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Presentation date: December, 2023
Date of acceptance: April , 2024
Publication date: May, 2024

PROPOSAL

FOR A SOLAR PHOTOVOLTAIC SYSTEM. CASE STUDY EMBOTELLADORA AGA

PROPUESTA DE UN SISTEMA SOLAR FOTOVOLTAICO. CASO DE ESTUDIO EMBOTELLADORA AGA

Francisco Alejandro Alfaro Ferreyra[1]
E-mail: falfaro@coreysolar.com
ORCID: https://orcid.org/0009-0005-8184-3820
Fernando Ortiz Vergara[1]
E-mail: fortiz@coreysolar.com
ORCID: https://orcid.org/0009-0007-3778-5867
Alexis Jacob Partida Acuña[1]
E-mail: apartida@coreysolar.com
ORCID: https://orcid.org/0009-0000-5960-2856
Julio Valencia Chalita[1]
E-mail: jvalencia@coreysolar.com
ORCID: https://orcid.org/0009-0005-7149-839X
Luis Angel Iturralde Carrera[1*]
E-mail: liturralde@coreysolar.com
ORCID: https://orcid.org/0000-0002-5595-9329
* Author for correspondence: liturralde@coreysolar.com
[1] Corey Solar, Jalisco, México.

Suggested citation (APA, seventh ed.)

Alfaro Ferreyra, F. A., Ortiz Vergara, F., Partida Acuña, A. J., Valencia Chalita. J. & Iturralde Carrera, L. A. (2024). Proposal for a solar photovoltaic system. Case study Embotelladora AGA. ***Universidad y Sociedad, 16***(3), 189-197.

ABSTRACT

This study investigates the potential for photovoltaic generation through the use of roof surfaces in a specific case. A constructive survey of the building was carried out to identify areas suitable for the installation of photovoltaic panels, considering dimensions, orientation and inclination of the roofs. In addition, territory-specific meteorological information was collected for generation calculations, using the specialized software HelioScope (HS). The simulation with HS revealed that it is feasible to install a total of 914 photovoltaic modules in the studied company, with a generation capacity of 498.1 kWp and an actual annual production of 882.7 MWh. This detailed analysis provides a clear picture of the exploitable energy potential and highlights the feasibility and significant contribution of solar PV in the context of the case study.

Keywords: Photovoltaic modules, Photovoltaic solar systems, Energy analysis, Sizing.

RESUMEN

Este estudio investiga el potencial de generación fotovoltaica mediante el aprovechamiento de las superficies de cubiertas en un caso específico. Se realizó un levantamiento constructivo de la edificación para identificar áreas aptas para la instalación de paneles fotovoltaicos, considerando dimensiones, orientación e inclinación de las cubiertas. Además, se recopiló información meteorológica específica del territorio para los cálculos de generación, utilizando el software especializado HelioScope (HS). La simulación con HS reveló que en la empresa estudiada es factible instalar un total de 914 módulos fotovoltaicos, con una capacidad de generación de 498.1 kWp y una producción anual real de 882.7 MWh. Este análisis detallado proporciona una visión clara del potencial energético aprovechable y destaca la viabilidad y la contribución significativa de la energía solar fotovoltaica en el contexto del caso de estudio.

Palabras claves: módulos fotovoltaicos, sistemas solares fotovoltaicos, análisis energético, dimensionamiento.

INTRODUCTION

Solar energy is crucial for combating climate change and promoting sustainable production systems as part of Renewable Energy Sources (RES). Although technologies have been developed to improve the efficiency of photovoltaic systems, their widespread adoption remains a challenge in the energy transition. Despite this, the solar energy market has experienced remarkable growth due to cost reduction and increasing environmental concerns (Liu et al., 2023; Louwen & Sark, 2020).

Photovoltaic modules are composed of photovoltaic solar cells that can be connected in series and/or in parallel. However, their efficiency decreases with increasing temperature. Factors such as concentrated sunlight and partial shading also affect efficiency, creating hot spots and irreversible damage. To optimize efficiency, a balance between short-circuit current and open-circuit voltage, known as the maximum power point, is sought (Ebhota & Tabakov, 2023; Hosseini et al., 2023; Panda & Gupta, 2023; Rouholamini et al., 2016).

The efficiency of photovoltaic (PV) systems is highly dependent on their orientation. Deviations of 48° from the optimal azimuth angle can result in energy losses of 5%, while deviations of 21° from the optimal tilt angle can have the same effect. These losses vary with geographic location (Abdelaal & El-Fergany, 2023; Al-Ghussain et al., 2023; Carrera et al., 2022; Jing et al., 2023).

Before installing any photovoltaic system, it is crucial to assess its feasibility, considering its estimated yield. This assessment involves the use of several methods, such as numerical modeling, geoparameter analysis and experimental modeling. Simulation using power modeling tools, such as PVsyst, SketchupPro, PVGIS, PV Watts, SISSIFO and RETScreen, is the most commonly used approach (Cox et al., 2023; Modu et al., 2023; Shrivastava et al., 2023).

The efficiency and energy production of solar photovoltaic (PV) systems are influenced by irradiance, relative humidity, outdoor and operating temperature, as well as geolocation and layout angles. Optimizing these characteristics and layouts is crucial, as they can determine the success or failure of solar energy projects.

This study aims to calculate the solar photovoltaic energy production capacity using the roof surfaces of the buildings of a bottling plant as a case study, through simulation in HelioScope (HS).

MATERIALS AND METHODS

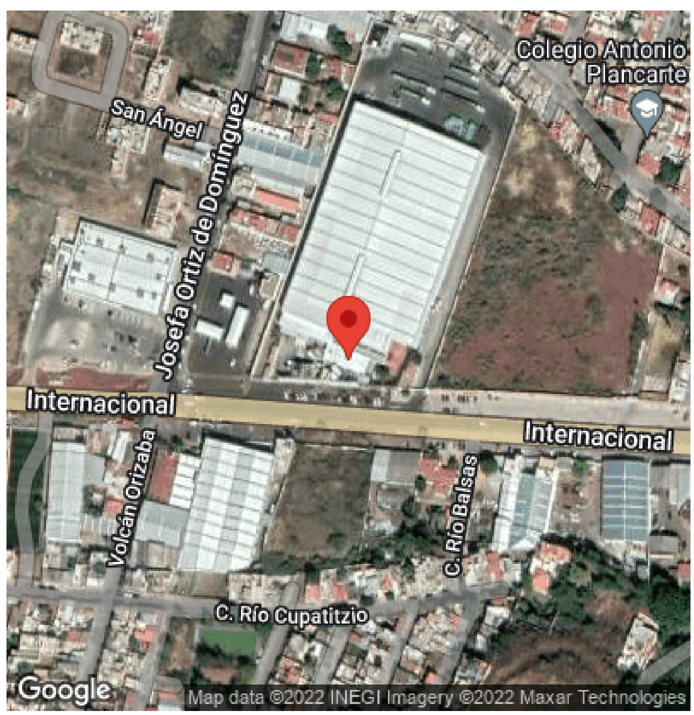
Simulation model using HS

HS is a software widely used in the design and evaluation of solar power plants, taking advantage of meteorological data and technical information on photovoltaic technology. It enables researchers and engineers to understand the performance of PV systems and improve their design. To simulate a grid-connected PV system, steps such as identifying the location, obtaining meteorological data, selecting the orientation and system components are followed (Carrera et al., 2023; Guzman et al., 2017; Carrera et al., 2021)

Location of the site for the installation of the FVSS.

The bottling plant is located at 19.9544377 N, -102.312588 W., and its roofed surface has a Tilt 15⁰ and Azimuth 198,98⁰.

Fig.1: Geographic location of this site.



Source: Own production.

Table 1 presents the monthly meteorological data generated by the Meteo7.2 software database, corresponding to the locality where the case study is located.

Table 1: Meteo for EMBOTELLADORA AGA. Synthetically generated data from monthly values.

	GlobHor (kWh/m2)	DiffHor (kWh/m2)	T_amb 0C	WindVel m/s	GlobInc (kWh/m2)	DifSInc (kWh/m2)
January	156.7	41.14	17.46	1.6	201.1	25.21
February	175.2	34.31	17.85	1.8	210.5	20.15
March	220.5	46.43	19.09	2.0	239.4	25.80
April	238.9	39.98	21.55	1.9	234.9	22.07
May	223.8	69.81	22.48	1.9	205.9	34.56
June	199.6	65.61	22.16	2.0	178.3	39.77
July	189.0	75.83	20.25	1.4	172.1	46.73
August	171.7	80.30	19.74	1.9	164.8	51.55
September	164.1	66.49	19.89	1.3	169.3	42.83
October	157.9	53.76	19.14	1.6	178.6	35.48
November	158.9	35.96	17.90	1.8	199.6	22.04
December	151.6	36.48	17.29	1.6	200.2	22.28
year	2 207.9	646.09	19.57	1.7	2 354.8	388.46

Source: Own production.

Technical characteristics of the photovoltaic module and inverter

LONGI SOLAR Hi-MO-5m-LR-5-72-HPH-545

LONGi's HPH series combines high-efficiency mono PERC cells with half-cut Muti busbar technology to improve performance and output. With a maximum system voltage of 1500 V and Class C rating to UL790, these modules feature 35 mm frames that reduce weight without compromising strength, supporting static loads up to 5400 Pa at the front and 2400 Pa at the rear. Table 2 and Table 3 present the general characteristics of the PV module and Table 4 those of the inverter.

Features:

High module conversion efficiency: up to 20.3%.

Slower power degradation due to Low LID Mono PERC technology

Robust PID resistance guaranteed by optimized solar cell processing and careful selection of module materials

Reduced resistive loss with lower operating current

Higher energy yield with lower operating temperature

Reduced risk of hot spots due to optimized electrical design

Table 2: Mechanical characteristics.

Cell type	144 (6x24)
Junction Box	IP68, three diodes
Dimensions	2 278x1 134x35 mm
Weight	27.5 kg
Output cable	4 mm2,+400,-200mm/1400mm length can be customized

Frame	Anodized aluminum alloy frame
Packaging	31 pcs per pallet /155 pcs per 20´GP /620 pcs per 40´HC
Glass	Single glass, 3.2 mm coated tempered glass

Source: Own production.

Table 3. Temperature coefficient.

Operational temperature	**-40 0C~+85 0C**
Power Output Tolerance	0~3%
VOC and ISC Tolerance	+ 3 %
Maximum System Voltage	DC 1 500 V(IEC/UL)
Maximum Series Fuse Rating	25 A
Nominal Operating Cell Temperature	45 + 2 0C
Protection Class	Class II

Source: Own production.

Table 4: Features of the Sunny Tripower CORE1 62-US inverter.

Input (DC)	
Maximum array power	93750 Wp STC
Rated MPP voltage range	550 V…800 V
Output (AC)	
AC nominal power	62500 W
Maximum apparent power	66000 VA
Maximum output current	79.5 A
CEC efficiency (preliminary)	98%

Source: Own production.

Calculations of the entity's photovoltaic generation potential. Proposed sub-arrangements for buildings

To properly calculate a PV system, it is crucial to consider several key sizing parameters, including the surface area available for the modules and the distances between them. This involves leaving space for aisles between panels to facilitate maintenance. In addition, on flat surfaces such as roofs or land, it is important to determine the horizontal distance between rows of modules, referred to as "D". This distance is calculated taking into account the projection of shadows from nearby obstacles, using the expression 1-3.

$$D = a + \frac{h}{\tan(61^{0} - \text{latitude})}$$ Ec.1

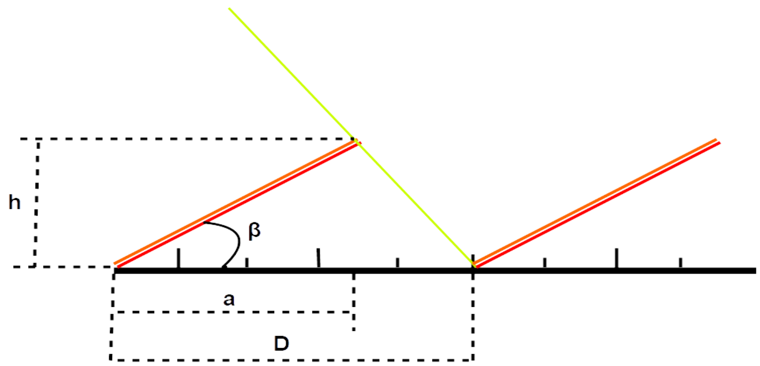
Donde:

$$a = l * \cos \beta$$ Ec.2

$$h = l * \sin \beta$$ Ec.3

length of modules or objects that cast shadows.

Fig 2: Scheme to determine the distance between modules.



Source: Own production.

RESULTS AND DISCUSSION

The proposed FVSS array has a rated power STC of 498.1 kWp. This FVSS is composed of LONGI SOLAR's LR-5-72-HPH-545 Hi-MO photovoltaic module. The system. The FVSS is accompanied by a Sunny Tripower CORE1 62-US model inverter with an output of 375 kWac.

In the summary of results shown in Table 2 it can be seen that from the simulation with HS, the FVSS allows the possibility of installing 914 photovoltaic modules, has an annual generation capacity (real) of 882.7 MWh/year and a performance factor (expresses the relationship between the final and reference productivity of the installation) of 79.8%, in addition to a kWh/kWp ratio of 1.77.

Table 2: Simulation results with HS of the FVSS.

Module DC	498.1 kW
Inverter AC	375 kW load ratio:1.33
Annual production	882.7 MWh
Performance Ratio	79.8 %
kWh/kWp	1.772

Source: HelioScope

Table 3 and Figure 3 show the energy delivered to the system's monthly grid, the months of March-August are the most favorable for the whole year, corresponding to the months of highest irradiance in the locality. In addition, the table 3 show the behavior of the Global Horizontal Irradiance (GHI) and Solar irradiance on a PV panel in the Plane of Array (POA) is presented, as well as the energy per square meter in the presence of shading.

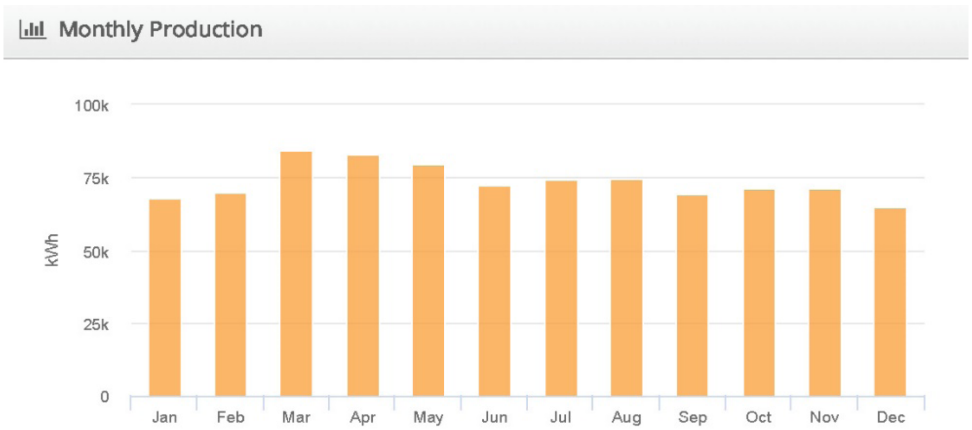
Table 2: Simulation per month with HS of the FVSS.

Month	GHI (kWh/m2)	POA (kWh/m2)	Shaded (kWh/m2)	kWh (kWh)	Grid (kWh)
January	142.9	168.9	166.0	78 686.3	67 973.5
February	159.0	179.1	176.9	84 122.9	69 765.4
March	205.3	218.7	217.1	103 315.0	84560.7
April	212.0	212.4	211.1	100 041.9	82 824.1
May	211.2	201.1	199.8	94 487.0	79 734.0
June	191.3	178.6	177.4	83648.6	72 192.9

July	191.6	182.5	181.2	85482.5	74 135.4
August	188.8	185.4	184.2	86 980.4	74 697.1
September	167.9	172.7	171.4	81 143.3	69 345.9
October	163.5	179.2	177.3	84 070.5	71 345.7
November	152.3	179.7	175.9	83 443.8	71 112.0
December	133.7	161.8	157.3	74 471.3	65 011.4

Source: Own production.

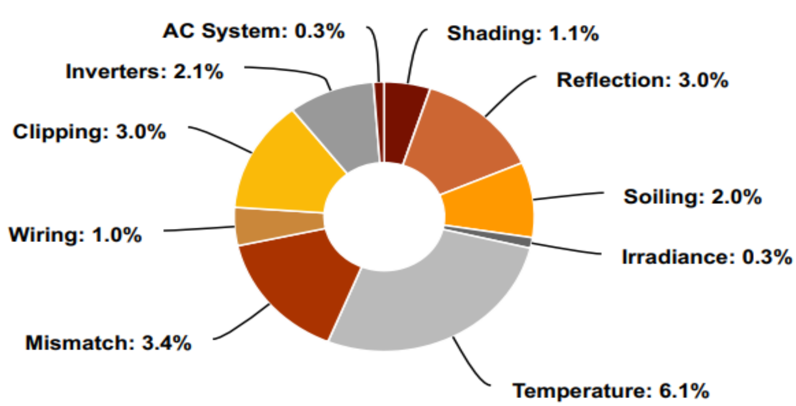
Fig 3: FVSS production by month



Source: HelioScope

In terms of installation losses, Figure 4 shows that the increase in temperature contributes significantly to these losses, representing approximately 6.1% of the total. This observation highlights the importance of controlling and mitigating the effect of heat in FVSS, as high temperatures can reduce the efficiency of the panels and, therefore, decrease energy production. Proper temperature management, through adequate ventilation and other cooling methods, can help minimize these losses and optimize the performance of the FVSS.

Fig 4: Distribution of system losses.



Source: HelioScope.

Figure 5 provides a visual representation of the evaluated installation, showing the design and layout of the solar modules in the case study. This setup provides a clear view of how the panels are organized in the available area, highlighting the spatial distribution and orientation of the PV modules. It also allows visualization of any special considerations, such as the inclusion of aisles between panels for easy access and maintenance. This representation helps to better understand the physical configuration of the installation and provides useful information for analysis and optimization of the PV system.

Fig 5: FVSS assembly for the case study.

Source: Own production.

CONCLUSIONS

The HelioScope simulation reveals that the company has a roof area that allows the installation of 914 PV modules, generating a total capacity of 498.1 kWp and an actual annual production of 882.7 MWh. It is highlighted that the temperature rise contributes significantly to the losses of the installation, representing about 6.1% of the total, which underlines the importance of controlling this factor to optimize the performance of the photovoltaic solar systems (FVSS).

The visual representation of the SSFV assembly provides a clear understanding of how the panels are arranged in the available area, highlighting the spatial distribution and orientation of the PV modules. This detailed analysis of the PV array design and performance provides valuable information for decision making and ongoing optimization of the PV system.

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