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ECONOMIC FEASIBILITY OF PHOTOVOLTAIC SYSTEMS IN A EDUCATIONAL BUILDING

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ABSTRACT

This work consists in the study of the economical feasibility in the use of a photovoltaic system, connected to the electric grid. In order to encourage the use of alternative energies, such as solar energy, the parameters for the installation of a photovoltaic system in the educational building of the Salesian University Center of São Paulo, São Joaquim campus in Lorena, are analyzed and calculated. The bibliographic content, presented in the first chapters, corroborates with data specific to the area of electrical engineering and autonomous energy generation the efficiency of this method of generating energy. In the third chapter, calculations and data analysis of the study site are carried out for the design of the electrical system. Finally, the fourth chapter concludes the case study, referring to the economy that the generation system may provide, related to the initial investment payback.

Keywords: Photovoltaic System - Alternative Energies - Solar Energy - Economy - Payback.

1 INTRODUÇÃO

With population growth, the search global for renewable energy sources has been growing steadily gradually, being the subject of much research, In order to generate clean electrical energy and with less aggression to the environment.

Over the decades, it was observed the need to implement other ways of generating energy to assist hydroelectric plants, main source of electricity generation, That presented a reduction of 3.7% in 2015 compared to the year 2014 (EPE, 2016). Between the end of 2014 and the beginning of 2015, there was a noticeable decrease in rainfall events, causing the reduction in the generation of hydroelectric plants of the National Interconnected System - SIN (TIEPOLO, 2014).

Among all renewable energy sources, It stands out the solar energy, cleaner and less polluting source. According to ANEEL, this type of energy base for all other sources, why solar light is needed for the generation process in other power plants. Used in several countries, such as the United States, France, Canada, Israel, India, among others, the solar energy is gaining more and more space in Brazilian society, even with high cost in structural issues.

In scale, the Brazil for being a tropical country, located near the Ecuador line, it is one of the countries that the most receives solar radiation, having thus, a relevant potential to take advantage of this type of energy. The least sunny region in Brazil, have an average radiation index of 1642 kWh / m² and compared in Germany, country with advanced technology in the field of solar energy, it Is with a value above the radiation exerted in the sunniest place in the country, with about of 1300 kWh / m² (SALAMONI E RÜTHER, 2007).

Some ways to generate electricity through solar radiation is by means of photovoltaic system, which directly converts the light obtained into electrical energy through interconnected panels. This system can be in two ways, isolated (*off-grid)* when there is energy storage, Or system connected to the network (grid-tie) when there is no power storage.

In this way, the search for alternative energies is more frequent and strategic, highlights the importance of this new method of electricity generation that begins in solar power plants and extends to smaller generation systems located in industries, commercial buildings and homes.

In this context, this work studies feasibility, Considering payback regarding lighting, Of the implantation of a photovoltaic system connected to the electrical network in the educational building, Of higher education engineering, Mário Bonatti of the University Center of São Paulo, in the municipality of Lorena, in the interior of São Paulo.

For case study of the installation of photovoltaic panels in the building is essential specific research in the area of alternative and solar energy, photovoltaic panels in system *grid-tie*, Survey of structural data of the place studied, Index of energy consumption and solar potential of the city. Thus, resulting in the completion of the study, with the design of a new electrical system and check if an installation of this photovoltaic system in the environment is viable.

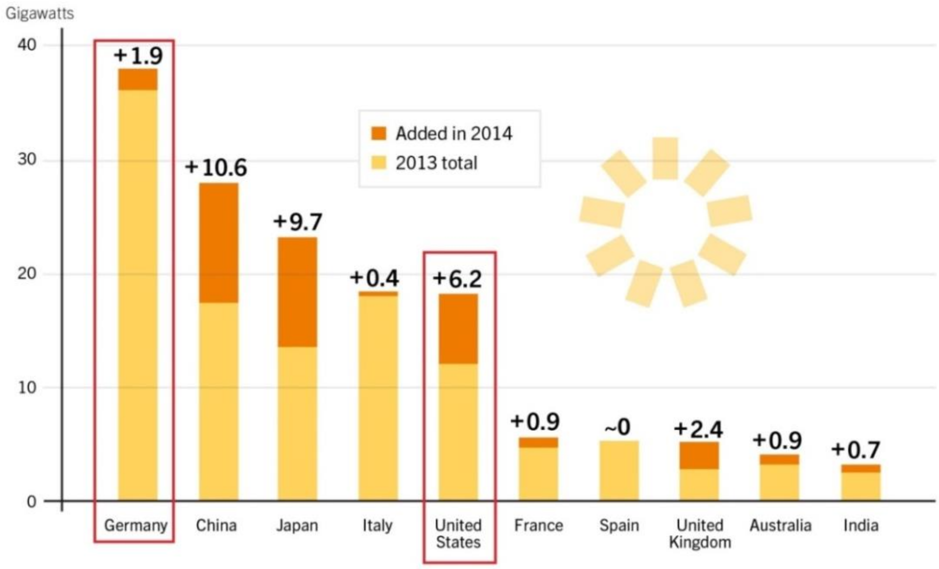
The research method of the work consists of the case study of installation of the photovoltaic system *grid-tie* in a school building to support the lighting of the place and consequently decrease in the energy cost consumed. This methodology “It is an empirical study that investigates a current phenomenon in the context of real life” (Miguel, 2012). This method is divided into three phases. The first is equivalent to the plan of analysis and data survey which will corroborate the specific objective of the work, delimit maximum and minimum limits of consumed energy consumption, inserting a suitable and demonstrative interval to analyze the data lifted and obtained at the end of the research. The second stage consists of collecting the information considered relevant, Such as data and measurements of the local and equipment, as well as the quantitative and qualitative data of the theme. The third phase will be of analysis of results, based on the data obtained in the field and calculated.

2.0 CONCEPTUALIZATION

2.1.2 Photovoltaic energy in the world

In 1973, with the oil crisis, there was a considerable increase in investments in programs that reduced the cost of producing solar cells, since then, there has been an intensification in the interest in application for photovoltaic solar energy. In the USA, Oil companies have invested in the production of solar energy in their business areas, being the world's leading producer of this technology during most of the 1990s. After this year, interest is expanding for governments in other countries, such as the Germany and Japan, being driven in part by a strong commitment to CO2 reduction (Manual de Engenharia, 2014).

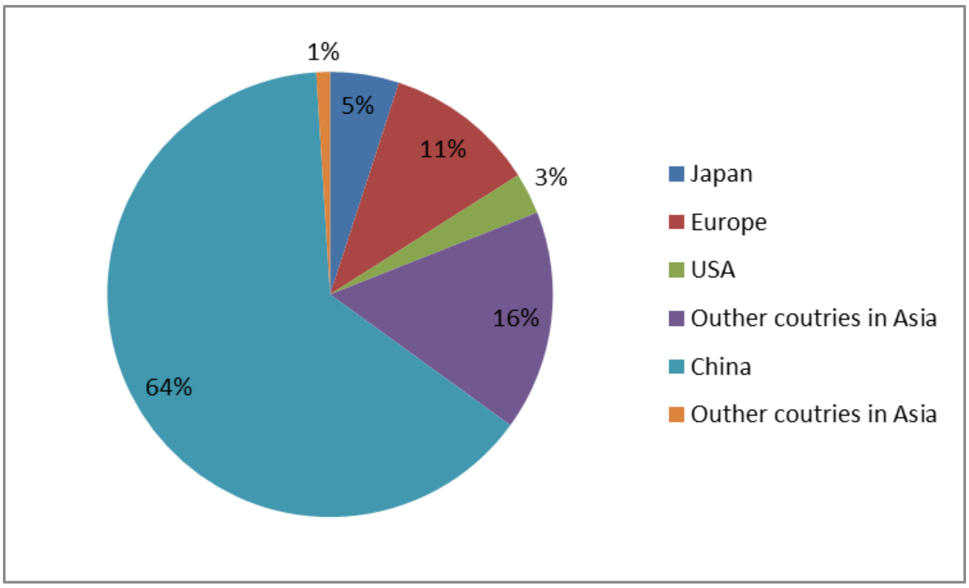
Figure 1 - Capacity and photovoltaic technology, the 10 best countries



Reference: REN21, 2014

The China stood out among the top ten panel manufacturers in the world, taking the lead in manufacturing modules in 2009 (Manual de Engenharia, 2014).

Figure 2 - Distribution of the worldwide production of photovoltaic cells in 2012

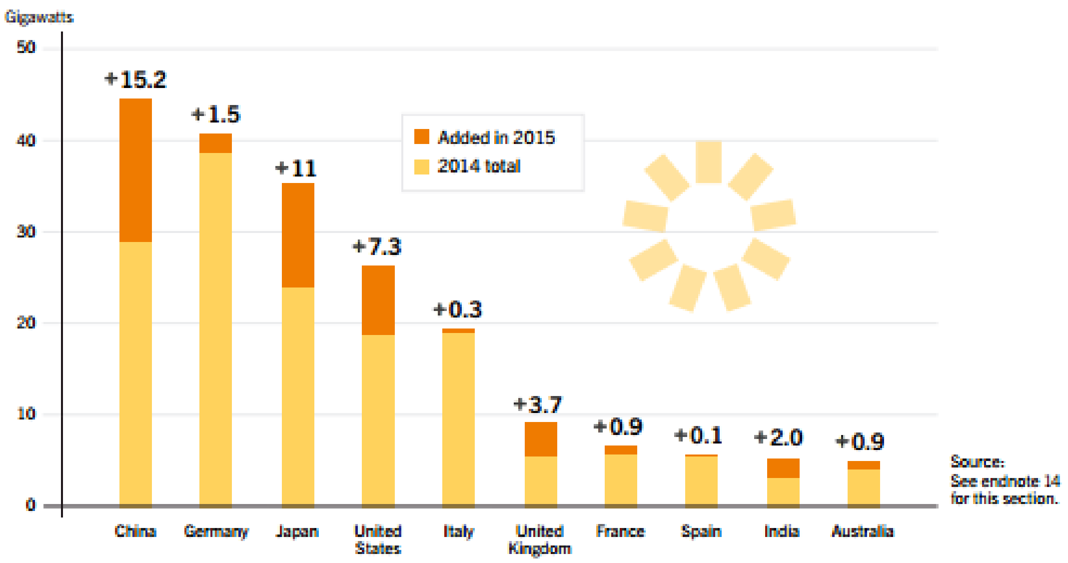


Reference: *GTM RESEARCH*, 2013.

The largest market for photovoltaic modules has been, in recent years, the Germany with an installed capacity of 32.3 GWp, then Italy with 16 GWp of installed capacity. The Germany held top positions in the world ranking in 2012, being the leader in solar photovoltaic capacity in which it represents about 32%. (SOUZA CABRAL, 2013). Approximately 74% of the world production is installed in Europe. Behind Europe, the largest photovoltaic systems were found in Japan and the USA.

In the ranking of the 10 countries with solar capacity of photovoltaic energy in the world referring to the year 2015, provided by the magazine *Renewables* 2016, at the top of the list is a China with greater solar photovoltaic capacity. Soon after, it is in Germany in second position, Japan in the third position, USA in fourth and in the sequence other European countries. In the Figure 3, it is possible to verify the classification of the countries.

Figure 3 - Capacity and addition of photovoltaic technology, top 10 countries



Reference: REN21, 2015

2.1.3 Photovoltaic energy in Brazil

In Brazil, there is one of the largest reserves of silicon in the world, but still lacks national industries for the production of this system. With a total capacity of collectors and a vacuum in operation with about 16,8 kWth / 1000 inhabitants, the Brazil still lags behind European countries (SOUZA CABRAL, 2013).

The Brazil, according to the *Bloomberg (2016)* In 2012, reached the '*grid parity*', which states that in some cases an installation of solar modules instead of buying electricity from the grid is considered an advantageous investment.

In 2012 Brazil was in fifth position with 0.7% of solar heating capacity, located between the five countries in this market (SOUZA CABRAL, 2013). The BEN 2016, Based on 2015 data, indicates that the installed capacity of electric power generation in the solar field is at 21 MW, including independent producers, hydroelectric plants and public service concessionaires. (EPE, 2016).

With encouragement in this type of energy generation can collaborate, especially on the hottest days summer when the peak time is at 2:30 p.m., Because of the intense heat and a lot of air conditioners being used at the moment. (ANEEL, 2014, 2015).

For a 100 kWp installation, according to EPE in 2012, how modules and inverters are imported, the tax burden is around 25% of the international reference values, taxes already deducted from places of origin. Therefore, referring to the modules, inverters and installation and assembly prices, with the costs analyzed in EPE with the nationalized prices, Adopting a rate of US $ 1 = R $ 1.75 and national taxes of 25%.

Table 1 - Cost of investment in SFV - Brazil (R $ / Wp)

Power rating	Generator FV	Inverter	Installation Assembly	Total
Residential (4-6 kWp)	4,88	1,25	1,53	7,66
Residencial (8-10 kWp)	4,42	1,09	1,38	6,89
Commercial (100 kWp)	3,81	0,92	1,18	5,91
Industrial (>= 1000 kWp)	3,5	0,66	1,04	5,2

Reference: EPE, 2012

The ABINEE in 2012 carried out the nationalization of the costs international of photovoltaic systems, using different methodology. With the exception of modules and inverters, the other components and the installations and assembly will have national costs, with an exchange rate of R $ 2.30.

Table 2 - Nationalized costs of SFV - R $ / Wp

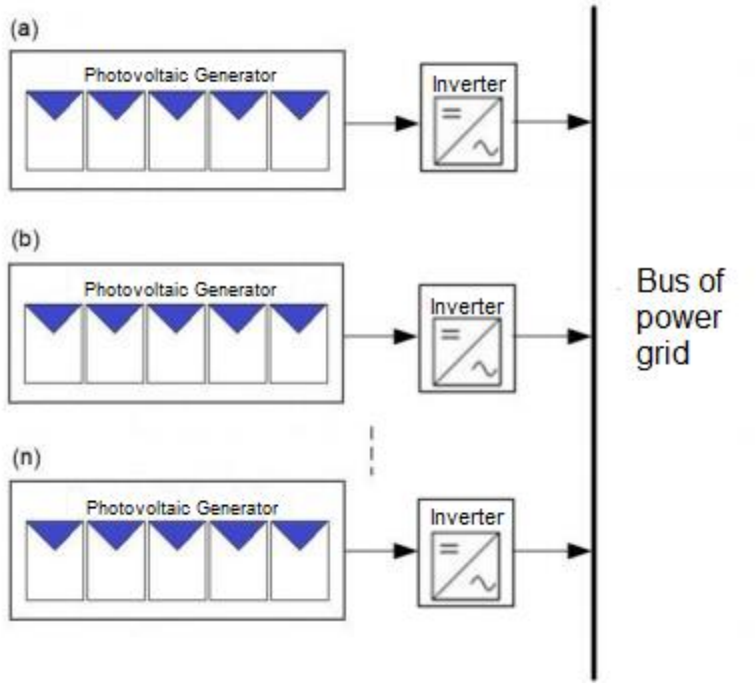
Application	Residential	Commercial	Plant
Capacity (kWp)	3	30	30000
Modules and inverters (R$)	11605	116047	116047414
Cables and protections (R$)	2250	18000	13100000
System and fixation (R$)	3750	24000	14000000
Other costs (R$)	3750	30000	18000000
Total (R$)	21358	188077	161177414
Total (R$/Wp)	7,12	6,27	5,37

Reference: ABINEE, 2012 and CRESESB Manual de Engenharia, 2014

2.1.4 Network-connected photovoltaic system

In an integrated system for network in certain location, the materials used by solar panels and fastening system to the construction wrap, CC-AC conversion system (inverter), diodes *by-pass* and blocking diodes, fuses and circuit breakers, electric cables, terminals, surge protection, atmospheric discharges and connection boxes. In this system, there is need of the energy of the solar arrangements to be reconciled with the voltage, phase and frequency of the electrical grid. In the figure below, is possible to visualize the scheme of the photovoltaic system connected to the grid.

Figure 3 - Photovoltaic system connected to grid



Reference: CRESESB Manual de Engenharia, 2014

According to CRESEB, the installation of a system connected to the grid should follow the local electricity utility's standard, which according to PRODIST (2016) should be accessible on the company's online page.

> It is the responsibility of the distributor to carry out all the studies for the integration of micro and minigeneration distributed, without negatives costs to anyone who accesses, And must inform the generating central the data necessary for the preparation of studies that must be presented when requesting access (Section 3.7 of PRODIST, 2016).

In Table 3 Can observe the impositions to the systems connected to the grid (PRODIST, 2016). The voltage level of the central generating plant is defined by the local distribution, due to the technical limitations of the grid.

Table 3 - Voltage levels for connection of micro and mini-stations

Installed Power	Connection voltage level
< 10 kW	Low Voltage (single phase)
10 a 75 kW	Low Voltage (three phase)
76 a 150 kW	Low Voltage (Three Phase) / Medium

	Voltage
151 a 500 kW	Low Voltage (Three Phase) / Medium Voltage
501 kW a 10 MW	Medium Voltage / High Voltage
11 a 30 MW	Medium Voltage / High Voltage
> 30 MW	High Voltage

Reference: PRODIST, 2016

2.1.*5* Independent system stored on battery

In 2012, due to the potential of using the different configurations of this system, ANEEL published resolution No. 493/2012, which became the procedure and the conditions of supply by means of Isolated Microsystem of Generation and Distribution of Electric Energy (1), in addition to the Individual Power Generation System with Intermittent Sources (2), which has been regulated by resolution No. 83/2004 (CRESESB, Manual da Engenharia). In this context, as quoted in the ANEEL resolution, the consumer assistance, being for 1 or 2, must follow the standard of electric power monthly, shown in Table 4.

Table 4 - Regulatory Regulation ANEEL 493/2012

Guaranteed monthly availability (kWh/ Month /UC)	**Daily reference consumption** (Wh/day/UC)	**Minimum inverter power** (W/UC)	**Minimum battery life** (hours)
13	435	250	48
20	670	250	
30	1000	500	
45	1500	700	
60	**2000**	**1000**	
80	2650	1250	

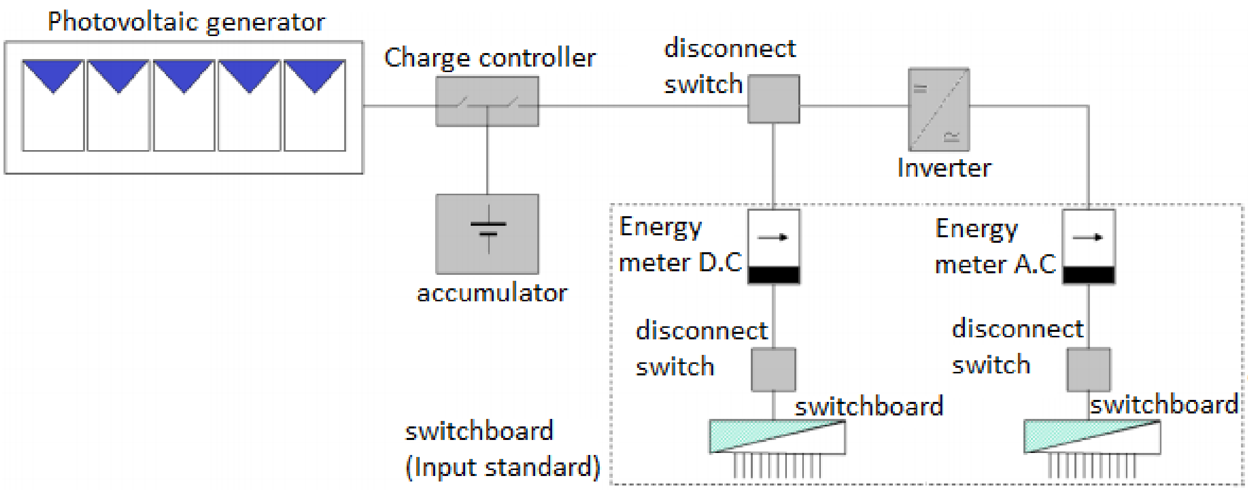
Reference: ANELL 493/2012

A photovoltaic system with storage in batteries allows besides the generation of energy the storage of the same one, it can be used at night or when solar radiation is insufficient compared to the demand of the place.

For these systems can be used three configuration, being only in direct current (DC), exclusively in alternating current (AC) or mixed continuous and alternating current (DC / AC). In Brazil, ANEEL regulations do not authorize the use of system exclusively in DC.

However, in mixed systems a DC circuit is used for lighting or cooling and, an AC circuit for powering lower-load equipment. This configuration has an advantage of maintaining the supply of energy for the direct current and lighting equipment, if the inverter fails. However, a disadvantage may be the greater complexity of Installation management and in the inverter failure there is a partial interruption of the system, also the cost of using equipment with two types of voltage levels.

Figure 4 - Mixed system DC/AC

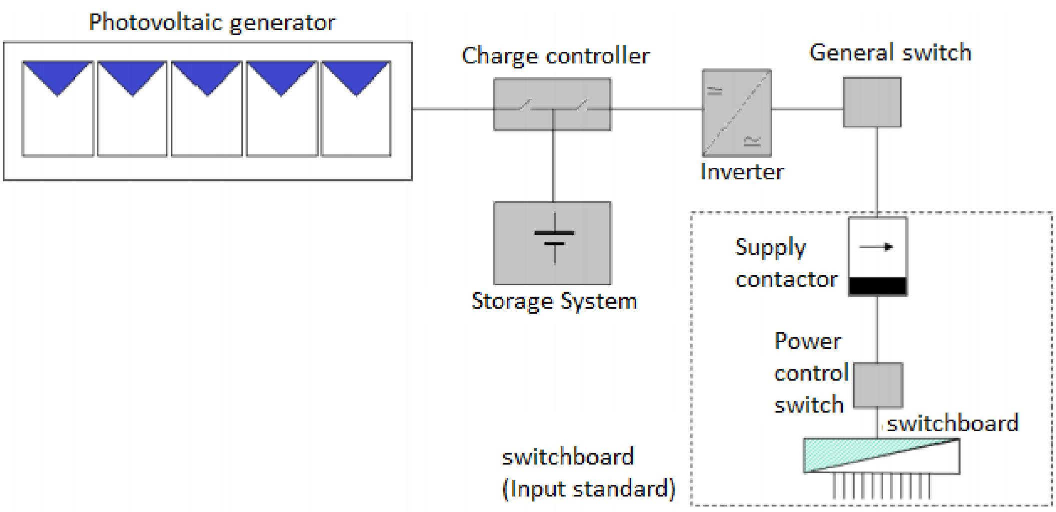


Reference: CRESEB Manual de Engenharia, 2014

In a AC system configuration, in relation to the DC, it has smaller diameter cabling and equipment of greater availability in the market, in addition to quality and efficiency, in the control and consumption. (CRESESB, Manual de Engenharia 2014).

However, the efficiency of the system depends on the inverter, which most of the time it works on partial loading.

Figure 5 - System AC with a inverter



Reference: CRESEB Manual de Engenharia, 2014

2.2 Solar Plates

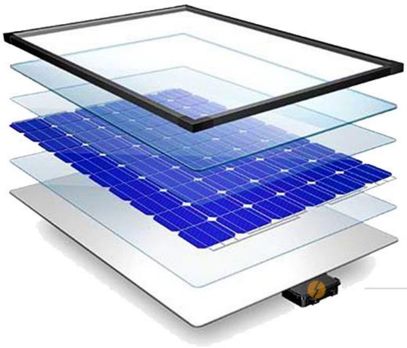
Solar panels are the main components of a photovoltaic system. Composed of photovoltaic cells that generate electricity by means of radiation, The panels do not produce residue and aggression to the environment.

Currently, there are several panel models, but the standardized panel will be about one square meter weighing about 10kg, composed of 36 solar cells, with capacity of 17 volts in direct current, in a power of up to 140 Watts. The type of the solar panel is delimited according to the proposed photovoltaic system. There are several panels, each with its own specifications, however, with the same function of generating electricity.

The operation of the panels are the same as the difference is the effectiveness, value and yield. Every solar panel has haze resistant 3.2 mm tempered glass.

The photovoltaic panel is composed of an aluminum frame, special glass, encapsulating film (EVA), background shield (*Backsheet)* and junction box.

Figure 6 - Composition of the photovoltaic plate



Reference: Portal Solar (2016)

To produce the panel, each photovoltaic cell is placed in series, being connected by a very thin conductive strip, so all the cells are attached forming a circuit. After this layer of cells, there's the glass, treated with a non-stick and antireflective substance, framed by an aluminum frame. Behind the panel there are two conductor of junction box, being used to connect the solar panels and form a set of panels. The set is connected by means of direct current cables to the inverter.

There are other materials besides silicon that are used for the manufacturing of photovoltaic cells and other ways of manufacturing the same.

2.3 Brazilian solar potential and the city of Lorena

The Brazil, because it is a tropical country, Presents a considerable rate of irradiation received, even with different climates noted in different seasonal periods.

According to Pereira (2006), the maximum value of global irradiation reaches 6.5 kWh / m² and the minimum equivalent to 4.25 kWh / m². With this scale, the values of irratiation of Brazil exceed the values of european contryes, such as Germany that has a range of 0,9 to 1,25 kWh/m², France with a range of 0.9 to 1.65 kWh / m² and Spain whose values are 1.2 to 1.85 kWh / m² (Pereira et al., 2006).

the Figure 8, It presents the average annual potential of solar energy between 2006 and 2016.

Figure 7 - Distribution of average irradiation in the Brazilian states

Description:

$$North: Average\ global\ radiation\ 5{,}5\frac{kWh}{m^2}$$
$$Average\ global\ radiation\ on\ the\ inclined\ plan\ 5{,}4\frac{kWh}{m^2}$$

$$Central-West: Average\ global\ radiation\ 5{,}7\frac{kWh}{m^2}$$
$$Average\ global\ radiation\ on\ the\ inclined\ plan\ 5{,}7\frac{kWh}{m^2}$$

$$Northeast: Average\ global\ radiation\ 5{,}9\frac{kWh}{m^2}$$
$$Average\ global\ radiation\ on\ the\ inclined\ plan\ 5{,}8\frac{kWh}{m^2}$$

$$Southeast: Average\ global\ radiation\ 5{,}6\frac{kWh}{m^2}$$
$$Average\ global\ radiation\ on\ the\ inclined\ plan\ 5{,}7\frac{kWh}{m^2}$$

$$South: Average\ global\ radiation\ 5{,}2\frac{kWh}{m^2}$$
$$Average\ global\ radiation\ on\ the\ inclined\ plan\ 5{,}0\frac{kWh}{m^2}$$

As shown, Brazil has favorable characteristics for technological advancement in this type of energy generation. There are regions with greater viability, Due to the radiation that it receives, however, Regions such as the southeast also have feasibility of implantation of photovoltaic technology system, having global average radiation of 5.6 kWh / m², as shown in Figure 19.

According to ABESCO, the technical potential of photovoltaic in Brazil can reach 30.000 GW. This number exceeds the some of other energy sources, and still exceed in 200 times, the installed capacity of the current Brazilian energy matrix, with 143 GW (ABESCO, 2015)

In the city of Lorena, interior of the state of São Paulo and site studied in this work, the radiation undergoes oscillations during the seasons of the years. In the Table 5, composed of data from CRESESB, there are monthly values, referents for the year 2014, with all irradiation indices with their respective inclination angles.

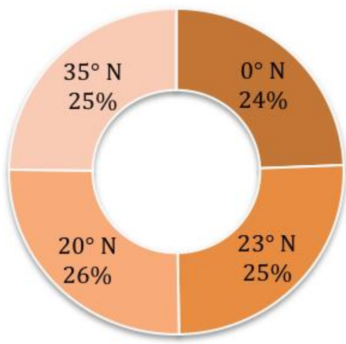
Table 5 - Solar irradiation of monthly averages (kWh/m²)

Angle	**Inclination**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Set**	**Out**	**Nov**	**Dec**	**Average**
Horizontal Plane	0° N	5,35	5,23	4,65	4,07	3,49	3,02	3,49	3,95	3,95	4,65	5,35	5,12	4,36
Angle equal to latitude	23° N	4,85	4,99	4,76	4,57	4,27	3,84	4,41	4,62	4,16	4,53	4,91	4,59	4,54
Highest annual average	20° N	4,94	5,05	4,78	4,54	4,2	3,75	4,32	4,56	4,16	4,58	4,99	4,68	4,55
Highest monthly minimum	35° N	4,4	4,65	4,61	4,62	4,48	4,08	4,68	4,75	4,09	4,28	4,48	4,15	4,44

Reference: CRESESB, 2014

For better performance of the panels, the tilt angle should be less than the latitude of local, and they should be directed to the north. The inclination of the plate is of great importance for the generation, since the angle is the index that will facilitate the capture of the irradiation of the solar plate.

Figure 8 - Average irradiation, referring to the angle of the solar plate

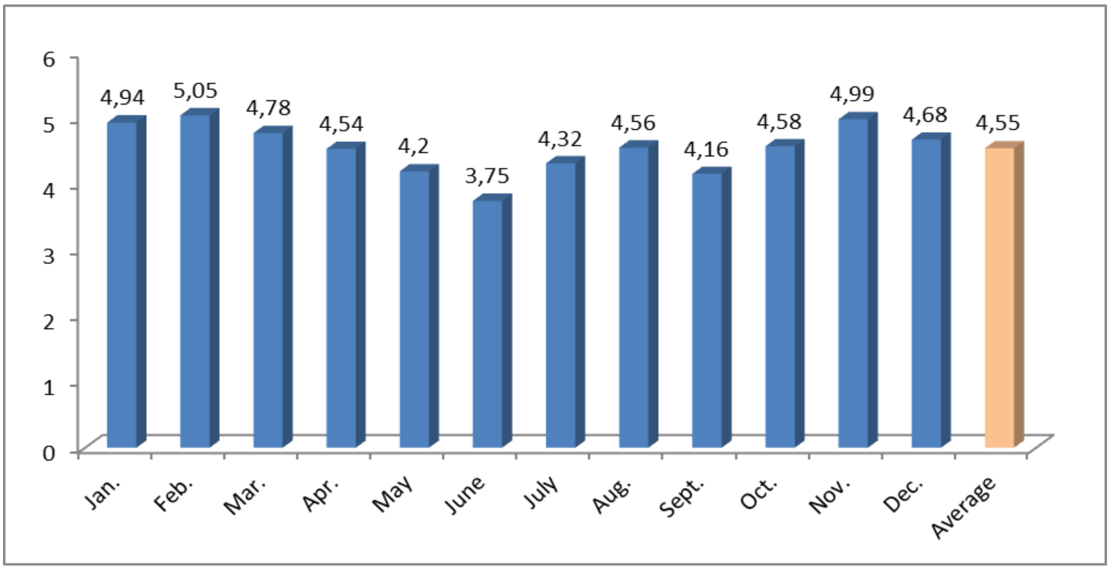


Reference: Author

For the study, It will be considered the highest irradiation index, being the angle of highest annual average, with inclination of 20 ° N, with 26% of irradiation, as shown in Figure 9.

Thus, using the inclination values of 20 ° N, there are the variations, shown in Figure 10, with lower index of irradiation in specific months. However, it will be used to calculate the annual average.

Figure 9 - Monthly Irradiation Index in Lorena, with inclination of 20 ° N



Reference: CRESESB, dados de 2014

The values of irradiation in the horizontal plane have latitude in the range of 12 ° North, 40 ° South and of longitude 30 ° West and 80 ° West.

According to the Figure, the highest monthly average irradiance is in the months of January and November, periods characteristic of higher temperatures.

3.0 SIZING OF PHOTOVOLTAIC SYSTEM

3.1 Demand Survey

The studied educational building, Mário Bonatti, has a specific area for the installation of the system with dimensions of 25 m and 45 m. In this dimension, the roof area will be the basis for calculations of the area and implantation of the solar panels, it will be the photovoltaic system that must feed an illumination of the three floors of the building.

Table 6 - Areas of application of the system

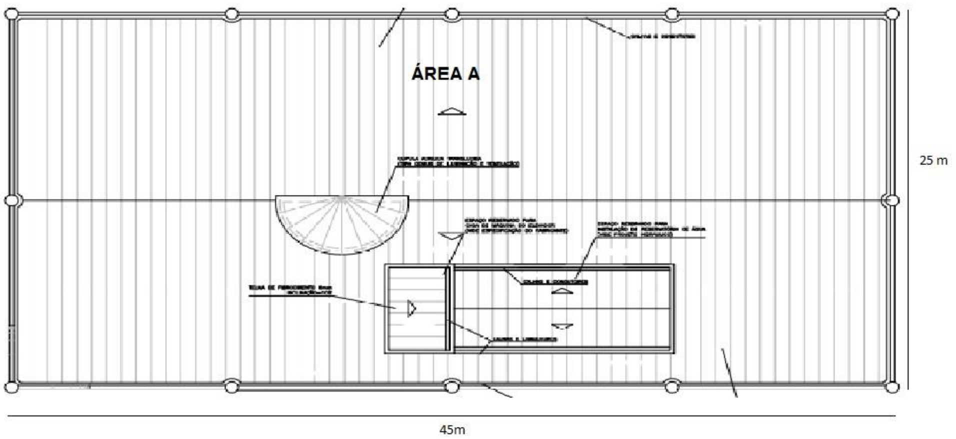
	Length (m)	**Width** (m)	**Area** (m^2)
Roof	45	25	1125

Area A	45	12,5	562,5

Reference: Author

According to these data, the rectangular space indicated as area A, has 562.5 m².

Figure 101 – Roof of bulding Mário Bonatti



Reference: disclosure/Salesian University Center , 2016

The lighting of the place is composed by 308 luminaires, in total 616 lamps are used, fluorescents with 54 W, together with the respective reactors. The student service period begins at 8:00 a.m. ending at 10:30 p.m. However, classes take place in the morning, from 08:30 a.m. to 11:35 a.m., and a night from 07:00 p.m. to 10:30 p.m.

Table 7 - Consumption relationship

Amount	Equipament	Consumo (W)		Sunshine hours	Consumption W/day
		Unitary	Total		
616	Lamps	54	33264	5	232.848

Reference: Author

The building contains installed load of 300 kW, adding all the luminaires and outlets of all areas. However, the load of the lighting installation is calculated in Equation 1, shown below.

Beign:

C_{ilc} – Installed Lighting Charge

Q_{lamp} – Number of lamps in place

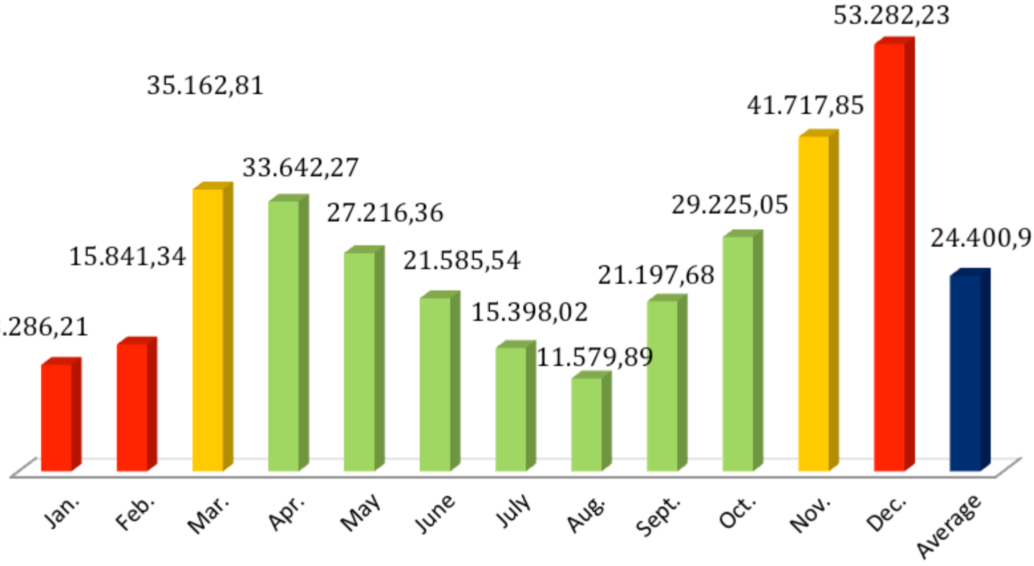
C_{lamp} - Unit consumption of each lamp

$$C_{ilc} = Q_{lamp} . C_{lamp} \quad (2)$$
$$C_{ilc} = 616 * 54 = 33.264\ w$$

As the total installed load of the building equals 300 kW, the lighting load equals 11% of all load of the site.

The monthly consumption of the building, in reais, are shown in Figure 12. All amounts are average, paid to the local concessionaire, Bandeirantes, referents of the year 2014.

Figure 12- Consumption (R $) of the building



Reference: Author

For the calculation of consumption, demonstrated in Equation 2, Will be taken into account the values of the installed load of the lighting and the hours in which there are classes in the building.

In this calculation, they will be in full 24 days a month, since the building operates from Monday to Saturday, being six days a week and considering the month composed by four weeks.

$$\text{Consumption} = \text{N}^{\text{o}}\ \text{Lamps} * \text{Power Lamps} * \text{Days} * \text{Consumption Hour}$$

(3)

$$\text{Consumption} = 33.264 * 24 * 7$$

$$\text{Consumption} = 5.588.352 \frac{Wh}{Month}$$

To calculate the average monthly consumption, by means of Equation 2, the consumption value, found in Equation 3, per 1.000 for the value to be transformed into kWh.

$$\text{Average monthly consumption} = \frac{Consumption}{1000}$$

$$\text{Average monthly consumption} = \frac{5.588.352}{1000}$$

$$\text{Average monthly consumption} = 5.588{,}352 \frac{kWh}{Month}$$

With the average monthly consumption, found in Equation 3, it is possible to obtain the average daily consumption, in Equation 4, to find the necessary quantity of plates to generate the relevant power to the day.

$$\text{Average daily consumption} = \frac{\text{Average monthly consumption}}{Days} \quad (4)$$

Considering that the building operates six days a week and for four weeks: 24 days a month.

$$\text{Average daily consumption} = \frac{5.588.352Wh}{24\ days}$$

$$\text{Average daily consumption} = 232.848\frac{Wh}{day}$$

With monthly consumption, and considering the red tariff rate on level II, Is charged R $ 0.045 for each kWh consumed in the month plus the tariff of R $ 0.27. In this way, the partial cost of consumption is calculated, without taxes, for lighting for one month, as found in Equation 5.

$$C_{monthly} = \text{Monthly Consumption} * \text{tariff} \quad (5)$$

$$C_{monthly} = 5.588{,}352 * 0{,}50057 = R\$2.797{,}36$$

The value of monthly lighting consumption equals 10% of the cost of the average, as shown in Figure 12.

3.2 Projection of the photovoltaic System

For the design of the photovoltaic system, was chosenthe the plate photovoltaic of 320 W, With dimensions of 1.95m x 0.98m.

To calculate the number of plates needed to supply the demand, as calculated in Equation 4. Was relevant to choose the cost benefit of the plate and its economic value, When compared to the other plates of several powers.

Figura 113 - Photovoltaic plate of 320Wh

Reference: CanadianSolar

The amount of solar plates needed to generate the average daily power can be calculated in Equation 4, considering the installed load of lighting and energy of plate solar.

Being:

N – Number of plates required

Pt – Total power of installed lighting load

Pp – Power plate

$$N = \frac{P_t}{P_p} \qquad (6)$$

$$N = \frac{33.264}{320} = 104$$

To meet demand for the installed load, will be usedmore than 105 solar panels of 320 Wh. The area of each plate corresponds to the width value multiplied by the height, totaling 1.91 m².

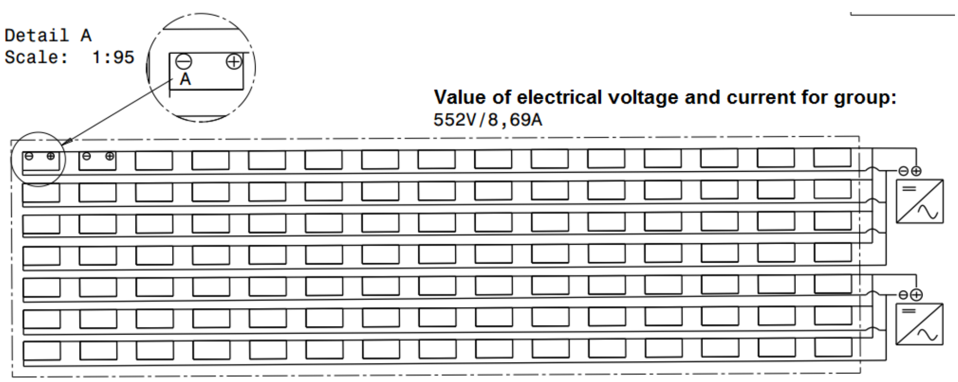
$$\text{Area of plate} = \text{width} * \text{height} = 0{,}98 * 1{,}95 = 1{,}91m^2 \qquad (7)$$

To meet a demand, panels will have to generated at least 33,264 Wh, taking into consideration, the entire period in which electric energy is consumed, Through the illumination of the sections of the establishment.

The Solar panels, as previously mentioned, generate electricity in DC, have two poles, one negative and one positive. In this way, they obey Ohm's Law, for calculations of the electric system, when studied for projection.

In this way, The system will be assembled by the sequences of plates in series and then, with other groups of plates in series, will be connected in parallel, as shown in Figure 14.

Figura 14 - PS in the roof of bulding



Reference: Author

With regard to the dimensioning of the inverter, Equipment that converts the electricity generated by the panels into DC to AC, adequate current equivalent to the grid, it will be selected by means of the electrical specifications of the solar system, for better performance. The main characteristic of this equipment is the possibility of being interconnected to the electricity grid of the power distributor, Doing so, the synchronization of the frequency and output voltage.

For reverse sizing, will be considered the photovoltaic system, represented in Figure 14, for the next calculations.

Each block, with 15 plates in series, has current of 8.69 A, Because when connected in series the current has a single value for all the plates and the total voltage is the sum of all the cells placed in series.

In Equation 8 and 10, the current and voltage of serially attached plates.

Being:

V – Voltage;

Nplates – Number of solar plates connected in series

Vplates – Solar plate Voltage.

$$V = V_{plate} * N_{plate} = 15 * 36{,}8 = 552\,V \quad (8)$$

Therefore, in each circuit with 15 series plates the voltage will be 552 V and the current equivalent to 8.6 A.

Thus, the final system, with all 105 plates, has an equivalence of 552 V, because as plates in series are in parallel with other. However, the current will be the sum of the currents of the circuits with solar panels connected in series, as calculated in Equation 10.

Being:

Vt – Total Voltage;

V – Total Voltage of plates in serie;

At – Total Current;

A1 – Current of plater connected in series, Block 1;

A2 – Current of plater connected in series, Block 2;

A3 – Current of plater connected in series, Block 3;

A4 – Current of plater connected in series, Block 4;

A5 – Current of plater connected in series, Block 5;

A6 – Current of plater connected in series, Block 6;

A7 – Current of plater connected in series, Block 7.

$$Vt = V \quad (9)$$

$$Vt = 552\ V$$

$$At = A1 + A2 + A3 + A4 + A5 + A6 + A7 \qquad (10)$$

$$At = 8{,}69 * 7 = 60{,}83\ A$$

Getting the data of total voltage and total current, consecutively, voltage and current of input of inverter, the power that will scale the inverter is calculated.

Being:

P – Power;

Vt – Total Voltage;

At – Total Current.

$$P = Vt * At \qquad (11)$$

$$P = 552 * 60{,}83 = 33.578{,}16\ Wh$$

By means of Equation 11, it is possible to choose the inverter for the system. However, the equipment must have the appropriate technical specifications for the system, for better use of electrical design.

According to the data obtained, by means of calculations, will be considered for this study, two inverters three-phase s of 25 kW, with nominal input voltage of 580 V and DC current of 66.3 A.

Figura 12 – Frequency inverter 25 kW

Reference: *Fronius*

With this inverter, is possible to increase the generation of the photovoltaic system. Because, with the use of two inverters, the power will be above the value of the system, There is the possibility of future insertions of solar panels in the same system.

3.4 Monthly income and economy in the consumption of energy

The monthly yield can be calculated by means of Equation 12. For this, will be considered the generation values in Wh, Hours of sunshine of one day and of whole month.

Being:

Rm – Monthly income;

Gh – Generation hour

hsol – Daily sunshine hours;

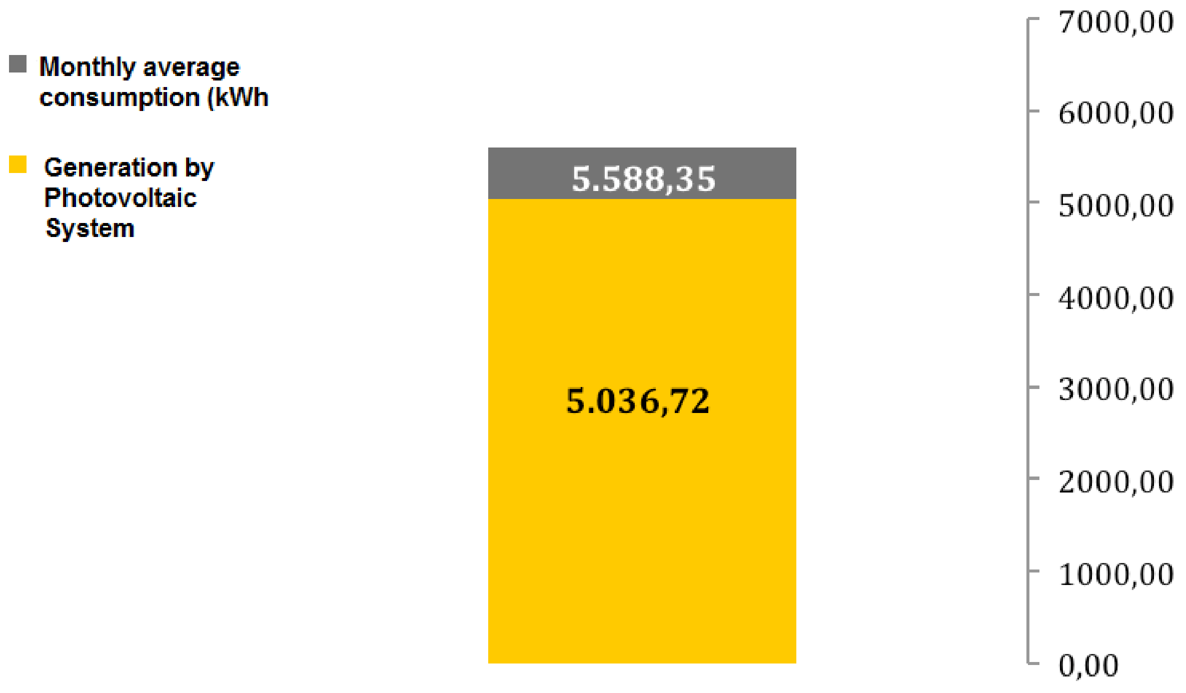
dias – Number of days in the month.

$$R_{monthy} = G_{hour} * h_{sun} * days \qquad (12)$$

$$Rmonthly = 33.578{,}16 * 5 * 30 = 5.036.724 \frac{Wh}{mês}$$

Thus, The amount of energy generated Is close to the value of the average monthly consumption of lighting, Represents about 90% of the energy consumed per month, As shown in Figure 16.

Figure 16 - Comparison of monthly average consumption with the generation of Photovoltaic System



Reference: Author

Thus, the monthly economy, is calculated by Equation 13, Using the values of monthly partial consumption, which considers only the tariff red flag level II and more the energy tariff.

Being:

E – Economy;

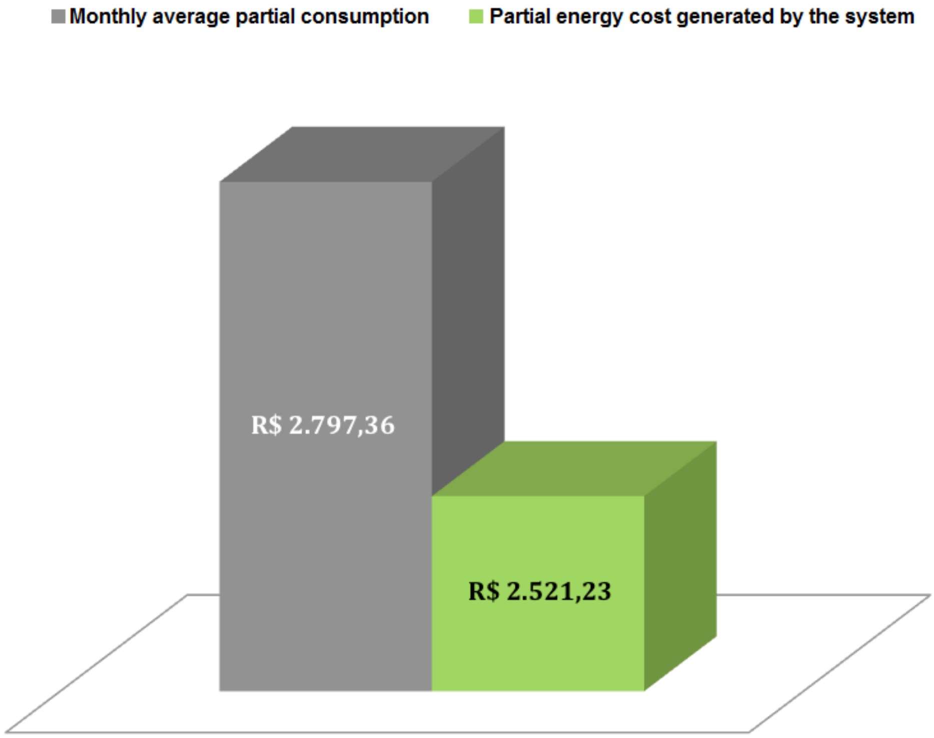
Cmps – Average cost of Photovoltaic System;

Gm – Average of Average of the monthly energy generated by the system

$$E = Cmps = Gm * Cost\ kWh \quad (13)$$

$$Cmps = 5.036{,}724 * 0{,}50057 = R\$ \ 2.521{,}23$$

Figure 17 - Cost of average monthly consumption compared to cost of generating Photovoltaic System, with no tax rates



Reference: Author

With the photovoltaic system operating properly, There is an economy of R $ 2,266.52, the gross value of electricity consumption per kWh.

3.5 CALCULATION OF THE RETURN TIME OF THE INVESTMENT

With investment in new technologies, There is the questioning in when and how we have the return of the initial value invested. In photovoltaic power generation technologies, the return on initial investment is the economy caused by investing in the photovoltaic system.

In this topic, is calculate the fundamental principle of the elaboration of this study, Because the economic viability of this work will be diagnosed by the calculation of simple payback.

However, for the calculation of the payback is necessary for the amount invested in the photovoltaic system. For this, will be added the costs of all used equipment, Cost of investment of the system considering 25% of the values of the equipment Including the maintenance value of the photovoltaic system.

> For internalization in Brazil, of the costs described in the previous item, should be considered the incidence of taxes. Disregarding taxes in places of origin, there is, in net terms, the internalization in Brazil of the costs of investment in photovoltaic generation system would amount to an increase of around 25% of the values assigned as an international reference. (EPE, 2012)

In the Table 8, find is the relation of the equipments used in survey the photovoltaic system

Table 8 - Cost survey

Equipment	Quantity	Value ($)	Value (R$)	Amount (R$)
Solar plates 320 Wh	105	$ 234,00	R$ 737,10	R$ 77.395,50
Inverter *Grid-tie*	2		R$ 22.590,97	R$ 45.181,94
Cables and structure				R$ 19.348,88
Total				R$ 141.926,32

Reference: Author

Before calculating paybackwill be consider the values of the monthly average consumption and the energy generated by the system, as calculated by the local utility. The formula for the calculation of consumption is shown in Equation 1 above.

$$Average\ Price = \frac{Te + Bt}{1 - (ICMS + PIS + COFINS)} \quad (14)$$

$$Average\ Price = \frac{(0{,}39555 + 0{,}40717) + 0{,}045}{1 - (0{,}18 + 0{,}82 + 0{,}376)}$$

$$Average\ Price = \frac{0{,}84772}{0{,}7742} = 1{,}09$$

$$Vconsumer = Quantity\ of\ kWh * average\ price \quad (15)$$

$$Vconsumer = 5588{,}352 * 1{,}09 = R\$\ 6.091{,}30$$

$$Vconsumer = Quantity\ of\ kWh * average\ price \quad (16)$$

$$Vconsumer = 5.036{,}72 * 1{,}09 = R\$\ 5.490{,}02$$

Thus, when using the photovoltaic system for the generation of energy, The college will pay the concessionaire only the value of kWh that was not generated by the PV system. The value in reais is shown by Equation 17.

$$Valor = R\$\ 6.091{,}30 - R\$\ 5.490{,}02 = R\$\ 601{,}28 \quad (17)$$

Thus, the TRI can be calculated by Equation 18.
(TRI = Investment return time)

$$TRI = \frac{initial\ investment}{Period\ gain} \quad (18)$$

$$TRI = \frac{141.926{,}32}{5490{,}02} = 26\ meses$$

Therefore, the TRI will be after 26 months, that is, two years and two months after the implantation of the system.

Considering that the implementation of the Photovoltaic System, be carried out in January 2017And your operation beging that month, the TRI will be in March 2019.

In table 9, it is possible to analyze the return on investment during the period of 26 months.

Table 9 - Investment return time

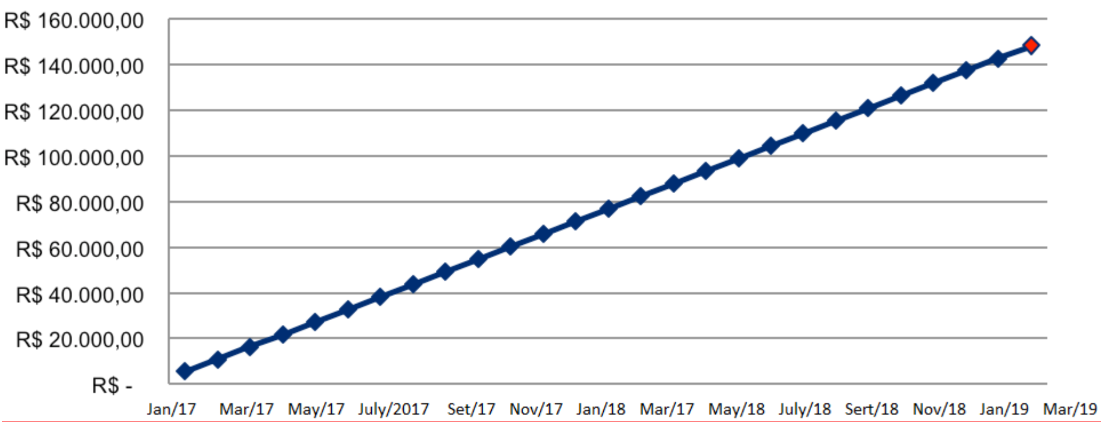
Month	Cash flow	Balance
0	-R$ 141.936,32	-R$ 141.936,32
1	R$ 5.490,02	-R$ 136.446,30
2	R$ 5.490,02	-R$ 130.956,28
3	R$ 5.490,02	-R$ 125.466,26
4	R$ 5.490,02	-R$ 119.976,24
5	R$ 5.490,02	-R$ 114.486,22

6	R$	5.490,02	-R$ 108.996,20
7	R$	5.490,02	-R$ 103.506,18
8	R$	5.490,02	-R$ 98.016,16
9	R$	5.490,02	-R$ 92.526,14
10	R$	5.490,02	-R$ 87.036,12
11	R$	5.490,02	-R$ 81.546,10
12	R$	5.490,02	-R$ 76.056,08
13	R$	5.490,02	-R$ 70.566,06
14	R$	5.490,02	-R$ 65.076,04
15	R$	5.490,02	-R$ 59.586,02
16	R$	5.490,02	-R$ 54.096,00
17	R$	5.490,02	-R$ 48.605,98
18	R$	5.490,02	-R$ 43.115,96
19	R$	5.490,02	-R$ 37.625,94
20	R$	5.490,02	-R$ 32.135,92
21	R$	5.490,02	-R$ 26.645,90
22	R$	5.490,02	-R$ 21.155,88
23	R$	5.490,02	-R$ 15.665,86
24	R$	5.490,02	-R$ 10.175,84
25	R$	5.490,02	-R$ 4.685,82
26	R$	5.490,02	R$ 804,20

Reference: Author

In the Figure 18, is represented, graphically, the return time of the investment, allowing a visualization of the month in which the return of the initial investment of the system occurs, with 5.036,72 kWh installed per month, considering that the each month there is reduction of R$ 5.490,02, in energy expenses monthly of the Mário Bonatti building.

Figure 18 - Investment return time



Reference: Author

However, with the calculation of discounted payback, when there is inclusion of TMA, that is, minimum rate of attractiveness, considering 12% of the rate per year, will have the following period of TRI. For this calculation it is necessary to calculate the VPL, net present value, by means of Equation 18.

$$VPL = \frac{cash\ flow}{(1 + TMA)^{year}} \quad (18)$$

Thus, with the economic evaluation of discounted payback, will have the TRI, represented in Table 10.

Table 10 - TRI Discounted

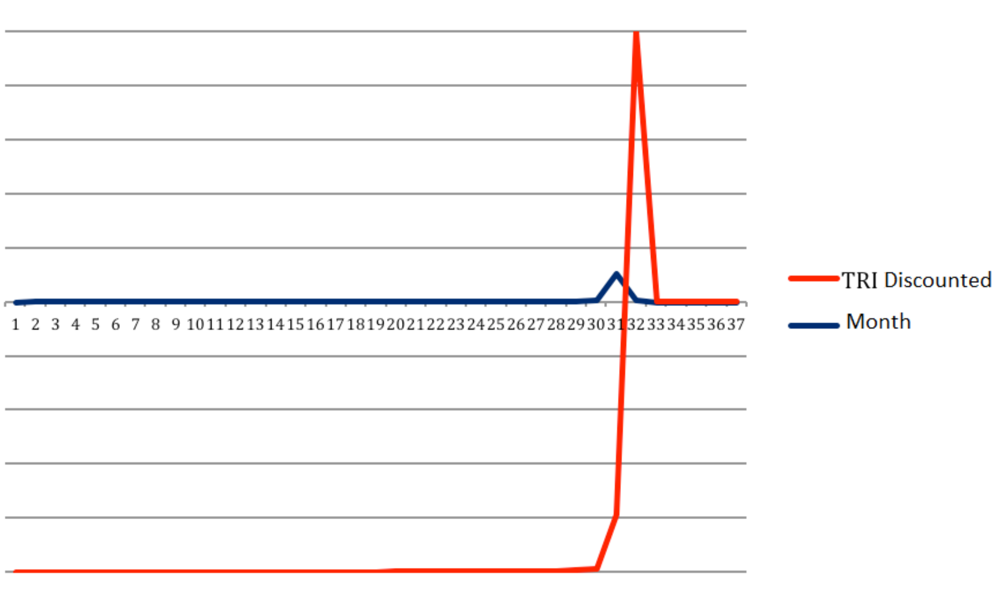
Month	Economy	Accumulated Present Value	TRI Discounted
0	-R$ 141.936,32		-R$ 141.936,32
1	R$ 5.490,02	R$ 5.435,66	-R$ 136.500,66
2	R$ 5.490,02	R$ 5.381,84	-R$ 131.118,81
3	R$ 5.490,02	R$ 5.328,56	-R$ 125.790,25
4	R$ 5.490,02	R$ 5.275,80	-R$ 120.514,45
5	R$ 5.490,02	R$ 5.223,57	-R$ 115.290,89
6	R$ 5.490,02	R$ 5.171,85	-R$ 110.119,04
7	R$ 5.490,02	R$ 5.120,64	-R$ 104.998,40
8	R$ 5.490,02	R$ 5.069,94	-R$ 99.928,46
9	R$ 5.490,02	R$ 5.019,74	-R$ 94.908,71
10	R$ 5.490,02	R$ 4.970,04	-R$ 89.938,67
11	R$ 5.490,02	R$ 4.920,84	-R$ 85.017,83
12	R$ 5.490,02	R$ 4.872,11	-R$ 80.145,72
13	R$ 5.490,02	R$ 4.823,88	-R$ 75.321,84
14	R$ 5.490,02	R$ 4.776,11	-R$ 70.545,73
15	R$ 5.490,02	R$ 4.728,83	-R$ 65.816,90
16	R$ 5.490,02	R$ 4.682,01	-R$ 61.134,90
17	R$ 5.490,02	R$ 4.635,65	-R$ 56.499,25
18	R$ 5.490,02	R$ 4.589,75	-R$ 51.909,50
19	R$ 5.490,02	R$ 4.544,31	-R$ 47.365,19
20	R$ 5.490,02	R$ 4.499,32	-R$ 42.865,87
21	R$ 5.490,02	R$ 4.454,77	-R$ 38.411,11
22	R$ 5.490,02	R$ 4.410,66	-R$ 34.000,44
23	R$ 5.490,02	R$ 4.366,99	-R$ 29.633,45
24	R$ 5.490,02	R$ 4.323,75	-R$ 25.309,70
25	R$ 5.490,02	R$ 4.280,94	-R$ 21.028,75
26	R$ 5.490,02	R$ 4.238,56	-R$ 16.790,20
27	R$ 5.490,02	R$ 4.196,59	-R$ 12.593,60

28	R$	5.490,02	R$	4.155,04	-R$	8.438,56
29	R$	5.490,02	R$	4.113,90	-R$	4.324,66
30	R$	5.490,02	R$	4.073,17	-R$	251,49
31	R$	5.490,02	R$	4.032,84	R$	3.781,36

Reference: Author

In the Figure 20, is possible view the TRI graphically.

Figure 20 – Discounted Return on Investment Time



Reference: Author

Considering the discounted TRI, will have that the return of time will be of 31 monthsEquivalent to two years and seven months, for the return of the initial investment of the project.

4.0 CONCLUSÃO

Among the various means of generating electricity, in a cleaner way, photovoltaic energy, in grid-tie system, stands out for efficiency and effectiveness, besides being economically viable.

In this work, the study was carried out to analyze the economic feasibility of implementing a photovoltaic system connected to the grid, with the investment value equivalent to R $ 141,926.32, for the average monthly consumption of 5.588,352 kWh of all the illumination of the educational building Mário Bonatti, of UNISAL in Lorena, interior of São Paulo.

The financial analysis was made from the time of return of the initial investment, *payback* Simple and discounted, considering that each month, it will have a economy of 5,036.72 kWh, equivalent to R $ 5,490.02, deducted in the total amount that is paid to the local concessionaire.

The *payback* simple, which is equivalent to the time that the investor will have the return of the amount invested initially in the project, obtained the period of 26 months, that is, two years and two months, after the installation of the system. As of the 26th month, the investor will only have profits with the Photovoltaic System. Already with the payback discounted, the investment return time will be higher, due to the fact of consider calculations the TMA. Thus, the discounted TRI will be 31 months, which is equivalent to two years and seven months, in this way, from that period, the investor only will have profits with the system. In both cases profitability occurs, even with differentiated TRI, and the profit occurs until 25 years of use of the equipment, when the owner needs to perform the maintenance and check the performance of the system, according to the manufacturer's specifications and guidelines.

With the analysis, the values obtained in the calculations, even with the high initial investment, due to lack of government incentives, all values corroborate that the investment is feasible and rewarding for the university. Because, besides encouraging the use of renewable energies, with electricity generation in a cleaner way, stresses the need for the country to seek new technologies and consumer market incentives in the Vale do Paraíba region and among others to use differentiated and less aggressive mechanisms for the environment for the generation of energy. Besides making Brazil one of the countries of power and prominence in the use of photovoltaic energy.

Therefore, with the intention of the work achieved, to propose the use of the photovoltaic system connected to the electric grid and economically feasible, it is that the photovoltaic energy is one of the main solutions of the country's energy problems, because it presents issues of social, economic and environmental preservation. In the environmental field, there is concern about the environment and the correct allocation of the resources necessary for the generation of energy. In the economic concept, with projection of autonomous systems in residences and areas of greater insolation, for improve technology and transform the country into a gran potency, when it comes to solar energy. And, essentially, in the social aspect, with the development of a more conscious society And encourages students, children and adults, to use energy correctly. In addition to boosting new research in this area and instigating more and more study in the new researchers.

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