ISSN No:-2456-2165

Electric Power Generation in Rural Homes of the Province of Cañar - Ecuador

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Abstract:- This paper analyzes the design of an autonomous electric power generation system for homes in rural areas of the Cañar province, located in the southern part of Ecuador, specifically in places where public companies that supply electric power cannot reach or economically the expansion projects of energy networks are not feasible. A house that has a daily consumption of 9444Wh/day was analyzed, that is, a social housing. The number of photovoltaic panels needed, the charge controller, the inverter, and the number of batteries needed to supply the house were calculated. Households found in agricultural production areas were used as the basis for the study, as these are located in the most remote parts of rural communities. A total of nine 375 W photovoltaic panels and twelve batteries were found to be sufficient to provide 120% of the demand. Taking into account that the study area of the present investigation is in a temperate climate most of the year, factors such as heating equipment for the interior of the house or thermal components such as the construction materials of the houses were not analyzed.

Keywords:- *Energy; Photovoltaic; Renewable.*

I. INTRODUCTION

The 58% of the total population in the province of Cañar is located in rural areas or classified as such, and this percentage of inhabitants is engaged in agricultural and livestock production, which are their main sources of income. Therefore, generating plans for decent housing for this group of inhabitants is of utmost importance.

Access to an electric power grid is often impossible in many rural households due to the geographical location of the dwellings, causing the population to seek alternative ways of energy generation. The condition of the roads leading to different communities in the province of Cañar creates a situation where public companies responsible for providing electricity to the population are unable to reach all inhabited areas. There are even communities that lack access roads, and the only means of reaching them is by foot or on horseback.

The use of firewood for heating water, cooking, or generating heat inside homes is very common in rural areas of the province of Cañar, which results in suboptimal living conditions for this population.

According to the Provincial Development and Territorial Ordering Plan (PDyOT) of Cañar Province [1], only a percentage of 0.04% of the total households in the province use electricity generated by solar panel systems.

Table 1 Generation of Electric Power in the Province of Cañar.

Type of Origin	Houses	%
1. Power network provided by state companies	56188	95,26
2. Solar Energy	22	0,04
3. Own light generator	47	0,08
4. Other	206	0,35
5. Does not have	2521	4,27
Total	58984	100

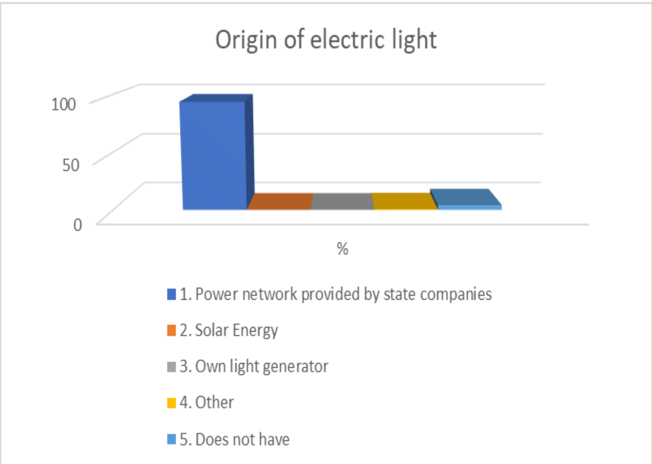

Fig 1 Origin of the Electric Light

Only a small percentage of global electricity production is generated through solar energy, but over the years this method of energy generation has been growing rapidly, not only because it has gained popularity among users, but also due to the support of state entities for these alternative design methodologies. It is also worth noting that

ISSN No:-2456-2165

there has been technological maturity and significant economic competitiveness over the years, which has made solar energy a viable alternative source of generation to conventional methods [2].

The scarcity of fossil fuels and their negative impact on the environment are driving humanity to seek renewable and sustainable fuel alternatives. Thanks to technological advancements, the search for alternative energy sources to conventional ones has intensified, and the efficiency in renewable energy collection has been continuously improved. One of the most viable options is solar energy, as it is clean, renewable, and widely available in most regions. In fact, in just 90 minutes, the sun provides enough energy to cover the world's energy demand for a year. Despite this, solar energy represents a small fraction of the world's current energy mix, but this situation is changing rapidly due to global initiatives to improve energy security, ensure access, and mitigate climate change [3].

The energy obtained from solar generation has a high initial cost compared to conventional generation sources, but over time, its cost will decrease as the investment for production and maintenance is minimal. Additionally, we must consider that solar energy generation is environmentally friendly, durable, and sustainable. According to statistical data, for every 100 kW of solar power installed in civil infrastructure, we can avoid emitting approximately 75,000 kg of carbon dioxide into the environment each year, which significantly helps mitigate climate change [4].

Autonomous electrical power generation systems for rural areas in the Province of Cañar are a way to obtain sufficient energy to meet the electricity needs of rural households. These systems provide the opportunity for residents in remote locations to have decent and fully habitable homes. A typical autonomous system is shown in figure 2.

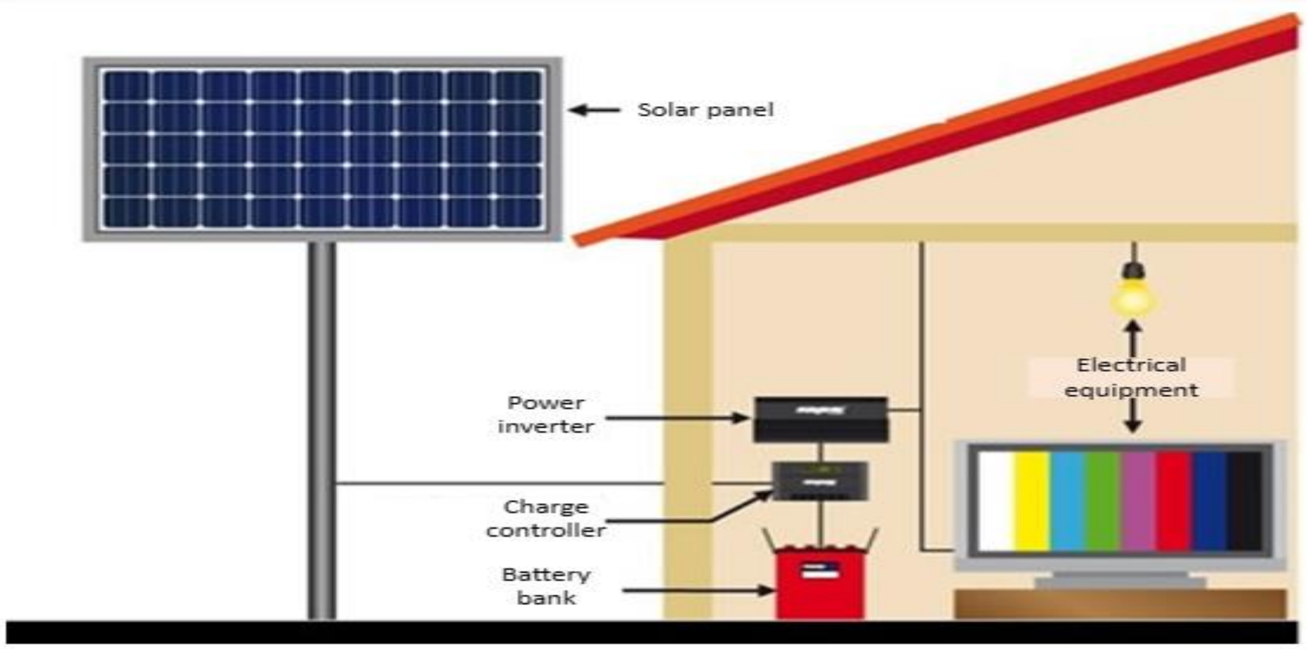

Fig 2 Example of Solar Power Generation System

Currently, there are several social housing programs in the country that are focused on rural areas, aimed at providing low-income individuals with decent housing. However, a problem arises when these individuals own land in remote locations far from main roads, and public utility companies cannot access these areas or have to lay lengthy electrical connection lines for just one house. In such cases, autonomous electrical power generation through photovoltaic panels becomes a viable solution, as it can be compared to the cost of laying an entire new electrical wiring network and monthly service charges, versus the cost of acquiring all the elements that comprise an electrical generation system.

II. GEOGRAPHY OF THE STUDY AREA

The Province of Cañar is located within the territory of the Republic of Ecuador, which is comprised of 24 provinces. It is situated in the southern part of the country in the Sierra region, also known as the inter-Andean region. The capital city of Cañar is Azogues. According to the division by Planning Zones of Ecuador carried out by "La Secretaría Técnica Planifica Ecuador", the province of Cañar is part of the Central-Southern Region of the country, also known as zone 6, which it shares with the provinces of Morona Santiago and Azuay [1].

Table 2 Geography of the Study Area

Total area	4106,76 Km2
Population Growth Rate	0.98% (according to the census 2010)
Population	231508 people

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Fig 3 Location of the Province of Cañar

Relief is the main modifying factor of climate and plays a significant role in this aspect. In fact, the different climate types are closely related to the relative altitude determined by the relief. This factor influences all the biophysical elements of the system, making its analysis fundamental for understanding the climatic characteristics of a region. In Ecuador, relief is the primary factor that determines four distinct geographical regions (Secretaría Nacional de Gestión de Riesgos y Emergencias [5].

The present study focuses on the area of the Cañar province, which is located at an altitude of approximately 3000 meters above sea level. Altitude and exposure are key factors that determine temperature and precipitation values in this area. Maximum temperatures rarely exceed 20°C, and minimum temperatures are consistently below 0°C. Annual averages vary considerably, but generally range between 4°C and 8°C. Annual precipitation amounts range from 800 to 2000 mm, and most rainfall events are of long duration but low intensity. Relative humidity is always above 80%. The natural vegetation, known as shrub land at lower elevations, is replaced by a dense herbaceous cover saturated with water at higher elevations, characteristic of paramo ecosystems [1].

The elevation ranges between 2500 and 3400 meters above sea level (with temperatures ranging from 13°C to 8°C) is ideal for potato cultivation, making it the most suitable ecological level for its production. In addition, other agricultural products native to tropical climates can also be grown at this elevation, similar to the temperate zone. On the other hand, potatoes have been introduced in temperate and cold areas of the Andean mountains with excellent results, despite being native to the intertropical zone [1].

The annual temperatures in this zone range from 4.1°C to 24.5°C, although they can be lower in areas with less exposure to sunlight. The lowest temperatures can reach 3.9°C, while the maximum temperatures do not exceed 13.9°C, depending on altitude and exposure. Relative humidity ranges from 6% to 80%, and sunshine duration varies from 2000 to 2200 hours per year. Annual precipitation ranges from 1000 to 2000 mm, with two rainy seasons from February to May and October to November. The dry season from June to September is very pronounced. The second rainy season, known as "veranillo del Niño", has a more random duration and location, but usually occurs in late December. In this zone, natural vegetation has largely been replaced by grasslands and crops such as cereals, corn, and potatoes [1].

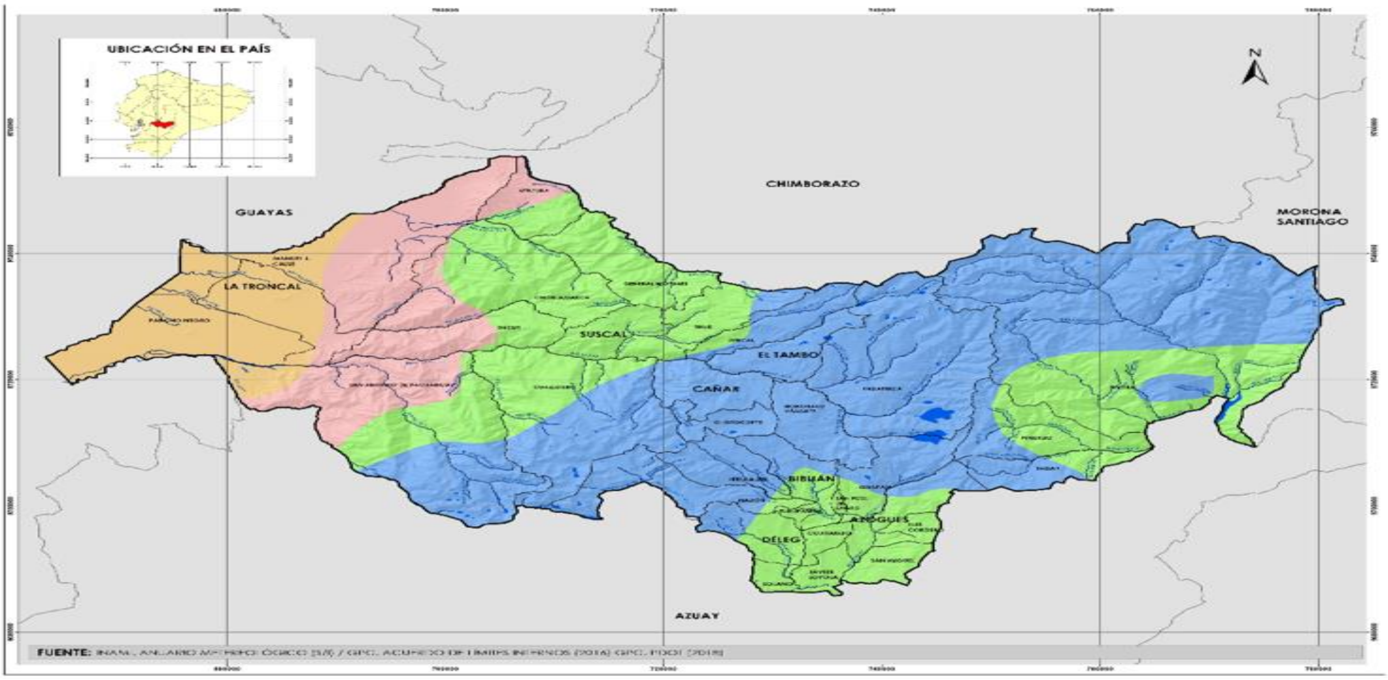

Fig 4 Cañar Province Map.

According to the [1], the least served parishes with basic services in the Province of Cañar are General Morales and Chontamarca in the highlands, while the best served are Guapán, Solano, including the cantons of Azogues, Cañar, Biblián, and the coastal canton of La Troncal. Taking into account the percentage of electricity coverage in the province, we can observe that 95.26% of the population has access to this service, while 4.74% do not have electricity supply, with the canton of Biblián having the highest coverage at 97.88%, and the canton of Suscal having the lowest coverage at 90.25%.

Taking into account one of the least served parishes, such as General Morales, this study will focus on the conditions of this place, considering that it is one of the economically most vulnerable parishes, mainly reliant on agriculture and livestock. Our study aims to generate an efficient solution to provide families in this area of the Province of Cañar with a dignified life and a decent place to live.

Local communities heavily rely on small-scale agricultural and livestock production for their economy. Most of the crops are used to meet their food needs, while a small portion is sold. As for livestock production, it is mainly done to generate additional income in case of economic emergencies and to market products such as milk, cheese, and "quesillo" [1].

Fig 5 Location Map of the Study Area

III. METHODOLOGY

An analysis of the study area will be conducted in order to determine the location, ambient temperature, and all necessary conditions for sizing the autonomous system for electricity generation. Likewise, the basic electronic components required for a social housing unit will be taken into consideration. Lastly, using the Biosol software, the different values of irradiance, luminosity, and sun positioning with respect to the study area will be determined in order to position the necessary photovoltaic panels for supplying electricity to the housing unit.

IV. SYSTEM CALCULATION

➢ *According to [7], it is important to keep in mind four things in order to conduct a proper analysis and meet the necessary or required energy supply:*

- *Daily Energy Amount Required by the Home or Business.*
- *Autonomy Days.*
- *Battery Discharge Limit.*
- *Ambient Temperature at which the Batteries will be Exposed. [7].*

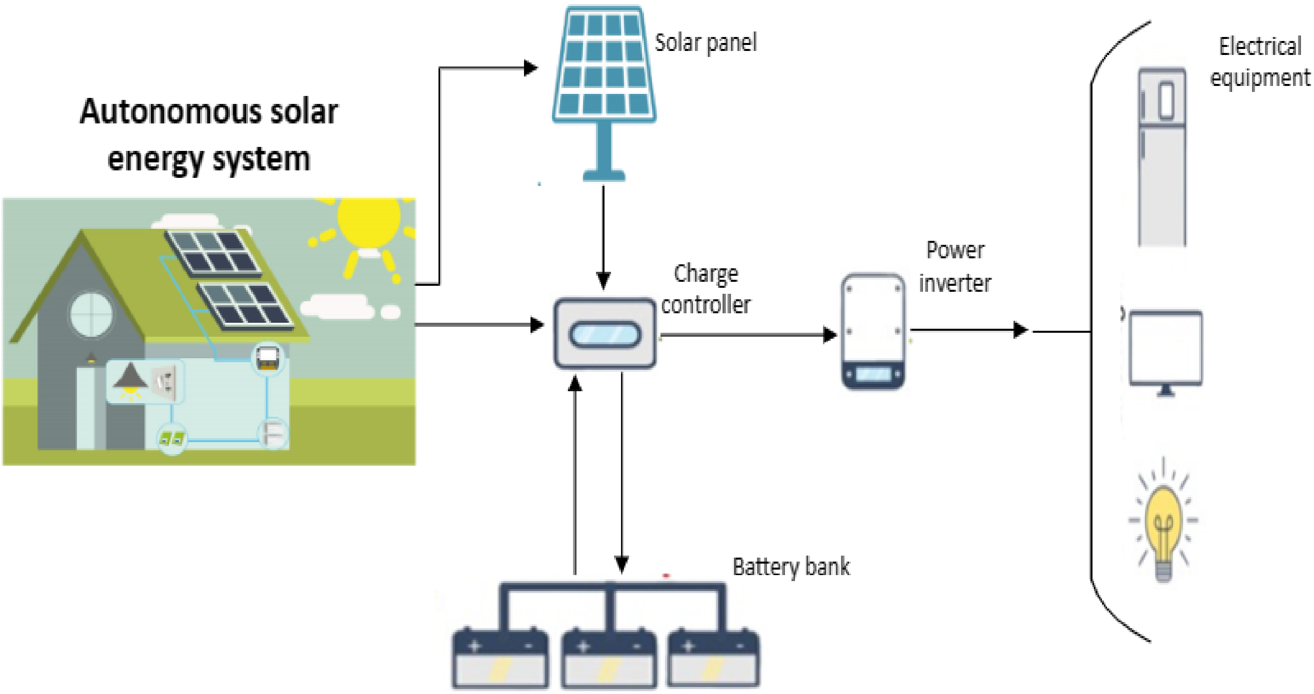

Fig 6 Example of Autonomous Solar Energy System

➢ *The Elements that are Part of an Autonomous Electric Power Generation System are the following:*

- *Photovoltaic Panels.*
- *Batteries.*
- *Regulator or Charge Controller.*
- *Power Inverter*

For the design of the autonomous electric power generation system, the main appliances that a rural home in the Cañar Province could have were analyzed, taking into account their power, quantity, daily usage hours, daily consumption, and maximum demand.

A system protection factor of 20% was considered, which can also include the connection of low-consumption appliances to the system [7].

The calculation of daily consumption is obtained by multiplying the number of units of each appliance by its power and daily usage hours, while the demand is obtained by multiplying the quantity of each appliance by its power. In the case of water pump demand, a safety factor of 3 times the demand is taken into account due to the sudden surges that this equipment can experience [7].

ISSN No:-2456-2165

Table 3 Study of Loads

Electronic Equipment	**Number of Equipment in the House**	**Power of Each Equipment (Watts)**	**Voltage of Each Equipment (V)**	
Television	1	150	110	
Refrigerator	1	250	110	
Lighting	10	15	110	
Water pump 0,5HP	1	370	110	
Electric Shower	1	4000	110	
Electronic equipment	Daily usage time of each equipment	Daily consumption by equipment (Wh/día)	Maximum demand per equipment (Watts)	
Television	4	600	150	
Refrigerator	8	2000	250	
Lighting	6	900	150	
Water pump 0,5HP	1	370	1110	
Electric Shower	1	4000	4000	
		7870	5660	TOTAL
PROTECTION FACTOR	20%			
DAILY CONSUMPTION (Wh/día)	9444			

The daily consumption to calculate the system is 9.44 kWh/day. The equipment comprising the autonomous system are as follows:

Table 4 System Equipment

EQUIPMENT	**QUANTITY**	**FEATURES**
Solar panels	9	375W
Charger controller	1	48V, 3200W
Batteries	12	12V, 150Ah
Inverter	1	3500W, 48V

V. POSITIONING OF PHOTOVOLTAIC PANELS

Using the software presented by [9], we can identify the optimal tilt and orientation for our photovoltaic panels to better capture solar irradiation in the study area.

The data for relative humidity, minimum and maximum temperature, and daily average global irradiation values were obtained through the interactive maps from [10], [11].

The orientation of a photovoltaic generator is defined by the following coordinates:

Azimuth (α): It is the angle formed by the projection on the horizontal plane of the perpendicular to the surface of the generator and the south direction. Its value is 0º if it coincides with the south orientation. For a photovoltaic generator located in the northern hemisphere, as in our case, the optimal orientation would be towards the south [12].

Inclination (β): It is the angle formed by the panel with the horizontal surface tangent to the earth at the point. The best use is obtained when the radiation falls perpendicularly on the panel [12].

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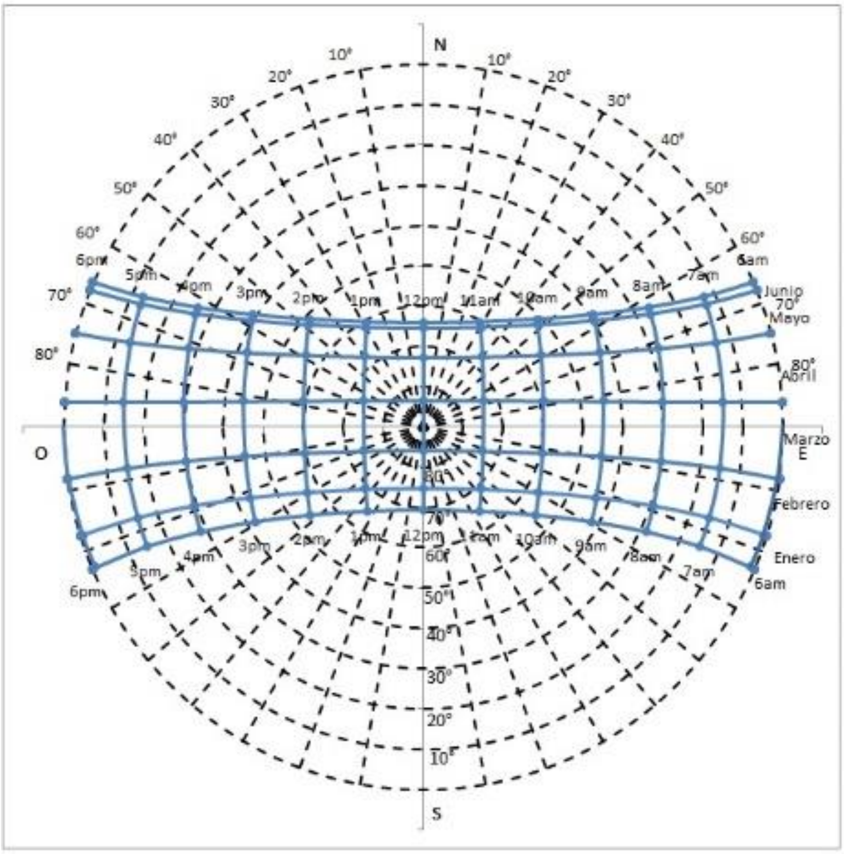
GRÁFICA SOLAR EQUIDISTANTE							
1er SEMESTRE							
Localidad	General Morales, Cañar, E	Latitud	-2.407975	Longitud	-79.022948	Altitud [m]	2594



GRÁFICA SOLAR CILÍNDRICA							
1er SEMESTRE							
Localidad	General Morales, Cañar, E	Latitud	-2.407975	Longitud	-79.022948	Altitud [m]	2594

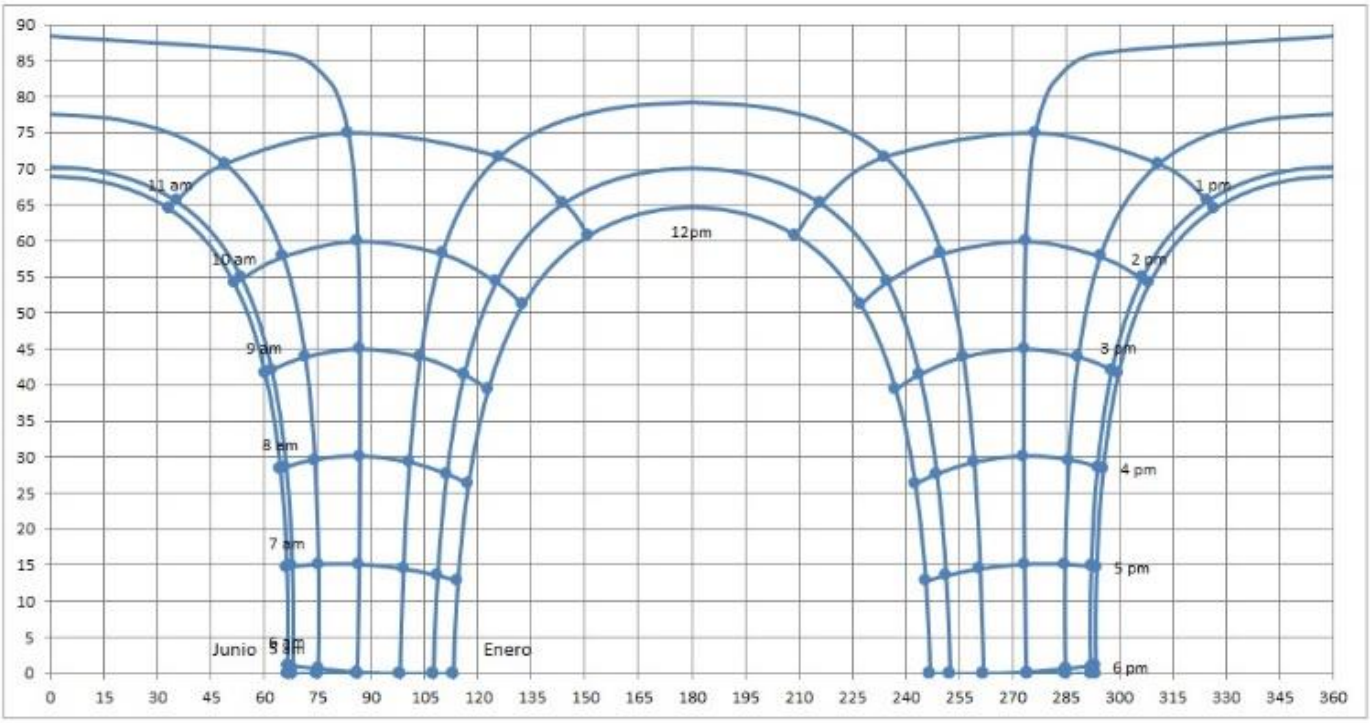
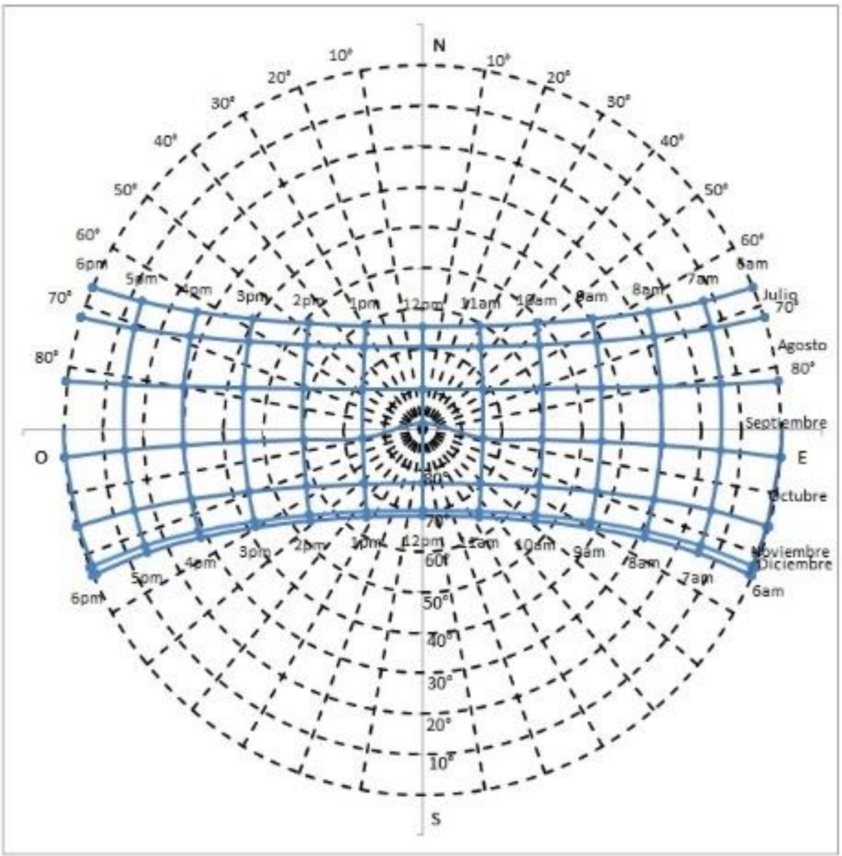


Fig 7 Solar Graph Equidistant 1st Quarter of the Year

GRÁFICA SOLAR EQUIDISTANTE							
2do SEMESTRE							
Localidad	General Morales, Cañar, E	Latitud	-2.407975	Longitud	-79.022948	Altitud [m]	2594



GRÁFICA SOLAR CILÍNDRICA							
2do SEMESTRE							
Localidad	General Morales, Cañar, E	Latitud	-2.407975	Longitud	-79.022948	Altitud [m]	2594

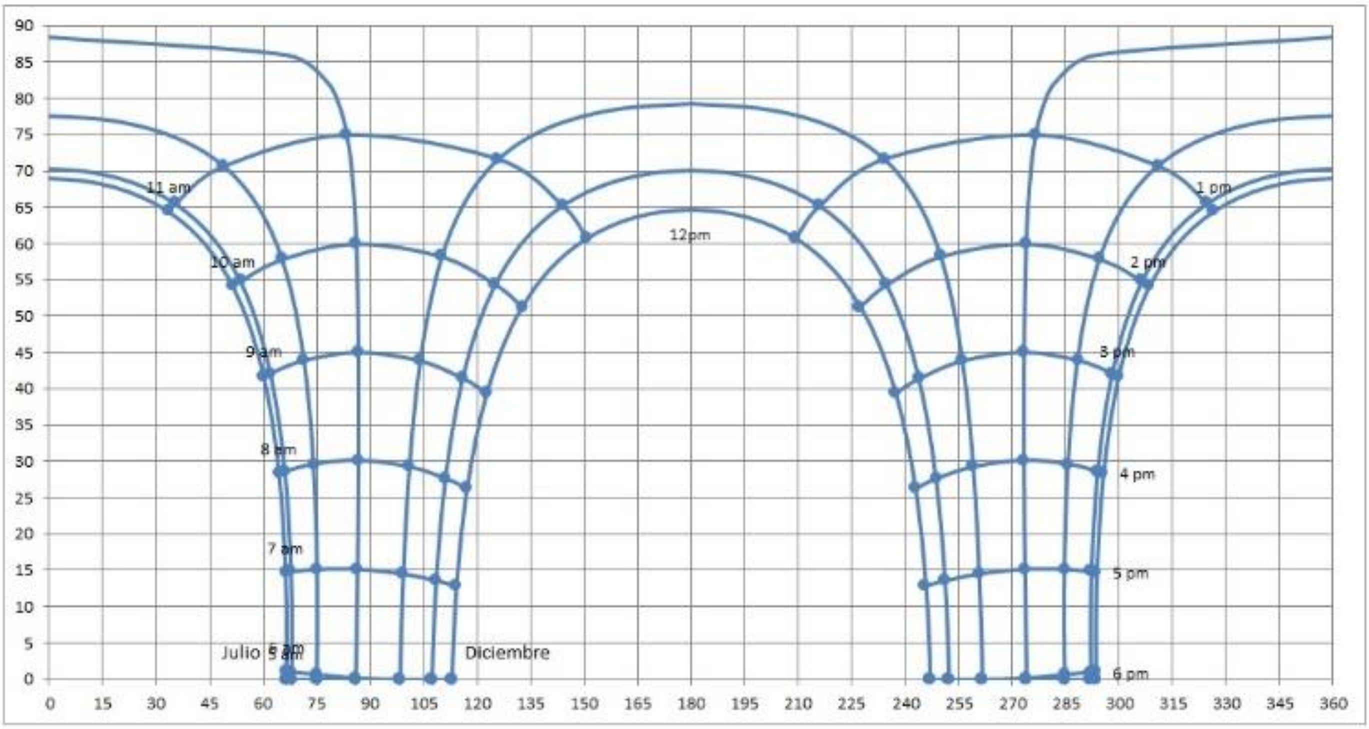


Fig 8 Solar Graph Equidistant 2nd Quarter of the Year

ISSN No:-2456-2165

Hour	[W/m^2]											
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	5.88	3.21	0.11	-	-	-	-	-	0.06	3.36	5.98	6.94
07H00	121.56	119.38	116.85	114	111.77	110.84	111.69	113.95	116.81	119.51	121.64	122.43
08H00	258.1	256.9	255.5	253.9	252.65	252.13	252.61	253.88	255.47	256.97	258.14	258.57
09H00	397.47	397.51	397.55	397.57	397.57	397.56	397.57	397.57	397.55	397.51	397.47	397.45
10H00	518.28	519.52	520.95	522.54	523.76	524.26	523.8	522.56	520.98	519.45	518.23	517.78
11H00	600.38	602.5	604.93	607.65	609.75	610.63	609.83	607.69	604.97	602.38	600.3	599.54
12H00	629.47	631.9	634.7	637.84	640.26	641.27	640.35	637.89	634.76	631.77	629.38	628.51
13H00	600.38	602.5	604.93	607.65	609.75	610.63	609.83	607.69	604.97	602.38	600.3	599.54
14H00	518.28	519.52	520.95	522.54	523.76	524.26	523.8	522.56	520.98	519.45	518.23	517.78
15H00	397.47	397.51	397.55	397.57	397.57	397.56	397.57	397.57	397.55	397.51	397.47	397.45
16H00	258.1	256.9	255.5	253.9	252.65	252.13	252.61	253.88	255.47	256.97	258.14	258.57
17H00	121.56	119.38	116.85	114	111.77	110.84	111.69	113.95	116.81	119.51	121.64	122.43
18H00	5.88	3.21	0.11	-	-	-	-	-	0.06	3.36	5.98	6.94
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-
00H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 9 Horizontal Global Irradiance

Hour	[W/m^2]											
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	4.49	2.46	0.09	-	-	-	-	-	0.04	2.58	4.56	5.29
07H00	79.87	78.67	77.27	75.67	74.41	73.88	74.36	75.64	77.24	78.74	79.92	80.34
08H00	150.12	149.69	149.19	148.61	148.14	147.94	148.12	148.6	149.18	149.72	150.13	150.28
09H00	210.44	210.68	210.95	211.24	211.46	211.55	211.47	211.25	210.96	210.67	210.43	210.34
10H00	256.73	257.48	258.34	259.3	260.04	260.35	260.07	259.32	258.36	257.44	256.7	256.43
11H00	285.82	286.9	288.13	289.52	290.58	291.03	290.62	289.54	288.16	286.84	285.78	285.4
12H00	295.75	296.93	298.29	299.82	301	301.49	301.04	299.84	298.32	296.86	295.7	295.28
13H00	285.82	286.9	288.13	289.52	290.58	291.03	290.62	289.54	288.16	286.84	285.78	285.4
14H00	256.73	257.48	258.34	259.3	260.04	260.35	260.07	259.32	258.36	257.44	256.7	256.43
15H00	210.44	210.68	210.95	211.24	211.46	211.55	211.47	211.25	210.96	210.67	210.43	210.34
16H00	150.12	149.69	149.19	148.61	148.14	147.94	148.12	148.6	149.18	149.72	150.13	150.28
17H00	79.87	78.67	77.27	75.67	74.41	73.88	74.36	75.64	77.24	78.74	79.92	80.34
18H00	4.49	2.46	0.09	-	-	-	-	-	0.04	2.58	4.56	5.29
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-
00H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 10 Horizontal Diffuse Irradiance

ISSN No:-2456-2165

	[W/m^2]											
Hour-Month	january	february	march	april	may	june	july	agost	september	october	november	december
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	1.39	0.75	0.03	-	-	-	-	-	0.01	0.78	1.42	1.65
07H00	41.69	40.71	39.58	38.33	37.36	36.96	37.33	38.31	39.56	40.76	41.73	42.08
08H00	107.98	107.2	106.31	105.3	104.51	104.18	104.48	105.28	106.29	107.25	108.01	108.29
09H00	187.03	186.83	186.6	186.32	186.11	186.02	186.1	186.32	186.59	186.84	187.04	187.11
10H00	261.55	262.05	262.61	263.24	263.72	263.92	263.73	263.25	262.62	262.02	261.53	261.35
11H00	314.56	315.6	316.8	318.14	319.17	319.6	319.21	318.16	316.82	315.54	314.52	314.14
12H00	333.72	334.97	336.41	338.02	339.26	339.78	339.3	338.04	336.44	334.9	333.68	333.23
13H00	314.56	315.6	316.8	318.14	319.17	319.6	319.21	318.16	316.82	315.54	314.52	314.14
14H00	261.55	262.05	262.61	263.24	263.72	263.92	263.73	263.25	262.62	262.02	261.53	261.35
15H00	187.03	186.83	186.6	186.32	186.11	186.02	186.1	186.32	186.59	186.84	187.04	187.11
16H00	107.98	107.2	106.31	105.3	104.51	104.18	104.48	105.28	106.29	107.25	108.01	108.29
17H00	41.69	40.71	39.58	38.33	37.36	36.96	37.33	38.31	39.56	40.76	41.73	42.08
18H00	1.39	0.75	0.03	-	-	-	-	-	0.01	0.78	1.42	1.65
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 11 Horizontal Direct Irradiance

	[klux]											
Hour-Month	january	february	march	april	may	june	july	agost	september	october	november	december
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	0.823	0.438	0.018	-	-	-	-	-	-9	0.458	0.835	0.96
07H00	13.535	13.323	13.03	12.651	12.325	12.177	12.294	12.612	12.986	13.312	13.531	13.609
08H00	29.206	29.159	28.985	28.657	28.312	28.138	28.257	28.579	28.9	29.113	29.183	29.201
09H00	45.621	45.793	45.785	45.545	45.192	44.997	45.115	45.426	45.661	45.709	45.576	45.514
10H00	59.427	59.848	59.987	59.791	59.355	59.087	59.208	59.55	59.738	59.675	59.342	59.204
11H00	69.238	69.824	70.082	69.952	69.503	69.213	69.332	69.668	69.795	69.615	69.136	68.94
12H00	72.733	73.381	73.682	73.577	73.122	72.825	72.943	73.276	73.379	73.158	72.624	72.406
13H00	69.234	69.823	70.078	69.951	69.499	69.209	69.327	69.662	69.788	69.611	69.131	68.935
14H00	59.423	59.847	59.983	59.792	59.351	59.082	59.202	59.543	59.732	59.669	59.337	59.2
15H00	45.621	45.796	45.785	45.548	45.192	44.997	45.115	45.427	45.662	45.709	45.576	45.514
16H00	29.209	29.164	28.988	28.662	28.314	28.141	28.261	28.583	28.906	29.117	29.186	29.205
17H00	13.538	13.327	13.032	12.655	12.327	12.18	12.297	12.616	12.991	13.316	13.534	13.612
18H00	0.824	0.438	0.018	-	-	-	-	-	-9	0.458	0.835	0.961
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 12 Horizontal Global Illuminance

	[klux]											
Hour-Month	january	february	march	april	may	june	july	agost	september	october	november	december
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	0.823	0.438	0.018	-	-	-	-	-	-9	0.458	0.835	0.96
07H00	10.82	10.705	10.505	10.258	10.017	9.881	9.923	10.103	10.336	10.631	10.792	10.862
08H00	19.858	19.874	19.777	19.653	19.464	19.32	19.295	19.361	19.469	19.722	19.801	19.851
09H00	27.282	27.394	27.368	27.359	27.222	27.08	26.993	26.952	26.95	27.175	27.204	27.243
10H00	35.277	35.458	35.442	35.466	35.292	35.107	34.98	34.901	34.869	35.136	35.158	35.208
11H00	38.661	38.872	38.869	38.956	38.811	38.63	38.463	38.316	38.228	38.504	38.528	38.585
12H00	39.78	2-abr	4-	40.113	39.975	39.796	39.613	39.44	39.331	39.615	39.641	39.703
13H00	38.649	38.866	38.857	38.953	38.8	38.618	38.448	38.299	38.209	38.49	38.514	38.573
14H00	35.265	35.457	35.429	35.467	35.28	35.093	34.964	34.882	34.849	35.12	35.143	35.194
15H00	27.282	27.407	27.368	27.375	27.221	27.08	26.994	26.954	26.952	27.176	27.205	27.244
16H00	19.875	19.902	19.792	19.682	19.479	19.338	19.317	19.388	19.498	19.744	19.823	19.87
17H00	10.839	10.73	10.523	10.283	10.034	9.901	9.947	10.132	10.368	10.655	10.816	10.883
18H00	0.824	0.438	0.018	-	-	-	-	-	-9	0.458	0.835	0.961
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 13 Horizontal Diffuse Illuminance

	[klux]											
Hour-Month	january	february	march	april	may	june	july	agost	september	october	november	december
01H00	-	-	-	-	-	-	-	-	-	-	-	-
02H00	-	-	-	-	-	-	-	-	-	-	-	-
03H00	-	-	-	-	-	-	-	-	-	-	-	-
04H00	-	-	-	-	-	-	-	-	-	-	-	-
05H00	-	-	-	-	-	-	-	-	-	-	-	-
06H00	-	-	-	-	-	-	-	-	-	-	-	-
07H00	2.71	2.62	2.52	2.39	2.31	2.3	2.37	2.51	2.65	2.68	2.74	2.75
08H00	9.35	9.29	9.21	9	8.85	8.82	8.96	9.22	9.43	9.39	9.38	9.35
09H00	18.34	18.4	18.42	18.19	17.97	17.92	18.12	18.47	18.71	18.53	18.37	18.27
10H00	24.15	24.39	24.54	24.33	24.06	23.98	24.23	24.65	24.87	24.54	24.18	24
11H00	30.58	30.95	31.21	31	30.69	30.58	30.87	31.35	31.57	31.11	30.61	30.35
12H00	32.95	33.38	33.68	33.46	33.15	33.03	33.33	33.84	34.05	33.54	32.98	32.7
13H00	30.59	30.96	31.22	31	30.7	30.59	30.88	31.36	31.58	31.12	30.62	30.36
14H00	24.16	24.39	24.55	24.33	24.07	23.99	24.24	24.66	24.88	24.55	24.19	24.01
15H00	18.34	18.39	18.42	18.17	17.97	17.92	18.12	18.47	18.71	18.53	18.37	18.27
16H00	9.33	9.26	9.2	8.98	8.83	8.8	8.94	9.2	9.41	9.37	9.36	9.33
17H00	2.7	2.6	2.51	2.37	2.29	2.28	2.35	2.48	2.62	2.66	2.72	2.73
18H00	-	-	-	-	-	-	-	-	-	-	-	-
19H00	-	-	-	-	-	-	-	-	-	-	-	-
20H00	-	-	-	-	-	-	-	-	-	-	-	-
21H00	-	-	-	-	-	-	-	-	-	-	-	-
22H00	-	-	-	-	-	-	-	-	-	-	-	-
23H00	-	-	-	-	-	-	-	-	-	-	-	-

Fig 14 Horizontal Direct Illuminance

ISSN No:-2456-2165

As we can see in the solar graphs, Irradiance and Illuminance tables corresponding to the study area, photovoltaic panels should be directed towards the Southwest. Due to our proximity to the equator, the inclination of our panels should be between 0° and 10° in relation to the horizontal.

VI. CONCLUSIONS

An autonomous system with photovoltaic panels can generate enough electrical energy to supply an average rural home in the Province of Cañar, specifically in the General Morales Parish. This can prevent public companies responsible for supplying electricity to the population from having to make large investments to serve extremely isolated homes.

It should be noted that for very cold areas, we can analyze the envelope of the home, the amount of glass, and other materials to improve internal temperature conditions, in order to avoid the need for additional heating systems that would increase the daily need for electrical energy and cause our generation system to be insufficient, ultimately leading to increased costs.

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