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MATHEMATICAL MODEL TO CONVERT SMALL COMBUSTION ENGINE TRUCKS FOR ELECTRIC TRACTION WITH PHOTOVOLTAIC PANEL ON THE VEHICLE ROOF

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Abstract. *According to the latest National Energy Balance of 2023, the Transport sector is the one that consumes the largest amount of energy used in Brazil. Of this total, almost half comes from diesel oil, showing the high dependence of this sector on fossil fuels. The use of electric traction in Brazil is appropriate since the production of electricity in the country is predominantly renewable. This approach was the basis for the preparation of this work, which describes a methodology for converting urban freight trucks, with an internal combustion engine, into electric traction, the so-called "retrofit". Regenerative braking and a photovoltaic panel on the vehicle roof are included, aiming at greater autonomy. This article aims to contribute to increasing energy efficiency and reducing the emission of greenhouse gases and various pollutants. Theoretical calculations were prepared to establish a code in MATLAB, which allows entering the original data of the internal combustion truck and obtaining the necessary values to select the most suitable electric motor to replace the original engine. Therefore, the proposed "retrofit" enables the electrification of existing fleets, which provides a new job market and a viable technical option to accelerate the transition towards sustainable mobility in freight trucks.*

Keywords: *Electric Vehicle, Traction Conversion, Energy Efficiency, Environment, Photovoltaic Panel*

1. INTRODUCTION

Demand for urban freight transport has increased significantly due to urbanization and population growth, along with the greater spread of e-commerce, and new management principles such as the so-called "just-in-time" known by de acronym "JIT". It means a process that requires having an idea of the right time, sufficient quantity, and correct location as well the introduction of pervasive new technologies (Perboli and Rosano, 2019).

Ever-increasing e-commerce volumes, which still saw a global growth rate of 23.3% in 2018. The COVID-19 pandemic, has led to huge parcel volumes requiring daily deliveries, especially in large urban areas. More and more delivery vehicles are needed to go the "last mile" to customers (Schwerdfeger and Boysen, 2020). This scenario is currently maintained.

Due to the increasing movement of trucks in urban areas, modern cities face congestion, lack of public space, air and noise pollution, affecting the quality of life. In accordance with Janjevic et al. (2019) urban freight logistics activities have a considerable impact on three different aspects of sustainability: the economic, because there is prejudice to efficiency and operations costs, the environment due to $CO_{2\text{-}eq}$ emissions and the social, due to congestion. The symbol $CO_{2\text{-}eq}$ considers all greenhouse gases, that is, the seven direct greenhouse gases under the Kyoto Protocol: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride (SF_6), Nitrogen trifluoride (NF_3).

According to the latest Brazilian Energy Balance, prepared by the Energy Research Office (EPE, 2023) the Transport Sector consumes the largest amount of energy in Brazil, 33% as shown in Table 1.

Table 1. Energy consumption by economic sectors in 2022 (EPE, 2023).

Sector	Value
Transport	33.0 %

Industries	32.0 %
Residences	10.7 %
Energy	8.7 %
Farming	4.8 %
Services	5.0 %
Non-energy use	5.9 %

In practice, almost 1/3 of Brazilian energy is utilized by the Transport sector and approximately half comes from Diesel oil, with 44.6%. As a matter of fact, there is a high dependence on fossil fuels.

Table 2 shows the percentage shares of fuel consumed in the Transport sector in Brazil in 2022 (EPE, 2023). Diesel oil is the largest and it is used to supply trucks and buses, followed by gasoline with 27.1%, in general, to supply automobiles.

Table 2. Percentage shares of fuel consumed by the Transport sector in Brazil (EPE, 2023).

Fuel consumed	**Percentage**
Diesel oil	44.6 %
Biodiesel	4.6 %
Gasoline	27.1 %
Ethanol	16.9 %
Aviation kerosene	3.5 %
Natural gas	2.2 %
Others	1.0 %

Consequently, the transport sector also stands out in $CO_{2\text{-}eq}$ emissions, with 49.73% of total emissions in accordance with Table 3.

Table 3. Brazilian $CO_{2\text{-}eq}$ emissions (EPE, 2023).

Sector	**Total emissions (2022) in Mt $CO_{2\text{-}eq}$**	**Percentage**
Transport	210.4	49.73 %
Industries	76.7	18.13 %
Residences	18.6	4.40 %
Others sectors(1)	117.4	27.74 %

(1) Includes the agricultural, services, energy, electricity and fugitive emissions sectors.

Despite the Brazilian transport sector being concentrated in road vehicles with road combustion engines, and therefore there is low efficiency and high $CO_{2\text{-}eq}$ emissions, it is important to mention Brazil has a privileged position worldwide in the electric energy sector. Renewable sources represent 86.1% of the domestic electricity supply in the country with emphasis on the hydroelectric plants, which account for 61.9% and the use of wind and solar energy is growing as shown by Table 4 in accordance with (EPE, 2023).

Table 4. Total electricity supply by source (EPE, 2023).

Source	**Percentage**
Hydro	61.9 %
Biomass	8.0 %
Wind	11.8 %
Solar	4.4 %
Coal and coal products	2.1 %
Natural gas	6.1 %
Oil products	1.8 %
Nuclear	2.1 %

Based on this presented data, the investment and use of electric traction in Brazil is adequate since the production of electric energy in the country is predominantly renewable. Another favorable argument for the electrification of transport in Brazil is due to the country's extensive, fully interconnected electrical grid. In this way, it can be stated that the refueling of electric vehicle fleets using renewable energy sources allows a significant reduction of environmental impacts in the country. In this context, electric vehicles emerge as an alternative for sustainable urban freight, especially for freight transport in cities.

This work will address the retrofit. It is a technique to transform combustion-powered vehicles into electric vehicles, by replacing the combustion engine and other mechanical components with an electric motor, a set of high-capacity batteries and other complementary peripherals.

The types of existing electric vehicles, the components of a battery electric vehicle, photovoltaic cells, and the modeling of a photovoltaic electric vehicle were researched.

As a basis for modeling, the Hyundai HR light commercial vehicle was considered. In fact, it is designed mainly for cargo transport purposes and is also widely used in large urban centers for many applications, which makes it a great option for urban transport goods in large cities. Table 5 presents the characteristics of the Hyundai HR.

Table 5. Hyundai HR catalog data.

Fuel	Diesel
Fuel tank (liters)	65
Urban consumption (km/l)	8
Useful load capacity + body (kg)	2004
Total gross weight (kg)	3480
Number of occupants	2
Time from 0 to 100 (s)	20
Maximum speed (km/h)	140

Figure 1 shows a diagram for the proposed road vehicle in order to a better project understanding.

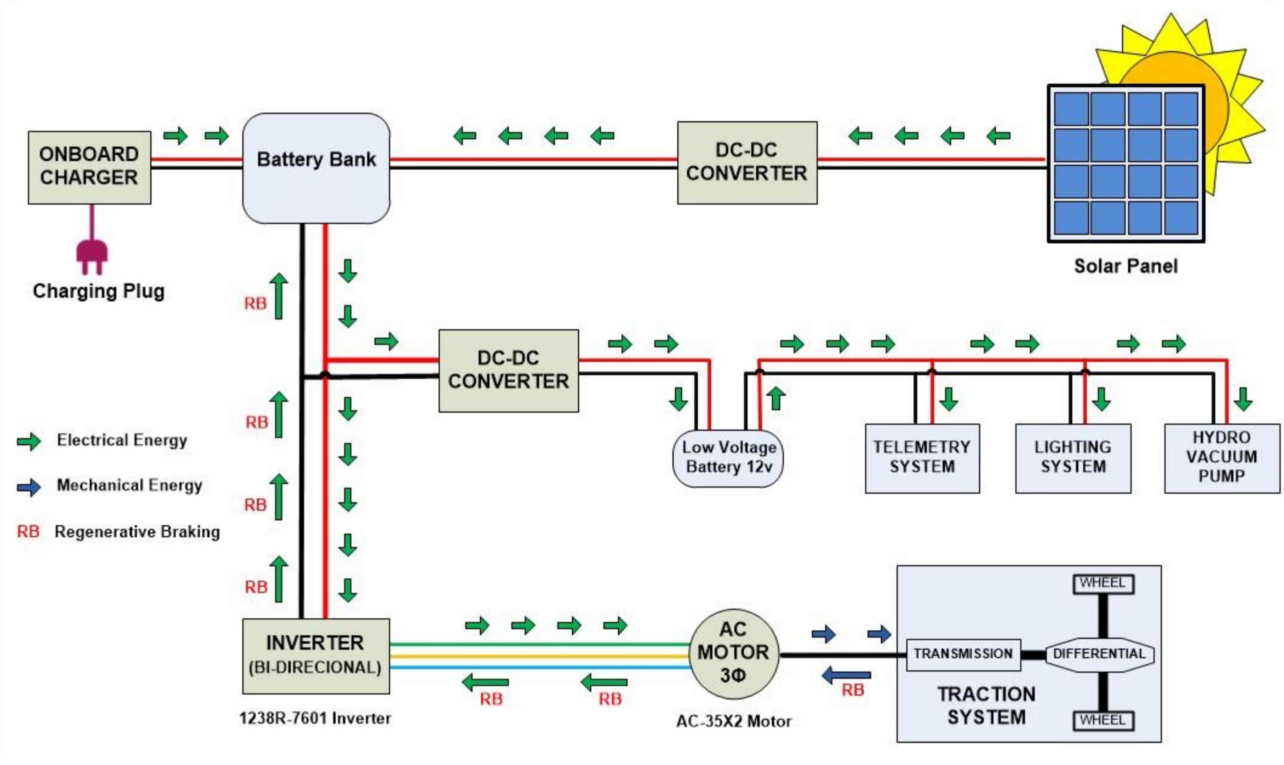

Figure 1. Diagram of photovoltaic electric vehicle.

2. INTERNAL COMBUSTION ENGINE TRUCK CONVERSION TO ELECTRIC TRACTION

The beginning of the elaboration to convert the internal combustion truck was considered the space available for the engine and the battery bank. Then, taking the total mass of the vehicle as a basis, two important displacement conditions were taken into account: the start, when the vehicle will need to overcome inertia, assuming the highest uphill inclination angle of the route and the maximum speed that the vehicle can reach on a flat path (Costa, 2009).

Mathematical simulations were utilized to predict extreme system operating conditions: torque required for the vehicle to overcome the highest route angle to be performed and the system behavior when the vehicle reaches its maximum speed on the wheels. These conditions make it possible to define the necessary torques for each condition presented and, as a result, choose the most suitable electric motor available on the market.

Basically, the vehicle's traction system sizing consists of the performance specifications meeting established in the project in accordance with the physical laws that govern vehicle dynamics (Tanaka, 2013).

The first step in vehicle performance modeling is to consider the tractive effort equation. The tractive force propels the vehicle forward and is transmitted to the ground through the drive wheels (Larminie and Lowry, 2012).

Consider a vehicle of mass m, proceeding at a velocity v, up a slope of angle θ, as in Figure 2. The force propelling the vehicle forward, the tractive effort, needs to overcome the rolling resistance, overcome the aerodynamic drag, and provide the force needed to overcome the component of the vehicle´s weight acting downwards, for example, in a slope and still accelerate the vehicle with a non-constant speed (Larminie and Lowry, 2012).

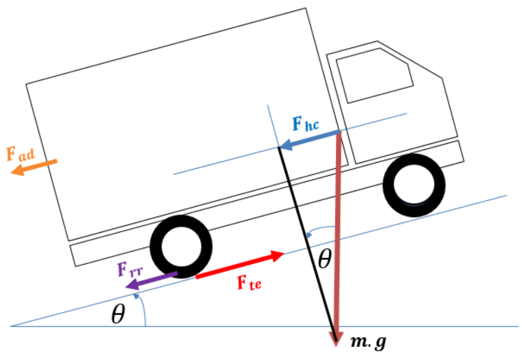

Figure 2. The force acting on a vehicle moving along a slope.

According to Costa (2009) and based on Larminie and Lowry (2012), the total tractive effort, seen in Eq. (1), is the sum of the components to overcome the rolling resistance, the aerodynamic resistance, the slope resistance of the course and resistance to overcome inertia.

$$F_{te} = F_{rr} + F_{ad} + F_{hc} + F_{la} + F_{\omega a} \tag{1}$$

Where F_{rr} is the rolling resistance force, F_{ad} is the aerodynamic drag, F_{hc} is the hill climbing force, F_{la} is the force required to get linear acceleration and $F_{\omega a}$ is the force required to get angular acceleration to the rotating motor.

Considering Eq. (1) it is possible to get Eq. (2) with all respective terms expressed by its equations.

$$F_{te} = (\mu_{rr} \times m_e \times g) + (\frac{1}{2} \times \rho \times A \times C_d \times v^2) + (m \times g \times \sin\theta) + (m_e \times a) + (I \times \frac{G^2}{\eta_g \times r^2} \times a) \tag{2}$$

Where μ_{rr} is the rolling resistance coefficient, m_e is the equivalent vehicle mass, including rotational inertia which is approximately equal to 1.03 multiplied by the vehicle mass in kg, g is the gravity acceleration in m/s^2, ρ is the air volumetric density equal to 1,23 kg/m^3, A is the vehicle frontal area in m^2, C_d is the drag coefficient, v is the velocity in m/s, m is the vehicle mass in kg, θ is the inclination angle in degrees, I is the rotor inertia moment, G is the system gear ratio connecting the motor to the axle, η_g is the gear system efficiency and r is the tyre radius in m.

Observing the total tractive effort, the torque required on the wheels to move the vehicle is determined using Eq. (3) that follows:

$$T_w = F_{te} \times r \tag{3}$$

By defining the torque on the wheels, it is possible to determine the torque of the electric motor, which depends on the transmission ratio of the system, as indicated by Equation (4).

$$T_m = \frac{T_w}{\eta_g \times G} \tag{4}$$

As the objective is to convert a combustion engine vehicle to electric traction, the aim is to take advantage of the transmission components in the original vehicle. The transmission ratio between the differential input and the wheels must be observed, and after carrying out the calculations to determine the engine's torque and power it is important to evaluate the possibility of using the preexistent gearbox. Considering the motor torque value, the developed power can be calculated.

The rotation in the wheels is expressed by Equation (5).

$$R_w = \frac{\left(\frac{v}{60}\right) \times 1000}{2 \times \pi \times r} \tag{5}$$

The engine rotation is expressed by Equation (6).

$$R_m = R_w \times G \tag{6}$$

The wheel angular velocity is expressed by Equation (7).

$$\omega_w = 2 \times \pi \times \frac{R_w}{60} \tag{7}$$

The motor angular velocity is expressed by Equation (8).

$$\omega_m = \omega_w \times G \tag{8}$$

The engine power is expressed by Equation (9).

$$P_m = T_m \times \omega_m \tag{9}$$

Equations (1) to (9) became possible to get torques on the wheel and on the motor, rotation on the wheels, rotation on the motor, angular velocity on the wheel and on the motor, and power on the motor. Therefore, a computational code was developed using the Matlab mathematical software. It was considered a simple version that only shows the relevant results to choose the engine which is possible to present the theoretical calculations results by this program. See, Figure 3, the vehicle's original data input with an internal combustion engine, it presents in yellow fields the necessary values to choose an equivalent electric motor to the combustion engine vehicle.

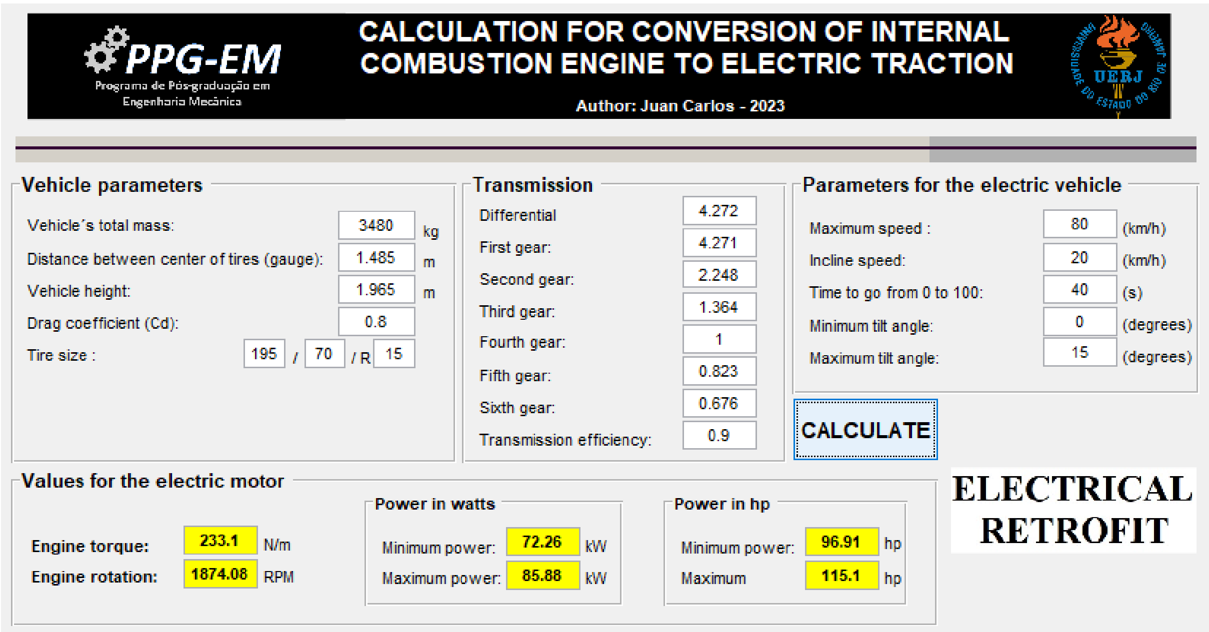

Figure 3. Computational calculate sheet to convert an internal combustion engine vehicle for electric traction.

The choice of engine requires three values: the maximum engine torque, the maximum speed, and the maximum engine power. As for torque, the calculation for going up a ramp in first gear was considered. It was also considered the rotation that the vehicle will reach the maximum speed in a horizontal plane. As for the maximum power, it was based on the vehicle starting from rest, where it needs to overcome inertia, requiring a higher engine power for a few moments, called the peak value.

Based on the values mentioned in the yellow fields, according to Figure 3, the chosen set is composed by the motor Model AC-35x2, produced by Hi Performance Electric Vehicle Systems, with the following specifications: of 96 V, 650 A, 94.55 kW and maximum torque of 349.6 N/m, together with a controller Model 1238E-7621, made by Curtis, with 96 V and 650 A (HPEVS, 2022).

The battery bank dimensioning and the vehicle autonomy were proposed in a simple cycle test as presented in Figure 4. This cycle covers a distance of 500 meters, at a maximum speed of 50 km/h, with 0.372 kWh energy consumption and utilizing regenerative braking. This regeneration process makes the total energy drop to 0.338 kWh, generating savings of around 15%. Based on these data, 0.676 kWh is required for every kilometer travelled.

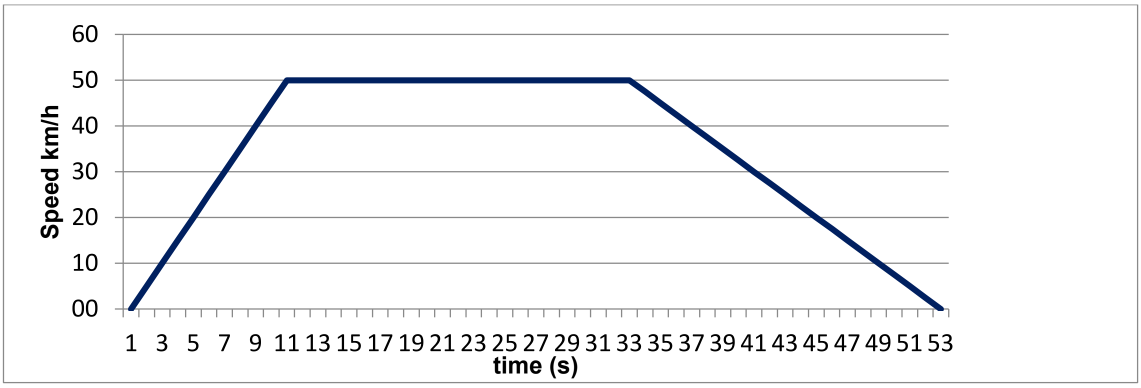

Figure 4. Test cycle.

Equation (10) establishes the energy consumption as follows:

$$E = \frac{1}{36 \times 10^5 \times n_A} \int_{t_0}^{t_1} P(t)\, dt \quad (10)$$

The Lithium Iron Phosphate battery - LiFePo4, 48 V 200 Ah, with nominal energy of 10.24 kWh was selected (Redway, 2023). To meet the power supply of the inverter, which works with 96 V, it was considered a mixed association of batteries, according to Figure (5), resulting in a battery bank with 61.44 kWh.

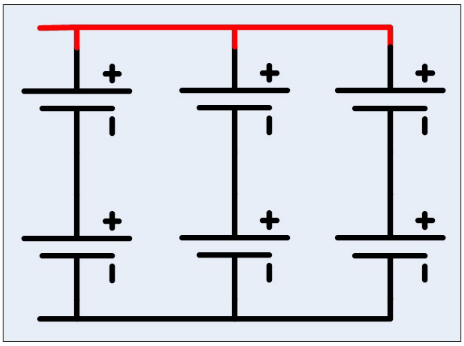

Figure 5. Battery bank.

However, it is necessary to apply a safety margin on the battery energy value, 61.44 kWh, due to all electrical devices installed consumption as well various auxiliary systems as follows: lighting, signaling, vacuum pump for braking, etc. An amount of energy available in the battery bank based on the vehicle with 90% autonomy has been adopted as a safety margin. Therefore, the new value will be 55.3 kWh. From the data obtained with the test cycle, a range of 81.8 km can be estimated. For greater accuracy, a test cycle with a wider variety of routes would need to be calculated in order to stablish the performance.

The battery bank requires a 7 kW charger with 220 V and 32 A. In order to get a complete recharge, it takes approximately nine hours.

As the converted vehicle requires several auxiliary systems working with 12 V, a DC/DC converter with 96 V is necessary to connect to the battery bank to get the mentioned supply voltage.

The operation of the original braking system is ensured by the internal combustion engine with an adequate vacuum for the hydrovacuum device to activate the master cylinder, pushing the brake oil to the calipers, which in turn perform the braking via the brake friction pad with the brake disk.

To replace the internal combustion engine with electric traction, it is only necessary to install a 12 V vacuum pump and a vacuum interrupter.

Table 6 presents a comparison of the vehicle´s mass after changing the selected components.

Table 6. Masses and capacity comparisons.

Components	Original mass (kg)	Mass with retrofit (kg)
Vehicle mass	1476	1634.39
Useful load capacity	2004	2004
Total gross mass (kg)	**3480**	**3638,39**

The proposed electric truck presents an operational performance equal to 0.676 kWh/km equivalent to 2.43 MJ/km, without any tailpipe emission while the combustion engine truck its consumption is 0.1111 liters/km and considering the diesel oil S10 adopted in Brazil with 36 MJ/liter gets 4 MJ/km.

Based on data on carbon emissions in Brazilian electrical generation (EPE, 2023) and the average emission factor for Diesel oil, composed of the average value of CO_2 emitted in the production and distribution of Diesel (Carvalho, 2011) plus the emission resulting from burning of the Diesel S10 (Lima, 2021), it was possible present in Table 7 a comparison between the converted electric truck and the original combustion engine one.

Table 7. Efficiency and emission comparison.

Parameter	Hyundai HR with electrical retrofit	Diesel Hyundai HR
Consumption per km	2.43 MJ	4 MJ
CO_2 emission per km	41.7092 g	315.524 g

3. PREDICTION OF ENERGY PRODUCTION BY THE ROOFTOP PHOTOVOLTAIC PANEL

The available truck roof dimension is 1.8 meters wide by 3 meters long. The high efficiency heterojunction (HJT) cell module was selected to be installed on the truck roof due to its high efficiency in energy conversion, allowing it to adhere to the installation surface. Table 8 presents its electrical and dimensional characteristics, reproduced from the manufacturer's technical data sheet (CSI Solar, 2023).

Table 8 - Panel CS6R-445H-AG 445W's characteristics, from manufacturer datasheet.

Maximum power (Pmax)	445 W
Voltage at Pmax (Vmp)	33.9 V
Current at Pmax (Imp)	13.15 A
Short-circuit current (Isc)	13.53 A
Open-circuit voltage (Voc)	40.3 V
Thermal coefficient of Pmax	-0.26%/°C
Thermal coefficient of Isc	0.04%/°C
Thermal coefficient of Voc	-0.24%/°C
Efficiency	22.8%
Normal Operation Cell Temperature	41°C
Dimensions	(1722x1134x30) mm
Weight	23 kg

The predicted monthly average hourly energy output was calculated as follow. The average monthly daily solar irradiation data obtained from *SunData v.3.0* on the horizontal plan, and 0° N azimuth for the city of Rio de Janeiro were transformed into monthly average hourly data using Eq. (11) as described in (Duffie and Beckman, 2013).

$$rt = [(\pi \div 24) \times (a + b \times cos\omega)] \times \{(cos\omega - cos\omega_s) \div \{sin\omega_s - [(\pi \times \omega_s) \div 180] \times cos\omega_s\}\} \quad (11)$$

The coefficients a and b are given by:

$$a = 0.409 + 0.5016 \times \sin(\omega_s - 60) \quad (11.1)$$

$$b = 0.6609 - 0.4767 \times \sin(\omega_s - 60) \quad (11.2)$$

Where $\boldsymbol{\omega}$ is the hour angle in degrees for the time in question (i.e., the midpoint of the hour for which the calculation is made), $\boldsymbol{\omega_s}$ is the sunset hour angle and $\boldsymbol{rt}$ ratio hourly total to daily total solar radiation. The sunset hour angle $\boldsymbol{\omega_s}$ is given by:

$$\omega_s = -(tan\,\phi \times tan\,\delta) \quad (12)$$

Where ϕ is latitude and δ is solar declination.

The declination (δ) can be found approximately by Equation (13).

$$\delta = 23.45 \times \sin\{360 \times [(284 + n) \div 365]\} \quad (13)$$

Where $\boldsymbol{n}$ corresponds to the day of the year. There is a day in each month for which the extraterrestrial solar radiation is very close to its monthly average, allowing direct obtaining the averages with Equation (13). They are January 17th (n = 17), February,16th (n = 47), March 16th (n = 75), April 15th (n = 105), May 15th (n = 135), June, 11th (n = 162), July, 17th (n = 198), August, 16th (n = 228), September, 15th (n = 258), October, 15th (n = 288), November, 14th (n = 318), December, 10th (n = 344) (Duffie and Beckman, 2013).

The monthly average hourly ambient temperature was calculated using the hourly data from the São Cristóvão weather station of the Precipitation Monitoring System from the Rio de Janeiro City Hall (ALERTA RIO), considering the years 2010 to 2020. The monthly average hourly temperature of the photovoltaic cell was calculated using Eq. (14), reproduced from (Kamuyu et al., 2018).

$$T_{Cell} = T_{NOCT} + (T_{amb} - T_{amb\,NOCT}) \times (G \div G_{NOCT}) \quad (14)$$

Where $\boldsymbol{T_{Cell}}$ is cell temperature, $\boldsymbol{T_{NOCT}}$ is defined as the cell or module temperature that is reached when the cells are mounted in their normal way at a solar radiation level of 800 W/m², a wind speed of 1 m/s, an ambient temperature of 20°C, and no-load operation (with $\eta c = 0$), $\boldsymbol{T_{amb\,NOCT}}$ is ambient temperature, $\boldsymbol{G}$ is incident solar radiation in W/m² and $\boldsymbol{G_{NOCT}}$ is solar irradiation of the test for determining $\boldsymbol{T_{NOCT}}$, its value is 800 W/m².

The monthly average efficiency of the photovoltaic panel was calculated using Equation (15).

$$E_\eta = E_{\eta STC} + (T_{célula} - T_{STC}) \times K_{MP} \times E_{\eta STC} \quad (15)$$

Where $\boldsymbol{E_\eta}$ is efficiency of the photovoltaic panel, $\boldsymbol{E_{\eta STC}}$ is efficiency at Standard Test Conditions (STC), $\boldsymbol{T_{STC}}$ is temperature at Standard Test Conditions (STC) and $\boldsymbol{K_{MP}}$ is maximum power temperature coefficient.

The monthly average hourly electricity production was determined by multiplying the hourly values of incident solar radiation by the corresponding values of photovoltaic panel efficiency. Monthly electricity production was determined by summing the hourly values for the given month. The annual production was determined similarly. Table 9 presents the predicted monthly average hourly energy production available to recharge the vehicle's batteries.

Table 9 – Predicted monthly average hourly energy production (Wh) by the rooftop PV panel

	Jan	**Fev**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
07-08 AM	124	121	90	68	48	41	42	62	75	97	104	120
08-09 AM	191	195	157	132	105	97	97	126	137	161	163	188
09-10 AM	253	263	219	193	162	152	151	188	195	220	217	250
10-11 AM	299	314	267	241	206	195	194	236	240	266	259	297
11-12 AM	323	341	293	267	230	220	217	263	264	290	281	322
12-13 PM	322	341	294	266	231	220	218	262	264	290	281	321
13-14 PM	297	312	267	240	206	195	194	235	239	265	258	295
14-15 PM	251	261	219	193	162	152	151	187	194	219	217	248
15-16 PM	190	194	157	132	105	97	97	126	136	160	163	187
16-17 PM	123	121	91	68	48	41	42	62	75	97	104	120
Daily production	2373	2464	2054	1800	1504	1409	1404	1746	1818	2065	2047	2347
Production of 2 panel	**4747**	**4929**	**4107**	**3601**	**3007**	**2817**	**2807**	**3492**	**3635**	**4130**	**4094**	**4695**

The final calculation was the photovoltaic energy production. Two panels, each one, with 445 W, was specified and considered a sun exposition with the vehicle both moving and parked throughout the day. The total daily production is 3,838 W and it is sufficient to increase the autonomy by 6.94%, equivalent to 5.68 km.

4. CONCLUSION

Electric vehicles have already become a reality, although its price is higher than that of internal combustion engine vehicles and it is due mainly to the traction batteries high cost.

This paper presented the conversion of the Hyundai HR light commercial vehicle with an internal combustion system to electric traction. Also, it was considered to install a photovoltaic module on its roof in order to contribute to its autonomy.

The developed study demonstrates the feasibility of urban freight transport electrification and its conversion. In fact, there is a market maturation to equipment supply parts such with several specific motors sizes for electric traction, as well, inverters, automatic gearboxes, batteries, battery management system, and peripherals. In a search scenario of new alternatives to minimize impacts to the environment, due to the emission of greenhouse gases, it can be recommended electric vehicles for the so-called last mile transport, that is, the final stretch that the goods travel before arriving at their destination. It provides a new mobility alternative, due to the advantages related to the electric vehicle's energy efficiency, reducing pollution emissions, low noise pollution with enabling night work and lower maintenance costs. In addition, the Brazilian energy matrix is predominantly composed by renewable sources, reducing the environmental impacts related to the life cycle of electric vehicles. Therefore, the retrofit allows electrifying existing fleets, generating a new market and becoming a viable option to accelerate the transition from fossil fuel vehicles to sustainable mobility in cargo trucks.

A considerable contribution was also seen from regenerative braking which reuses the energy that would be lost in the form of heat during braking with a traditional combustion engine truck as well from the solar energy generated from the vehicle roof.

The presented project leaves the possibility for additional studies aiming for further efficiency in the following devices: replacement of the vehicle's lighting system for LED lamps, DC/DC converters to be installed between the panel and the battery bank, ultracapacitors bank utilization, a test cycle more detailed in order to get more accuracy to the vehicle's range and an energy management system composed by a controller/converter with multiple inputs (solar energy, battery bank, and capacitor bank), employing a RS232 type communication supervisory system.

Finally, it is desirable to point out the converted electric vehicle and considered in this article is aimed at an urban environment that does not require a high autonomy. Despite the lack of high-power charging stations for electric vehicles, which represents a significant bottleneck in the infrastructure for their widespread adoption, "opportunity charging" can be used as a workaround, so that during stops for charging or discharge, it can be partially charged using 7 kW sockets. The global internal combustion vehicle fleet is estimated at around 1.44 billion road vehicles (Oliveira, 2023). Therefore, the conversion to electric traction could be a prospect for creating new jobs when many are currently being lost.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

The authors Juan Carlos Azeredo Coutinho dos Santos, Luiz Artur Pecorelli Peres and Manoel Antônio da Fonseca Costa Filho are the only responsible for the printed material included in this paper.