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Design of a Solar Charging Station for Electric Vehicles in Shopping Malls

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DESIGNOFASOLARCHARGINGSTATIONFORELECTRICVEHICLESINSHOPPINGMALLS

Design of a Solar Charging Station for Electric Vehicles in Shopping Malls

C Peña [α] & M Céspedes [σ]

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I. Introduction

There are two alternatives to mitigate greenhouse gas emissions, the first is the electrification of transport and the second is the generation of electricity using renewable energy.

For electro mobility to be successful, it is necessary that the used energy comes from renewable energies such as solar, wind or biomass.

This article proposes the design of a solar charging station for electric vehicles in shopping malls. Which consists of the dimensioning of a grid-connected photovoltaic system and analysis, evaluation and selection of the charging components for electric vehicles.

In this sense, one of the ways to charge the energy of the batteries of electric vehicles is to use the recharging points that the shopping mall install in their parking lots, all this while users come to make purchases or spend their leisure time in the malls.

II. Methodology

a) Background

i. *Current situation of electric vehicles*

Currently the battery of new versions of electric vehicles has a capacity that varies between 38 and 64 kWh, except for high-end cars such as the Taycan by Porsche and the Model S by Tesla, whose capacity varies between 70 and 100 kWh. In most electric cars the internal charger is 7.2 kW except for Tesla which is 10 kW. Figure 1 shows the electric vehicle charging system [1].

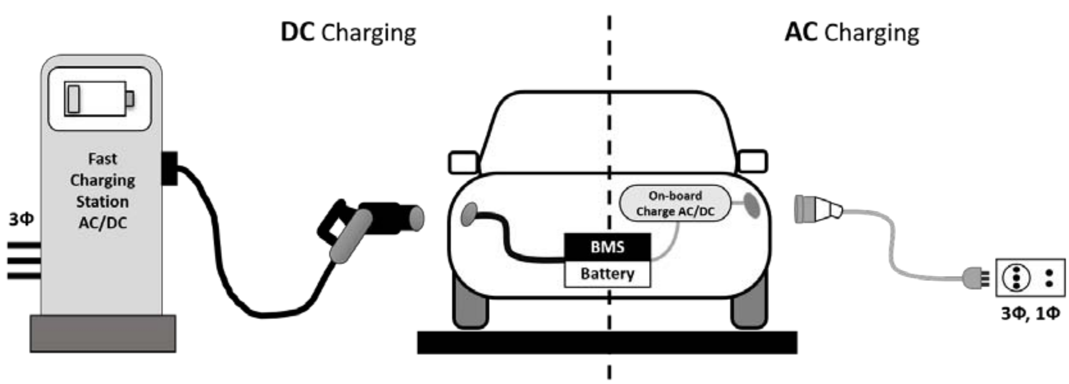

Figure 1: Electric vehicle charging system

The time (hours) of charging in AC of the battery (kWh) of the electric vehicle will depend on the power of the internal charger (kW) of the electric vehicle.

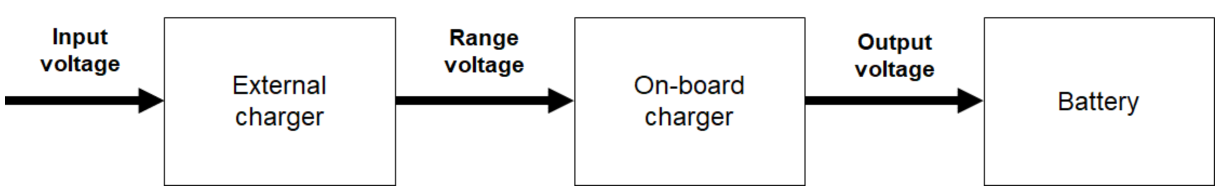

Figure 2: Charging an electric vehicle with an external charger

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Below are the technical data of 2019's electric vehicles.

Table 1: Technical data of electric vehicles

Make and Model of the Car	Hyundai Ioniq Eléctrico	Kia eSoul Standard	Kia eSoul Autonomía Extendida	Nissan Leaf S	Nissan Leaf S Plus	BYD E5-400
Type	EV	EV	EV	EV	EV	EV
Year of production	2019	2019	2019	2019	2019	2019
Maximum speed (km/h)	165	155	167	144	157	130
Battery capacity (kWh)	38.3	39.2	64	40	62	60.5
Autonomy (km)	293	277	452	270	385	400
Motor power (kW)	100	100	150	110	160	160
Torque (N.m.)	295	395	395	320	340	310
Internal charger power (kW)	7.2	7.2	7.2	6.6	6.6	7
Fast charge time from 100 kW to 80% (min)	54	42	42	40 (50kW)	45 y 60 (50 kW)	
Price (USD.)	38639.00	40121.00	47320.00	29990.00	36550.00	34760.00

Table 2: Battery capacity and autonomy for one hour of charge

Brand and model of the car	Battery capacity for one hour of charge (kWh)	Autonomy for one hour of charge (km)
Hyundai Ioniq Eléctrico	7.2	55.08
Kia eSoul Standard	7.2	50.88
Kia eSoul Autonomía Extendida	7.2	50.85
Nissan Leaf S	6.6	44.55
Nissan Leaf S Plus	6.6	40.98
ByD E5-400	7.0	46.28
Porsche Taycan 4S	9.6	49.33
Porsche Taycan Turbo	9.6	46.25
Tesla Model S - Perfomance	10	56.00
Average	8.00	49.00

ii. *Current situation of charging stations with renewable energies*

In Spain, the SIRVE project (Integrated Systems for Recharging Electric Vehicles) was developed, the objective of which is to desaturate the electrical network in LV, if the aggregate demand for fast charging and moderate charging systems exceeds the capacity of the line or of the transformation malls from which it is supplying. The SIRVE project is made up of a 1kWp photovoltaic system, which provides power to the 30 kWh lithium batteries. [2]

In 2017, Shanghai launched its first solar-powered charging station for electric vehicles as a test. It is made up of 40 solar panels on the roof of the building. In addition, it had backup batteries and was connected to the electrical network. In half an hour with fast charge the battery was charged with 70% and around two hours to completely fill the electric vehicle. [3]

b) *Descriptive memory*

i. *Description of the study area*

For the study analysis of the project, the "Molina Plaza" shopping mall was selected, located in the La Molina district, Lima, Peru.

The Molina Plaza shopping mall was selected for two reasons. The first is that it is located in an area of considerable solar radiation during the year. According to the Global Solar Atlas, the specific output photovoltaic energy is 1435 kWh/kWp [4]. The second reason is because the residents of the district have enough purchasing power to buy electric vehicles.

Table 3: Geographical data of the study area

Geographical data	
South latitude	12° 05' 28"
West longitude	76° 57' 01"
Medium altitude	234 m

Table 4: Temperature data of the study area

Temperature Data	
Maximum temperature	28 °C
Medium temperature	18 °C
Minimum temperature	11 °C

ii. *Objectives*

- Dimension the grid-connected photovoltaic system to provide 50% of the energy needed by electric vehicle batteries during the hours that the solar resource is available.
- Encourage and spread the use of renewable energy for electrified transport.

c) *Memory of Justifying Calculations*

i. *Solar irradiation*

With geographic coordinates and using NASA's Power Data Access Viewer application. Monthly global horizontal mean irradiance is obtained from the NASA database (1983– 2005) and NASA (1984-2013).

Table 5: NASA Monthly Weather Values

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Hor. global	6.48	6.32	6.72	6.17	5.04	3.86	3.73	4.09	4.83	5.84	6.31	6.52	kWh/m^2.day

The optimal inclination is determined using the following formula:

$$\beta_{opt} = 3.7 + 0.69\phi \quad (1)$$

Where:

β_{opt} : optimal tilt angle in degrees.

ϕ : latitude of unsigned place in degrees.

The optimal inclination of the photovoltaic modules is approximately 12°, using NASA's Power Data Access Viewer application the monthly global mean irradiation on a surface tilted at its optimal angle, facing north.

Table 6: Monthly average global irradiation on a 12° inclined surface

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Año	
Global Average Monthly Irradiation in a 12° angle	6.63	6.33	6.79	6.62	5.87	4.53	4.24	4.37	4.90	5.84	6.41	6.72	5.77	kWh/m^2.day

The month that has the least irradiation according to the previous table, is the month of July [5][6]. If the irradiance is considered equal to 1000 W/m^2, then the peak solar hours (HSP) equals 4.24 h.

ii. *Calculation of the energy consumed by charging electric vehicles*

To calculate the energy consumed, the following should be considered:

- Eight Wallbox chargers [7] 11 kW are being taken into account for charging electric vehicles.
- According to Table 2, the average battery capacity per 1 hour of charge is equivalent to 8 kWh. Thus, if the charging time is 1 hour, 8 vehicles can be charged simultaneously every hour.
- The energy consumed from 9:00 a.m. until 06:00 p.m. is 576 kWh, while the energy consumed from 06:00 p.m. until 09:00 p.m. is 192 kWh.
- The grid-connected photovoltaic system will be dimensioned to provide 50% of the energy consumed during 09:00 a.m. until 06:00 p.m. which is equivalent to 288 kWh.
- The chargers will be available from 09:00 a.m. until 09:00 p.m. Being 12 hours the available time considering the 37.5% supplied by the photovoltaic system and 62.5% by the electrical network.

The energy consumed during the day is estimated to be 768 kWh. If the charging time increases and considering the number of cars constant for the respective charging time (1, 2, 3 or 4), the energy consumed is the same, the only thing that changes is the number of cars supplied per day.

Table 7: Energy consumed by charging electric vehicles

Loading time (h)	1		2		3		4	
Hours available	Quantity EV (und.)	Energy EV (kWh)	Quantity EV (und.)	Energy EV (kWh)	Quantity EV (und.)	Energy EV (kWh)	Quantity EV (und.)	Energy EV (kWh)
09:00 a.m. – 10:00 a.m.	8	64	8	128	8	192	8	256
10:00 a.m. – 11:00 a.m.	8	64						
11:00 a.m. – 12:00 p.m.	8	64	8	128				
12:00 p.m. – 01:00 p.m.	8	64						
01:00 p.m. – 02:00 p.m.	8	64	8	128	8	192	8	256
02:00 p.m. – 03:00 p.m.	8	64						
03:00 p.m. – 04:00 p.m.	8	64	8	128				
04:00 p.m. –05:00 p.m.	8	64			8	192		
05:00 p.m. –06:00 p.m.	8	64	8	128			8	256
06:00 p.m. –07:00 p.m.	8	64						
07:00 p.m. –08:00 p.m.	8	64	8	128	8	192		
08:00 p.m. –09:00 p.m.	8	64						
Total	96	768	48	768	32	768	24	768

Table 8: Technical specifications Wallbox charger

Technical specifications Wallbox charger 11 kW	
Brand and model	EV Box
Charging mode	Mode 3
Connector load capacity	11 kW
Number of connectors	1
CE certification	Yes
Output values	1 phase o 3 phases, 230 V - 400 V, 16 A - 32 A
Temperature range	Since -25°C until 60°C
Cable length	4 m.
RH	0.95
Activation / Identification	Automatic start / card or keychain RFID
Status indicator	Ring LED

iii. *Calculation of the power of the photovoltaic generator*

The power of the photovoltaic generator is determined using the following formula:

$$P_G = \frac{1.11\ W_d}{HSP.PR} \tag{2}$$

Where:

P_G :Photovoltaic generator power in Wp.

W_d : Daily energy consumption for the calculation of the PV generator in kWh, which is equivalent to 288 kWh.

HSP: Peak solar hours in h, which equals 4.24 h.

PR : Energy performance of the installation, which is equivalent to 80%.

03 photovoltaic generators will be required whose power amounts to 31415.09 Wp. Considering 330 Wp polycrystalline photovoltaic modules, from the manufacturer Amerisolar [8]. Thus, the power of each real photovoltaic generator is 31350 Wp. Each one will be made up of 95 photovoltaic modules, distributed in 5 chains of 19330 Wp polycrystalline photovoltaic modules.

Table 9: Technical specifications of the photovoltaic module

Technical Specifications of the Selected Photovoltaic Module	
Type	Policristalino
Power	330 Wp
Imp	8.85 A
Vmp	37.3 V

Isc	9.26 A
Voc	45.9 V
β	-0.14229 V/°C
α	0.00463 A/°C

Table 10: Technical characteristics of the photovoltaic generator

Technical characteristics of the photovoltaic generator	
Generator power PV	31350 Wp
Module power PV	330 Wp
Number of chains	5
Number of PV modules, by serie	19
Number of PV modules	95
Isc, by chain	9.26 A
Voc , by chain	872.10 V

iv. *Selection of grid interconnect inverters*

Each photovoltaic generator will be connected to a grid interconnection inverter [9]. The following parameters must be taken into account when selecting the Inverter:

- Inverter nominal power, must be between 80% and 90% of the power of the photovoltaic generator.

$$P_{Inv} = \quad 0.8 \ \ldots \ 0.9 \ P_G \tag{3}$$

Where:

P_{inv} : Inverter power in W.

P_G : Photovoltaic generator power in Wp.

- Inverter MPP follower voltage range*($U_{inv.min}$ … $U_{inv.máx}$)*:

This range must contain the maximum and minimum values that the photovoltaic generator can supply at the point of maximum power specified for a cell temperature of -10° C and 70° C respectively($U_{Gmpp\ (70°C)}$ y $U_{Gmpp\ (-10°C)}$).In both cases with an irradiance of 1000 W/m^2.

$$\boldsymbol{U_{inv.mín} \leq U_{Gmpp\ (70°C)}} \tag{4}$$

$$U_{Gmpp\ (70°C)} = N_S \,.\, U_{mpp\ (70°C)} \tag{5}$$

$$U_{mpp\ (70°C)} = U_{mpp} + \beta \,.\, (T - 25) \tag{6}$$

$$\boldsymbol{U_{inv.máx} \geq U_{Gmpp\ (-10°C)}} \tag{7}$$

$$U_{Gmpp\ (-10°C)} = N_S \,.\, U_{mpp\ (-10°C)} \tag{8}$$

$$U_{mpp\ (-10°C)} = U_{mpp} + \beta \,.\, (T - 25) \tag{9}$$

Where:

U_{Gmpp} : Voltage of the photovoltaic generator at its maximum power point (V) at a certain temperature.

U_{mpp} : Voltage of the photovoltaic module at its maximum power point (V) at standard measurement conditions.

N_S: Number of panels in series.

β: Voltage coefficient - module temperature (V/°C).

T: Temperature (°C).

- Inverter maximum voltage *($U_{máx.\ vacío}$)*:

The inverter must withstand the maximum voltage that the open-circuit photovoltaic generator can produce with a cell temperature of -10° C and an irradiance of 1000 W/m^2.

$$U_{máx.vacío} \geq U_{Goc\ (-10°C)} \tag{10}$$

$$U_{Goc\ (-10°C)} = N_S \,.\, U_{Goc\,(-10°C)} \tag{11}$$

$$U_{oc\,(-10°C)} = U_{oc} + \beta \,.\, (T - 25) \tag{12}$$

Where:

U_{Goc}: It is the voltage of the photovoltaic generator in vacuum (V) at a certain temperature.

U_{oc} : It is the voltage of the photovoltaic module in vacuum (V) at standard measurement conditions.

- Maximum intensity *($I_{inv.\ máx}$)*:

The inverter must withstand the short-circuit current of the generator with a cell temperature of 70 ° C and an irradiance of 1000 W / m^2.

$$I_{máx.vacío} \geq I_{Gsc\ (-10°C)} \tag{13}$$

$$I_{Gsc\ (70°C)} = N_P \,.\, I_{sc\,(70°C)} \tag{14}$$

$$I_{sc\,(70°C)} = I_{sc} + \propto . (T - 25) \tag{15}$$

Where:

I_{Gsc}: It is the maximum short-circuit current intensity of the photovoltaic generator in (A) at a given temperature.

I_{sc}: It is the short circuit current intensity of the photovoltaic module (A) or string at standard measurement conditions.

N_P: Parallel panel chain number.

α: Current coefficient - module temperature (A/°C).

T: Temperature (°C).

Taking into account the above, 03 three-phase inverters for grid interconnection of 27 kW - 380/220 VAC, from the Fronius brand [10] with their respective Smart Meter 50kA-3 are selected.

Table 11: Parameters calculated to select the inverter

Parameters calculated to select the grid interconnect inverters	
Inverter power	25080 … 28215 W
Minimum value of the MPP voltage range	587.10 V
Maximum value of MPP voltage range	803.32 V
Maximum no-load voltage	966.72 V
Maximum intensity	47.35 A

Table 12: Main technical specifications of the inverter

Main technical specifications of the inverter	
Brand and model	Fronius Eco 27.0-3-S
Inverter power	27 kW
MPP voltage range (Ucc min - Ucc max.)	580 V – 850V
Maximum no-load voltage	1000 V
Maximum PV input intensity	47.7 A
Maximum short-circuit current per PV series	71.6 A
Number of MPP followers	1
Number of DC inputs	6
Maximum PV generator output	37.8 kWp
Link to the network	3~ NPE 400/230, 3~ NPE 380/220 V
Frequency	50/60 Hz
Nominal output current at 400 V	39 A

v. *Selection of protection devices*

PV generator protection: For each photovoltaic generator, 1 string box will be installed to connect 5 chains in parallel with 19 photovoltaic modules connected in series. Each string box must have at least 10 cylindrical rifle bases for 10 x 38 mm fuses.

- The fuse rating is determined with the following formula:

$$I_F = 1.5\ \ldots\ 2 I_{SC} \quad (16)$$

Where:

I_{sc}: It is the short circuit current intensity of the photovoltaic module (A) or string at standard measurement conditions.

I_F: It is the current intensity (A) that the fuse supports.

- The assigned voltage is determined with the following formula:

$$U_F \geq 1.2\ U_{GOC'} \quad (17)$$

Where:

$U_{GOC'}$: It is the voltage of the photovoltaic generator in vacuum (V).

U_F: It is the rated voltage (V) that the fuse supports.

- In the string box, for each chain there must be two 16 A (gR) fuses with a rated voltage of 1000 VDC cylindrical 10 x 38 mm. One will be connected to the positive pole and the other to the negative pole of each chain.

Investor Protection: A thermomagnetic switch will be placed at the output of each inverter, having to meet the output characteristics of the inverter.:

- Nominal intensity: $\mathrm{I_n} \geq 48.26\ \mathrm{A}$
- Nominal working voltage: $\mathrm{U_n} = 380\ \mathrm{VAC}$

Wallbox charger protection: A thermomagnetic switch will be placed in each circuit of each 11 kW Wallbox charger.:

- Nominal intensity: $\mathrm{I_n} \geq 19.66\ \mathrm{A}$
- Nominal working voltage: $\mathrm{U_n} = 380\ \mathrm{VAC}$

vi. *Network connection*

For the connection of the electric chargers and the grid interconnection inverters, a new MV power supply (10 kV or 22.9 kV) and a new primary network will be necessary. The conventional three-phase substation must have a 250 kVA encapsulated dry transformer - 10-22.9 / 0.38-0.22 kV.

For the analysis, the inverters are considered as a load, and a power factor of 0.85.

Table 13: Load chart

Load chart						
Load	Pot.unit (kW)	I. currents total (A)	Quantity(Und.)	P. total (kW)	I. currentstotal (A)	Pot. transformer (kVA)
Grid connection inverter - de 27 kW. 380/220 V- Fronius	27	48.26	3	81	144.78	250
Wallbox charger 11Kw – 380/220 V	11	19.66	8	88	157.28	
Street lighting luminaires	0.07	0.00040	8	0.56	0.0032	
Total				169.56	302.0632	250

d) Estimated annual energy produced per year

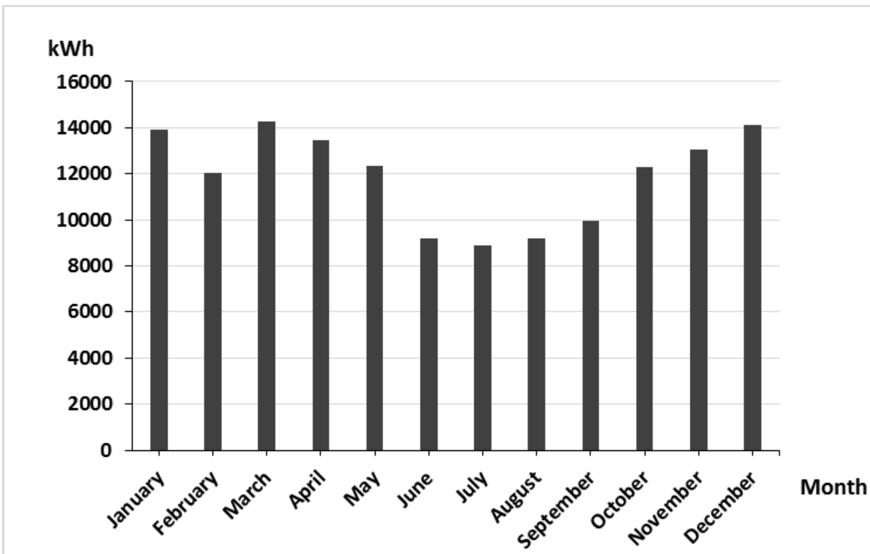

Figure 3: Estimated annual energy produced per year

With the data in Table 6 and 10, the annual energy produced by the grid-connected photovoltaic system is calculated. Which amounts to 142705 kWh. The plant factor is 17.32%. According to the Global Solar Atlas [11], the energy produced is 135675 kWh and the specific production 1443 kWh / kWp.

Table 14: Energy produced annually

Month	Monthly energy (kWh)
January	13932
February	12014
March	14268
April	13462
May	12335
June	9212
July	8910
August	9183
September	9964
October	12272
November	13035
December	14121
Annual (kWh)	**142708**

The solar charging station will be available from 09:00 a.m. until 09:00 p.m. Being a total period of 12 hours. The energy produced by the photovoltaic system during the first hours of the morning may be used for other uses such as refrigeration, ventilation or any other auxiliary circuit. With the information obtained from the report generated by the Global Solar Atlas. The energy produced by the photovoltaic system in the early hours of the day destined for others would be 14666 kWh per year.

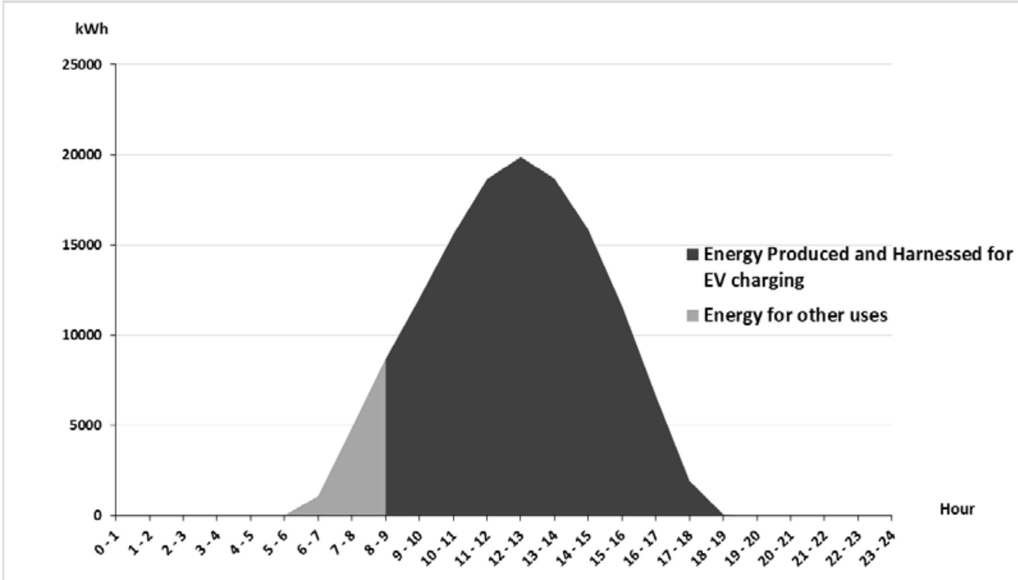

Figure 4: Estimated annual energy produced per year

e) Estimation of the reduction of CO_2 emissions

According to the Peruvian Ministry of Energy and Mines, the emission reduction factor [12] for 2016 is 0.4082 tCO_2/MWh. They consider a degradation factor of 0.5% of the photovoltaic modules. It is estimated that 1111.33 tCO_2 would no longer be emitted.

Table 15: Reduced CO_2 emissions

Period	Energy produced (kWh)	Emission factor ($_tCO_2$/MWh)	CO_2emissions (tCO_2)
1	142708	0.4082	58.25
2	141994	0.4082	57.96
3	141284	0.4082	57.67
4	140578	0.4082	57.38
5	139875	0.4082	57.10
6	139176	0.4082	56.81
7	138480	0.4082	56.53
8	137788	0.4082	56.25
9	137099	0.4082	55.96
10	136413	0.4082	55.68
11	135731	0.4082	55.41
12	135052	0.4082	55.13
13	134377	0.4082	54.85
14	133705	0.4082	54.58
15	133037	0.4082	54.31
16	132372	0.4082	54.03
17	131710	0.4082	53.76
18	131051	0.4082	53.50
19	130396	0.4082	53.23
20	129744	0.4082	52.96
	Total		1111.35

f) Simulation with PVsyst software and Helioscope

i. *Simulation with the software PVsyst*

To perform the simulation in the PVsyst software, the Typical Meteorological Year (TMY) was selected, which the software obtains from the PVGIS platform data. The PVGIS platform works with the 2005-2015 database, provided by the National Renewable Energy Laboratory (NREL).The main parameters of the system and the main results of the simulation with the PVsyst software are as follows:

Table 16: Main parameters for the PVsyst simulation

Main parameters for the PVsyst simulation	
PV field orientation and inclination	Azimuth 0° y 12° tilt
PV modules	Model AS6P33-330 Pnom.330 Wp
PV set	285 modules Pnom total 94.05 kWp
Investor	Model Fronius Eco 27.0-3-S
Amount of Investors	3 units Pnom. Total 81 kW AC

Table 17: Main simulation results in PVsyst

Main simulation results in PVsyst 6.8.1.	
Energy produced	138.3 MWh/year
Specific production	1471 kWh/kWp/year
Performance index (PR)	86.58%

ii. *Simulation with Helioscope software*

The Helioscope software performs the simulation with the Typical Meteorological Year (TMY), which it obtains from the data from Meteonorm. In addition, it distributes the photovoltaic modules on the roof of the Molina Plaza shopping mall.

Table 18: Main results of the simulation in Helioscope

Main results of the simulation in Helioscope	
Energy produced	144.4 MWh/year
Specific Production	1535.5 kWh/kWp/year
Performance Index (PR)	78.2%
Investors	3 Fronius Eco 27.0-3-S. Total 81 kW AC
Chains	15
PV modules	285, Amerisolar, AS-6P-330. Total 94.1 kWp

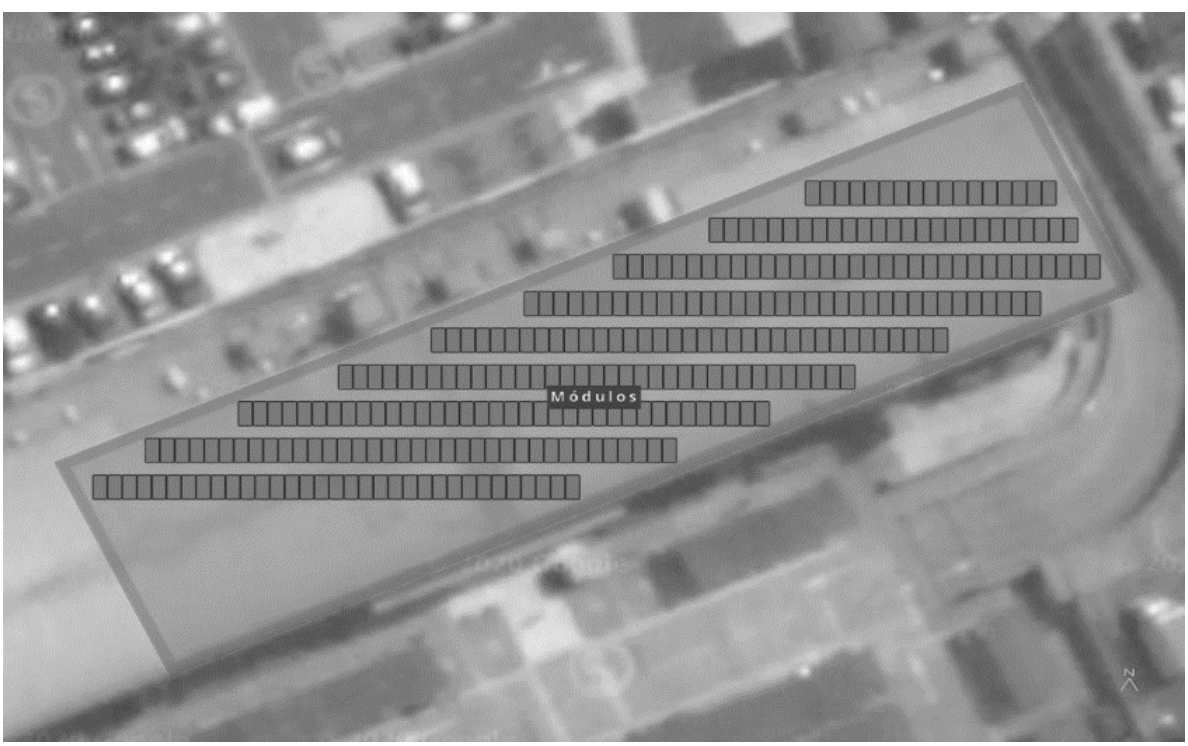

Figure 5: Distribution of photovoltaic modules with Helioscope

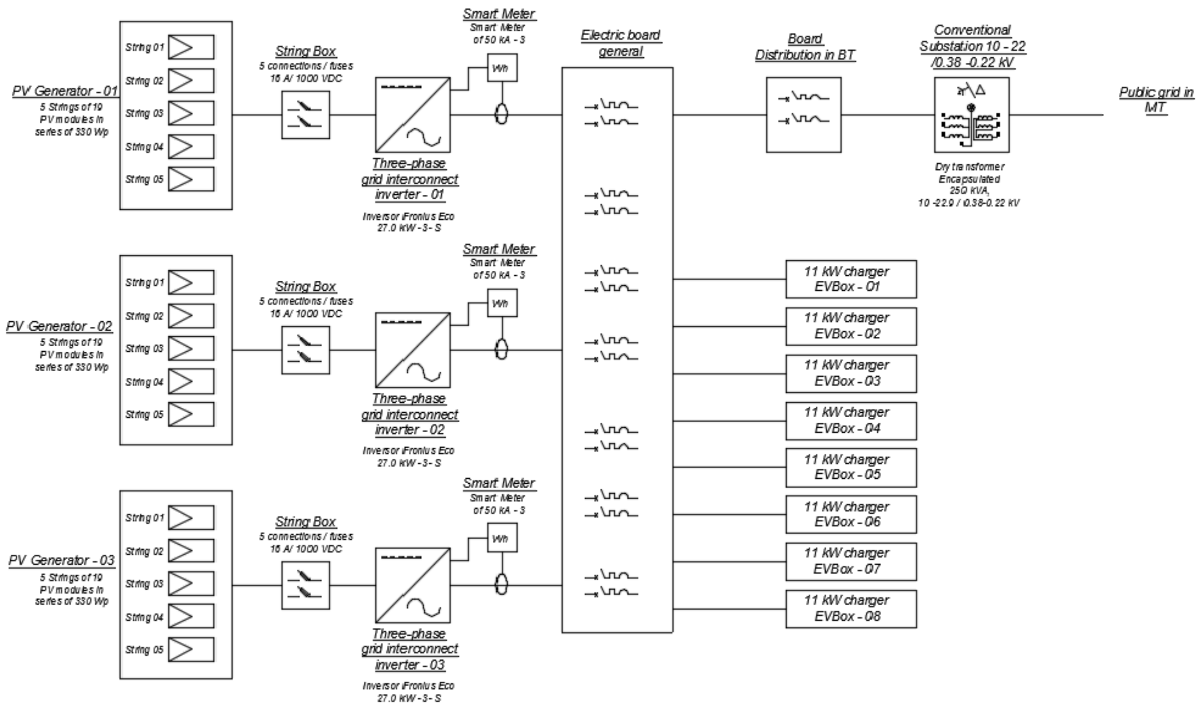

Figure 6: Blocks diagram

g) Materials supply

Table 19: Materials supply

Ítem	Description	Und.	Qty.	Price Unit.	Total
1.00	Components of the photovoltaic system				
	Polycrystalline photovoltaic modules330 Wp	und	285.00	563.90	160711.50
	Mains connection inverter 27 kW - three-phase - 380/220 VAC	und	3.00	19666.57	58999.71
	Aluminum fixing bracket for 19 panels	und	15.00	6090.48	91357.20
					S/.311068.41
2.00	Additional components of the photovoltaic system				
	Supply of electrical boards, string box, conductors and hardware, grounding.	glb	1.00	46660.26	S/.46660.26
3.00	Wallbox chargers				
	WallBox Charger - 11 kW. - 230 V a 230/400 V three phase - 50/60 Hz. - Connector Type 2 o Mennekes - Cable length 4m.	und	8.00	5252.12	S/.42016.96
4.00	Materials for medium voltage pipes and networks	und	1.00	7207.76	S/.7207.76
5.00	Materials of the conventional substation of 250 kVA 22.9-10 / 0.38-0.22 kV	glb	1.00	96056.18	S/.96056.18
6.00	Protective and sectional structure materials	glb	1.00	60684.36	S/.60684.36
	Total				S/.563693.93

Table 20: Total budget

Ítem	Detalle	Total
A	Suministro de materiales	563693.93
B	Montaje electromecánico	121329.17
C	Gastos adicionales aproximados	28252.20
D	Gastos administrativos	34870.00
	Total	S/.748145.30

h) Economic evaluation

To perform the investment valuation, it was necessary to determine the FC (Cash Flow). For this, it is necessary to determine the net operating flow, thus we consider the following parameters:

Table 21: Parameters to determine the operational cash flow

Parameters		
Item	Detail	Total
r	Discount rate	7.5%
d	Degradation rate	0.5%
e	Energy cost as a free client	0.1510 S/./kWh
i	Rate of inflation	2.0 %
s	Hourly rental price of each parking space	2.54 soles
p	Project period	20 years

Once the net operating flow has been determined, the net financial flow of the project is determined:

Table 22: Financial cash flow

Values		
Item	Detail	Total
NPV	Net present value	S/. 161113.86
IRR	Internal rate of return	10.04%
PRI	Return on investment period	8 years

For this project, the NPV is: S /. 161113.86, which indicates that the project is financially viable since the NPV is> 0.

In this case the IRR is 10.04%, compared to the discount rate, it is feasible to invest in a project under these conditions.

It is evident that the PRI period of time to recover the investment is up to about 8 years, which determines that it would make viable the start-up of the project under the proposed scenario.

III. Conclusions

- The project is economically viable, as the NPV and IRR are viable, and the return on investment time is around 8 years.
- The project is technically feasible, current technology would allow this project to be carried out.
- With this project, 1111.35 tCO2 would no longer be emitted, contributing to the environment and demonstrating that the use of renewable energy is the solution to environmental pollution.
- According to the simulations and calculations, the proposed objectives will be able to meet. More than 50% of the energy consumed by the charge of electric vehicles would be covered during the hours of 9:00 am - 6:00 pm.
- Interconnection inverters will be configured so that they do not inject energy into the public grid and are only used for self-consumption.
- The interconnect inverter will stop working if there is a grid disconnection. It is because the inverter needs to be synchronized with the frequency of the public electrical network.
- In order for the grid interconnection inverters to work with a backup system such as a generator set in the event of a disconnection from the public grid. It is recommended to make a modification and change the Smart Meter 50kA-3, for a Fronius PV system controller with its two accessories to optimize the operation of the photovoltaic system with the

generator set. The technical specifications of the generator set will be required. This solution is called Fronius Fronius PV - Genset Easy.

References Références Referencias

1. López Redondo, N. (June 11, 2020). Electric cars with the best price-to-autonomy ratio of the market with which car is most economical each kilometer of cargo[online]. Retrieved June 2020, 13, from Web site Electric Mobility: https://movilidadelectrica.com/coches-electricos-mejor-relacion-precio-autonomia/
2. Urbener. (2015). Project Serves, Integrated Systems for Recharging Electric Vehicles [online]. Retrieved May 25, 2020, from Urbener Web site: https://www.urbener.com/sirve
3. El País. (October 25, 2017). Shanghai debuts its first solar station to charge electric vehicles [online]. Retrieved May 20, 2020, from El País Web site: https://negocios.elpais.com.uy/shanghai-estrena-primera-estacion-solar-cargar-vehiculoselectricos.html
4. Global Solar Atlas. (February 2020). Global Solar Atlas [online]. Retrieved May 20, 2020, from Global Solar Atlas Web site: https://globalsolaratlas.info/map?c=12.097403,76.935883,11&s=%2012.090977,76.95035&m=site
5. González Pinzón, C. L., Ponce Corral, C., Valenzuela Nájera, R. A., & Atayde Campos, D. (2013).Selecting a solar photovoltaic system for an electric vehicle[online]. (U. A. Juárez, Ed.). Scientific and Technological Culture, 10(Extra 50 ,2), 11-26. Retrieved May 25, 2020, fromhttp://erevistas.uacj.mx/ojs/index.php/culcyt/article/view/927/863
6. Pereira Micena, R., Llerena P., O. R., de Queiróz Lamas, W., & Luz Silveira, J. (June 30, 2018). Technical study of the use of solar energy and biogas in electric vehicles in Ilhabela - Brazil[online]. Ingenius. Journal of Science and Technology (20), 58-69. Retrieved May 26, 2020, from https://ingenius.ups.edu.ec/index.php/ingenius/article/view/20.2018.06
7. EVBox. (s.f.). Technical specifications of electric vehicle chargers [online]. Retrieved May 20, 2020, from EVBox Web site: https://evbox.com/en/products/business-chargers/businessline
8. Amerisolar (s.f). AS-6P Module Technical Specifications [online]. Retrieved May 20, 2020, from Amerisolar Web site: http://www.weamerisolar.com/english/product/pro1/255.html
9. Castejón, A., & Santamaría, G. (2010). Photovoltaic solar installations. Madrid: Editorial Editex.
10. Fronius (2014). Fronius Eco Inverter Technical Specifications 27.0-3-S [online]. Retrieved May 20, 2020, from Amerisolar Web site: https://www.fronius.com/es-es/spain/energia-solar/productos/todos-losproductos/inversor/fronius-eco/fronius-eco-27-0-3-s.
11. Global Solar Atlas. (February 2020). Global Solar Atlas Report[online]. Retrieved Jun 7, 2020, from Global Solar Atlas Web site: https://globalsolaratlas.info/map?c=-12.091024,-76.950302,11&s=-12.090977,-76.95035&m=site&pv=ground,0,12,94.05.
12. Directorate-General for Energy Efficiency - Ministry of Energy and Mines, Peru (2018). Monthly Renewable Energy Bulletin (2018) [power point slides].