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RESEARCH ARTICLE

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METHODOLOGY FOR IMPLEMENTING A PHOTOVOLTAIC PLANT IN A SMALL FOOD INDUSTRY

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ABSTRACT

O aprender é uma arte, até Brazil needs to increase the supply of sustainable and renewable energy such as solar and wind, especially in the northern region, where it has the highest electricity tariff in the country. The region is distinguished from other regions of the country by the existence of several isolated systems, most of them of small size with low reliability and quality of services with very high costs, in view of the need for thermal generation using diesel and fuel oil, as amount represents about 92% of all the fuel planned to be used in Brazil in the generation of thermoelectric energy, indicating a fuel cost in 2021 that exceeds R$ 2 billion reais, which is largely exceeded by the transfers of resources obtained through the Fossil Fuel Consumption Account (CCC). This work aims to develop a methodology for the production of on-grid photovoltaic energy in order to be integrated into the utility grid as a reference in energy generation. It is a great alternative to reduce electricity consumption, and Brazil has the necessary conditions to take advantage of such technologies. However, this strategic action must be integrated, in order to develop society in the economic, social and environmental areas. The development of the work provided the generation of economic, technical and environmental results on the use of solar energy in regions that have high energy generation costs, in this way we train the techniques and structures to benefit, including small industries and businesses with a capture of energy resources. The general objective is to evaluate the results of the implementation of a 40 Kwp Solar Energy on-grid photovoltaic system at Empacotadora Amazonas, in order to reduce operating costs and environmental impacts.

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INTRODUCTION

The need for more affordable electricity has also brought the search for other forms of production, in order to minimize environmental impacts and meet the necessary demand. So, studies and applications of said alternative sources were intensified in order to try to generate energy through renewable natural resources such as biomass, sunlight among others, so in this work a study will be carried out on the implementation of a photovoltaic system (SILVA, 2017). The sun is the main source of energy on our planet, the earth's surface receives annually an amount of solar energy in the forms of energy and heat. The classification of solar energy can be defined as any type of capture of light energy, thermal energy from the sun, which when transformed, produces the fuel force usable by man, whether used as a way of heating water or as electrical energy. or thermal energy, only a small portion of this energy is used (RAMACHANDRA, 2007). The energy that a wave can transmit is associated with its frequency. The higher the frequency, the greater the transmitted energy. Electromagnetic waves coming from the sun can produce different effects on objects and living beings. The entire spectrum of radiation, including waves visible to the human eye and those not visible, transport energy that can be captured in the form of heat or electrical energy (GENUIS, 2008 and BATOOL, 2019). A quantity used to quantify solar radiation is irradiance, commonly called radiation, expressed in W/m2.

When the Earth performs its translational motion around the Sun, the Earth is exposed to 1353 W/m² of energy, measurement made on a surface normal to the Sun, the irradiance of 1000 W/m² is adopted as a standard in the photovoltaic industry for specification and evaluation of photovoltaic cells and modules. Of this volume of energy, approximately 19% is only absorbed by the atmosphere and approximately 35% of this energy is reflected through clouds. When this energy passes through the Earth's atmosphere, most of it is in the form of visible light and ultraviolet light (PAULESCU, 2012 and KALOGIROU, 2013). The energy from solar radiation, complemented with other secondary power resources, such as wind and wave energy, hydroelectricity and biomass, are responsible for much of the renewable energy available on earth. However, only a tiny fraction of the available solar energy is used (TWIDELL, 2015 and AVTAR, 2019). Irradiation is the quantity used to express the solar energy that falls on a given area of flat surface over a given time interval. Its unit is the Wh/m^2, the watt hour is a physical energy unit of energy and the watt hour per square meter expresses the energy density per area. Based on assessments of the climate, solar irradiation, rainfall, the cost of purchasing electricity with a high tariff level, which has a great impact on production costs, the project to implement a photovoltaic plant was considered. Which will have the ability to generate energy for the packaging machine's own consumption, lowering very high costs and contributing to the environment (DEMARTINO *et al*., 2020).

LITERATURE REVIEW

The Amazon region concentrates most of the isolated systems and, despite having a great potential for the local generation of electric energy, whether through the use of hydroelectricity, thermal generation using natural gas, biomass and photovoltaic solar energy, the supply of energy electricity is precarious, of low quality and with high operating costs. Thus, the main problems of isolated systems arise from:

- Geographic dispersion in the region;
- Low population density of the electricity market;
- Thermal generation with diesel oil supplying internal combustion engine;
- Difficulty in logistics with the transport of diesel oil to feed the generators;
- Dependence on operators for operational control of small power plants;
- Lack of investment by the regional concessionaire.

In 2015, fuel expenses reached the level of R$ 7.6 billion. Diesel oil is the most used fuel in thermal power plants of small isolated systems. Research on sustainable energy is crucial, with a particular focus on the supply of electricity to the Amazonian population, which clearly has great demands in the region with significant ecological importance (MANYARI *et al*., 2007). In the search for energy solutions, the size and complexity of their problems must be taken into account, since one of the main flaws in the analysis of the performance of isolated systems is to consider them as uniform in their size and availability of resources. The large electric power generation projects for the region proved to be ineffective for its development and, therefore, a solution that is envisaged today is generation close to the consumer, using technology appropriate to the energy potential of each place (SHAIKH, 2015). In terms of electricity prices in Brazil in 2020, Figure 1.1 shows a graph of electricity production costs (R$/MWh) of the main energy sources such as photovoltaic (PV), diesel, wind, natural gas (NG), nuclear, coal, large hydroelectric plant (GCH), small hydroelectric plant (SHP) and biomass. On the other hand, to get an idea of the values of investments in renewable energy sources. A comparative analysis of prices between some renewable sources, considering the time of return on investment (pay-back), the Net Present Value (NPV) and the Internal Rate of Return (IRR), both without incentive and considering the resources of the CCC and transfer of the VN as established in ANEEL Resolution 233 (COSENTINO, 2012).

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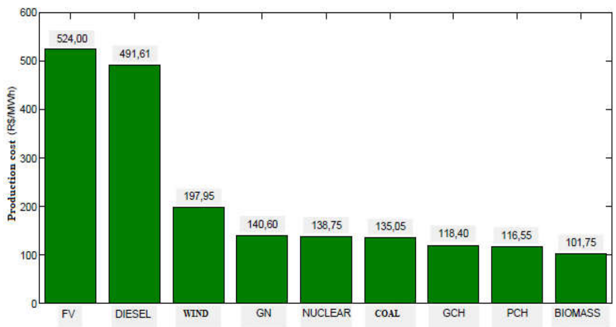


Source: ANEEL (2020).

Figure 1. Cost of producing electricity

In 2012, CHIA-HUNG *et al*. (2012) published a study that considers the insertion of a photovoltaic generation as DG, in a feeder of the electrical distribution system of the city of Taipower (Taiwan), whose purpose was to carry out the hourly and annual evaluation of the photovoltaic generation, considering the solar irradiation curve and temperature of the solar module, whose concern of the authors stemmed from the intermittence of the primary source. In terms of technical standards, the IEEE published in 2000 the document IEEE Std 929-2000, in which technical and operational recommendations are presented for the integration of GFVs in electrical distribution systems, whose generator powers are less than or equal to 10 kW , including personal safety recommendations, islanding and non-islanding, inverter operating conditions, electrical energy quality, in addition to defining several terms related to DG provided by GFVs, through inverters with voltage range from 106 V to 132 V, rated voltage of 120 V and frequency of 60 Hz. In Brazil, in terms of DG regulation, the National Electric Energy Agency (ANEEL) establishes through Resolution 482, issued on 04/17/2012 and published on 04/19/2012, the rules for the interconnection of DGs in the electricity grid, which can be a source of water, solar, wind, biomass and cogeneration based, with a description of the procedures for access of micro and mini distributed incentivized generation. Distributed generators may be interconnected to the distribution system in the low voltage, single-phase network with power less than 10 kW, in the three-phase network with powers between 10 kW and 500 kW and in the medium voltage network with powers between 500 kW and 1 MW (YANG, 2013). ANEEL defines distributed microgeneration as a generator with a power equal to or less than 100 kW and mini-generation with a power greater than 100 kW and less than or equal to 1 MW, and also establishes the minimum requirements of generators according to their power and provided with disconnection devices, under and over voltage protections, with synchronism relay, anti-islanding system and with generated energy meters, among other specifications (YAN, 2018).

Other resolutions and documents published by ANEEL that deal with DG are:

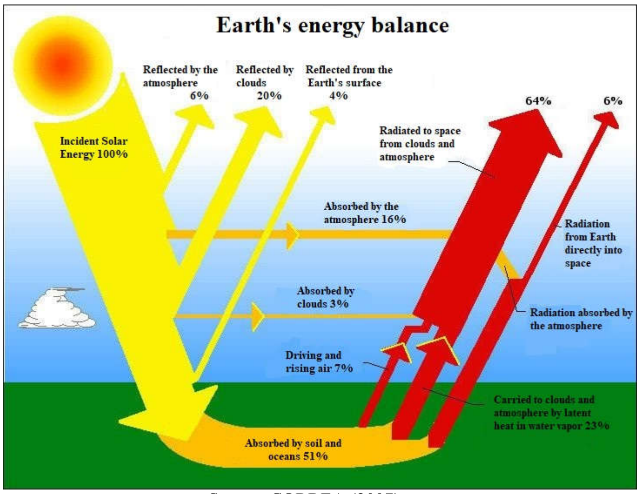
- Resolution 481: In this resolution, issued on 04/17/2012 and published on 04/20/2012, the rules for the discount from 50% to 80% in the tariffs for the use of distribution and transmission systems (TUSD and TUST) are established. for plants with solar source for projects that start commercial operation by December 2017, with the discount valid for the first ten years of the plant's operation.
- Resolution 493: Issued on 06/05/2012 and published on 06/08/2012, establishes the technical procedures and conditions for the supply of electricity through the Isolated Microsystem of Electricity Generation and Distribution (MIGDI) or Individual System of Electric Power Generation with Intermittent Source (SIGFI).

O custo de investimento em sistemas FVs pode ser decomposto em três itens principais: os módulos solares, o line inverter and the system composed of accessory materials and labor, known as balance of the system (BoS), such as mechanical support structures, auxiliary electrical equipment, electrical cables, connections and the engineering necessary for the adequacy of the system components, as well as the general installation and assembly costs (TURCHI and CENGIZ, 2015). The motivation of this work is to contextualize the current situation of photovoltaic energy in the state of Amazonas, in addition to updating the information that regulates distributed generation connected to the electrical grid. Despite the enormous potential for generating energy through PV systems, its presence is still not significant in the energy matrix in the state. However, the amount of energy produced has been growing every year, driven by regulatory updates that have encouraged distributed generation, such as remote generation and the increase in the validity period of solar credits. In addition, most states already exempt from ICMS the energy produced by the micro generator, provided that the energy consumed is made in properties of the same holder.

THE SOLAR ENERGY: Currently, solar energy in Brazil is used in small isolated systems in places not served by the electricity grid, places of difficult access, where the installation of electricity distribution lines is not economically viable. The potential for exploiting this energy is extremely huge for the application of mini and micro photovoltaic generation systems, planet Earth receives approximately 174 petawatts (GT) of solar radiation (insulation) in the upper atmosphere. Of this radiation, about 30% is reflected into space, while the rest is absorbed by clouds, seas and land masses. The spectrum of sunlight at the Earth's surface is most widespread across the visible and infrared range and a small range of ultraviolet radiation. Affirmed by (BOYLE, 2012) apud (CABRAL *et al*., 2015), in his text on renewable energies, where it was indicated that if current trends are maintained, the world population should have an increase of around 50%, which in itself already raises a warning cry, but at least there is a consensus around the world that energy sources should generate negligible impacts on climate change. In a series called "Sustainability", it is manifested in several ways that the world energy demand is still oil, even with all the inverse opinions about its use and solar occupying the simple 9th place, participating with 11% of this demand and affirming categorically that the government is silent on a matter of such importance, leaving aside even the speeches made at Rio+20 (CABRAL, 2015). Thus, when the air reaches a high altitude, where the temperature is low, the water vapor condenses, forming clouds, which later cause precipitation on the Earth's surface, completing the water cycle.

The latent heat of water condensation increases convection, producing atmospheric phenomena such as wind, cyclones and anticyclones. The sunlight absorbed by the oceans and land masses maintains the surface at an average temperature of 14 °C (MENDONÇA and BARBIRATO, 2007). Unlike solar thermal systems, which are used to heat or produce electricity from the sun's thermal energy, photovoltaic systems have the ability to directly capture sunlight and produce electric current. This current is collected and processed by controller devices and converters, and can be stored in batteries or used directly in systems connected to the electrical grid, Among the renewable energies that have been showing an effective worldwide growth in the last decades, is the photovoltaic solar energy, for allowing the generation of electric energy in a distributed way, not needing, therefore, extensive transmission and distribution lines, as it is a silent source. , which allows the installation of systems of different powers and also for being integrated into buildings in the urban environment, without needing extra areas for their installation (DOS SANTOS, 2020). The use of this source has been encouraged mainly in countries belonging to the European Union, through the adoption of government programs, launched with the purpose of stimulating the increase in the number of installations, thus creating scale gains, which consequently reduce costs and contribute to the increased competitiveness of the photovoltaic industry in relation to conventional energy sources. In these countries, the growth in installed capacity occurs mainly in systems connected to the electricity grid, with more than 69 GW installed worldwide by 2011, which represents a production of 85 TW/h of electricity per year (NAJAFI and HOSSAIN, 2016). The use of solar and wind energy sources around the world in recent years. In the year 2000 the world had less than 5 GW (gigawatts) or 5,000 MW (megawatts) of electricity generation capacity with photovoltaic systems. This capacity jumped to about 40 GW in 200 and continues to grow (VILLALVA, 1983).

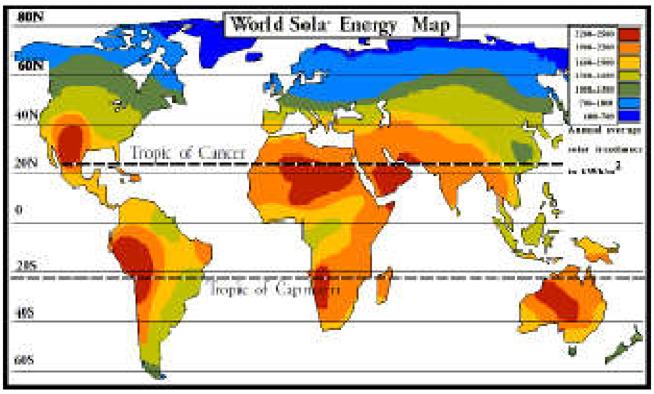
This current increasing energy consumption can cause serious damage to human health and nature, particularly due to carbon dioxide (CO_2) and other greenhouse gases released by the burning of fossil fuels, which threaten to cause unprecedented changes in the Earth's climate, with the most adverse consequences (SHAHSAVARI, 2019). In addition, if current trends continue, the world population is expected to increase the world's primary energy demand could increase by around 50%, which represents for those involved with the energy issue. At the very least, there is now broad consensus that the world must switch to low-emission, or zero-carbon energy sources, if the impacts of climate change are to be mitigated (PALMER, 2013). In Figure 2 we have the complete irradiation diagram. Solar radiation is a term used to refer to the transfer of energy from the sun through the propagation of electromagnetic waves. The amount of solar radiation that reaches each point on Earth depends on the obstacles such waves encounter in the atmosphere. However, the radiation reaching any point at the top of the atmosphere is constant and known as the "Solar Constant" (ROGELJ, 2015). The capture of solar heat is the transformation of electromagnetic energy into thermal energy by the bodies and materials that receive its radiation. When electromagnetic waves strike a body that has the ability to absorb radiation, electromagnetic energy is transformed into kinetic energy and transmitted to the molecules and atoms that make up that body. This process corresponds to the transmission of heat or thermal energy.



Source: CORREA (2007).

Figure 2. Reading of Solar Irradiation. They

Visible radiation corresponds to approximately 43% of the total energy emitted by the Sun, the infrared radiation region corresponds to approximately 49% of the emitted energy, the ultraviolet region with emission around 7% and approximately 1% of the solar radiation corresponds to X-ray, gamma-ray and radio wave emissions. After reaching the top of the atmosphere, solar radiation undergoes absorption and scattering processes along its path and approximately 25% of this radiation falls on the Earth's surface without any interference from the atmosphere, the remainder being absorbed or scattered towards the Earth's surface. Earth or towards space (SEM and WALD, 2009). Short-wave electromagnetic radiation corresponds to radiation emitted by the Sun with wavelengths less than 4 µm and long-wave radiation is radiation emitted by the Earth with wavelengths greater than 4 µm.



Source: SEM and WALD (2009).

Figure 3. World distribution of average annual solar irradiation (kWh/m^2)

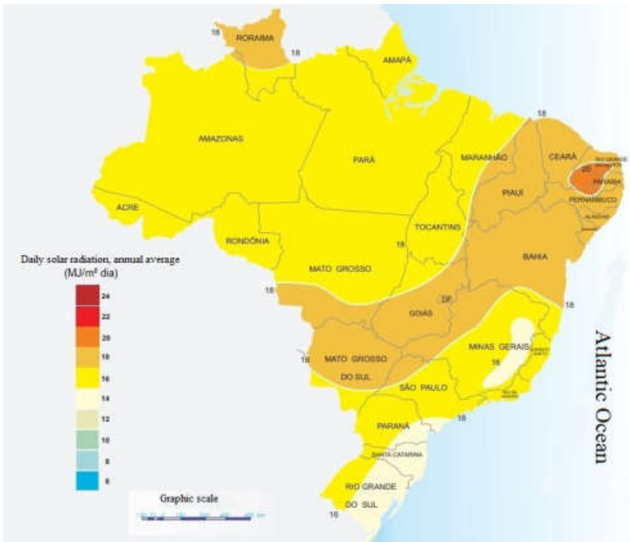
The photovoltaic effect, which is the basis of photovoltaic solar energy systems for the production of electricity, consists of transforming the electromagnetic radiation from the Sun into electrical energy through the creation of a potential difference, or an electrical voltage, on a cell formed by a sandwich of semiconductor materials. If the cell is connected to two electrodes, there will be electrical voltage across them. Atmospheric constituents absorb different wavelengths of solar radiation and terrestrial radiation differently, changing the spectrum of radiation as it propagates in the atmosphere. In the absorption of solar radiation, gas molecules such as CO_2 and O_3 acquire energy, which is transformed into internal molecular motion, resulting in heating that is transmitted to the atmosphere (GOODY and PIERREHUMBERT, 2011). The solar constant is estimated at 1,366 W/m². Upon reaching the Earth's surface, it reaches a maximum of 1000 W/m². So, if the efficiency of a given solar panel is 10%, it means that it will be able to capture a maximum of 100 W/m². As shown in Eq. (1) of irradiation.

$$\frac{4,4397\ x\ 10^{16}.60}{1,278\ x\ 10^{14}.1000} = 20,84\ min \quad (1)$$

In comparison with other countries, Brazil is very privileged for the exploitation of photovoltaic energy, according to the average irradiation values presented above. Germany, which is the country that most uses photovoltaic energy, has an installed capacity greater than 20 GW, which exceeds that of all other countries combined, representing approximately 4% of all electrical energy produced in that country (ROSAS -FLORES and GIL, 2020). Solar irradiance in Germany is around 3500 Wh/m^2 per day, available only in a small southern part of its territory. Brazil receives an average daily irradiation of 2.5 to 7.5 kWh/m^2/day (or 9 to 27 MJ/m^2), depending on the location and time of year, latitude of the location, in addition to other occurrences, such as clouds, atmospheric aerosols and gases that make up the atmosphere, having an average distribution of solar irradiation by regions of Brazil in the order of:

- North: 5462 Wh/m^2;
- Northeast: 5688 Wh/m^2;
- Midwest: 5630 Wh/m^2;
- Southeast: 5478 Wh/m^2;
- South: 5015 Wh/m^2.

Figure 4 shows a map of average solar irradiation in Brazilian territory, up to the city of Manaus, with 100% irradiation corresponding to 5.09 kWh/m^2/day or 1195 kWh/m^2/year.



Source: ATLAS SOLAR DO BRASIL (2019)

Figure 4. Map of average solar irradiation in the Brazilian territory

For a better understanding of this subject, when reporting the possible power obtained, it is necessary to define the measure of power, which is the Watt-peak (Wp), normally associated with photovoltaic cells. The most commonly used units are multiples of Wp, such as kWp or MWp. Since the conditions of electric energy production depend a lot on factors external to the cell, the power value given in Wp is a value obtained under specific ideal conditions. Thus, the value of Wp of a particular photovoltaic system that works in direct current is the power measured when this system is irradiated by a light that simulates sunlight with a power of 1000 W/m2, at a temperature of 25°C. The watt (symbol: W) is the unit of power in the International System of Units (SI). It is equivalent to one joule per second (1 J/s).

The unit watt was named in honor of James Watt, for his contributions to the development of the steam engine, and was adopted by the second congress of the British association for the advancement of science in 1889. It results from Eq. (2) of unit watt structured by James Watt and Eq. (3).

$$1\,\mathrm{J} = 1\,\mathrm{kg} \cdot \frac{\mathrm{m}^2}{\mathrm{s}^2} \quad (2)$$

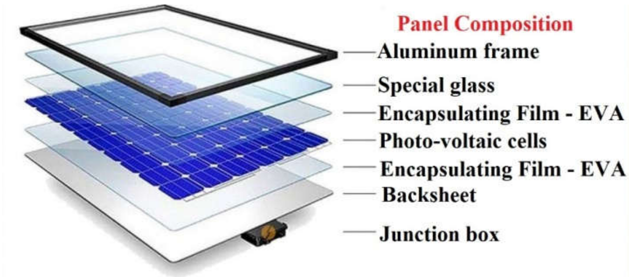
$$1\,\mathrm{W} = \frac{1\mathrm{J}}{\mathrm{s}} \quad (3)$$

Where:

J mechanical power unit
W electrical power unit

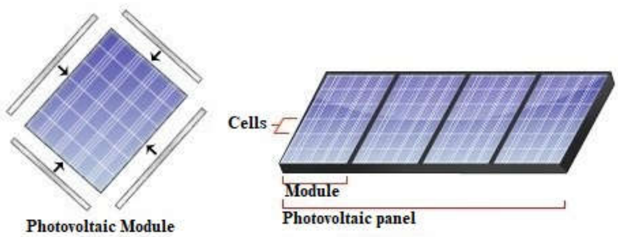
Solar radiation is influenced by atmospheric air, clouds and pollution before reaching the ground and being captured by photovoltaic cells and modules. Global radiation is the sum of direct radiation and diffuse radiation. Direct radiation corresponds to solar rays that arrive directly from the Sun in a straight line and fall on the horizontal plane with an inclination that depends on the zenith angle of the Sun (LOSHKAREV, 2019). In terms of electromagnetic energy, Albert Einstein postulated in 1905, extending a suggestion made two years earlier by Planck, that a beam of light consists of small packets of energy called light quanta or photons. The energy of a photon, EG, is proportional to its frequency f, which, h = 6.63 × 10−34 (Js) is Planck's constant ef in c/s or Hz. Light propagates with a constant velocity in the vacuum of extraterrestrial space, having the expression presented below, which relates the frequency f, the length of the electromagnetic wave and its speed, which, c = 3×108 m/s is the speed of light in vacuum and λ(m) is the wavelength. A quantity used to quantify solar radiation is irradiance, usually also called irradiance, expressed in the unit of W/m^2 (watt per square meter). It is a unit of power per area. As is known, power is a physical quantity that expresses the energy transported during a certain time interval, or the rate of change of energy with time. The greater the power of solar radiation, the more energy it carries in a given time interval (MARTIENSSEN and SMIL, 2015). The solar radiation sensors shown on the previous pages provide irradiance measurements. At the earth's surface, the irradiance of sunlight is typically around 1000 W/m^2. The irradiance of 1000 W/m^2 is adopted as a standard in the photovoltaic industry for the specification and evaluation of photovoltaic cells and modules. Like the air mass AM1 5, the irradiance of 1000 W/m^2 is mentioned in practically all the catalogs of photovoltaic device manufacturers (LORENZO and HAMADANI, 2020). The measurement of irradiance in W/m^2 is very useful for evaluating the efficiency of photovoltaic devices and systems. With the default value of 1000 W/m^2, the efficiencies of photovoltaic cells and modules from different manufacturers can be specified and compared based on a standard condition of solar radiation (MAKRIDES, 2012 and VEMULA, 2013). Insolation is the quantity used to express the solar energy that falls on a given flat surface area over a period of time. Its unit is the Wh/m^2 (watt-hour per square meter) (EFFAT 2016 and NELSON, 2020). The watt-hour is a physical unit of energy and the watt-hour per square meter expresses the energy density per area. The measure of insolation in Wh/m^2 is very useful for sizing photovoltaic systems, as we will see later (EFFAT, 2015 and TAHA, 2016). In practice, we find insolation tables and maps that provide daily values expressed in Wh/m^2/day (watt hour per square meter per day). Weather stations with solar radiation sensors are used to survey the insolation at various points on the globe. A huge set of worldwide insolation data is freely available from the SWERA (Solar and Wind Energy Resource Assessment) project, of the United Nations Environmental Programmes, on the website swera.unep.net.

The temperature has an influence on the voltage that the module supplies at its terminals and, consequently, on the power supplied. At lower temperatures, the voltages are higher, and the opposite also occurs at high temperatures, the module current does not change with the module temperature. Since the module heats up by exposure to solar radiation, decreasing efficiency (SUKAMONGKOL, 2002). Solar efficiency will not be the focus of this work, so we will see other elements responsible for the exact characterization of the generation levels, deserving a separate study, since this topic is not the focus of the present work. Let's just observe the relationship between radiation and generation levels, but that there are also other factors that can change generation levels, as shown in Figures 5 and 6.



Source: PORTAL SOLAR (2021).

Figure 5. Composition of the Solar Panel.es)



Source: PORTAL SOLAR (2021).

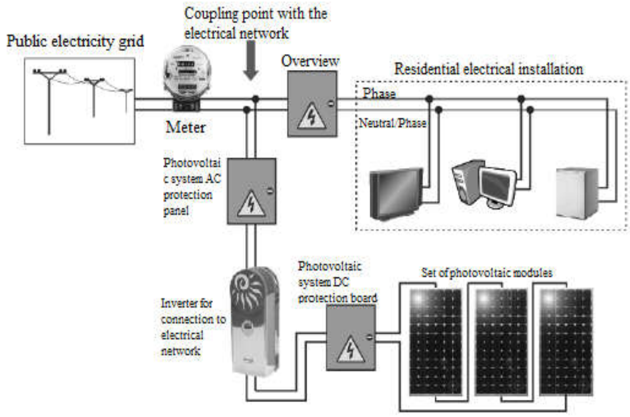
Figure 6. Polycrystalline silicon module

In the year 2000 the world had less than 5 GW (gigawatts) or 5,000 MW (megawatts) of electricity generation capacity with photovoltaic systems. This capacity jumped to around 40 GW in 2010 and continues to grow (MEISEN and WANG, 2010). The growth of electricity generation with wind systems also grew a lot, starting from around 25 GW in 2001 and jumping to more than 200 GW in 2010 with a very expressive growth. There is a lot of room for the growth of photovoltaic solar energy in the country. More than an alternative source, photovoltaic energy is a viable and promising option to complement and expand electricity generation. Photovoltaic systems can generate electricity in any space where a photovoltaic panel can be installed. Roofs and facades of buildings and residences will be able to generate electricity in urban areas and power plants can be built in open areas of any size, near or far from consumption centers.
Given the territorial dimensions and the high rates of Brazilian solar irradiation, it is reasonable to expect for Brazil a potential for photovoltaic generation at least ten times greater than the installed capacity in Germany today.

That would represent 200 GW of electricity from sunlight, or twice as much electricity as we produce today. Germany's best insolation is around 3500 Wh/m2 (watt-hours per square meter) per day, available only in a small southern part of its territory. Most of the German territory does not have more than 3500 Wh/m^2 of solar energy daily. For comparison, Brazil has daily insolation values between 4500 and 6000 Wh/m^2 (DARCOVICH and HILLER, 2014). Currently, Germany is the country that most uses photovoltaic solar energy. Its installed capacity is around 20 GW, higher than that of all other countries combined. This represents approximately 4% of all electricity produced in that country. The reduction in greenhouse gas emissions achieved by this clean energy source was 489,000 tons per year, even surpassing its initial target of 400,000 tons. At another point, in March 2013, the largest photovoltaic plant in the world was inaugurated in the United Arab Emirates, with a capacity of 100 megawatts and a cost of 600 million dollars, allowing to supply energy to 20,000 homes. It also highlights that the energy coming from the sun is so great that three weeks of solar energy received on Earth is equivalent to all the reserves of fossil fuels on earth. The presence of an enormous hydroelectric potential not yet explored in the country is also a negative factor for the insertion of photovoltaic energy in our energy matrix. The existence of this potential makes investment in other energy sources less attractive. However, when taking into account the difficulties to build hydroelectric plants, related to environmental licensing and the confrontation of public opinion about the impacts caused by the construction of dams, other energy sources, including photovoltaic, become more advantageous (GÜR and STRIELKOWSKI, 2019).

In April 2012, the National Electric Energy Agency (ANEEL) approved the draft of normative resolution nº 482, which allows microgeneration and mini-generation of electric energy from renewable and alternative sources with distributed generation systems connected to the electrical grids of low tension. The publication of this resolution constitutes a regulatory framework in our country, benefiting the population and forcing electric energy concessionaires to adapt to the entry of distributed generation systems with alternative sources, including photovoltaics, in their low voltage distribution networks. (DOILE, 2021). ANEEL Resolution No. 482 establishes that each Brazilian citizen or company may have a photovoltaic plant on their roof producing electricity to supplement their own consumption or to export energy (in this case, complementing the energy need of another location, according to ANEEL rules). In general terms, the resolution establishes the conditions for the access of microgeneration and distributed minigeneration to the electric energy distribution systems and creates the electric energy credit compensation system for energy self-producers. When installed in an urban area and connected directly to the low voltage electrical grid, the photovoltaic system produces electricity at a very competitive cost and can be used to reduce the consumer's electricity bill. Photovoltaic systems become even more advantageous if we consider the inflation of electricity prices. A home or business that installs a photovoltaic system on its roof is immune to price increases and guarantees the supply of electricity for at least 25 years, which is the minimum lifespan of a photovoltaic system, and is able to pay off the investment in a few years with the energy produced (DEAMBI, 2011 and CHIRAS, 2016). In addition to increasing the availability of electricity and the environmental benefits of using a renewable source, the insertion of photovoltaic solar energy in the country will boost technological development, create jobs and move the national economy. In the State of Amazonas, most of the energy generated uses fossil fuels that involve the emission of carbon dioxide and is harmful to the environment and to the depletion of fossil fuel resources (LE QUÉRÉ *et al*., 2021). The excessive price of fuels has added a great concern about its sustainable use for energy needs. Thus, to reduce the degradation of the environment during the energy production process and mainly due to harmful gas emissions, the use of renewable energy sources is presented as the correct use of natural resources and has the remarkable characteristic of being classified as clean and sustainable energy (DINCER *et al*., 2014).

PHOTOVOLTAIC SYSTEM (PV): The research firm released a study on the expectation for the photovoltaic sector in the first quarter of 2021, indicating that at least 160 GW of solar will be installed this year. Taking into account the projections of outstanding performance in China and India, in the most optimistic juncture, the volume will reach 209 GW of solar. Even with this speed of growth, the company reduced the concern related to the low availability of raw materials, turning its attention to large expansions aimed at the production capacity of glass, polycrystalline silicon and wafers. Agreements were signed and new factories were presented, aiming to respond to the sector's demand. Despite the persistence of some obstacles in the polycrystalline silicon chain, the price of the raw material is expected to remain at around US$ 12 kilo this year. Photovoltaic systems have the ability to directly capture sunlight and produce electrical current. This current is collected and processed by controller devices and converters, and can be stored or used in systems connected to the electrical grid (KELLY *et al*., 2017). There are two types of photovoltaic generation used, centralized generation and distributed generation. The first, in places not served by the public electricity grid and the second, the generation system includes small generation parks connected to the distribution concessionaire's electrical system. In applications in the residential area, there may be use on a generation scale for the grid, using thin films and, possibly, new technologies may emerge, such as more efficient PV materials. The photovoltaic energy market is artificial, with subsidies in all cases, having incentives for systems connected to the grid, mainly in Japan and Germany, which were of great importance and, in the year 2000, 40% of the installed power in systems PVs went to grid connections, with costs currently being five to ten times higher than those of the commercial grid, but with great prospects for reduction in the short/medium term and the appropriate combinations of incentives/market niches should promote entry large-scale use of these technologies (AZADIAN, 2013 and RATURI, 2016). The photovoltaic system connected to the electrical grid operates in parallel with the utility grid, the connected system is used only where there is an existing distribution grid. Aiming to generate electricity for local consumption, being able to reduce or eliminate consumption from the public network. According to Figure 7.



Source: EUDORA SOLAR (2012).

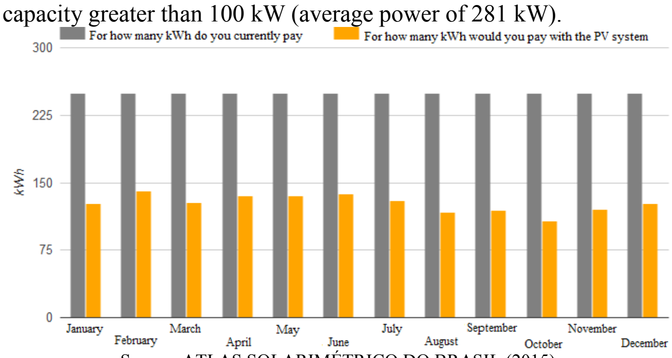
Figure 7. Example of On Grid Photovoltaic System

Connected photovoltaic systems can be centralized, constituting electric power generation plants, as shown in Figure 7, or decentralized micro and mini-systems installed in any type of consumer. According to ANEEL, systems connected to the grid can be classified in three ways:

- Microgeneration;
- Minigeneration;
- Electricity plants.

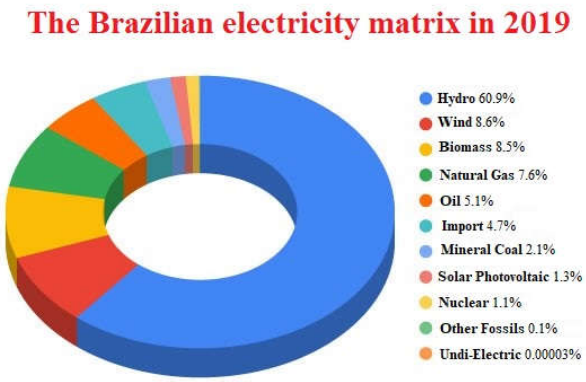
The photovoltaic effect, which is the basis of photovoltaic solar energy systems for the production of electricity, consists of the transformation of electromagnetic radiation from the sun into electrical energy through a potential difference, on a cell formed by a sandwich of semiconductor materials (GUNEY), 2016 and SAMPAIO, 2017). As shown in Figure 8 and Figure 9. It is possible to notice that the use of solar energy does not even want to appear in the Brazilian energy matrix, on the other hand, the main source of energy is exhaustible, which is the fossil, which must require a great global reflection on this issue.

REDUCTION OF ECONOMIC COSTS WITH THE USE OF SOLAR ENERGY: A recent study of the cost of implementing photovoltaic systems, published in 2005, analyzed the price of 47 isolated systems from 100 to 6600 W, from 1987 to 2004, indicating that these systems have a tendency to reduce prices of approximately 1 U$/ W per year, with costs varying between 7 and 10 U$/W (HEGEDUS and OKUBO, 2005). Another study, published by the International Energy Agency's Photovoltaic Power Systems Program, confirms that prices are falling year after year, and indicates that stand-alone systems tend to cost approximately twice as much when compared to grid-connected systems, as they do not need batteries and other associated components. In 2004, isolated systems of up to 1 kW present a price variation from 9 to 25 U$/W, with the typical value being around 13 U$/W. Systems larger than 1 kW have similar variation and slightly lower prices. Another market worth mentioning is the North American one. In that country, according to a survey carried out in 2011, data were obtained on more than 150,000 installed PV systems, obtaining an average price of 6.13 $/W for residential and commercial systems, considering a power equal to or less than 10 kW, price of 4.87 $/W for commercial system with capacity greater than 100 kW (average power of 281 kW).



Source: ATLAS SOLARIMÉTRICO DO BRASIL (2015).

Figure 8. Monthly progression of expenses between the thermal and photovoltaic systems



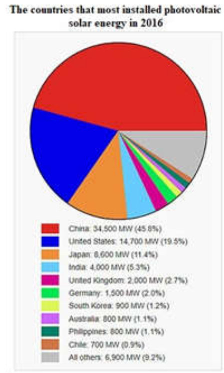
Source: ANEEL (2019).

Figure 9. Brazilian Electric Energy Matrix

In the case of a PV system for grid connection, average power of 18.3 MW, the price obtained was 3.42 $/W [60], according to data presented in Figure 2.8. In this figure, in addition to the prices of installed systems, the prices of modeled PV systems are presented, obtaining a price of 5.90$/W for a 4.9 kW residential system, a price of 4.74$/W for a 217 kW and price of 3.93 $/W for a grid-integrated system with a power of 187.5 MW. If energy is obtained in a decentralized way, all regions will have equal access to electricity, allowing several rural areas to prosper, increasing the need for labor and consequently reducing the social problems of cities. Therefore, the hybrid renewable energy system (HRES) combines two or more renewable energy sources, such as wind and solar energy to maintain reliability levels adequate to demand (KHARE *et al*., 2016).

Another account that is usually performed when this comparison is made is the power generation capacity in a day. A system equipped with an intermittent source can generate energy 24 hours a day, while a solar system with the same installed capacity can generate, depending on its geographical location, an average of 6 equivalent hours of rated power throughout the day. Therefore, in order for the photovoltaic system to produce the same amount of energy in one day, it must have its power increased by 4 times the integrated photovoltaic (PV) system, not only reduces the area requirement, but also reduces material costs. and infrastructure and therefore fulfills the technical impetus for smart building requirements. These integrated systems consider not only electrical energy, but also thermal energy, to have adequate and promising performance level for most real-life applications, especially where both forms of energy are needed simultaneously, 2016). It has become imperative for engineers to look at renewable energy sources such as solar, wind, geothermal, wave and biomass as sustainable and profitable alternatives, the advantage of being friendly to the environment and to conventional energy sources. However, the lack of availability of these renewable energy resources all the time throughout the year, considered that hybrid systems are more cost-effective (SEM *et al*., 2019). Many researches were carried out in order to optimize, operate and control renewable energy systems. It is certainly evident that in this area there is still a vast field of research and development of scientific and professional works. Research development on the modeling of renewable energy resources and photovoltaic systems with power conditioning units, MPPT converters, Buck/Boost converters, battery chargers. As shown in Figure 10.

1	China	78.07	19	Chile	1.61
2	Japan	42.75	20	South Africa	1.45
3	Germany	41.22	21	Taiwan	1.38
4	United States	40.3	22	Romania	1.3
5	Italy	19.28	23	Austria	1.08
6	United Kingdom	11.63	24	Bulgaria	1.0
7	India	9.01	25	Pakistan*	1.0
8	France	7.13	26	Israel	0.91
9	Australia	5.9	27	Philippines	0.9
10	Spain	5.49	28	Denmark	0.9
11	South Korea	4.35	29	Turkey	0.83
12	Belgium	3.42	30	Portugal	0.51
13	Canada	2.72	31	Honduras*	0.39
14	Greece	2.6	32	Algeria	0.35
15	Thailand	2.15	33	Mexico	0.32
16	Czech Republic	2.1	34	Malaysia	0.29
17	Netherlands	2.1	35	Sweden	0.18
18	Switzerland	1.64	36	Norway	0.027
			37	Finland	0.015



Source: ANEEL (2019).

Figure 10. Use of photovoltaic energy in the world

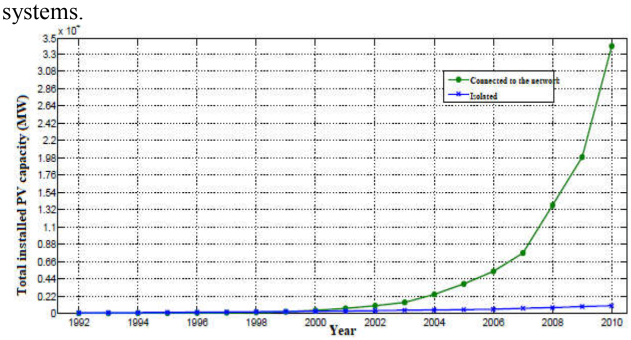
Since 2012, about 1.3 billion people, or 18.41% of the world's population, have been without electricity eventually. Many of these people live in remote areas where decentralized generation is the only method of electrification. Most mini-grids are powered by diesel generators, but new hybrid systems, incorporating renewable energy sources, are becoming an efficient method of reducing the total cost of the diesel system. Hybrid solar stations with the proprietary GridStability System ("GSS") maximize the input of solar energy to the grid without interfering with existing diesel generator control systems, thus maximizing fuel economy. Data from the installed system was used to validate GSS capabilities and performance (CHAUDHARY *et al*., 2014). Public awareness of the need to reduce global warming and the significant increase in the prices of conventional energy sources have encouraged many countries to provide new energy policies that promote the applications of renewable energy. Such renewable energy sources, such as wind, solar, water-based energies, etc., (SEM *et al*., 2019). They are friendly environments and have the potential to be more widely used.
Combining these renewable energy sources with back-up units to form a hybrid system can provide an attractive, cost-effective offering with a higher degree of reliability, generating an electric power environment in all demand load conditions compared to single use. of such systems (WANG *et al*., 2018). One of the most important issues in this type of hybrid system is to optimize the utilization of the hybrid system components as sufficient to fulfill all load requirements with possible minimum investment and operating costs. There are many studies on the optimization and dimensioning of hybrid renewable energy systems since the recent popular use of renewable energy sources (ERDINC and UZUNOGLU, 2012). Examples such as the case of Iran, to which almost every village consisting of more than 20 families in Iran is already connecting to the renewable resources network with the strong five-year Economic Development Plan proposed by the Iranian government (2005-2010). However, there are many isolated communities with less than 20 families that still need electrification. Currently, the only technology that provides electricity to these communities is diesel generators, which not only cause environmental and human health problems, but also high maintenance and operating costs (GHASEMI *et al*., 2013).

Hybrid renewable energy systems, combining various types of technologies, have demonstrated relatively high capabilities to solve reliability problems and reduced cost challenges. The use of hybrid electricity production/storage technologies as stand-alone off-grid systems is reasonable to overcome related shortcomings. Solar and wind energy are the renewable sources that take precedence compared to the other types. Based on solar radiation and average wind speed maps, cost-effective systems technologies are designed by simulating the behavior of various combinations of different sized renewable energy systems, including wind turbine (WT), photovoltaic (PV), cell (FC), and battery banks (HOSSEINALIZADE *et al*., 2016). A modern quest for the development of renewable energy (RE), ideal conditions for the production and use of energy system are considered as an indispensable economic resource for energy costs. This is a fact of rationalization taking into account the increase in energy prices for socioeconomic development (MOHAMMED *et al*., 2014). The area of operation using solar energy is quite wide, and it is worth mentioning some of the most well-known applications, such as:

- Electrification - Used for electrifying homes, schools, commerce, farms, fences, roads, industries, stations and outposts for surveillance and broadcasting.
- Telecommunications – Rural telephony, towers and relays, land stations, radiotelephony and radiocommunications.
- Aerial and nautical signaling – Nautical lighthouses, signaling in antennas for transmission of electricity and radio broadcasting, signaling in ports and airports.
- Road-rail signaling – random and variable message panels, for luminous signs and in the lighting of signposts.
- Tele surveillance – Warehouses and silos, road traffic, rivers, and points subject to flooding.
- Refrigerators and freezers.
- Water pumping.
- Water heating (PALZ, 2002).

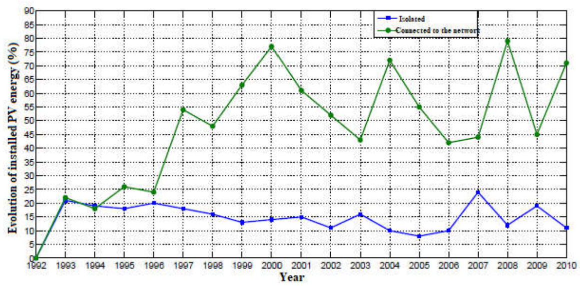
According to AMARAL (2006) a correctly installed solar storage system can save up to 40% of the electricity consumed per unit of consumption. This proportion, however, depends on the correct dimensioning of the equipment to meet the level of need intended by users. Studies by Companhia Energética de Minas Gerais SA, which is one of the main electricity concessionaires in Brazil, headquartered in the city of Belo Horizonte, capital of the State of Minas Gerais - CEMIG (2015) indicates that most failures are due to errors in solar storage design is 44%; Inadequate architectural designs account for the malfunction of 33% of solar heating systems and errors in the system itself, such as wrong installation or poor quality boards account for only 11% of failures. However, according to Cemig, when properly installed, the solar storage system is surprisingly efficient, reaching the mark of 78% to 86% of its capacity. In technical terms, for a better use of solar collectors, they must be facing the north face and, if this is not possible, towards the northwest or northeast. If the east or west face of the structure is used, an additional 25% of the solar collector area must be added (AMBIENTEBRASIL, 2015). The collector inclination must also be observed, which must be equal to the local latitude + 5 degrees. When this is not possible, an inclination of 15 degrees should be considered. A difference of 60 cm between the lower level of the plate and the distribution outlet of the house must be considered, so that natural convection takes place, in the case of natural circulation systems (CEMIG, 2015).

PHOTOVOLTAIC AND ELECTRIC GRID GENERATION: Two sectors that drive PV technology should be highlighted, space, for the supply of energy from satellites, and the first applications of this technology were for the supply of power to consumers not served by the conventional electrical grid, as well as to serve telecommunications stations, signal repeater station, water pumping (ACKER *et al*., 2011). The Japanese incentive program for small grid-connected PV generators (PV Roofs) was one of those responsible for the rapid growth of the photovoltaic industry, as well as, later, the German and American incentive programs. According to Figure 11 and Figure 12. Currently, in addition to the aforementioned sectors, the residential, commercial and industrial classes use PV solar energy, which totaled an accumulated installed PV energy capacity of almost 35 GW by the end of 2010, with 69% of the systems installed in Germany. and Italy and 18% of this total distributed in the USA, Japan and France. Thus, in the period from 2009 to 2010, the growth rate in the cumulative installed PV capacity was 68%, with the vast majority of PV systems for grid integration (Figure 12) (OCAK *et al*., 2010). These systems are being widely used because of the efficiency in integrating new or already used systems.



Source: ACKER *et al.* (2011).

Figure 11. World evolution of installed PV energy capacity

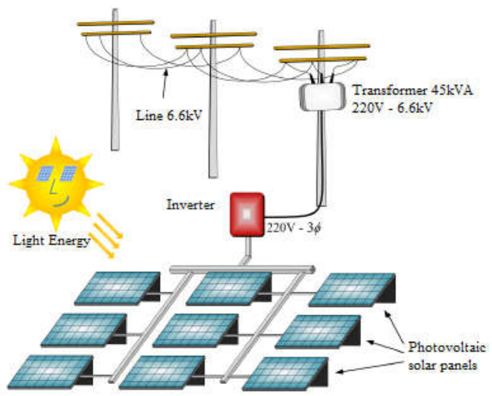


Source: OCAK *et al.* (2010)

Figure 12. World evolution in percentages of installed PV energy capacity

Complementation is one of the main points, because in the system on days when the sky is cloudy and the energy obtained from the photovoltaic plate is reduced, the diesel generator continues its production without interference and sustains the system. A hybrid system can operate directly connected to the load, which can be used for pumping water and applications that do not require stability and efficiency, for example. Again citing the wind/solar system, wind and light cannot be stored, so during low generation periods and for later use, the conventional method of storage is batteries. Technically, the retention and passage of energy, the generators can operate according to the associations in series or parallel, however, for the “generation”, the association in parallel is usual, since the current generated by the different energy sources is added together. to the electrical grid, increasing the total power. A comparison of the energy generated in the state of Amazonas and distributed by the concessionaire between solar energy can be made, using exclusively technical criteria, disregarding environmental and social effects and other factors whose valuation can be considered subjective (ZERRIFFI, 2010).

The following methodology is used: Comparison using the price of generated energy, instead of installed power. As photovoltaic solar energy has a negligible operation and maintenance cost, mainly because it does not need fuel to operate and does not have moving parts to undergo complex maintenance, its installation investment is diluted throughout its useful life, corresponding to energy generated; Comparison with the price of energy delivered by the distributor that is paid by the consumer unit, after the transmission and distribution system, instead of the value recorded after implementation of the photovoltaic plant. The photovoltaic system used in distributed generation produces energy directly in the consumer's supply, using the roof of this unit for energy generation. Therefore, the value that should be used as a reference was the value of consumption in Kw/h charged by the local energy distributor. It has become imperative for engineers to look at renewable energy sources such as solar, wind, geothermal, wave and biomass as sustainable and profitable alternatives, the advantage of being friendly to the environment and to conventional energy sources. However, the lack of availability of these renewable energy resources all the time throughout the year, considered that hybrid systems are more cost-effective. The development in research on the modeling of hybrid energy resources (photovoltaic systems), backup energy systems (Fuel Cell, Battery, Ultra-Capacitor, Diesel Generator), power conditioning units (MPPT converters, Buck/Boost converters), battery chargers) and energy techniques. Since 2012, about 1.3 billion people, or 18.41% of the world's population, have been without electricity eventually. Many of these people live in remote areas where decentralized generation is the only method of electrification. Most mini-grids are powered by diesel generators, but new hybrid systems, incorporating renewable energy sources, are becoming an efficient method of reducing the total cost of the diesel system. Hybrid solar stations with the proprietary GridStability System ("GSS") maximize the input of solar energy to the grid without interfering with existing diesel generator control systems, thus maximizing fuel economy. Data from the installed system was used to validate GSS capabilities and performance (CHAUDHARY *et al*., 2014). Public awareness of the need to reduce global warming and the significant increase in the prices of conventional energy sources have encouraged many countries to provide new energy policies that promote the applications of renewable energy. Such renewable energy sources such as wind, solar, water based energy etc. are environment friendly and have the potential to be more widely used. Combining these renewable energy sources with back-up units to form a hybrid system can provide an attractive, cost-effective offering with a higher degree of reliability, generating an electric power environment in all demand load conditions compared to single use. of such systems. There are many studies on the optimization and design of hybrid renewable energy systems since the recent popular use of renewable energy sources (ERDINCE and UZUNOGLU, 2012).



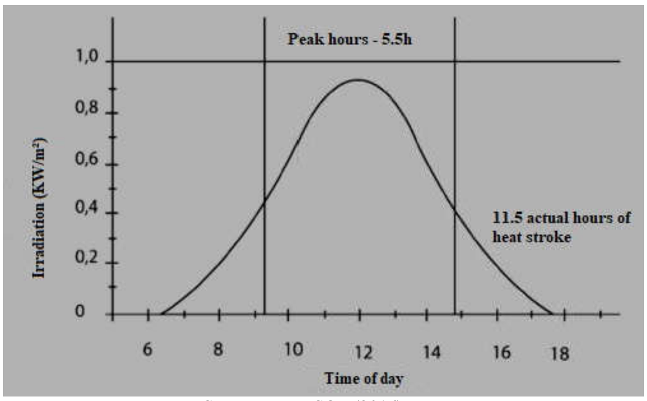
Source: CLAUDIO GONÇALVES (2013).

Figure 13. Structure on grid

Examples such as the case of Iran, to which almost every village consisting of more than 20 families in Iran is already connecting to the renewable resources network with the strong five-year Economic Development Plan proposed by the Iranian government (2005-2010). However, there are many isolated communities with less than 20 families that still need electrification. Currently, the only technology that provides electricity to these communities is diesel generators, which not only cause environmental and human health problems, but also high maintenance and operating costs (GHASEMI *et al*., 2013).
Renewable energy systems, combining various types of technologies, have demonstrated relatively high capabilities to solve reliability problems and reduced cost challenges. The use of hybrid electricity production/storage technologies as stand-alone off-grid systems is reasonable to overcome related shortcomings. Solar and wind energy are the renewable sources that take precedence compared to the other types. Based on solar radiation and average wind speed maps, cost-effective systems technologies are designed by simulating the behavior of various combinations of different sized renewable energy systems, including wind turbine (WT), photovoltaic (PV), cell (FC), and battery banks (HOSSEINALIZADEH *et al*., 2016). A recent study of the cost of implementing photovoltaic systems, published in 2005, analyzed the price of 47 isolated systems from 100 to 6600 W, from 1987 to 2004, indicating that these systems have a tendency to reduce prices of approximately 1 U$/W per year, with costs varying between 7 and 10 U$/W (HEGEDUS and OKUBO, 2005). Another study, published by the International Energy Agency's Photovoltaic Power Systems Program, confirms that prices are falling year after year, and indicates that stand-alone systems tend to cost approximately twice as much when compared to grid-connected systems, as they do not need batteries and other associated components. In 2004, isolated systems of up to 1 kW present a price variation from 9 to 25 U$/W, with the typical value being around 13 U$/W.

Considering the typical value of 13 U$/W for isolated photovoltaic systems, this number, by itself, is extremely uneconomical and uncompetitive when compared to the cost of implementing other sources. Typical installation values, both reported by the National Electric Energy Agency and published in a study by CESP and IMT. Another account that is usually performed when this comparison is made is the power generation capacity in a day. A system equipped with a non-intermittent source can generate energy 24 hours a day, while a solar system with the same installed power can generate, depending on its geographical location, an average of 6 equivalent hours of rated power throughout the day. Therefore, in order for the photovoltaic system to produce the same amount of energy in a day, it must have its power increased by 4 times, which increases its implementation cost to 52 U$/WPICO (13 * 4).

SIZING PHOTOVOLTAIC SYSTEMS: Solar radiation varies during the day and has its greatest intensity at solar noon. From the moment the sun appears on the horizon until sunset, solar radiation goes from minimum to maximum (at solar noon), and back to minimum. Clouds influence the Direct Irradiance, so that even at noon we can capture less energy than in the early morning or late afternoon. If we plot the variation of Irradiance in an average day, we can observe the hours of the day when the Irradiance is close to or equal to 1000 W/m² (Figure 14).



Source:BLUE SOL (2016).

Figure 14. Hourly graph of irradiation peaks.

Angle of Incidence (γ): it is formed between the sun's rays and the normal to the capture surface. The smaller this angle, the more energy will be captured. Azimuthal Surface Angle (aw): Between the projection of the normal to the surface of the solar panel and the north-south direction. For the southern hemisphere the azimuth is north and therefore the angular displacement will be from this cardinal point, being positive clockwise (east) and negative counterclockwise (west). The Surface Azimuthal angle will be between: -180° ≤ aw ≤ 180°. Internationally, the azimuth 0° is conventionally referred to as the South, and the North has an azimuth angle of 180°. Azimuthal Angle of the Sun (as): is the angle between the projection of the sun's rays in the horizontal plane and the North-South direction. It has the same conventions as the Azimuthal Surface Angle. Solar Height (α): angle between the sun's rays and their projection on a horizontal plane. Tilt (β): angle between the solar panel and the horizontal plane. Hourly Angle of the Sun or Angular Hour (ω): is the angular displacement of the sun, in the East-West direction, from the local meridian, due to the rotation of the Earth.

The Earth makes a complete revolution (360°) around itself in 24 hours. Therefore, each hour corresponds to an offset of 15°. Zenith Angle (θz): is the angle formed between the sun's rays and the vertical (Zenith). The zenith angle is the inverse of the solar height. The sun only reaches the zenith in locations between the tropics (tropical zone). Outside the tropics, in no location will there be a zenith angle equal to zero at solar noon. The power produced by a GFV depends on factors such as voltage losses in the electrical cabling, differences between the cells that make up the solar modules, but the two main factors that affect the output power of the GFV (MACEDO, 2006). Are:

- Radiação solar incidente no plano dos módulos solares que compõem o GFV;
- Temperatura de operação das células dos módulos solares.
- Neste trabalho, o GFV será utilizado para suprir alimentação para um inversor CC/CA, o qual será uma unidade fotovoltaica para integração à rede.

In sizing the active power of the GFV (ZILLES *et al*., 2010) data from the PLUTO245-Wde model solar module were used, whose main technical specifications are in the description of materials. Data on solar radiation and ambient temperature, both hourly, were obtained from the website of the Instituto Nacional de Meteorologia (INMET, 2012). As an example of the technical characteristics of a three-phase inverter for grid integration, the main technical data of an inverter with a nominal power of 40 kW are described in the description of the equipment used.

Financial indicators: As mentioned, there are several methods of analysis for the economic viability of systems, one of them is the discounted Payback, in which the simple Payback model has the concept that the time required for the project's cash inflows to equal the amount to be invested, that is, the payback time of the investment made. Thus, the discounted payback method basically has this same concept, but it considers the time value of money. An exact number of periods is verified for the payback of the investment. Along with this method, the Net Present Value (NPV) is taken into account, which is a financial mathematical formula that takes into account the time value of money.
The same corresponds to the difference between the present value of the net cash inflows associated with the project and the initial investment required (MACKEVIČIUS, 2010).

Payback Solar: Investing in a photovoltaic solar energy system has become a more attractive and viable solution for Brazilians. With the gains already known as being able to enjoy clean and renewable energy, in addition to greater control over energy spending, the consumer also has the advantage of knowing how profitable it is to invest in distributed solar generation and the deadline for the return of this energy. investment, the so-called payback, a calculation that predicts when the consumer will start to have a return on the investment in the system. The payback is the period necessary for the installation cost to pay itself and, from then on, to start "making a profit". This calculation must take into account the total investment made and the average monthly generation of the photovoltaic system.
The savings on the energy bill in the first month of installation is a good indication of how profitable the photovoltaic system is. According to experts, it can generate savings of up to 95% on the consumer's bill. And according to analyzes by the Brazilian Photovoltaic Solar Energy Association (Absolar), the payback time of a residential distributed generation system is estimated at up to four years.

Net Present Value (NPV): The net present value is an indicator that makes an analysis related to the present value of cash flows that are generated by the project during its useful life. In the NPV, positive and/or negative entries are considered, discounting at an appropriate interest rate according to the situation. In order to calculate the NPV, it is necessary to develop a cash flow, indicating all inflows and outflows during the period in which that project will be executed. After building this cash flow, to then calculate the net present value, the Minimum Attractive Rate (TMA) of each of these inputs and outputs, for the period of that project, must be discounted. The (TMA) represents the minimum rate at which the client wants to invest in order to have a minimum return on investment.

Internal Rate of Return (IRR): Another indicator to verify the feasibility of a project with photovoltaic systems is the Internal Rate of Return (IRR). The IRR is a rate that, when used as a discount rate applied to cash flow, results in an NPV equal to zero. Bearing in mind, as we saw earlier, that when the NPV is equal to zero, this indicates that it makes no difference to invest financially in that project. This method is one of the ways to measure the profitability of cash flow, in order to find an intrinsic rate of return. In summary, mathematically, when you calculate the cash flow, for an NPV equal to zero, you will find a value of the discount rate "i". In practice, after calculating the IRR, it is compared with the TMA. Thus, if the IRR is greater than the TMA, it implies that the project is financially viable.

MATERIALS AND METHODS

MATERIALS

Photovoltaic system is a system composed of a set of solar panels also known as photovoltaic modules, which are responsible for capturing sunlight through a composition of silicon cells, their voltage and current characteristics vary with the solar irradiance collected by the module. and with the temperature at which the cells operate. A device known as a solar inverter receives this voltage and current generated by the solar cells in direct current, converts it to alternating current leaving the energy generated in the same quality as the energy distributor. Because it is a study of the implementation of a photovoltaic system in general, and not just a specific subject related to it, one of the points addressed in this work is the financial analysis of a project of this size for the university, and what it represents economy for the same.

Table 1. Initial cost estimates

EQUIPMENT AND MATERIALS	PRICE
Photovoltaic Project	R$ 15.000,00
Photovoltaic and Structural Materials and Equipment	R$ 200.000,00
Labor and equipment installation	R$ 50.000,00
TOTAL PARTIAL	**R$ 265.000,00**

Source: Authors, (2021).

Equipment Description

Three-Phase Photovoltaic Inverter: The photovoltaic inverter is a device that receives the energy in direct current generated by the photovoltaic modules, and converts it to alternating current, leaving it in the same quality as the energy received by the distribution network. This type of device can only be used if it complies with Brazilian or international standards, so that it meets all safety and quality requirements, that is, if the distributor's network is turned off due to any fault or maintenance, the inverter turns off and interrupts the distribution of energy to the consumer or to the electrical network.

Three-phase on grid inverters, brand GROWATT, Sunny Island line (SMA)

- Model: SI 8.0H-10;
- Manufacturing: SMA;
- Rated AC output power: 3.0 kW;
- Rated output voltage AC: 127V;
- Total harmonic distortion: <4%;
- DC input voltage (battery): 48V (41 to 63 Vdc);
- Maximum battery charging current: 30 A;

- Multi-stage automatic charge controller, with automatic float and equalization charge;
- Maximum efficiency: 95%;
- Self-consumption at no load/stand-by: <26W / <4W;
- Electronic protections against overload and short circuit on the AC output, fuses against polarity reversal on the DC input, over temperature, deep battery discharge;
- Category III surge protections (according to IEC 60664-1);
- Accessories: battery temperature sensor, communication cables;
- Built-in automatic generator start;
- Degree of protection: IP54;
- Operating temperature: -25 to +60 °C;
- External dimensions: 612 x 467 x 242mm;

TYPE OF FIXING THE MODULES

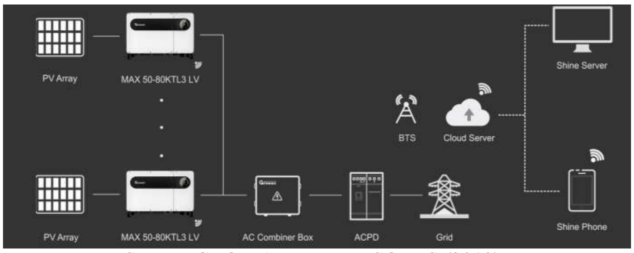
Support structures of photovoltaic modules: The support structures were manufactured in hot-dip galvanized steel angles and profiles, and will be mounted on columns driven directly into the ground. Alternatively, if the soil is not in good condition. The PHB Photovoltaic Module Support Structures, in anodized aluminum, are exclusive to PHB. Being easy to install and highly durable, they serve roofs, flat surfaces (slabs), floors and parking areas. They will be designed to resist aggressive environments and wind speeds up to 35 m/s (Region II, according to NBR 6123). For all types of structures to support photovoltaic modules, PHB Solar offers the Complete Grounding System via CLIPS and CLIPS, which allows the grounding of the structure and photovoltaic modules in a safe and practical way.

PHOTOVOLTAIC MODULES

The JA 335W solar panel model JAM6(K) -72-335/PR, has high efficiency and is classified by INMETRO with class "A". Ideal for on-grid (grid connected) and off-grid (with batteries) Polycrystalline silicon photovoltaic modules, built with high efficiency photovoltaic cells (>17%), encapsulated between EVA layers, PVF bottom protection, transparent glass top cover, and anodized aluminum outer frame.

- Quantity: 120 pieces;
- Model: JAM6(K)-72-335/PR;
- Manufacture: JA SOLAR;
- Cells per module: 72;
- STC specifications (25ºC, AM 1.5, radiation 1.0 kW/m²);
- Maximum power: 335 W;
- Maximum power voltage: 37.96 V;
- Maximum power current: 8.83 A;
- Open circuit voltage: 46.68 V;
- Short-circuit current: 9.38 A;
- Efficiency: 17.6%;
- Connections: Cables with MC-4 compatible connectors;
- External dimensions (L x W x H): 1956 x 991 x 45 mm;
- Approximate weight: 26.5 kg;
- Certifications: UL 1703, IEC 61215, IEC 61730, TUV;
- INMETRO Certification, Class "A" (more efficient).

Protection of photovoltaic systems: As with all low or medium voltage electrical installations, solar systems must contain their own protections, systems that must interrupt the generation and/or delivery of energy from the system if the grid or the solar generator itself fails. In general, inverters are adapted to protect the system itself, they have functions to detect any fault that may arise, and thus protect the system. 1.5 line spacing). Even so, the system must mainly comply with NBR 5410 and have auxiliary protection devices such as the installation of surge protectors both for generating energy from the panels (Direct Current), as well as connecting this energy to the consumer unit, as well as sending the same for the electrical network (Alternate Current). The grounding of the panels and all metallic parts, such as the supporting structures of the panels, as well as the inverter, must follow NBR 5419. Most grid-connected and stand-alone inverters also contain the Maximum Power Point Tracking (MPPT) function. The Maximum Power Point (MMP) is the ideal voltage and current for the PV array to operate at the highest power point at any given time. The MPPT plotted on an I–V curve is at the elbow of the curve where the highest values to produce energy are forced electronically by the input of the array. The I–V curve graphically plots the relationship of current and voltage. The MPPT function is also found on charge controllers in standalone systems with battery storage. As shown in Figure 15.



Source: GROWATT INVERSORES (2019).

Figure 15. Power supply scheme

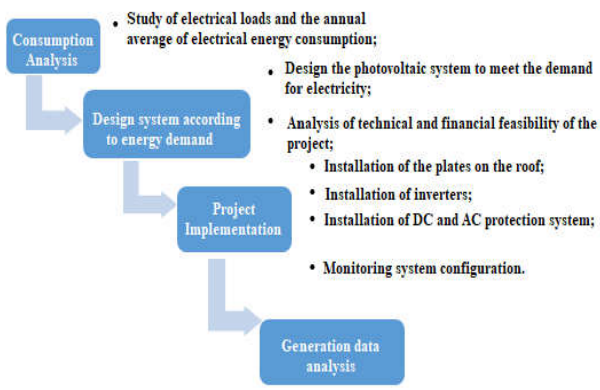
Every inverter has a slightly different and limited MPPT window where it will accept DC voltage and current and convert it to AC power. There are two factors to consider:

- The maximum DC conversion capacity and inverter capacity. will transform excess DC power into AC power.
- Code voltage and current window versus MPPT voltage and current window.

Consequently, when we design a high-performance or at least a good-performing system to satisfy the MPPT window, we do so using the 80% rule. In simple terms, a 10,000 watt inverter (remember that the inverter is rated for AC output) will allow approximately 8,000 watts DC connected to it. Divide the power output of the inverter by the power sent to the inverter to find its instantaneous efficiency. Inverters create a small amount of output loss during the DC to AC conversion process. The load affects the efficiency of the inverter and it is estimated that most inverters experience the highest efficiency when the output is equal to approximately 30% to 70% of their rated capacity.

DC and AC Electrical Cabling: The photovoltaic modules are supplied with interconnecting cable tails, equipped with connectors compatible with the Multicontact MC-4 type. The interconnections between photovoltaic modules to form the strings will be made through the interconnection cables.

Applied Methodology Flowchart



Source - Authors, (2021).

Figure 16. Flowchart of the Applied Methodology

METHODS

Procedures: The procedure used in this study was performed through the analysis of electricity consumption before the implementation of the photovoltaic system, with results which demonstrate the use of photovoltaic energy in addition to reducing economic costs, environmental impacts and financial costs, it also brings gains for the use of solar energy. types of energy generation in businesses and small industries in the region of Manaus and metropolitan region. The study seeks a form of economic stability and environmental sustainability, being possible its application to any unit that has this same type of economic activity. Another evidence is the fact that after the conclusion of this study, small industries and medium-sized businesses in the region can structure themselves for the implementation of their photovoltaic power generation plants. For an energy autonomy process, environmental sustainability in accordance with current legislation.

Delimitation: This research was applied in a small food industry in the center of Manaus-AM, having the same with its only power supply to the utility grid, applied a model of photovoltaic energy on grid in an attempt to reduce operational, financial and environmental impacts. AMAZONAS EMPACOTADORA was chosen, because it has similarities with the small packaging industries located in the city of Manaus-AM with the difficulty of maintaining an energy system with acceptable economic levels, as we find ourselves with the second highest energy tariff in Brazil, where we have 80% of energy generation with thermal generation. However, other units of the institution also have much lower rates, which reveals another attraction of the project: the possibility of reproduction in other units. From this approach, the present research has as its delimitation the study on the use of solar energy from a 40 KWp on grid power plant, as a replacement for the generation of fuel forms in large parts of the Amazon region with the same energy difficulties.

Search limitation: The research is limited by temporal, particularity and segment aspects. As temporal aspects: the research results are valid for the analyzed period, excluding other influencing factors, such as climate, demography and resource contingency. As an aspect of Particularity: the research results are restricted to the specificity of the operational unit to which it is intended, that is, its routine, its weaknesses, its performance and its operational context. Segment aspects: the research results come from the experimental photovoltaic model for generating energy from a small riverside residence and a set of solar luminaires, in this way, the difficulties in performance will be inherent to the operational unit under study, not having the responsibility to close the question about the efficiency and effectiveness of the techniques used in this project.

Analysis procedure: (Espaçamento de 1,5 entre linhas)The present work was elaborated with the main focus on the difficulty of supplying electricity in isolated communities in riverside regions, seeking to insert alternatives to reduce fuel costs in the generation of thermal energy, the only form of energy available today in these communities. The Proposal for the implementation of photovoltaic microgeneration as an Energy Alternative in a small food industry, which has as a relevant justification before society, the reduction of costs in the generation of electricity and the correct use of natural resources. As scientific relevance, it can be said that the result of the study will serve as a basis and example for other industries and businesses in the region with the same characteristics and are facing difficulties with the high cost of energy, that is, sharing organizational aspects in order to contribute to solving similar problems.

Step 1: Project Procedures and Success Criteria

•Avaliar os resultados após a implantação da microgeração de energia fotovoltaica e eliminação da compra mensal de energia elétrica, com a finalidade de reduzir os custos operacionais, impactos ambientais e de atender níveis satisfatórios, na geração de energia elétrica para o autoconsumo.

Step 2: Success Criteria

All project cost made by the object of no labor costs; Detailed planning in the execution;

Procedure with quality, processes, and use of technologies to reduce costs with time, financial and logistical expenses.

Step 3: Key customer requirements

- Project with Development.
- Equipment used with up-to-date technology;
- No logistics costs, paid by the equipment manufacturer;
- Easily accessible geographic location.

Step 4: Project Product

Use of Solar Energy as an Energy Alternative to replace the energy supplied by the concessionaire. The use of solar energy will reduce the cost of production with the financial impact, decrease in the generation of carbon in nature, since 60% of the generation of electric energy in the state of Amazonas comes from the generation of thermal plants, thus reducing the contamination of the environment with CO2 and reduction of products from petroleum.

Step 5: Project Approval Requirements

The project already has the physical space (roof of the building), hired labor with proven experience in other facilities, has an extremely low cost in terms of cost/benefit, and already has financing approved by a financial agent with a line of credit. specifically for renewable energy.

Step 6: Key Stakeholders

- The main stakeholders identified preliminarily are:
- The related industry itself, students involved in the project and traders and industries with similar systems.

RESULTS AND DISCUSSIONS

DEFINITION OF THE STUDY AREA AND ENERGY USE

The choice of the study area allowed a daily demand curve with a study of electricity consumption of a small food packaging industry in Manaus, for small houses characteristic of these locations, all with roof area to support the demand necessary for the installation. of photovoltaic panels.

PROJECT DETAILS AT EMPACOTADORA AMAZONAS-AM

The Empacotadora Amazonas-AM region has Latitude: 0 ° 38" 53.58", Longitude 47 ° 13 "39.81" and is in the Bioclimatic zone 1.

Source:GOOGLE (2021).

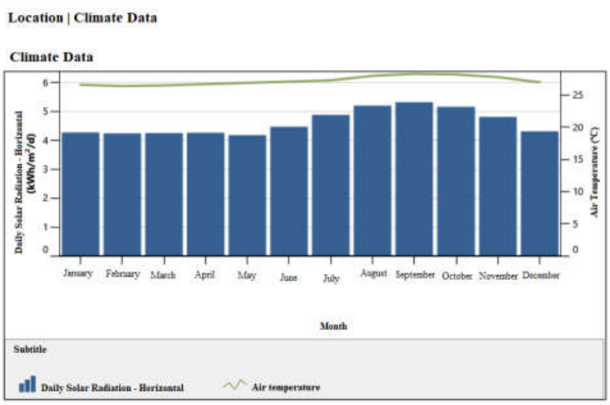
Figure 17. Map of the Region

As shown in Figure 17 and Figure 18. From the technical observations of irradiance, computer programs are used that can assist in consulting the data of incident solar radiation in a given location.

Source: Authors, (2021).

Figure 18. AMAZONAS PACKAGING area

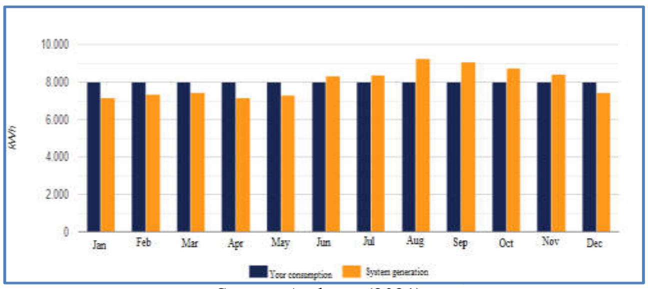
The databases have information about the horizontal surface, but the SFV panels are installed on inclined planes with different orientations. In addition, there are programs that use suitable algorithms to computationally synthesize sequences of meteorological data that, in the absence of measured sequential data, can feed simulation programs of photovoltaic systems in operation. The developed RADIASOL2 program allows the user to define the inclination angle and azimuth orientation of the modules plane. The user must enter monthly averaged area irradiation data on a horizontal plane and monthly temperature data (or use data incorporated in the program installation) and select the location and orientation of the plane under study.



Source: Authors, (2021).

Figure 19. Climatic data

IDENTIFICATION OF THE IMPLEMENTATION OF THE PHOTOVOLTAIC PLANT: As an important step, a consumption analysis was carried out, for the sizing of the necessary photovoltaic plant according to the consumption characteristics. Considering an average electricity consumption of 8,814.57 Kw/month (Figure 20).



Source: Authors, (2021).

Figure 20. Consumption x Project generation

In this work, the GFV will be used to supply power to a DC/AC inverter, which will be a photovoltaic unit for grid integration. In the dimensioning of the active power of the GFV, the data of the solar module model JAP72S01 335/SC were used, whose main technical specifications are presented in Table 2. The data of solar radiation and ambient temperature, both hourly, were obtained from the website of the National Institute of Meteorology (INMET). As an example of the technical characteristics of a three-phase inverter for grid integration, Table 3 presents the main technical data of the inverter used, a Growatt 33000TL3-S inverter with a nominal power of 33 kW.

Table 2. AT STC Electrical Parameters

TYPE	JAP72S01
Rated Maximum Power(Pmax)	335
Open Circuit Voltage(Voc) [V]	46.7
Maximum Power Voltage(Vmp) [V]	37.86
Short Circuit Current(Isc) [A]	9.35
Maximum Power Current(Imp) [A]	8.87
Module Efficiency [%]	17.2
Power Tolerance	0~+5W
Temperature Coefficient of Isc(α_Isc)	+0.058%/□
Temperature Coefficient of Pmax(γ_Pmp)	-0.400%/□

Source: JASOLAR (2021).

Table 3. Datasheet x Growatt 33000TL3-S

Input Data	
Max. DC power	36300W
Max DC voltage	1000V
Start Voltage	250V
PV voltage range	200V - 1000V
Nominal voltage	580V
Full load MPP voltage range	480V - 800V
Max. input current	36A / 36A
Max. input current per string	12A
Number of MPP trackers / strings per MPP tracker	2/4

Output (AC)	
Rated AC output power	33KW
Max. AC apparent power	33KVA
Max. output current	50A
AC nominal voltage	230V/400V
AC grid frequency	50/60Hz
Power fator	0.8 leading - 0.8 lagging
THDi	<3%
AC grid connection type	3W+N+PE
Efficiency	
Max.efficiency	98.8%
Euro – eta	98.4%
MPPT efficiency	99.5%

Source:DATASHEET GROWATT (2019).

For a given ambient temperature, Ta, and incident irradiance, Gi, the solar module temperature (or cell temperature), Tc (oC), can be obtained from Eq. (4).

$$T_c = T_a + (NOTC - 20)\frac{G_i}{800} \quad (4)$$

Being:

NOTC= Nominal or nominal cell operating temperature, under Concentration conditions of 20°C, 800 W/m2 and wind speed of 1 m/s. Average NOCT values are around 45 to 46 °C.

The maximum power supplied by a GFV, Pmp, for a given operating condition, can be obtained through Eq. (5).

$$P_{mp} = P_{GFV}\frac{G_i}{G_0}[1 - \gamma_{mp}(T_c - T_0)], \quad (5)$$

Being:

Tσ = 25°C is the module reference temperature, G0 = 1000 W/m2 is the reference irradiance and γmp is a coefficient that relates the power at the maximum power point with the module temperature.

The nominal power of the GFV, under reference conditions, PGFV, can be obtained from Eq. (6).

$$P_{GFV} = N_{ms}V_{mp}N_{mp}I_{mp}, \quad (6)$$

Being:

Nms= the number of solar modules in series;
Nmp= the number of rows of modules connected in parallel;
Vmp= the voltage at the maximum power point;
Imp= the module current at the maximum power point.

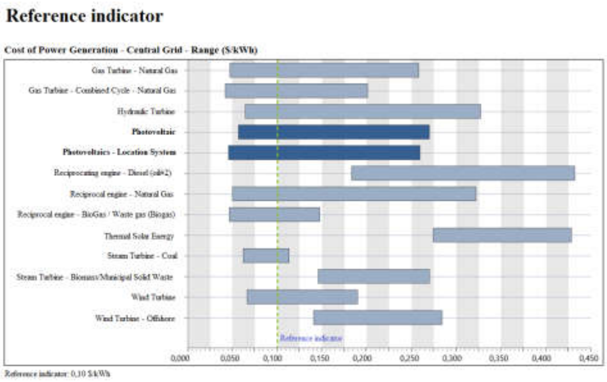
Making the substitution and considering γmp = -0.0040/oC, NOCT = 45oC and T0 = 250oC, the active output power (W) of the GFV can be obtained as a function of incident irradiance (W/m^2) and ambient temperature (oC), from Eq. (7).

$$P_{mp} = 1.10 \, x \, 10^{-3} P_{GFV} G_i - 1,25 \, x \, 10^{-7} P_{GFV} G_i^2 - 4.0 \, x \, 10^{-6} P_{GFV} G_i T_o. \qquad (7)$$

The active power (W) of the inverter output, considering its efficiency ηinv, can be obtained by applying Eq. (8).

$$PO_{INV} = \eta_{inv} P_{mp} \qquad (8)$$

In this work, the DC/AC inverter will be the photovoltaic DG unit that will be integrated into the primary distribution network. This unit will be called a photovoltaic generator for grid integration (GDFV), whose DC power supply will be determined, according to the guidelines established for the GFV dimensioning. In this article we analyze the risks of choosing the energy matrix according to the values of kw/month generated with each matrix and we found that the most coherent would be the photovoltaic generation (Figure 21).



Source: RETSCREEN (2021).

Figure 21. Generation cost indicators by matrix.

For the project to become viable, a reference value was set, with the consumption and cost ratio of the implementation of the photovoltaic plant (Table 4).

Table 4. Summary

Target

Resume

	Electricity exported to the grid kWh	Revenue from exported electricity $	Reduction of GHG emissions tCO₂
Proposed Case	130.926	0	8,9

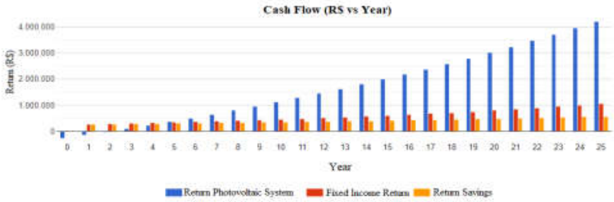
Source: Authors, (2021).

To verify if the project costs were integrated with the monthly generation values, thus verifying the feasibility of implementing the plant, according to Table 5. After all the data and calculations of the system, based on a financial analysis and cash flow of the company in question, we scale the project to meet the calculated needs. So following the necessary steps to implement it. According to the project and single-line diagram, the plates were mounted on the roof of the related company, inverter system and protections according to the project. After installing the equipment, monitoring of the system's behavior began to verify that the project's calculations were in accordance with the projected ones. We verified with the collection of generation data that there is a big difference in the rainy days of the Amazonian winter as shown in Figures 26 and 27.

Table 5. Financial viability of the project

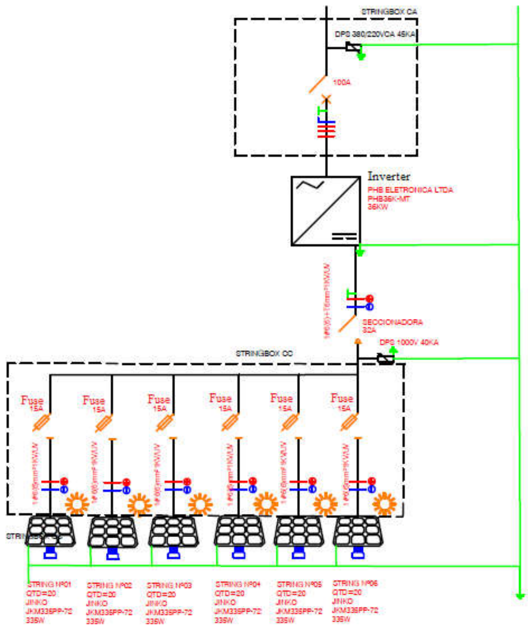
Status	Year	Price/Tariff (R$/kWh)	Energy production (kWh/year)**	Total energy production (R$)	Financial Result (R$)	CDB 130% CDI (R$)***	Savings (R$)****
Investment	0	0,000	0	0,00	-265.000,00	0,00	0,00
Investment	1	1,250	96.012	120.015,00	-144.985,00	280.058,00	273.347,50
Investment	2	1,300	95.244	243.832,20	-21.167,80	296.383,04	281.957,95
Profit	3	1,352	94.482	371.571,86	106.571,86	313.124,71	290.839,62
Profit	4	1,406	93.726	503.350,62	238.350,62	331.035,44	300.003,07
Profit	5	1,462	92.976	639.281,53	374.281,53	348.970,67	309.491,12

Source: Authors, (2021).



Source: Authors, (2021).

Figure 22. Cash flow analysis



Source: Authors, (2021).

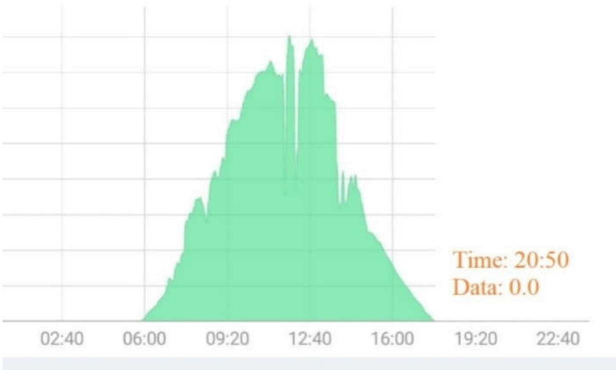
Figure 23. Single-line diagram of the photovoltaic system

Source: Authors, (2021).

Figure 24. Image of photovoltaic panels

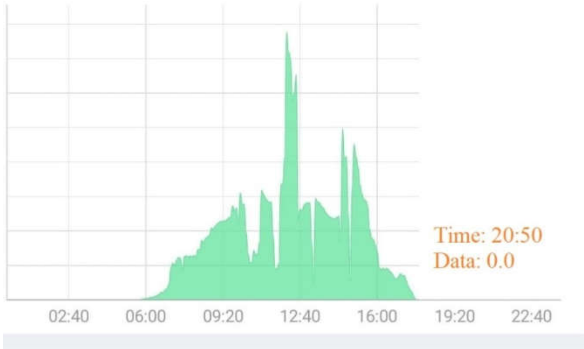
Source: Authors, (2021).

Figure 25. Mounting the inverter and protections



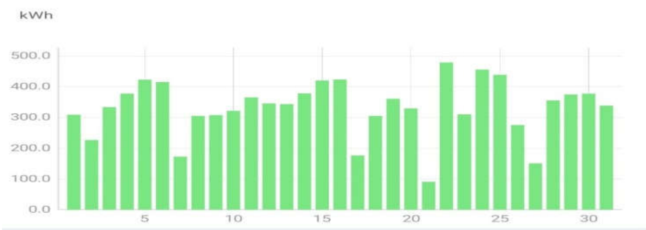
Source: Authors, (2021).

Figure 26. Power generation on a summer day



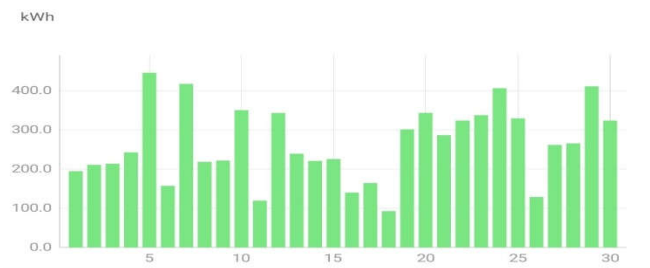
Source: Authors, (2021).

Figure 27. Power generation in Amazonian winter days



Source: Authors, (2021).

Figure 28. Energy generation diagram for the month of July (summer)



Source: Authors, (2021).

Figure 29. Energy generation diagram for November (winter)

It is attested that the generation data on summer days without rain, the values approach the nominal values, thus satisfying the initial conditions. On the days of severe winters in the region, we see a great loss of generation. The range of coverage for ink days and the reliability and accuracy of the generation data were increased, with this we can configure the generation to the exact value within the consumption needs as shown in Figure 28. It was found that the consumption of electricity before the implementation of the project, to me*et al*l the company's functionalities, the average consumption was 8814.57 Kw/month.

Month	Consumption (kWh)	Generation (kWh)	Credit of the Month (kWh)	Accumulated Credit (kWh)	Invoice without system (R$)	Invoice with system (R$)
Jan	8.000	7.155	0	0	10.000,00	1.056,81
Feb	8.000	7.345	0	0	10.000,00	818,72
Mar	8.000	7.463	0	0	10.000,00	670,79
Apr	8.000	7.151	0	0	10.000,00	1.061,43
May	8.000	7.308	0	0	10.000,00	864,95
Jun	8.000	8.312	312	312	10.000,00	125,00
Jul	8.000	8.384	384	696	10.000,00	125,00
Aug	8.000	9.257	1.257	1.954	10.000,00	125,00
Sep	8.000	9.054	1.054	3.007	10.000,00	125,00
Oct	8.000	8.745	745	3.752	10.000,00	125,00
Nov	8.000	8.399	399	4.151	10.000,00	125,00

Source: Authors, (2021).

Figure 30. Comparison of energy consumption and generation.

With the implementation of the project, it was made to me*et al*l the electricity demand, after supplying the system with the photovoltaic generation, only the costs of public lighting, basic rate of 100 kw/month and costs with tariff flags. With this, we reduced the monthly consumption from approximately 8814.57 kW/month to 100 kW/month. Thus satisfying the expected financial and economic assumptions. simple). With this, we arrive at the expected financial return, according to the projection of the calculated and predicted financial return. In addition to the environmental results provided in this work, in view of the thermoelectric power generation in the Amazon region. Decarbonization emerges as a solution to address the climate and environmental issues currently in vogue. The implementation of more and more solar energy systems in the country contributes to the reduction of CO2 in the atmosphere.

According to Adnan Amin, director of the International Renewable Energy Agency (IRENA), renewable sources should represent, by 2050, two thirds of all energy produced on the planet, that is, the growth of SOLAR ENERGY will contribute to decarbonization, as there is no emission of gases during energy production; in 25 years, the use of a photovoltaic system prevents 108,641 kg of CO2 from being dumped into the atmosphere and savings on the electricity bill can reach 90%, improving the financial management of homes and giving more competitiveness to industries, businesses and services, in Figure 4.20 shows the contribution of this project with the reduction of CO2 according to the generation of solar energy and consequently the amount we stop consuming thermoelectric energy.

Source: GROWATT INVERSORES (2021).

Figure 4.20. Climate Reductions

Normative Resolution 482/12 of the National Electric Energy Agency (Aneel) determines the provisions for the energy compensation system, known as solar energy credits. This law, encourages the production and use of photovoltaic energy, allows the consumer who generates solar energy to make a kind of exchange with the electricity concessionaire. With this, an energy efficiency study was carried out on machines and equipment of the company in question, we exchanged old light bulbs, incorrectly dimensioned cabling and motors, reducing consumption and thus transforming a part of generation into surplus, thus being able to be used in other units. from the company.

CONCLUSION

With the development of this work, we can demonstrate that the application of a photovoltaic system on grid in small businesses and industries can represent a reduction of financial costs, environmental impacts with great relevance. The benefits are not limited only to the small industry mentioned, but to all with the same production similarity in the same region and same procedures, as it can obtain significant economic, environmental, financial benefits over the months, being this economy an alternative to invest in various sectors of the economy. The results brought a strong answer to the proposed problem. Solar energy can be used as a way to reduce costs and impacts with energy provided by the concessionaire, with high costs and mostly with thermal generation. Noting that the purpose of this project is basically to zero the energy consumption requested by the local utility, where it distributes, for the most part, thermal energy. As solar energy is considered an inexhaustible source of energy, it is important to replace the large consumption of diesel with a generation of energy that does not bring environmental damage and with low costs. In addition to financial viability, the great importance of installing photovoltaic systems should be highlighted when evaluated under the focus of reducing environmental impacts, as we can highlight in the category of clean energy, the results are more expressive due to their environmental character. The method used proved to be adequate for the objective of the study: to select the process for applying the Case Study, to conceptualize solar energy and its practical possibilities, to draw up plans for the application of the photovoltaic system, which showed benefits, advantages and financial impacts. achieved with the implementation of a project such as the photovoltaic system for a small food industry. The present study not only represents an economic and energy milestone for a unit, but also represents a possibility of sustainable energy generation for riverside communities throughout the Amazon region. After analyzing the entire process, it was verified the feasibility of investing in solar energy generation with a medium and long-term return, as the equipment costs are considered high, however, according to a price survey in quotation, in three years and six months the solar energy equipment, with the programmed energy generation, will occur the return on investment. The present study had with a divisor in economic, financial and environmental character with an energetic relation in small industrial of foods. There is also an irreversible possibility in the generation of medium-sized energy in this region that goes through so many difficulties and from the total costs of the system for each situation, we sought to price them and determine the value paid by the user for each kilowatt hour used end of life of the photovoltaic system used. Given the above, it is concluded that the investment in the standard of entry of solar energy is profitable and beneficial in the medium and long term. Because, as the state of Amazonas has the second highest electricity tariff, there is a relationship between the tariff value and the cost of the equipment. The trend of this market is the expansion and reduction of the price of the material used, thus, the financial perspectives of savings with the energy bill are very favorable, including for partial or complete reproduction of the current project in other locations with the same characteristics.

(Space As recommendations for undertakings and research to be carried out which will have a line of reasoning related to this work, we list some suggestions:

- Application of the same methodology to other types of processes. In case this project is reproduced in other process units that face the geographic and isolation challenges of the North Region;
- More tax benefits for photovoltaic equipment used in energy generation for customers in the Amazon region;
- Search for equipment with more advanced technology than those used in the research period, with more profitable prices, thus lowering the cost-benefit of the equipment.
- Seek greater territorial coverage.

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