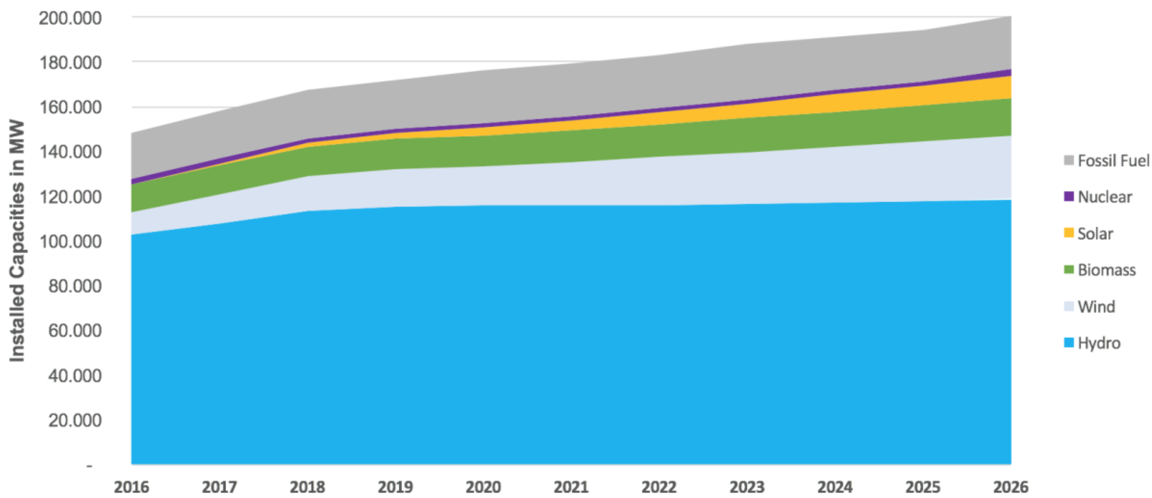
### A. Figures

Figure 21 Electricity Flux – BEN 2016 / year 2015




Source: (EPE, 2016)

Figure 22 10-Year Energy Expansion Plan, 2016 - 2027



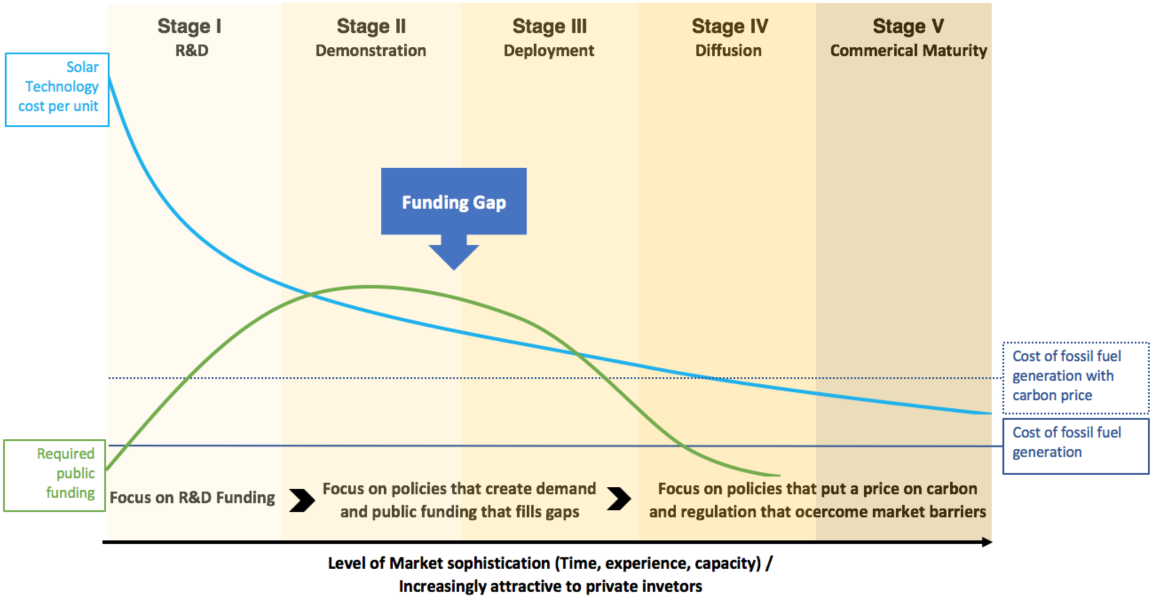

Source: own illustration with data from MME & EPE 2017

Figure 23 Interest Rate Comparison between solar financing mechanisms available in Brazil as of July 2017


Note: Interest rates are only indicative and don't distinguish between company size (MSME or Large Scale) or lending duration (short or long-term). Thus, some interest charges of regional banks are lower than BNDES' key interest rate of 9.1% as they refer to shorter amortization and grace periods as BNDES. The trend is nevertheless visible: state-subsidized loans are much cheaper than those of commercial banks like Itaú or Santander.

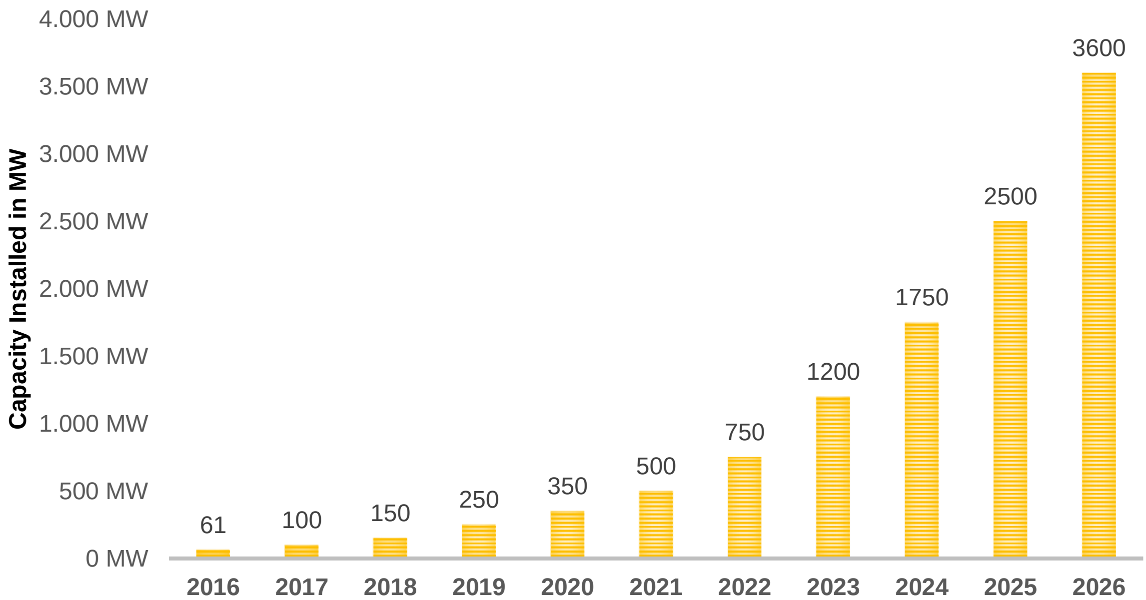
Source: Own elaboration based on Big Data – Websites of individual banks

Figure 24 Innovation Pathway for solar: Funding Gap and Policy need




Source: adapted and modified from IRENA (2012), Lueg et al (2015), and KfW (2005)

Figure 25 10- Year Expansion plan for distributed solar generation in Brazil




Source: Source: own illustration with data from MME & EPE 2017

# B. Tables

Table 8 Financing instruments available for solar projects in Brazil

| Type | Bank | Financing Mechanism | Local Content Requirement | Loan Amount | Interest Rates (per annum) | Repayment Period | Max Participation | Description |
|---|---|---|---|---|---|---|---|---|
| National Development Bank | BNDES | Climate Fund: RE | 60% | > R$ 3 Mio / EUR 800.000 | **2.3% - 6.76%** | 16 years (8 years grace period) | up to 90% of total investment | Support for the implementation of ventures, acquisition of machinery and equipment and technological development related to reduction of GHG emissions and adaptation to climate change and its effects (Interest rates differ based on size of the company) |
| | | PRONAF ECO | 60% | < R$ 165 mil / EUR 45.000 | **2.5% - 5.5%** | up to 10 years (3 year grace) | up to 100% of total investment | Financing to farmers and family farmers (individuals) for investments into renewable energy and environmental technologies, water storage, etc, aiming at improvement of productive capacity. |
| | | FINAME | 60% | n.a. | **9,10%** | up to 10 years (2 year grace period) | up to 80% of total investment | General subsidized loans programm for financing the purchase and sales of machines and equipment incl. solar power projects (BNDES interest rate varies per project between 1.6% and 2.2%) |
| | | FINEM Energia | 60% | > R$ 20 Mio / EUR 6.5 Mio | **9,1% - 13,56%** | up to 20 years | up to 80% of total investment | Subsidized loans programm for financing the expansion and modernization of the power generation infrastructure incl. Renewable energy generaton as well as energy efficiency projects. Loans can also be below R$ in certan cases |
| | | Automatico | 60% | < R$ 20 Mio / EUR 6.5 Mio | **9,10%** | varies | up to 80% of total investment | BNDES Automatió offers directly via BNDES or through accredited financing institutions funding for projects of Micro, small and mediuma sized enterprises that expand their production capacitites e.g. PV systems. Funding varies depending on company size |
| Public Banks | CAIXA | Linha BCD: Durable Consumer Goods | 60% | < R$ 10 Mil / EUR 2700 | **8,9% - 10%** | 5 years (1 year grace) | up to 100% of total investment | General credit line to finance the purchase of new and used machinery, equipment and other goods |
| | | PROGER Investgiro | 60% | < R$ 600 mil / EUR 162.000 | **10,0%** | 5 years (1 year grace) | up to 100% of total investment | Fund directed towards SMEs to support the purchase or sale of machinery and equipment and technological development incl. Solar power installations |
| | BANCO DO BRASIL | PROGER URBANO | 60% | R$ 1 Mio / EUR 268.000 | **9% - 10%** | up to 6 years (1 year grace) | up to 80% of total investment | General subsidized loans programm to finance the renovation of facilities or the purchase of machinery, equipment and motor vehicles (incl. Energy efficiency projects that involve solar technology) |
| Regional Banks | BRDE | BRDE Energia | 60% | R$ 150.000 - 3 Mio EUR 40.000 - 800.000 | **8,1% - 10,5%** | up to 8 - 20 years (2 years grace) | up to 90% of total investment | Subsidized credit line for energy efficiency and renewable energy micro generation projects in Brazil's three soutern states |
| | Banco do Nordeste | FNE Sol | 60% | n.a. | **7.65% - 10.18%** | up to 12 years (1 year grace) | up to 100% of total investment | Subsidized financing for micro- and mini-generation of photovoltaic, wind, or biomass energy systems, as well as the installation of these. Fund is specifically directed towards companies from the North East Region |
| | | FNE Verde | 60% | n.a. | **7.65% - 10.14%** | 12 years (4 years grace period) | up to 100% of total investment | A financing program directed torwards envionmental protection by providing loans to comanies that want to invest in RE |
| Commerical Banks | Sicredi | Solar Energy | - | n.a. | **15% - 19,56%** | 5 years | up to 80% of total investment | Directed towards corporate Loan client associated with Sicredi in need of financing for electric power through solar energy |
| | Itaú | Line of credit BID | - | R$ 330.000 - 1.8 Mio EUR 90.000 - 490.000 | **15% - 19,56%** | 5 years | up to 80% of total investment | Credit line aimed at enhancing sustainability projects. The focus is on investments in renewable energy, energy efficiency and "clean" production methods. |
| | Santander | CDC - Energy Efficiency of Equipment | - | n.a. | **15% - 19,56%** | 5 years | up to 80% of total investment | Any Corporate Loan client in need of financing for machinery and equipment for the promotion of energy efficiency, rational use of water, sustainable construction and accessibility, residue treatment, and corporate governance. |

* TJLP = Taxa de Juros de Longo Prazo (Brazil's long term interst rate, which as of 10.07.2017 is recorded at 7% p.a.)

The interest rates shall only be indicative and typically vary according to the values, terms and other conditions (project purpose) chosen by the customer at the time of purchase

Source: Own elaboration based on Big Data – Websites of individual banks

Table 9 Renewable Energy Auctions in Brazil 2007-2015

| Auction | Date | Type | Wind (MW) | Solar (MW) | Biomass( MW) | Small Hydro (MW) | Large Hydro (MW) |
|---|---|---|---|---|---|---|---|
| Rule MME 070/2015 | 13. Nov 15 | Solar + Wind Reserve | x | 929 | | | |
| Rule MME 069/2015 | 14. Aug 15 | Solar reserve | x | 834* | | | |
| Rule MME 672/2014 | 24. Jul 15 | A3 new | x | | x | | |
| Rule MME 653/2014 | 30. Apr 15 | A5 new | | | x | x | x |
| Rule MME 563/2014 | 10. Apr 15 | Alternative | x | | x | | |
| 010/2014 | 05. Dec 14 | A1 existing | | | 0 | | |
| 008/2014 | 31. Oct 14 | A3 reserve | 769,1 | 889,6 | x | | |
| 006/2014 | 28. Nov 14 | A5 new | 929 | 0 | 611 | 43,88 | |
| 005/2014 | 30. Apr 14 | A0 exisiting | | | 1 | 4 | 1467 |
| 003/2014 | 06. Jun 14 | A3 new | 551 | | | | 417 |
| 010/2013 | 13. Dec 13 | A5 new | 2337,8 | | 161,8 | 307,7 | 700 |
| 009/2013 | 18. Nov 13 | A3 new | 867,6 | 0 | 0 | 0 | 0 |
| 006/2013 | 29. Aug 13 | A5 new | | | 647 | 218,5 | 400 |
| 005/2013 | 23. Aug 13 | Wind reserve | 1505 | | | | |
| 006/2012 | 14. Dec 12 | | 281,9 | | 0 | 0 | 292,44 |
| 007/2011 | 20. Dec 11 | A5 new | 976 | | 100 | 0 | 135 |
| 003/2011 | 18. Aug 11 | Wind + Biomass reserve | 861 | | 357 | | |
| 002/2011 | 17. Aug 11 | A3 new | 1067,6 | | 197,8 | 0 | 450 |
| 007/2010 | 26. Aug 10 | Alternative A3 | 2047,8 | | 712,9 | 131,5 | |
| 005/2010 | 25. Aug 10 | Alternative reserve | | | | | |
| 004/2010 | 17. Dec 10 | Hydro A5 | | | | 0 | 2120 |
| 003/2010 | 20. Jul 10 | Hydro A5 | | | | 79 | 729,9 |
| 003/2009 | 14. Dec 09 | Wind Reserve | 1805,7 | | | | |
| 001/2008 | 14. Aug 08 | A1 reserve | | | 2379,4 | | |
| 003/2007 | 18. Jun 07 | Alternative | 0 | | 541,9 | 96,7 | |
| | | **TOTAL** | 13999,5 | **2652,6** | 5709,8 | 881,28 | 6711,34 |

"X" values existing but not added
"O" means technology eligible but not contracts awarded
* is also reported as 1048 MW
Note: 8.8 GW of solar projects where accredited to participate in the 2014 auction

Source: adapted and modified from IRENA (2015)

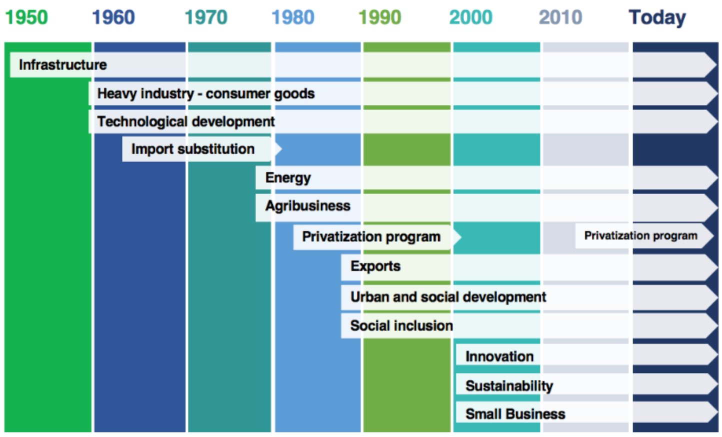
Table 10 Solar auction winners in Brazil from 2014 to 2015: No. of plants, contracted capacities and investments

| | Origin | Plants | | Capacity Potential | | Investment |
|---|---|---|---|---|---|---|
| Companies | | Units | % | MW | % | R$ |
| **Enel** | Italian | 22 | 23,4% | 619,98 | 23,4% | 3.620.872,35 |
| **Candadian Solar Inc** | Candadian | 11 | 11,7% | 360,86 | 13,6% | 1.409.288,06 |
| **Lintran do Brasil Participações S.A.** | Brazil | 9 | 9,6% | 269,97 | 10,2% | 1.151.302,86 |
| **Solairedirect SAS** | France | 7 | 7,4% | 199,98 | 7,5% | 894.048,59 |
| **Sune Solar B.V.** | Netherlands | 5 | 5,3% | 148,57 | 5,6% | 608.626,63 |
| **Renova Energia S.A.** | Brazil | 5 | 5,3% | 129,59 | 4,9% | 622.529,00 |
| **STEELCON** | - | 3 | 3,2% | 90,00 | 3,4% | 610.965,00 |
| **Rio Energy EOL IV Geração e Comercialização de Energia Ltda** | Brazil | 3 | 3,2% | 89,91 | 3,4% | 20.021,00 |
| **European Energy A/S** | Denmark | 2 | 2,1% | 60,00 | 2,3% | 360.468,00 |
| **Fotowatio do Brasil Projetos de Energia Renováveis III Ltda.** | Brazil | 2 | 2,1% | 60,00 | 2,3% | 279.540,00 |
| **SPE CESP COREMAS** | Brazil | 2 | 2,1% | 60,00 | 2,3% | 268.414,00 |
| **Grupo Gransolar S.L.** | Spain | 2 | 2,1% | 60,00 | 2,3% | 252.594,00 |
| **Kawa** | Brazil | 2 | 2,1% | 54,00 | 2,0% | 242.392,00 |
| **KROMA COMERCIALIZADORA DE ENERGIA LTDA** | Brazil | 2 | 2,1% | 46,56 | 1,8% | 186.240,00 |
| **RODRIGO PEDROSO INVESTIMENTOS E PARTICIPAÇÕES SA** | Brazil | 1 | 1,1% | 43,44 | 1,6% | 173.760,00 |
| **Quaatro Participações S/A** | Brazil | 2 | 2,1% | 40,00 | 1,5% | 158.946,10 |
| **Solatio Gestão de Projetos Solares Ltda.** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 129.428,22 |
| **INTECO ADX** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 171.541,00 |
| **RIO ALTO** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 143.042,00 |
| **EXITO IMPORTADORA E EXPORTADORA SA** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 120.000,00 |
| **TRACTEBEL ENERGIAS COMPLEMENTARES PARTICIPAÇÕES LTDA.** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 149.769,02 |
| **Construtora A. Gaspar S/A** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 133.265,67 |
| **NSG INDUSTRIA DE CONSTRUÇÃO E PARTICIPAÇÕES EIRELI** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 129.168,70 |
| **Supernova Investimentos e participações Em energia** | Brazil | 1 | 1,1% | 30,0 | 1,1% | 126.389,48 |
| **ORIGIS INVEST LTD** | USA | 1 | 1,1% | 24,0 | 0,9% | 94.878,40 |
| **Eólica Tecnologia Ltda** | Brazil | 1 | 1,1% | 15,0 | 0,6% | 90.071,94 |
| **FCR VII Usina de Energia** | Brazil | 1 | 1,1% | 10,0 | 0,4% | 529.210,00 |
| **Companies with less than 10 MW contracted capacity** | - | 3 | 3,2% | 32,0 | 1,2% | 134.482,72 |
| **TOTAL** | | **94** | **100%** | **2653,8** | **100,0%** | **12.811.254,74** |

Source: adapted and modified from Andreão et al (2017)

Table 11 Evolution of BNDES’ development efforts in Brazil

The Brazilian Development Bank, Banco Nacional de Desenvolvimento Econômico e Social (BNDES), was founded in 1952 as a government agency with the objective of “developing and carrying out national economic development policies” (BNDES, 2017a). Initially, the then called “BNDE”[41] financed mostly infrastructural projects to fund Brazil’s catch up strategy after the 2nd World War. In the 1960s, however, its mandate incrementally broadened to include the agricultural, livestock and small and medium-sized (SME) sectors, followed in the 1970s by the promotion of Brazil’s import substitution industrial policy and support for energy and agribusiness in the 1980s. In the 1990s, it played a fundamental role in supporting Brazil’s privatization efforts, assisting in the sale of large state-owned companies, next to an increasing focus on rural development through more investments into micro, small & medium enterprises (MSMEs) and social inclusion. After 2000, BNDES further widened its operational scope towards financing innovation-led growth while focusing increasingly on sustainability issues such as green lending and renewable energy finance (BNDES, 2017a).




Source: adapted from BNDES, 2017b

Despite its successful promotional role, most prominently seen with its countercyclical response[42] to the global financial crisis in 2008/2009, BNDES also faced increasing criticism in recent years for its excessive credit expansion strategy during the economic boom years that contributed the ongoing economic crisis (Bolle, 2015).

Table 12 Key Facts about the Brazilian Development Bank as of May 2017

| | | | | |
|---|---|---|---|---|
| **Vision** | To be the development bank of Brazil, innovative, outstanding, and to proactively tackle the current and relevant challenges of our society | | | |
| **Mission** | To foster sustainable and competitive development in the Brazilian economy, generating employment while reducing social and regional inequalities | | | |
| **Ownership** | 100% state-owned company under private law | | | |
| **Team & Offices** | Team of 2,791 employees<br>HQ in Rio de Janeiro, offices in São Paulo, Brasília, Recife, Belém | | | |
| **Funding** | National Treasury (50%)<br>FAT – Workers’ Assistance Fund[12] (27%) | | International borrowings (5%)<br>Revolving Funds | |
| **Financials 2016 *** | Loan Portfolio: | US$ 182 billion | Loan Portfolio: | US$ 1.96 billion |
| | New commitments: | US$ 27 billion | Assets | US$ 269 billion |

* All figures as of 31 Dec 2016 / Exchange rate R$ 1 = US$ 3.26

Source: own elaboration based on data from BNDES website and annual reports (BNDES, 2017b; Mazzucato & Penna, 2015)

[41] *Initially only called “Banco Nacional de Desenvolvimento Econômico”*
[42] *BNDES provided cheap credit to Brazilian companies during the financial crisis and was thus able to “counter” or minimize the negative effects on the economy*

Table 13 Old Methodology: Local Content Requirements for Thin-Film PV Technology

**B. Thin-film Technology**

**Table 1: PHOTOVOLTAIC MODULE**

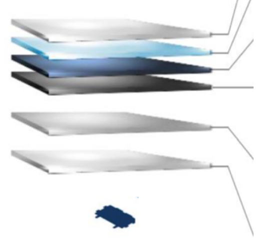
| | | | 2014-Dec/2017 | | Dec/2018 - | |
|---|---|---|---|---|---|---|
| | **Components** | **Level of Requirement** | **Classification** | **% Adjustment** | **Classification** | **% Adjustment** |
| Photovoltaic Module – Materials | Front (Substrate) Glass | Made in Brazil with local content Glass (low iron), Plastic or metal | Red | 20% | Red | 20% |
| | Thin-Film Compounds | Made in Brazil | Yellow | 10% | Yellow | 10% |
| | Junction Box | Made in Brazil with local content | Yellow | 5% | Green | 70% |
| | Back (cover) Glass | Made in Brazil with local content Glass (common) or metal | Green | 60% | Green | |
| | Frame | Made in Brazil with local content | Green | | Green | |
| Photovoltaic Module – Processes | Module encapsulation | Lamination processes and final assembly | Green | | Green | |
| | Definition of cells | Laser marking process or other method | Red | 10% | Green | |
| | Deposition of layers | Fine Film Deposition Processes | Red | 20% | Green | |
| | | **Minimum Module Nationalization factor - "N Factor" (%) (Only basic items)** | **60%** | | **70%** | |

**Table 2: PHOTOVOLTAIC SYSTEM**

| | | | 2014-Dez/2017 | | Jan/2018 - | |
|---|---|---|---|---|---|---|
| | **Components** | **Level of Requirement** | **Classification** | **% Adjustment** | **Classification** | **% Adjustment** |
| Photovoltaic System – A' | Minimum Module Nationalization factor - "N Factor" (%) | | | 60% | | 70% |
| A' | of the MODULE in the system (%) | | | 60% | | 60% |
| A | Module | Basic items defined in Table 1: Photovoltaic Module Thin Film Technology | Green | **36%** | Green | **42%** |
| B | Electrical Components (String box + Cabling) | Made in Brazil with local content | Green | **20%** | Green | **40%** |
| B | Metal structure (lift) | Made in Brazil with local content | Green | | Green | |
| C | Inverter | Made in Brazil with local content | Yellow | **20%** | Green | |
| | | **Minimum Module Nationalization factor - "N Factor" (%) (Only basic items)** | **56%** | | **82%** | |
| | | **Minimum Module Nationalization factor - "N Factor" (%) (basic items + inverter)** | **76%** | | **82%** | |

Yellow: Optional Items; Green: Basic Items; Red: Premium Items

**NOTE**: A 6% adjustment to the "N Factor" will be considered if the PV module used has ENERGY CLASSIFICATION "A" according to ENERGY EFFICIENCY TABLE - PHOTOVOLTAIC ENERGY SYSTEM - MODULES available on the INMETRO website.







Source: adapted, translated and modified from BNDES, (2016 a, b)

## C. Photos

UNCCC 2015 Paris Climate Change Agreement: Brazil’s (Temer) long-term commitment to solar

Source: Sauaia (2017)

Lapa Solar Park in Bahia - Brazil's first utility scale solar plant

Source: (Enel, 2017b)

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