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Implementation of a Photovoltaic Panel to Supply Electric Cars Energy Demands

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ABSTRACT

The gradual shifting of the energy matrix to renewable sources is one of the main global strategies for sustainable development. According to studies, the use of electric energy by automobiles would lead to a reduction in gasoline consumption of 40.7% in 2031, accompanied by an increase in electricity consumption of 42.1% in relation to official projections. However, the gradual and constant dissemination and use of electric vehicles, a new paradigm emerges, which is the need to supply the energy demand of this new charge in the electric system The use of solar radiation to generate electricity to meet this new demand presents a sustainable alternative. From these questions, a structure was designed with the installation of a photovoltaic solar panel linked to the use of electric vehicles, analyzing estimated values of energy production and avoided emissions of CO_2, compared to the average consumption of several models to cover 21,900km per year. The results show that the Renault Twizy was the only model whose consumption was below the energy production of the projected photovoltaic system. In contrast, all models had a positive balance in the estimates of avoided CO2, forming an environmentally sustainable solution.

Key words: Photovoltaic energy, electric car.

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INTRODUCTION

Electrical energy suply is currently fundamental in human relations and needs. Its uninterrupted availability is a strategic and a critical factor in nations and city systems of our contemporary society. Eletric supplies interruptions may cause economic and safety instability. In Brazil, whose hydroelectric generation corresponds to about 68.1% of the country's energy matrix[1] hydrological crises due to droughts caused the blackout crisis between 2001 and 2002, exposing the system´s vulnerability.

The use of renewable energy for electricity generation is one of the alternatives for sustainable development. Solar energy, with relative abundancy and availability over the Brazilian territory, is a viable and sustainable alternative for electric generation.

Photovoltaic energy, based on solar energy, begins with the direct and diffuse radiation focusing on a certain surface. The direct radiation corresponds to the rays of sun that come directly at the surface, and the diffuse radiation corresponds to the rays of sun that come indirectly to the surface due to atmospheric dust, clouds or other possible surroundings objects. The photovoltaic modules are composed of cells that convert light into electric energy through the photovoltaic effect of semiconductor materials[2].

In the automotive industry, electric cars have always been linked to the power source, or lack thereof, either by the autonomy of the accumulators (batteries) or the engines efficiency. Nowadays, the electric vehicles have autonomies beginning at 60 km (Volteis X4), to 426 km (Tesla S)[3], but a new problem arises: the need to supply the energy demand of this new load in the electrical system. According to Baran[4] the use of electric energy by automobiles would lead to a 40.7% reduction in gasoline consumption by 2031, accompanied by an increase in electricity consumption of 42.1% in relation to official projections.

PHOTOVOLTAIC CAR PORCH

From a commercial perspective, Car Porchs can be an attractive investment for suppliers of energy solutions, who seek to combine design with micro solar energy generation.

This type of structures can be installed independently, reducing or eliminating the need for interventions in existing buildings and structures. Such interventions can lead to higher risks and installations costs, and its construction at ground level allows some advantages in time and construction costs.

The integrated solution, where the modules and panels play a dual role, acting as both roof material and a component of the electric power generation system, reduces costs compared to a building where the panel is simply applied to an existing roof. BIPV systems (Building-integrated photovoltaics) architecture, aesthetics, functionality and energy generation in a holistic solution, where the photovoltaic element assumes a prominent role in design, fulfilling two or more roles in building materials. Thus, replacing roofing materials with photovoltaic components, the original material cost is avoided, makingthis solution economically feasible.

However, it is necessary to solve seals and infiltration between the modules, since most PV products are not manufactured to be used as a cover structure, therefore it is necessary to use specially designed rails and ruffles as a roofing material.

CAR PORCH DESIGN

The cover will be installed at the Neoville Campus, of the Federal Technological University of Paraná, in the city of Curitiba. Some criteria and conditions for coverage design were established:

- Easy assembly structure;
- Maximum size of a standard parking space, 2.5m x 5.0m;
- Ideal modules Tilt with ideal azimuth deviation angle (Curitiba 25,51 S; 49,27 W);
- Use of a maximum of four PV modules;

According to the criteria adopted for the elaboration of the project, the grid-connected photovoltaic power system will have the following characteristics and specifications:

- Photovoltaic array composed by four modules of 315 Wp connected in series, measuring about 1.0m x 2.0m;
- EcoSolys Ecos 1000 model inverter;
- Modules tilt 25º angle and 0º azimuthal deviation (North orientation).
- Structure plan measuring 2,5m x 4,0m (10,0m²);

Other devices were projected like electric plugs and electrical plumbing, attached to a fixed totem. The design of the structure is illustrated in Figure 1.

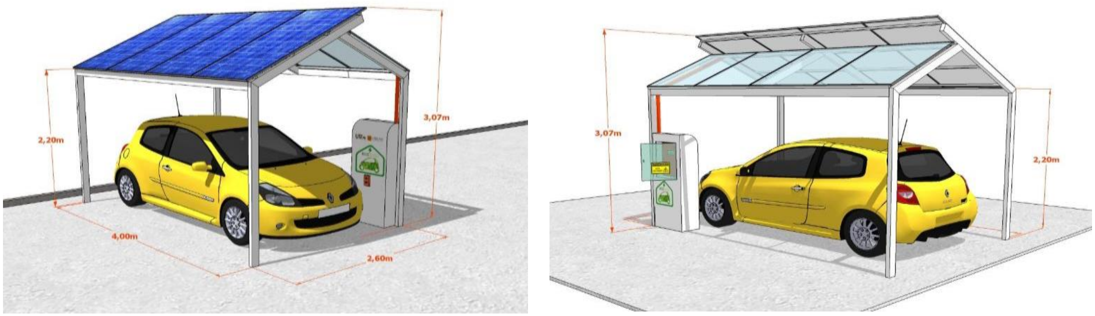

Figure 1- Car porch Design.
Source: Tha autors 2017.

ELECTRIC VEHICLES

Electric cars are a more environmentally friendly option. However, in Brazil there are no government incentives, so the purchase values are still high. Silva, Tonin, Urbanetz[5] explains that when the electric motor is turned on, it absorbs 90% of the amount of electrical energy and turns it into torque, that is, mechanical power. The electric engine transforms the electrical power into mechanical power, with a reduced percentage of losses.

The world scenario highlights that electric cars will trend in the next few years, but Brazil is moving slowly into this future scenario. The automotive industry market makes it clear that the trend for the coming years is electric vehicles. Countries such as Norway and Holland were the largest buyers of electric vehicles in the first quarter of 2015.[6]

To calculate the autonomy and average consumption of electric vehicles, the manufacturers data of these vehicles are shown in Table 1.

Table 1- electric vehicles autonomy

Model	Energy Consumption in 100 km (kWh)	Autonomy km)	Battery Energy (kWh)
Renault Twizy 45	5.10	120	6.10
Mega City	9.00	100	9.00
Mia Electric	10.00	80	8.00
Lumeneo Neoma	10.10	140	14.20
Renault Zoé	10.50	210	22.00
Citroën C-Zéro	10.70	150	16.00
Little 4	11.00	100	11.00
Renault Fluence Z.E	11.90	185	22.00
Bolloré Bluecar	12.00	250	30.00
Smart Fortwo E.D.	12.10	145	17.60
Renault Kangoo Z.E.	12.90	170	20.00
Nissan Leaf	13.70	175	24.00
Ford Focus EV	14.30	160	23.00
FAM F-City	14.40	100	14.40
Tesla Roadster	15.10	350	53.00
Volteis X4	19.10	60	14.50
Tesla S	19.90	426	85.00

Source: Adapted.[3]

METHOD

The photovoltaic energy generation estimate was performed initially using the number of modules to calculate their power. The power of each module is multiplied by the number of modules to achieve the system installed power (Pfv).[7]

$$P_{Fv} = P_{mód} \; x \; N_{mód} \qquad (1)$$

where:
P_{Fv} is ther installed power;
$P_{mód}$ Is the nominal power of each PV module
$N_{mód}$ is the total number of modules.
The daily energy can be achieved through equation 2 based on the work of Mariano, Santos, Brito, Urbanetz, Casagrande[8]. The value of Htot considered was 5.55 kWh/m²/day. This value was applied in the calculation of the daily electric energy generation (equation 2) resulting in 5.24 kWh / day, which multiplied by 365 days results in an average annual energy of 1,912.60 kWh / year.

$$E_{fv} = \frac{P_{FV} \; x \; H_{tot} \; x \; PR}{G} \; x \; 365 \qquad (2)$$

Where:
Efv is annual electricity to be generated (kWh/year);
Htot is the solar radiation available (kWh/m² x day);
PR is the Performance Ratio (between 70% to 80%);
G is the average irradiance at the Earth's surface (1,000 W/m²).

According to Silva, Tonin, Urbanetz[5] "after a number of surveys the manufacturers have concluded that 60 km per day is an average of the distance traveled by drivers to carry out their daily activities, that average varies from 40 km (UK) to an average of 80 km (Poland)". Thus, it was adopted as base 60km/day, which multiplied by the amount of annual days, results in 21,900km/year. This value was used to estimate the energy needed for each model to travel one year according to table 2, calculated by equation 2:

$$Eyear = (E1/100) \times 21{,}900.00 \text{ km/year} \qquad (3)$$

Where:
Eyear is the energy required to run 21,900 km/year
E1 is the energy to run 100km (kWh)
These values were used to estimate the amount of CO_2 avoided by the SFVCR/vehicle set, according to each model.

RESULTS AND DISCUSSIONS

The electric car will be used during the daytime period, exactly when the panel will be generating power, and charged at night, using the distributor's energy to charge it. As the generation and use of the vehicle occurs concurrently, the energy produced must be sent to the distribution system, so the energy generated by the panel during the day will be sent to the public grid using the electric compensation system.

With the result of equations 2 and 3, it was possible to verify the energy balance, that is, the difference between the demanded energy E1 and the generated energy Efv. This result represents the energy that will have to be served by the network, or in case of a positive energy balance, credits are obtained from the distribution company. This value was calculated by equation 4.

$$Er = Efv - Eyear \qquad (4)$$

Where:
Er is the energy that will be served by the grid (kWh/year).
This result was used in equation 5, which represents the percentage of energy supplied by the SFVCR in relation to the energy demanded (kWh) for each model to cover 21,900km per year.

$$Eb = Efv/Eyear \qquad (5)$$

Where:
Eb is the percentage of energy served by SFVCR in relation to the energy demanded (kWh) for each model to cover 21,900km per year.

Then it was calculated the CO_2 avoided, having 3 factors. The first is the amount of CO_2 avoided for electricity generation, that is, each kWh generated by the panel with a renewable source avoids emission corresponding to the emissions of the Brazilian energy matrix. Each kWh generated with a renewable source would avoid 0,1013 kg of CO_2 in the atmosphere. The second factor corresponds to the CO_2 avoided per km driven by electric energy, that is, the amount of CO_2 avoided in comparison to the amount of CO_2 emitted by the use of a combustion drive vehicle. On average, a ride vehicle with 1.0cc to 2.0cc engine emits on average 0.06329 kg of CO_2 for each kilometer driven, which multiplied by 21,900km / year results in about 1,386.05 kg of CO_2/year. And the third factor refers to the energy balance, that is, the amount of energy that needed to be complemented by the network energy multiplied by the emissions compatible with the Brazilian electricity generation matrix to produce each kWh.[1] This CO_2 balance, released or avoided, was calculated by equation 6.

$$CO_2 = (Efv \times 0.1013) + CO_2R + (-Er \times 0.1013) \quad (6)$$

Where:
CO_2 is the amount of CO_2 avoided (kg);
CO_2R is the amount of CO_2 avoided by running with an electric source (1,386.05 kg/year);
E_r is the energy that will be served by the grid (kWh/year).

Table 2- Comparison between estimated energy production and consumption of several electric cars

Model	E1(kWh)	Eyear (kWh/year)	Er(kWh)	Eb(%)	CO2 avoided
Renault Twizy 45	5.10	1,116.90	-795.70	171.24	1,660.40
Mega City	9.00	1,971.00	58.40	97.04	1,573.88
Mia Electric	10.00	2,190.00	277.40	87.33	1,551.70
Lumeneo Neoma	10.10	2,211.90	299.30	86.47	1,549.48
Renault Zoé	10.50	2,299.50	386.90	83.17	1,540.60
Citroën C-Zéro	10.70	2,343.30	430.70	81.62	1,536.17
Little 4	11.00	2,409.00	496.40	79.39	1,529.51
Renault Fluence Z.E	11.90	2,606.10	693.50	73.39	1,509.54
Bolloré Blueca	12.00	2,628.00	715.40	72.78	1,507.33
Smart Fortwo E.D.	12.10	2,649.90	737.30	72.18	1,505.11
Renault Kangoo Z.E.	12.90	2,825.10	912.50	67.70	1,487.36
Nissan Leaf	13.70	3,000.30	1.087.70	63.75	1,469.61
Ford Focus EV	14.30	3,131.70	1.219.10	61.07	1,456.30
FAM F-City	14.40	3,153.60	1.241.00	60.65	1,454.08
Tesla Roadster	15.10	3,306.90	1.394.30	57.84	1,438.55
Volteis X4	19.10	4,182.90	2.270.30	45.72	1,349.81
Tesla S	19.90	4,358.10	2.445.50	43.89	1,332.07

Source: Authors, 2017.

The results obtained in Table 2 demonstrates that the Renault Twizzy has the lowest consumption of electricity, having at the end of the year a surplus of energy, according to the average of 21,900 km/year traveled. According to the Agencia Nacional de Energia Eletrica (ANEEL) – National Electric Energy Agency, this surplus would generate energy credits in energy distribution companies. However, the solar panel would generate only 44% of energy for the Tesla S vehicle, being the use of energy from the distributor necessary, to run 21,900 km/year.

However, the use of photovoltaic energy reduces the impacts caused by the greenhouse effect, resulting from the burning of fossil fuels. According to Santos[9] the amount of carbon dioxide that can be avoided, the energy generation of the photovoltaic has to be linked to it, which should be multiplied by 0.064; resulting in the value in kg of CO_2.

It can be noticed that even with positive energy balance, all models would have a positive CO_2 balance, that is, they would generate carbon credits.

CONCLUSIONS

With the increasing accessibility and demand for fossil fuel-powered motor vehicles, and the characteristic pollution factors of these types of engines, electric vehicles appear as a less polluting and environmentally responsible alternative. The increase in the demand for electric energy, as an inherent consequence and collateral to this process, demands the search for renewable sources of generation, since the electric generation from fossil sources would imply in the increase of the emissions, which could have a reverse environmental effect. In this articled a SFVCR was designed with 1.26kWp, which is intended to be implemented to generate electric energy concomitantly to the use of electric vehicles, seeking to combine generation, mobility and electric demand in a sustainable set. According to the characteristics of each model, there is a higher or lower balance of energy used in the power grid. The results demonstrate a positive CO_2 balance for all models due to avoided emissions, either by photovoltaic electric generation or by the utilization of electric vehicles, which implies a coherent and responsible environmental solution, in line with the overall path in the sustainable development.

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