OVERVIEW OF NEW SOLAR PV PROJECTS IN BRAZIL

Database of technically accepted projects for the 2nd Reserve Energy Auction in 2016

Empresa de Pesquisa Energética

MINISTÉRIO DE MINAS E ENERGIA

BRASIL GOVERNO FEDERAL

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FOREWORD

This report presents an overview of the solar photovoltaic projects that have been technically accepted by EPE for the 2nd Reserve Energy Auction of 2016 – 2nd LER/2016[1], object of Ordinance MME (Ministry of Mines and Energy) 104/2016.

This work is part of an effort to monitor the evolution and trends related to photovoltaic projects in Brazil, aiming to increase the visibility of this energy resource in the country and produce useful information for project developers. This report is the fourth in a series published after previous auctions, as follows:

- 2nd LER/2015 (nº EPE-DEE-NT-023/2016-r0), dated February 24st, 2016, available in English and Portuguese;
- 1st LER/2015 (nº EPE-DEE-127/2015-r0), dated September 24st, 2015, available in Portuguese;
- LER/2014 (nº EPE-DEE-NT-150/2014-r0), dated November 21st, available in Portuguese.

The 2nd LER/2016, which aimed to contract energy from wind and solar photovoltaic generation projects, was initially scheduled to occur on 28th October, 2016. However, it has been rescheduled[2] for 16th December, 2016 and then postponed[3] to 19th December, 2016. Finally, the auction was cancelled according to Ordinance MME 705/2016 and the reasons for that have been explained in the report "Contratação de Energia de Reserva para o SIN - 2º Leilão de Energia de Reserva de 2016" (nº EPE-DEE-RE-105/2016-r0), available in Portuguese at EPE's website.

Specifically regarding solar photovoltaic, 419 projects were submitted for technical qualification prior to the auction, representing a total offer of 13,439 MW of installed capacity. Despite the cancellation, EPE carried out all the analysis and technical qualification of these projects, so it is possible to continue monitoring the evolution and trends related to solar photovoltaic projects in Brazil.

Although there were no contracted projects in the 2nd LER/2016, the characteristics of the projects submitted to EPE will be addressed. Additionally, we highlight some of the trends reported in comparison to the solar photovoltaic projects of previous auctions.

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[1] Also named "11º Leilão de Energia de Reserva (Edital ANEEL nº 004/2016)".
[2] Ordinance MME 390/2016.
[3] Ordinance MME 621/2016.

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SUMMARY

1. INTRODUCTION

Ordinance 104, dated 23rd March 2016, established the guidelines for the 2nd Reserve Energy Auction of 2016, aiming to contract power generation from wind and photovoltaic plants.

Among these guidelines, the following can be highlighted:

- Electricity supply of contracted projects must begin from 1st July, 2019 (it can be anticipated, as long as transmission or distribution systems are available);
- 20-year power purchase agreement (PPA, called "CER");
- Contracted plants must be exclusively dedicated to the Reserve Energy Contract ("CER"). If the entire physical guarantee is not sold in the auction, the remaining cannot be sold anywhere until the end of the CER.
- Projects under 5 MW of installed capacity were not accepted; and
- Annual electricity prices adjustment is based on the Brazilian Consumer Price Index – IPCA (inflation index).

Regarding the accounting methodology of the energy production of photovoltaic projects under this PPA, it was kept what was previously established in 2014, according to the Technical Note EPE-DEE-NT-079/2014-r1, available in Portuguese at EPE's website.

It should be noted that the 1st LER/2016, subject of the same Ordinance, had also initially established the participation of photovoltaic projects. After Ordinance MME 390/2016, this auction ended up restricted to small hydro.

It's also relevant to mention the issue of Ordinance MME 444/2016, which established the general guidelines for the definition of the available transmission system capacity of the National Interconnected System (SIN). This ordinance set the main premises, criteria and procedures used for the assessment of the remaining transmission capacity, contributing to the transparency and predictability of the results.

2. SCHEDULE

The schedule of the main activities is presented in Table 1.

Table 1 – Schedule of activities related to Technical Acceptance

ACTIVITY	DATE
Issue of Ordinance with auction guidelines	23th Mar 2016
Project submission (beginning date)	1st Jun 2016
Deadline for project submission[4]	8th Aug 2016
Deadline for presentation of the Environmental License	27th Sep 2016
Deadline for presentation of Grid Connection Report	3rd Oct 2016
Issuance of technical acceptance certificate	1st Dec 2016
Auction date (cancelled)	19th Dec 2016

3. SUBMISSION AND TECHNICAL ACCEPTANCE

Submission

The submission and technical acceptance of projects for the auction must follow MME's guidelines, according to Ordinance MME 102/2016, as well as EPE's Instructions ("Instruções para Solicitação de Cadastramento e Habilitação Técnica com vistas à participação nos Leilões de Energia Elétrica"), published at EPE's website.

On August 08th, 2016, EPE published on its website a summary of the submission status for 2nd LER/2016.

[4] Initially the submission ended on 17/July/2016, having been reopened according to Ordinance MME 390/2016.

Table 2 – Submitted PV projects for the 2nd LER/2016

State	Region	Number of Projects	DC Power[5] (MWp)	AC Power[6] (MW)
Bahia	Northeast	101	3,953	3,207
Rio Grande do Norte	Northeast	58	2,070	1,640
Piauí	Northeast	55	2,853	2,057
São Paulo	Southeast	53	1,961	1,597
Ceará	Northeast	36	1,315	1,045
Pernambuco	Northeast	33	1,160	887
Minas Gerais	Southeast	24	1,135	890
Mato Grosso do Sul	Central-West	21	1,685	1,220
Tocantins	North	20	564	415
Paraíba	Northeast	18	615	480
Total		**419**	**17,311**	**13,439**

Considering all 419 projects, it was possible to account:

- 72% of the projects are in the Northeastern Region;
- 13 PV modules manufacturers;
- 13 inverters manufacturers; and
- 14 independent certification companies for power production assessment.

With respect to the previous PV energy auction (2nd LER/2015):

- Number of submitted projects reduced from 649 to 419 (-35%);
- Number of project developers reduced from 80 to 45 (-44%);
- Number of PV modules manufacturers reduced from 22 to 13 (-41%);
- Number of inverters manufacturers reduced from 17 to 13 (-23%).

The smaller number of submitted projects is due to the requirement of having at least one year of solar resource measurement at very the site of the project (defined as within 10 km from the measurement station), what was previously not required (assessment used to be based on secondary data sources only). In fact, it was verified

[5] DC Power is the sum of the rated capacities of all PV modules.
[6] AC Power is the sum of the rated capacities of all inverters, considering possible power limitations.

that most of the available data series had completed one year shortly before the deadline for project submission.

Regarding the connection to the grid of PV projects, the following was noted:

- 369 submitted PV projects (88%) initially chose to connect directly to the main transmission grid;
- 50 submitted PV projects (12%) initially chose to connect directly to the distribution grid;
- 110 different main transmission grid substations were initially chosen as the connection points;
- 24 different distribution substations were initially chosen as the connection points;

Technical acceptance

EPE's process of analysis and technical acceptance covers various aspects of a project and a number of submitted documents, aiming to select projects that meet the minimum requirements to demonstrate their technical feasibility and capacity to deliver the amount of contracted electricity.

Concerning the 2nd LER/2016, EPE qualified 78% (328) of the total number of submitted PV projects. The results can be seen in the Figure 1.

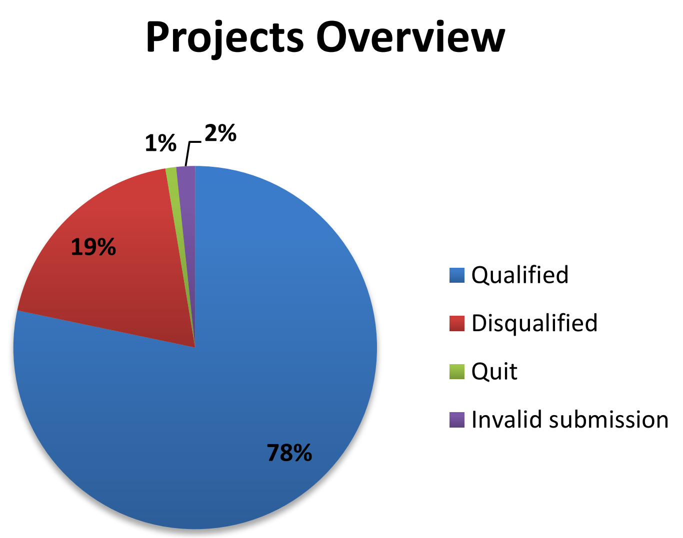


Figure 1 – Final Status of technical acceptance of PV projects (2nd LER/2016)

Table 3 below shows a summary of the technically accepted projects and installed capacity according to their location (state).

Table 3 – Technically accepted PV projects for 2nd LER/2016

State	Projects	DC Power (MWp)	AC Power (MW)
Bahia	80	2,658	2,141
Piauí	51	2,533	1,817
São Paulo	44	1,653	1,328
Rio Grande do Norte	41	1,449	1,150
Pernambuco	33	1,160	887
Ceará	26	938	746
Paraíba	18	615	481
Mato Grosso do Sul	14	1,131	820
Tocantins	13	337	225
Minas Gerais	8	295	240
Total	**328**	**12,769**	**9,833**

The map found in Appendix I shows the location of the technically accepted PV projects for 2nd LER/2016, as well as the sum of installed capacity per city.

Figure 2 shows a graph with comparative data from the previous four reserve energy auctions. By comparing the results of the 2nd LER/2016 to the 2nd LER/2015, the percentage of technically accepted PV projects in relation with the total quantity of submitted projects has practically remained the same.

In addition, the same graph indicates that the number of PV projects submitted for the 2nd LER/2016 was reduced when compared to the 2nd LER/2015. As previously mentioned, this is likely to be a consequence of the just established requirement of one-year solar resource measurement at the site of the project.

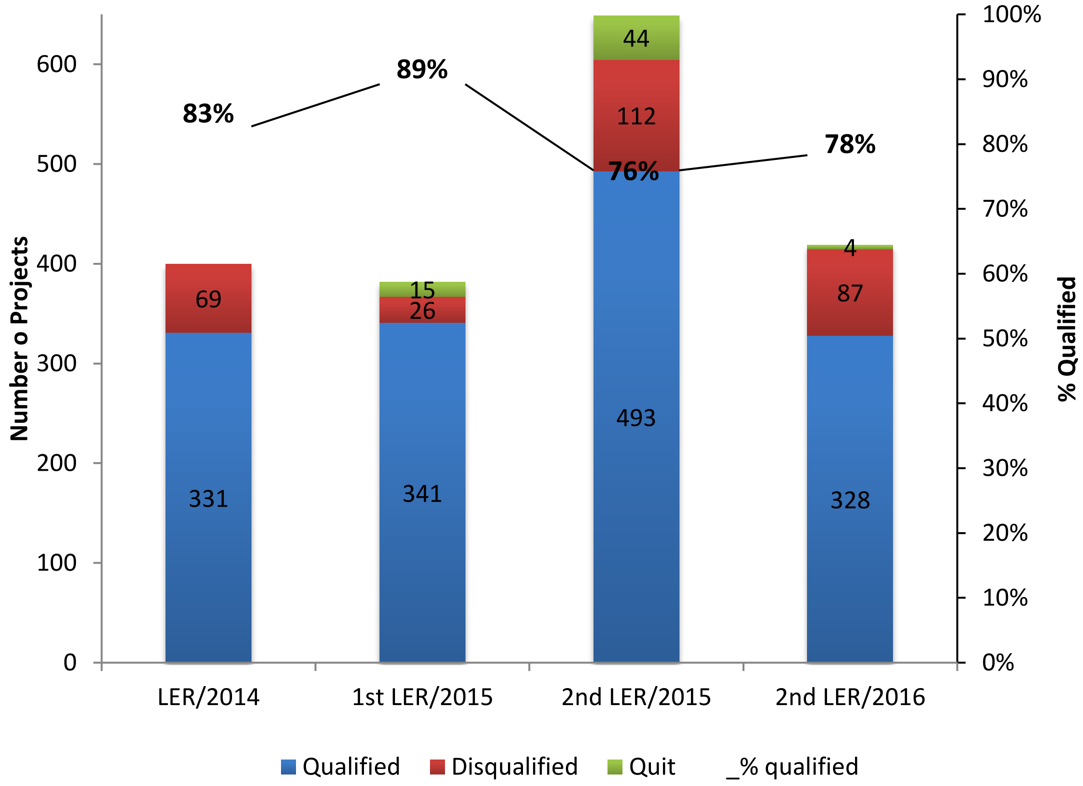


Figure 2 – Technical acceptance rates in the last energy auctions

As shown in Figure 2, among the total of 91 projects that have not been qualified by EPE, it is possible to state that there were:

- 4 projects quit the process;
- 7 invalid submissions, due to not having the required measurements of global horizontal irradiation for at least twelve consecutive months;
- 80 technically disqualified projects which have failed to fulfill the minimum technical requirements.

Figure 3 shows a summary of the reasons for having qualification denied in the 2^{nd} LER/2016.

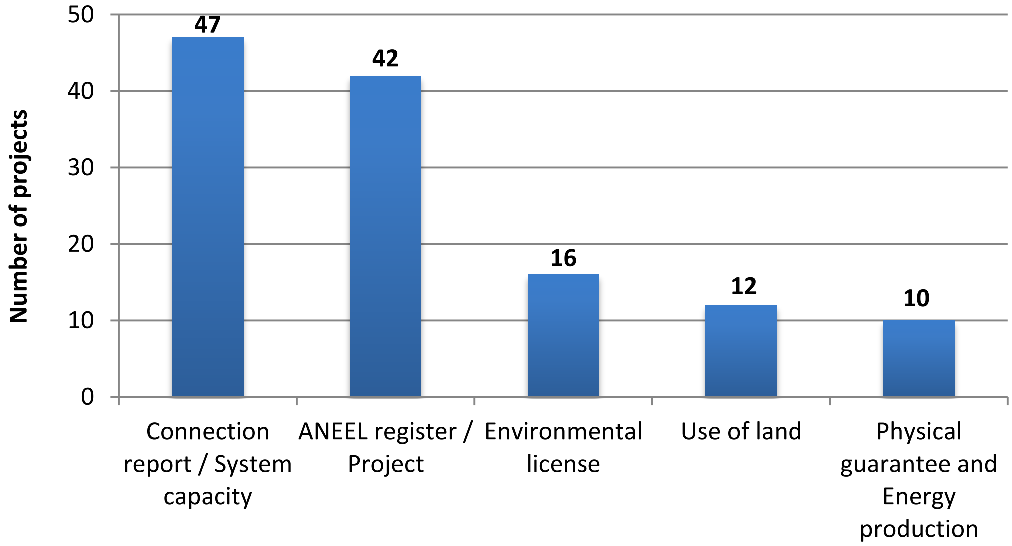


Figure 3 – Main disqualifying reasons in 2nd LER/2016 (PV projects)

The main reason for disqualifying projects in 2nd LER/2016 is related to either the lack of a valid grid connection report (it needs to be stated by the distribution companies whenever they're responsible for the appointed substation), or insufficient grid capacity to the new project, what is assessed by the ONS (system operator). A total of 47 projects have been disqualified.

The available transmission capacity was evaluated by the National System Operator (ONS) and the result of this assessment was published in the Technical Note 0121/2016. This document presented the available capacity of the transmission grid of each busbar that was indicated as a connection point for the submitted projects.

It should be noted that the results of the simulations carried out by the ONS to define the transmission grid capacities were strongly influenced by the delays in the construction of the ABENGOA transmission lines, which have contributed to a significant reduction of the transmission capacity levels.

ABENGOA's assets include an expressive set of 500 kV transmission lines and substations that play a fundamental role in the Brazilian transmission system. Besides allowing an expressive energy exchange between the Northern, Northeastern and Southeastern regions of the country, these transmission lines are also responsible for allowing the integration of a significant number of renewable power plants scattered over the Northeast region. Since these transmission lines were not considered to be operational by the time established for the PV power plants start of operation, the ONS studies have concluded that a lot of substations could not accommodate any additional generation. This condition has especially affected Rio Grande do Norte and Bahia states.

In order to avoid technical disqualification, some project developers have requested to change their original connection points to other substations with remaining system capacity. As established by Ordinance MME 104/2016, PV project developers were allowed to change their initial connection point to the grid after the issue of the ONS Technical Note 0121/2016, in accordance with its results.

Table 4 below presents a distribution of connection points among the Brazilian states in two distinct moments: (i) at the submission of the project (the initial choice); and (ii) after ONS Technical Note 0121/2016 (the final choice). It should be noted that due to the results presented in the ONS Technical Note, a significant number of projects had their connection points changed.

Table 4 – Comparison between the location of initially chosen connection point and their final choice

State	Number of Submitted projects (after registering period)	Number of Projects after having their connection points changed
Bahia	101	25
Piauí	55	96
São Paulo	53	46
Rio Grande do Norte	47	5
Ceará	46	100
Minas Gerais	37	29
Pernambuco	34	34
Mato Grosso do Sul	21	28
Paraíba	18	49
Tocantins	7	7
Total	**419**	**419**

As shown in the table, in most cases connection point were asked to be changed. Due to lack of transmission capacity, projects located in the states of Bahia and Rio Grande do Norte were the ones that have presented expressive requests for change of connection point, mostly to the neighboring states of Piauí, Ceará and Paraíba.

For some projects, however, the available options for change in the connection point were not at all feasible for the project developers, who decided to maintain the originally appointed grid connection points and, for this reason, were not technically accepted by EPE.

4. RESULTS AND EVALUATIONS

In the previous reports[7], the results of each auction and the technical features of the contracted projects were assessed. Given that the 2nd LER/2016 was cancelled, the upcoming analyses take into account the universe of photovoltaic projects that were qualified to participate in the auction.

It is worth mentioning that the assessments presented here are based on the projects submitted to EPE by the project developers for the purpose of technical acceptance in the 2nd LER/2016. They do not necessarily represent the final configuration that would be actually built in case the projects were contracted, since developers are allowed to promote changes in the technical characteristics of their projects in accordance with current rules, as long as authorized by the MME. Such changes are natural, given the fact that before the auction the project is in a stage of "feasibility study", while after PPA is signed, the detailed design is defined, considering equipment suppliers, technical and economical optimization, more reliable information (as for foundations, i.e), etc.

For further details about concepts and terminologies used in this document (DC Power, AC Power, Enabled Power, Generating Unit, etc.), refer to EPE's Technical Note EPE-DEE-NT-150/2014-r0 ("2014 Reserve Energy Auction - Participation of Solar Photovoltaic Projects: Overview") and ANEEL's Normative Resolution 676/2015 (both available in Portuguese).

4.1 Aspects related to the solar resource

2016 was the first year in which *in-situ* solar resource measurements were required, according to article 6 of Ordinance MME nº102/2016:

> *Art. 6º Project developers must meet the conditions for Registration and Technical Acceptance, established in art. 4 and also the following requirements:*

[7] 2nd LER/2015 (EPE-DEE-NT-023/2016-r0, available in English and Portuguese); 1st LER/2015 (EPE-DEE-127/2015-r0, in Portuguese); and LER/2014 (EPE-DEE-NT-150/2014-r0, in Portuguese).

(...)

II – (...) a record of continuous measurements of global horizontal irradiance, for a period no shorter than twelve consecutive months, carried out at the site of the project (...) for photovoltaic projects without irradiation concentration technology.

This requirement aims to increase the reliability of reference solar resource data in order to reduce the overall uncertainty of the projects.

As expected, the availability of data from local irradiance measurements has led to a reduction in the uncertainty regarding to energy resource assessment and, therefore, to lower standard uncertainty of energy production. Figure 4 compares the mean values of these two variables for all the accepted photovoltaic projects in the energy auctions conducted so far. It should be noted that in 2013 it was not mandatory to inform the uncertainty components.

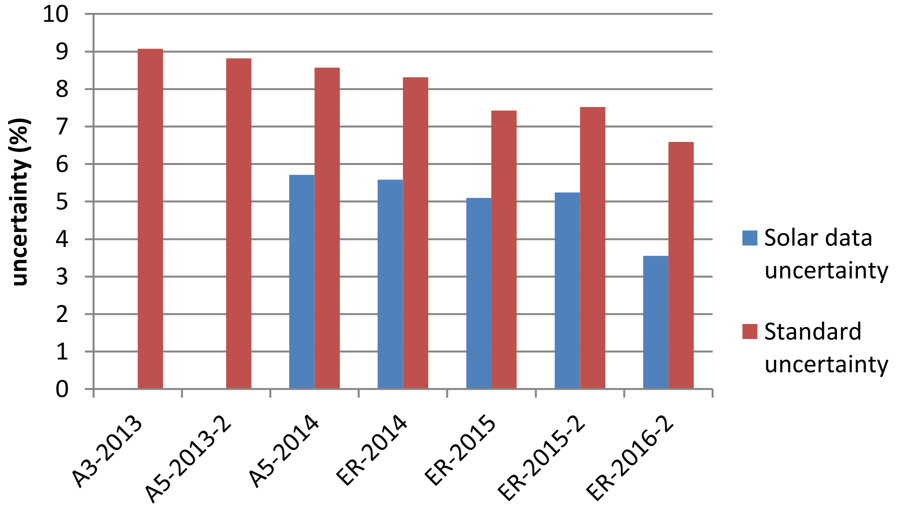


Figure 4 – Historical variation of the averages of the uncertainties of the projects

For several projects, the use of locally measured data had a relevant impact for correction of long-term data series obtained from models. For example, Figure 5 compares the same period of measurement to mesoscale data, allowing to identify and correct a bias.

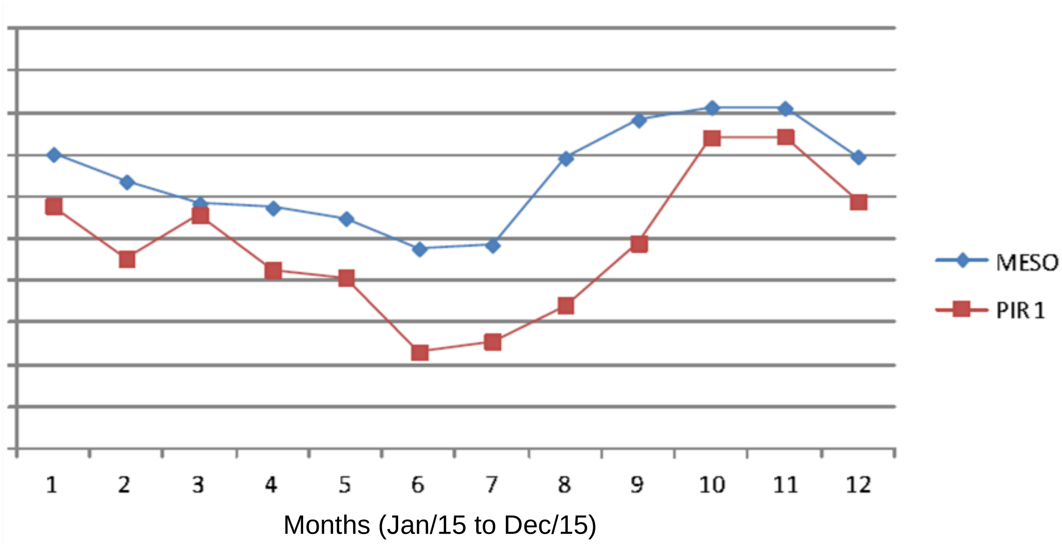


Figure 5 – Comparison of locally measured data (red) to data series from model (blue)

For other projects, however, there was no clear bias. Figure 6 depicts another example in which the model data showed to better fit those obtained by the measurements.

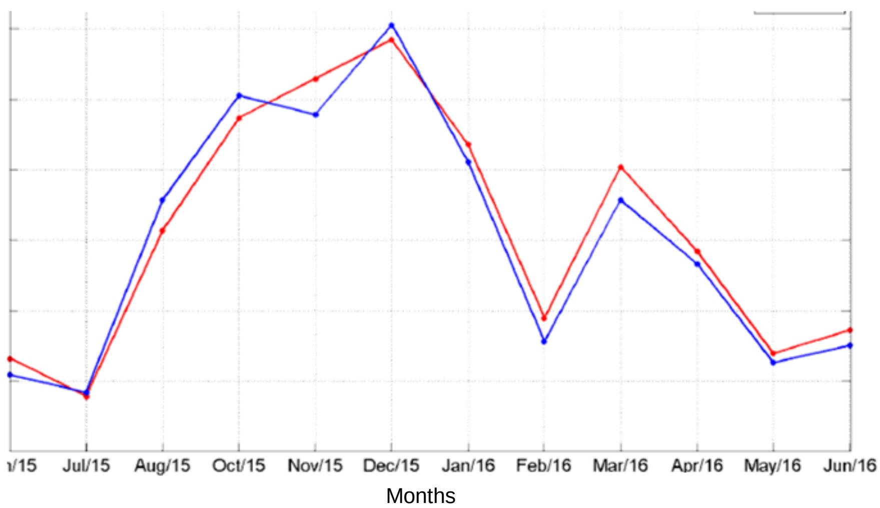


Figure 6 – Comparison of locally measured data (red) to data series from model (blue)

Since several projects share the same measuring station, data from 67 solar stations distributed along the country, as shown in the map of Appendix II, were used for the power production assessment of the 419 submitted projects.

The annual GHI (global horizontal irradiance) values calculated by the independent certification companies in their energy production assessment studies varied from 1,910 kWh/m².year to 2,334 kWh/m².year.

Figure 7 shows a histogram with the irradiation values for all the projects that have presented solarimetric data in accordance with the technical requirements. It is accounted by station - i.e., projects that share the same station were accounted only once.

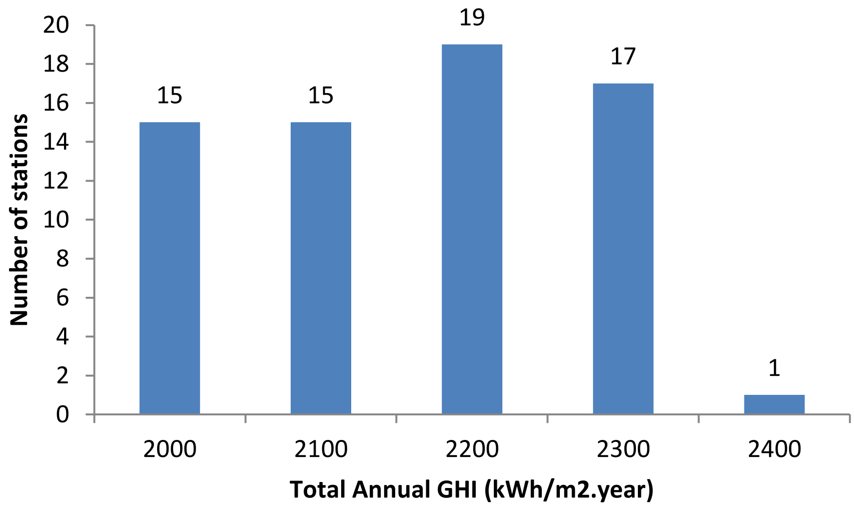


Figure 7 – Histogram of GHI

Regarding GHI seasonal profile, Figure 8 and Figure 9 respectively illustrate the certified values for the state of Bahia and for the combination of the states of São Paulo and Mato Grosso do Sul. Each curve represents a group of projects that share the same measuring station.

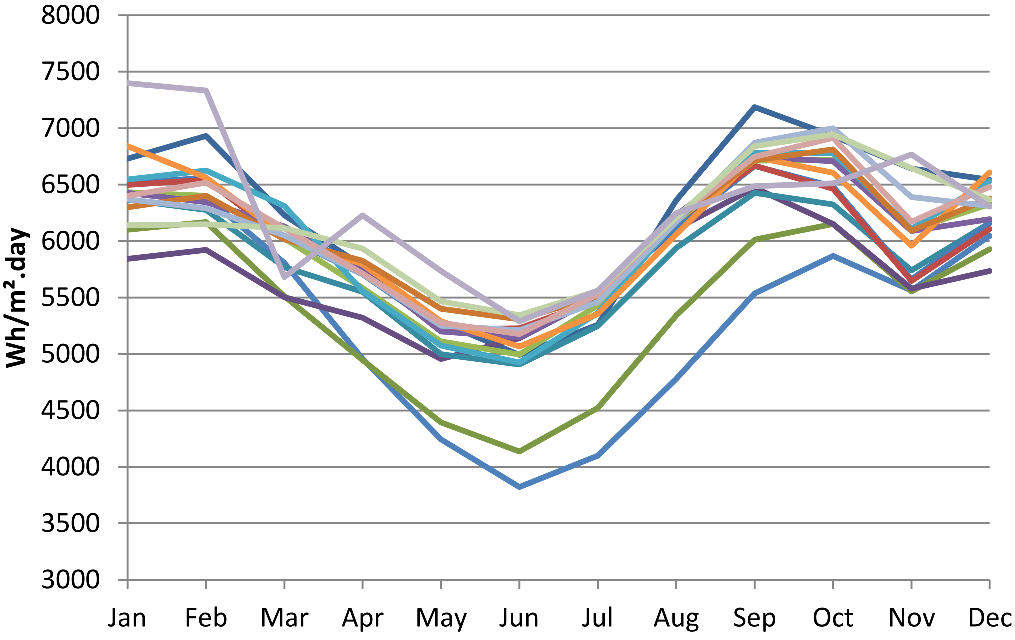


Figure 8 – GHI seasonal profile (stations in the state of Bahia)

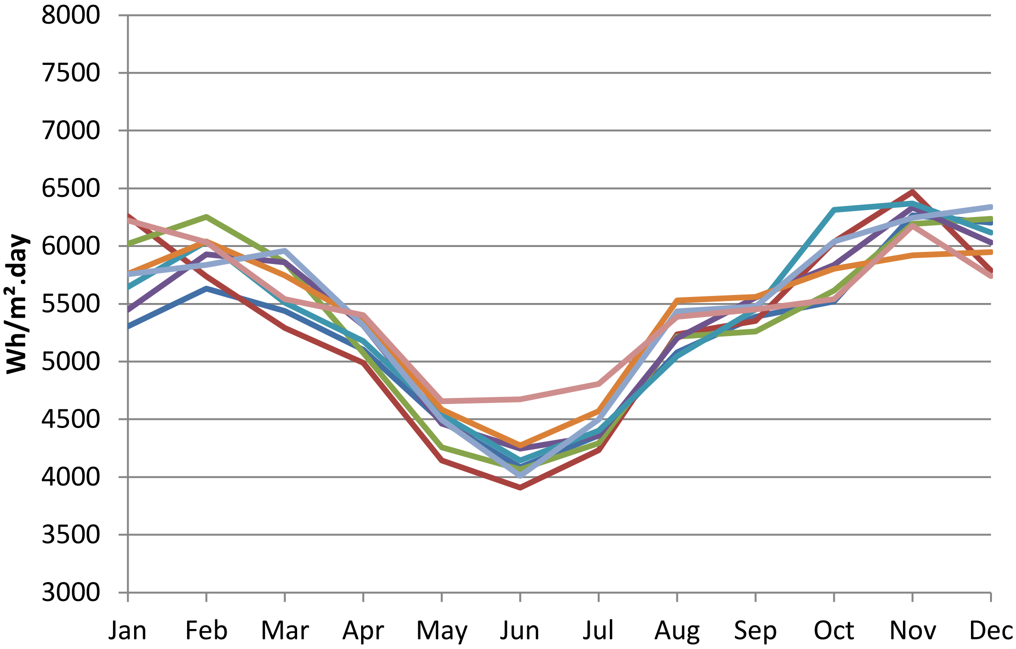


Figure 9 – GHI seasonal profile (stations in the states of São Paulo and Mato Grosso do Sul)

Comparing these two regions, it is possible to notice the difference in seasonal behavior of the global solar irradiation. In Bahia, the typical GHI variation range was 5,000 Wh/m².day in June and July and it is up to 7,000 Wh/m².day in October. Stations in São Paulo and Mato Grosso do Sul, at a higher latitude, measured as low as 4,000 Wh/m².day, in June, and as high as 6,500 Wh/m².day, in November.

This seasonal variation in GHI is mainly due to the angle of incidence in the horizontal plane, less favorable near the winter solstice and more favorable during months close to summer. Besides, contribution of local climate is also added. Since summer months are typically rainy, it is common for annual peaks to occur between September and November in these regions.

4.2 Equipment

4.2.1 Photovoltaic modules

Photovoltaic modules chosen for the submitted projects have an average unit power of 330 Wp and an average efficiency over 17%.

In terms of technology, 14% are cadmium telluride (CdTe), 23% are monocrystalline silicon and 63% are polycrystalline silicon (Figure 10). As seen, only one thin-film technology was chosen. Regarding nominal capacity, CdTe modules presented power ratings around 115 Wp, while monocrystalline silicon have up to 435 Wp.

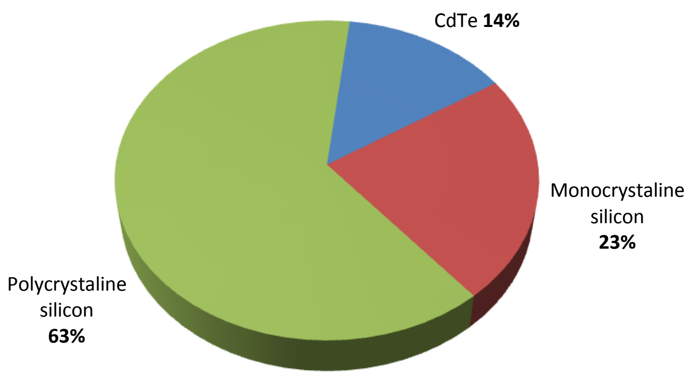


Figure 10 – PV module technology types among technically accepted projects in the 2nd LER/2016 (relative to the total number of accepted projects)

The participation of module manufacturers can be observed in terms of total installed for each auction, as shown below in Figure 11.

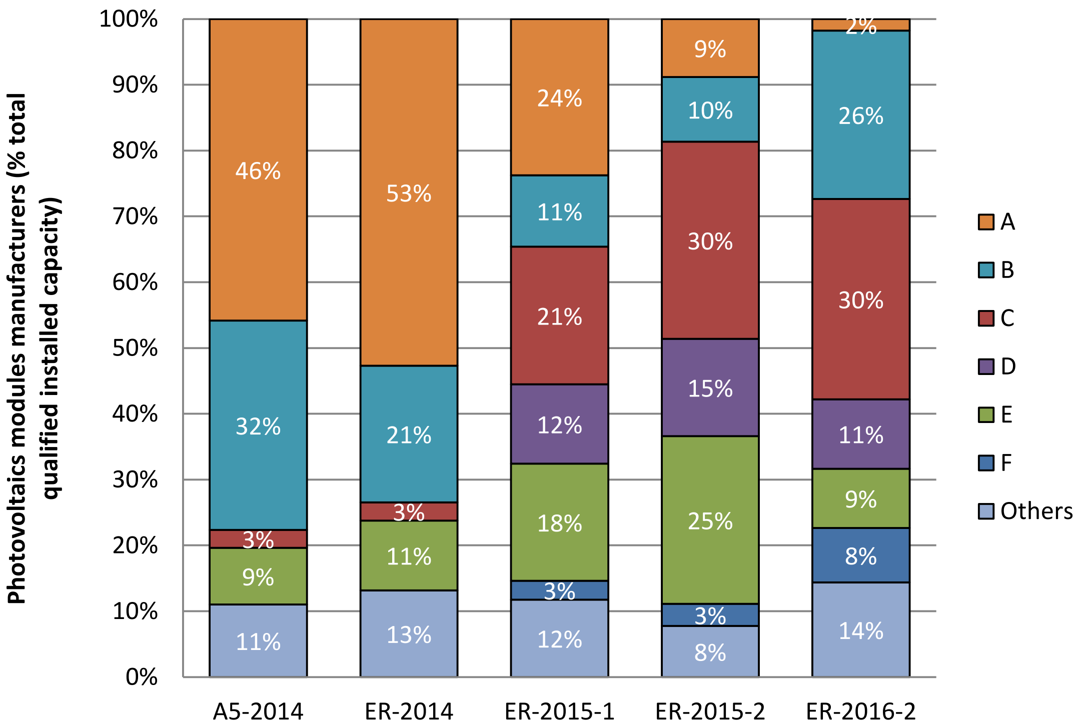


Figure 11 – PV modules manufacturers chosen by developers (accepted projects)

It is possible to note an evolution of the participation of some module manufacturers, such as the "C", which in 2014 accounted for about 3% of the authorized power and in 2016 accounted for 30%. Meanwhile, manufacturer "A" share plummeted from around 50% in 2014 to 2% in 2016.

However, it is important to note that these data do not represent at all actual market share, since they refer to projects still at an early development phase and the final choice of equipment provider is usually made only after PPA is signed.

Another trend observed is the greater participation of the CdTe modules in qualified projects for the 2nd LER/2016, compared to previous auctions, as shown in Figure 12.

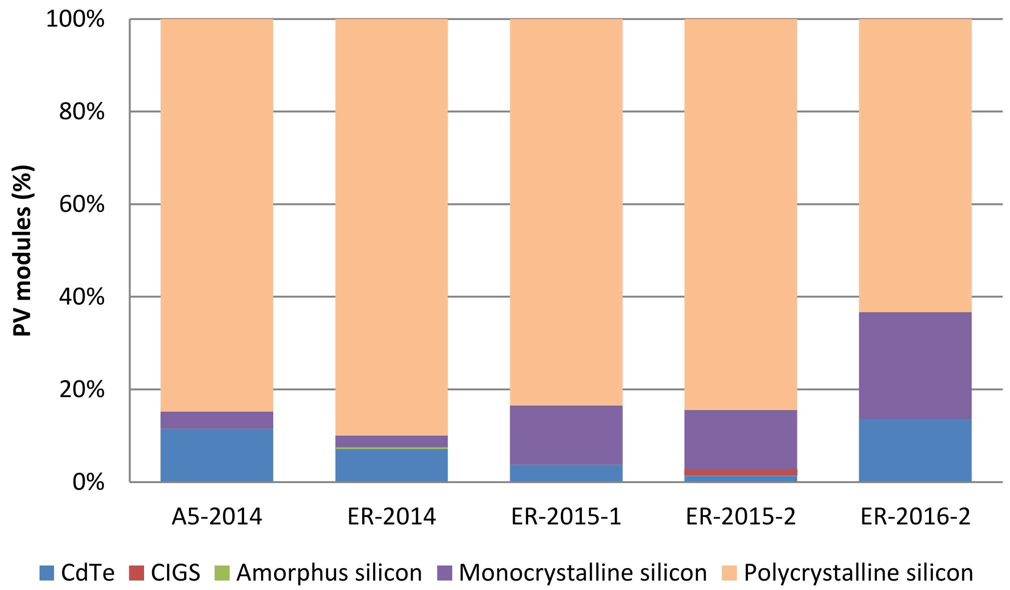


Figure 12 – Module technology (as relative to total installed capacity of accepted projects): comparing 2nd Reserve Auction to previous auctions

Among the crystalline silicon modules (mono and poly), there is also a trend towards modules with larger number of cells, according to Figure 13.

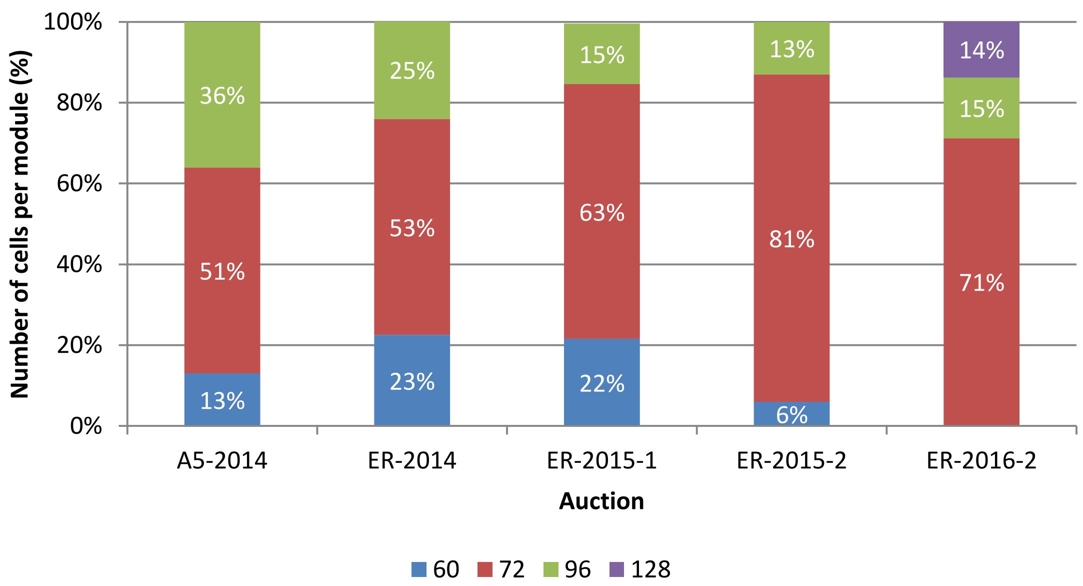


Figure 13 – Number of cells per module (as relative to total installed capacity of accepted projects): comparing 2nd Reserve Auction to previous auctions

4.2.2 Inverters

The technically accepted projects in the 2nd LER/2016 were designed with inverters ranging from nominal power of 510 kW to 3,000 kW.

It should be noted that when designing a PV project, it is usual to have higher DC Power than AC Power, like many of the submitted projects. This is because actual irradiation and temperature conditions in the field are rarely like reference lab conditions. Consequently, PV modules would not achieve, most of the time, its rated power. Therefore, "oversizing" PV modules allows a more efficient operation of the inverter, which will be working closer to its rated conditions.

Each project developer chooses, as a design criteria, an Inverter Sizing Factor (ISF), corresponding to the ratio of the AC power and the DC power. The adopted ISF depends on a cost-benefit analysis, since it can result, on one hand, in lower investment cost and more efficient inverter operation and, on the other hand, in higher curtailment due to inverter power limitation[8]. The ISF of qualified projects ranged from 66% to 104%. More information about the ISF is found in Section 4.3.

Regarding the share of inverter manufactures chosen for project design, this can be observed in terms of total power, as shown in Figure 14.

[8] Under certain conditions, the inverter may operate above its nominal power.

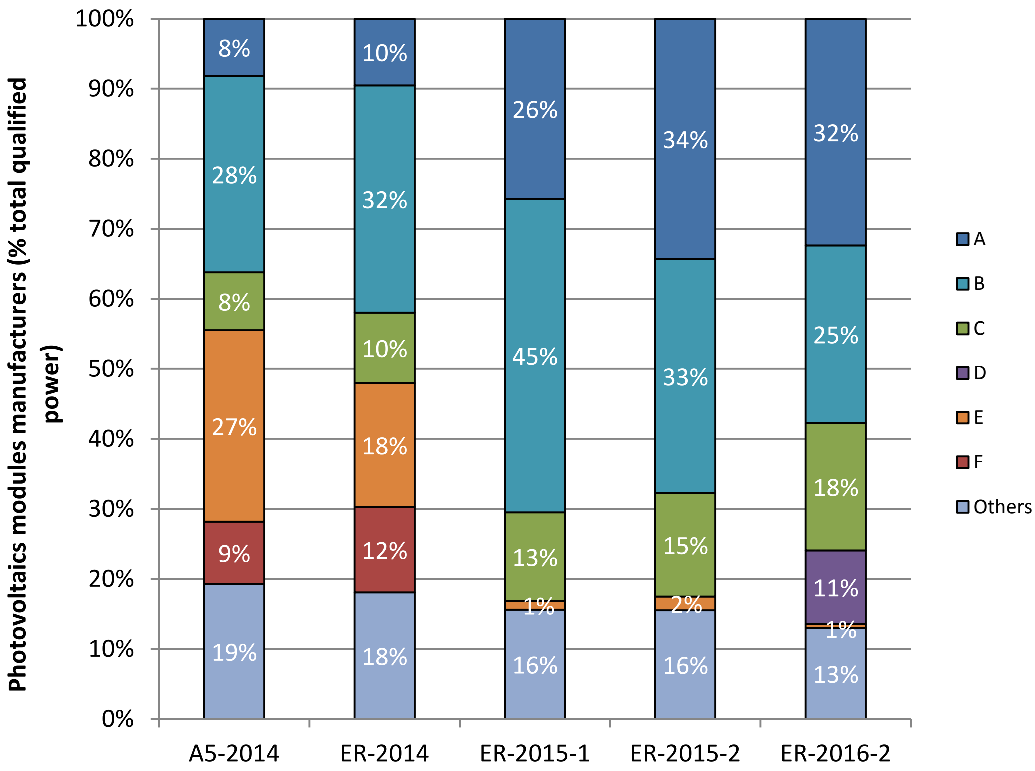


Figure 14 – Inverter manufacturers (as relative to total installed capacity of accepted projects):

As seen in the case of the modules, the participation of some manufacturers changed considerably from auction to auction. Manufacturers A, B and C together accounted for about 75% of the power of the 2nd LER/2016. However comparing 2nd Reserve Auction to previous auctions, it is important to note that these data do not represent at all actual market share, since they refer to projects still at an early development phase and the final choice of equipment provider is usually made only after PPA is signed.

4.2.3 Mounting structures

Among the total 328 qualified projects, 292 (or 89%) adopted one-axis tracking system (following the sun during the day, in the East-West direction).

As shown in Figure 15 below, there has been a growth in the number of projects with single-axis tracker over the ones with fixed structures (no projects adopted two-axis tracking system, though). The sample of data considered in the graph comprises all the technically accepted projects in the various auctions which had PV projects, except for 2013, when this information was not filled in the AEGE/EPE database.

This trend can be explained by the significant increase in the capacity factor provided by the tracking systems, despite the higher investment cost of this kind of structure, which will be mentioned in chapters 4.3 and 4.7.

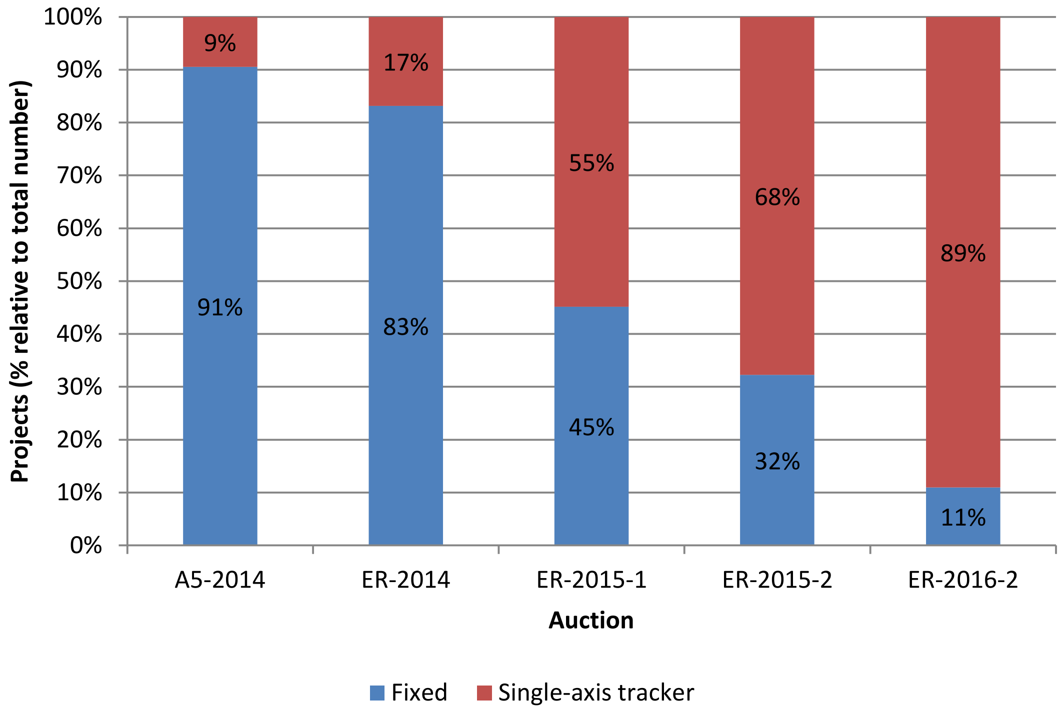


Figure 15 – Support structure, as relative to the total number of accepted projects: comparing 2nd Reserve Auction to previous auctions

4.3 Capacity Factor

The capacity factor of a power plant is defined as the ratio, over a certain period of time, of the actual energy yield and the energy that could potentially be generated if it operated continuously at its rated power.

For the purpose of this document, the capacity factor of a project was calculated as the ratio of the expected energy[9] yield of the power plant, in MWa, and its installed capacity, in MW.

In order to provide a comprehensive comparison with international data and reports (either DC or AC-based), the capacity factors is shown in terms of both Qualified Power

[9] In accordance with MME Ordinance 258/2008, in the case of photovoltaic projects, the physical guarantee of the project corresponds to the expected energy production in the long-term.

and DC Power. As AC Power and Qualified Power are usually lower than DC Power, AC-based capacity factors will normally be higher than DC-based.

DC Power

(sum of the rated capacities of PV modules)

$$\boldsymbol{CF_{DC}} = \frac{Physical\ Guarantee\ (MWa)}{Power_{DC}\ (MWp)}$$

Qualified Power

(sum of the power of the generating units)

$$\boldsymbol{CF_{Qual.P}} = \frac{Physical\ Guarantee(MWa)}{Qualified\ Power\ (MW)}$$

Figure 16 – Capacity Factor (CF): in terms of DC or Qualified Power

Regarding Qualified Power, among technically qualified projects in the 2nd LER/2016, capacity factors were within the range of 18% and 34%. On the other hand, regarding DC Power, capacity factors were between 17% and 26%.

Note that higher capacity factors are associated with the choice of using sun-tracking systems, which contributes to increase energy yield of the plant, as shown in Figure 17.

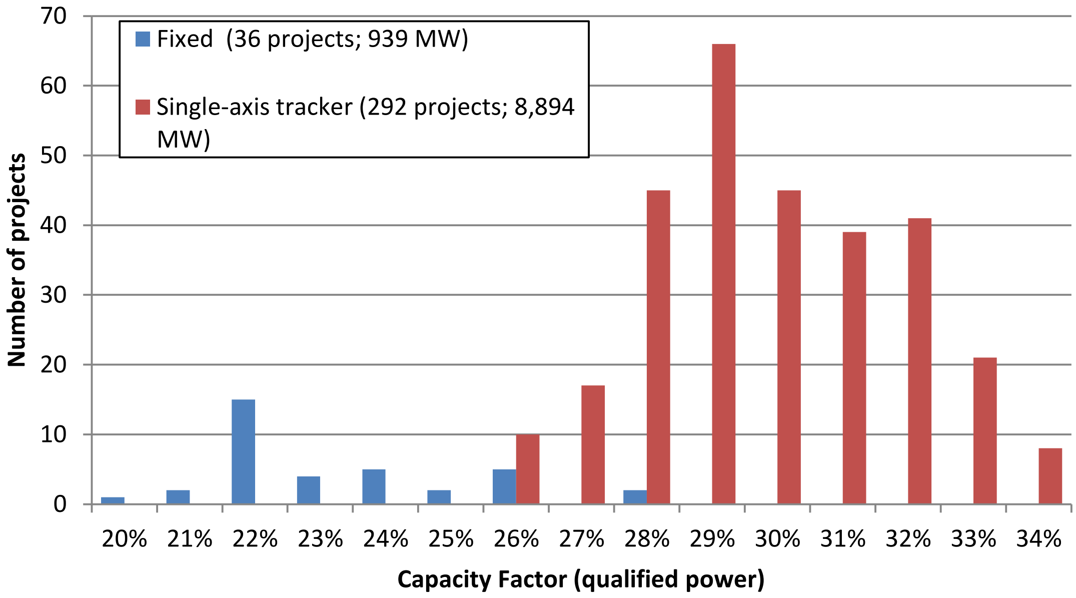


Figure 17 – Histogram of Capacity Factors

Capacity factor of the technically accepted projects using single-axis tracking system varied from 25% to 34% (AC-based) / 19% to 26% (DC-based). On the other hand, those with fixed support structure presented values from 18 to 28% (AC-based) / 17% to 21% (DC-based).

Other features are also relevant for the calculation of the capacity factor: ISF and solar resource. Figure 18 shows (for the qualified projects for the 2nd LER/2016), grouped in three irradiation ranges, type of mounting structure as well as three ISF ranges.

Figure 18 shows the an increase in capacity factor (CF) is expected under higher local irradiation. Also, the use of structures with single-axis tracking leads to an increase in the CF. Regarding ISF, lower values means that there are more modules (more DC power) connected to a same inverter, what increases the capacity factor in AC base, since the yield in energy production grows for the same inverter installed capacity. Therefore, larger capacity factors tend to be observed in projects with single-axis tracking structures, places with higher global horizontal irradiation and with lower ISF.

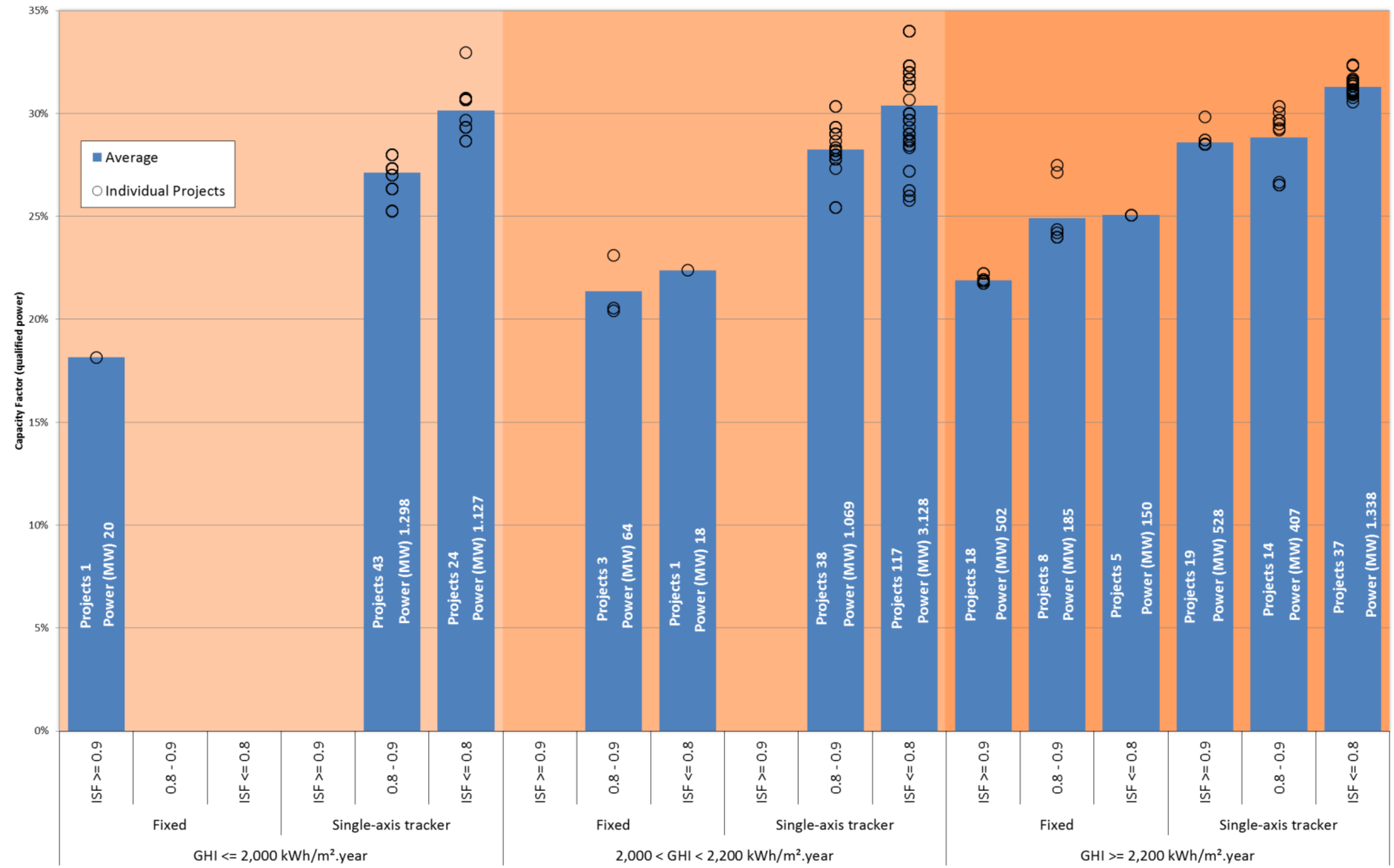


Figure 18 - Capacity Factor (based on qualified power) according to GHI, mounting structure type and ISF

4.4 Construction time

According to Ordinance MME 104/2016, new plants contracted in the 2nd LER/2016 were supposed to begin power supply on 1st July, 2019.

Evaluating the submitted schedules of the PV projects, it was possible to verify that 72% of them consider a construction period of up to 1 year and 15% inform up to 6 months as the required time for construction.

It should be noted that according to the ANEEL's Auction Notice for the 2nd LER/2016, in its Appendix XII (Estimated Schedule of Events), the estimated date for signing the PPA would be about 7 months and a half to 8 months and a half after the auction. This means that, under this condition, the projects would have less than 2 years for the construction of the PV power plants.

Most of the qualified projects considered:

- 4 to 7 months for terrain, foundation and structure works;
- 6 to 9 months for assembly of equipment; and
- 7 to 11 months for the substation and/or transmission line works

It should be noted that these figures are only indicative and that the particularities of each project must be noted.

4.5 CAPEX

Investment costs of the technically accepted projects, as stated by project developers, were estimated within the range of R$ 3,149/kWp to R$ 5,884/kWp. On average, these costs are similar to those verified among the technically accepted projects for the auctions of 2014 and 2015. The average, minimum and maximum CAPEX are represented in Figure 19. It should be emphasized that such investment amounts do not consider interest during construction and are referenced to December 2015.

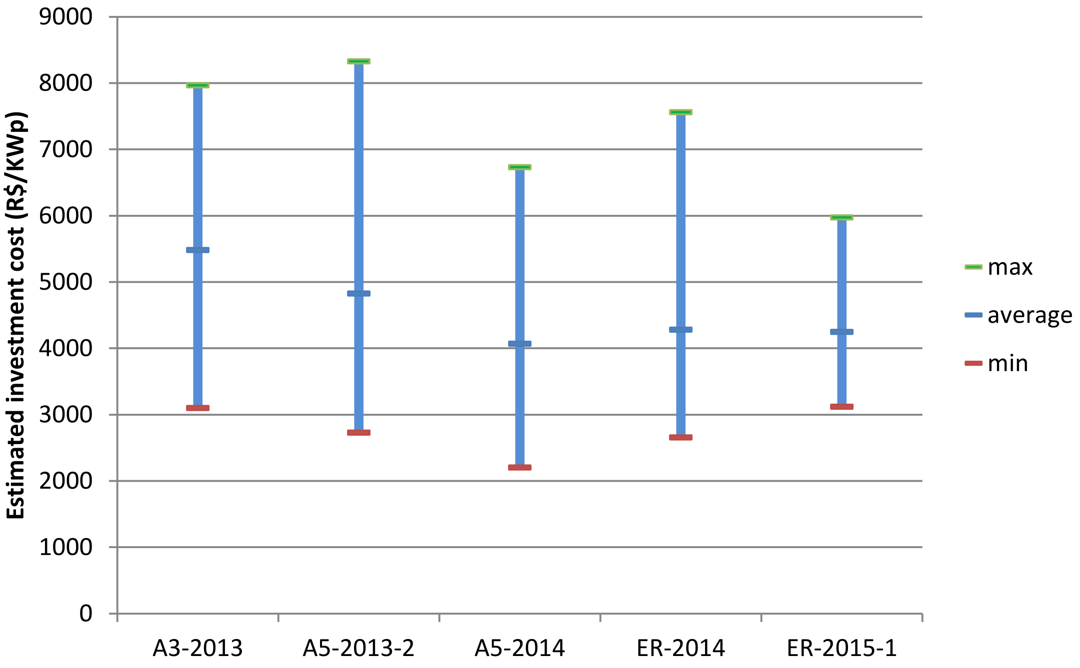


Figure 19 – CAPEX, in R$/kWp: comparing 2nd Reserve Auction to previous auctions

As the investment costs for PV projects are strongly related to the US dollars (imports), the range of CAPEX, in US$/kWp, is shown in Figure 20. The amounts were adjusted to the exchange rate of December prior to the respective auction[10]. Note that the average cost, in terms of US$/KWp, has decreased over the last three years, what was also noticed in several national and international references[11].

[10] Average exchange rate values in December of the year prior to the 2014, 2015 and 2016 auctions, in real per US dollar, respectively: 2.3455; 2,6394 and 3,8711. Source: http://www.ipeadata.gov.br/.
[11] NREL (U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016), Solar Power Europe, Berkeley (Utility-Scale Solar 2015 and Tracking the Sun IX), manufacturers and local suppliers.

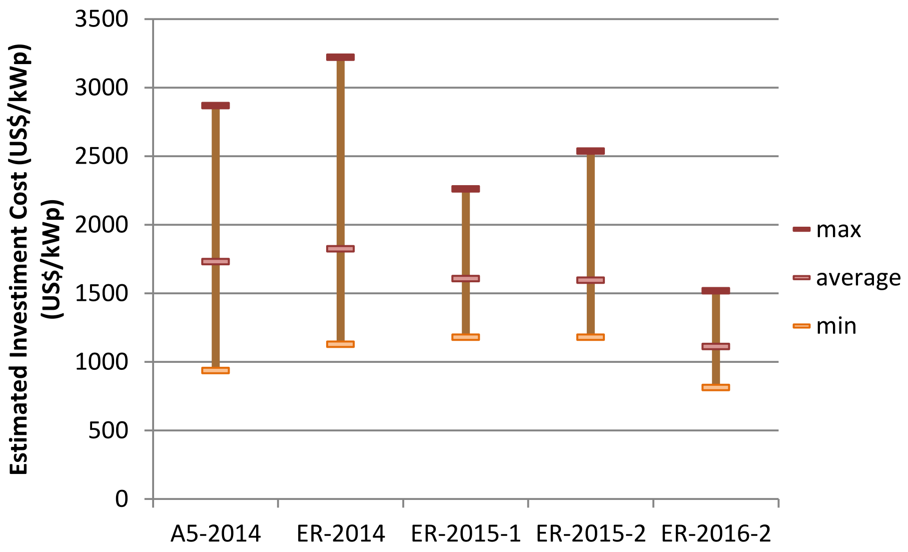


Figure 20 - CAPEX, in US$/kWp: comparing 2nd Reserve Auction to previous auctions

Figure 21 shows the inflation rate (IPCA) and the exchange rate (R$/US$) between December/2013 and December/2016.

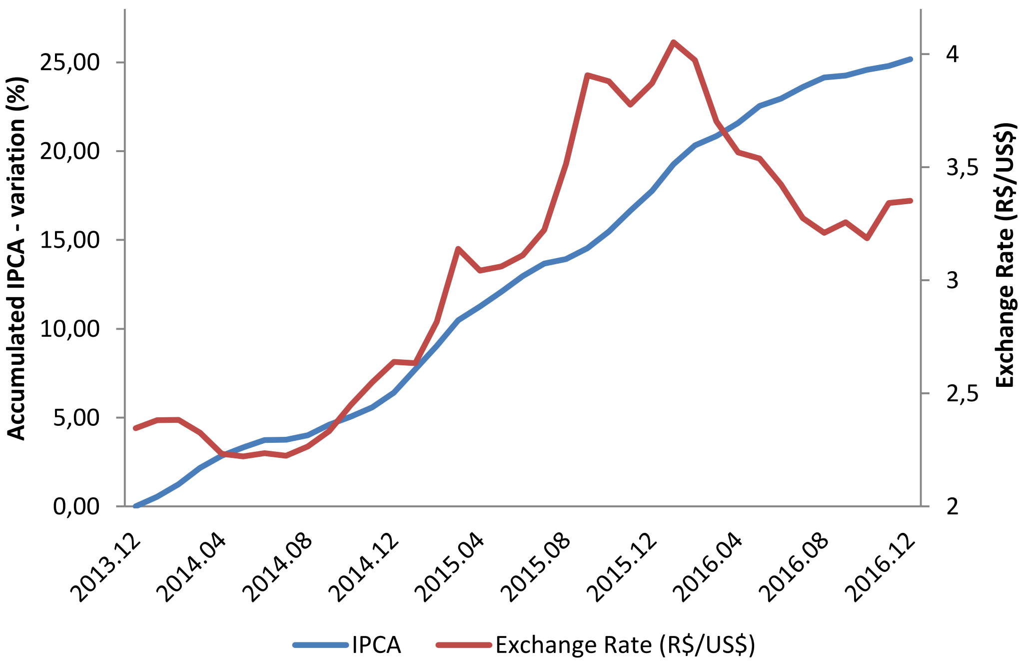


Figure 21 – Variation of accumulated inflation rate (IPCA) in % and Exchange Rate in R$/US$

It is worth to mention that in addition to the exchange rate and national inflation, other factors influence the cost of projects, such as the maturing of domestic and international markets and economies of scale.

Figure 22 depicts the average of investment costs for the projects enabled in R$/kWp, by cost categories, as declared by the project developers. Equipment accounts to the majority of costs, about 70%.

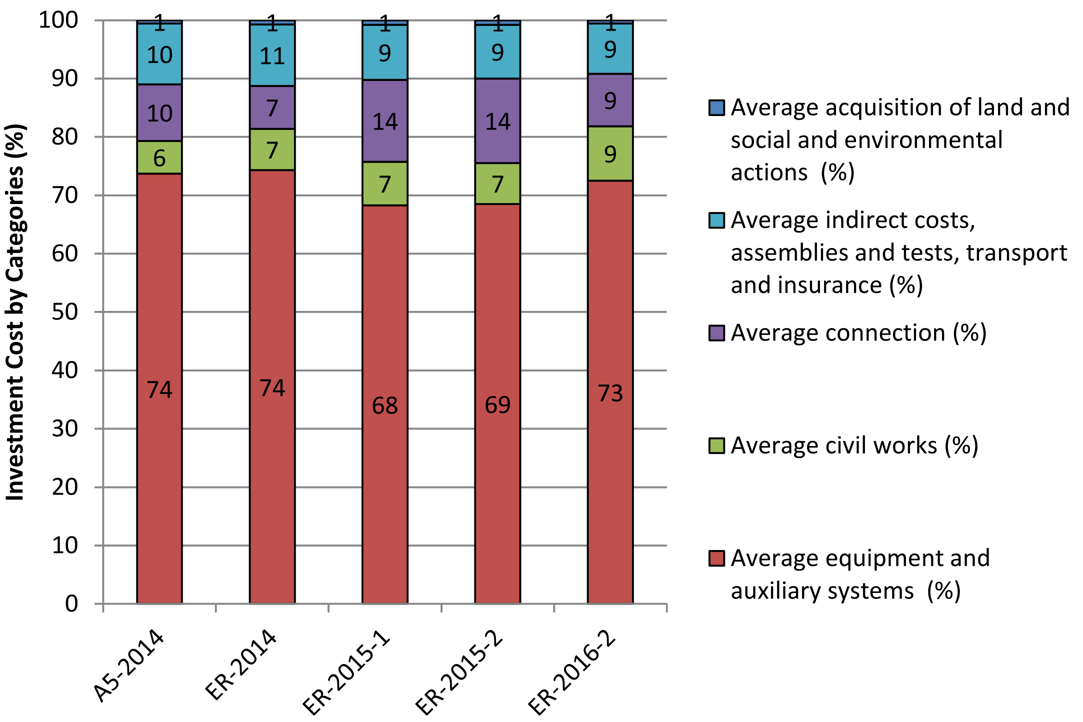


Figure 22 – Allocation of costs in the total project budget

In the 2nd LER/2016, about 63% of total equipment costs refers to modules, 19% to mounting structure, 13% to inverters and 5% to others, as shown in Figure 23.

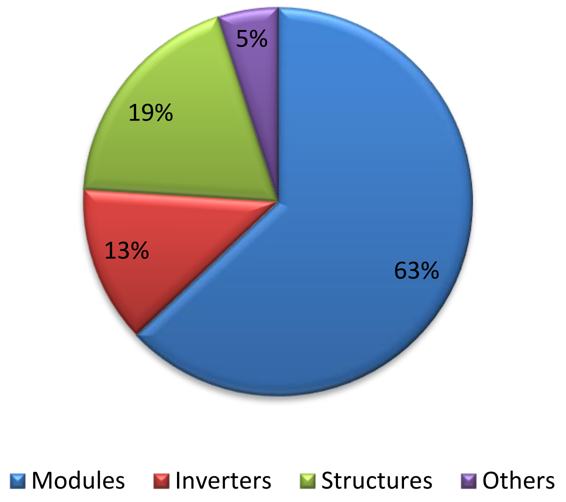


Figure 23 – Equipment Costs (technically accepted projects for the 2nd LER/2016)

As already mentioned in section 4.2.3, of the 328 technically accepted projects, 89% adopted single-axis tracking systems in their design. Regarding this sample, investment costs in mounting structures were, on average, around R$ 600/kWp. Compared to fixed-mounted, structure costs were about 70% higher.

Average informed costs of PV modules, among the qualified projects, ranged between R$ 1,200/kWp and R$ 2,800/kWp, with an average of R$ 1,930/kWp. No clear differences between costs for each module technology were noticed (even though expected).

On average, inverters cost R$ 500/kW.

4.6 Operation and maintenance fixed costs

The annual fixed cost of operation and maintenance (O&M) of a project is usually a percentage of its total investment cost. Among the qualified projects for the 2nd LER/2016, the average annual fixed O&M cost informed by developers was 0.8% of the total investment cost for projects with a fixed structure and 1.2% for those with a single-axis tracking. These values are similar to those verified in previous auctions.

4.7 Energy price

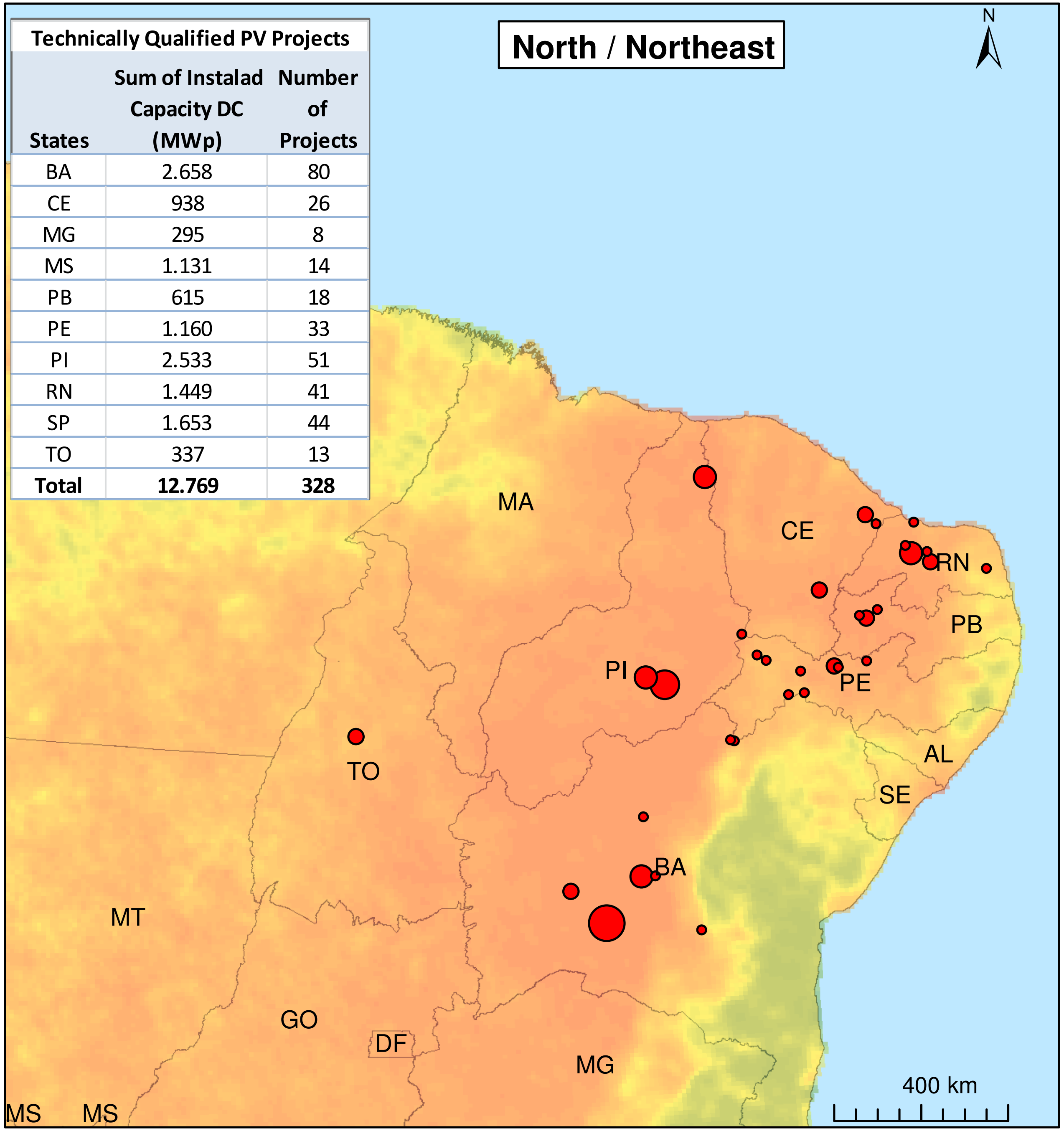
Despite the cancellation of the 2nd LER/2016, a price cap of R$320.00/MWh was established, which represents around US$ 95.52/MWh, considering an exchange rate of R$ 3.35/US$, referring to December 2016.

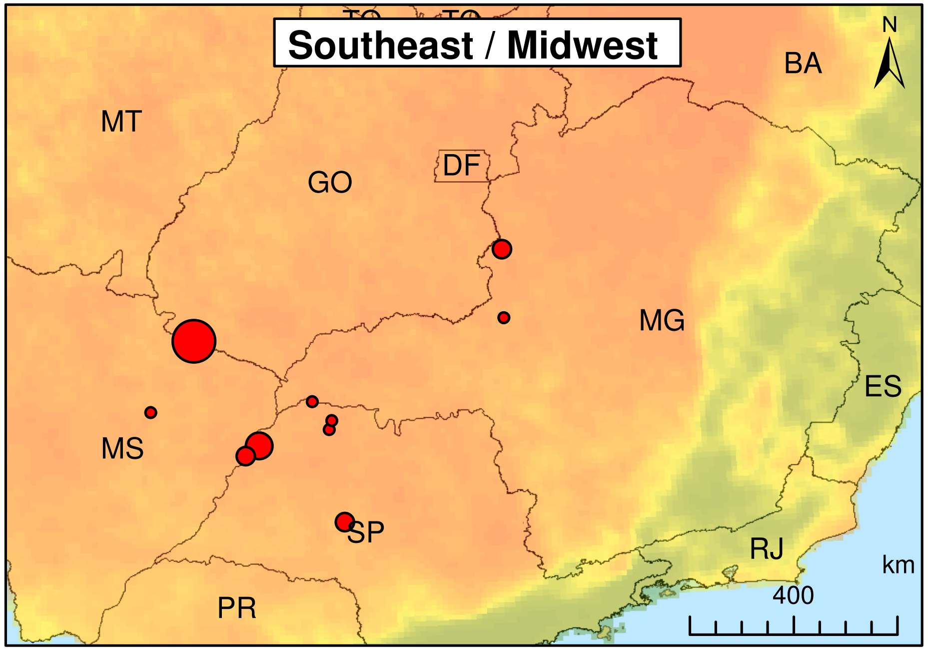
EPE-DEE-NT-030/2017
APPENDIX I

2nd LER/2016
Technically Accepted PVProjects
(Sum of Installed Capacity by city)

Empresa de Pesquisa Energética

Technically Qualified PV Projects		
States	Sum of Instalad Capacity DC (MWp)	Number of Projects
BA	2.658	80
CE	938	26
MG	295	8
MS	1.131	14
PB	615	18
PE	1.160	33
PI	2.533	51
RN	1.449	41
SP	1.653	44
TO	337	13
Total	**12.769**	**328**





Technically Accepted Sum of Instaled Capacity by city (MWp)

- Up to 200 MW
- 201 MW to 500 MW
- 501 MW to 800 MW
- 801 MW to 1.000 MW
- Above 1.000 MW

Back Ground: Global Horizontal Irradiation (kWh/m².ano) Color Grade:

1.600
1.800
1.900
2.150

Source: Atlas Brasileiro de Energia Solar (INPE, 2006)

Date: 01/27/2017
Source: AEGE/EPE System
Citys: IBGE 2010

EPE-DEE-NT-030/2017 APPENDIX II	2nd LER/2016 Solar Resource Measurement Stations

Empresa de Pesquisa Energética