Analysis of Generation Photovoltaic Potential at NIPE Building

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ABSTRACT: The use of photovoltaic systems, through the Net Metering System, existing in the Brazilian Electric Sector, can contribute significantly to the environment. Once integrated into the building envelope, generating energy near the center of consumption, prevent new and existing buildings consume energy from non-renewable sources. In this sense, this work is to analyze the best way to integration and adaptation of a photovoltaic system connected to the network at building of Interdisciplinary Center of Energy Planning (NIPE) at State University of Campinas, located in Campinas - SP, Brazil. Evaluates the potential for electricity generation and most efficient technology in terms of architectural volumetry, existing shaders in building envelope and the environmental impacts caused by the adoption of different types of cells (Monocrystalline, Polycrystalline, Copper-Indium-Gallium-Selenium - CIGS and Cadmium Telluride- CdTe). They are used the software Sketchup and Radiasol for shading analysis and potential for electricity generation in demand peaks. The results show that the power supply tracks are up to 45%, representing a significant reduction of the total energy consumed by the building.

Keywords *BIPV, Energy efficiency, Nearly Zero Net Buildings.*

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1. INTRODUCTION

The Normative Resolution No. 482/2012, developed by National Electrical Energy Agency, that set the standards for power compensation through renewable energy sources, significantly increased the share of photovoltaic systems connected to the network, especially the smaller capacity systems in order to provide to small residential central and small business. According to the Bank of Information Generation (BIG) of ANEEL's report of October 2015, about 1074 plants were connected to the grid. Most buildings already constructed do not have the ideal and favorable conditions for implementing these systems. The integrated system in buildings near the point of consumption, helps in reducing peak demand, decreasing the dependence on fossil fuels and non-harmful to the environment. The integration of architecture and engineering is therefore essential for better energy utilization technology. The objective of this study is to evaluate the energy potential with the implementation of a photovoltaic system in the research building of the Interdisciplinary Center of Energy Planning, located at Unicamp.

2. METHODOLOGY

According (Lima,2012), the method used to evaluate the best way to adapt and integrate the photovoltaic system proposed in building the NIPE is given according to the flowchart of Figure 1:

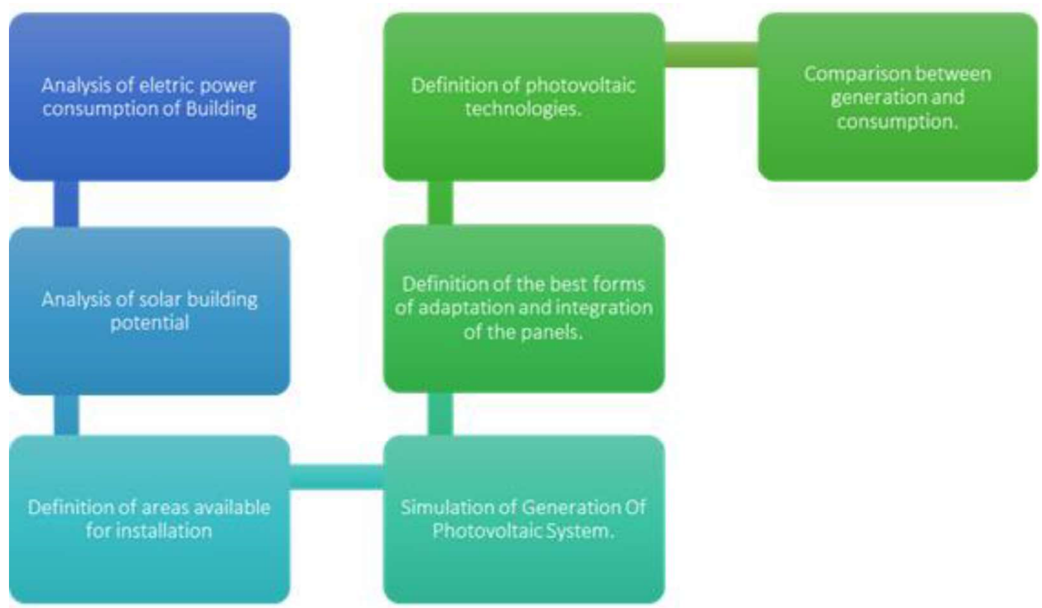

Figure 1 - Flowchart for photovoltaic project.

Initially the power consumption of the building was measured. As the building does not have a clock electricity meter, current measurements were performed on the transformer output that feeds the building through the data logger *SmartReader Plus 3* and *Trend Reader* software for reading and processing data values of current versus time for energy values. Measurements were made during three consecutive days of April. Is noteworthy that were

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planned measurements for 7 days a week, including over the remaining months and seasons, however operational problems with the NIPE unfeasible its implementation until the end of this article. If possible, new measurements will be carried out and its results will be reported. It held an average of these three days to determine the average daily consumption. Then multiplied this consumption in the days of operation of the building activities of the same month.

After determining the consumption through the collected data was carried out an analysis of the solar potential of the areas available for implementation of the photovoltaic system. This required the use *Radiasol* software to get the data of solar radiation at different inclinations and orientations of the assessed areas, *Scketchup* and *Design Builder* to simulate and analyze building 3D shading. It was necessary to use two software for shading analysis due to computer problems, which led to loss of software Design Builder as well as some data collected.

With the defined areas the third stage of this work is to raise the existing photovoltaic technologies available in the market and its main characteristics.

Subsequently were defined the best forms of integration and adaptation of photovoltaic systems in the building. For that they were raised the experiences of countries that have large-scale implementation of this technology in the types of adaptation and integration of these systems for the various types of applications such as roofs, facades and external structures.

The final stage of the work consisted of simulate the amount of energy generated from each form of adaptation and integration adopted for each technology through the technical data of the selected panels models, data losses involved in each part of the system connected to the network and the *Radiasol* radiation data. After estimating for each technology generation comparison with consumption of the building was performed.

3. ANALYSIS OF NIPE'S SOLAR POTENTIAL

In this work as the goal is to estimate the solar energetic potential of the building, shading free areas were selected on the roof and facade of NIPE. A simulation was performed using the *Sketchup and Design Builder,* software to select the best areas of implementation of the system, according the Figure 2 and 3:

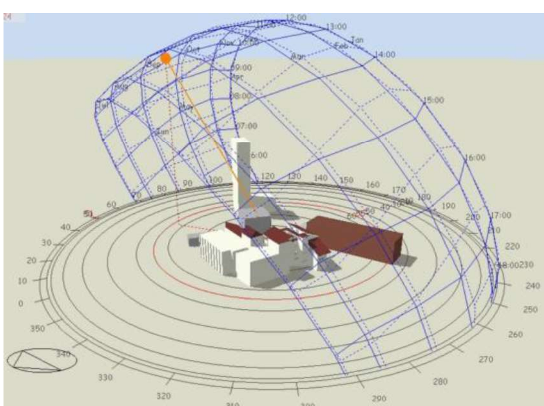

Figure 2 - Shading simulation throughout the year. (Tassinari, 2015)

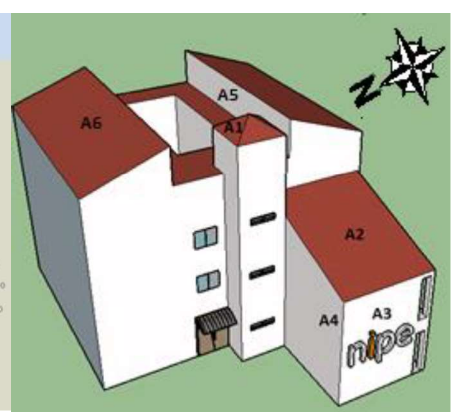

Figure 3 - Implementation areas for panels at the NIPE building.

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The area A6 was discarded due to the shadowing in all its extension throughout the year due to existing building next to the NIPE.
The incidence angle of sunlight depends on factors such as time of day, day of the year, guidance and flat slope. For each area selected were verified the proper orientation and inclinations and based on the software *Radiasol 2.0* were raised irradiance and the average irradiation, from 6:00 to 18:00 hours, during the days of the year. Values are shown as Table 1:

Table 1 - Irradiance e Irradiation for each area selected at NIPE.

Area	Orientation	Inclination	Radiasol Data	
			Irradiance (MJ/m^2)	Irradiation (MJ/m^2.day)
A1,A5	North	22°	3,48	18,97
A2	West	22°	3,12	16,99
A3	West	90°	1,81	9,79
A4	North	90°	1,99	10,87

4. TYPES OF TECHNOLOGIES

To evaluate the photovoltaic energy potential at the NIPE building were studied the most consolidated technologies in the market, monocrystalline and polycrystalline silicon, and also those that have been developed for integration on the surfaces of buildings as cadmium telluride (CdTe) and copper indium gallium selenide CIGS, according Figure 4 to 7. The main data of the selected panels are shown in the table 2, as the standard test conditions (1000 W/m^2, 25ºC e AM = 1,5):

Figure 4 - Sunpower SPR-333NE-WHT-D. Source: Datasheet of Manufactures.

Figure 5 - Canadian Solar CS6P-255P BLK. Source Datasheet of Manufactures.

Figure 6 - First Solar FS-397-PLUS. Source Datasheet of Manufactures.

Figure 7 - PowerFLEX™ BIPV 300W. Source Datasheet of Manufactures

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Table 2. Specifications of the PV modules used in application testing standards (STC). Source: Datasheet of Manufactures.

Technical data	Sunpower SPR-333NE-WHT-D	Canadian Solar CS6P-255P BLK	First Solar FS-397-PLUS	PowerFLEX™ BIPV 300W
Type technology	Monocrystalline (m-Si)	Polycrystalline (p-Si)	CdTe	CIGS
Maximum Power (Wp)	333	255	97,5	300
Area (m^2)	1,63	1,6	0,72	2,81
Efficiency (%)	20,4	15,54	13,2	12,6

5. TYPES OF INTEGRATION AND ADAPTATION

According Zomer (2014) there are several types of integration of photovoltaic panels in buildings. The main types of integration are shown in Figure 8:

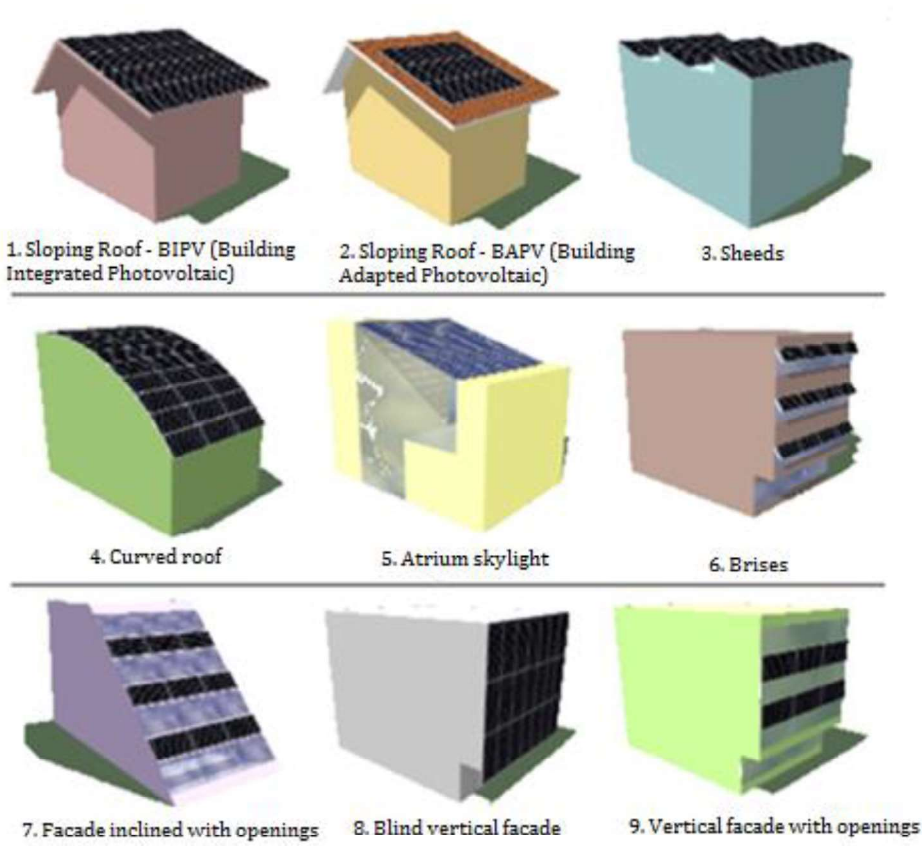

Figure 8 - Types of integration and adaptation of photovoltaic panels. Source: (Zomer,2014).

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The final simulation of the installation for each technology is given as the Figure 9 to 12:

Figure 9 - Integration with SunPower.

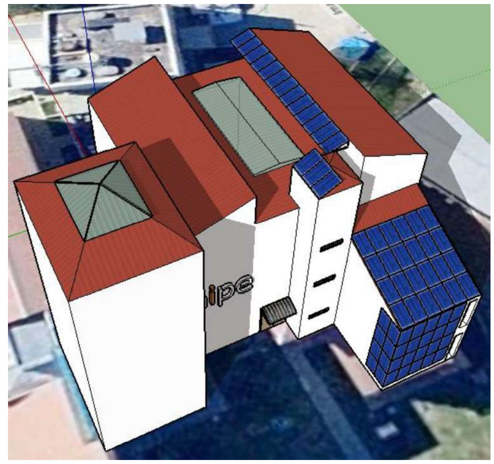

Figure 10 - Integration with Canadian Solar.

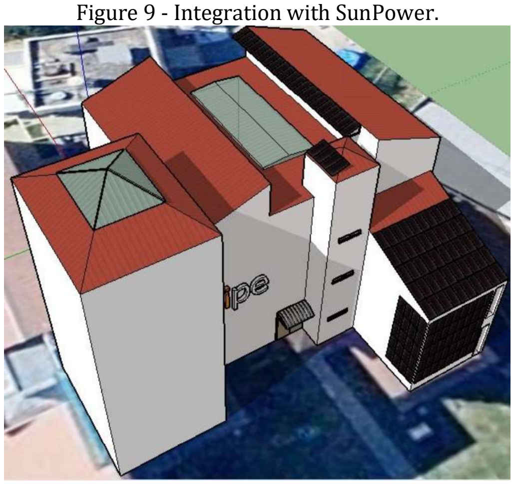

Figure 11 - Integration with First Solar.

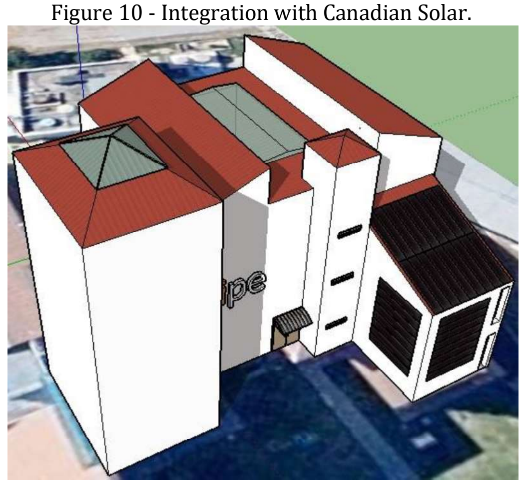

Figure 12 - Integration with PowerFlex.

6. CALCULATION OF POTENTIAL ENERGY

According Almeida (2012) is possible to calculate, based on values found in Radiasol, the value of total solar resource available in selected areas, by technology, and considering the losses values adopted in his thesis it is possible to analyze the energy use as shown in Table 3:

Table 3 - Analysis of Energy Use of Each Technology

	SunPower	Canadian	First Solar	PowerFlex
Solar resource available (GJ/year)	516,39	580,52	507,93	483,18
Losses in PV conversion	79,6%	84,5%	86,8%	87,4%
Losses due to degradation	5,0%	5,0%	5,0%	5,0%
Losses due to temperature	7,12%	7,12%	7,12%	7,12%
Losses due to dirty	5,86%	5,86%	5,86%	5,86%
Losses D.C	6,0%	6,0%	6,0%	6,0%
Losses on the Inversor	7,84%	7,84%	7,84%	7,84%
Losses on the transformer	2,0%	2,0%	2,0%	2,0%
Losses due to conection	4,54%	4,54%	4,54%	4,54%
Energy util (GJ/year)	70,92	60,73	45,13	40,98
Global efficiency	14%	10%	9%	8%

Analyzing the data obtained from the measured load curve in the transformer that supplies the building it is concluded that the average monthly consumption of the building is 13,716 MJ/month (3,810 kWh/month). Comparing the profiles of the building load curve in NIPE with the generation curve of the PV system for each technology, in selected areas, has the Figure 13:

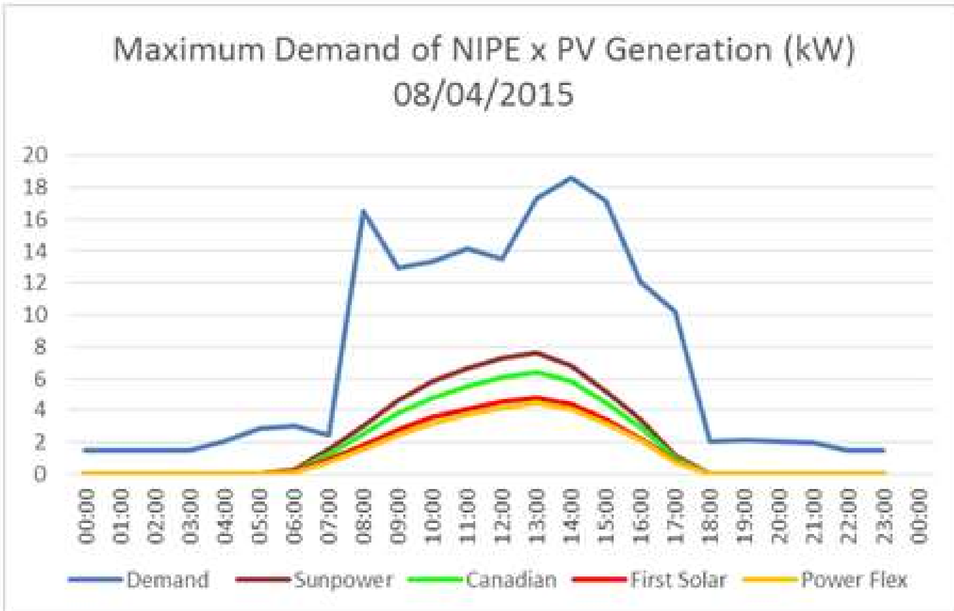

Figure 13 - Comparison of NIPE Demand Curve with PV generation curve for each selected area.

Analyzing the graphic, it is noticed that the peak demand coincides with the peak of photovoltaic generation that occurs around 13:00 on the basis that most PV modules have been incorporated in the simulation in the roof fall facing west. This is a typical feature of the commercial sector, especially in buildings with air conditioning (Salamoni, 2004). Table 4 shows the percentage of energy supply of Nipe from each photovoltaic technology at the conditions of the selected areas and in the ideal conditions:

Table 4 - Energetic supply percentage of photovoltaic generation at NIPE.

	SunPower	Canadian	First Solar	PowerFlex
Selected conditions	45%	38%	29%	26%
Ideal conditions	58%	50%	38%	35%

7. RESULTS

The types of integration taken to implement the panels are able to generate for the lower efficiency panels, CIGS, 3.415 MJ/month (949 kWh/month), while the panel more efficiently, m-Si generate about 5,910 MJ / month (1.641 kWh/month). If all panels were in ideal conditions (facing true north and inclination equal to local latitude) the monthly generation group would be 4,676 MJ/month to 7,621 MJ/month, respectively (1.300 kWh/month to 2.116 kWh/month). Table 5 shows the comparison between the photovoltaic generation adopted for the types of integration and optimal conditions:

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Table 5 - Comparison of photovoltaic monthly generation among selected types of integration and the ideal conditions in MJ/month.

	SunPower	Canadian	First Solar	PowerFlex
Selected conditions	5.910	5.061	3.761	3.415
Ideal conditions	7.621	6.567	4.984	4.676
Percentage difference	22,4%	22,9%	24,5%	26,9%

Analyzing the loss of irradiation relative orientation of the reference planes is perceived that by directing the panels to the west, keeping the slope equal to the latitude, you lose about 10.2% of energy. Regarding the inclination, to keep the panel oriented to the north and tilt it 90 °, you lose about 43.1%.

8. CONCLUSIONS

It is essential to make an energetic use of study to obtain the maximum of possible efficiency in buildings and then enter the utilization of PV systems.

No selected technology ensured 100% of the energy supply of the building. But even in unfavorable conditions the supply range was 26 to 45%, representing a significant reduction in dependence on energy from non-renewable sources and even helping to preserve reservoirs of hydroelectric plants.

A greater incentive for public policies that buildings already built in Brazil to carry out a retrofit study and improve their energetic use is necessary.

For new buildings is required greater interaction between professionals in architecture, civil construction and photovoltaic technology to obtain a better use of the benefits of this renewable generation source.

Therefore, it can be concluded that there is a great importance of designing buildings taking into account conditions that favor the generation of photovoltaic solar energy, especially in the commercial sector where the demand curve coincides with the solar generation curve. In this case the photovoltaic systems can contribute to reduction in peak demand.

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