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Analysis of the implementation of bifacial photovoltaic panels in homes

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ABSTRACT
Clean and renewable energy sources are strongly debated and are being seen as a great alternative to meet society's energy demand, either for economic reasons or for reasons of lower carbon emissions, consequently there is a growing search for these energy sources. In this way, solar energy is gaining more and more space, especially in homes. With this, the objective of this study is an analysis of the implementation of a bifacial solar system in a residence, aiming at a better use of generation by installed space of the system. The advantage of the bifacial is the generation from the lower face, which can increase the electrical production in each panel by up to 25%.

Keywords: Panels, Bifacials, Systems, Residences.

INTRODUCTION

With the growing demand in the global solar photovoltaic sector, progressively more countries have been standing out in this energy sector. Brazil has been following this growth, having improved more and more in the sector. One of the motivations for the gain of the Brazilian solar sector was the reduction in the price of photovoltaic modules and the publication of Normative 482/2012, which determined new guidelines for distribution and generation in Brazil. With Normative 482/2012, the customer is now based on legal terms, to generate and consume their own energy in an efficient, renewable and zero-waste generation in energy generation. A considerably good factor of Brazil is the climate, which is predominantly tropical, receiving a large amount of solar radiation every day of the year. With rates ranging from 5483Wh/m^2 and 4444 Wh/m^2 between the most different regions of Brazil, according to data from CRESESB, (2023).

Because of this Brazilian potential, it is absolutely likely that the execution of solar systems in businesses, industries and especially in homes, are ideal for our current scenario.

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With the broad search for solar panels, scholars in the area develop other technologies to innovate, as in the case of bifacial panels.

Solar energy from photovoltaic panels is in continuous growth in the country and on the world stage, but until some time ago there was distinction. Until in 2012, with the publication of Resolution No. 482, which involves the extension of small-scale distributed generation, a sector that gained strength in Brazil and that, in 2020, reached the mark of 6 GW of installed power, a high number compared to the total installed potential at the time, according to data from ABSOLAR (Brazilian Association of Photovoltaic Solar Energy) [GLOW SOLAR, 2021].

In mid-2012, the National Electric Energy Agency (ANEEL) consolidated the first Normative Resolution, REN No. 482, which defined the general conditions for access to distributed microgeneration and minigeneration in Brazil, in addition to completely elaborating the entire system so that it was possible to carry out the compensation of electricity. Despite this, after a few years, some adjustments to this resolution were indispensable, with the purpose of minimizing costs and time for connection and expanding the audience, which was modified in Resolution No. 687, of 2015. And, from then on, it is likely that each and every person with a CNPJ or CPF will generate their own energy, from renewable sources [GLOW SOLAR, 2021]. The new regulation of 2022 had some changes in deadlines, all the provisions of Law 14,300 that do not depend on ANEEL's specification or adequacy of the concessionaires' systems, can already be applied immediately. ANEEL had 180 days to regularize the Law, that is, to update Normative Resolution REN No. 482 to avoid conflicts with Law 14,300 [GOV 2022].

The main changes in Law 14,300/2022 were related to installed power, that there were some changes in the distributed minigeneration part, which for non-dispatchable sources reduced the limit from 5MW, as it was in REN482, to 3MW. And the higher limit of 75 kW (seventy-five kilowatts) was maintained, this for systems connected to the electricity distribution network through the installation of consumer units (GOV, 2022).

Associated with the compensation of electricity, before the resolution of Law 14,300 there was a total compensation system, which refers to a compensation system of 1 to 1. In the old model, everything that was injected into the network could be consumed without discounts for this, but evidently, still paying the PIS and COFINS tax rates, but this has no direct relationship with tariff components [GOV, 2022].

The main contributions of this work:

1) an analysis of a bifacial solar system mounted on a residence, and to ascertain the best use of these panels;
2) performing a comparative analysis with conventional panels and ascertaining the difference between them;

3) system sizing, with updated values;

4) prepare an economic feasibility study of the project. The project is aimed at a better use of generation by installed system space.

OBJECTIVE

The objective of this work is to analyze a system of bifacial solar panels, installed on the roof of a residence, in order to evaluate the best condition to install it and what values can be obtained with this theoretical installation, when compared to conventional panels.

METHODOLOGY

Data collection on bifacial panels.

Structure studies for installation. The most appropriate structure is the one that uses the upper part of the houses in built-in concrete roofs (slab), and built-in roofs can be chosen or also those of fiber cement that are not found in greater quantity, which have a good surface reflection.

The analysis methodology for the comparison and obtaining the results was carried out in an Excel spreadsheet, with all the base data for the calculations being noted in the spreadsheet. Base information of the installation region was captured on the CRESESB website, with the average solar irradiation data with values represented in (kWh/ m^2*day), also acquiring the ideal angle for the best use of the panel, which is 23° degrees positioned to the north.

The location chosen was the municipality of Rosana, in the interior of the state of São Paulo (SP), latitude 22° 34' 48'' S and longitude 53° 03' 32'' W.

DEVELOPMENT

FORMULATION OF THE PROBLEM

The study consists of the analysis of a system of bifacial solar panels in homes, analyzing the best way to obtain the best use of solar incidence. It is known that in large installations there is good use, but in homes some type of ideal mounting structure can be created for bifacial photovoltaic solar systems, with a reflective surface that better takes advantage of the rays reflected by the roof of the house and adequacy of the height of the panels in relation to the reflective surface, as well as with a well-sized structure it is possible to reduce the spaces used and consequently reduce the amount of equipment.

The types of constructions for the preparation of the project are, the built-in roof or building surfaces is an alternative for the installation of panels, since it contains a surface with a considerable reflection that most of the time is concrete, which if positioned correctly can obtain considerable use, linked to bifacial technology. Another alternative would be the installation of bifacial solar panels with 2 functions, which would be the roof with a secondary utility and the generation of electricity with the plates as the main purpose. This installation of the panels is possible with the utility of serving as a cover as well, as it is a material that serves to seal between the spaces of one plate and another. In the case of this study, asbestos cement roofs (former "asbestos" roofs) were the option, as they are in greater quantity and it would be good to have the results of the studies of this implementation of monofacial and bifacial panels for analysis.

Every part of the structure of the modules will be recorded and determined with the necessary seals for the panels used in the roof part. The equipment selected for the analysis, such as common and bifacial panels, inverter and other necessary items. Figure 1 shows the monofacial solar panel chosen for the comparison.

Figure 1. 555W Monocrystalline Solar Panel Sunova 72MDH 30mm

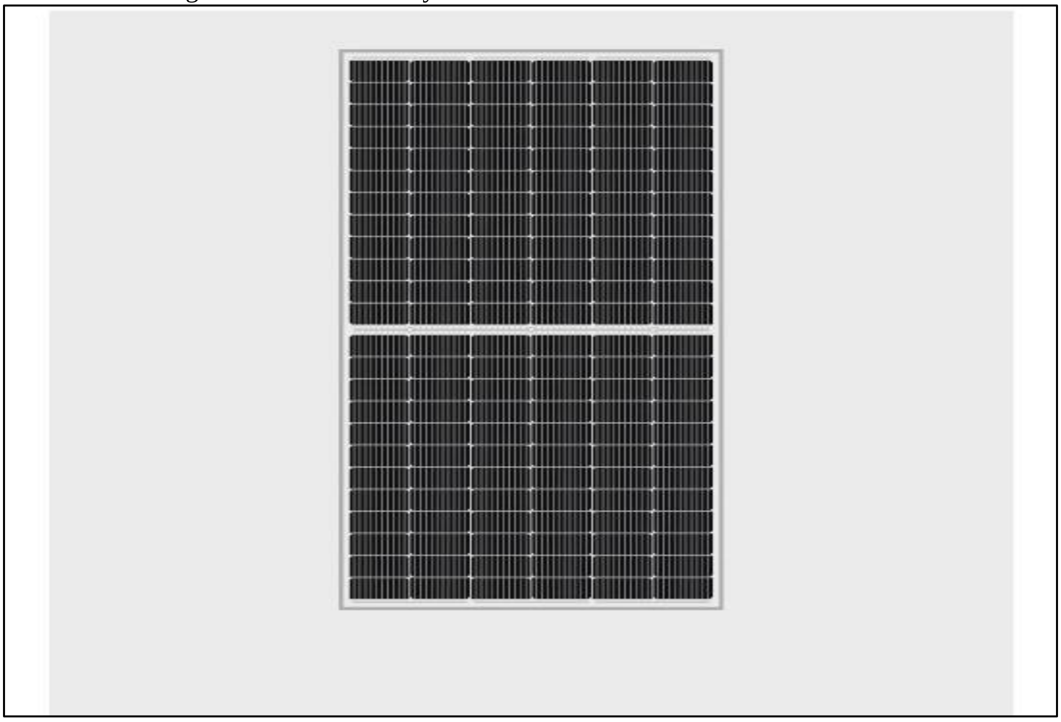


Table 1 provides the standard information for the common cell monocrystalline solar panel.

Table 1. Specifications 555W Monocrystalline Solar Panel.

Rated Power	**555W**
Tension	**40.89Vdc**
Current	**13.58A**
Efficiency	**Face Frontal 21,5%**
Cell Type	**Monocrystalline**
Maker	**Sunova**

In the midst of several innovations, Sunova Solar's panels are developed with Half-Cell technology (that is, cells cut in half to make the system more efficient) and protection against the problem of Hot Spots (with a circuit designed eventually to avoid the occurrence of hot spots that may arise due to shading in the solar panels).

Sunova's solar panels have a high performance and are differentiated by their resistance and durability, with quality assured by the double inspection in el Test (a rigorous test that proves the robustness of photovoltaic cells).

Figure 2 shows the bifacial solar panel chosen for the comparison.

Figura 2. Painel Solar 575W Monocristalino Bifacial Half-Cell Sine Energy - SN575-144MTB

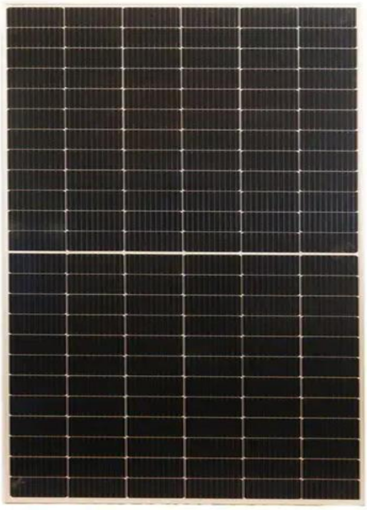


Table 2 shows the standard information of the monocrystalline solar panel of bifacial cells.

Table 2. Specifications 555W Monocrystalline Solar Panel

Rated Power	**575W**
Tension	**42.24Vdc**
Current	**13.63A**
Efficiency	**Face Frontal 22,25%** **Bifacial 27,81%**
Cell Type	**Monocrystalline**
Maker	**Sine Energy**
INMETRO Registration	**003207/2023**

With a high power generation on account of the combination of technologies, Half-Cell, TopCon, Multi-busbar, monocrystalline cells and Bifacial Design offer an average efficiency of 27.81%. This bifacial photovoltaic solar panel reaches an average output of 2,875W per day with just 5 hours of full sun and can reach up to 3,594kW per day with 25% bifacial power gain.

Panel service time increased with Anti-PID technology, induced potential degradation is less over the life of the panel. In this way, the loss of power occurs at a slower pace and has less impact on power generation.

The SN575-144MBT solar module has a robust structure to last a long time, to withstand harsh weather conditions, allowing for superior durability.

With the 575W bifacial solar module, we have the possibility of a number of applications, being more suitable for grid-connected systems in open areas, homes and businesses that are installed on the ground or on fiber cement roofs (former "asbestos" roofs) to take advantage of the sunlight reflected on the surface and captured by the cells at the bottom.

Figure 3 contains the chosen solar inverter.

Figure 3. GROWATT on-grid photovoltaic solar inverter

Table 3 shows the most relevant technical specifications of the inverter:

Table 3. Specifications GROWATT on-grid solar PV inverter

Rated Power	**2kW**
Maximum Input Voltage	**500Vdc**
Rated Voltage(Output)	**(180V-280)**
Max. DC Current by MPPT	**13A**
Max. Current output	**16A**
Efficiency	**97,2%**
Type of Investor	**On-grid**
Maker	**GROWATT**

The built-in roof or building surfaces is an alternative for the installation of panels, since it contains a surface with a considerable reflection that most of the time is concrete, which if positioned in the right way obtains considerable use, when considering bifacial technology.

In the analysis of this installation, it was considered that the panels were designed with the intention of generation at the bottom, that is, corresponding to the bifacial solar panel model, to be later compared with the monofacial solar module, being installed in the same frame. The structure must be positioned a little higher than the slab or, in the case of this study, above the fiber cement roof of the leisure area of the residence, at a height of at least 1.2 meters.

Figure 4 below shows how the panels should be grouped and inclined, with only two panels having to be adjusted in the height part of the roof in relation to the roof.

Figure 4. Installation of modules with the inclination for bifacial panels on concrete roof

The next section exposes the results and tests of the proposed formulation.

TESTS AND RESULTS

The most appropriate structure is the one that uses the upper part of the houses in built-in concrete roofs (slab), and built-in roofs can be chosen or also those of fiber cement that are not found in greater quantity, which have a good surface reflection.

The analysis methodology for the comparison and obtaining the results was done in an Excel spreadsheet, with all the base data for the calculations being noted in the spreadsheet. Base information of the installation region was captured on the CRESESB website, with the average solar irradiation data with values represented in (kWh/m^2*day), also acquiring the ideal angle for the best use of the panel, which is 23° degrees positioned to the north.

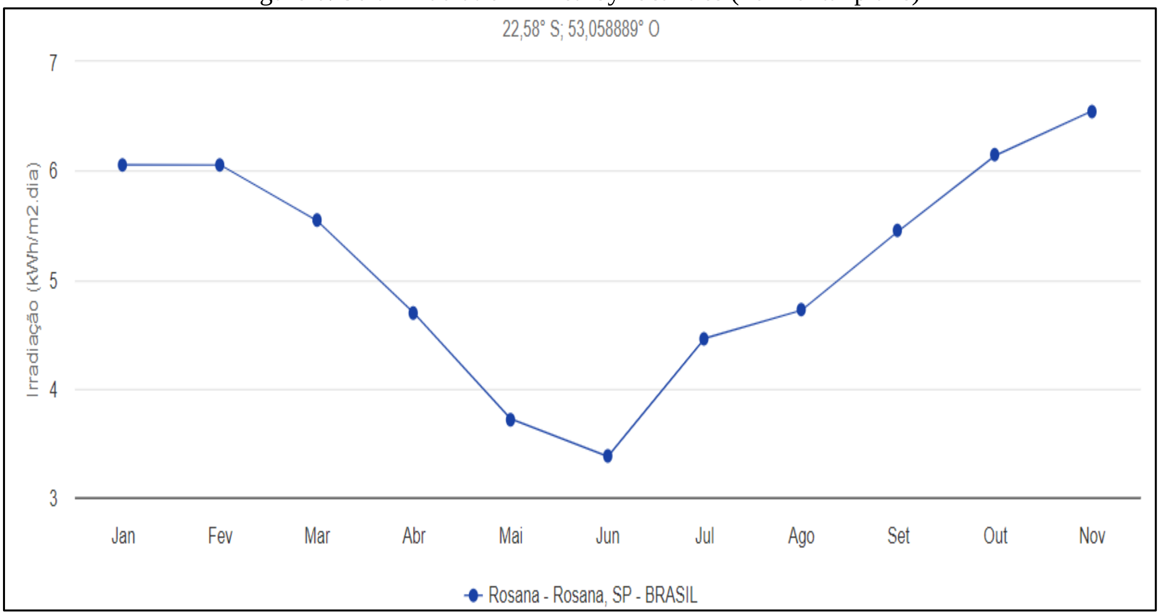
The location chosen was the municipality of Rosana, in the interior of the state of São Paulo (SP), latitude 22° 34' 48'' S and longitude 53° 03' 32'' W. Next, the climatic data were obtained from CRESESB, which are expressed in figures 5 and 6 below:

Figure 5. Solar irradiation values in Rosana – SP

Estação: Rosana
Município: Rosana , SP - BRASIL
Latitude: 22,601° S
Longitude: 53,049° O
Distância do ponto de ref. (22,58° S; 53,058889° O) :2,5 km

#	Ângulo	Inclinação	Irradiação solar diária média mensal [kWh/m^2.dia]													
			Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Out	Nov	Dez	Média	Delta
☑	Plano Horizontal	0° N	6,05	6,05	5,54	4,69	3,72	3,37	3,56	4,46	4,72	5,45	6,14	6,55	5,02	3,17
☑	Ângulo igual a latitude	23° N	5,45	5,76	5,71	5,33	4,59	4,35	4,51	5,27	5,02	5,31	5,60	5,78	5,22	1,43

Figure 6. Solar irradiation in nearby localities (horizontal plane)



The place of theoretical implementation of the system was a residence in the municipality of Rosana, district of Primavera – SP. The selected installation point was the leisure area of the house. Figures 7 and 8 below show the roof where the structure with the panels will be designed:

Figure 7. Roof of Implementation Analysis in Residence

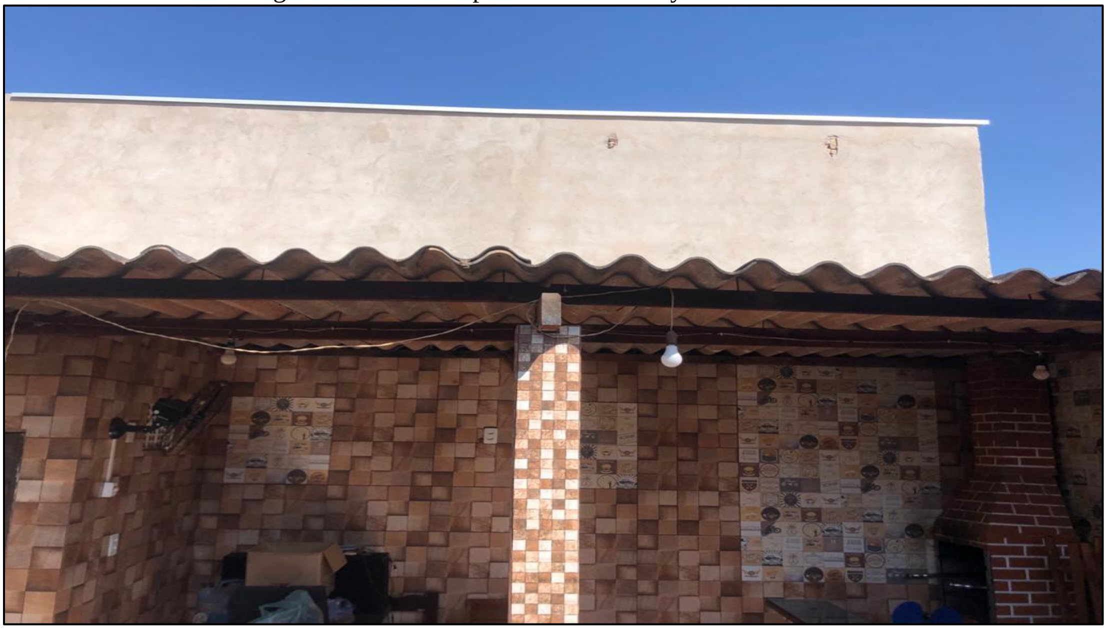


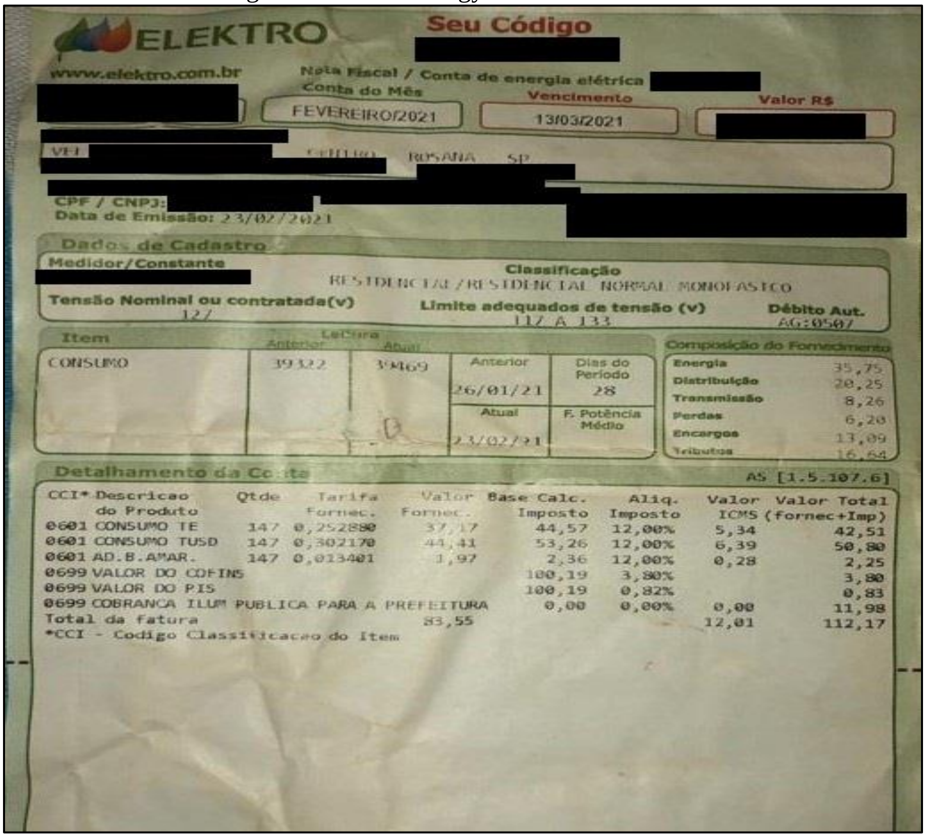
Figure 8. Place of residence where implementation will be analyzed

The structure assembled with the panels will be positioned facing the geographic north, with an inclination of 23 degrees, which would be inclined towards the trees in figure 8, the structure would be adapted to a height of 1.3 meters from the fiber cement roof, a structure that would be fixed to the upper wall next to the roof, giving more security in the matter of supporting the project.

The dimensioning of the monofacial system to compare with the values of the bifacial system was performed with data from the chosen residence. With the house defined, the energy bill for the month was purchased, but in addition to the data for the month for the month, there was other important information from previous months.

Figures 9 and 10 show the energy bill for the pandemic period in 2021, as the new energy tariffs were placed in automatic debit, and it will no longer be printed from this date on.

Figure 9. Elektro energy bill of the residence



ELEKTRO
Seu Código
[redacted]
www.elektro.com.br
Nota Fiscal / Conta de energia elétrica [redacted]
[redacted]

Conta do Mês	Vencimento	Valor R$
FEVEREIRO/2021	13/03/2021	[redacted]

[redacted]
VEI [redacted] CENTRO ROSANA SP
[redacted]
CPF / CNPJ: [redacted]
Data de Emissão: 23/02/2021

Dados de Cadastro

Medidor/Constante
[redacted]
Classificação
RESIDENCIAL/RESIDENCIAL NORMAL MONOFASICO
Tensão Nominal ou contratada(v): 127
Limite adequados de tensão (v): 117 A 133
Débito Aut.: AG:0507

Item	Leitura Anterior	Leitura Atual	Anterior	Dias do Período
CONSUMO	39322	39469	26/01/21	28
			Atual	F. Potência Médio
			23/02/21	

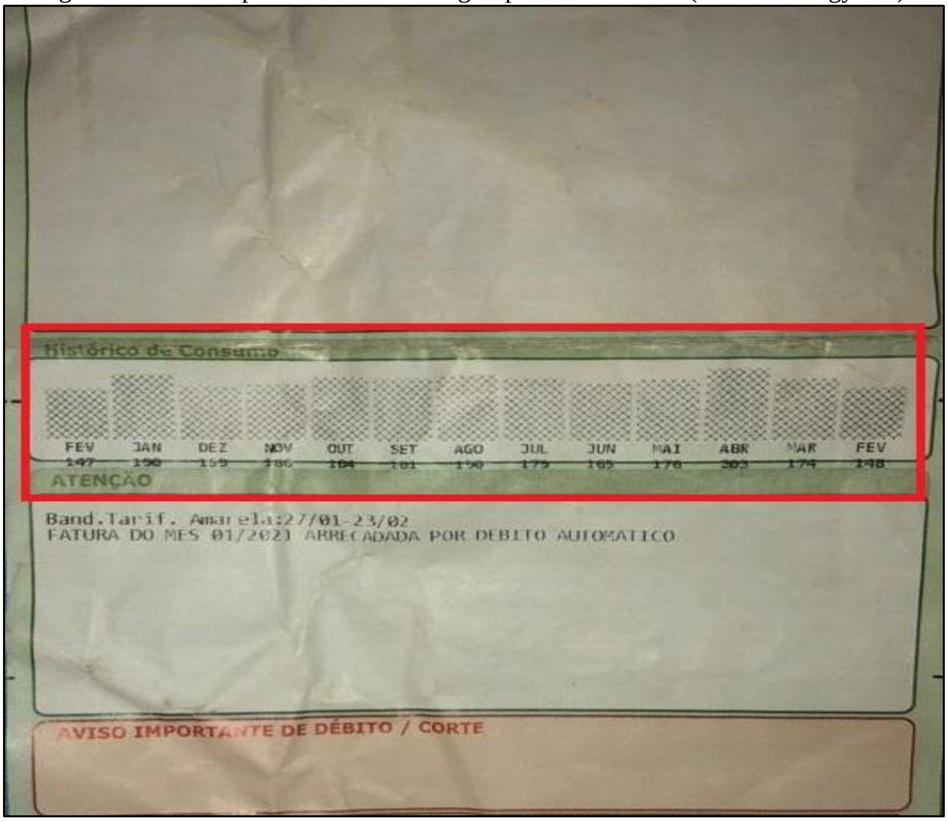
Composição do Fornecimento	
Energia	35,75
Distribuição	20,25
Transmissão	8,26
Perdas	6,20
Encargos	13,09
Tributos	16,64

Detalhamento da Conta AS [1.5.107.6]

CCI*	Descricao do Produto	Qtde	Tarifa Fornec.	Valor Fornec.	Base Calc. Imposto	Aliq. Imposto	Valor ICMS	Valor Total (fornec+Imp)
0601	CONSUMO TE	147	0,252880	37,17	44,57	12,00%	5,34	42,51
0601	CONSUMO TUSD	147	0,302170	44,41	53,26	12,00%	6,39	50,80
0601	AD.B.AMAR.	147	0,013401	1,97	2,36	12,00%	0,28	2,25
0699	VALOR DO COFINS				100,19	3,80%		3,80
0699	VALOR DO PIS				100,19	0,82%		0,83
0699	COBRANCA ILUM PUBLICA PARA A PREFEITURA				0,00	0,00%	0,00	11,98
Total da fatura				83,55			12,01	112,17

*CCI - Codigo Classificacao do Item

Figure 10. Consumption values referring to previous months (Elektro energy bill).



In both systems they will be connected to the grid (On-grid), for this reason it is not necessary to implement a battery bank for the storage of excess electricity not consumed, this excess energy being exported to the electricity grid itself and used in periods when energy production is zero. In this way, making the project much more advantageous, as batteries have a high cost.

The methods used to obtain the calculation of the sizing of the quantity of solar panels and inverters will be shown below:

The Monthly Consumption (kWh) is equal to the sum of all 12 months present on the bill and consequently equal to the annual consumption, equation 1 indicated below:

$$Annual\ Consumption(kWh/ano) = Monthly\ consumption(kWh) \quad \text{(Eq.1)}$$

The average monthly consumption (kWh/year) is the annual consumption divided by 12 months, which was the period considered, equation 2:

$$Average\ monthly\ consumption(kWh/mês) = \frac{Annual\ Consumption(kWh/year)}{12\ months} \quad \text{(Eq.2)}$$

Daily consumption (kWh/day) is the result of the average monthly consumption divided by the average of the total days of the 12 months, which is 30 days.

$$Daily\ consumption(kWh/dia) = \frac{Average\ monthly\ consumption(kWh/mês)}{30\ days} \quad (Eq.3)$$

Peak power (kW/Peak) is given by the average daily household consumption divided by the average daily irradiation, expressed in equation 4 below:

$$Peak\ power(kW/Pico) = \frac{Daily\ consumption(kWh/dia)}{Average\ irradiation\ per\ day(kWh/m^2.dia)} \quad (Eq.4)$$

After the formulas and other necessary parameters, the Excel spreadsheet was assembled based on CRESESB data and the equations presented. The first step in assembling the spreadsheet was the construction of table 4 with the survey of household consumption.

Table 4. Survey of electricity consumption data (Excel)

1				
2	**Levantamento de dados do consumo de energia elétrica**			
3	**Mês**	**Consumo [kWh]**	**Energia mínima disponivel por mês [kWh]**	**Consumo consideravel [kWh]**
4	Jan	148	50	98
5	Fev	174	50	124
6	Mar	203	50	153
7	Abr	176	50	126
8	Mai	165	50	115
9	Jun	179	50	129
10	Jul	190	50	140
11	Ago	150	50	100
12	Set	161	50	111
13	Out	184	50	134
14	Nov	166	50	116
15	Dez	159	50	109
16	Média	171,25	-	121,25
17			Consumo diário médio anual [kWh/dia](considerando mês 30 dias)	5,708333333

(Eq.4) will be used to obtain the peak power of the system, together with the variable of the average annual daily consumption that was presented in table 4 and the lowest solar daily irradiation index of the year, in figure 6, identified in the line of the angle equal to latitude. With this will occur an addition, which is 25% in relation to the peak power of the photovoltaic solar sizing, a safety measure used in any solar project to have a margin in case something occurs in a way that was not initially foreseen. Table 5 shows the peak power, which will be the demand of the system.

Table 5. Peak Project Power(Excel)

kW/pico	1,749680715	[kW/p]
Em Watts	1749,680715	[W/p]

The monofacial sizing was carried out in the Excel spreadsheet, with the equipment presented above, 4 555W Half-cell modules from Sunova and a Growatt 2kW inverter will be used for the construction of the experimental photovoltaic solar project.

System 1, which is bifacial sizing, being the best option, was prepared in the Excel spreadsheet, with the models of bifacial panels, presented in figure 2 above, 4 bifacial modules of 575W Half-cell from Sine Energy and an inverter from Growatt 2kW will be used for the construction of the experimental solar photovoltaic project.

Table 6 shows the values of the materials used in the implementation of the photovoltaic panels, including the structure and the panels themselves.

Table 6. Installation Values Monofacial PV Modules (Excel)

Painéis Fotovoltaicos	Sistema 1 / 575 W (Bifacial)	Sistema 2 / 555W (Monofacial)	
Quantidade de Painéis Fotovoltaicos necessários	3,042922983	3,888179367	Placas
Quantidade de Painéis considerados	4	4	Placas
Potência do sistema/dia	2,3	2,22	kW/dia de Geração
Preço do Placas	R$ 4.234,40	R$ 3.692,00	R$
Preço de Instalação	R$ 1.000,00	R$ 1.000,00	R$
Preço Total do Sistema(Painéis)	R$ 5.234,40	R$ 4.692,00	R$

In relation to the inverter chosen for the monofacial and bifacial systems, it will be the same, for a better comparison between both and because the difference in the power of the set of panels of both systems, despite the bifacial system having a higher production value, are within the value allowed by the 2 kW inverter, which reaches a maximum power of up to 2.8kW, according to data from Growatt's datasheet. The final estimated price of the structure is composed of the structures of the panels for the fiber cement roof, cables and the circuit breakers responsible for the safety of the system, and will be the same cost for both projects.

Table 7. Value referring to the number of inverters and price of the structure (Excel)

Inversores	Sistema 1 / 2kW (Bifacial)	Sistema 2 / 2kW (Monofacial)	
Quantidade de Inversores necessários	0,874840358	0,874840358	Invesores
Quantidade de Inversores considerados	1	1	Invesores
Potência do sistema	2	2	kW
Preço do Invesores	R$ 2.449,00	R$ 2.449,00	R$
Preço de Instalação	R$ 500,00	R$ 500,00	R$
Preço Total do Sistema(Inversores)	R$ 2.949,00	R$ 2.949,00	R$
Preço de Materiais(Estrutura)	R$ 1.500,00	R$ 1.500,00	R$

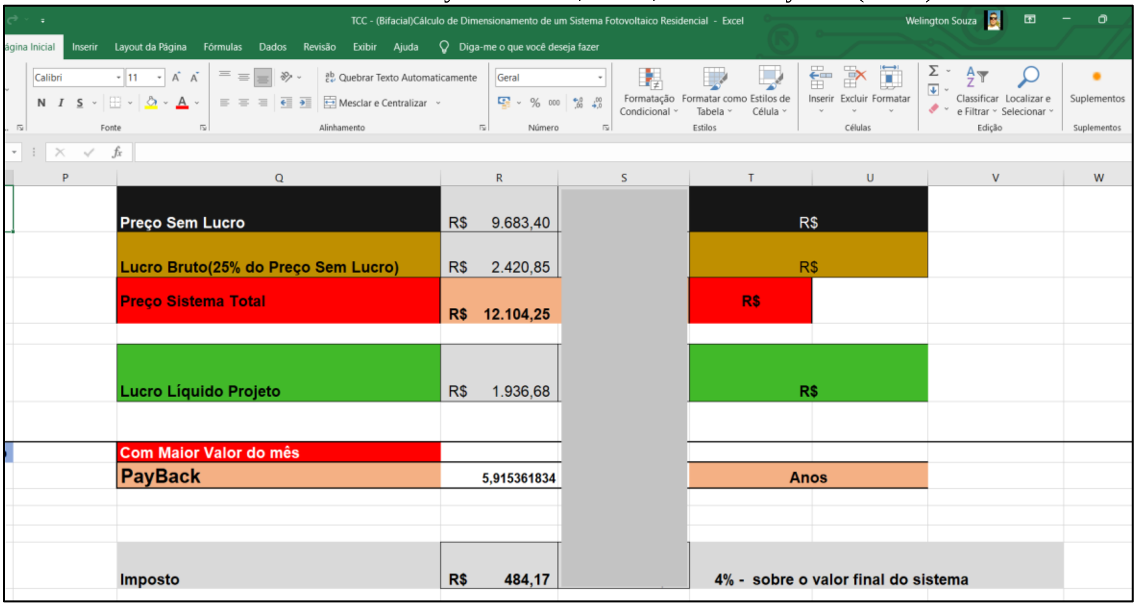
Soon after, with the sum of the prices of panels with the installations, together with the inverter and the rest of the materials (structure), we obtained the value of the monofacial project (system 2) without profit, which is 9,141.00 reais (R$), where the estimated profit on the project would be 25%, as it is a small project. However, on top of this amount, the 4% of taxes on the assembled system will be deducted, achieving a net profit of R$ 1,828.20. The value of this project considering all charges and the amount that will be paid by the client is R$ 11,426.25. All the data of this system with monofacial panels are in table 8 below.

Table 8. Monofacial PV System Value, Profit, Tax and Payback(Excel)

Preço Sem Lucro	R$ 9.141,00	R$
Lucro Bruto(25% do Preço Sem Lucro)	R$ 2.285,25	R$
Preço Sistema Total	R$ 11.426,25	R$
Lucro Líquido Projeto	R$ 1.828,20	R$
Com Maior Valor do mês		
PayBack	5,584022402	Anos
Imposto	R$ 457,05	4% - sobre o valor final do sistema

Subsequently, with the sum of the value of bifacial modules with the installations, together with the inverter and the rest of the materials (structure), with this we have the value of the bifacial project without profit, R$ 9,683.40. In this way, the estimated profit on top of the project would be 25%, where on top of this value will be deducted the 4% taxes on the system after assembly, concluding with a net profit of R$ 1,936.20. The value of this project considering all charges and the amount that will be paid by the client is R$ 12,104.25, with a difference in the final cost of the project of R$ 678.00, when compared to the monofacial system, being below the cost of the benefit that the photovoltaic bifacial system will provide. Table 9 contains the data on the values of the bifacial design.

Table 9. Bifacial PV System Value, Profit, Tax and Payback (Excel)



Preço Sem Lucro	R$ 9.683,40		R$
Lucro Bruto(25% do Preço Sem Lucro)	R$ 2.420,85		R$
Preço Sistema Total	R$ 12.104,25		R$
Lucro Líquido Projeto	R$ 1.936,68		R$
Com Maior Valor do mês			
PayBack	5,915361834		Anos
Imposto	R$ 484,17		4% - sobre o valor final do sistema

As a result, for the calculation of Payback, the value of 0.84 R$/kWh was used with the charges already considered, because at the time of the invoice we had a scenario of tariff increase due to the flags, being a value slightly higher than the current cost, which would be 0.754 R$/kW according to data from NEOENERGIA [2023]. With this scenario considered, the value of 5.915 years was reached for the return on investment in the implementation of the bifacial panels and the time of 5.584 years for the system of common modules.

In the scenario of the bifacial system, there will be an addition in the production of the panel due to the lower face, in view of this the panel will produce in general at least 12.5% more of its nominal power, and this number of generation from the back of the panel is limited due to the wall on the side of the roof (figure 7), which makes it impossible to produce in the infra part of the project in the afternoon, losing 6 hours of full sun on this side. If there were no such limitation in the case of this installation, this value could reach 25% of addition to the overall energy production, when compared to the system with monofacial modules. With this installation there is a possibility of exponentially increasing energy production in relation to monofacial panels on cloudy days, where there are few direct rays and many reflected rays from the sun, and can reach more than 40% of production on cloudy days, being another huge advantage compared to a photovoltaic system with monofacial solar panels.

In analogy with the monofacial module, the bifacial can have a useful life of 5 years longer than its competitor, and can reach up to 30 years of use. The degradation index is different between the two panel models and can be observed graphically. Light-induced degradation (LID) starts at 2% and annual power degradation of 0.45% in bifacial panels and 0.55% in monofacials, that is, bifacials degrade less over time and have a higher efficiency, due to the glass at the bottom [CANASOLAR, 2022].

FINAL CONSIDERATIONS

The implementation of a photovoltaic solar project in a home is a promising alternative for the customer, as it obtains the long-awaited minimum energy bill, paying only the charges of electricity distribution and saving a large part of the value in the residential electricity bill. We have more than 70 million homes without a photovoltaic solar energy project, data on the number of houses in Brazil obtained from [IBGE, 2022]. According to G1 data, more than 1.1 million homes already have solar energy on their roofs, with a large number of houses for the implementation of new solar photovoltaic projects [BRASIL, 2023].

Consequently, it would be interesting to obtain a higher yield for the implementation of solar energy in homes, with a better use of the available space, generating more energy with a smaller occupied space, and the differential, with few changes, was shown in this theoretical analysis, that few structural changes are necessary in the implementation of bifacial photovoltaic systems, in other words, a great alternative to improve the project's electricity productivity. The bifacial solar system obtained the advantage of having a higher power compared to monofacial panels, this is due to the production of energy by the lower face, and can be even greater, if the project when assembled does not have a wall that impairs the reflection of the sun in the afternoon, which is the case of this system, which loses 6 hours of full sun at the bottom.

The installation of the bifacial system in this study has a cost of R$ 12,104.25, referring to the total value of the investment for the project, with all the charges involved. The amount can be financed, to be paid with an amount close to that of the energy bill. The difference when compared to the monofacial photovoltaic system has a value of R$ 678.00 higher, and this increase is compensatory, taking into account the higher return on energy production. Payback is slightly higher, 3 months, due to the final price of the project with bifacial panels of 5.9 years and 5.6 years for single-sided panels. This difference is irrelevant when comparing production gains.

REFERENCES

ABSOLAR. (2023). Panorama da solar fotovoltaica no Brasil e no mundo. https://www.absolar.org.br/mercado/infografico/

Aldo Solar. (2023). Inversor solar fotovoltaico on grid Growatt. https://www.aldo.com.br/produto/68208-4/inversor-solar-fotovoltaico-on-grid-growatt-mic2000tl-x-2kw-monofasico-220v-1mppt-monitoramento

Pereira, J. (2023, March 31). Brasil tem 1,1 milhão de residências com telhado solar; São Paulo lidera lista: Veja o ranking dos dez estados com maior número de casas que utilizam este tipo de energia no país. G1. https://umsoplaneta.globo.com/energia/noticia/2023/03/31/brasil-tem-11-milhao-de-residencias-com-telhado-solar-sao-paulo-lidera-lista.ghtml

CanalSolar. (2022, June 21). Diferença entre módulos bifaciais e monofaciais: Além das diferenças estruturais, existe a distinção da durabilidade. https://canalsolar.com.br/diferenca-entre-modulos-bifaciais-e-monofaciais/

CanalSolar. (2023). Entenda os módulos fotovoltaicos bifaciais. https://canalsolar.com.br/modulos-fotovoltaicosbifaciais/

Centro de Referência para as Energias Solar e Eólica Sérgio de S. Brito (CRESESB). (2023).

U.S. Energy Information Administration (EIA). (2023). What is U.S. electricity generation by energy source? https://www.eia.gov/tools/faqs/faq.php?id=427&t=3#:~:text=Solar%20(total),3.4%25

CanalSolar. (2023, August 17). Energia solar ultrapassa 33 GW de capacidade operacional. https://canalsolar.com.br/energia-solar-ultrapassa-33-gw-de-capacidade-operacional-no-brasil/

Empresa de Pesquisa Energética (EPE). (2020). Caderno sobre Ações de Eficiência Energética em Indústrias Brasileiras.

Frontin, S. de O. (2017). Usina fotovoltaica Jaíba Solar: planejamento e engenharia. Brasília: Teixeira Gráfica e Editora Ltda.

Glow Solar. (2021, February 3). O que é micro e minigeração distribuída. https://glowsolar.com.br/noticias/o-que-e-micro-e-minigeracao-distribuida

GOV. (2022). Lei nº 14.300, de 6 de janeiro de 2022. https://in.gov.br/en/web/dou/-/lei-n-14.300-de-6-de-janeiro-de-2022-372467821

Greenyellow. (2023, April 25). Energia solar no mundo: saiba quais os maiores países. https://www.greenyellow.com.br/blog/energia-solar-no-mundo-saiba-quais-os-maiores-paises

IBGE. (2022). Domicílios brasileiros. https://educa.ibge.gov.br/jovens/conheca-o-brasil/populacao/21130-domicilios-brasileiros.html#:~:text=Segundo%20os%20resultados%20da%20PNAD,(11%20milh%C3%B5es)%20eram%20apartamentos

Lira, A. G. de. (2022). Análise comparativa entre módulos solares fotovoltaicos dos tipos monocristalino half-cell, bifacial e PERC, aplicação de estudo de caso em uma usina de minigeração.

Luz Solar. (2021). Como funciona o sistema fotovoltaico? https://luzsolar.com.br/como-funciona-o-sistema-fotovoltaico/

Medeiros Filho, R. M. de. (2021). Projeto e implantação de usina solar fotovoltaica com módulos de tecnologia bifacial.

Nacional Energia Sustentável. (2023). https://www.nacionalenergia.com/kitsolar

Neoenergia. (2023, August 22). Tarifas de energia elétrica. https://www.neoenergia.com/documents/d/sp/neoenergia-elektro-tarifas-energia-eletrica-grupo-b

Neosolar. (2023). Sistemas de energia solar fotovoltaica e seus componentes. https://www.neosolar.com.br/aprenda/saiba-mais/sistemas-de-energia-solar-fotovoltaica-e-seus-componentes

Pereira, O. L. S., & Gonçalves, F. F. (2008). Dimensionamento de inversores para sistemas fotovoltaicos conectados à rede elétrica: Estudo de caso do sistema de Tubarão-SC. Revista Brasileira de Energia, 14(1), 25-45.

PV Magazine. (2023, January 3). China aims to add 160 GW of wind, solar capacity in 2023. https://www.pv-magazine.com/2023/01/03/china-aims-to-add-160-gw-of-wind-solar-in-2023/#:~:text=The%20NEA%20said%20that%20if%20China%20reaches%20its%202023%20installation%20target%20of%20160%20GW%20of%20wind%20and%20solar%2C%20it%20would%20represent%20year%2Don%2Dyear%20growth%20of%2033%25.%20It%20added%20that%20it%20expects%20the%20country%27s%20cumulative%20solar%20capacity%20to%20reach%20490%20GW%20by%20the%20end%20of%202023%2C%20including%20430%20GW%20of%20wind%20power

Santander. (2023). Entenda como funciona a energia solar. https://www.santander.com.br/hotsite/santanderfinanciamentos/energia-solar-fotovoltaica.html

Villalva, M. G. (2015). Energia solar fotovoltaica: Conceitos e aplicação: sistemas isolados e conectados à rede (2nd ed.). São Paulo: Érica.