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PHOTOVOLTAIC SOLAR ENERGY IN BRAZIL AND THE CONTRIBUTION OF FEDERAL INSTITUTE OF RIO GRANDE DO NORTE (IFRN)

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KEYWORDS

Solar Photovoltaic Energy, Generation of Electricity, Distributed Generation

ABSTRACT

Photovoltaic solar energy is presented as a promising source for Brazil, considering that most of the Brazilian territory is located near the equator, which implies days with the highest number of hours of sunlight. The participation of this energy source in the Brazilian energy matrix corresponds to only 0.01% of installed capacity. Important actions are being made to increase this participation: R & D programs of electric utilities, regulation of distributed microgeneration and minigeneration, energy auctions of the Federal Government and publication of technical standards by the Brazilian Association of Technical Standards (ABNT). This paper presents the initiatives for the implementation of photovoltaic solar energy in Brazil, the prospects for its consolidation as a source of energy, and the contribution of the Federal Institute of Rio Grande do Norte (IFRN) for this scenario. The analysis of the economic and financial viability of photovoltaic solar plant installed at the Rectory of IFRN and the consequent reduction of expenses with electricity are also presented.

INTRODUCTION

Renewable energy plays an important role in global energy matrix. The prices of renewable energy technologies, mainly wind and solar, are declining, making them increasingly popular and competitive with conventional energy sources. In addition, massive investments are being directed to renewable energy. The Federal Institute of Rio Grande do Norte (IFRN) implemented a broad program of installation of eight solar photovoltaic plants, the first federal educational institution in Brazil to produce electricity for their own consumption.

PHOTOVOLTAIC SOLAR ENERGY IN BRAZIL

The electricity generation in Brazil is strongly based on hydroelectric generation, which accounts for over 70% of its energy matrix (EPE, 2014a).

The electricity rationing occurred in 2001-2002 due to lack of rainfall, resulted in the increase in the share of alternative energy sources and greater use of regional energy potential, especially solar and wind power.

Most of the Brazilian territory is located near the equator, resulting in days with the highest number of hours of sunlight. Practically all regions of Brazil receive more than 2200 hours of sunshine per year, with a potential equivalent to 15 million TWh (15×10^{18} Wh) (Rodrigues and Matajs, 2005), corresponding to 25 000 times the Brazil´s electricity consumption, which in 2013 reached 610 TWh (EPE, 2014a).

Although Brazil has a high solar radiation index, the use of this energy source for generating electricity is very recent. Historically, solar photovoltaic energy has been used in Brazil mainly targeting the power supply for rural and/or isolated communities in the North and Northeast. However, important actions for the implementation of photovoltaic solar energy in Brazil have been implemented in the last few years.

The Energy Development Program for States and Municipalities (PRODEEM), implemented in 1994 by the Federal Government, incorporated the photovoltaic solar energy to the Brazilian energy matrix. This program installed 5 MWp of photovoltaic systems in nearly 7000 communities around Brazil (MME, 2009).

In august 2011, the National Electric Energy Agency (ANEEL) published the Call for Strategic Project Research & Development Nº 013/2011, entitled "Technical Arrangements and Commercial for Insertion of Solar Photovoltaic Generation in Brazilian Energy Matrix". 18 projects were qualified, totaling a generation of 24.5 MWp within three years (ANEEL, 2011).

Another major initiative was the publication of Resolution Nº 482/2012 by ANEEL, laying down the general conditions for the micro-generation and mini-generation access to electricity distribution systems and the power compensation system (ANEEL, 2012).
The big moment for the consolidation of photovoltaic solar energy in Brazil was the realization of the energy auction A-3 of the Federal Government. Held in 10/31/2014, this auction contracted electricity to supply the domestic market from 2017. In this auction, solar photovoltaic generation had 31 winning projects, with a total contracted capacity of 1048 MW, exceeding the contracted capacity for wind energy developments (EPE, 2014b).
Brazil has currently (2015) 317 photovoltaic solar plants in operation with a total installed capacity equal to 15 179 kWp (ANEEL, 2015).
Photovoltaic solar energy appears on the ten-year planning horizon in the electricity sector from 2014. The Ten-Year Energy Plan with horizon in 2023 provides an installed capacity of 664 MWp of photovoltaic roofs in homes and commercial sector in low voltage, making a generation of 877 GWh (MME/EPE, 2014).

SOLAR RADIATION IN BRAZIL

The daily solar radiation incident on a plane with slope equal to the latitude location of photovoltaic module installation is shown in Figure 1 (Pereira et al., 2006). This figure shows that the highest irradiation levels in slope occur in the range that goes from the Northeast to the Southeast.

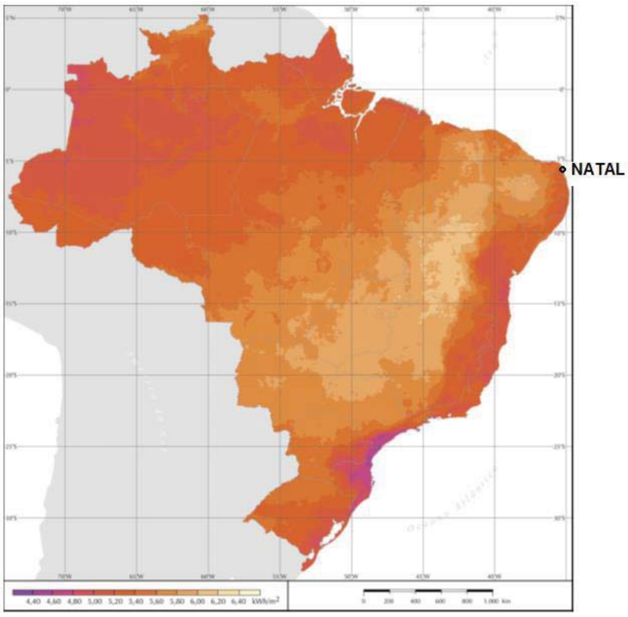

Figure 1: Solar radiation on the inclined plane - Annual average in Brazil.
[Pereira et al., 2006] adapted.

The Northeast of Brazil, to be closer to the Equator line than other regions, is the one with largest area of solar radiation and also where solar radiation is more effective, ranging from 5700 Wh/m².day and 6100 Wh/m².day.
The Rio Grande do Norte (RN) is the state where there are the largest solar incidence rates in the Northeast of Brazil.
Natal, the state capital, is located in an area with much solar radiation, with an annual average of 7 hours of daily sunshine.
Some climatological data of Rio Grande do Norte, according to the database of the National Institute for Space Research (INPE) and the Solar and Wind Energy Resources Assessment (SWERA), are presented in Table 1 (Buiatti, 2013).

PHOTOVOLTAIC SOLAR ENERGY IN IFRN

In an innovative way, the Federal Institute of Rio Grande do Norte (IFRN) took an important step for the use of alternative energy sources. By the end of 2015, IFRN will have eight photovoltaic plants in operation. The installed capacity of solar photovoltaic plants of IFRN will correspond to 620 kWp (Buiatti, 2013).
The installation of these solar power plants aims to generate electricity to meet the needs of the Rectory and the campi, and with the injection of existent power in excess on the medium-voltage utilities distribution network, generating credits to be deducted from subsequent electricity consumption.

Table 1: Climatological data of Rio Grande do Norte

Month	Global Irradiation on Horizontal Plane (kWh/m².day)	Ambient Temperature (°C)	Wind Speed (m/s)
January	5.503	26.07	4.78
February	5.865	26.29	4.17
March	5.289	26.33	3.49
April	5.59	26.38	4.01
May	4.845	26.37	4.85
June	3.887	26.03	5.89
July	4.789	25.64	6.26
August	5.304	28.82	6.63
September	5.788	25.94	6.94
October	5.632	26.08	6.65
November	5.788	26.08	6.55
December	5.081	26.05	5.77
ANNUAL	**5.280**	**26.09**	**5.49**

(Buiatti, 2013).

SOLAR PHOTOVOLTAIC PLANTS IN THE RECTORY OF IFRN

The photovoltaic plant operating in the Rectory building, called PVP Rectory IFRN, is located in Natal and was the first solar photovoltaic plant to be installed by IFRN, being connected to the network of the electric utility in December 2013.

With total investment of R$ 319,000.00, the PVP Rectory IFRN covers an area of 480 m², consisting of 240 photovoltaic modules, which are divided into four arrangements.

The initial estimate of production was 30% of total building consumption and in January 2015 was recorded a production 8,1 MWh, which represented 36% of energy consumed.

The PVP Rectory IFRN is installed on the roof of the main building and an annex building with the following coordinates with reference to the center of the installation: latitude 5.81138° South and longitude 35.20028° West (Figure 2).

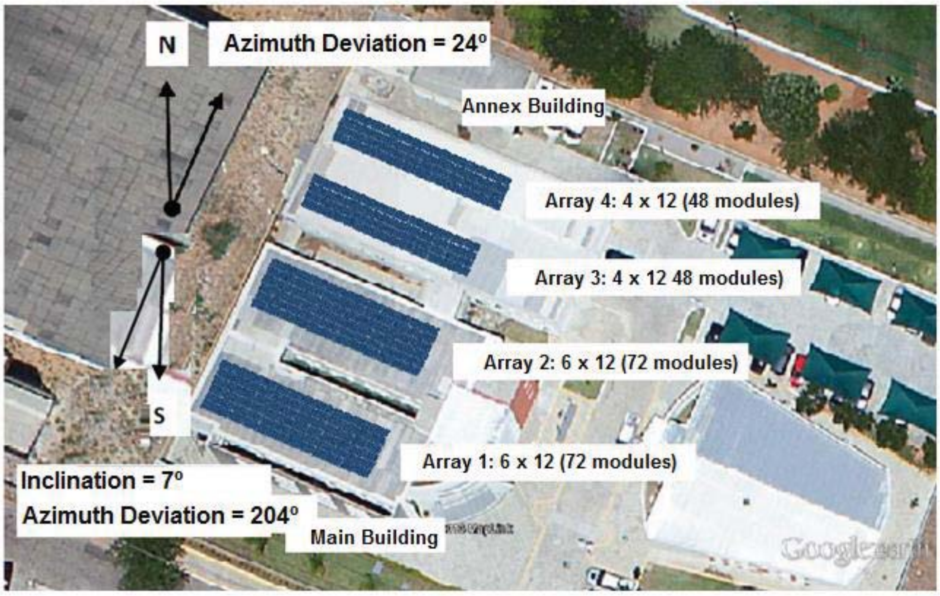

Figure 2: Top view of PVP Rectory IFRN. (Buiatti, 2013) adapted.

This central has 235 modules of 240 Wp each, which corresponds to a total capacity of 54.6 kWp. The modules are made of polycrystalline silicon cells and are mounted on supports or rails with fixed slope of 7º, which is the roof slope. Figure 3 shows a single-line diagram of the PVP Rectory IFRN.

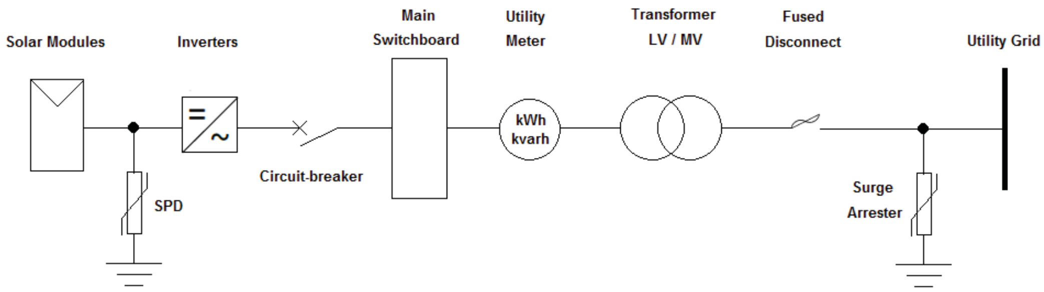

Figure 3: Single-line diagram of the PVP Rectory IFRN.

The management of this plant is done through a software that records: the energy produced by the plant, electrical parameters, avoided CO_2 emissions, events (alarms). Figure 4 shows the records obtained for the day 02/27/2015, highlighting the energy generated graphic on this date.

Figure 4: Management software of the PVP Rectory IFRN.

COST REDUCTION WITH ELECTRICITY IN RECTORY OF IFRN

The PVP Rectory IFRN is supplying an average of 30% of the total electricity consumption of the Rectory building. The generation of surplus, which usually occurs on weekends and holidays, for there hours these days, is injected into the network average utility voltage distribution through the exclusive transformer building of the Rectory. The surplus is measured by a bi-directional meter approved by the utility and regulated in accordance with Resolution Nº. 482/2012 of the National Electric Energy Agency (ANEEL), which deals with the power compensation system (Net-Metering).
From January to December 2014, the PVP Rectory IFRN produced 92 965 kWh, representing an approximate savings of R$ 23,969.00. With its operation, the Rectory of IFRN avoided in 2014 the emission of 8.2 tons of CO_2 in the atmosphere (Silva Jr., 2015a).
Figure 5 shows a comparison between the cost of the consumption of active energy of the Rectory of IFRN for the year 2014, with the photovoltaic plant and if it was not installed, showing the reduction in expenses for electricity.
Figure 6 shows the monthly savings that the Rectory of IFRN obtained in expenses with active energy in 2014 after the installation of the PVP Rectory IFRN.

ECONOMIC AND FINANCIAL VIABILITY OF PVP RECTORY IFRN

Some data used in the study of economic and financial viability of PVP Rectory IFRN are presented below (Silva Jr., 2015b):

- average monthly energy production: 7644.1 kWh;
- average annual energy production: 91 728.9 kWh;
- active energy tariff: R$ 0.25/kWh;
- cost of implementing the photovoltaic plant: R$ 319,000.00;
- solar panels depreciation period: 25 years;
- equipment depreciation period: 40 years;
- Minimum Aceptable Rate of Return – MARR or Cost of Capital: 5%.

The results of the economic and financial viability study of PVP Rectory IFRN are as follows:

- Internal Rate of Return – IRR: 5.49% (year);
- Present value of net cash flows: R$ 16,755.88;
- Payback Period: 13 years and 10 months.

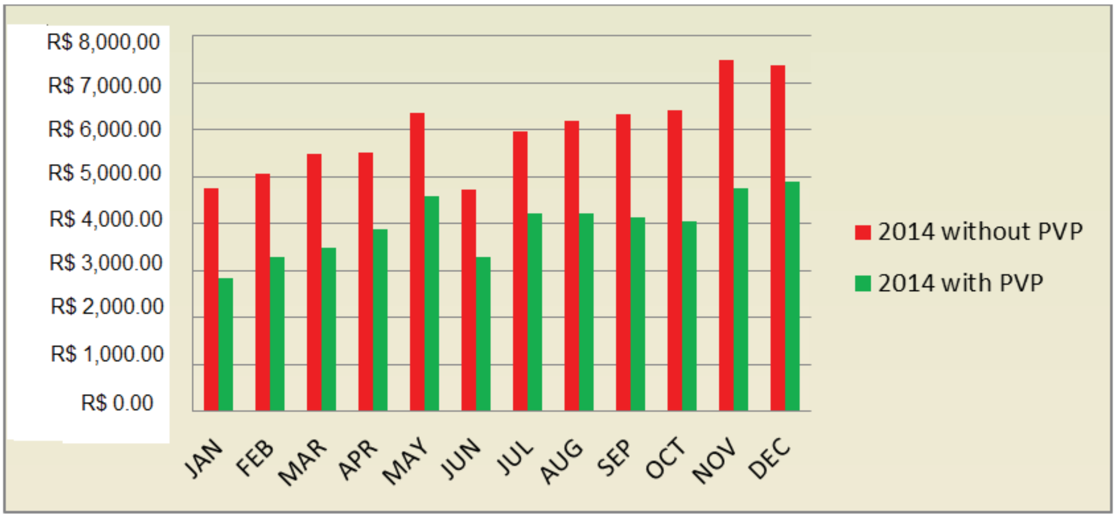

Figure 5: Expenses for active energy of the Rectory of IFRN - 2014.
(Silva Jr., 2015a) adapted.

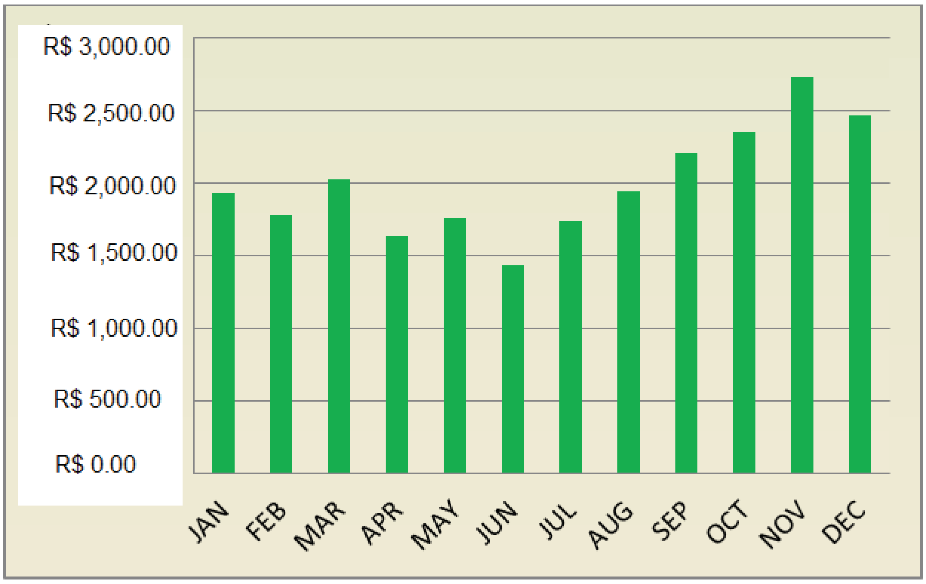

Figure 6: Monthly savings in expenses with active energy - 2014.
Fonte: (Silva Jr., 2015a) adapted.

ANALYSIS OF ENVIRONMENTAL ASPECTS EXPECTED FOR IMPLEMENTATION OF PVP RECTORY IFRN

The PVP Rectory IFRN is generating on average 7644 kWh/month, 91 729 kWh/year and in 25 years of life expectancy will generate 2293 MWh.
Due to hydropower, Brazil is one of the lowest greenhouse gases emitter countries as far as power production is concerned, only 64 gCO_2/kWh (EPE, 2012). Thus the operation of the PVP Rectory IFRN will avoid the emission into the atmosphere of 147 tons of CO_2 in its 25 years of operation.
Comparing the production of energy PVP Rectory IFRN with other non-renewable energy sources, during the 25 years of its operation, will be avoided the use of:

- 197.16 tons of oil equivalent (assuming that 1 ton of oil equivalent - toe is equivalent to 11,630 kWh) or
- 224 144.67 cubic meters of natural gas (assuming that the burning of 1 m³ of natural gas is equivalent to 10.23 kWh) or
- 442 664.09 cubic meters of steam coal (considering that burning 1 m³ of steam coal is equivalent to 5.18 kWh).

CONCLUSIONS

This paper showed that important advances have been and are being given to the implementation and consolidation of photovoltaic solar energy in Brazil, for the development of the production chain and national services.

However, to expand the use of solar photovoltaics in the energy matrix of Brazil, measures should be taken that meet the characteristics of the electrical system of the country, as well as: tax policy and funding, the consolidation of a production chain, development of research and technological innovation project, long-term policies of governments, a good regulatory structure and the dispersion of installations of photovoltaic solar energy generation for larger geographic areas.

With the initiative to install solar photovoltaic plants, the Federal Institute of Rio Grande do Norte (IFRN) gives a good example in the use of this form of energy, as well as for reducing its expenditure on electricity, and also confirming that the Northeast region is very favorable for the use of solar energy. From the academic point of view, the photovoltaics solar plants of IFRN enable the development of research in the photovoltaic solar energy sector.

The use of photovoltaic solar energy is economically viable and will reduce consumption of fossil fuels, reducing the production of greenhouse gases produced by the combustion of these fuels.

REFERENCES

Buiatti, G. 2013. *Memorial descritivo de Sistema de Microgeração Fotovoltaica conectado à rede elétrica com potência instalada de 56.4 kWp em Natal, RN (Reitoria IFRN)*. São José dos Campos, SP.

Energy Research Office (EPE) (Brazil). 2012. *Brazil: Renewables for Development*. *Empresa de Pesquisa Energética, Rio de Janeiro.*

Energy Research Office (EPE) (Brazil). 2014a. *Brazilian Energy Balance 2014 Year 2013.* Empresa de Pesquisa Energética, Rio de Janeiro.

Energy Research Office (EPE) (Brazil). 2014b. *Leilão de Energia de Reserva 2014 atrai investimentos de R$ 7,1 bilhões.* Empresa de Pesquisa Energética, Rio de Janeiro. *(Nov).*

Ministry of Mines and Energy (MME) (Brazil). 2009. *Estudo e propostas de utilização de geração fotovoltaica conectada à rede, em particular em edificações urbanas*. Ministério de Minas e Energia, Brasília.

Ministry of Mines and Energy (MME), Energy Research Office (EPE) (Brazil). 2014. *Plano Decenal de Expansão de Energia 2023*. Ministério de Minas e Energia, Brasília.

National Electric Energy Agency (ANEEL) (Brazil). 2011. *P&D 013/2011 - Arranjos Técnicos e Comerciais para Inserção da Geração Solar Fotovoltaica na Matriz Energética Brasileira*. Agência Nacional de Energia Elétrica, Brasília.

National Electric Energy Agency (ANEEL) (Brazil). 2012. *Resolução Normativa nº 482*. Agência Nacional de Energia Elétrica, Brasília. (Apr).

National Electric Energy Agency (ANEEL) (Brazil). 2015. *Banco de Informações de Geração*. Agência Nacional de Energia Elétrica, Brasília.

Pereira, E.; F. Martins; S. Abreu; and R. Rüther. 2006. *Atlas Brasileiro de Energia Solar*. Instituto Nacional de Pesquisas Espaciais. São José dos Campos, SP.

Rodrigues, D. and R. Matajs. 2005. *Um Banho de Sol para o Brasil: O que os Aquecedores Solares podem fazer pelo Meio Ambiente e a Sociedade*. Vitae Civilis, São Lourenço da Serra, SP.

Silva Jr., F. 2015a. *"Acompanhamento Energia Elétrica Reitoria"*. Instituto Federal do Rio Grande do Norte. Natal, RN. (Feb).

Silva Jr., F. 2015b. *"Estudo de Viabilidade Econômico-financeira – Usina Fotovoltaica"*. Instituto Federal do Rio Grande do Norte. Natal, RN. (Jan).