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Integration of a Pilot PV Parking Lot and an Electric Vehicle in a University Campus Located in Curitiba: a Study Case

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HIGHLIGHTS

- Increasing electric vehicles against utility grid energy supplying capacity.
- Solar Carport system as a solution to provide energy for EV recharging needs.
- Performance analysis of a real solar carport energy production.
- Comparison between energy production and electric vehicle consumption for a day use.

Abstract: Considering the increasing adoption of Hybrid Plug-in and Electric Cars, there are concerns about recharging process of these vehicles considering the capacity of grid to provide sufficient energy to that purpose. In the past years, the growth of distributed energy generation from renewable and clean energy sources, especially photovoltaics, represents a possible and feasible solution to supply the energy used on recharging electric vehicles and reduction of greenhouse emission gases as CO_2. This article is a study case that analyzes the energy production of a solar carport, located at Federal Technological University of Paraná (UTFPR) at Neoville Campus, comparing with energy consumption of a commercial electric car for a city use purpose. Based on solar energy generation, data from the web monitoring platform, real positioning characteristics of the solar carport installation, irradiation data collected from the National Institute of Meteorology basis and with a solarimetric station located at the same place as the solar carport is installed, the solar energy production is rated using three different metrics: yield, performance ratio and capacity factor. These metrics are calculated with RADIASOL2 software, a free and precise tool, developed by Federal University of Rio Grande do Sul (UFRGS) to execute computational simulation of photovoltaic systems using mathematical models. The results showed a slightly low energy production performance than expected, but more than enough energy to recharge an electric vehicle for a day use, demonstrating that a solar carport system could be a good solution to meet the energy demand for this application.

Keywords: solar carport; electric vehicles recharging; energy production analysis.

INTRODUCTION

With the introduction of electrical energy as the driving force of machines since the Industrial Revolution, technological innovations have been increasingly associated with electricity, making economic growth contingent on this form of energy [1].

The degradation of the environment and the projected shortage of fossil fuels in the near future highlight the importance of generating energy with a minimum environmental impact, thus asserting the relevance of including different sources of energy to the national energy matrix [1].

The transport sector is a major user of fossil fuel, increasing greenhouse gas emission and the global warming. In 2019, the transport sector produced 8.2 Gt of CO_2 emission, representing 24% of direct emissions from fuel combustion [2,3]. Due to the necessity to reduce air pollution, the number of electric vehicles (EVs) and plug-in electric vehicles (PEVs) has been continuously increasing in the last years, as well as the use of renewable energy sources. In 2019, the global stock of electric cars reached 7.2 million and the number of charging points worldwide were approximately 7.3 million, representing an increase of 60% from the previous year [3,4]. In this same year, the global renewable energy installed capacity had its highest increase and grew 200 GW, in which more than 50% were from photovoltaic generation [5].

Despite the environmental benefits that electric vehicles can bring, their large-scale integration on distribution system can cause several negative impacts such as increased system peak demand, transformer overload operation and power quality problems. In this scenario, the integration of photovoltaic (PV) generation into EVs and PEVs charging station infrastructure can be a possible solution to properly integrate them on grid and reduce their negative impacts. It could reduce carbon emission and system peak demand, avoiding transformer overload condition [3].

The joint of the two technologies could be done through solar parking lots, a structure also known as carport system. They can be installed in the most diverse places, such as: markets, hotels, shopping malls, restaurants, public institutions, etc., benefiting areas that may already be free for installation [6]. Reference [12] emphasize that the creation of infrastructure stimulates the offer, since manufacturers avoid the production and marketing of EV in countries or regions that do not exploit the infrastructure necessary to operate them.

The dynamics of charging EVs through the carport system can be done in an optimized way [6]. The charging can be done by making an adjustment between solar generation and the fleet needs, also considering factors such as electricity price, or local demand. The fact that the EV fleet also represents a storage capacity, implies the possibility of a bidirectional energy flow, in which the EV is no longer a passive element in the network, but also provide services to it. This concept is known as vehicle-to-grid (V2G) and results in another possibility for smart energy networks (smart-grids) [6].

In [7] and [8] a theoretical study about the energy generation potential of a carport is explored, discussing technical, environmental, and financial aspects. In [9], a carport with 12 glass-glass PV modules, with a total of 3kWp was installed. The system is generating electrical energy since May 2015 in Poland. The project was developed to charge a small, urban vehicle. In [10], two years operation of two solar carports, one with twelve and other with six parking positions, and ten electric vehicles are presented.

Although some research has been done, the use of PV generation into EVs charging infrastructure have some challenges that need to be addressed. The output power of photovoltaic generation may have diurnal and seasonal fluctuations and electric vehicles demand also have an uncertain pattern, which varies with drivers' behavior and preferences. Due to the difficulty in supply-demand matching, this problem must be modeled based on stochastic approach exploring different scenarios to account these variabilities [3] and although the electric mobility and the deployment of its charging infrastructure has been widely studied [13,14], no studies have focused on planning the charging facilities in existent public car parks based on real mobility patterns, which is essential to enable a correct public investment plan; in order to drive penetration of electric mobility [13,15].

This paper aims to assess the integration of a carport system with an electric vehicle in a university campus building located in Curitiba, Paraná, Brazil. A case study is performed based on city irradiance data and building electricity demand measurements collected by a local monitoring system. The research includes the identification of the capacity of a photovoltaic carport system to meet the demand for electric vehicles, manage the local energy demand and reduce the levels of CO_2 emissions into the environment. The research is limited to the Federal Technological University of Paraná (UTFPR), Curitiba, campus Neoville, where a pilot parking plant was developed for two parking spaces.

Solar parking lot – the carport system

The usage of solar energy for electricity generation is a solution capable of supplying the demand for electric vehicles. More specifically, useful parking areas already deployed can be converted into solar car parks, capable of generating energy and recharging EV [6]. In fact, the potential for implanting these solar systems into parking lots already in use is extremely high. As an example, parking spaces occupied 25% of the total built area in the city of São Paulo in 2012 [6, 12]. With high availability of solar parking, it is easier to charge the EV more often, which encourages users to join this technology.

Solar parking lots can be used as educational tools when installed in schools and universities. This would allow the increase in social awareness regarding the concepts of solar generation technologies and electric vehicles, stimulating their usage by society [13].

Solar carports are roofs built from photovoltaic panels to cover parking areas and generate energy. However, they are different from the panels installed in an existing roofed parking lot. Solar carports have many things in common with solar panels installed on the ground. Both eliminate the need for a surface on which the panels can be attached, such as a roof. The main difference between a solar carport and a ground installation is that the carports are higher to allow cars to be parked below the panels [14]. Usually, a solar carport is two spaces wide, however they can be large enough to cover dozens of parking spaces. Depending on consumption, installing a solar carport can generate enough energy to power your home, business cover or industry. Although a typical parking cover offers shading for the car, its simplicity is a missed opportunity with the existence of carports, the mayor advantage of them is to use their cover to generate energy.

Carport pilot project development

The execution of the CARPORT project at the Neoville campus of Federal University of Technology – Paraná (UTFPR) was possible due the donation of equipment by companies of the solar energy field, as well as the union of Solar Energy Laboratory (LABENS) students and researchers from UTFPR, for its construction.

The first item donated, provided by the company Sonnen Energia, was the aluminum structure to support the photovoltaic modules, in the model of solar garage with two parking spaces (see Figure 1) [6].

This structure has a sealing system to prevent leakage of water between the modules, there is an intermediate clip that accompanies all the length of the row of modules vertically, as well as a rubber that is fixed between the contact of each module horizontally. Figure 1 shows the structure dimensions and some aspects of the model.

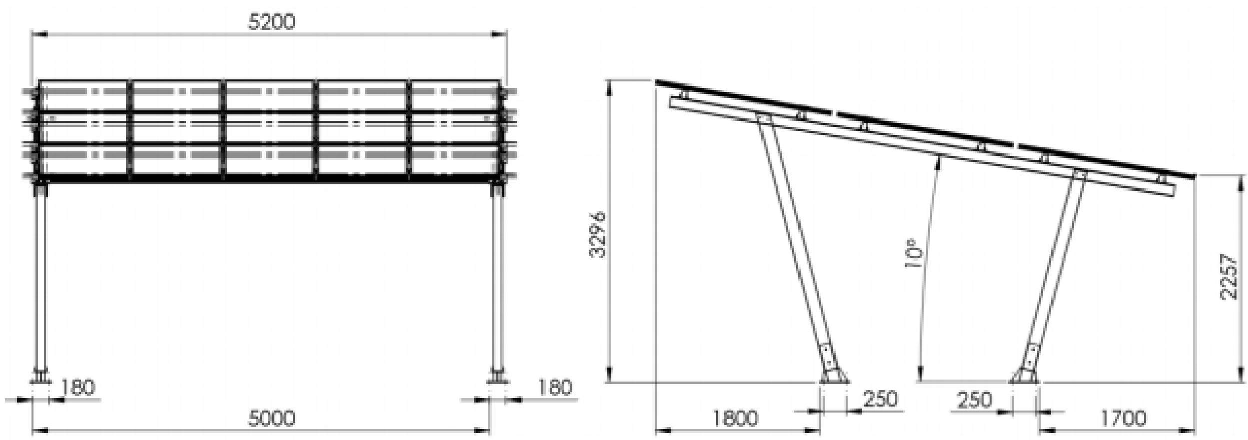

Figure 1. Carport structure for 2 parking spaces [6]

The CARPORT's cover structure is made up by 15 photovoltaic modules, arranged in 5 rows of 3 modules each. The company L8 Energy donated 6 units of the polycrystalline module model CS6U-335P, with 335 Wp each of Canadian Solar company and 9 units of the polycrystalline module model JKM320PP-72-V, with 320 Wp each, from Jinko Solar company. The Table 1 describes the modules main characteristics [6].

Table 1. Photovoltaic Modules Characteristics

	JKM320PP-72-V	CS6U-335P
Pmax	320Wp	335Wp
Vmp	37.4V	37.4V
Imp	8.56A	8.96A
Voc	46.4V	45.8V
Isc	9.05A	9.54A
Efficiency (%)	16.49%	17.23%

Source: Jinko Solar and Canadian Solar Datasheets, adapted [28][29]

There are two models of different photovoltaic modules and they were separated into two distinct strings. As a result, the inverter to be used in this system must have at least two independent maximum power point tracking (MPPT).

The photovoltaic arrangement is composed of a 2.01 kWp string, from the set of 6 modules with 335 Wp; and a 2.88 kWp string, composed of 9 modules of 320 Wp. Thus, the total power of the system, composed of the sum of the two strings, is 4.89 kWp.

The company Fronius supplied an inverter, model Fronius Primo 5.0-1, which has 5 kWp of power and an integrated monitoring system. In the Figure 2, the inverter used is showed in the upper right of the image. The Table 2 presents the main characteristics of the referred inverter.

Table 2: Technical Data – Inverter Fronius Primo 5.0-1

	Fronius Primo 5.0-1
MPPT number	2
MPPT1/MPPT2	12A/12A
Maximum Input DC	1000A
Voltage Range MPPT	80 – 800V
Rated Output Power AC	5000W
Maximum AC output Current AC	21.7A
Connection Network Voltage	1 – NPE 220V/230V
Network Frequency	50/60Hz

Source: Fronius Primo Datasheet, adapted [30].

For the system protection, the company Proauto donated a string-box, or connection board, with 4 inputs and 2 outputs, which allows to separate the strings and connect them to its respective MPPT inverter channel. The connection board contains, for each string, a set of a Dehn type II surge protection device (SPD) with a range of 1000 V DC, specific for photovoltaic applications, and a switch-disconnector with 1000 VDC and 25 A. For protection and sectioning on the AC side of the inverter, an electrical panel with a circuit breaker and an SPD were placed.

In the design of the pilot plant, it was defined that a short wall in front of the CARPORT would be built, with the measurements of 3.17m x 1.63m. The equipment would be sheltered from the rain, and also be exposed to the public, which contributes to the awareness of technologies. In the wall, the inverter, the string-box and the switchboard with AC protection were installed.

In addition, two standard plugs were installed, enabling EV Level 1 Charge Mode. When designing the wall, additional space was also provided for the installation of three additional vehicle chargers. In the conception of the design of this wall, space was provided for the installation of three vehicle chargers, because a multinational manufacturer was negotiating the donation of three equipment to the University. It means that the three vehicles rechargers were just planned in this carport development phase. Figure 2 shows the project wall firstly planned.

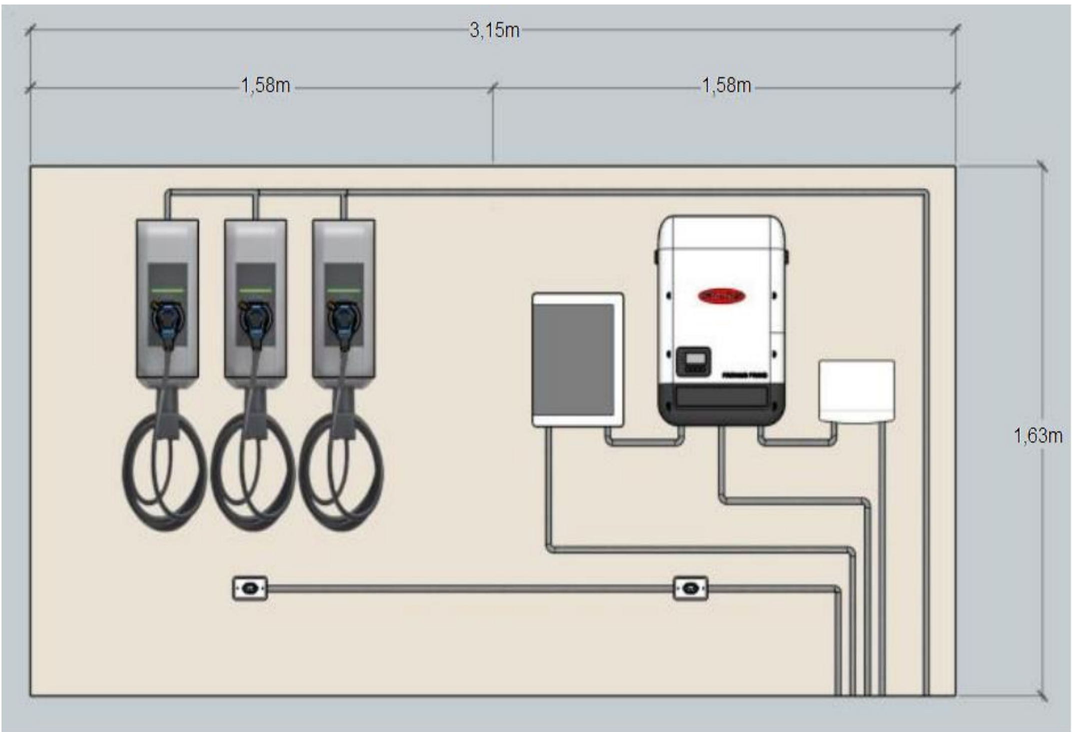

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Figure 2. Carport wall project to allocate the equipments [6]

The negotiation for the donation of the three vehicle chargers did not materialize and, at first, the University received a donation of only one charger. The first vehicle charger was donated and installed by EGNEX. The chosen model is ProEV1. The Figure 3 shows the model of the vehicle charger.

Figure 3. Charger EGNEX ProEV1, [11]

The parking lot at UTFPR's campus Neoville was available for the implementation of the pilot plant, as shown in Figure 4. The exact definition of the location was based on the spot with the lowest incidence of shading, due to the trees and lampposts present in the environment, as well as the proximity to the Neoville's powerhouse.

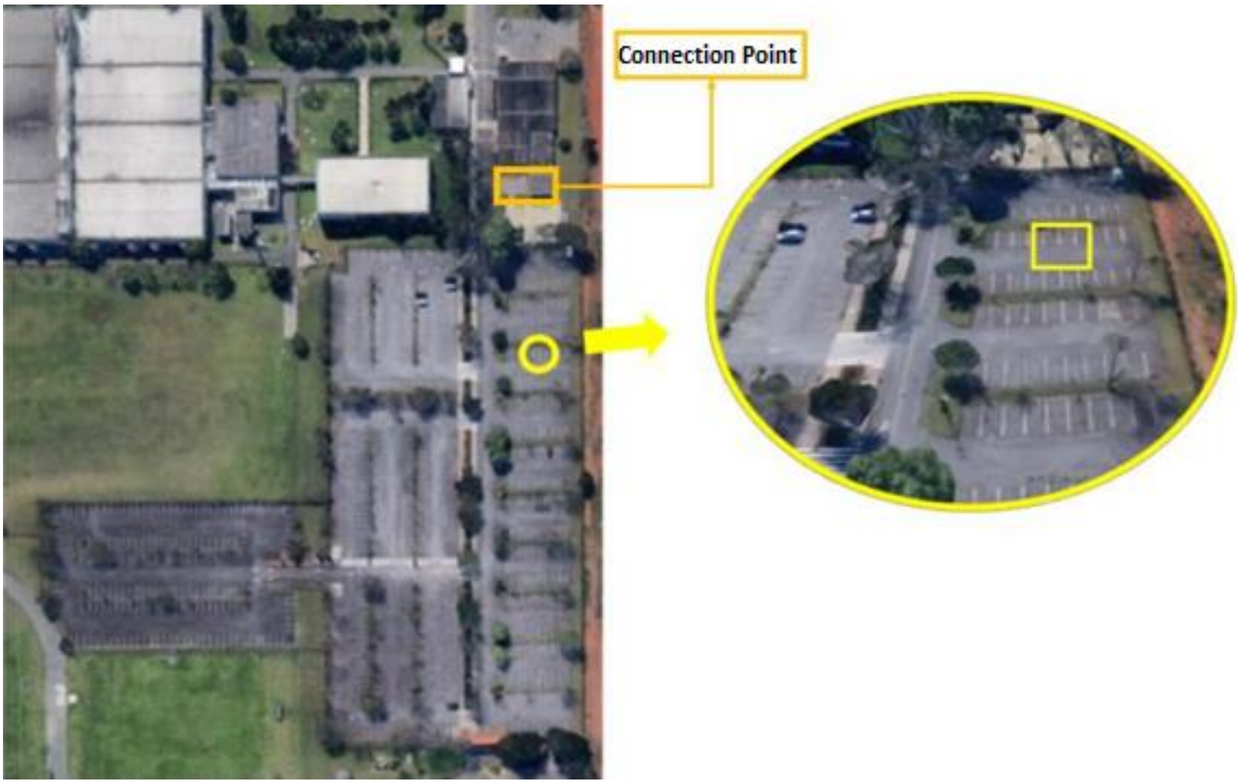


Figure 4. Carport location [6].

The steps and the final result of the implementation of the Carport pilot project can be seen in Figure 5 and 6. Comparing Figures 2 and 6, it can be seen the difference between the Carport wall project and the Carport wall executed after the electrical charger donated.

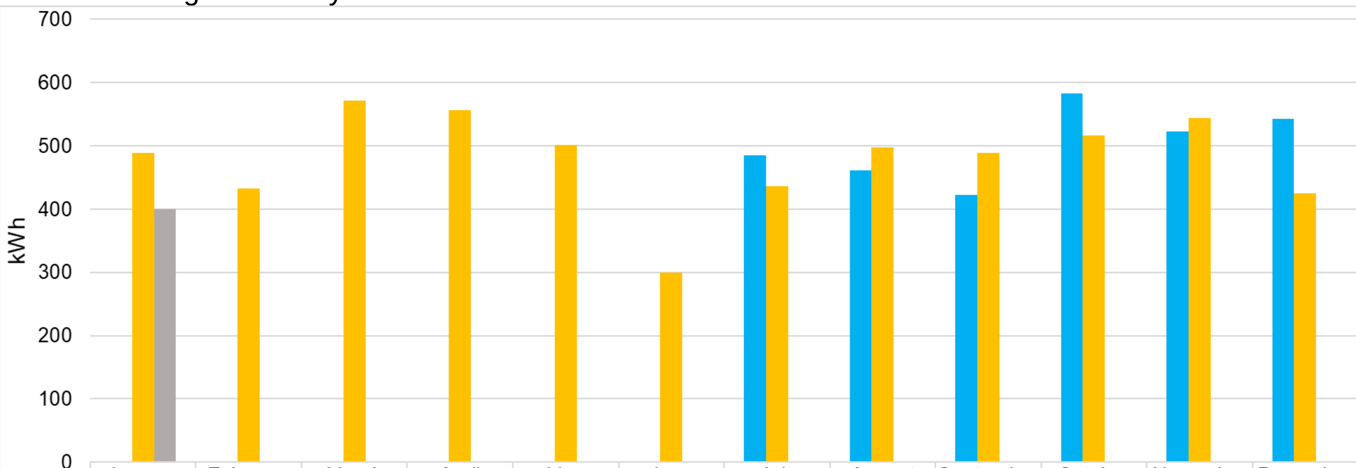
Figure 5. Pilot Project CARPORT - Result

Figure 6. CARPORT wall executed to allocate the equipments

Grid-connected photovoltaic system

A grid-connected photovoltaic system is composed basically by a photovoltaic panel, an inverter and electrical protections [16]. The Neoville's campus CARPORT has a power of 4.89kWp (6 modules Canadian Solar, polycrystalline silicon technology, model CS6U-335P and 9 modules Jinko Solar, polycrystalline silicon technology, model JKM320PP-72-V) connected in series in two different strings into a single-phase 220Volts with 5kW – rated power inverter and has started operating in July 2019. The structure occupies an area of 30m² and there is an inclination of 10º according to the manufacturer's instructions. It is located in the parking lot of UTFPR's campus Neoville, which has the following coordinates: -25.506039 latitude and -49.316472 longitude with an azimuth angle of -22º (22º West).

The electrical generation data of the photovoltaic system is obtained by accessing the mass memory of the inverter, through the website made available by the manufacturer, with restricted access defined by the user with an individual password. The collected generation data can be observed in Graph 1, starting in July 2019 and ending in January 2021.



	January	February	March	April	May	June	July	August	September	October	November	December
2019							485.01	461.21	422.06	582.13	521.9	541.93
2020	488.72	432.54	571.15	556.07	501.02	299.53	436.63	496.96	488.39	516.33	543.31	424.69
2021	400.08											

Graph 1. Inverter production historic.

One way of evaluating the generation of a photovoltaic system is by analyzing the merit indexes. These are important indices that show if the energy being generated by the systems in an optimized way and also make possible the comparison between other PV installations or other energy source. They consist of three calculations, as presented below [24].

Yield is the ratio between the generated energy (kWh) and the installed PV peak power (kWp) as shown in equation 1. With this index it is possible to compare different technologies or systems of diverse power rating [25].

$$YIELD = \frac{Energy\ Generation\ (kWh)}{PV\ Power\ (kWp)} \tag{1}$$

Performance Ratio (PR) is the relation between the previously calculate Yield (kWh / kWp) and the number of hours of sunshine at 1,000 W / m² incident on the PV panel. In practice, it is not possible to achieve a final value of 100%, but the higher the result, the lower the losses and the better the performance of the system. For dimensioning photovoltaic systems, a value between 70% and 80% is commonly adopted [19].

$$PR = \frac{\frac{YIELD}{Irradiation\ (kWp)}}{1000}, \tag{2}$$

Capacity Factor (CF) aims to compare different types of energy source, it is the ratio between the energy generated and the energy it would generate if it could stay in operation for 24 hours a day during a chosen period of days at nominal power. As the PV is an intermittent source, it remains between 13% and 18% in Brazil.

$$CF = \frac{Energy\ Generation\ (kWh)}{PV\ Power\ (kWp) \times 24 (hours) \times Days} \tag{3}$$

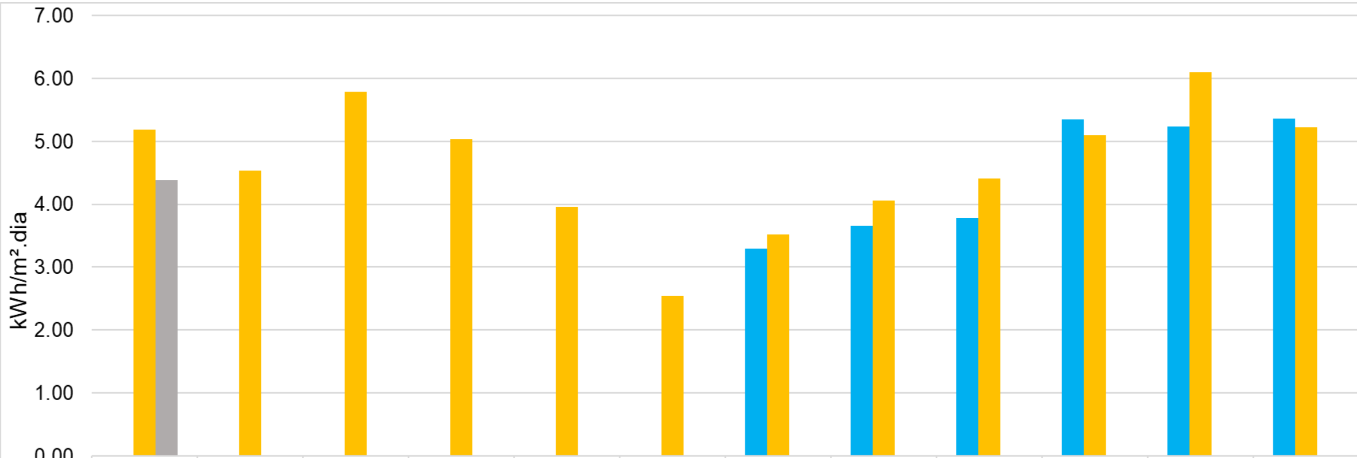
Merit Indexes

To calculate the merit indexes, the generation data of the inverter installed in the Carport System was collected and presented in Table 3. They are the same values previously presented on Graph 1. The data are given in kWh.

Table 3: Carport energy generation [kWh].

	2019	2020	2021
January		488.72	400.08
February		432.54	
March		571.15	
April		556.07	
May		501.02	
June		299.53	
July	485.01	436.63	
August	461.21	496.96	
September	422.06	488.39	
October	582.13	516.33	
November	521.9	543.31	
December	541.93	424.69	
Annual	3,014.24	5,755.34	400.08

The irradiation values were collected from the solarimetric station EPESOL - Solar Energy Research Station, located at UTFPR's Neoville campus, where the Carport System analyzed in this article is also installed. The UTFPRS's solarimetric station has been in operation since March 2020. Data from previous months were obtained from INMET (National Institute of Meteorology) base. All the irradiation data are in the horizontal plane and presented in Graph 2.



	January	February	March	April	May	June	July	August	September	October	November	December
2019							3.29	3.66	3.78	5.35	5.23	5.36
2020	5.19	4.53	5.79	5.03	3.96	2.54	3.52	4.05	4.41	5.10	6.10	5.22
2021	4.39											

Graph 2. Average daily irradiation in the horizontal plane [kWh/m². day].

For more efficient operation, photovoltaic modules must be oriented towards true north, when installed in the southern hemisphere, and facing south, when installation is carried out in the northern hemisphere. Another important parameter is the installation with an inclination equal to the local latitude, but this is not always possible, whether for architectural or financial reasons. The impact on electricity generation due to the difference between the real and the ideal configuration is measured by comparing them. One way to measure it, is by determining the difference in the amount of radiation that reaches the modules in both situations [27, 28].

The ideal solution would be to install pyranometers on the horizontal plane and at the same inclination and azimuth angle as the photovoltaic system, but the cost of implementation is relatively high. To make this operation simpler and less costly, software that converts data from monthly irradiance in the horizontal plane to any other angle of inclination and orientation were developed.

The Solar Energy Laboratory (LABSOL) of the School of Engineering of the Federal University of Rio Grande do Sul (UFRGS) in Porto Alegre - RS, developed mathematical models for computational simulation of irradiance data and made available two free software, called RADIASOL and RADIASOL2.

According to [28], a comparison between the two available software for the city of Curitiba, determined that RADIASOL2 presents results with less variations and errors in relation to the real data, therefore it was chosen to be used in the analysis.

Thus, to start using RADIASOL2, a new station must be configurated, inserting the data taken by INMET and EPESOL, with which the irradiance on the Carport modules plane can be calculated. The inclination and azimuthal angle were also inserted, which in the case of the study are 10º and 22º West, in addition to the geographic coordinates as shown in Figure 7.

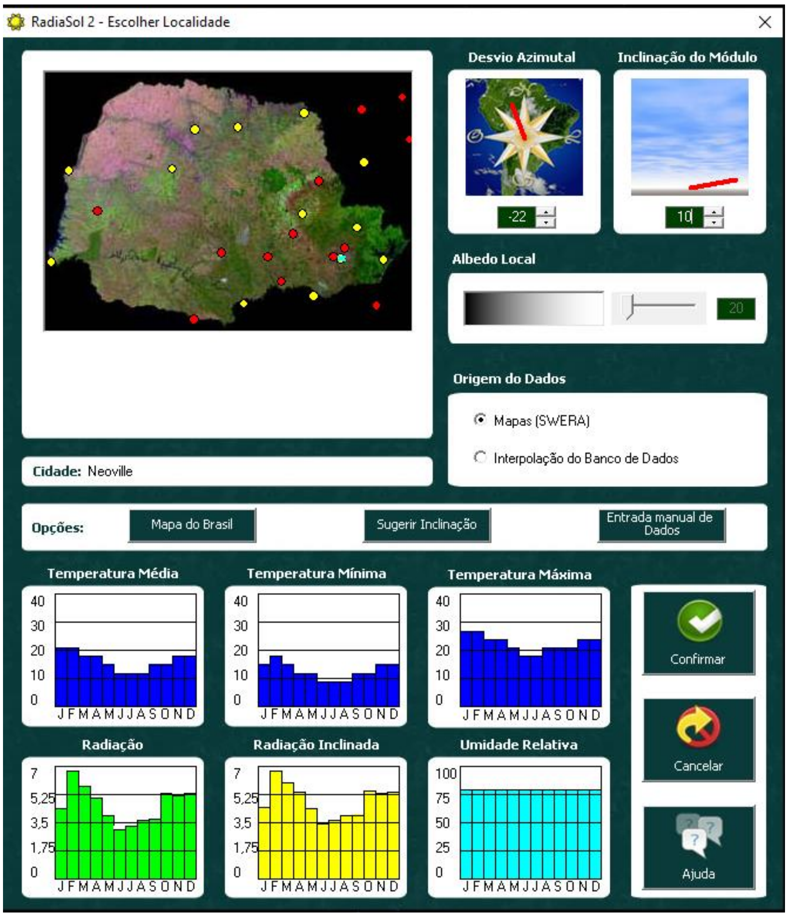
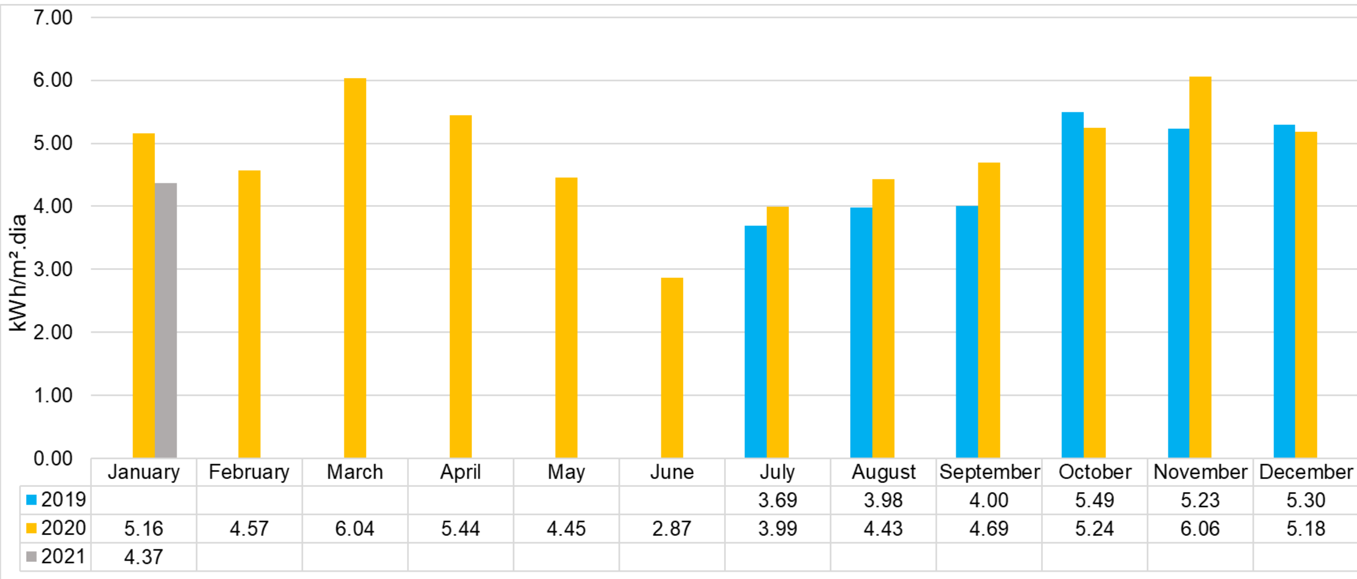


Figure 7. Radiasol 2- irradiation data from the new station created for the study.

After all the configurations, Radiasol2 performs the calculation of the data with the inclination and azimuth angle needed and provide a result for each month, as presented in Graphic 3.



	January	February	March	April	May	June	July	August	September	October	November	December
2019							3.69	3.98	4.00	5.49	5.23	5.30
2020	5.16	4.57	6.04	5.44	4.45	2.87	3.99	4.43	4.69	5.24	6.06	5.18
2021	4.37											

Graph 3. Average Daily Radiation on the Inclined Plane [kWh/m².day].

With the energy generation data collected from the inverter and the irradiation on the PV panel, is possible to calculate all the three merit indexes.

Yield

Table 4 shows the yield data from 2019 July until 2021 January. The calculation was made from Equation 1, considering 4.89kWp of PV power and the generated energy data presented in Table 3.

Table 4. Productivity values in the generation period [kWh/kWp].

	2019	2020	2021
January		99.94	81.82
February		88.45	
March		116.80	
April		113.72	
May		102.46	
June		61.25	
July	99.18	89.29	
August	94.32	101.63	
September	86.31	99.88	
October	119.04	105.59	
November	106.73	111.11	
December	110.82	86.85	
Annual	-	1,176.96	-

As the Yield is a division between the energy generation and the PV installed power, months with higher generation record also have the higher final yield values. For annual Yield taking 19 months into account, the annual equivalent is 1,184.33 kWh/kWp.

Performance Ratio

Table 5 shows the performance ratio results presented as a percentage. Some periods in which the results are lower than 70% could be interpreted as an alert, which may indicate long periods of shading or that the modules are dirty. Ideally, according to the literature, the final result should be between 70% and 80%.

Table 5. Performance Ratio [%].

	2019	2020	2021
January		62.48%	60.39%
February		66.74%	
March		62.38%	
April		69.68%	
May		74.27%	
June		71.14%	
July	86.71%	72.19%	
August	76.44%	74.00%	
September	71.93%	70.98%	
October	69.95%	65.00%	
November	68.02%	61.11%	
December	67.45%	54.08%	
Annual	-	67.01%	-

Performance ratio is the solar panel efficiency in a specific place after losses and it is used as a quality factor. In a PV system it is intended to achieve the higher possible results. Considering the 19 months analyzed of the system's operation, an average of 68.68% of performance Ratio is reached.

Capacity Factor

Table 6 shows the Carport Capacity Factor results. It must be observed that each month presents a varied number of days.

Table 6. Capacity Factor [%].

	2019	2020	2021
January		13.43%	11.00%
February		12.71%	
March		15.70%	
April		15.79%	
May		13.77%	
June		8.51%	
July	13.33%	12.00%	
August	12.68%	13.66%	
September	11.99%	13.87%	
October	16.00%	14.19%	
November	14.82%	15.43%	
December	14.90%	11.67%	
Annual	-	13.40%	-

The capacity factor makes possible the comparison between different energy generation systems, and it is usually linked to hydroelectric. For the PV point of view, as an energy source that can only operate during the day and depends on the weather conditions, the final values are typically low. The average of the Productivity Factor for the 19 months of acquired data results in an average of 13.45%.

Electric vehicles and solar energy

The costs to install a photovoltaic solar system in Brazil have decreased in the last years, attracting new potential customers and investors. The payback is usually five years, but also varies according to climatic factors of each region [16,20]. One way to reduce the payback time for investment in photovoltaic systems and also reduce the emission of global warming gases, is the combinate use of Grid-Connected Photovoltaic System with Electric Vehicles [20]. In the moment that the two systems are combined (Grid-Connected System and EV use), occurs the elimination of the cost of fossil fuel and therefore the payback of the photovoltaic installation system is reduced.

When an electric motor is started, it absorbs about 90% of electrical energy and turns it into torque, the process of converting energy into work result in mechanical power [21]. The Electric Vehicles are currently an alternative to internal combustion engines.

Due to the high cost of oil and the seek for environmentally friendly solutions, the manufactures are working on the development of Electric vehicles that are economically competitive and provide the same comfort of conventional combustion cars, implementing measures on an industrial scale for technological development and use of components less related to fossil fuels [16].

For studies purpose, a market research was done in the EVs catalog, and Nissan Leaf was used as an object for analysis and comparison. Based on technical parameters, other EVs in the same category can have lower electrical consumption compared with the study case, but the Nissan Leaf has the autonomy of 175km and can run 7.3km for each kWh consumed by the electrical motor [24].The values are related to autonomy, corresponding to the number of kilometers that the vehicle can travel without recharging the battery [21].

RESULTS AND DISCUSSION

From Table 4, it can be calculated that the carport generates an average 483 kWh/month from July 2019 to January 2021. Admitting the Nissan Leaf as a popular electric car for the basis of the study among electric vehicles sold in Brazil, although there are other EVs in the same category with lower consumption, this EV was used to present the case study as conservative.

Calculating an average consumption of 0.137 kWh per kilometer traveled, it is estimated that it is possible to drive in the city of Curitiba, 3,525.5 km with the energy generated by the carport in a month [12].

According to Quatro Rodas magazine, in 2018 the best-selling car in Brazil it was the Chevrolet Ônix, with more than 210 thousand units sold. Taking the consumption and energy efficiency for motor vehicles, from National Institute of Metrology, Quality and Technology (INMETRO), is determined that the combustion-powered car emits 100 grams of dioxide of carbon per kilometer traveled (gCO_2/km), or 0.1 kg/km [16]. The

Ônix 2018 consume is about 12,1km/l according the manufacturer, chevrolet. According National Agency of Petrol (ANP), the medium price to gasoline in the Curitiba city nowadays is about R$ 4,997/l [23].

Based on the distance that can be traveled with the car only with the electricity from the carport, 3,525.5 km, it is possible to determine that the electric car would avoid the emission of 352.55 $kgCO_2$ monthly, or 4.23 $tonCO_2$ in a full year. The total distance that could be traveled with the energy generation of the carport in twelve months, is about 42,310.8 km [16]. The table 7 shows the numbers exposed.

Table 7. Avoided carbon dioxide (CO_2) emission by Nissan Leaf EV with the carport energy generation, consumption in kWh, autonomy and total distance traveled in one year.

VE Model	Consumption of kWh per km traveled (kWh/km)	km/kWh	Battery (kWh)	Autonomy (km)	km/kWh x carport energy generated x 12 months (km)	ton of CO2 avoided per year (tonCO2.year)
Nissan Leaf	0.137	7.3	24.00	175	42,310.80	4.23

Source: Adapted [16,24]

Considering this study case with only the photovoltaic generation of a carport with two parking spaces and for an EV, the results present in table 3 show that the use of photovoltaic systems in urban environments is one of the alternatives for reducing CO_2 emissions and for power generation.

Compared to the combustion vehicle Ônix, considering a consumption of 12.1km/l, the average price of gasoline 4.997R$/l nowadays, to run the monthly 3,525.5km generated by the carport, the Ônix would spend around R$ 1,455.94 with gasoline monthly, it means R$ 17,471.33 per year. It is important to note that this cost is completely avoided if the Ônix vehicle is replaced by the Nissan Leaf EV, recharged by the UTFPR's carport campus Neoville (the value of the electric car is disregarded in this study).

CONCLUSION

In a scenario where we still have a large amount of greenhouse gases emissions that increase global warming, particularly carbon dioxide and growth of cities in developing countries like Brazil, including the increase in vehicles powered by fossil fuels, it is necessary a review of our construction systems and photovoltaic integration is urgently needed, use of electricity and mobility, aimed at a sustainable urban model [16].

The expansion of the availability of electricity from renewable sources in Brazilian cities and an integration of photovoltaic systems to buildings is one of the ways in which technology can be used to establish a change in the paradigm in the coming years as a result of the distributed generation of electricity, promoting urban environments that are less dependent on non-renewable sources.

The reduction of carbon dioxide emissions using vehicles results in the reduction of greenhouse gases, which contribute for the global warming, and distributed electricity generation could supply the demand for recharging batteries of electric vehicles daily. In an optimistic scenario, this would allow a progressive reduction in emission of carbon dioxide and other gases harmful to the Earth's atmosphere, produced by vehicles powered by combustion [16]. This fact would lead an improvement in air quality in large urban centers and a consequent improvement in people's health and quality of life.

The merit indexes presented that performance ration of the PV system is in most of the months is lower than 70%, value considered slightly below the expected standard in the calculations. It can indicate that a cleaning might be necessary.

The carport installed at Neoville presented a monthly average energy generated of 483 kWh, which is enough to drive a Nissan Leaf for 3,525.5 km, representing 117.5 km per day. These make possible for a person that lives and work in the city to have an electric car without worries of not being able to recharge the car.

The PV solar system is generating an average of 463 kWh/month of electric energy, contributing for a reduction in the University final energy consumption, proving that it can be considered a viable investment. From the educational point of view, the carport is a laboratory, which can be used in numerous amounts of studies regarding to energy generation, EV charging, electrical mobility. Offering a recharging center may also be a stimulus for an increase in the usage of EV.

Other relevant aspect is regarding the return on investment (ROI) in a photovoltaic system. When analyzed the aspect of electricity only, it is about 5 years, but if the analysis is also in the aspect of the fuel saved, comparatively a vehicle similar to combustion, the payback on the investment of the photovoltaic system falls to about 1 year. The money saved without paying the fossil fuel yearly is near the costs to install all the photovoltaic system nowadays.

The analyzed Carport has two parking spaces, thereby, based on the production and consumption results of a vehicle, when considering two vehicles with the existing characteristics occupying the parking and being loaded by this carport, each vehicle would have a range of 58 km per day, reaching 1,762 km per month. This autonomy, per parking space, is perfectly adherent to the profile of using an urban vehicle in daily activities.

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