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Design of a 0.6 kWp Photovoltaic Central for a House Located in Chone Canton Ecuador

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Abstract

Grid-connected renewable energy systems are one of the most widely used applications in recent years, due to their great potential in semi-urban areas close to the electricity grid. An electric demand study was carried out in a house located in the Chone canton, province of Manabí, Ecuador, to determine the nominal power for the dimensioning of the system. Chone canton has a great potential for a photovoltaic generation thanks to the high levels of solar radiation it receives. The software PVsyst v. 6.70 was used to design the photovoltaic system, together with other parameters such as energy demand and consumption patterns over time. The analysis revealed a nominal power of 0.6 kWp that would satisfy the diurnal consumption of the dwelling. In addition, the implementation of this system would avoid the emission of 0.81 tons of CO_2 per year.

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1 Introduction

Conventional energy resources have more and more limitations, due to multiple factors, such as environmental pollution, overexploitation of natural resources, natural processes, among others. From this problem arises the need to explore alternative sources of energy, environmentally friendly, such as solar energy (Montecinos & Carvajal, 2018).

The sun is an inexhaustible source of energy. Many areas of the world have opted to generate electricity from systems that take advantage of the sun's energy. Countries such as China, the United States or Japan are the greatest exponents of photovoltaic power generation (Hemetsberger & Schmela, 2019). In Ecuador, photovoltaic plants are rare, as the main source of generation in this country is hydropower, followed by diesel-fired thermal plants (Constante, 2016). Studies conducted in the province of Manabí, Ecuador (Rodríguez & Vázquez, 2018), show that the region has great potential for solar energy. This potential would allow the generation of energy from photovoltaic cell modules with nominal loads. The application of small-scale systems in places where electrification is deficient can become a solution to the problems of energy supply in the province. In Chone canton, Manabí province, there is considerable potential for solar energy, where the implementation of small-scale, grid-connected photovoltaic systems can provide good yields (Rodríguez & Vázquez, 2018; Gamez *et al.*, 2016).

The design of grid-connected PV plants is complex by manual methods, i.e. mathematical models based on equations. Fortunately, today there are software applications that make work much easier (Mermoud, 2010; Sauer *et al.*, 2014; Arcentales *et al.*, 2017). In this way, it is practical and efficient to carry out analyses of energy demand, shadows, space availability, among others (Córdova, 2019; García *et al.*, 2018; Tacuma & Valencia, 2018).

It is of vital importance to analyze and evaluate the design and implementation of small-scale photovoltaic systems, focused on housing (Vázquez *et al.*, 2019; Aguaded, 2018; Gamez *et al.*, 2017), and its impact on the situation of Manabí province, where the potential of this resource is colossal. The aim of the work is to design a photovoltaic plant capable of satisfying the daytime electricity demand of a house located in Chone canton, Manabí province.

So that the research and linking activities of the students can be accomplished, a geoportal has been designed (Rodriguez *et al.*, 2019), which show the information of the potentials of renewable energy sources studied and that are already they see the results in their consultants (Rodríguez *et al.*, 2019). The web project is designed to achieve sustainable investments in energy, environmental and risks that enhance local development (Vázquez *et al.*, 2019).

2 Materials and Methods

The methodology used is a documentary. Environmental parameters, techniques and design procedures of photovoltaic power plants were reviewed in order to obtain the necessary information to create a frame of reference. The reference material was obtained from specialized information banks in the area, in addition to research work related to the subject. In order to carry out the design, the Engineering Design Process (Chapman *et al.*, 1992; Haik & Shahin, 2011; González *et al.*, (2017), was used as a reference methodology. This allowed to establish the load needs, taking into account the restrictions; from this, the design criteria were established. A preliminary study of the different solutions to the problem was carried out, selecting the most suitable one for the proposed specifications.

The software used for this work was: PVsyst v. 6.70 (PVsyst Development Team, 2019), HOMER Pro Versión 3.13.1 (HOMER Pro Development Team, 2019), and Microsoft Excel 2010 (Microsoft, 2019). For the design of the photovoltaic plant, a set of parameters and criteria were established, as detailed below.

3 Results and Discussions

Dwelling electric charge assessment values are shown in Table 1. The characteristics and values of the plate of each existing charge connected to the circuit were taken.

Table 1
Dwelling electric charge assessment

Devices	Power consumption (W)
Lights	20
Kitchen	10.96

Television	250
Computer	64.35
Cellphone	5
Fridge	230
Radio	18
Water Pump	5500
Total Consumption	6098.31

Dwelling electricity demand

Electricity demand assessment of dwelling is shown in

Table *2*. The dwelling charge profile is also shown.

Table 2
Dwelling electricity demand

Devices	Power consumption (W)	Number of devices	Usage hours	Maximum power (kWh)
Lights	20	7	4	0,56
Kitchen	10.96	1	0.02	0.00022
Television	250	2	3	1.5
Computer	64.35	1	2	0.1287
Cellphone	5	4	1	0.02
Fridge	230	1	24	5.52
Radio	18	1	1	0.018
Water Pump	5500	1	0.3	1.65
Total Consumption	6098.31	Peak demand for dwelling		9.39691

Dwelling electric energy consumption behavior

Figure 1 shows the graphical analysis of the consumption behavior of dwelling according to the time set.

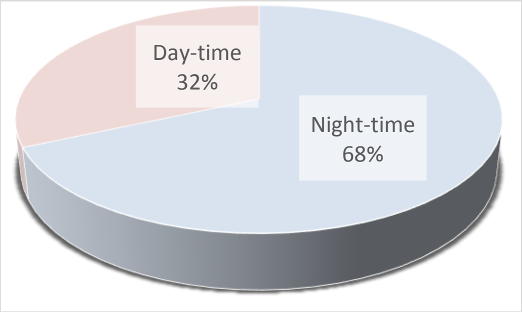

Figure 1. Electric energy consumption behavior

Electricity demand during day-time

In order to establish the daily consumption, a power value of 0.57331 kW was determined. This value was oversized to 0.6 kW to ease the plant design parameters. The details of this evaluation are shown in Table 3.

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Table 3
Charges considered for plant design

Devices	Power consumption (W)
Kitchen	10.96
Television	250
Computer	64.35
Cellphone	5
Fridge	230
Radio	18
Total demand	573.31

Dwelling average solar radiation

Figure 2 shows the average solar radiation incident on Chone canton, where the dwelling is located.

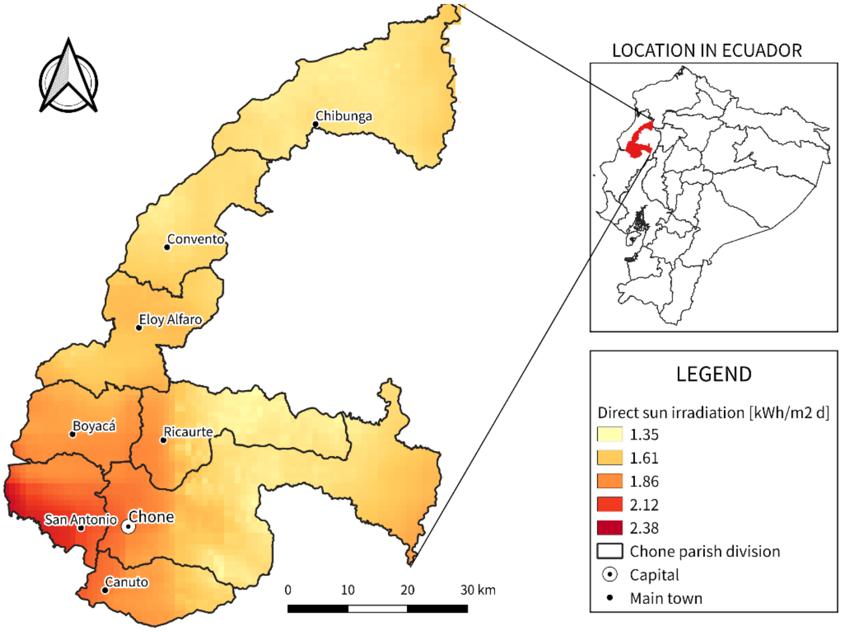

Figure 2. Direct sun irradiation in Chone canton
Source: SIGDS Project, 2019

Shadow assessment

This study evaluates all the obstacles that prevent the passage of solar radiation to photovoltaic modules. The main obstacle of the system to be implemented is an adjacent house that casts a shadow. Figure 3 shows a diagram of the location of the photovoltaic system and the house that obstructs solar radiation.

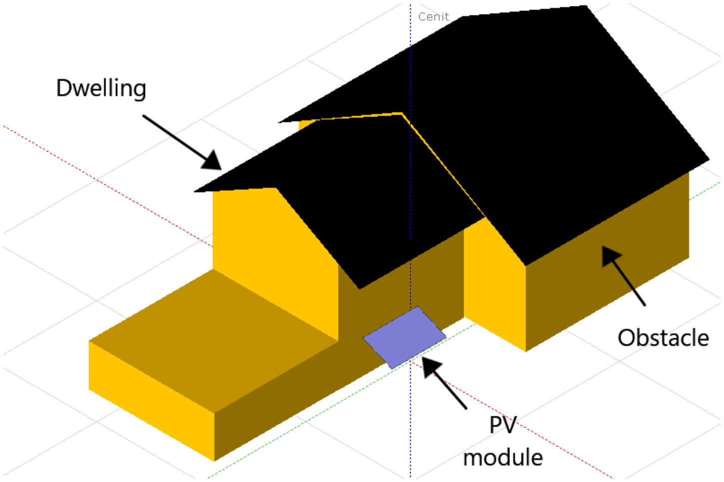

Figure 3. Photovoltaic system and obstacle location

Photovoltaic plant design

Once the value of the power to be supplied has been determined (Table 3), the system is simulated in the PVsyst software. The simulation was carried out considering the following parameters: latitude -0.70° S; longitude 80.11° W; 23° panel inclination with respect to the horizontal; 13 m altitude; 90° azimuth and 0.2 albedos. The simulation made it possible to determine the most suitable characteristics for the proposed plant configuration.

From the software results, the equipment that would make up the system was selected, such as 4 photovoltaic modules AXI Power AC-150 P/156-36S of 150 W_p (50° C) unit capacity, with V_{mpp}=33 V, I_{mpp}=16 A, and 4 m^2 of surface, installed in series of 2 modules in parallel; and 2 inverters MI-600 of the Hoymiles brand, with voltage range of 16-48 V, with MPPT=50%, total power of 600 W in A.C. The expected losses are detailed in table 4.

Table 4
Expected technical losses in the proposed photovoltaic plant

Loss factors incurred	Value
Thermal loss	20 W/m^2 K
Cable Ohmic Loss	1.5 % in STC
Module Quality Loss	-0,80 %
Modules mismatch loss	1.0 % in MPP
String Mismatch loss	0.10 %
Incidence effect (bo)	0.05

Table 5 shows the balance sheet and the main results of the simulation. Figure 4. Left: Standard output (per kWh installed). Right: Performance ratio of simulated system Shows the monthly values of the standard output and the Performance Ratio (PR). The highest PR is in June with 0.732, while the lowest performance radius is in March with 0.67. This differs from the standard output chart, as the maximum energy generated is given in March.

Table 5
Balance sheets and main results

	GlobHor* [kWh/m^2]	DiffHor* [kWh/m^2]	Amb. T* [°C]	GlobInc* [kWh/m^2]	GlobEff* [kWh/m^2]	EArray* [kWh]	E_Grid* [kWh]	PR
Jan	141.8	85.54	25.70	134.4	107.7	57.61	55.55	0.689

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Feb	157.6	77.58	25.65	148.1	117.2	61.94	59.77	0.673
Mar	188.7	81.78	25.90	179.9	143.7	74.98	72.32	0.670
Apr	165.1	79.46	25.45	158.9	129.8	68.63	66.19	0.694
May	147.7	78.25	25.15	141.7	117.8	63.05	60.79	0.715
Jun	133.3	71.94	23.60	128.7	108.3	58.59	56.52	0.732
Jul	129.1	80.85	23.69	122.9	102.1	55.51	53.54	0.726
Aug	132.4	75.09	23.53	124.9	102.1	54.97	52.99	0.707
Sep	153.6	70.89	22.99	146.8	118.0	62.72	60.46	0.686
Oct	142.3	83.92	23.58	135.0	107.4	57.86	55.78	0.688
Nov	126.0	75.57	23.69	124.4	102.1	54.86	52.89	0.708
Dec	143.0	78.91	24.94	137.7	110.9	59.28	57.16	0.692
Annual	1760.6	939.80	24.48	1683.5	1367.1	730.01	703.96	0.697

***GlobHor**: Global Horizontal Radiation. **DiffHor**: Diffuse Horizontal Radiation. **Amb. T**: Ambient Temperature. **GlobInc**: Global Inclined Radiation. **GlobEff**: Global Efficiency. **EArray:** Effective energy at generator output. **E_Grid**: Re-injected energy into the grid.

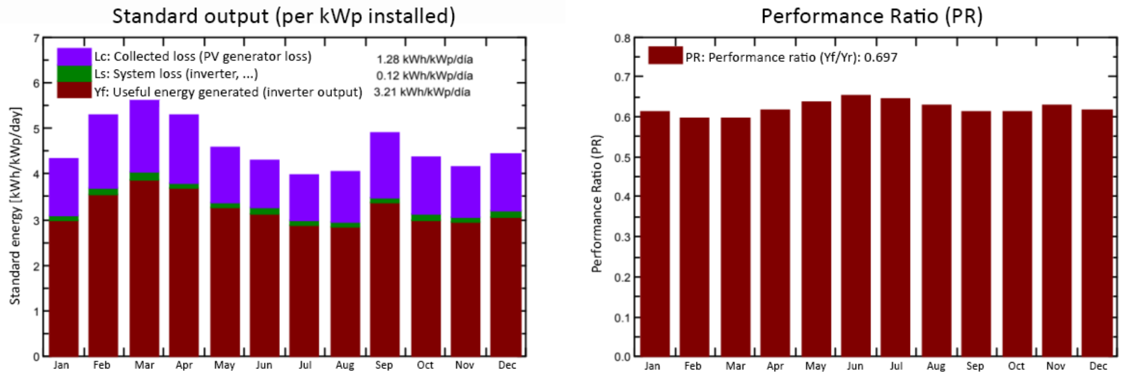

Figure 4. Left: Standard output (per kWh installed). Right: Performance ratio of simulated system

Environmental implications

There is no doubt that the small-scale implementation of photovoltaic systems has more benefits than harm. It can prevent the emission of up to 1.36 tons of CO_2 per installed kW of photovoltaic energy annually (ARE Solar, 2016). That is to say, for the system proposed in this work (0.6 kW) it would be avoided to emit up to 0.81 tons of CO_2 annually. However, the indirect impacts of manufacturing and transporting equipment and materials can be significant and must be considered. In addition, visual and space loss impacts may have implications for small and medium scale projects (USAID, 2014).

4 Conclusion

The PVsyst software made it possible to properly design and simulate the system to provide renewable electric energy to a house in Chone canton, Ecuador. The system implementation makes it possible to reduce CO_2 emissions by 0.81 tons per year, which shows that this type of system can become a practical and eco-friendly solution, as long as the resulting impacts are mitigated. This project has contributed to the reaffirmation of the potential of the region in the production of electricity, in addition to being a valid methodology to increase the welfare of the local population.

Conflict of interest statement and funding sources
The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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