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Preliminary Study of Solar Photovoltaic Potential During the Rainy Season in Villanueva, Honduras

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Abstract*– This thesis study focuses on the evaluation of the solar photovoltaic potential in Villanueva, Honduras, especially during the rainy season. The research was carried out using specialized measuring instruments, such as pyranometers and solar multimeters, with the purpose of collecting accurate data on solar radiation and photovoltaic power generation in this specific region. The main objective of this research was to analyze the feasibility and performance of solar energy in a climatic context marked by recurrent rainfall. Detailed information was collected on incident solar radiation, solar panel efficiency and PV power production during the rainy season. These data were meticulously analyzed to understand the behavior of solar radiation under adverse weather conditions. The results obtained provide a deeper understanding of the availability of solar resources during the rainy season in Villanueva, Honduras. This information is crucial for the development of effective strategies to optimally harness solar energy under challenging climatic conditions. Furthermore, these findings provide valuable guidelines for the planning and implementation of solar energy systems, thus contributing to the advancement of energy sustainability in the region.

***Keywords*-- solar energy, photovoltaic potential, pyranometer, solar multimeter, solar radiation, energy efficiency.**

I. Introduction

The growing global interest in renewable energy sources has driven the research and development of sustainable technologies, with the aim of mitigating environmentalimpacts and reducing dependence on non-renewable resources. Solar radiation has been a fundamental source of energy throughout human history. Since the dawn of civilization, people have harnessed the sun's light and heat for a variety of needs.

Climate plays a crucial role in the amount and distribution of solar radiation reaching the earth's surface. Honduras is a country that has an excellent potential for solar energy, so since 2007 the government of the Republic has promoted the generation of electricity through this technology and since2014 many companies have heeded the call and have decided to bet on clean energy generation [1].

The region of Villanueva, Honduras, faces climatic challenges, especially periods of intense rainfall. These events pose a problem for solar energy harvesting, as cloud cover and precipitation can significantly affect solar energy capture.

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Understanding climate variability and its impact on solar radiation is essential to develop effective strategies and optimize the efficiency of solar systems in this environment.

Consequently, this research focuses on the detailed characterization of the solar potential in Villanueva, especially considering the adverse climatic conditions associated with rainfall. The purpose of the research is to provide valuable information to guide decisions in the implementation of solar technologies, considering the local climatic particularities and ensuring the long-term viability and sustainability of renewable energy systems in Villanueva, Honduras.

This research will be divided into several chapters. The first chapter will include the problem statement, where the background and objectives of the research will be defined. The second chapter will present the theoretical framework where an analysis of the current situation will be provided for the understanding of the research. The third chapter will present the methodology carried out, as well as the variablesconsidered for this research. The fourth chapter will include the results obtained by applying the proposed study methodology and an analysis of these results. The fifth chapter will contain the conclusions that will respond to the objectivesset out in the research, as well as the recommendations.

II. Context

A. Solar Photovoltaic Systems

Some of the reasons that have driven the promotion of renewable energies worldwide have been, among others: the urgent need to mitigate climate change, the dependence of several countries on fossil fuels and the uncertainty or volatility of their price, which in turn affects the price of electricity generation [2]. The generation of electricity from solar photovoltaic systems has experienced exponential growth in recent decades, driven by the growing awareness of the need to move towards clean and sustainable energy sources.

In recent years, several countries around the world have been promoting initiatives to include non-conventional renewable resources in their generation systems to replace conventional thermal energy, with the aim of reducing the adverse effects of climate change and achieving a more sustainable development thanks to the innumerable benefits they offer. [3].

Solar energy in Central America depends on technical progress in production systems, in Honduras energy is the cheapest and most efficient of the conventional energy cost development.[4]. As Central America navigates its energy transition, the emphasis on technical progress not only propels economic advantages but also positions the region as a potential hub for innovative and environmentally responsible energy practices.

B. National Context

In Honduras, the lack of electricity supply to the entire population, both urban and rural, has indirectly affected economic growth, the quality of education and poverty reduction. The supply of electricity has a positive impact on the local economy [5]. Access to electricity is a key factor for socioeconomic development. It facilitates the operation of businesses, job creation and improved productivity, which in turn drives economic growth.

By 2015, the country only had 388 (MW), and by 2019 it already had an increase to 510.8 (MW) of nominal installed power. With the passage of time, technological advances have increased, thus helping the development and implementation of photovoltaic technology, providing much more efficientand better performing equipment. [6].

C. Solar Radiation

Solar systems take advantage of the conversion of solar radiation into electricity through photovoltaic cells, thus becoming a promising alternative to conventional energy sources. However, the efficiency of PV systems is intrinsically linked to the availability of sunlight, which makes them susceptible to weather conditions and to seasonal variability in solar radiation.

The performance of solar photovoltaic and solar thermal systems is correlated in solar resource data. The valuation of the solar resource used in these systems is based on previously measured data [7]. As the renewable energy sector continues to evolve, the emphasis on precise solar resource data contributes to the advancement and effective utilization of solar technologies, ultimately promoting a more sustainable energy landscape.

The solar radiation incident on the collector surface on Earth is a combination of direct, diffuse and reflected radiation. These three components constitute the total radiation on the collector surface [8].

The efficiency of solar photovoltaic systems is considerably reduced due to certain non-linear variations found in the output voltage and current. This is due to the behavior of certain variables such as solar radiation and the operating temperature of the solar modules. [6].

The evaluation of solar energy resources needs specific radiation observation data of high accuracy. Currently, radiation observation stations typically use thermopile pyranometers to observe radiation [9].

Compared to ground-based measurements, satellite-derived hourly irradiance data has been shown to be the most accurate option due to its ability to accurately delineate relative differences between neighboring locations, although the absolute accuracy for a given point may not be perfect [10].

D. Use of the Solar Resource

One of the types of information often required to study the energy balance or the growth of a particular crop is solar radiation. [11]. Solar radiation is essential in determining the amount of energy available for plants to photosynthesize, which is the process by which plants convert sunlight into chemical energy for growth and development.

The estimation of solar potential requires a detailed analysis of spatial information from different data sources that must be reviewed for further analysis. [12].

E. Efficiency of Solar Photovoltaic Systems

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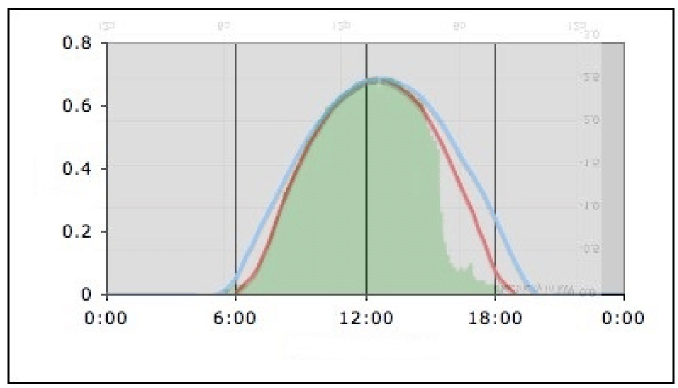

Figure 1: Typical power output curve of a photovoltaic power plant

In areas where water resources are not suitable for generation, solar systems are the most important source of energy since the radiation time is greater than six hours throughout the country [13].

F. Pyranometer

Thermopile pyranometers measure the total incident irradiance on a flat surface. Using a dome with a 180° field of view, this technology can measure irradiance from alldirections [14].

Quality control of any type of measurement is understood as the set of stipulated procedures aimed at detecting errors and, eventually, completing missing data or correcting anomalous values. For solar radiation measurements, quality control generally consists of defining a series of filters that impose lower and upper limits of acceptance to the different magnitudes obtained [15].

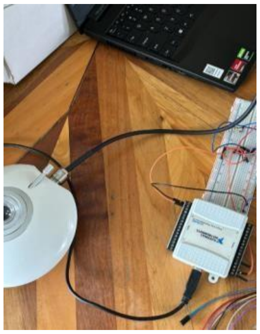

Figure 2: Pyranometer configuration

IV. METHODOLOGY

A. Approach

This project adopts a quantitative approach since numerical techniques are used to perform calculations andanalysis of the variables and phenomena under study. The purpose of this research is to acquire objective and validated data, through the collection of quantifiable information and the application of various techniques for subsequent analysis. It consists of the analysis of daily measurements of data numbersand variables to be analyzed, to determine the changes in power generated according to the orientation of the solar modules with measurements taken for 30 days in the city of Villanueva, Cortés.

B. Variables

The independent variables established for this study were geographic location, topographic characteristics, and climatic factors.

The dependent variables established for this study were solar radiation (W/m2), temperature, environmental impact,and solar panel efficiency.

C. Data collection

The study was carried out by collecting data over a 30- day period, from 8:30 a.m. to 4:30 p.m., on the roof of a house. Measurements were taken on both solar modules (north and south facing), the entire 4 weeks, Monday through Friday.Each day eight measurements were taken one hour apart during the period mentioned above.

Starting on Thursday, November 2, 2023 (Thursday), measurements of electrical power, open-circuit voltage and solar radiation began. These measurements were carried out using a solar multimeter that provides data in watts for power and volts for open circuit voltage by connecting the positive and negative terminals of the solar module to the multimeter terminals. In addition, the pyranometer that measures solar radiation was used, but first its respective configuration and calibration was performed to proceed to take the measurements on the same 30 days, at 12:30 m time.

Figure 3: Photovoltaic solar module

C. Location

The installation of the solar photovoltaic modules was carried out in the residential area "La Joya", in Villanueva, Cortés. The panels were installed facing north and south respectively, with an inclination of 15°.

Figure 4: North-facing solar panel

Figure 5: South-facing solar panel

D. Materials

- Two solar modules used for rooftop measurements. PEIMAR OR10H460M SE460M 120-cell module has been designed to guarantee a high production yield that cannot be achieved with standard technology. Module with 460 W of power.

- Elejoy solar multimeter model EL40088. Used to measure open circuit voltage (Voc), current (Imp) and power (W) of solar modules.
- SR20-T2 pyranometer, used to measure solar radiation at the selected location.

V. Results

A. Power generated by photovoltaic modules

The first week of measurements began on November 2, 2023, making measurements between 8:30 a.m. and 4:30 p.m. of power (W) at one-hour intervals. Figure 8 shows the results of the week 1 measurements, oriented to the north and south. There are noticeable changes in the power generated between the north-facing module and the south-facing module, being higher in the south-facing module. The peak of the power generated this week was reached on November 06, with 1,709.45 W, oriented to the south.

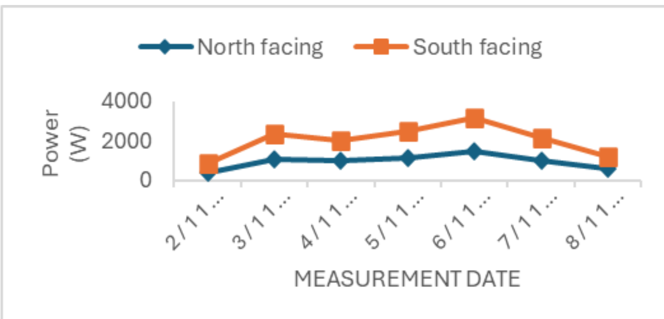

Figure 6: Power generated, north facing vs. south facing - Week 1

The second week of measurements began on November 9, 2023, making measurements between 8:30 a.m. and 4:30 p.m. of power (W) at one-hour intervals. Figure 9 shows the results of the week 2 measurements, oriented north and south. There are noticeable changes in the power generated between the north-facing module and the south-facing module, being higher in the south-facing module. The peak of the power generated this week was reached on November 9, with 1,442.54 W, oriented to the south.

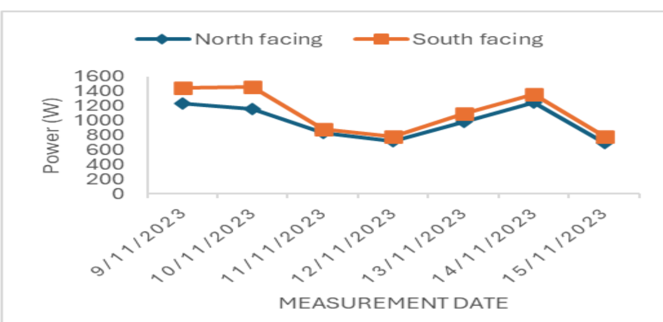

Figure 7: Power generated, north facing vs. south facing - Week 2

In the third week of measurements, measurements were started on November 16, 2023, by taking measurements between 8:30 a.m. and 4:30 p.m. of the power (W) at one-hour intervals. Figure 10 shows the results of the week 3 measurements, oriented north and south. There are noticeable changes in the power generated between the north-facing module and the south-facing module, being higher in the south-facing module. The peak of the power generated this week was reached on November 21, with 1,719.45 W, oriented to the south.

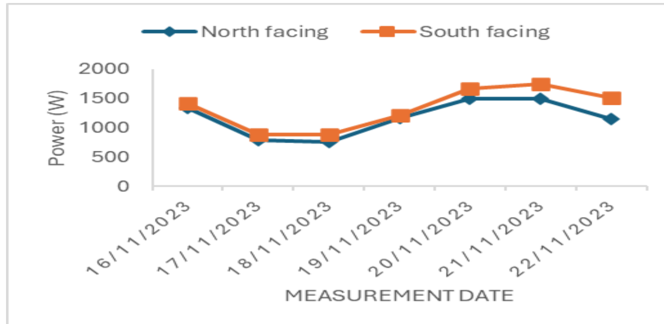

Figure: 8 Power generated, north vs. south orientation – Week 3

The fourth week of measurements began on November 23, 2023, making measurements between 8:30 a.m. and 4:30 p.m. of power (W) at one-hour intervals. Figure 11 shows the results of the week 4 measurements, oriented north and south. There are noticeable changes in the power generated between the north-facing module and the south-facing module, being higher in the south-facing module. The peak of the power generated this week was reached on November 27, with 1983.55 W, oriented to the south.

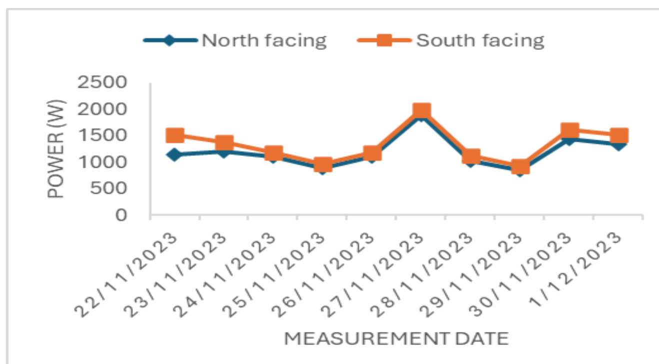

Figure 9: Power generated, north vs. south orientation - Week 4

Figure 12 shows the results of the full month measurements, with north and south orientation. It can be observed the difference in the power generated between the module oriented to the north and the module oriented to the south, being greater with orientation to the south. However, the largest difference in generated power was recorded on November 22, 2023, being produced with south orientation 339.55W more than north.

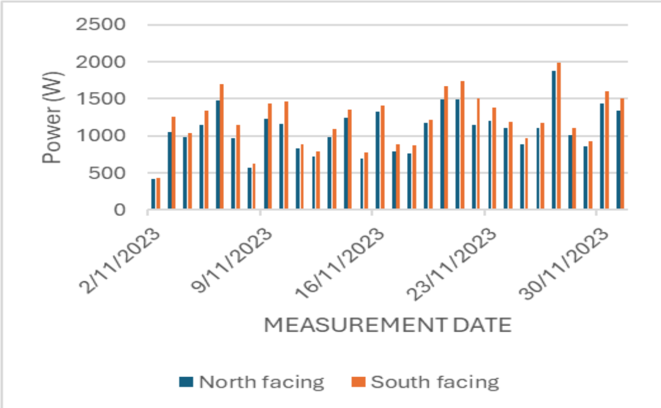

Figure 10: Power generated, north facing vs. south facing - Full Month

Figure 10 presents the results of the measurements taken on November 22, with north and south orientation. It can be observed the difference in the power generated between the module oriented to the north and the module oriented to the south, being greater with orientation to the south. It is observed in more detail that the largest difference in power generated was recorded on November 22, 2023, with a south- facing orientation producing 339.55W more than north-facing on the full day.

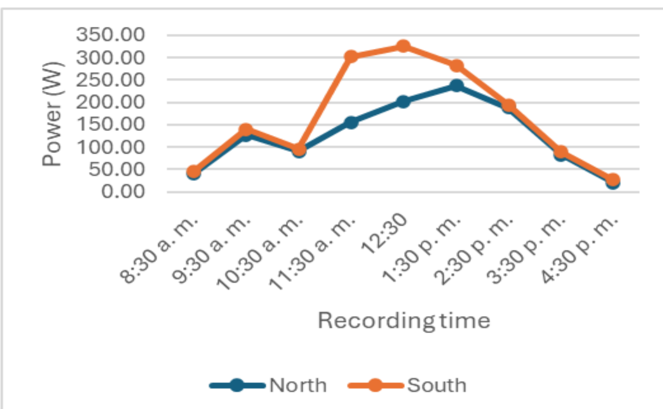

Figure 11: Largest difference in generated power on November 22, 2023

Figure 14 presents the results of the measurements of November 27, with north and south orientation. It can be observed the difference in the power generated between the module oriented to the north and the module oriented to the south, being greater with orientation to the south. It is observed in more detail that the day with the highest power was recorded on November 27, 2023, at 12:30 m., producing the highest power recorded with a south-facing orientation, 344 MW.

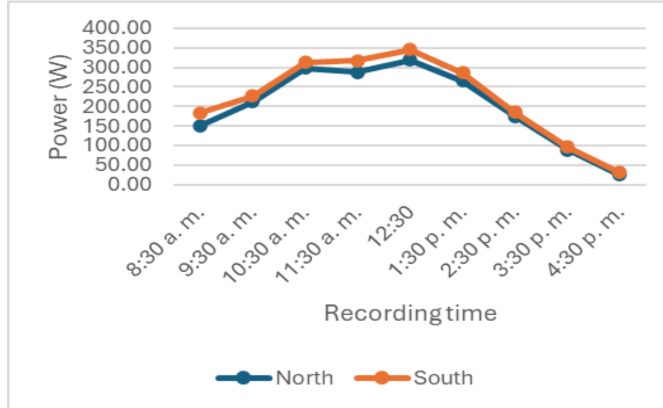

Figure 12: Largest power generated on November 27, 2023

Figure 12 presents the results of the measurements on November 2, with north and south orientation. It can be observed the difference in the power generated between the module oriented to the north and the module oriented to the south, being slightly higher with orientation to the south. It is observed in more detail that the day with the lowest power was recorded on November 02, 2023, at 2:30 p.m. producing the lowest power recorded with a south facing orientation, 13.07 W.

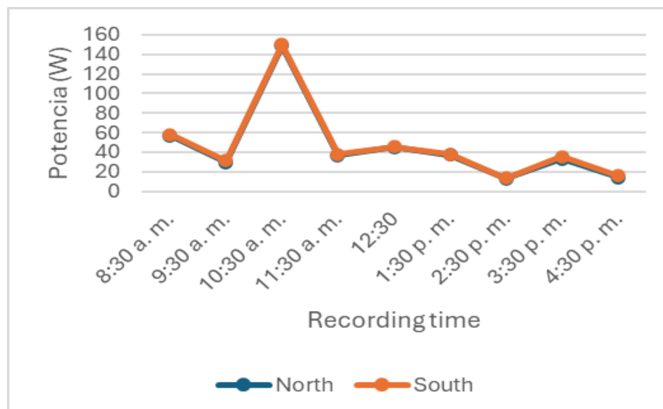

Figure 13: Lower power generated on November 2, 2023

Table 2 provides an overview of a 30-day period, detailing the power surplus generated by the solar panels oriented towards the south compared to those facing north.The data show a notably higher power generation when panels are directed southward. This comparison shows the significant impact of solar panel orientation on energy output.

TABLE I.
SOUTH-FACING SURPLUS SUMMARY

Date	Day	Power difference generated south facing (W)	Average surplus (W)	Average surplus (%)
2/11/2023	1	2.22	1.33	4.66%
3/11/2023	2	66.32	22.92	23.09%
4/11/2023	3	20.24	6.56	5.81%
5/11/2023	4	68.46	21.27	4.17%
6/11/2023	5	113.00	24.29	13.38%
7/11/2023	6	63.73	21.51	19.07%
8/11/2023	7	28.27	6.11	10.92%
9/11/2023	8	62.36	20.36	23.73%
10/11/2023	9	104.55	33.63	20.72%
11/11/2023	10	11.87	5.32	6.17%
12/11/2023	11	10.75	7.36	18.84%
13/11/2023	12	57.62	12.63	9.07%
14/11/2023	13	38.30	12.19	8.95%
15/11/2023	14	18.87	9.02	19.37%
16/11/2023	15	17.16	8.77	7.34%
17/11/2023	16	25.94	10.20	16.01%
18/11/2023	17	30.68	12.83	22.26%
19/11/2023	18	8.55	4.52	4.19%
20/11/2023	19	41.90	20.15	12.98%
21/11/2023	20	56.78	27.44	17.40%
22/11/2023	21	146.57	39.77	27.28%
23/11/2023	22	62.77	19.14	14.45%
24/11/2023	23	15.20	9.29	8.12%
25/11/2023	24	20.09	8.45	9.83%
26/11/2023	25	17.60	8.63	7.36%
27/11/2023	26	31.76	18.05	10.98%
28/11/2023	27	26.31	10.77	13.60%
29/11/2023	28	21.93	7.81	10.41%
30/11/2023	29	63.47	18.35	12.83%
1/12/2023	30	115.02	18.55	16.15%

A. Solar radiation data using pyranometer

The pyranometer was installed and calibrated. The first week of measurements started on November 2, 2023, taking measurements at 12:30 m. Graph 10 shows the results of the measurements for the entire month, with the pyranometer installed in a site without shadows. There are noticeable changes in the incident solar radiation, due to the rainy season and partly or completely cloudy skies. The peak of solar radiation in this month of measurements was reached on November 3rd, with 441.98 W/m2.

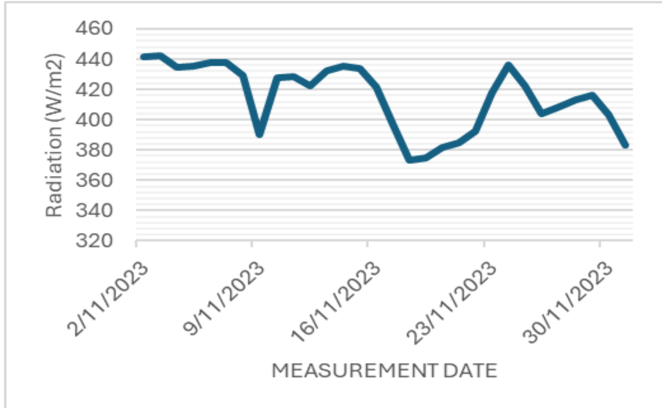

Figure 14 Solar radiation in Villanueva, Cortés

VI. CONCLUSIONS

In this research, the effect of rainy weather on solar energy generation was analyzed using two solar modules installed on the roof, facing north and south, and then daily measurements of the power delivered by the photovoltaic solarmodules were taken over a period of 30 days. The comparison was carried out by taking daily measurements in one-hourintervals, from 8:30 a.m. to 4:30 p.m. The installation, calibration, and data recording of thepyranometer was also carried out on the same 30 days, recording the data at 12:00 m. The most relevant results of thisresearch were the following:

1. An accurate calibration of the pyranometer was achieved, allowing reliable measurements of incident solar radiation at a representative site in Villanueva. During the rainy season in November, solar radiation was observed to reach a maximum of 441.98 W/m².
2. The establishment of a continuous recording and monitoring system allowed for consistent data collection over a specific period, providing a comprehensive view of seasonal variations in solar radiation and, likewise, indicating that up to 27.28% more generation can be achieved by setting the orientation of the solar module to the south.
3. Seasonal patterns in solar energy generation were identified, showing a direct correlation with the variability of solar radiation during the rainy season in Villanueva. These findings underscore the importance of considering seasonal conditions when designing solar systems in this region.
4. Based on the results obtained, solid recommendations and guidelines can be proposed for the effective

design and implementation of solar systems in Villanueva, considering the variability of solar radiation and adapting to seasonal conditions. However, despite seasonal variations in solar radiation, the results suggest that a solar installation in Villanueva during the rainy season is still feasible.

In summary, this study provides valuable information on the solar potential in Villanueva, Honduras, offering concrete data on incident solar radiation, seasonal variations, and their impact on solar energy generation. The proposed recommendations may be fundamental for the development and implementation of more efficient solar systems adapted to the specific conditions of this region.

VII. RECOMMENDATIONS

1. It is suggested to improve the orientation of the solar panels towards the south, as this increases solar generation by 27.28%. Configuring the panels in this direction will maximize solar radiation capture throughout the year. To adapt to seasonal changes and improve efficiency, it is beneficial to use solar tracking systems or adjustable structures.
2. Integrating cleaning and maintenance systems is important because dirt accumulation can affect solar radiation during the rainy season. Establishing regular cleaning and maintenance programs will ensure that the panels are free of contaminants that can reduce their efficiency.
3. For future projects, a flexible and adaptable design that considers the variability of solar radiation and adapts to seasonal conditions in Villanueva is advised. Design flexibility, adjustability, and the incorporation of innovative technologies will be essential to maximize solar performance in a variety of climatic conditions.

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