Financing the expansion of photovoltaic power generation in Brazil: challenges of using similar mechanisms for different renewable sources[+]

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Overview
The Brazilian Development Bank (BNDES) has been the main source of funding for wind generation. Its main financing program (Finem) is considered a success in its attempt to promote wind generation in Brazil. It was expected from solar generation to go down a similar successful path, using the same promotion and financing mechanisms as wind power generation. However, this has not been verified. There are several delayed solar power plants and most of them are unlikely to go into operation on schedule. Therefore, we analyse how using for solar generation the same financing mechanism used for wind generation accounts for Brazil's unsuccessful attempt to promote solar farms when in comparison with its successful attempt to promote wind farms. For that we will: compare solar and wind technical and economic differences; describe the financing mechanisms used; and show the results for both sources, relying on data and analysis currently available. The development of a solar program in Brazil must choose between the development of stronger policies and financing mechanism to internalize the production of solar generation in Brazil; or the promotion of a policy to increase solar capacity in the country (changing the local content restrictions). The current financing mechanism became a barrier to expand the use of solar energy which is a waste of the Brazilian enormous solar potential.

Keywords – Photovoltaics, PV, finance, State Financing, Financing mechanisms, BNDES, Brazil

1. Introduction

Brazil is a country with a largely clean and renewable electric mix, alongside an extraordinary use of hydro power generation. Lately, there's been a great expansion of wind power generation (in its centralized form) in Brazil. The other important new renewable, solar power generation, is undergoing its first steps towards a similar expansion in the country. Brazil aims to foment solar farms taking advantage of its high potential for solar energy. However, there's a low viability of most of the Brazilian solar expansion, especially relative to the schedule and construction of its already planned and contracted solar farms. Most are not currently under construction.

The scope of this work refers to centralized photovoltaic (PV) power generation. We chose this over the distributed generation partially because of the fact that Brazil relies heavily on a traditional model of generation with large centralized power plants. Also, decentralized generation can be done by various agents (from small to large producers). This would broaden significantly the scope of analysis and also require the examination of various mechanisms that are not present in the other kinds of (centralized) power generation. Lastly, the main objectives of grid-connected centralized and distributed PV generation are different: centralized power generation aims to generate and transmit energy from the power plant to the consumer; whereas distributed power generation aims to reduce the dependence on the grid or the consumption of electricity (from the grid) through self-production and self-consumption.

Therefore, we analyze the reasons behind the issue. As such, this article is divided in five sections, apart from this introduction. In the first section we analyze the mechanisms behind the promotion of renewables in the country. Then we investigate how the evolution of solar developments. We then analyze the compatibility between financing mechanisms and financing objectives. Lastly, we present our closing remarks.

2. Current Brazilian framework to promote renewables

Brazil is a country with favorable numbers and projections for most renewable sources: it largely uses hydro power; it is promoting wind power generation in a rapidly growing context; and is now starting to promote solar power generation. Since 2004[1] there has been a resumption of medium and long term planning in the Brazilian electrical sector. There's a real possibility of a clean and renewable expansion of the Brazilian electric mix (PEPITONE, 2016; CAMPOS NETO, 2016). That follows the call for the maintenance of the

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[1] According to Campos Neto (2016), the expansion of new renewables is fairly recent in Brazil, happening since mid to late 2000's.

clean Brazilian energy mix[2] (ALMEIDA; BICALHO, 2014) and follows the international move towards a more renewable and sustainable electric mix (PODCAMENI, 2014; GREEN; STAFFEL, 2016).

There are two severe problems in the renewable promotion in Brazil: on the spot market; and on the stock market (Vazquez, 2015). Both problems are solved through state decisions: through generation auctions; and through state financing. According to Pepitone (2016), auctions played an important role in the current expansion of Brazil's installed capacity. Ferraz (2015) also understands that auctions in Brazil play an important role in solving the problems related to the intermittence of renewable sources, being this mechanism different from the European solution. Also, through the auction mechanism, the developments access special state financing lines. This is cardinal in order to promote infrastructure in the country.

It is expected that, in 2024, the wind farms installed capacity will add up to 24 GW, and that the solar farms installed capacity will add up to 7 GW (EPE, 2015). In October 2016, 9.71 GW (6.12%) and 27 MW (0,02%) were the numbers for, respectively, solar and wind sources installed capacity (ANEEL, 2016a). Wind and solar power generation were responsible for 21,626 GWh (3.72%) and 59 GWh (0.01%) of the total electricity generated in Brazil in the year 2015 (EPE, 2016). Therefore, it is expected from the new renewables to be promoted through State planning and funding.

We now analyze their roles, first the auction mechanism, then the state financing mechanism.

2.1. Incentives by market Design - Auctions

The Brazilian framework for promoting the expansion of its installed capacity is an auction mechanism for power generation[3]. It emphasizes *ex-ante* competition, selecting competitive projects. Ferraz (2015) understands that the contracted power is verified through the monitoring of the negotiated coverage or physical guarantee. Auctions mitigate risk and facilitate the access to state funds regarding infrastructure investments.

There are different auction mechanisms depending on its objective. Its main auctions are those aimed for new projects. The most common types are A-3 and A-5 auctions, i.e., auctions happening three or five years prior to the auctioned plants commercial operation (PINTO JUNIOR, 2007). Several wind farms were auction winners on those, in which there's open competition between different sources. This means that wind power generation in Brazil is currently competitive when in comparison whit its rival sources[4].

Wind farms have been present in auctions ever since the Reserve Energy Auction (LER[5]) of March 2009. This type of auction is aimed at enhancing the safety of the Brazilian power system, and by having less sources competing, it is easier for less competitive power sources to win. Therefore, it[6] is the best suited type for incipient sources of undeveloped industrial chains, such as the wind power was in the late 2000's and the solar power currently is[7]. From 2009 until 2016, there were 509 wind farms contracted, spanning 13,370.45 MW of contracted capacity (ANEEL, 2016i).

Solar farms are in a less developed state, with only three auctions (all of them LER auctions), with 94 plants and 2,652.8 MW of installed capacity contracted. Also, from the first to the last auction, the average MWh price has fallen from US$ 88 to US$ 78 according to ABSOLAR (2016). According to Jannuzi (2009) and Sekiguchi (2014), specific solar auctions are a major incentive in the promotion of the solar source generation[8]. They could also incentivize its industrial chain (of parts, components and also assembly processes) through a planned and expected demand. According to Ferraz (2016) and Sitawi and CEBDS (2016), annually solar auctions (LERs) adding up to 1 additional GW per year are expected, being this the least necessary for structuring a supply chain in Brazil (ABSOLAR, 2016).

We now analyze the companies that won the three auctions involving PV generation, LER 08/2014, LER 08/2015 and LER 09/2015. The four main companies (Enel, Canadian Solar Inc, Lintran do Brasil Participações S.A., and Solairedirect SAS) together have 52.12% (49 units) of all solar power plants and

[2] They emphasized the promotion of new renewables, especially, solar and wind power generation.
[3] There are also auctions for transmission, which we do not analyze.
[4] However, its generation auctions history begun in more specialized auctions, aimed at promoting such source.
[5] Acronym for "Leilão de Energia Reserva" in portuguese.
[6] Alongside the rarely used Alternative sources auction ("Leilão de Fontes Alternativas" in Portuguese).
[7] For more information on Brazilian power auctions, we suggest readers to check ANEEL's explanation on them: http://www.aneel.gov.br/resultados-de-leiloes
[8] According to Moreno and Weiss (2016), the solar source in Brazil is currently one of the less competitive generation sources. This is due to the high internal costs of its components and to a still low capacity factor when compared to its competitors.

54.13% (1,419.9 MW) of all installed capacity[9]. Just the two biggest companies regarding capacity (Enel and Canadian Solar Inc) have almost 1 GW of planned capacity combined. From this, regarding power plants and capacity, these companies are extremely important to the promotion of solar power generation in Brazil. Having analyzed the auction mechanism, we now analyze the financing mechanism in the following section.

2.2. Incentives by financing mechanisms – the role of the Brazilian Development Bank

According to Campos Neto (2016) and Tomelin (2016), the National Bank of Development[10] (BNDES) plays an important role regarding the electrical sector in Brazil. The role it plays regards financing and funding. Since BNDES financing schemes have lower interest taxes than most private financing mechanisms, accessing its financing lines is essential to most infrastructure companies in Brazil.

BNDES' mechanism is not the only one (private or public) available in Brazil, however it is the prominent one (TOMELIN, 2016). Regarding BNDES, the Finem (Financing to Enterprises)[11] fund is the most important financing mechanism for infrastructure (and therefore, power), and regarding wind farms it is especially important, rising in disbursements as this source begin to gain importance in the auctions: it has financed up to 90% of the installed capacity of wind power generation. (SITAWI; CBDES, 2016; TOMELIN, 2016).

BNDES, through its financing mechanisms, promotes the internalization of industrial chains, i.e., it exercises industrial policy through local content criteria. The bank has rather strict access criteria. For one to access the Finem fund, one must respect its local content requirements. Although there are other financing mechanisms and funds inside BNDES, we focus on the Finem fund and its access criteria. Those are progressive, starting on easier (regarding technology, costs and other factors) sectors and moving up to more technologically developed (and therefore challenging) sectors (PODCAMENI, 2014; FERREIRA, 2013). There are also means of monitoring if one is respecting the required levels of local content, that are different for each source. This is basically done through the "Computerized Manufacturers Accreditation"[12] (CFI): the component seller company must be accredited there.

The required segments in the production of parts or its assembly must be done inside the Brazilian territory by national or multinational companies. BNDES has some fine tuning to do: too high of a local content requirement and the companies will not be able to access its funds; too low of a local content requirement and the national industry will not be incentivized through it.

Solar and wind sources have different access criteria and methodologies. We now analyze them separately.

2.2.1. Financing wind power generation

Focusing on weight and parts, the local content criteria for accessing BNDES' fund to finance wind turbines is already on its last phase as of January 1st 2016 (BNDES, 2012). However, according to Ferraz (2014), there is still room for a better development of the wind farms industrial chain, albeit rather consolidated as it is.

According to Sitawi and CEBDS (2016), from 2003 to 2014, BNDES has financed 237 power generation projects, with 48 of them being wind farms, respectively, 47,236 MW and 4,912 MW. The bank has financed about 90% of the Brazilian wind installed capacity (TOMELIN, 2016).

There are criteria which the manufacturer must choose between (starting point) and different levels for wind turbines with or without a certain part (multiplier box) (BNDES, 2012). From this point on, the responsible for the enterprise must follow the calendar of national components, regarding the parts and weight.

Regarding the actual funding, BNDES fixes its maximum participation on 70%. The financing can be done directly through BNDES, with an interest rate between 9.4% and 13.86% per year (a fixed 7.5% of Long term interest rate (TJLP[13]) of Brazil and a margin for BNDES) for companies. For indirect financing, done through a financial institution accredited by BNDES, besides the TJLP and the BNDES' margin, there's also a rate negotiated between the organization and the client. The amortization period is 16 years and there are collaterals for all modalities (BNDES, 2016).

We now analyze the financing mechanism of solar power generation in Brazil.

2.2.2 Financing solar power generation

With a mechanism heavily inspired by BNDES' prior successful attempt at financing wind power generation (BNDES, 2014a), it lets go of the weight and parts criteria, introducing a more sophisticated method: N factor.

[9] For more information, the complete table is available in the Appendix.
[10] "Banco Nacional de Desenvolvimento Econômico e Social" in portuguese
[11] "Financiamento a empreendimentos" in portuguese.
[12] "Credenciamento de fabricantes informatizado" in portuguese.
[13] "Taxa de Juros de Longo Prazo" in portuguese

This number is achieved by adding up the individual percentages of items and processes. BNDES financial support is equal to its maximum participation percentage (80%) multiplied by the N factor. Higher N factors lead to larger BNDES' participation. Such change was done allegedly to permit a more flexible internalization of this industrial chain (BNDES, 2014a). Similar to the financing of wind farms, it can be done directly through BNDES, with an interest rate between 9.4% and 13.86% per year (a fixed 7.5% of TJLP and a margin for BNDES) for companies. For its indirect counterpart, done through financial institutions accredited by BNDES, besides the TJLP and the BNDES' margin, there's also a rate negotiated between the organization and the client. The amortization period is 20 years and there are collaterals in both direct and indirect modalities (BNDES, 2016).

Regarding the access criteria (BNDES, 2014b), it differentiates between thin film and silicon solar panels[14], and also has a criteria for solar systems. There are three kinds of items: basic, optional and premium. Basic items must be made out of national components or processes, respecting each individual N factor. Optional items and premium items are not part of the obligatory items required for access, however, their N factor is added up to the total N factor of the enterprise[15].

The bank differentiates between silicon solar panels and thin film panels. Its methodology also differentiates the N factors for the panels and the whole PV system (module, electrical components, structures and the inverter). All technologies are currently on its first period (generally divided between two or three internalization periods). The N factors[16] range from 40% to 82% between the first and the last period.

Having analyzed the two mechanisms for promoting renewables in Brazil, we now review the evolution of the solar planned expansion. First we analyze the differences between the solar and wind power generation sources, regarding economical and technical characteristics.

3. Development of solar and wind power generation in Brazil

Brazil is investing and expanding wind power generation according to various sources and different authors (ANEEL, 2016a, 2016b, 2016g, 2016i; CAMPOS NETO, 2016; FERREIRA, 2013; PODCAMENI, 2014; SITAWI; CEBDS, 2016). This expansion, since the late 2000's, was phenomenal in the country (ANEEL, 2016b, 2016i) and wind is now a fairly important power source in Brazil (ANEEL, 2016a).

For us to analyze the evolution of the investments in the solar source (in comparison with the wind source), first we analyze the technical and economical differences between both sources.

3.1. Technical and economic characteristics of the new renewable sources

The new renewables[17] are a rather technologically heterogeneous group. Wind and solar plants generate power through different sources, each with its characteristics and specificities that we now analyze.

3.1.1 Wind Power Generation

Wind energy is a form of kinetic energy, resulting from air pressure differentials due to solar irradiation and geographical characteristics. The wind turbine is the equipment that transforms wind energy in electric power, between certain determinants (as wind behavior, direction, velocity, etc.). The amount of generated power is a function of air density, the blade area (covered while spinning) and the wind speed (PODCAMENI, 2014). That means that wind turbines can improve its performance through the blade area and by accessing more fast or stable winds.

According to the author, wind turbines are divided by three classifications: regarding its axis direction; its location; and its potency. Regarding the axis direction, it can be vertical or horizontal, being the last one the most used. Regarding its location, the turbines can be located on shore or off shore. Lastly, regarding its potency, there are three sizes of wind turbines: small (up until 0.5 MW); medium (from 0.5 MW to 1 MW); and large (from 1 MW upwards). This is the one generally used in wind farms[18].

In regards to the horizontal axis wind turbine, there are blades (generally three) connected through an axis to a generator inside a component named "nacelle" that can have other components, such as a multiplier box or a

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[14] The next section expands on the technical and economic characteristics of solar power generation (and also wind power generation), explaining this division.

[15] The difference between the last two is that optional items add up its N factor *after* being incorporated into the solar module, whereas premium items do it *before*. The reason for such differentiation is that premium items are more technologically advanced or costly than optional items.

[16] For more specific information on the matter, we strongly suggest the reading of BNDES (2014b)

[17] Renewables with the exception of hydro power generation

[18] Brazil (and most countries) utilizes horizontal, on shore and large wind turbines in its wind farms.

gear box. All these components are put on top of a tower, for the wind turbine to access more fast and stable winds[19].
For Podcameni (2014), the industrial chain of wind turbines is a rather concentrated one, largely dominated by big transnational companies. However, all of them have, in its country of origin, a still relevant market for their products and most of them were able to grow in size and capture market share through state policies regarding economic viability and innovation. The author states that the policies, spanning industrial, innovative, energy and other classifications were a determinant factor in their entry success and in the maintenance of their prominent position.
We now analyze the characteristics of solar power generation.

3.1.2. Solar Power Generation

We will focus our analysis on the PV solar generation[20]. Sunlight strikes the earth in different ways, and the PV generation depends largely on the diffuse horizontal irradiation (sunlight that goes through clouds, dust, etc.), part of the horizontal global irradiation (EPE, 2012).
The solar cell is the *locus* of the photovoltaic effect, which is the transformation of sunlight in electrical energy (EPE, 2012), generating direct current electricity in each of those 1 W to 1.5 W solar cells. Those are combined into solar panels (generally up to 250W (EPE, 2012)), which can be made out of different materials, being the ones made from silicon the most predominant and widely available types of panels (JANNUZI, 2009; EPE, 2012). Silicon panels can be made out of monocrystalline or policrystaline silicon. Silicon solar panels are positively affected by solar irradiation levels and negatively by temperature, although thin film panels are not as affected by it. Thin film panels are cheaper but have less output than its silicon counterpart: they need larger areas for a power generation as effective as silicon panels. This source does not generate noise and has no inertia (ABSOLAR, 2016; GREEN; STAFFELL, 2016), which can make the electric power generation range from ±50% in between 30 and 90 seconds intervals and ±70% in between 2 and 10 minutes intervals (EPE, 2012). However, like wind power generation, the dispersion of solar farms can largely reduce this variability.
When on-grid systems (centralized generation) are used, there needs to be a conversion from direct current to alternate current, through inverters (EPE, 2012). Also, on-grid solar power generation cannot substitute other generation sources, because of its intermittence. However it can be used in place of more costly or polluting sources[21] (EPE, 2012; GREEN; STAFFELL, 2016).
Brazil has a great daily average solar irradiation number per year, which is a strong incentive in the promotion of such source. Also, the solar resource in Brazil is well distributed countrywide, and the solar potential is higher than the wind potential, in regards to power generation (ABSOLAR, 2016). The worst area regarding PV power generation in Brazil (1500 (kWh/m²)/year) is greater than the German average (1250 (kWh/m²)/year) (PEPITONE, 2016). There is possibility of coordination and integration between solar power generation and hydro power generation (PEPITONE, 2016; ABSOLAR, 2016). According to EPE (2012), the Brazilian solar resource also has intra-year variability lower than that observed in hydro and wind generation. The best irradiation numbers (regarding average irradiation and cloudiness) appear on the northeastern region of Brazil, and the worst on its southern region[22] (EPE, 2012).
Regarding the industrial chain of silicon solar panels, it is divided by EPE (2012) into five segments: raw material production, i.e., making of metallurgic grade silicon out of quartz; refinement, i.e., production of solar grade silicon; treatment, generating wafers, solar cells and PV modules; complementary equipment, such as batteries, converters, inverters and brackets; and lastly, application, i.e., generating power. EPE (2012) projects an increase in thin film solar panels participation among the total, however, silicon based panels will maintain its major importance
Refining metallurgic grade silicon (99.5% purity) to solar grade (99.9999% purity) is generally done through the energy intensive Siemens process, producing a toxic and corrosive waste (EPE, 2012). The energy costs are responsible for 25% of the total in such process. This stage is much more concentrated than all other stages in this already concentrated chain. Brazil has large high quality quartz reserves and already holds refining

[19] They are positively correlated to the altitude.
[20] We leave out the heliothermic generation, which uses solar irradiation to generate heat, which in turn generates steam that powers a steam turbine, rather similar to other thermic power plants.
[21] At least until storage is not a possible or practical solution in large scale.
[22] The northeastern region is at the same time adequate for solar and wind power generation in the country.

industries, albeit they only can refine up to metallurgic grade silicon. Brazil is currently unable to produce solar grade silicon[23].

Having differentiated between the two sources, we now analyze the evolution of investments regarding solar farms in Brazil.

3.2. The evolution of investments

According to the auction's results, (ANEEL, 2016b, 2016i) up until September 2016[24] there were 2652.8 MW contracted for commercial operation beginning in 2017 and 2018. However, the figures clash with the planned expansion. ANEEL (2015a, 2016c, 2016d, 2016e) analyze the expansion of planned plants by: viability (probability of entering operation on schedule); schedule (how close the construction is to its schedule); and progress of construction (if they are on construction or not, or halted).

Table 1 – Forecast for entry into operation – October 2016 to August 2022 – Brazil

PV Power Plants - UFV - MW									
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**without forecast**	**∑**
-	202.00	-	-	-	-	-	-	-	**202.0**
-	885.99	1.029.47	835.66	-	-	-	-	-	**2,751.1**
-	-	-	-	-	-	-	-	-	-
-	**1,087.99**	**1,029.47**	**835.66**	**-**	**-**	**-**	**-**	**-**	**2,953.1**

No restrictions for entering operation	(green)
Some restrictions for entering operation	(yellow)
Severe restrictions for entering operation	(red)

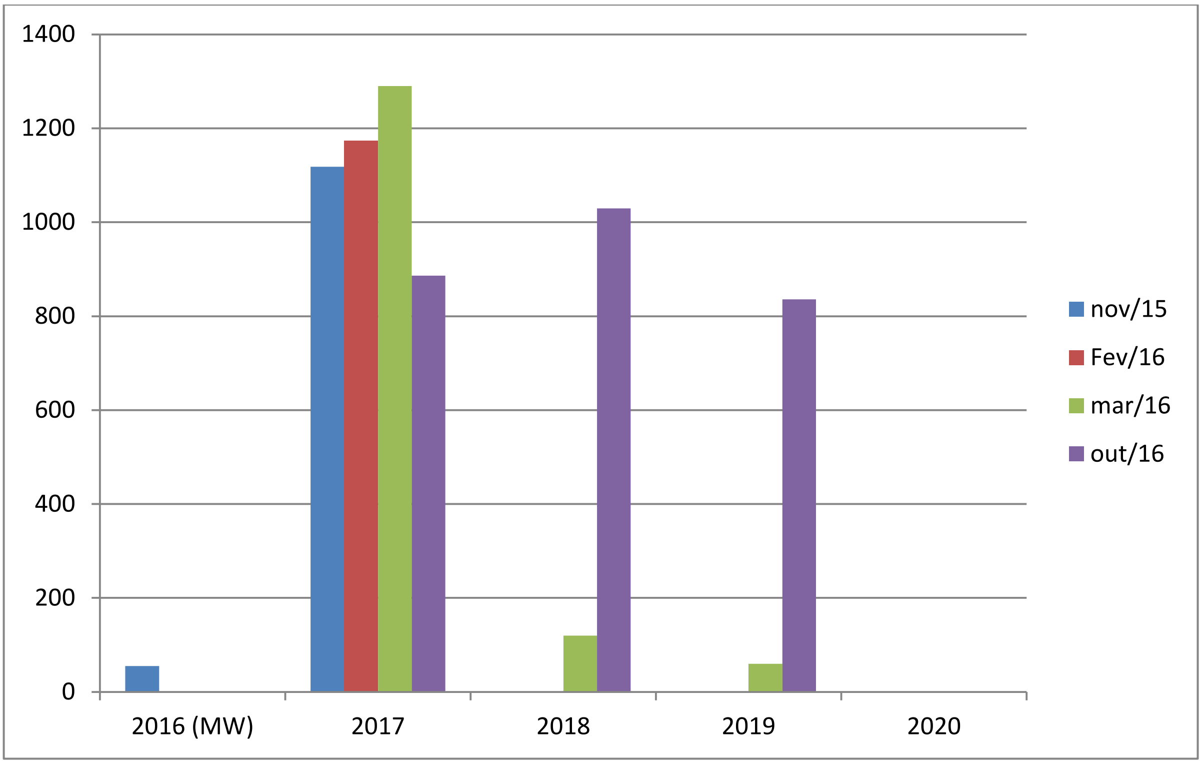
Source: Own translation from ANEEL (2016g)

Regarding the viability of enterprises, the table 1 shows a concerning figure, that only 7.34% of all planned solar capacity has no restrictions for entering operation in 2017. That accounts for 202 MW out of the 2,953.1 MW expansion expected for 2017-2019 period (ANEEL, 2016f). Analyzing the commitment to schedule and the progress of construction of the Brazilian solar plants, the numbers are concerning: until October 2016 there were no plants with an advanced schedule; and until the same month there were no plants under construction (ANEEL, 2016e).

Graph 1 – Solar Farms power entry forecast – MW – November 2015 to October 2016 - Brazil

[23] According to EPE (2012), the Rio Grande do Sul state has a (competitive) solar panel pilot plant. In that way, Brazil can internalize such industrial chain first through: its most concentrated end (refining silicon until solar. grade); or through solar cells, panels and modules industries (EPE, 2012), if the focus is on items.

[24] From September on there were later auctions, but none had solar farms as winners.



Source: Own elaboration based on ANEEL (2015a, 2016c, 2016d, 2016e)

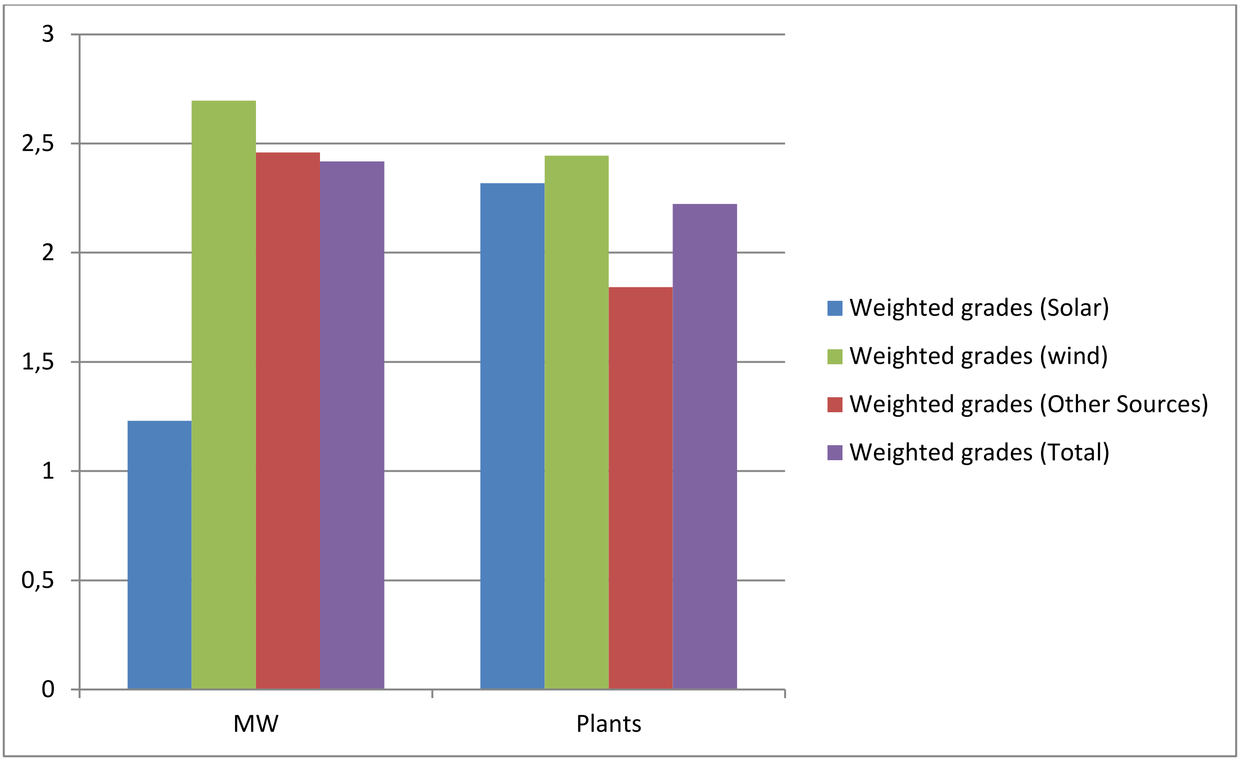
At November 2015 of the review there were 55 MW scheduled for commercial operation in 2016 (ANEEL, 2015a). All were revised to enter operation in 2017 as of the February 2016 report (ANEEL, 2016c). Only at the last review (ANEEL, 2016e), in October 2016, there were 9 plants under construction (270 MW total), with only 6 of them also with high viability (180 MW) and only 5 also with an advanced schedule (150 MW). All 9 plants were owned by the Enel group.

Therefore, out of the 2.9 GW of planned installed capacity expansion only 9.14% were under construction (8,91% of all planned solar farms) as of October 2016 (ANEEL, 2016e). In contrast with wind power generation, in October 2016, 2,910.4 MW or 34.78% of the capacity were under construction (34.82% of plants , or 49 wind farms) and 15.61% of the plants were on advanced schedule (ANEEL, 2016g).

ANEEL has an indicator regarding the delivery of the enterprises called ESCALADA, reviewing the RAPEEL report. This report must be completed and sent by the entrepreneur every four months, regarding schedule, construction, environmental license condition, etc. (ANEEL, 2016h). There are four grades regarding the commitment to the RAPEEL report monitoring: 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). Such grades are the quarterly average of the monthly agent behavior that are indicated from zero to four: a “zero” indicates that the agent did not send the report; a “one” indicates that the report was sent out of the tolerance period; a “two” indicates that it was uncompleted, incorrectly answered or answered without standards; a “three” indicates that it was sent in the tolerance period albeit delayed; and a “four” indicates that it was sent on schedule. This report analyses 110 solar power plants (ANEEL, 2016e). The graphs 2 and 3 summarize its results.

We elaborated the graph 2 through a simple weighted average of the grades regarding installed capacity (in MW) and plants (in units). The number three corresponds to the “A” grade and the number zero to the “D” grade. The table shows that the grades regarding the installed capacity of wind power generation is higher than other sources and than the total average. However, the solar power generation grades are lower than all three grades (between “C” and “B” grades), meaning that the average solar MW is less committed than the average MW of wind, other sources and all power plants analyzed. We also emphasize, as means of comparison, that the wind farms grades, regarding plants and capacity, are much higher than the other sources (without solar) average and also higher than the total average.

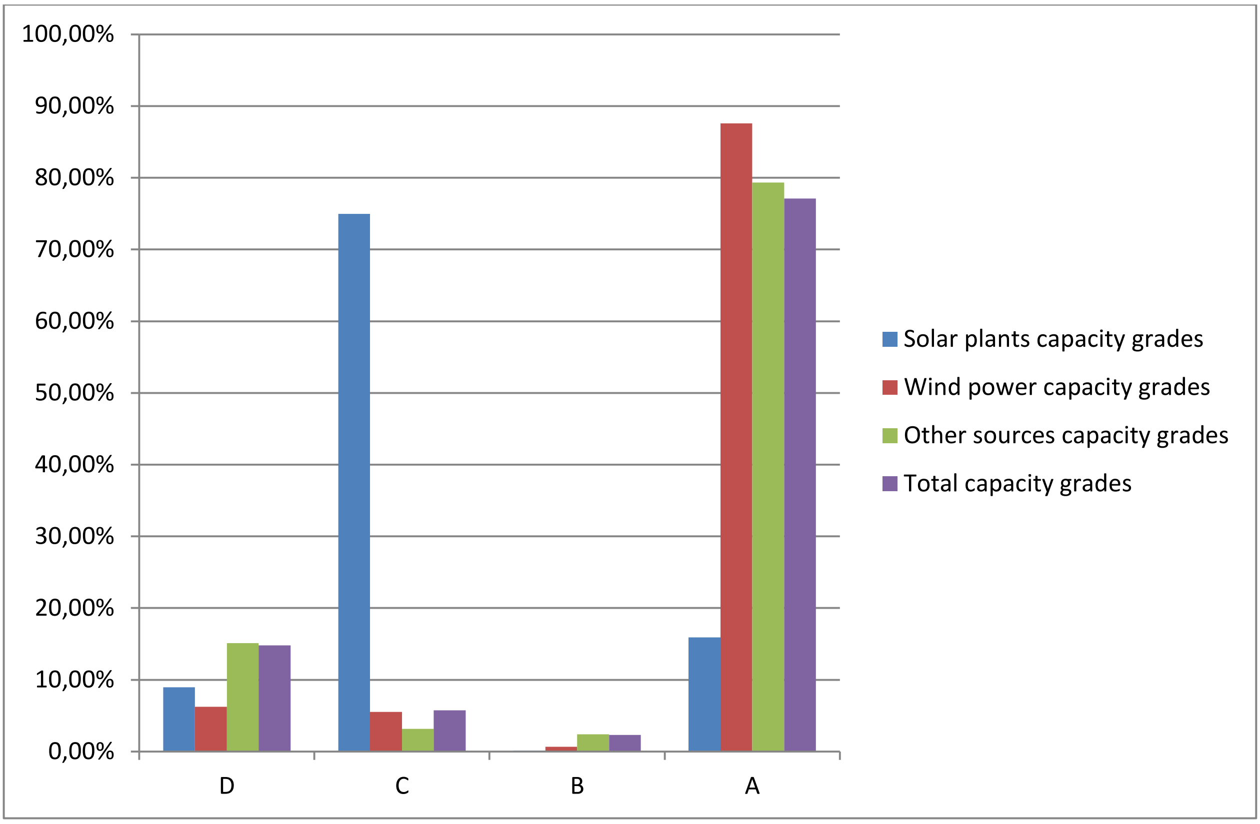
Graph 2 – RAPEEL grade (weighted) regarding Solar, Wind, Other Sources and the total plants and capacity – MW and Units – May 2016 to August 2016 – Brazil



Source: Own elaboration based on ANEEL (2016h)

Analyzing the distribution of grades through sources in the graph 3, we conclude that most of the MWs of solar farms are allocated under the "C" grade, unlike all other sources. With 74.96% of all solar capacity under such low grade, we understand that most of this source capacity fails to commit to the RAPEEL report. That confirms the problems regarding the financing of the construction and other issues, such as environmental licenses. The distribution of grades regarding wind power generation is again praiseworthy, with almost 90% of this source having an "A" grade.

Graph 3 – Distribution of RAPEEL grades regarding installed capacity of solar, wind, other sources and total power plants – Grades – May 2016 to August 2016 – Brazil



Source: Own elaboration based on ANEEL (2016h)

Both graphs show how much of the planned expansion of solar power generation is currently jeopardized. It also confirms the problems and issues regarding this source in Brazil, at least when analyzing its centralized generation. Lastly, four out of the five plants from Enel under construction, with high viability and an advanced scheduled were awarded with an "A" grade (ANEEL, 2016h)[25].

In conclusion, the investments in solar farms are falling short in regards to their viability, commitment to schedule and prevision of the beginning of commercial operation. Expanding such source to 2.65 GW of installed capacity between 2017 and 2018 seems rather unlikely. We also analyzed that their grades are much worse than all the sources grades regarding installed capacity. It confirms our analysis of an evolution of investments much slower than expected, alongside with performance issues. That jeopardizes the planned expansion of such source.

We now analyze the compatibility between the objectives and the mechanisms of the financing of solar power generation in Brazil.

4. Compatibility between finance mechanism, financed projects and the funding objectives

The fact that Brazil disregarded centralized solar power generation until the early 2010's unlike wind power generation, incentivized since the early 2000's, is relevant to this day. Nascimento (2015) states that, leaving it out of PROEÓLICA and PROINFA[26] accounts for the different stages of the development of their markets.

Ferraz (2014) stated the importance of the continuity and stability of the demand for solar panels in respect of the structuration and consolidation of a mature PV industrial chain in Brazil. However, the majority of PV panels in use in the country are imported, and there is only one big national manufacturer (NASCIMENTO, 2015)[27].

[25] Only the "Bom Jesus da Lapa II" Solar Plant was awarded with a "C" grade.

[26] Respectively, "Programa Emergencial de Energia Eólica" and "Programa de Incentivo às Fontes Alternativas de Energia Elétrica" in portuguese, incentivized wind, run of the river hydro generation and biomass power generation only. Both programs aimed to remedy Brazil's problem with its over-reliance on hydro power generation because of the emergency situation of its dams. Pinto Junior (2007) has more information on Brazil's early 2000's electrical crisis. For more information on the programs, we suggest Podcameni's (2014) review of them.

[27] According to Sitawi and CEBDS (2016), the only relevant accredited manufacturer is incapable of supplying for all the demand.

Regarding the technical constrains in Brazil, Sekiguchi (2014) addresses the lack of a market that would justify the training and contracting of specialized labor: with no relevant demand there will be no interest in such expenditure. The material used in the panels is also an issue, since Brazil does not produce solar grade silicon. The author also cites the connection to the grid as a technical problem, although its economic consequences are severe, for it increases the project cost, which can make it economically unfeasible. Sitawi and CEBDS (2016) explain that the BNDES' local content policy and criteria are highly dependent upon the (progressive) internalization of the production of the solar panel technology, which in turns depends on a persistent demand of these products. In sum, the supply will not settle in unless there are good reasons for such. Signaling and maintaining solar auctions every year are good measures, but they are not enough for the nationalization of this technology supply chain (ABSOLAR, 2016; SITAWI; CEBDS, 2016)[28].

Regarding regulatory constraints in Brazil, Jannuzi (2009) and Sekiguchi (2014) do not understand it as neither a barrier nor a facilitator factor. However, the environmental regulation is considered a hindrance, specifically because of the non-uniformity between different Brazilian states regarding charters, permits, etc. Nevertheless, according to Sitawi and CEBDS (2016) and Pepitone (2016), in 2015 there were major regulatory and tributary improvements in the solar power generation, especially related to its distributed counterpart.

At last, regarding non-regulatory economic constraints in Brazil, Sekiguchi (2014) addresses its current price, which makes it less competitive than other sources in Brazil, although all components show signs of reduction of cost internationally (EPE, 2012). Being the financing of solar power generation by BNDES inspired by the previous wind case (BNDES, 2014a), it becomes a hindrance at the start of the process if the national content requirements are too high at first. Also, the BNDES' funds (with smaller interest rates) are a mandatory solution for such problem (VAZQUEZ, 2015).

EPE (2012) states that there are three basic conditions for a reasonably promotion of centralized solar power generation: specific auctions for this source, more suited contracts; and more specific technical accreditation requirements for PV panels and related equipment. Basically, its differences and specificities need to be taken in account in order for it to become a viable power source. Without this, competitiveness of PV power generation will not be achieved. Therefore, the inspiration in the previous wind power generation case for the elaboration of the methodology and access criteria of the financing of solar power generation by BNDES can be appointed as a problem: it does not acknowledge most differences regarding the characteristics of both sources.

Regarding the scientifically and research situations in Brazil, Nascimento (2015) understands that there is a clear gap between wind power and solar power research when comparing Brazil to the rest of the world. According to him, the little research done in solar power generation in the country can become a hindrance factor if Brazil aims to become a reasonably important (and innovative) player in such market. The solar market in Brazil is still incipient, which, alongside its weak R&D situation in such area, can restrict a future Brazilian solar industry to a less dynamic and innovative position than other countries that took the lead in such market. Therefore, the country would be left off of the innovative process related to the PV panel industrial chain.

Nevertheless, EPE (2012) was optimistic about the solar insertion in the Brazilian electricity mix:

> "Today, large-scale photovoltaic solar energy is not economically competitive with other sources of energy, such as hydro and wind [in Brazil]. However, the analysis of the case of wind energy can be, to some extent, elucidative about the importance of initial stimuli and their impacts on the costs and development of a [new] energy source. [...] In this way, initial stimuli could be traced to make possible the greater penetration of the solar source in the electric mix. Associating these with national industry development policy incentives for the manufacture of equipment for the use of solar energy would be an additional way of boosting this source of competitiveness in the not-too-distant future."[29] (EPE, 2012: 51-52, own translation).

EPE (2012) predicted the growth of the solar power generation based on the success of wind power generation. There are several comparisons between those two sources, especially drawing similarities from

[28] As such, most agents in this market fear that, an investment in Brazil (regarding factories) will not be concluded in time for it to supply the demand related to the enterprises planned to enter operation in 2017 (SITAWI; CEBDS, 2016).

[29] "Assim, hoje a energia solar fotovoltaica de grande porte não é competitiva economicamente com outras fontes de energia, como hídrica e eólica [No Brasil]. No entanto a analise do caso da energia eólica pode ser, em certa medida, elucidativa sobre a importância de estímulos iniciais e seus impactos sobre os custos e o desenvolvimento de uma [nova] fonte de energia. [...] Desta forma, estímulos iniciais poderiam ser traçados para viabilizar a maior penetração da fonte solar na matriz elétrica. Associando-se a esses estímulos politicas de desenvolvimento da indústria nacional para fabricação de equipamentos para aproveitamento da energia solar seria, inclusive, uma forma adicional de alçar essa fonte a competitividade em um futuro não muito distante." (EPE, 2012: 51-52) in the original.

both. The methodology proposed by BNDES for solar promotion was inspired by its prior experience (BNDES, 2014a).
However, we understand that this is the cornerstone of the financing problems regarding the Finem fund and the funding of solar farms. By not respecting the economic and technical differences between both sources, BNDES developed a unsuited mechanism for the financing of solar power generation, as the lack of companies accessing such fund suggests (SITAWI; CDEBS, 2016). We emphasized that there is already contracted demands for solar power generation, with schedules for construction and for entering commercial operation. The lack of financing by BNDES for these projects (SITAWI; CBEDS, 2016) can be appointed as a major reason for their several delays and high uncertainties regarding its schedule (ANEEL, 2016a, 2016b, 2016e, 2016h, 2016i).
One important factor is the Brazilian exchange rate. It grew steadily since the first auction (IPEADATA, 2017). This made the imported PV panels, the option to the BNDES funded panel, an unfeasible possibility. However, it does not impact in the outcome of the mechanism: were the exchange rate low, the companies could easily import solar panels. That changes the outcome of the scenario, as there would probably be more plants under construction, albeit it does not change the fact that the mechanism is not working: it simply would imply a bypass of this problem. Additionally, even if most auction winners are foreign companies, the traditional mechanism is the bank, which means that they entered the auctions counting on such mechanism: using other financing sources is a second best option (for the few companies capable of such).
BNDES fails to incentivize the internalization of this industrial chain and also hinders the construction and expansion of the solar power generation. The bank fails to achieve its local content objective (industrial policy) and by consequence implies on the failure of the electrical mix objective (its expansion). Therefore, the bank, the regulator and other instances of decision and policy makers have to decide its objective: the incentive of a local industry of PV panels, a highly concentrated market that would require a serious development plan; or the incentive of the use of solar source in the country, by allowing and financing imported solar panels. Defining its objective, Brazil can start to work on mechanism to goes accordingly to it.
To keep both objectives, BNDES would need to seriously revise its methodology and its access criteria. That would probably incur on the reduction of the N factors or in a large revision of periods. A suggestion would be focusing on assembly as the local content initial incentive, as it is a far less technological demanding step and also a rather important one: in Europe, a large portion of the aggregate value is added on site. According to EPE (2012), about 50% of the aggregated value of a PV system corresponds to electromechanical components, engineering, assembly and margins of the vendors, added at the installation site.
In conclusion, not only BNDES needs to revise its methodology, but the overreliance of companies on the Finem fund is a concern that should also be addressed. Again, we stress the problems related to the financing of infrastructure and renewables in Brazil addressed by Vazquez (2015, 2016).

5. Conclusion

The two mechanisms for promoting renewables in Brazil (auctions and BNDES' financing) are not being capable of successfully promoting the expansion of centralized PV generation in the country. The contracted capacity Brazil is not under construction.
Analyzing the several differences between the two sources and by knowing that the financing mechanism for solar power generation was heavily inspired by BNDES' prior attempt at funding the expansion of wind farms, the reason of the outcome becomes clear. By not acknowledging the technical and economic differences between both sources (BNDES, 2014a), BNDES underestimated the size of this challenge.
We understand that BNDES' objective with its subsidized financing of investments, in this case, is actually two: the promotion of the source in the country; and the internalization of certain parts of the industrial chain of solar panels. Tackling such challenge with a mechanism heavily influenced by the severely different wind power generation only increased this challenge.
Possible solutions for this incompatibility between objective and mechanism can be proposed, however. BNDES can decide to tackle the hardest challenge that is internalizing a very concentrated industrial chain, requiring a reimagining of this mechanism and the combining of others[30]. However, this would probably take more time than the planned for the expansion of centralized PV generation in Brazil. Therefore, if promoting and supporting solar farms is considered the most important objective, then a different shift in the mechanism is needed: imported solar panels will have to financed, for sake of time and to keep schedules intact.

[30] As some countries did to internalize wind turbine industrial chains.

Nevertheless, not all is lost for local content, for even with imported solar panels, there are ways of promoting income generation in the country and some internalization of the chain. In Europe, most of the added value comes in the site of the enterprise, through the assembly of pieces, parts and the solar panels. That could be a solution to the unsuccessfulness of this mechanism.

The biggest conclusion to be drawn from the analysis is that if BNDES and the policy makers persist with their current objective and mechanism, the planned expansion of the solar power generation, and in consequence, the implantation of a national industry in this industrial chain will remain highly jeopardized. Brazil has to decide its short-run and long-run objectives and to adapt its mechanisms to them. Without a serious revision of this financing mechanism, neither objective can be achieved.

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Appendix

The table 2 was elaborated from ANEEL's reports on the auctions winners and ANEEL's report on the shares of companies in each consortium. Since ANEEL releases data about consortia and not about single companies, we multiplied the number of power plants, the capacity and the investment by the share of each company inside each specific consortium. That's why we encountered companies that have no power plant but have some potency related to them. They are part of consortia that have power plants with significant capacity and a significant investment: even multiplying it by almost insignificant percentages, the result was a number different than zero.

Table 2 – Capacity, Plants and investment from winners of the LER 2014, the 1st LER 2015 and the 2nd LER 2015, grouped from highest potency in MW to lowest – MW, units, percentage and Brazilian reais – 2014 to 2015 – Brazil

Auctions from 2014-2015	Plants		Potency		Investment numbers	
					in uninflated R$	In Nov. 2016 R$ (IGP-M)
Companies	Units	%	MW	%	R$ 1.000,00	R$ 1.000,00
Enel	22	23,40%	619,98	23,64%	R$ 3.620.872,35	R$ 4.037.939,82
Canadian Solar Inc	11	11,70%	329,97	12,58%	R$ 1.409.288,06	R$ 1.559.566,51
Lintran do Brasil Participações S.A.	9	9,57%	269,97	10,29%	R$ 1.151.302,86	R$ 1.356.888,48
Solairedirect SAS	7	7,45%	199,98	7,62%	R$ 894.048,59	R$ 953.189,81
Sune Solar B.V.	5	5,30%	148,57	5,66%	R$ 608.626,63	R$ 651.463,56
Renova Energia S.A.	5	5,32%	129,59	4,94%	R$ 622.529,00	R$ 722.581,38
STEELCON	3	3,19%	90,00	3,43%	R$ 610.965,00	R$ 651.380,27
Rio Energy EOL IV Geração e Comercialização de Energia Ltda	3	3,19%	89,91	3,43%	R$ 420.021,00	R$ 495.023,23
European Energy A/S	2	2,55%	60,00	2,29%	R$ 360.468,00	R$ 384.312,92
Fotowatio do Brasil Projetos de Energia Renováveis III Ltda.	2	2,13%	60,00	2,29%	R$ 279.540,00	R$ 329.456,84
SPE CESP COREMAS	2	2,13%	60,00	2,29%	R$ 268.414,00	R$ 303.340,31
Grupo Gransolar S.L.	2	2,13%	60,00	2,29%	R$ 252.594,00	R$ 274.736,11
Kawa	2	2,13%	54,00	2,06%	R$ 242.392,00	R$ 263.639,82
KROMA COMERCIALIZADORA DE ENERGIA LTDA	2	1,65%	46,56	1,78%	R$ 186.240,00	R$ 198.559,76
RODRIGO PEDROSO INVESTIMENTOS E PARTICIPAÇÕES SA	1	1,54%	43,44	1,66%	R$ 173.760,00	R$ 185.254,21
Quaatro Participações S/A	2	2,13%	40,00	1,53%	R$ 158.946,10	R$ 171.169,76
Solatio Gestão de Projetos Solares Ltda.	1	1,07%	30,02	1,14%	R$ 129.428,22	R$ 138.015,40
ADX	1	1,06%	30,00	1,14%	R$ 171.541,00	R$ 182.888,42
RIO ALTO	1	1,06%	30,00	1,14%	R$ 143.042,00	R$ 152.504,21
EXITO IMPORTADORA E EXPORTADORA SA	1	1,06%	30,00	1,14%	R$ 120.000,00	R$ 127.937,99
TRACTEBEL ENERGIAS COMPLEMENTARES PARTICIPAÇÕES LTDA.	1	1,06%	30,00	1,14%	R$ 149.769,02	R$ 159.676,23
Construtora A. Gaspar S/A	1	1,06%	30,00	1,14%	R$ 133.265,67	R$ 157.062,63
NSG INDUSTRIA DE CONSTRUÇÃO E PARTICIPAÇÕES EIRELI	1	1,06%	29,97	1,14%	R$ 129.168,70	R$ 137.713,20
Supernova Investimentos e participações Em energia	1	1,06%	29,97	1,14%	R$ 126.389,48	R$ 137.468,65
ORIGIS INVEST LTD	1	0,85%	24,00	0,92%	R$ 94.878,40	R$ 101.154,60
Eólica Tecnologia Ltda	1	0,64%	14,99	0,57%	R$ 90.071,94	R$ 96.030,19
FCR VII Usina de Energia	1	1,06%	10,00	0,38%	R$ 529.210,00	R$ 623.709,87

Fotovoltaica Ltda.						
Companies with less than 10 MW of contracted capacity	3	3,43%	31,99	1,22%	R$ 134.482,72	R$ 145.332,90
TOTAL	94	100%	2623	100%	R$ 13.211.254,76	R$ 14.697.997,07

Source: Own elaboration based on ANEEL (2015b, 2015c, 2016b, 2016j) and Banco Central Do Brasil (2016)

We also grouped companies in different consortia that belong to a same company. This was done in order to correctly measure and compare the different companies by units of PV plants, capacity and investment. Without grouping, we would compare underestimated companies to themselves and to others. For us, this aided largely the comparison. The previewed investment in un-inflated Brazilian reais presents the total of investment without correction according to inflation. In order to correctly analyze the investment numbers, we inflated them according to the Brazilian inflation index IGP-M.