International Journal of Life Sciences
Available online at www.sciencescholar.us
Vol. 4 No. 3, December 2020, pages: 31-40
e-ISSN: 2550-6986, p-ISSN: 2550-6994
https://doi.org/10.29332/ijls.v4n3.476

Environmental Impact of Sustainable Housing in Rural Area of Pilot Plan, Santo Domingo de Los T'sachilas, Ecuador

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Manuscript submitted: 18 September 2020, Manuscript revised: 09 October 2020, Accepted for publication: 27 November 2020

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Keywords

environmental impact;
households;
local development;
renewable energy;
sustainability;

Abstract

This article proposes the design of a sustainable home, which has considered climatic and environmental parameters of the province of Santo Domingo de Los T'sáchilas, in the Plan Piloto parish, from where the endemic natural resources of the area, to build a decent and pleasant home with the material of its environment, respecting the environment to meet the basic needs of the inhabitants, managing to sustain itself with efficient electrical energy. The position of the sun will be considered for the orientation and distribution of the day and night spaces, to minimize the consumption of electrical energy; 8 photovoltaic panels will be used in series that during the day capture the energy of solar radiation and the surplus is stored in 8 batteries that at night provide energy to the house. To meet this objective, it is proposed to build a sustainable home with materials provided by nature, using the resources of the environment, respecting the environment, making the most of the natural resources of the sun and the earth, largely reducing energy consumption and the environmental impact.

Contents

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1 Introduction

Since industrialization, humanity has been the only cause of the destruction of the planet, as science and technology have advanced, mega construction projects have been created, which generates a demand for material resources to satisfy urban needs, causing negative effects on the environment. The world energy crisis in recent years, the rise in the cost of traditional fuels, and the high level of environmental pollution produced by the use of fossil fuel derivatives such as coal and oil have led to the development of new technologies based on the implementation of photovoltaic systems, as an alternative energy resource (Chacón, 2001).

We use different types of energy to illuminate our houses, thanks to the fact that energy resources are constantly being renewed (Beres, 2011; Dincer, 2000; Koroneos et al., 2003). As technology advances and with environmental regulations, articles such as photovoltaic panels have been experimented with and created that help satisfy the basic needs of humanity using natural resources, avoiding pollution and creating sustainability, taking advantage of renewable sources. The undeniable benefit of renewable energies from an exclusively environmental point of view is to help reduce the presence of CO2 and other gases in the atmosphere, thereby allowing to reduce of climate change due to human factors (Oviedo-Salazar et al., 2015).

In our country, currently taking a little conscience, it tries to look for alternative energies that are renewable and friendly to the environment, investing in hydroelectric plants, photovoltaic panels, and windmills using the resources, sun, wind, and water. The province of Santo Domingo de Los T'sáchilas is a young province that has grown very fast and in disorder, building houses on a massive scale, which has caused a drop in tension in the surrounding towns, in this case, the Plan Piloto parish where the energy that reaches the sector does not it is adequate. Based on the problem, the objective is to propose a sustainable housing system, through environmentally friendly alternative energies to improve the quality of life: considering the Pilot Plan, rural area of Santo Domingo, an ideal sector to propose sustainable housing with photovoltaic panels replacing conventional energy, after the existing voltage drop.

2 Materials and Methods

To carry out the study, the Geographic information system for sustainable development (SIGDS) was used, which provides information on radiation in the area (Gamez et al., 2019) and the PvSyst (Pvsyst, 2019), to design the number of solar panels that will be used to obtain a sustainable home with clean energy. A field investigation was carried out, where the natural resources, climate, and average demand for the energy consumption of a house in the Plan Piloto parish were appreciated, the observation and bibliographic method was applied, the main sources of research are similar theses, scientific articles, engineering books, and web pages, on photovoltaic generation system with storage

3 Results and Discussions

According to the methodologies used, the analysis of the results for the proposal of a sustainable home in Santo Domingo is presented, with the implementation of an autonomous photovoltaic generation system. The promotion of the production and consumption of energy from renewable sources is marked by a change that has been developing in global conditions both from an economic, social, or environmental point of view (Correa Álvarez et al., 2016).

Ecuador has little variation in the position of the sun throughout the year since there is an average of 12 hours of sunshine during the day because it is crossed by the Equinoctial Line (Orellana Martínez & Quimis Castro, 2015). Construction strategies would be used to see the orientation of the house, the distribution of its areas depending on whether they are used in daytime or at night, the use of natural materials such as reed blinds that reduce the wintering effect that during the day will remain open giving clarity to the home, reducing the use of electrical energy, allowing storage in batteries for night consumption.

Figure 1. Wooden lighthouse with bamboo cane blinds
Source: (Artisan Wood Curtains | Decorative Blinds, 2020)

It is a good method because the Pilot Plan area has wood and bamboo cane crops without affecting the environment so much, it is re-sown and reproduces in a short time, thanks to its tropical climate the house will stay fresh and bright, avoiding the turning on of lights during the day. In Ecuador, the bamboo that stands out the most is the guadua cane, due to its exceptional physical-mechanical thermal characteristics (Jara & Dennisee, 2018). Solar PV energy also avoids maintenance and transportation costs of power lines, both in areas of difficult access, where the grid does not reach, and in urban areas, where the grid does not reach, and in urban areas, where the peaks of electrical demand with the moments of maximum insolation. Once installed, it has a zero energy cost (Puig & Jofra, 2007).

Autonomous photovoltaic systems

Due to the voltage drop in the area, an autonomous photovoltaic system is intended. Taking into account the book by Rodriguez Gamez & Vázquez Pérez (2018) states: Autonomous Photovoltaic Systems (SFA) is made up of a set of technical elements interconnected with each other, to provide electrical energy to a certain load, understood as charge lighting devices, household appliances, and others. Autonomous photovoltaic systems consist of a solar collection system (solar cells arranged in panels); the batteries to store the electricity generated in direct current and the control system to ensure the correct operation of charging and discharging the batteries. Specifically, when they are designed to supply alternating current, a DC-AC inverter is added.

Autonomous systems are created to supply electrical energy in remote and isolated places, there are different alternatives: extension of networks, individual or community power plants, rechargeable batteries, generators, Diesel, photovoltaic systems, etc. (Almeida, 2006). The photovoltaic effect; converts the light energy carried by light photons into electrical energy capable of driving the electrons fired from the semiconductor material through a circuit (Barrera, 2010). To know the number of solar panels that a sustainable home needs, one must know: how much energy the home is going to consume, the climate, and the maximum sunlight in the area.

Installed power

According to the isolated photovoltaic generation system, the monthly energy consumption of the home must be known and 310 kWh / month is established. The Peak Solar Hour (HSP) in Santo Domingo de Los T'sáchilas is 5 hours. Equation 1 is applied to determine the installed capacity. Equation 2 is applied 1.

$$Capacidad\ Instalada\ = \frac{\sum_{i=mes\ 1}^{mes\ 12} \mathrm{Emensual_i(kWh)}}{\mathrm{Factor_{planta\ de\ diseño}}*8760\ (h)} \quad (1)$$

Determine the monthly energy. Monthly energy. Equation 2 is applied

$$\text{Energía mensual} = 310\,\frac{\mathrm{kWh}}{\mathrm{mes}} * \frac{\mathrm{12\ meses}}{\mathrm{1\ año}} = 3720\,\frac{\mathrm{kWh}}{\mathrm{año}} \quad (2)$$

For the calculation of the plant factor, equation 3 is used.

$$Factor\ planta = \frac{Hsp}{24\ h} \quad (3)$$

Resulting in a factor of 0.208

$$Capacidad\ Instalada\ = \frac{\mathrm{3720\ kWh/año}}{\mathrm{0,208*8760\ (h)}} = 2{,}04kW$$

Inverter

It is the element of the installation that converts direct current into alternating current, they are inserted between the charge regulator and the alternating current devices. It is essential in systems that use storage devices, such as a battery (Sánchez Quiroga, 2012; Heinrich & Teoh, 2004; Marsden & Smith, 2005). Inverter power is given as a function of the installed capacity of the system and is calculated as shown in equation 4.

$$\mathrm{P_{inv}} = 1{,}2 * \text{ Capacidad Instalada} \quad (4)$$

$$P_{inv} = 1{,}2\ (2{,}04kW) = 2.5kW$$

For the selection of the inverter, it must be considered that there are 2, 3, 5 kW in the market, among others, the 3kW inverter that is above the calculated value is chosen, when making a comparison with two brands of Inverters shown in table 1, it is decided to use the InfiniSolar, since when starting up the inverter it needs the panels to generate at least 116 VDC, operating on cloudy days.

Table 1
Inverter technical specifications for InfiniSolar and Renogen inverters

Brands	InfiniSolar	Renogen
Grid-tied operation		
Pv input		
Nominal dc voltage / maximum dc voltage	360 VDC / 500 VDC	450 VDC
Start-up voltage / initial supply voltage	116 VDC / 150 VDC	
Voltage range mpp	250 VDC ~ 450 VDC	220 VDC ~ 430 VDC
Maximum input current	18 A	
Grid output (ac)		
Nominal output voltage	208/220/230/240 VAC	220/230/240 VAC
Nominal output current	13 A	13A
Power factor	>0.99	>0.99
Off grid operation		
Ac input		
AC start-up voltage	120 - 140 VAC	
Input voltage range	170 ~ 280 VAC	170 ~ 280 VAC
Maximum ac input current		30A
Communication	USB OR RS232	USB OR RS232

Slot smart optional	SNMP, MODBUS, AS-400

Source: (Ola & Salas, 2020)

Photovoltaic panel

Panels take advantage of light energy from the sun to produce electricity through semiconductor plates that are altered by solar radiation, these systems are called photovoltaic solar panels (PFV) (Garrido, 2009).

Select Solar Panel

A solar panel is selected that is in a maximum voltage range (Mpp) 250 to 450 VDC, the values in which your inverter works and supplies the installed power of 3 kW, it is compared between panels of 270W and 150W. For panel selection, They will value the brands in table 2, hence the 270 W panel was selected, to supply the demand, reach the voltage of the maximum power point, and for the inverter to work without any problem, having two 270 W solar panels.

Table 2
solar panel selection options

Marks	Sunmart	Sunmart
Pmp	270 W	150 W
Vmp	31.47 V	3.18 V
Imp	8.58	8.2 A
Voc	37.81V	22.4 V
Isc	9.11 A	8.72 A
TONC	47 ° C	45 ° C
Efficiency	16.59%	15.33%
CCT- I_{SC}	$0.05\frac{\%}{°C}$	$0.01\frac{\%}{°C}$
CCT- V_{OC}	$0.35\frac{\%}{°C}$	$0.31\frac{\%}{°C}$
CCT- P_{Max}	$0.45\frac{\%}{°C}$	$0.40\frac{\%}{°C}$

Source: (Ola & Salas, 2020)

Total number of Solar Panels

For the selection of the number of panels, the climatological base of the study area was taken into account, shown in table 3.

Table 3
Meteorological data for Santo Domingo de los T'sachilas

Maximum ambient temperature (Ta max)	26 °
Ambient temperature minina (Ta min)	17 °
Maximum irradiance (I max)	1100 W / m2
Minimum irradiance (I min)	90 W / m2

The panel temperature was calculated using equation 5, taking the TONC as the panel mark, for calculating the maximum and minimum values.

$$Tp = Ta + \frac{TONC-20}{800} I \quad (5)$$

The maximum panel voltage and the minimum voltage and the voltage difference were evaluated from the temperature values obtained, in many cases these parameters are offered by the manufacturer.

$$\frac{\delta\, Voc}{\delta\, T} = \frac{\delta\, Vmp}{\delta\, T} = 37.81\, V * \frac{0.35\%}{°\, C} * \frac{1}{100\%} = 0.1323\, \frac{V}{°\, C}$$

$$\Delta T = 26\, °\, C - 22.64\, °\, C = 3.36\, °\, C$$

$$\Delta V = \Delta T * \frac{\delta\, Voc}{\delta\, T} = 3.36\, °\, C * 0.1323\, \frac{V}{°\, C} = 0.44\, V$$

$$Vmax\ panel = Voc + \Delta V$$

$$Vmax\ panel = 37.81 + 0.44 = 38.25\, V$$

The maximum number of panels in series was also determined and the minimums as shown in the following analyzes.

$$Nps \leq \frac{Vmax\ inverter}{Vmax\ panel}$$

Minimum series panels

$$Nps \geq \frac{Vmin\ inverter}{Vmin\ panel}$$

Maximum number of rows

$$Nhp \leq \frac{Iadmissible\ inverter}{Isc}$$

As calculated, an arrangement of 8 panels in series is chosen.

$$P_{PANELS} = 270\, W\, x\, 8 = 2160W$$

$$Installed\ Power \leq P_{PANELS}$$

$$2040\, W \leq 2160\, W$$

In compliance with the installed power required by sustainable housing, the 8 panels in series must enter the maximum power range. The random availability of renewable energy sources results in periods with excess energy and periods with energy deficiency requiring the use of batteries (Kastillo Estévez & Nasimba Tipán, 2017). The battery will be in charge of providing energy to the installation when there is little or no solar irradiation (Aparicio, 2006).

Battery bank

For the sizing of the batteries, it was carried out with equation 6, from the battery capacity (Cb) is the daily energy consumption (ED) between the product of the nominal voltage of the system (Vn), battery performance (nb), and inverter performance (nI).

$$C_b = \frac{E_D}{V_N * n_b * n_I} \qquad (6)$$

$$E_D = \frac{310\ kW\ /\ month}{30\ days\ /\ month} = 10.33\ kW\ /\ day$$

$$C_b = \frac{10330\ \frac{W}{day}}{(0.7)\ (0.93)\ (48\ Vdc)} = 330.58\ Ah$$

Discharge rate of the battery

The time in which the battery is discharged will depend on the energy demanded and the total installed power. The PI of an average house is 1200 W which is used as a reference (Jay et al., 2007; Duinker & Greig, 2007). To find a commercial battery in the market that are given in C10 to size the batteries and so that their size is optimal and there is never a lack of capacity, above, the batteries have technology with 4 extra days of storage capacity for safety reasons in case there are rainy or cloudy days.

$$t = \frac{E_D}{P_I}$$

$$t = \frac{10330\ W\ /\ day}{1200\ W} = 8.61$$

$$C_b = C_5 = 330.58\ Ah$$

$$\frac{C_{10} - C_5}{(10 - 8.61)} = \frac{0.25\ C_{10}}{90}$$

$$\frac{C_{10} - 330.58}{1.39} = \frac{0.25\ C_{10}}{90}$$

$$90\ C_{10} - 29752.2 = 0.35\ C_{10}$$

$$C_{10} = \frac{29752.2}{89.65} = 331.87 Ah$$

The Number of Batteries in series depends on the nominal voltage of the system between the nominal voltage of the battery as noted in the equation

$$Number\ of\ batteries\ in\ series = \frac{V\ nominal\ of\ the\ system}{V\ nominal\ battery}$$

$$Number\ of\ batteries\ in\ series = \frac{48\ V}{6\ V}$$

$$Number\ of\ batteries\ in\ series = 8\ batteries$$

Selected 8 batteries to be connected in series model Leoch Deep Cycle CarbonLDC6-350, to reach the level of the voltage of 48 VDC, with a capacity of 350 AH and 6V each.

4 Conclusion

Sustainable housing takes advantage of natural resources in every way, reducing the environmental impact considering architectural and energy aspects by implementing a photovoltaic electricity generation system that consumes directly, accumulates energy in a battery bank. A sustainable home was proposed with the implementation of an isolated photovoltaic system of 8 panels connected in series with a total power of 2.04

kWp, and the inverter power of 3kW, it has 8 Gel batteries of 6V and 350Ah capacity Each one, the inverter is in charge of transforming direct current into alternating current, managing the panel and the batteries to feed 220V single-phase loads.

Acknowledgments
To the additions of the magazine for allowing us to make the publications in our student stage.

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