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PHOTOVOLTAIC POWER: Review and Trends for Brazil

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ABSTRACT

The objective of this paper is to assess photovoltaic power to contribute in public policies development to promote strategically the objectives of the current model of the Brazilian electricity sector. It presents an overview of photovoltaic power worldwide and in Brazil, its evolution and technical and economic trends. It defines the regulatory environment for the use of this source in Brazil. Therefore, it is concluded that this technology is not yet at a mature stage commercially, the advancement of this source in the energy matrix is slow, with some exceptions such as Germany, and there is significant expectation of cost reduction and efficiency increase due to innovations in production processes. This market, in Brazil, is incipient and it demand governmental incentives for development in the short term. But it is expected that this source will be attractive in the medium term.

Keywords: *Power Energy, photovoltaic, trends, Brazil*

1. INTRODUCTION

Solar energy is present across the planet's surface and regions with intense incident solar radiation have a much higher capacity factor. The capacity factor - FC - is a measure of the availability of a technology for generating power energy is the capacity factor - CF - which measures the relationship between the generation of a plant and its capacity, ie, in a given period, what percentage of the installed capacity (wp) of this technology will effectively generate energy (Wh). The CF varies due to climatic parameters of the region, such as radiation, temperature, humidity and light period. For example, in high altitude regions the radiation is more intense because there is a lower layer of air filtering the sun's rays. The temperature as well as humidity, affects the efficiency of the modules. The larger the latitude the greater the difference in CF between winter and summer, since during the summer the sun shines longer than during the winter.

For a system that has a capacity factor of 10% and capacity of 1 kWp in a month will generate 73 kWh because one month has 730 hours. So, higher capacity factor implies a faster return on invested capital. The difference between sunny regions on earth can be more than twice the energy output per installed power.

For the PV modules CF is between 10% and 25% for fixed systems, but values outside this range may be found for specific regions (IRENA, 2013). In Europe, the average value measured in 2011 was close to 10%, and generated 44.8 TWh. For Germany this figure fell to less than 9% in 2011 data, this due to a higher latitude. In Brazil, the capacity factors are found between 10 and 20%. For the hydroelectric capacity factor varies with hydrology and reservoir capacity. Small hydropower - PCH - do not have reservoirs often, which greatly reduces your CF. In Brazil, hydroelectric plants have an average of 55% CF. The Brazilian Northeast has relatively more constant wind regimes, wind farms present granddaughter CF region have an average of 35%, higher than the world average of 30%. The biomass of sugarcane bagasse generates only at harvest time, your CF is around 60%. The thermal average CF have 80% nuclear and 90% (EPE, 2007).

The Energy Payback Times – EPT – from the source, ie, how long the installation takes to generate the energy needed to manufacture the equipment that compose it. This ratio is important because solar cells require a large amount of power to be produced. Studies indicate EPT between 1.5 and 2.5 years (Yue et al., 2014). It is hoped that advances in construction techniques and technologies available will reduce production costs considerably, reducing the energy cost for six months in the coming years (EPIA, 2013).

2. ANALYSIS OF PRODUCTION AND INSTALLED CAPACITY EXPANSION OF PV GENERATION

Although solar energy harnessed by PV generation is now the third most exploited renewable source in the world, after hydro and wind, it represents less than 1% of world primary energy production (EPIA, 2013). Primary energy production is understood as the use of energy resources that are available in nature (oil, natural gas, hydropower, wind power, biomass, solar) for conversion into another form of energy useful to humans for non-biological processes.

Countries with higher manufacture of PV cells are China, Taiwan, Germany and Japan. Given that China and Taiwan accounted for over 60% of world production.

The countries with the largest PV generation in 2012 are, respectively, Germany, Italy and China. However, Germany, China and USA are countries that plan to keep investing in this resource in the coming years (EPIA, 2014).

The Chinese BYD in 2014 announced investments of 200 million reais to build a factory of PV modules and batteries in Campinas, SP. The plant is expected to generate 450 new direct jobs.

In Brazil, photovoltaic generation is not used in large scale, connected to the grid, but as remote power, just like weather monitoring, telecommunications and power generation equipment to isolated communities. However, in recent years many countries have begun to invest heavily in PV generation and Brazil joined this trend from 2013.

The ten-year Brazilian expansion plan foresees investment of 21% of GDP in infrastructure for energy production in the period between 2013 and 2022 most of this investment focuses on oil and gas. To produce electricity, it is estimated investments of around 4% of GDP (EPIA, 2013) to expand actual installed capacity in Brazil. Brazil has 129 GW of installed capacity, of which only 0.01 GW are solar photovoltaic. The expansion focuses on hydroelectric 26%, 38 GW, almost located in the northern region of the country and wind farms 11,6%, 15 GW, in the northeast, thermoelectric 4,7%, 6 GW, Biomass 3,9%, 5 GW, and solar 1%, 1,4 GW (EPE, 2012).

Hydroelectric generation has a low production cost of energy (R$/MWh), however, as the major energy consumption centers are in the southeast, it needs heavy investments in transmission and the environmental impacts on the construction of these huge transmission lines are considerable. The integration of hydropower from different regions allows the system gain value because water complementarity occurs, ie, there is complementary seasonality of the various basins where dams are located, which may make energy production more constant. This is possible when large dams are constructed. For environmental reasons, the dams built in the north have small reservoirs, which prevent this synergy to be incorporated into the system.

Wind generation presents competitive values today. In auctions of energy is the energy that has less value. The production of wind energy has complementarity with river flows, generating value for the system. However, wind power is most pronounced during the night, where the load is smaller. Still, the production of wind energy varies throughout the day and its predictability is bad. With this in order to ensure reliable operation there is considerable waste of energy. So this is an interesting source to be exploited in the country, but has limitations.
It is important to know that in 2009 wind power was listed as an expensive and risky source. With a strong policy incentives supported by the Energy Research Company - EPE - this source is now one of the cheapest options and Brazilians are considered local parks with attractive wind regime, with little variation between years.

With solar PV source is no different. Today is quoted as expensive, but might be the most attractive option available in the country in five years. To do this requires investments in research to measure accurate prediction models with different generation technologies in different locations.

The solar PV generation has advantages as produce directly to centers of consumption, eliminating investments in transmission and energy losses that are inherent in this transport, producing more constant than wind energy, allows high bit sprayed investments and develop a local economy by generating direct and indirect distribution with higher income jobs.

3. REGULATORY ASPECTS IN BRAZIL

Although the principle of generating electricity with photovoltaic cells technology is known and used for a long time, the exploitation of photovoltaics still demand technology maturation on technique and commercially aspects in many regions. To understand the integration of this technology in the Brazilian market is necessary to review some concepts of the current model of the Brazilian Electric Sector - *BES*.

The current model, regulated by Law No. 10,848, enacted by the President on March 15, 2004, defines two environments for contracting energy, one set (Regulated Contracting Environment - R*CE*), bringing together all retail consumers and distributors, in which power purchases always make a bid, the criterion of lowest rate, and other free (*F*ree Contracting Environment - *FCE*), in which are inscribed the free consumers and traders, with their ability to negotiate supply contracts electricity. The objectives of the current model of the BES are: low tariffs; Energy security; Regulatory stability; and social insertion.

Promote the expansion of supply with low tariffs, which is an essential factor for attending the social function of energy and that contributes to improving the competitiveness of the economy. Sought to promote this goal by separating the potentially competitive functions of generation and retail from the natural monopoly functions of transmission and distribution; and establish the procurement of all necessary load for consumption jointly by all distributors by bidding in the form of auctions regulated by ANEEL and organized directly or through the Trading Chamber (CCEE), allowing the appropriation, the rate of economies of scale in purchasing energy power.

Ensure security of supply of electricity, a basic condition for sustainable economic development. For this hiring 100% of the demand from all consumer agents (distributors and free consumers) is required. Hiring energy, aiming at market expansion always occurs in advance of three and five years and through long-term contracts.

Ensure the stability of the regulatory framework with a view to the attractiveness of investments in system expansion. The winners of the bids get supply agreements for long term (15-30 years), which tends to reduce the cost of financing. And the new power plants and transmission lines are offered for bidding to study the technical and economic feasibility and preliminary environmental license granted, which reduces risks to the investor.

Promote social inclusion through the electricity sector, in particular the universal service programs. The restructuring of the sector planning, with price objection, allowing the choice of the most efficient designs and the most economical solutions for expanding the supply.

3.1 Supply Side by PV Generation - Energy Auctions

The auctions are made by the criterion of lowest rate, ie, a value is assigned to the ceiling lots auctioned energy and the winner is the one who undertakes to provide the energy for the lowest value. The new model segregates the market in new energy and energy existing ("old energy"). Be understood as new generation projects who until the beginning of the bidding process for the ongoing expansion: i) are not holders of a concession, permission or authorization; or ii) are part of existing development that will be the subject of expansion, restricted the increase in capacity. The new energy contracts should include validity of 15 and 35 years. And the existing power contracts 3-15 years.

"A" is considered as the year scheduled for the beginning of the supply of electricity purchased at auction, so the timeline for the completion of the auction is the following:

- A-5: In the fifth year preceding the year "A" the auction is held for the purchase of "new" energy;
- A-3: In the third year preceding the year "A" another auction of "new" energy is held;
- A-1:In the year prior to "A" year the auction to purchase power from existing ventures Generation is performed.

Also, are promoted Auctions Adjustment, having intended to supplement the power load required to meet the consumer market of the distributors, to the limit of 1% of this burden.

Also, Auctions Alternative Sources were regulated by Decree No. 6048, aiming to be one of the mechanisms to meet the consumer market of the distributors, promoting renewable energy.

The cost of generating electricity using photovoltaic (R $ / Wh), considering the cost of capacity (fixed costs) is higher than the cost of various alternatives available in Brazil, such as biomass, hydro (small to large) and wind. Therefore, through the new energy auctions is not possible for photovoltaics participate in the Brazilian energy matrix yet.

However, considering that this source is promising in the medium term, use it for commercial pilots would be an important step to be taken. Therefore, we discuss two ways of inserting this source: Through strong incentives for it to be economically competitive with other sources; and as was done with wind energy, this source before settling in Brazil, performing a specific auction for this energy source, an auction of photovoltaics.

3.2 Supply Side of the Distribution - Distributed Generation

From April 2012, the National Electric Energy Agency - ANEEL, issued Normative Resolution No. 482, which establishes the legal basis for the connection of micro-generation (up to 100 KW) and mini-generation (100 kW to 1 MW) of the power distribution and compensation for electricity dispatched in network systems. Ie, allows consumers to also act as producers, installing small generaton in your consumer unit. The energy produced by them can be used by themselves or injected into the grid in exchange for credits. This without losing the right to buy electricity whenever they need, exactly the same way they bought previously.

The Energy Efficiency Program - EEP - the Brazilian electricity sector provides investment in projects of photovoltaic generation to consumers, including resources repayable in the event of public or residential low-income consumers. These are resources of approximately 400 million dollars per year that can leverage the applications of solar photovoltaics on the consumption side.

4. COST ANALYSIS OF DEPLOYMENT AND OPERATION

To analyze the costs of deployment and maintenance of PV generation is necessary to understand all the necessary components for using this technology. The core of this technology are the PV modules, consisting of groups of cells responsible for converting light into electricity.

When a PV module is operating, energy generated is direct current, while the electricity distribution network operates on alternating current. Therefore it is necessary to couple the generation of an inverter system, responsible for reversing the Direct Current (DC) into Alternating Current (AC). This equipment is only dispensable for isolated applications and the equipment to be coupled to the PV generation system are powered by DC. The inverters are simple and available in different ranges of power equipment manufacturing.

Isolated systems often need to store energy for use at times of peak demand or when the system is not generating power. In this case, the battery banks are used. Currently there are special batteries for this application, with a useful life time of 15 years. To charge the batteries charge controllers that have great influence on the life of the battery bank are used.

Breakdown cost analysis for PV systems around the world consider a cost called Balance of System - BoS. This cost is heavily dependent on the application area and the degree of sophistication of the tracking systems when applied. Residential systems have BoS cost greater than large industrial applications because of economies of scale. BOS comprises structural costs of the system, such as transformers; Solar Trackers; Land use; Components for mounting and assembly modules; Various electrical components; Costs of installation service; Battery bank, if any; Project costs; and Fees and permissions. This cost may or may not also include the cost of inverters. The cost of services is a considerable share of the cost of BoS, reaching up to 50% and varies greatly by region. Cost BoS reaches 100% vary in different regions (IRENA, 2013).

The learning curve in this area is high because the technologies are new, and innovations recurrently generate greater reductions than expected, because they generate new innovations. It is interesting to note that the actual cost fell faster than expected for all price projections made since 2008 (Feldman et al., 2012). Observing the latest projection, it is expected that the price is coming very close to stabilize. However, this price can be drastically reduced with innovations in manufacturing processes of the cells and not just with the gain in efficiency. The researchers' goal is to reduce the cost of modules for $ 0.5 / Wp by 2020 (Powell et al., 2012).

It is very important to note that the cost of PV modules contribute significantly to the cost of generation of solar PV energy. The prices of acquisition and installation of PV generation using crystalline silicon solar cells are falling for decades and competitive values reached in relation to the cost of power purchased by consumers in the regulated market. In Germany this cost reached $ 2.20 / Wp, approximately R$ 5.50/ Wp, and in Brazil this cost, for large-scale varies between 8,00 to 6,00 R$/Wp (values from Institute energy and Environment at the University of São Paulo projects).

Publications indicate that organic PV cells - OPV - with an efficiency of 3% have a cost of £ 7.80 / Wp. But the expectation is that this technology can be produced on an industrial scale at a cost between 0.15 and 0.25 R $ / Wp with efficiency of 10%. The OPV cells are printed on a roll of film and spend 20 times less energy to be produced. So, it is much cheaper but it shows a much lower efficiency and are perishable (Machui, 2014). Studies indicate that this type of cell degradation is rapid. Over a year efficiency can drop by half or even 20% of the original cell efficiency (Krebs et al., 2007 and Gevorgyan et al., 2014). To evaluate the real cost of this technology it is needed energy production long-term studies to observe its cost and production throughout his life. However, there is great expectation for the evolution of this technology.

The measures that Brazil adopts to encourage this source are quite similar to those that led to the establishment of a wind industry in the country. Namely: i) the achievement of specific source for this federal and state auctions; ii) Discounts on Usage Rate of Distribution System - TUSD and Usage Rate Transmission System - TUST for larger plants (up to 30 MW) that use solar power: For enterprises that enter into commercial operation by December 31 2017, the 80% discount will apply for the first 10 years of operation of the plant and the discount will be reduced to 50% after the tenth year of operation of the plant; and for enterprises that enter into commercial operation after December 31, 2017, remains the 50% rate (the discount is applied to wind and biomass as well); and iii) Exemption of VAT for domestic producers of equipment for solar PV production.

With this, the Tecnometal Solar Energy, a Brazilian company that produces PV modules, provides systems for distributed generation R $ 6.83 / Wp, cost competitive with importing products from China. However, this cost does not allow this unit to be competitive with other options available.

With current costs, the financial return on investment in photovoltaic generation varies greatly according to the scale of generation (installed capacity), the technologies employed and where the generation is installed.

To evaluate the economic feasibility of installing residential photovoltaic generation are needed to set many parameters. Thus, different cases were analyzed for all distribution utilities in Brazil. As each has distinct rate. Each parameter and its respective analyzed values are given below:

a. As the incident energy bill ICMS varies in each state and in relation to consumption range, it sets the range of consumption of residence [Amounts in kWh used in the study: 650 and 50];
b. The capacity factor, as explained above, depends on the characteristics of each region, irradiation and temperature. Defined three ranges of load factor are found in different regions [Values used in the study: 20%; 17%; 14%];
c. The most important parameter, installation cost, dollars per kWatts peak (R $ thousand / kWp), the current value of R $ 6.50 / Wp and a value that can be reached in the near future of R $ 3.25 were defined / wp;
d. Hurdle rate, ie, the investor can get income by investing in another application such as direct treasure [Value used in the study: 12% pa] or savings [Value used in the study: 7% pa].

For this study only were considered ICMS, PIS and COFINS. As told, ICMS varies according to the state where it takes place. The PIS / COFINS was assumed the average value between 2011 and 2013 and as a fixed value of 4.8%.

5. RESULTS

Following the results of the Net Present Value – NPV – to cost R$6.50/Wp and R$3.25/Wp with consumption of 50kWh / month, high residential consumption, which covers the largest range of ICMS are presented.

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Table 1: Results for NPV costs of R$ 6.50 / wp (left) and R$ 3.25 / wp (right), consumption 650kwh/month.

	R$6,5/Wp - FC 14% - 12% a.a.	R$6,5/Wp - FC 14% - 7% a.a.	R$6,5/Wp - FC 17% - 12% a.a.	R$6,5/Wp - FC 17% - 7% a.a.	R$6,5/Wp - FC 20% - 12% a.a.	R$6,5/Wp - FC 20% - 7% a.a.
Rio Branco	-3.553,63	11.198,52	3.843,08	18.595,23	9.020,78	23.772,93
Maceió	-6.252,47	7.461,81	1.144,24	14.858,52	6.321,93	20.036,22
Macapá	-26.039,63	-19.934,71	-18.642,92	-12.538,00	-13.465,23	-7.360,31
Manaus	-13.159,58	-2.101,50	-5.762,87	5.295,21	-585,17	10.472,91
Salvador	-11.767,58	-174,19	-4.370,87	7.222,52	806,82	12.400,21
Fortaleza	-9.716,78	2.665,27	-2.320,07	10.061,97	2.857,62	15.239,67
Brasília	-14.778,35	-4.342,78	-7.381,64	3.053,93	-2.203,94	8.231,63
Vitória	-9.055,29	3.581,14	-1.658,58	10.977,85	3.519,11	16.155,54
Goiânia	-9.594,88	2.834,05	-2.198,17	10.230,75	2.979,52	15.408,45
São Luís	-4.321,78	10.134,97	3.074,93	17.531,68	8.252,62	22.709,37
Cuiabá	-5.139,75	9.002,44	2.256,95	16.399,15	7.434,65	21.576,84
Campo Grande	-9.908,60	2.399,69	-2.511,89	9.796,40	2.665,81	14.974,09
Belo Horizonte	-11.933,02	-403,25	-4.536,31	6.993,46	641,39	12.171,16
Curitiba	-10.894,17	1.035,10	-3.497,46	8.431,80	1.680,23	13.609,50
João Pessoa	-8.941,46	3.738,75	-1.544,75	11.135,46	3.632,95	16.313,15
Belém	1.088,45	17.625,77	8.485,16	25.022,48	13.662,86	30.200,18
Recife	-10.491,21	1.593,02	-3.094,50	8.989,73	2.083,20	14.167,43
Teresina	-5.505,83	8.495,58	1.890,88	15.892,29	7.068,57	21.069,99
Rio de Janeiro	-7.219,61	6.122,75	177,10	13.519,46	5.354,79	18.697,15
Natal	-11.215,44	590,28	-3.818,73	7.986,99	1.358,96	13.164,68
Porto Alegre	-13.898,15	-3.124,10	-6.501,44	4.272,61	-1.323,75	9.450,31
Porto Velho	-10.377,01	1.751,14	-2.980,30	9.147,85	2.197,40	14.325,55
Boa Vista	-18.597,37	-9.630,45	-11.200,66	-2.233,74	-6.022,97	2.943,96
Florianópolis	-10.230,38	1.954,16	-2.833,67	9.350,87	2.344,03	14.528,57
Aracaju	-9.517,38	2.941,35	-2.120,67	10.338,06	3.057,02	15.515,75
São Paulo	-16.712,62	-7.020,90	-9.315,91	375,81	-4.138,22	5.553,50
Palmas	-4.197,19	10.307,47	3.199,52	17.704,18	8.377,21	22.881,88

	R$3,25/Wp - FC 14% - 12% a.a.	R$3,25/Wp - FC 14% - 7% a.a.	R$3,25/Wp - FC 17% - 12% a.a.	R$3,25/Wp - FC 17% - 7% a.a.	R$3,25/Wp - FC 20% - 12% a.a.	R$3,25/Wp - FC 20% - 7% a.a.
Rio Branco	17.403,71	32.155,87	21.102,07	35.854,22	23.690,91	38.443,07
Maceió	14.704,87	28.419,15	18.403,22	32.117,51	20.992,07	34.706,35
Macapá	-5.082,29	1.022,63	-1.383,94	4.720,99	1.204,91	7.309,83
Manaus	7.797,76	18.855,85	11.496,12	22.554,20	14.084,97	25.143,05
Salvador	9.189,76	20.783,15	12.888,11	24.481,51	15.476,96	27.070,35
Fortaleza	11.240,56	23.622,61	14.938,91	27.320,96	17.527,76	29.909,81
Brasília	6.178,99	16.614,56	9.877,35	20.312,92	12.466,20	22.901,76
Vitória	11.902,05	24.538,48	15.600,40	28.236,83	18.189,25	30.825,68
Goiânia	11.362,46	23.791,39	15.060,82	27.489,74	17.649,66	30.078,59
São Luís	16.635,56	31.092,31	20.333,91	34.790,66	22.922,76	37.379,51
Cuiabá	15.817,59	29.959,78	19.515,94	33.658,13	22.104,79	36.246,98
Campo Grande	11.048,75	23.357,03	14.747,10	27.055,38	17.335,95	29.644,23
Belo Horizonte	9.024,32	20.554,09	12.722,68	24.252,45	15.311,52	26.841,29
Curitiba	10.063,17	21.992,44	13.761,52	25.690,79	16.350,37	28.279,64
João Pessoa	12.015,88	24.696,09	15.714,24	28.394,44	18.303,09	30.983,29
Belém	22.045,80	38.583,11	25.744,15	42.281,47	28.333,00	44.870,31
Recife	10.466,13	22.550,36	14.164,49	26.248,72	16.753,33	28.837,57
Teresina	15.451,51	29.452,92	19.149,86	33.151,28	21.738,71	35.740,12
Rio de Janeiro	13.737,73	27.080,09	17.436,08	30.778,44	20.024,93	33.367,29
Natal	9.741,90	21.547,62	13.440,25	25.245,97	16.029,10	27.834,82
Porto Alegre	7.059,19	17.833,24	10.757,54	21.531,60	13.346,39	24.120,45
Porto Velho	10.580,33	22.708,48	14.278,69	26.406,84	16.867,53	28.995,68
Boa Vista	2.359,97	11.326,89	6.058,32	15.025,25	8.647,17	17.614,09
Florianópolis	10.726,96	22.911,50	14.425,32	26.609,86	17.014,17	29.198,70
Aracaju	11.439,96	23.898,69	15.138,31	27.597,04	17.727,16	30.185,89
São Paulo	4.244,72	13.936,44	7.943,07	17.634,79	10.531,92	20.223,64
Palmas	16.760,15	31.264,81	20.458,50	34.963,17	23.047,35	37.552,01

Following the results of the NPV for cost of R$ 6.50/ Wp and R$ 3.25 / Wp with consumption of 650kWh / month, a consumption of low income, which focuses on the smallest range of ICMS or even exemption are presented.

Table 2: Results for NPV costs of R$ 6.50 / wp (left) and R$ 3.25 / wp (right), consumption 50kwh/month.

	R$6,5/Wp - FC 14% - 12% a.a.	R$6,5/Wp - FC 14% - 7% a.a.	R$6,5/Wp - FC 17% - 12% a.a.	R$6,5/Wp - FC 17% - 7% a.a.	R$6,5/Wp - FC 20% - 12% a.a.	R$6,5/Wp - FC 20% - 7% a.a.
Rio Branco	-575,16	443,56	-6,18	1.012,54	392,11	1.410,83
Maceió	-480,96	573,99	88,02	1.142,96	486,30	1.541,25
Macapá	-2.003,05	-1.533,44	-1.434,07	-964,46	-1.035,79	-566,18
Manaus	-1.012,28	-161,65	-443,30	407,32	-45,01	805,61
Salvador	-905,20	-13,40	-336,22	555,58	62,06	953,86
Fortaleza	-747,44	205,02	-178,47	774,00	219,82	1.172,28
Brasília	-1.249,29	-489,82	-680,32	79,16	-282,03	477,44
Vitória	-696,56	275,47	-127,58	844,45	270,70	1.242,73
Goiânia	-738,07	218,00	-169,09	786,98	229,19	1.185,27
São Luís	-628,20	370,12	-59,22	939,10	339,06	1.337,38
Cuiabá	-596,79	413,61	-27,82	982,58	370,47	1.380,87
Campo Grande	-925,85	-42,00	-356,88	526,98	41,41	925,26
Belo Horizonte	-917,92	-31,02	-348,95	537,96	49,34	936,24
Curitiba	-838,01	79,62	-269,04	648,60	129,25	1.046,88
João Pessoa	-687,80	287,60	-118,83	856,57	279,46	1.254,86
Belém	83,73	1.355,83	652,70	1.924,81	1.050,99	2.323,09
Recife	-967,69	-99,92	-398,71	469,05	-0,43	867,34
Teresina	-423,53	653,51	145,45	1.222,48	543,74	1.620,77
Rio de Janeiro	-555,35	470,98	13,62	1.039,96	411,91	1.438,24
Natal	-862,73	45,41	-293,75	614,38	104,54	1.012,67
Porto Alegre	-1.069,09	-240,32	-500,11	328,66	-101,83	726,95
Porto Velho	-798,23	134,70	-229,25	703,68	169,03	1.101,97
Boa Vista	-1.430,57	-740,80	-861,59	-171,83	-463,31	226,46
Florianópolis	-786,95	150,32	-217,97	719,30	180,31	1.117,58
Aracaju	-732,11	226,26	-163,13	795,24	235,16	1.193,52
São Paulo	-1.285,59	-540,07	-716,61	28,91	-318,32	427,19
Palmas	-322,86	792,88	246,12	1.361,86	644,40	1.760,14

	R$3,25/Wp - FC 14% - 12% a.a.	R$3,25/Wp - FC 14% - 7% a.a.	R$3,25/Wp - FC 17% - 12% a.a.	R$3,25/Wp - FC 17% - 7% a.a.	R$3,25/Wp - FC 20% - 12% a.a.	R$3,25/Wp - FC 20% - 7% a.a.
Rio Branco	1.036,95	2.055,67	1.321,44	2.340,16	1.520,58	2.539,30
Maceió	1.131,14	2.186,09	1.415,63	2.470,58	1.614,77	2.669,72
Macapá	-390,95	78,66	-106,46	363,15	92,69	562,29
Manaus	599,83	1.450,45	884,32	1.734,94	1.083,46	1.934,08
Salvador	706,90	1.598,70	991,39	1.883,19	1.190,54	2.082,33
Fortaleza	864,66	1.817,12	1.149,15	2.101,61	1.348,29	2.300,75
Brasília	362,81	1.122,28	647,30	1.406,77	846,44	1.605,91
Vitória	915,54	1.887,58	1.200,03	2.172,06	1.399,17	2.371,21
Goiânia	874,04	1.830,11	1.158,52	2.114,60	1.357,67	2.313,74
São Luís	983,90	1.982,22	1.268,39	2.266,71	1.467,53	2.465,85
Cuiabá	1.015,31	2.025,71	1.299,80	2.310,20	1.498,94	2.509,34
Campo Grande	686,25	1.570,11	970,74	1.854,59	1.169,88	2.053,74
Belo Horizonte	694,18	1.581,08	978,67	1.865,57	1.177,81	2.064,71
Curitiba	774,09	1.691,73	1.058,58	1.976,21	1.257,72	2.175,36
João Pessoa	924,30	1.899,70	1.208,79	2.184,19	1.407,93	2.383,33
Belém	1.695,83	2.967,93	1.980,32	3.252,42	2.179,46	3.451,56
Recife	644,41	1.512,18	928,90	1.796,67	1.128,04	1.995,81
Teresina	1.188,58	2.265,61	1.473,07	2.550,10	1.672,21	2.749,24
Rio de Janeiro	1.056,75	2.083,08	1.341,24	2.367,57	1.540,38	2.566,71
Natal	749,38	1.657,51	1.033,87	1.942,00	1.233,01	2.141,14
Porto Alegre	543,01	1.371,79	827,50	1.656,28	1.026,65	1.855,42
Porto Velho	813,87	1.746,81	1.098,36	2.031,30	1.297,50	2.230,44
Boa Vista	181,54	871,30	466,02	1.155,79	665,17	1.354,93
Florianópolis	825,15	1.762,42	1.109,64	2.046,91	1.308,78	2.246,05
Aracaju	880,00	1.838,36	1.164,49	2.122,85	1.363,63	2.321,99
São Paulo	326,52	1.072,03	611,01	1.356,52	810,15	1.555,66
Palmas	1.289,24	2.404,99	1.573,73	2.689,47	1.772,87	2.888,62

(Source: Aneel – Data from 18/11/2014)

Consumption of low-income is considered monthly consumption less than 80 or 50 kWh, depending on the state. To this class, ICMS are lower or even null. Note that even for consumption of 50 kWh / month there are already cases where there is economic viability to meet consumption with PV generation is an important result and should be followed.

Therefore, with current costs is possible, in some cases, investment in residential distributed generation using crystalline silicon modules. However, research on cooling of photovoltaic cells, methods of producing solar grade silicon cheaper, high efficiency cells and solar concentrators can facilitate the diffusion of this technology on a large scale globally (Powell et al., 2012).

In 2007, Brazil was created by CSEM - Centre Suisse d'Electronique and Microtechnique SA, the investment management group of FIR Capital, with the support of FAPEMIG, BNDES, Minas Gerais and FIEMG. This center has received investments of 40 million Reais and should be one of the world largest producers of electronic and print OFV.

One should also reflect, in each case, no economic gains that photovoltaic distributed generation can bring. In European countries, like Germany in June 2014 that generated 50% of its demand using solar photovoltaic (Mendonça, 2014), there is a consensus of the population spend a little more to have a renewable matrix.

6. CONCLUSIONS

In Brazil, the PV market is incipient. Although the legal framework for use of this source in homes, commercial facilities and produce electricity on a large scale is already consolidated, this market has not attracted investments yet. However, the trend indicates that there is economic feasibility of using this technology since commercial buildings midrange as supermarkets and even low-income housing. With this, surely resources PEE can be applied to power generation in low-income households and even small investors will have a promising opportunity to undertake.

Efforts are being made to promote large-scale pilot projects using this source, but with reliance on tax incentives. There are convergences of using this source with the objectives of the current model, as it can contribute to low tariffs, safety and social inclusion: i) It allows the consumer to have an option that limits the price charged by the market; ii) Allows expansion investments in the short term at a lower cost than thermal oil; iii) presents opportunities for small entrepreneurs to invest; vi) Bring generating jobs in greater quantity than thermal; v) spray any profits with self-generation. However, the use in centralized projects of great climbing with high incentives are the opposite, burdening the taxpayer indirectly, besides not enable investments in distributed generation also does not reinforce the competitiveness of energy prices, which impacts negatively on society.

There is a downward trend in production costs from this source by economies of scale, but not enough to make it competitive with other energy alternatives present today. A great expectation for significant drop in the cost of power generated from photovoltaic cells is mainly in efficiency gains arising from advances to overcome the bottlenecks present and development of more economical processes to produce solar grade silicon and multi junction concentrator modules.

The market for power generation using solar photovoltaic technology is clearly a growing market in the world today. The china stands out as the largest producer of PV cells and modules globally. However, the largest markets for this technology are consumers in Europe (Germany) and the USA besides China.

This technology has excellent environmental performance, but due to high cost, its insertion in the energy mix of countries is still slow, with rare exceptions such as Germany.

Changes within the planned expansion of the electric generators matrix in Brazil, deemed necessary, can promote the inclusion of this source without it being dependent on stimulus and government incentives.

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