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Presentation of the content

In the first article we present, *Optimizing solar dryer design: A multicriteria decision making approach for hybrid systems*, by HERNÁDEZ-DOMÍNGUEZ, Erick Alejandro, LASTRES-DANGUILLECOURT, Orlando, FARRERA-VÁZQUEZ, Nein and RUIZ-SUAREZ, Alison, with adscription in the Universidad de Ciencias y Artes de Chiapas; in the next article we present, *Measurement of solar energy parameters project in the facilities of the Universidad Tecnológica de Altamira*, by TORRES-MAR, Damián de Jesús, MERINO-TREVIÑO, Marco Antonio, SÁNCHEZ-CORTÉZ, José Alfonso and GONZALEZ-MORALES, Amparo, with adscription in the Universidad Tecnológica de Altamira, in the next article we present, *Duplex solar cooker with selective evacuated tube and compound parabolic concentrator*, by MARROQUÍN-DE JESÚS, Ángel, CASTILLO-MARTÍNEZ, Luz Carmen, OLIVARES-RAMÍREZ Juan Manuel and VAQUERO-GUTUIÉRREZ Maribel, with adscription in the Universidad Tecnológica de San Juan del Río; in the last article we present, *Data acquisition module for the operation of the web system for automatic irrigation in a Greenhouse*, by RAFAEL-PÉREZ, Eva, ESCOBAR-MORALES, Jafet Dafne, MORALES-HERNÁNDEZ, Maricela and CASTAÑON-OLGUIN, Eduardo, with adscription in the Tecnológico Nacional de México / Instituto Tecnológico de Oaxaca..

Content

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Optimizing solar dryer design: A multicriteria decision making approach for hybrid systems

Optimización del diseño de secadores solares: un enfoque de toma de decisiones multicriterio para sistemas híbridos

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Abstract

Solar dryers are a sustainable and efficient alternative for preserving agricultural products, offering numerous benefits for both the environment and the agro-industrial sector's economy. The objective is to develop a decision-making methodology based on environmental, economic, and social criteria, allowing the acquisition of data for the design of solar dryers using alternative energy sources to achieve the hybridization of one or more energy sources. The Analytic Hierarchy Process (AHP) methodology is based on breaking down a complex problem into a series of simple and manageable problems. This methodology evaluated alternatives based on different criteria and factors to consider. The AHP methodology was divided into three stages: the first was to define the problem to be solved, the second was to determine the criteria, and the third was to analyze the possible alternatives. This research provided information for the design of a solar coffee dryer in San Antonio el Porvenir, Chiapas. The solar dryer's design was based on criteria proposed by the producers, such as ease of repair, the product not being in contact with the ground, and ensuring safe operation due to the presence of children and women near the drying process.

Sustainable, Agricultural, Methods

Resumen

Los secadores solares son una alternativa sostenible y eficiente para preservar productos agrícolas, ofreciendo numerosos beneficios tanto para el medio ambiente como para la economía del sector agroindustrial. Desarrollar metodología de toma de decisiones basada en criterios ambientales, económicas y sociales que permita obtener datos para el diseño de secadores solares con fuentes alternas de energía para obtener una hibridación de una o más fuentes de energía. El análisis de procesos jerárquicos se basa en la descomposición de un problema complejo en una serie de problemas simples y manejables, esta metodología evaluó alternativas en función de diferentes criterios y factores a considerar, la metodología análisis de procesos jerárquicos (AHP) se dividió en tres etapas la primera fue cual era el problema a resolver, la segunda determinamos los criterios y la tercera analizamos las alternativas. Esta investigación permitió proveer información para el diseño de un secador solar de café en San Antonio el Porvenir Chiapas, el diseño del secador solar con base en criterios propuestos por los productores tal como de fácil reparación, producto sin contacto con el suelo y seguro de operar debido a que, niños y mujeres se encuentran cerca del proceso de secado.

Sustainable, Agricultural, Methods

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Introduction

Hybrid solar dryers have emerged as a sustainable solution for drying agricultural products and have received considerable attention in recent years. These systems harness solar energy along with other additional heat sources, such as biomass, electrical energy or waste heat, to create a more efficient and reliable method for the drying process (Goel, 2023).

Solar energy as the main source of heat in these dryers reduces dependence on fossil fuels and reduces greenhouse gas emissions. One of the challenges of conventional solar dryers is their dependence on weather conditions. During periods of low solar radiation, such as cloudy days or seasons with weaker solar intensity, drying efficiency may be affected and operation may be interrupted (Mohana, 2020).

This is where the solar hybrid dryer comes into play. By combining solar energy with other heat sources, these hybrid systems offer greater flexibility and reliability in the drying process. The integration of multiple heat sources allows the dryer to work continuously, even in conditions of low solar radiation, such as cloudy days or at night, additional heat sources come into play to maintain the drying process (Jha, 2021).

Additional heat sources used in compound dryers may vary based on local availability and feasibility. Biomass, such as firewood, agricultural residues or pellets, is often used as an additional heat source. Biomass burning not only provides heat for the dryer, but also a way to take advantage of agricultural and forestry by-products, contributing to the sustainable management of natural resources (Gorjian, 2022).

Combining multiple heat sources in a hybrid solar dryer ensures stable and reliable drying performance. Currently, for the design of solar dryers in general, it is carried out under the following steps

1. Determine Drying Requirements (Product)
2. Select the appropriate type of solar dryer
3. Solar Dryer Size
4. Design the solar collector
5. Design of the drying chamber
6. Installation of the solar dryer
7. Test and tuning

However, the growing demand for solar dryers faces not only technical issues but also economic, social and environmental situations, (Vera-Montenegro, 2014). Since although these devices tend to be friendly to the environment, operation, operation, maintenance, among other factors influence the acceptance and good use of the devices.

This research, through the use of the analytical hierarchical process (AHP) which is a multi-criteria decisión-making(MCDM), evaluates the best hybridization for solar dryers, and provides technology developers with extra information when designing the systems, such as the use of food contact materials, return of device investment, operating costs, adaptability among other criteria.

The AHP method has been used to evaluate criteria in the area of sustainability, energy, economy and others topics. a decentralized hybrid renewable energy system can go a long way to fill a power gap between generation and power demand when a single renewable energy system is neither sustainable nor reliable (Matheri, 2023).

MCDM are currently used for various applications since it allows evaluating criteria through different methods, for various applications from exergetic efficiency (Ren-E. Dong, 2023), to determining Optimization of a photovoltaic solar thermal collector (Das, 2023), or even using these methods in Selection of wastewater treatment technology analyzing the best alternatives (Ćetković, 2023).

In the introduction section, the reader into a context about hybrid solar dryers and the need for a tool to optimize their design based on a multicriteria analysis tool.

In the methodology section, the reader will appreciate the construction of the multi-criteria hierarchical analysis methodology from a conceptual way to obtaining the criteria selected for this research.

Methodology for selection of alternative energy source for solar dryers

The AHP technique (Analytic hierarchy Process) is a multi-criteria decision-making tool that is based on the hierarchical decomposition of a complex problem into a series of simpler and more manageable elements. This technique is used to evaluate and select alternatives based on multiple criteria or factors that must be considered (Atanasova-Pacemska, 2014).

The hierarchical structure was divided in three levels: the top level is the objective, which is the general problem to be solved; The second level is the criteria, which are the dimensions or factors that must be considered to achieve the objective; and the third level are the alternatives, which are the possible solutions to be evaluated (de FSM Russo, 2015).

Next, the methodology for the multi-criteria objective hierarchization

Step 1: Define the objective and selection criteria

1. Establish the main objective of the selection of alternative energy sources in solar dryers.

2. Identify the relevant criteria for the evaluation of the different energy sources, such as efficiency, availability, costs, environmental impact and technical feasibility.

Step 2: Create a hierarchical structure

1. Design a hierarchical structure that reflects the relationship between the objective, the criteria and the alternative energy sources.

2. Put the goal at the top of the hierarchy, followed by the criteria, and finally the energy sources.

Step 3: Comparison of criteria

1. Perform pairwise criteria comparisons using preference scales.

2. Ask experts in the field to assign numerical values to criteria comparisons based on their relative importance.

Step 4: Calculate relative weights

1. Saaty eigenvalue method to calculate the relative weights of the criteria.

2. Normalize the values to obtain a final weighting of the criteria validating the consistency of the matrix through the consistency index (IC) if (IC $\leq$ 0.1), it indicates a good decision (Jorge, 2015).

Step 5: Comparison of energy sources

1. Perform pairwise comparisons of energy sources using the same criteria defined above.

2. Obtain numerical values from the comparisons of energy sources by experts.

Step 6: Calculate relative weights of energy sources

1. Saaty 's eigenvalue method to calculate the relative weights of energy sources.

2. Normalize the values to obtain a final weighting of the energy sources.

Step 7: Analysis and decision making

1. Evaluate the results obtained and analyze the relative importance of energy sources according to the established criteria.

2. Make informed decisions based on relative weights and preferences for energy criteria and sources.

Step 8: Validation and sensitivity

1. Perform a sensitivity analysis to assess the stability of the results against changes in the comparisons of criteria and energy sources.

2. Validate the results obtained with experts in the field and make adjustments if necessary

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	Definition	Explanation
1	equal importance	Both values have equal contribution to the objective
3	moderate importance	one element is slightly more important than the other
5	Important	one element is more important than the other
7	Very important	One element is strongly more important than the other
9	Extremely important	One element is extremely more important than the other
2,4,6,8	intermediate values	Intermediate values between the previous ones of 1, 3, 5 and 7

Table 1 Saaty scale
Source: Own Elaboration

The hierarchy was important since it raises the central objective of decision-making as well as the criteria was evaluated

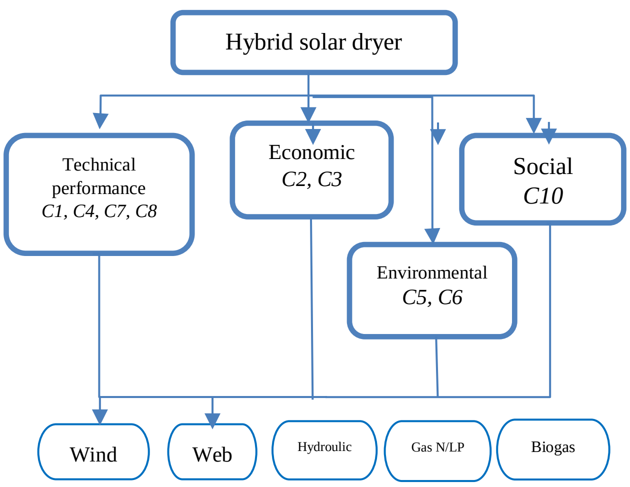


Figura 1 hierarchy AHP
Source: Own Elaboration

We select criteria that were considered important when performing solar hybridization as shown in the table.

id	Criterion	Description
C1	Energy efficiency	Capacity of the energy source to be used efficiently for the drying process
C2	installation cost	the costs associated with the acquisition and installation of the power source in the solar dryer
C3	operating cost	the recurring costs associated with the operation and maintenance of the energy source over time.
C4	Availability and access	the ease with which the power source can be accessed and its availability in the region or area where the solar dryer will be used.
C5	Environmental impact	the environmental footprint of the energy source, including greenhouse gas emissions and other pollutants.
C6	Sustainability	the ability of the energy source to be sustained in the long term without depleting natural resources and without causing significant damage to the environment
C7	Adaptability and flexibility	the ability of the power source to adapt to different climatic conditions and to the changing needs of the drying process
C8	stability and reliability	the ability of the power source to provide a stable and reliable supply of heat throughout the drying process
C9	Technical viability	The compatibility of the power source with the existing technology in the solar dryer and its ability to integrate seamlessly
C10	Social acceptance	the acceptability of the energy source by users and the community, considering factors such as risk perception, cultural acceptance and social considerations.

Table 2 Criteria to evaluate in the alternatives
Source: Own Elaboration

Once the criteria are determined, we will analyze the common alternative sources of heat that could be considered:

Biomass (firewood, agricultural residues, pellets, etc.) (Dhanuskodi, 2014).

1. Electrical energy (from the grid or generated through photovoltaic solar panels or other systems) (Amer, 2010).

2. Waste heat (for example, from industrial processes or cogeneration systems) (Arias, 2023).

3. Geothermal energy (taking advantage of the heat from the subsoil) (Hadibi, 2021).

4. Wind power (using the kinetic energy of the wind to generate heat) (Kong, 2022).

5. Hydroelectric power (through hydraulic turbines to generate electricity and heat).

6. Gaseous biomass energy (biogas, landfill gas, biomass gasification, etc.) (Maurer, 2019).

7. Energy from liquid fuels (such as biodiesel or ethanol) (Singh, 2018).

Considering these alternative sources of heat, we can combine them in different ways to create hybrid solar drying systems. However, the exact number of combinations will depend on the specific constraints and limitations of the solar dryer design, as well as the characteristics and availability of each heat source.

It is important to note that each combination will have its own advantages, disadvantages, and technical, economic, and environmental requirements. Therefore, a detailed AHP analysis and thorough evaluation of each combination will be carried out to determine which is the most suitable for a particular hybrid solar dryer case.

The pairwise comparison technique was originally proposed (Thurstone, 1927), it is a widely used and well-established methodology in Analytical Hierarchy Procedures (AHP) and Analytical Network Processes (ANP) (Saaty, 2004)This technique is used to compare two attributes or alternatives in pairs according to a criterion specific. All pairwise comparisons are organized in a matrix called the Pairwise Comparison Matrix (PCM), also known as the positive reciprocal matrix.

The PCM, represented by the matrix

$$A = [aij] \quad (1)$$

has the following definitions and associated notations. Each element *aij* of the matrix represents the comparison between the attribute or alternative *i* and the attribute or alternative *j* in terms of the considered criterion.

The matrix is symmetric, with

$$aij = \frac{1}{aij} \quad (2)$$

and the diagonal elements [*aij*] are equal to 1. Each *aij* is rated using a numerical scale that reflects the relative importance or preference between the elements compared.

$$A = \begin{bmatrix} a_1 & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (3)$$

Using a multi-criteria approach, different solar dryer design and configuration alternatives can be considered, as well as various variables related to performance and efficiency. Multi-criteria decision-making makes it possible to evaluate and compare these alternatives taking into account the different established criteria, such as energy efficiency, cost, drying quality and sustainability.

In this way, it is concluded that the methodology for the optimization of solar dryers through multicriteria decision making allows more informed and balanced decisions to be made, considering multiple aspects and relevant objectives. This can help improve the efficiency and performance of solar dryers, optimizing their design and configuration to achieve optimal results in terms of drying quality, energy efficiency, and sustainability.

Implementation the metodology propused

A group of coffee producers was selected for the design of a hybrid solar dryer to evaluate the methodology with a real case, the community is San Antonio el Porvenir, Municipality of Independencia, Chiapas, Mexico.

The average climatic conditions are reported through nearby actinometric stations and NASA data for the place report sunny with clear skies and low probability of precipitation, where favorable climates for drying occur, however, in an interview with the coffee growers they describe rainy, cold weather and excessive cloudiness during the coffee harvest season, which results in post-harvest losses.

Figure 2 San Antonio el porvenir extremely humid climate
Source: Own Elaboration

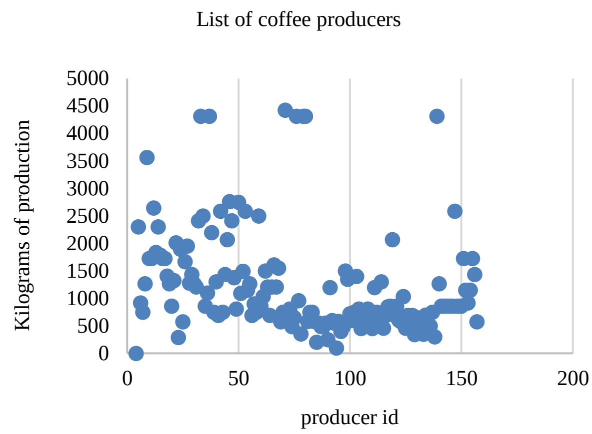
This community has access to electrical energy, however this energy is unstable and intermittent, on the other hand, the coffee growers request for the design proposal that the coffee is not in contact with the ground since their product must comply with certifications of organic product granted by the FDA among other certifications, in the interview the storage and use of pruning firewood from the coffee plantations were observed.

Figure 1 pruning coffee trees using for firewood
Source: Own Elaboration

The dryers need to be low cost and easy to maintain because the closest city to San Antonio el Porvenir is Comitan de Dominguez Chiapas, which is 2.5 hours away and which represents a considerable expense in transportation payment.

Figure 4 Red points are coffee zone far to Comitan
Source: Google Earth

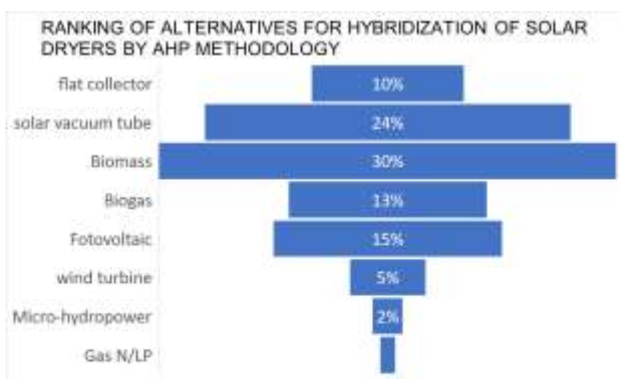
On the other hand, they request that the design proposal be modular since not all of them produce the same and they are not the same varieties of coffee.



Graphic 1 Production in kilograms of coffee from San Antonio El Porvernir
Source: Own Elaboration

Results

Once with the data obtained and evaluating the criteria with the information obtained, we proceed to qualify and analyze the criteria with the AHP model proposed below, a ranking of results for hybridizations for solar dryers is presented.



Graphic 2 AHP results for hybridization
Source: Own Elaboration

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The AHP Model ranks above the other alternatives the use of a main secondary source is biomass since we have availability and there is no deforestation as such to obtain this resource, later I pass to the vacuum tube collectors that have been used with blowers to inject cold air and extract hot air.

Hybridization alternatives considered all information provided by the user and was not limited to the study of energy potentials.

Gratitude

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Conclusions

In our opinion, AHP is a powerful method to solve complex decision-making problems with ease. The AHP is essentially a way of measuring intangibles through pairwise comparisons with judgments showing the superiority of one item over another because of the assets they share. Many examples are given by knowledgeable people without going into all the statements, but comparing only those that form a tree that encompasses all the elements, thus shortening the time of the exercise. AHP has found useful applications in decision making with respect to many intangible assets. It is a process of designing a framework that includes all the essential factors that influence the outcome of a decision. Pairwise comparative judgments are then made to demonstrate everyone's understanding of the importance, preference, or potential influence of these items on the final result by summarizing preferences derived from different sets of comparisons.

References

Amer, B. M. (2010). Design and performance evaluation of a new hybrid solar dryer for banana. *Energy conversion and management*, 813-820. https://doi.org/10.1016/j.enconman.2009.11.016

Arias, D. M.-V. (2023). A vision of renewable thermal technologies for drying, biofuels production and industrial waste, gas or water recovery. *Applied Thermal Engineering*, 223, 120022. https://doi.org/10.1016/j.applthermaleng.2023.120022

Atanasova-Pacemska, T. L. (2014). nalytical Hierarchical Process (AHP) method application in the process of selection and evaluation. *international scientific conference*, 373-380. https://eprints.ugd.edu.mk/id/eprint/11494

Ćetković, J. K. (2023). *Selection of Wastewater Treatment Technology: AHP Method in Multi-Criteria Decision Making.* https://doi.org/10.3390/w15091645

Das, B. J. (2023). *Optimization of a Photovoltaic Thermal Solar Collector Using Entropy-VIKOR Method. In: Das, B., Jagadish (eds) Evolutionary Methods Based Modeling and Analysis of Solar Thermal Systems. Mechanical Engineering Series.* springer. https://doi.org/10.1007/978-3-031-27635-4_6

de FSM Russo, R. &. (2015). Criteria in AHP: a systematic review of literature. *Procedia Computer Science*, 1123-1132. https://doi.org/10.1016/j.procs.2015.07.081

Dhanuskodi, S. W. (2014). Design and thermal performance of the solar biomass hybrid dryer for cashew drying. *Facta Universitatis, Series: Mechanical Engineering,*, 277-288. http://casopisi.junis.ni.ac.rs/index.php/FUMechEng/article/view/564/270

Goel, V. B. (2023). Identification of barriers and drivers to implementation of solar drying technologies. *Journal of Thermal Analysis and Calorimetry,*, 2977-3000. https://doi.org/10.1007/s10973-022-11631-x

Gorjian, S. F. (2022). Sustainable Food and Agriculture: Employment of Renewable Energy Technologies. *Current Robotics Reports*, 153-163. https://doi.org/10.1007/s43154-022-00080-x

Hadibi, T. B. (2021). Economic analysis and drying kinetics of a geothermal-assisted solar dryer for tomato paste drying. *Journal of the Science of Food and Agriculture*,, 6542-6551. https://doi.org/10.1002/jsfa.11326

Jha, A. &. (2021). Recent advancements in design, application, and simulation studies of hybrid solar drying technology. *Food Engineering Reviews*, 375-410. https://doi.org/10.1007/s12393-020-09223-2

Jorge, A. K. (2015). Analytic hierarchy process applied to the choice of a long-life tomato. *Drying Technology*, 1180-1187. https://doi.org/10.1080/07373937.2015.1020160

Kong, D. W. (2022). Experimental investigation of a novel hybrid drying system powered by a solar photovoltaic/thermal air collector and wind turbine. *Renewable Energy*, 705-718. https://doi.org/10.1016/j.renene.2022.05.102

Matheri, A. N. (2023). *Sustainable and circularity in the decentralized hybrid solar-bioenergy system. Environ Dev Sustain.* Springer. https://doi.org/10.1007

Maurer, C. &. (2019). Drying characteristics of biogas digestate in a hybrid waste-heat/solar dryer. *Energies*, 1294. https://doi.org/10.3390/en12071294

Mohana, Y. M. (2020). Solar dryers for food applications: Concepts, designs, and recent advances. *Solar Energy*, 321-344. https://doi.org/10.1016/j.solener.2020.07.098

Ren-E. Dong, S. Z. (2023). *Energy and exergoeconomic assessments of a renewable hybrid ERC/ORC integrated with solar dryer unit, PEM electrolyzer, and RO desalination subsystem*,. https://doi.org/10.1016/j.psep.2023.01.038.

Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes. *Journal of systems science and systems engineering*, 1-35. https://doi.org/10.1007/s11518-006-0151-5

Singh, P. S. (2018). Recent developments in greenhouse solar drying: A review. *Renewable and Sustainable Energy Reviews*,, 3250-3262. https://doi.org/10.1016/j.rser.2017.10.020

Thurstone, L. L. (1927). The method of paired comparisons for social values. *The Journal of Abnormal and Social Psychology*, 384. https://doi.org/10.1037/h0065439

Vera-Montenegro, L. B.-P.-Á.-C. (2014). Multi-criteria methodology: AHP and fuzzy logic in the selection of post-harvest technology for smallholder cocoa production. *International Food and Agribusiness Management Review*, 107-124. https://ageconsearch.umn.edu/record/167907

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Measurement of solar energy parameters project in the facilities of the Universidad Tecnológica de Altamira

Proyecto de medición de parámetros de energía solar en las instalaciones de la Universidad Tecnológica de Altamira

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Abstract

The objective of this research is to develop and design an experimental prototype that allows the capture and storage of irradiance data in real time. Access to this data is through public Mathworks web servers allowing entry from any device. The prototype includes an ESP32 development board, a photovoltaic cell, two temperature sensors and a current sensor, the main function is to measure irradiance, this being the amount of radiant energy received per specific area. This is achieved through the use of a photovoltaic cell, which transforms solar energy into electrical current, the current sensor provides an indirect measure of irradiance by recording the current produced by the photovoltaic cell. Temperature sensors are used to compensate for measurement differences caused by temperature changes in the environment. To get accurate readings, these sensors are strategically placed near the photovoltaic cell. The prototype is connected to the internet, which allows access to irradiance data, showing a practical solution for collecting and monitoring in real time, being useful in applications design and combination of technologies, such as a board of solar energy systems and in precision agriculture.

Irradiance, irradiation, temperature sensor, current sensor, photovoltaic module, solarimeter, ESP32 and ThingSpeak

Resumen

El objetivo de esta investigación es desarrollar y diseñar un prototipo experimental que permita la captura y almacenamiento de datos de irradiancia en tiempo real. El acceso a estos datos es a través de servidores web públicos de Mathworks permitiendo el ingreso desde cualquier dispositivo. El prototipo incluye una placa de desarrollo ESP32, una celda fotovoltaica, dos sensores de temperatura y un sensor de corriente, la función principal es medir la irradiancia, siendo esta la cantidad de energía radiante recibida por área específica. Esto se logra mediante el uso de una celda fotovoltaica, que transforma la energía solar en corriente eléctrica, el sensor de corriente proporciona una medida indirecta de irradiancia al registrar la corriente producida por la celda fotovoltaica. Los sensores de temperatura se utilizan para compensar las diferencias de medición causadas por cambios de temperatura en el entorno. Para obtener lecturas precisas, estos sensores se colocan estratégicamente cerca de la celda fotovoltaica. El prototipo está conectado a internet, que permite acceder a los datos de irradiancia, mostrando una solución práctica de recopilación y monitoreo en tiempo real, siendo útil en aplicaciones diseño y combinación de tecnologías, como una placa de sistemas de energía solar y en agricultura de precisión.

Irradiancia, irradiación, sensor de temperatura, sensor de corriente, módulo fotovoltaico, solarímetro, ESP32 y ThingSpeak

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Introduction

The use of solar energy is conditioned by the availability and intensity of solar radiation at a specific location. Irradiance, expressed in units of W/m², represents the magnitude of radiant energy deposited on a given surface per unit area. In the context of this study, radiation is considered to interact with a plane during a defined time interval, resulting in the transfer of a specific amount of energy. This energy transfer, quantified as the amount of energy received per unit area during a given period of time, is called irradiance (Falcón, N.; Peña, F. & Mavo, H., 2001).

Accurate and reliable irradiance records are therefore of vital importance and play a fundamental role in the design and optimisation of devices and systems that use solar energy. These records allow the assessment of the technical and economic feasibility of solar applications, as well as feasibility studies and performance modelling. This study contributes to the advancement of the field of solar energy by providing a solid basis for data collection and accurate interpretation of irradiance through a prototype solar energy meter whose purpose is to communicate information via the internet to databases that can be queried from anywhere in real time.

The hypothesis is that there is a relationship between the current and voltage values of a solar cell and the calculation of irradiance and solar irradiation. For this purpose, a circuit was fabricated that operates at the nominal allowed values, a cell connected to a current sensor, two temperature sensors, and a load equivalent to the nominal output value of the source data sheet.

The values are collected in an analogue-digital way and the main purpose is to be able to communicate these values wirelessly, to be able to use them in scripts whose function is to transform the data obtained into interpretations that can be taken as a reference in area studies, for the implementation of renewable energies.

Background

1.1. Microcontroller

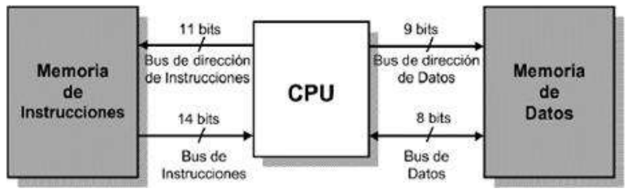

Figure 1 Operation of the Solarimeter
Source: http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1019-94032020000100048

It is an integrated circuit, whose interior has an architecture similar to computers, with components such as RAM, EEPROM, CPU and input and output peripherals or also called I/O.

It has the ability to replace a large number of circuits that use logic to function, for example, gates, decoders, timers, converters, etc., reducing the design to a simple PCB (Diaz, 2020).

1.2. Solar radiation

The global solar radiation obtained in any area is composed of two fundamental elements: direct radiation and diffuse radiation. Direct radiation refers to the solar radiation that reaches a surface unchanged in its original direction, coming directly from the Sun. In contrast, diffuse radiation is radiation that reaches the surface after being scattered or reflected, including also infrared radiation emitted by molecules after undergoing heating due to absorption of solar radiation.

Proper analysis of direct and diffuse radiation provides valuable information for the development of efficient strategies to capture and use solar energy in various applications (Wright, 2008).

1.3 Irradiance

Irradiance can be described as the measure of the intensity of solar radiation per unit area. In the international system, the unit of measurement used for irradiance is the Watt/square metre (W/m²). This magnitude exhibits minor temporal fluctuations related to solar activity, while its long-term average value is known as the solar constant, Gsc (Laguarda, 2021).

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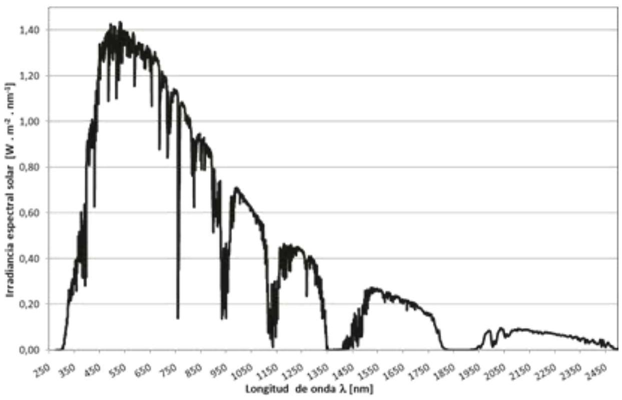

Graph 1 Solar spectral irradiance, ground level
Source:https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-77432018000200209

Description of the method

From the hypothesis of the existence of a way to measure the profitability of a photovoltaic module through its own performance, the idea of using a load in the circuit to be able to use a current sensor that is also capable of accurately calculating the voltage thanks to a shunt resistor was born, giving rise to the planning and subsequent search for materials to be used, as well as the correct way to connect each component in the circuit.

The next phase of the research belonged to the technical and practical, we had a 3W cell ideal for making a sensor, to which open-circuit measurements had to be made by means of a pair of resistors. A basic multimeter was used to check the data provided in the description of the cell and to obtain its real nominal values experimentally.

In the first instance, the sensors were tested on an Arduino R1 board, given the ease of finding compatible codes that would work as an example. Once the operation of the sensors and their potential usefulness had been verified, an equivalent programme compatible with the ESP32 development board was created.

The circuit consists of connecting the photovoltaic module in series to a resistor, to subsequently record the current and voltage drop every minute, from 5:00 a.m. to 08:00 p.m., to make comparisons with a calibrated solarimeter, which is currently owned by the Technological University of Altamira.

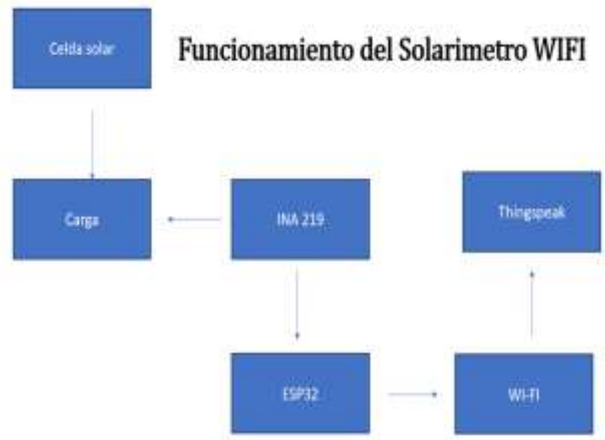

Figure 2 Operation of the Solarimeter
Source: Own Elaboration (2023)

The data collection part did not represent a great challenge for the purpose of this research, the most challenging part, due to the initial inexperience, was to elaborate the circuit that would allow measuring the data needed for the linearity calculation, i.e., in terms of programming, the sketch is relatively simple, however, the nature of the data will be mentioned later.

It is worth mentioning that the data received from the sensor was raw product that still needed to be processed to obtain relevance against a conventional solarimeter, it should be remembered that what was obtained, were powers calculated based on voltages and currents. Initially, a summation of all the data obtained in a day must be made, being Watts Minute, at the end the data must be converted to more useful units for the study of this article, in this case, Watts Hour, the reason behind this, is that the data consulted in NASA are given in Peak Solar Hours, therefore, the conversion must also be made, first, to Watts by multiplying by 1000 and finally in Watts hour by dividing by 60.

Having said that, the first method used the power values recorded by the prototype to make a comparison with the power data consulted at NASA. This consisted of summing the data provided by the cell for one day, which was then divided by 60 to obtain Watts/hour. However, the resulting number was lower because the cell has a capacity of 3 W compared to the values provided by the Data Access Viewer, which are given in Peak Holar Hours. With these two units in equivalence, a division was performed which gives a factor.

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The problem was that these factors changed considerably from day to day. From this, the average was calculated and then used as a basis for multiplying the Watts/hour, and finally the accuracy margin was obtained. However, the result was not as expected because the accuracy percentages varied between 90% and 75%, which caused a deviation after several measurements.

Days	WH Sensor	WH NASA	Percentage of Accuracyn	HSP NASA	HSP Sensor
14th June	7673.19444	7330	104.6820524	7.33	7.673194444
16th June	6974.65278	7180	97.14001083	7.18	6.974652778
17th June	7142.43056	7210	99.06283711	7.21	7.142430556
18th June	7933.75	7390	107.3579161	7.39	7.93375
20th June	6889.46429	7200	95.68700397	7.2	6.889464286
21st June	7310.59524	7520	97.21536221	7.52	7.310595238
				Average Accuracy	100.1908638

Table 1. Comparison of NASA data and data collected from the solarimeter (2023)
Source: Own Elaboration

Thus, another way of obtaining the irradiation values was considered, following the previous method with the difference that the comparison was not made with the values provided by NASA, but with those shown in a solarimeter. For this purpose, 10 data obtained every minute were used, following the same procedure as before.

The main advantage was that these values were immediate, so it was not necessary to have a waiting time to make the comparisons and calculate the factors. However, with this method, the accuracy had a large margin of error, so either system was definitely discarded. With the preliminary results and the tests carried out, it was decided to investigate another way of obtaining the irradiance, which consisted of applying the equation that relates the irradiance incident on a module with the temperature at that instant of time. With this new formula, standard temperature values were needed, which is usually 40°C, however, due to the size of the module, this value varied and was not known due to the lack of the DataSheet, so the irradiance results given were minimal with respect to the time they were taken. For the purposes of this study the formula was cleared to calculate irradiance instead of temperature.

$$Tc = Ta + G\,\frac{TONC - 20}{800}$$

Figure 3 Relationship between module temperature and irradiance (2023)
Source: https://www.helioesfera.com/dependencia-de-la-temperatura-y-la-irradiancia-sobre-el-modulo-fotovoltaico/

Luego del despeje:

$$G = \frac{(Tc - Ta)}{\left(\frac{(TonC - 20)}{800}\right)}$$

Figure 4 Ratio of module temperature to irradiance (2023)
Source: Own Elaboration

For the present study, this data of 800 W/m^2 is more accurate than using the standard 1000 W/m^2, while the TonC variable was obtained experimentally, using a commercial solar meter as a reference irradiance. (2023). Source.

Results

The information contained in the following table is from the public POWER DATA ACCESS VIEWER page, compared to the data collected on the prototype manufactured in this research. A breakdown of irradiation related data is available for the current study area in the form of Peak Solar Hours.

It is necessary to convert the data with the proposed equation. Once this is done, through the rule of 3, a daily precision margin is obtained, from which it is possible to obtain an average, after the census of different days.

The lack of continuity in the days presented in the table was a consequence of the discharge of the prototype's power supply, leaving no margin for the collection of information on the days omitted.

The ESP32 circuit board is a System On chip, designed by Espressif Systems and manufactured by TSMC. The developer itself defines this series as a solution for microcontrollers without connectivity. It is possible to use the ESP32 as a bridge to connect to such boards, and it is capable of running its own real-time applications, which makes it more suitable and capable for probing tasks than other circuit boards, for example, the Arduino R1.

One of the libraries available for free download creates a local web server, which is stored in the microcontroller's memory, its purpose is for the board to generate a request to be connected to a WI-FI network available in the surrounding area.

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In case the ESP32 has already been connected to a WI-FI network available in range, this last step will be skipped and the execution of the program will start, the local server is accessible via computers and mobile devices such as mobile phones and tablets.

The data is stored locally, in the ESP32's flash memory, however, in addition, all data is sent to the cloud whenever internet is available, in this case, to a public server hosted by Thingspeak, a free site that offers students access to customisable private or public clouds, without any kind of initial investment.

The information collected on the site can be downloaded in .csv format, an Excel-compatible file type, through which it is possible to perform the necessary calculations to convert the data.

Figure 5 Public server dedicated to collecting solarimeter data in Thingspeak (2023)
Source*: https://thingspeak.com/channels/2144052*

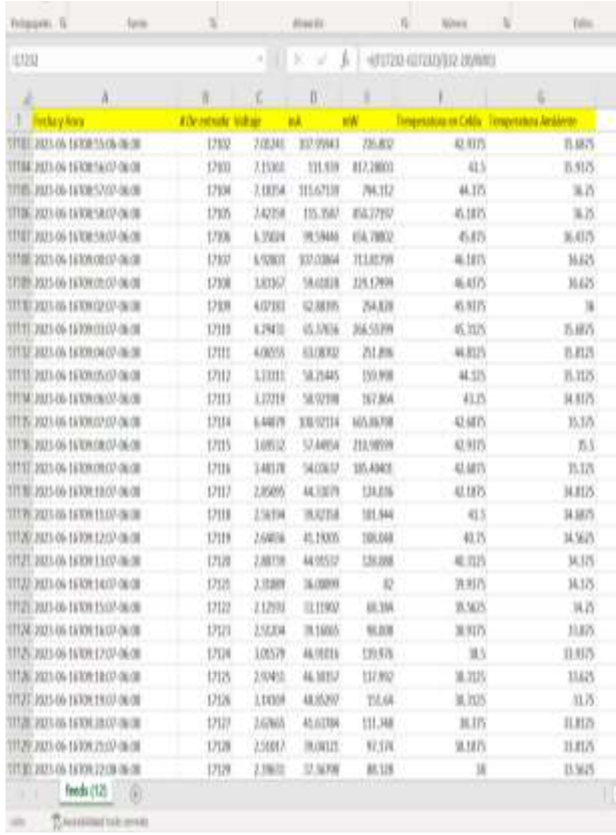
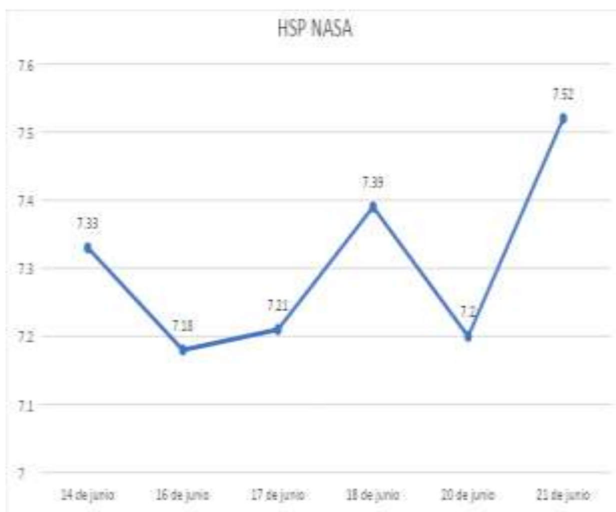


Figure 6 Example of data exported from Thingspeak (2023)
Source: Own Elaboration

With the data collected and worked on, it is possible to create graphs that work best to visually show the relationships between the data.



Graph 2 Graph of Peak Solar Hours from data consulted on the official NASA website (2023)
Source*: power.larc.nasa.gov/data-access-viewer/*

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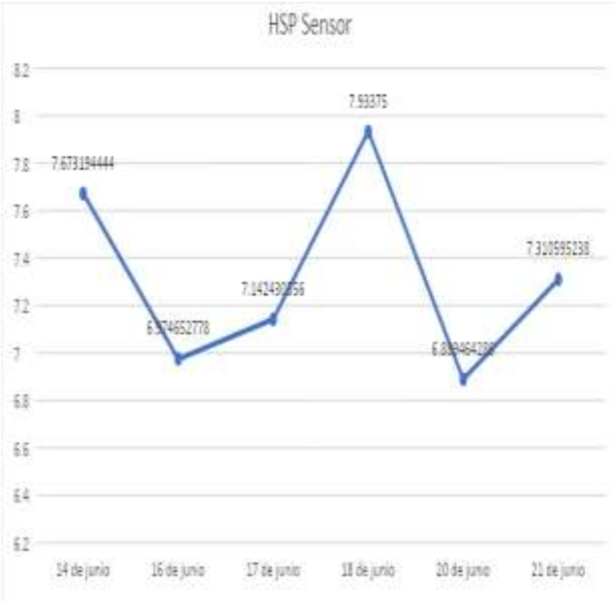

Graph 3 Graph of Peak Solar Hours of the data obtained by the prototype manufactured (2023)
Source: Own Elaboration

Difficulties in the process

During the development of the design, various issues arose that delayed the process, including the fact that the photovoltaic cell used did not have a DataSheet, so the adjustments had to be experimental, based on a sensitivity analysis and by means of calculations. When the resistance value was obtained, there was a problem with it, due to the fact that the ideal value (60 ohms) is not commercial, so it was decided to use a 39 ohms resistor in series with a 22 ohms resistor, reaching the correct value required.

The correct placement of the module and its power supply was of utmost importance to start the data collection, so both had to be accurate. In view of this, a series of tests were carried out to obtain results, which postponed the collection of information.

With regard to data collection, it was necessary to use the memory of the ESP32 sensor to store the information obtained, as otherwise the values would not be recorded if at any time it was disconnected from the selected Wifi network or if any mishap occurred with the electrical service. In terms of wording, certain doubts arose regarding the relationship between the irradiance measured in the photovoltaic cell and the data provided by Data Access Viewer. Also, the values are delayed by five days, so the comparison process requires a considerable waiting time.

Concluding remarks

For the sizing of a PV system, having the HSP parameter in the area is an essential part of the study. This information is key because, during the calculation of the number of modules, it determines the techno-economic feasibility and, above all, the cost of investment in the equipment, which at a business level can make the difference between attracting new customers and having a competitive advantage.

The prototype presented is capable of obtaining an average of 99% certainty with respect to the information consulted in Power Data Access Viewer, with the characteristic of being a database that can be consulted in real time, with an internal storage space and a potential autonomy of 48 hours, with the possibility of expanding this time.

Its application can be directed both to the dimensioning of photovoltaic and photothermal systems. In addition, it is a tool with enormous potential to be implemented in weather stations that combine a greater amount of information.

The advantages offered over a traditional circuit board, for example, the Arduino R1 model are remarkable at the time of setting strategic points, IOT (Internet Of Things) is undoubtedly a revolution in the scheme of the usefulness of current tools, providing great projection to studies such as the one presented in this article.

Summary of results

The data were captured efficiently, within the expected margin, the functionality of the wifi protocol was proven as a useful and powerful tool. Thus opening up the possibility of mapping areas that would normally be inaccessible with complex equipment and optimising methods that require periodic relocation of the equipment in question.

Conclusions

With the results obtained, the project's initiative was fulfilled by creating a solarimeter that works wirelessly to communicate area study data, which can function as a reference in the analysis of the profitability of renewable energy generation projects.

Recommendations

In order to extend the field of application of the present prototype, it is good practice to plan alternative designs and improvements in the field of the body that will use the circuit employed. During the research, it was confirmed that, in order to reach a more advanced level of utility, it is possible to insert a properly measured mechanism that allows the modification of certain parameters such as the installation angle of the photovoltaic module, as well as its orientation, a feature that greatly improves previous studies on the installation of photovoltaic systems.

Adding a charging circuit with a second module can also provide a very extended range of power supply for the circuit presented, regardless of not increasing the size of the battery used.

Further mathematical study can help implement a substantial improvement to the margin of error present, if more accuracy is needed, it is possible to program a percentage delimiter.

Given the wireless nature of the ESP32 board, it is also possible to design an app to be integrated into the operation, opening up the possibility of remote control and subsequent integration of more than one pyranometer per study.

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References

Bayón Alonso, E. (2018). *Diseño de un instrumento basado en Arduino para la medida de irradiancia solar.* Tesis Ing. Elec. Ind. Auto. Univ. De Valladolid.

Chacón Cardona, C.A, Eduardo Cely, O, Guerrero, F. (2008). *Diseño y construcción de un medidor de radiación solar. Proyecto Académico.* Univ. Distrital Francisco José de Caldas de Colombia.

Falcón, N., Peña, F, Mavo, H, Muñoz, R. (2001). *Irradiación solar global en la ciudad de Valencia*. Proyecto académico. Univ. De Carabobo de Valencia, Venezuela.

Galban Pineda, M.G, Sepúlveda Mora, S.B, Contreras Sepúlveda, W. (2018). *Análisis estadístico de la radiación solar en la ciudad de Cúcuta. Producto derivado del proyecto de investigación "Análisis de los efectos de un sistema solar fotovoltaico conectado a la red eléctrica de baja tensión en la UFPS".* Univ. Francisco de Paula Santander de Colombia.

García, A. R.; Quispe, H. W. & Silva, G. J. (2021). *Diseño e implementación de un medidor de irradiancia solar con registro de datos basado en arquitectura de código abierto.* Tesis Título Profesional de Ingeniero Electrónico.

Gualoto Cachago, J.A, Potosí Díaz, R.A. (2022) *Desarrollo de un seguidor solar automatizado usando un sistema embebido y algoritmo de posicionamiento solar (SPA).* Opción de Titulación en Maestría en Electrónica y Automatización. Univ. Politécnica Salesiana de Ecuador.

Herranz, A. B. (2019). *Desarrollo de aplicaciones para IoT con el módulo ESP32.* Trabajo Fin de Grado en Ingeniería en Tecnologías de Telecomunicación

Laguarda Cirigliano, A. (2021). *Modelado de la irradiancia solar sobre la superficie Terrestre.* Tesis de Doctorado en Ingenieria de la Energía.
Mathworks. (2023). M*ATLAB para Inteligencia Artificial.* Mathworks. Sitio web: https://la.mathworks.com/?s_tid=gn_logo

Rojas Lozano, A.D. (s.f) *Desarrollo y Automatización de un sistema para caracterización de celdas solares convencionales.* Tesis Maestría en Tecnología avanzada. Instituto Politécnico Nacional, 74 p.

Texas Instruments Incorporated. (2022). *INA219 Zero-Drift, Bidirectional Current/Power Monitor With I2C Interface*. Texas Instruments.

Tudor Coftas, D., Adrian Coftas, P., & Mihain Machidon, O. (2018, Marzo 25). *Study of Temperature Coefficients for Parameters of Photovoltaic Cells. Hindawi*, *2018*, 12. https://doi.org/10.1155/2018/5945602

Wright, J., (2008). *CÁLCULO ESPECTRAL DE LA IRRADIACIÓN SOLAR DIRECTA, DIFUSA Y GLOBAL EN HEREDIA*, COSTA RICA. Uniciencia, 22 (1-2), 71-85.

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Duplex solar cooker with selective evacuated tube and compound parabolic concentrator

Cocina solar duplex de tubo evacuado selectivo y concentrador parábolico compuesto

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Abstract

In the present work, an indirect solar cooking proposal is shown. The proposal combines three technologies: evacuated tubes, selective absorber, and compound parabolic concentrator (CPC). The absorber used is an evacuated glass tube, with a highly selectivity inner surface. The temperature reached by the solar cooker is approximately 160°C, enough to cover the cooking needs of all types of food; Irradiance, wind speed, ambient temperature was measured, food cooking tests were carried out, using an evacuated tube and a parabolic solar concentrator; as well as evacuated tube without parabolic solar concentrator. A compound parabolic concentrator was designed with an acceptance angle of 15 degrees, the base of the solar cooker was made with acrylic, the concentrator was made with simple reflection mirrors, the clips were printed on a 3D printer, the trays were made with food grade stainless steel, food cooking tests were carried out, recording the weather variables every 15 minutes. The development of this evacuated tube duplex solar cooker project is not only important because it involves the achievement of an academic purpose, but also involves a social purpose. It is intended to provide an efficient and economical solution that is attractive to multilateral organizations capable of supporting its manufacture, industrialization and distribution to achieve the massification of the product with a real and lasting impact.

Solar energy, Cooking food, Solar cookers

Resumen

En el presente trabajo, se muestra una proppuesta de cocina solar indirecta. La propuesta combina tres tecnologías: tubos evacuados, absorbedor selectivo, y concentradore parabólico compuesto (CPC). El absorbedor utilizado es un tubo de vidrio evacuado, con superficie interior de alta selectividad. La temperatura alcanzada por la cocina solar es de 160°C aproximadamente, suficiente para cubrir las necesidades de cocción de todo tipo de alimentos; se midió la irradiancia, velocidad de viento, temperatura ambiente, se realizaron pruebas de cocción de alimentos, utilizando tubo evacuado y concentrador solar parabolico; así como tubo evacuado sin concentrador solar parábolico. Se diseñó un concentrador parbólico compuesto con un ángulo de aceptación de 15 grados, la base de la cocina solar fue elaborada con acrilico, el concentrador fue elaborado con espejos de simple reflexión, los clips se imprimieron en una impresora 3D, las charolas fueron elaboradas con acero inoxidable grado alimenticio, se realizarón pruebas de cocción de alimentos, registrando cada 15 minutos las variables climatologicas. El desarrollo de este proyecto de cocina solar dúplex de tubos evacuados, no solo es importante porque envuelve la realización de un fin académico, sino que también involucra un fin social. Se pretende brindar una solución eficiente y económica que sea atractiva para organismos multilaterales en capacidad de apoyar su fabricación, industrialización y distribución para lograr la masificación del producto con un impacto real y duradero.

Energía Solar, Cocción de alimentos, Cocinas solares

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1. Introduction

The use of technologies that combine the sun's energy and energy efficiency, including the solar cooker, partly help the development of the world's population, especially the poor. The first solar cooker was developed in 1767 by Horace de Saussure, which reached a maximum temperature of 88º C and according to his writings, when a black surface was added to the inside of the box, it reached 160º C. (Resabala, 2023).

Solar cookers are thermo-converters that harness the sun's energy to generate sufficient heating power to cook food at varying time intervals. Generally, these systems are semi-stationary, because they require continuous orientation towards the sun, in order to make the best use of solar energy. There are different types of solar cookers: box type; parabolic concentrator; indirect collector; with tube type convective insulator; with compound parabolic concentrators; and with folding collector. (Sosa, 2023).

There are various types of solar cookers, in particular in Mexico, the Tolokatsin solar ovens and solar cookers have been developed, with high thermal performance, based on the application of anidolic optics (González-Avilés, 2023). In several regions of our country, the growing overexploitation of forest resources is a latent problem that must be addressed (in some cases immoderate clandestine logging has caused inter-community conflicts that have had irreparable consequences).

Cooking with solar energy is a wonderful experience. It means not only a daily saving on gas, charcoal, wood or electricity, but also a change in people's consciousness and a learning process that is oriented towards sustainable human development. It is a new way of taking care of our lives, which is being applied in more and more countries every day (Almada, 2023).

The habit of collecting and using firewood prevents people from realising what this means for most people and for the environment, but it is important to think about why firewood and charcoal are used:

Money is not always enough to buy gas, people live so far away from urban centres that it is the only fuel available, they want to make a gas cylinder last as long as possible, they want to use it as much as possible, and they want to use it as much as posible gas cylinder as long as possible, and people have always thought that firewood is free... but it's not!

The inhalation of fumes from the combustion of wood is the cause of respiratory diseases, which also produces carbon dioxide emissions that are harmful to the environment. Solar cookers represent an alternative to reduce carbon dioxide emissions; for the cooking of food, for every kilogram of LP gas that is not combusted, 2.8 kg of CO2 (CO2 emitted into the atmosphere) are reduced, or for every kilowatt hour that is not consumed in electric grills, 498 grams of CO2 can be mitigated. Likewise, in the rural sector, where LP gas is generally not consumed, emissions are associated with the burning of timber forest resources, where in addition to emissions, respiratory diseases are generated in the users of forest biomass. The use of alternative energy sources such as solar energy for cooking can contribute to solving this type of problem (Ialla N. D., 2023).

In order to access higher temperatures, parabolic trough concentrators have been developed over the years; usually the absorber element, the cooking pot, is placed directly at the focus of the system, making it a direct solar cooker. With this configuration, the limitation of the efficiency of the system is due to the fact that the pot is exposed to the three mechanisms of heat transfer to the environment.

At the Technological University of San Juan del Río, solar ovens have been built that reach 80°C to 90°C, the complicated thing is to exceed 100°C and, above all, to reach the usual cooking temperatures of conventional cookers and ovens, which start at 120º, from these temperatures the solar oven or solar cooker starts to be a good development.

(Duran, 2016), developed a four-phase prototype: The parabolic dish, the gear boxes and support device, the control system for solar tracking and finally the integration and operational testing. The conjunction of the four phases results in a fully operational prototype with the ability to reach up to 400 °C temperature above the focal point of concentration under partly cloudy day conditions.

One way to circumvent this last drawback is through the use of concentrators with anidolic optics, i.e. non-imaging. Devices employing this principle are called compound parabolic concentrators (Ialla N. D., 2011). In recent years, different designs of indirect solar cookers using CPC technology have been proposed. (Carrera, 2016), characterised a solar cooker made from two evacuated tubes that are used in solar water heaters to heat water for sanitary use, which were placed on supports, inside the tube a tray made of food grade stainless steel was inserted, which is used to place the food to be cooked, they have lids made with Nylomaq□, these evacuated tubes are placed on an aluminium base in a parabolic shape, the temperature values inside the tray where the food is placed, reported the cooking of foods such as: Mixiote, chicken in pipian sauce, chicken fajitas, beans, steak with potatoes, bread baking.

(Ialla N. D., 2023) presents a new indirect solar cooker design. The design combines three high-performance technologies: evacuated tube, selective absorber, and compound parabolic concentrators (CPCs). An alternative method developed for the calculation and layout of CPCs for absorbers of circular geometry is also shown.

The absorber used in the prototype is an evacuated glass tube with a highly selective inner surface. The heat transfer mechanism, from the absorber to the cooking vessel, is through the natural convection of ecological oil. The design features and the elements used allow a very efficient use of solar energy, thanks to which the system can easily access temperatures close to 170°C, sufficient to cover the cooking needs of all types of food.

(González-Avilés, 2015), presents the study of some aspects of thermal physics necessary for the development of small solar cookers, through the development of a semi-empirical computational thermal model. The free parameters of the model are adjusted with data obtained from an experimental design, which consists of heating a fluid, exposing the cookers to the radiation produced by an array of incandescent lamps to simulate solar radiation. The model allows estimating some parameters that serve to compare the operation of solar cookers, from the thermal point of view, with parameters established in standard test protocols at international level, such as: standardised cooking power and thermal efficiency.

There are two solar cooker systems: those based on the storage principle and those based on the concentration principle. In the former, an enclosure thermally insulated on all sides, except for the side facing the sun covered with a material transparent to solar radiation, usually glass or plastic, allows us to receive the sun's radiant energy and store it inside thanks to the greenhouse effect. In the case of using this system as a solar cooker, a container with the food to be cooked is placed inside. Depending on how the cooker is constructed, it can reach 90 to 120 degrees Celsius.

In the second case, a concentrating system, usually of a parabolic nature, also intercepts the solar radiant energy and brings it to its focal zone. Systems such as the K14 parabolic cooker, for an intersection of 2 square metres, offer an output of 1 kW with an efficiency of 50 percent. In this way, a high thermal utilisation is achieved in the pot where the solar energy is concentrated. In this second case, higher temperatures can be reached than with storage cookers, at least 200 °C, which allows not only boiling, stewing, steaming, but also frying and roasting (González, 2023).

In view of the above, the present work proposes a design for a direct solar cooker that uses CPC technology, absorbs solar radiation through a selective evacuated glass tube with vacuum insulation, and transmits the heat to the cooking receptacle, consisting of a tray made of food-grade stainless steel.

The device has an acceptance angle of 15°, i.e. it allows one hour of concentration without the need for redirection, and is capable of accessing temperatures necessary for the cooking of all types of food, the proposed cooker allows frying, boiling and baking.

At the Technological University of San Juan del Río, a prototype of a duplex solar cooker with evacuated tubes and a parabolic concentrator is being developed in the research unit, in the renewable energy laboratory, using affordable and low-cost materials.

Figure 1 Prototype duplex solar cooker with evacuated tubes and compound parabolic concentrator
Source: Own Elaboration

In contrast to box-type solar cookers, parabolic cookers and compound parabolic cookers, the present work shows a solar cooker that exploits three technologies

2. Design and description of the solar cooker prototype

2.1Theoretical underpinnings of design

Let us consider a concentrator system operating with an absorber isolated from the external medium, in such a way that the heat exchanged by conduction and convection (typical characteristic of vacuum insulation) is neglected. Then we can say that the maximum temperature that the absorber can reach can be calculated by establishing the equilibrium between the energy it absorbs and the energy it emits by radiation. This situation is given by the equality (1).

$$IC\rho A \propto = \varepsilon A\sigma T^4 \quad (1)$$

Where:

- I Solar irradiance in W/m^2
- A Absorber area
- C Geometric concentration of the system (ratio of the collector collector area to the absorber area)
- ρ Reflectivity of the concentrator surface
- ε Surface emittance
- α Surface absorptance
- σ Stefan-Boltzman constant, σ = 5.67·10-8 [W/m^2 K^4]

By subtracting T from (1) we obtain the maximum temperature that the absorber can reach in this situation, equation (2).

$$Tmax = \sqrt[4]{IC\beta\rho/_{\sigma}} \quad (2)$$

- T Maximum temperature that the absorber can reach
- β Abosorber surface selectivity, α/ε.

To obtain a device with high conversion efficiency and access to the highest temperatures: the absorber must have vacuum chamber insulation, it must operate at maximum concentration conditions, and it must have selective properties.

2.2 Design and calculation of the CPC profile

A two-dimensional CPC-type optical concentrator design was proposed for a receiver with a circular cross-section, in this case the evacuated tube, a geometry compatible with that of the vacuum-selective tubular absorber. The CPC was made from the complementation of two parabola sections and two circle envelopes, and has an acceptance angle of θ= 15°.

The starting point for the design, and for the drawing of the circle envelopes, was the absorber diameter, in our case the external diameter of a borosilicate tube (47 mm). Then, with the value of the radius of the base circle, R = 2.35 cm, its envelopes were plotted, taking into account the parametric equations (3) that model the pairs (x,y).

$$x(\propto) = R(\cos\propto + \propto sen \propto)$$

$$y(\propto) = R(sen \propto - \propto cos \propto) \quad (3)$$

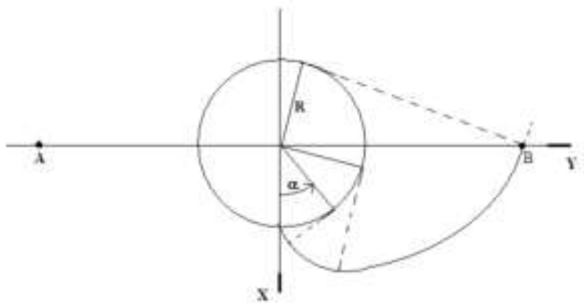

Figure 2 Truncated circle envelope at the height of horizontal diameter

The points A and B form a segment of length L, its practical value is obtained with the condition x = 0 in equation (3), thus obtaining the transcendental equation α = -cotg α. Finding an approximate solution of α (in this case α = 0.89π), and replacing its value in y(α) of eq.(3) gives the location of point B. The other branch is symmetrical, so the length of segment L is obtained, which in our case was 13.95cm.

2.3 Absorber tube

An evacuated borosilicate glass tube with an external diameter of 47 mm was used as absorber element, the length of the tube is 0.53 m. The tube has a double wall forming a double-walled absorber. It has a double wall forming a vacuum chamber, which gives it the fundamental quality of reducing the conductive and convective losses to the outside as much as possible. The tube has an absorber multilayer Cu / AlN (copper / aluminium nitride) structure deposited on the outer face of the inner glass, its average solar absorbance is α ≥ 94.5%, and its thermal emittance ε ≤ 5.5%. Figure 3 shows a schematic cross section of the absorber tube.

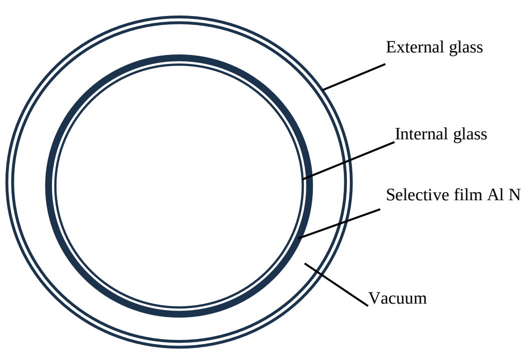

Figure 3 Cut of the absorber tube
Source: (Ialla N. D., 2011)

3. Description of the cooker

Once the curve has been obtained as indicated in fig 2, it is traced on white acrylic, three sections are cut out for the left side and three sections for the right side, which are joined at the base with 3/8 inch threaded rod with nut and pressure washer, and with metal hinges in the central part, mirrors are placed on these pieces in rectangular strips to form the reflecting surface, The evacuated tubes are supported by a metal structure in the shape of letter A, one at the front and one at the back, on the sides of this structure are placed the red supports, which are attached to the sides of the structure by means of screws, washers and nuts, the supports were made in a 3D printer.

Figure 4 Evacuated tube duplex solar cooker
Source: Own Elaboration

Figure 5 Duplex evacuated tube solar cooker, showing solar concentration on a copper tuve
Source: Own Elaboration

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3.1 Tray

The food tray is made of food grade steel, half-moon shaped, with a layer of nylomaq that seals the evacuated glass tube, and a wooden handle.

Figure 6 Tray for placing food
Source: Own Elaboration.

Experimental measurements

During the testing of the solar cooker, different food recipes were developed, as listed below:

a) Eggs with sausages

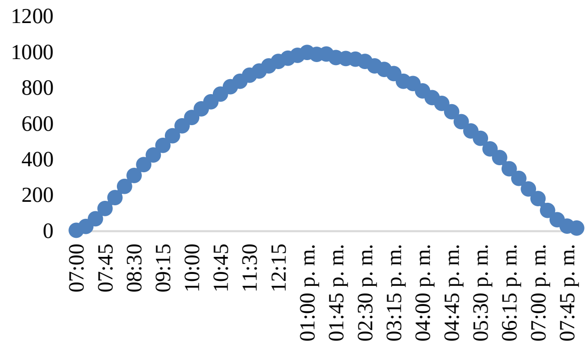
On 14 June this year, eggs with sausages were prepared in the solar cooker, the ingredients and how to prepare them are as follows.

No.	Quantity	Unit	Description
1	2	Pza	Hen's egg (Bachoco®)
2	2	Pza	Sausages with turkey (Swan®)
3	1	Pza	Iodised salt (La fina®)
4	100	ml	Sunflower oil (Girasol®)

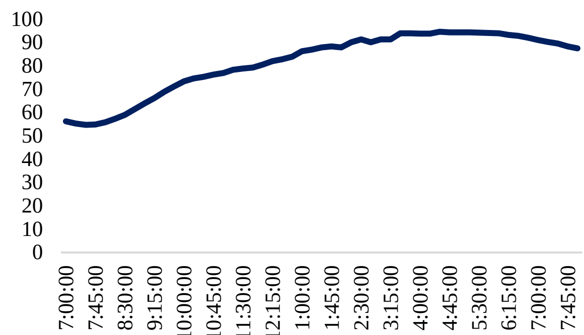
Table 1 Ingredients for making sausage and eggs
Source: Own Elaboration

How to prepare

Cut the sausages into slices, approximately one centimetre long, place a teaspoon of oil inside the pan, beat the eggs on a plate, add the sausages, cook for about 25 minutes, serve and serve as desired.



Graph 1 Irradiance for 14 June 2023, vertical axis Watts/m^2, horizontal axis, time of day
Source: https://www.wunderground.com/dashboard/pws/IQUERETA29/graph/2023-06-14/2023-06-14/daily



Graph 2 Ambient temperature for 14 June 2023, vertical axis °C, horizontal axis, time of day
Source: https://www.wunderground.com/dashboard/pws/IQUERETA29/graph/2023-06-14/2023-06-14/daily

Figure 7 Eggs with sausages
Source: Own Elaboration

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b) Mexican steak

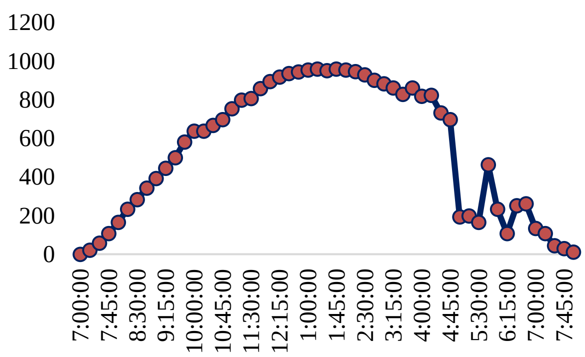
On 21 June this year, Mexican-style steak was prepared, the ingredients and how to prepare it are as follows.

No.	Quantity	Unit	Description
1	1	Pza	Serrano chili
2	2	Pza	Jitomáte
3	1	Pza	White onion
4	3	Pza	Tenmillo steak
5	100	ml	Sunflower oil (Girasol®)
6	10	Gramos	Iodised salt (La fina®)

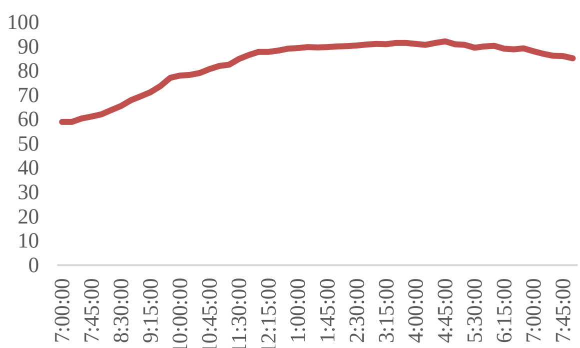
Table 2 Ingredients for steak a la mexicana
Source: Own Elaboration

How to prepare

Chop onion, tomato and serrano chili, cut the steak into fajitas, place a teaspoon of oil in the pan, add onion and serrano chili, cook for about 10 minutes, add the tomato and cook for 5 minutes, add the steak fajitas, add salt to taste, serve and serve to taste.



Graph 3 Irradiance for 21 June 2023, vertical axis Watts/m^2, horizontal axis, time of day
Source:
https://www.wunderground.com/dashboard/pws/IQUERETA29/graph/2023-06-21/2023-06-21/daily



Graph 4 Ambient temperature on 21 June 2023, vertical axis: °F, horizontal axis, time of day
Source:
https://www.wunderground.com/dashboard/pws/IQUERETA29/graph/2023-06-21/2023-06-21/daily

Figure 8 Solar cooker with CPC solar concentrator on the left side and without CPC concentrator on the right side, with Mexican-style steak in both tubes
Source: Own Elaboration

Figure 9 Mexican-style steak and degustation by a student of group ES01SM21
Source: Own Elaboration

Time	Irradiance W/m^2	Temperature °C, with concentration	Temperature °C, no concentration
10h45	698	76.5	71.2
11h00	754	77.2	72.4
11h15	798	79.5	74.6
11h30	807	80.9	75.6
11h45	858	85	81.0
Average	783	79.82	74.96

Table 3 Comparison of temperatures inside the tray, during the preparation of the Mexican steak

Note: With concentration refers to the tube receiving the light beam from the CPC and without concentration refers to the tube being exposed to sunlight.

It is observed that the solar concentration increases the temperature by 6.56% with respect to the temperature reached inside the tray with the tube without solar concentration.

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Consequently, the cooking time is reduced from one hour to three quarters of an hour for the Mexican style steak.

c) Carrot pancake

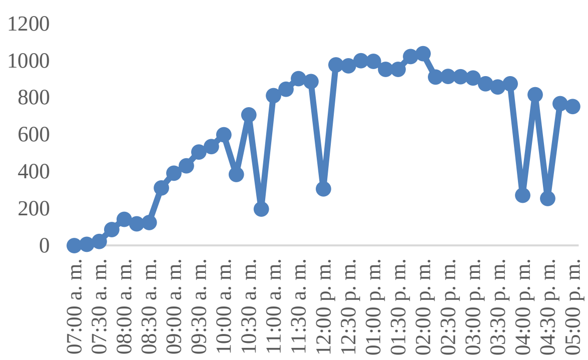
On 3 July of this year, carrot cake with walnuts was prepared, the ingredients and the way to prepare it are as follows.

No.	Quantity	Unit	Description
1	0.4	kg	Carrot
2	0.15	kg	Walnuts
3	0.1	kg	Wheat flour (Tres estrellas®)
4	0.1	kg	Brown sugar (Zulka®)
5	0.01	kg	Baking powder (Rexal®)
6	0.02	kg	Iodised salt (La fina®)

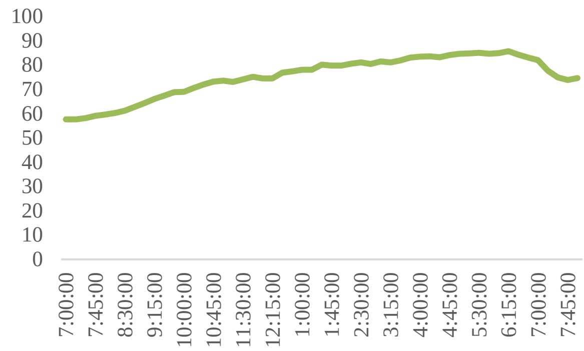
Tabla 4 Ingredients for preparing carrot and walnut cake

How to prepare

Beat the eggs with the sugar for a couple of minutes making sure they are well integrated, mix the dry ingredients, such as flour with the baking powder and a pinch of salt, join with the eggs and sugar previously beaten, until a homogeneous mass is obtained, peel the carrots, process until it is like a thick puree, chop the walnuts, mix all of the above, place on the baking tray and leave to bake for 20 to 30 minutes, process until a thick puree, chop the walnuts, mix all of the above, place on the baking sheet and bake for 20 to 30 minutes, test with a toothpick to ensure that it is not raw, once the toothpick does not stick residue, let it cool and serve and accompany it to taste.



Graph 5 Irradiance for 3 July 2023, vertical axis Watts/m^2, horizontal axis, time of day
Source: https://www.wunderground.com/dashboard/pws/IQUERETA29/table/2023-07-3/2023-07-3/daily



Graph 6 Ambient temperature on 21 June 2023, vertical axis: °F, horizontal axis, time of day. *Source: https://www.wunderground.com/dashboard/pws/IQUERETA29/table/2023-07-3/2023-07-3/daily*

Figure 10 Carrot cake with walnuts, baked in the evacuated tube duplex solar cooker
Source: Own Elaboration

Figure 11 Carrot cake with walnuts
Source: Own Elaboration

Time	Irradiance W/m²	Temperature °C, with concentration	Temperature °C, no concentration
10h45	197	73.5	68.3
11h00	812	74.2	66.9
11h15	846	73.5	66.5
11h30	904	75.9	67.6
11h45	888	74	67.2
Average	729.4	74.22	67.3

Table 4 Comparison of temperatures inside the pan during the preparation of the carrot cake with walnuts

Note: Concentration refers to the tube receiving the light beam from the CPC and non-concentration refers to the tube being exposed to sunlight.

It is observed that the solar concentration increases the temperature by 10.28% compared to the temperature reached inside the mold with the tube without solar concentration.

Consequently, the baking time is reduced from one hour to three quarters of an hour for the carrot cake with walnuts.

Acknowledgement

The authors of this work would like to thank the directors of the Universidad Tecnológica de San Juan del Río (UTSJR, 2023), Querétaro, for the facilities granted to carry out this work, as well as the members of the renewable energy academic body for the suggestions made, which contributed to the improvement of this work. Special thanks are also due to the students of the ES01SM-20 group for their support in the tasting of the food.

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Conclusions

A proposal for a solar cooker with evacuated tubes has been presented, with the aim of reaching appropriate temperatures for cooking food. The temperature reached without food inside the trays is around 150°C, which allows a variety of foods to be prepared; boiling, baking or frying is possible.

The concentration of light on the evacuated tube allows the food to be ready 15 minutes earlier, compared to food that is prepared without the concentration of light on the evacuated tube. The students who tasted the food agree that the food tastes very good, and that they would be willing to buy a solar cooker like the one developed at the Research Unit of the Technological University of San Juan del Río.

References

Almada, F. C. (16 de 08 de 2023). *ecotec.unam.mx*. Obtenido de https://ecotec.unam.mx/wp-content/uploads/Gu--a-de-uso-de-cocinas-y-hornos-solares.pdf

Carrera, G. D. (2016). Caracterización de una cocina solar dúplex de tubos evacuados. *Revista de prototipos Tecnológicos,* 52.

Duran, P. B. (2016). Concenrador solar PDR con seguimiento solar. *Revista de Aplicaciones de la Ingeniería*, 98-108.

González, J. G. (07 de 09 de 2023). *ub*. Obtenido de ub.edu: https://www.ub.edu/geocrit/b3w-376.htm

González-Avilés, M. (2015). Modelo térmico para estimar la potencia de cocción estándar de cocinas solares. *Scielo México*, 48-65.

González-Avilés, M. (17 de 07 de 2023). *researchgate.net*. Obtenido de https://www.researchgate.net/publication/317078518_ESTUDIO_DE_PROPIEDADES_TERMICAS_DEL_HORNO_SOLAR_TOLOKATZIN

Ialla, N. D. (2011). Cocina solar de alto rendimiento con aplicación de tubo evacuado selectivo y concentrador CPC. *Avances en Energía Renovables y Medio Ambiente*, 9-15.

Ialla, N. D. (20 de 08 de 2023). Obtenido de https://inis.iaea.org/collection/NCLCollectionStore/_Public/49/101/49101668.pdf

Resabala, V. F. (12 de 08 de 2023). *revistaespacios*. Obtenido de https://www.revistaespacios.com/a19v40n24/19402411.html

ISSN-2523-6830

Sosa, L. B. (02 de 09 de 2023). *sabermas*. Obtenido de sabermar.umich.mx: https://www.sabermas.umich.mx/archivo/tecnologia/237-numero-27/424-cocinas-solares-tecnologia-ecologica.html#:~:text=Las%20cocinas%20solares%20son%20termoconversores,en%20intervalos%20de%20tiempo%20variados.

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Data acquisition module for the operation of the web system for automatic irrigation in a Greenhouse

Módulo de adquisición de datos para el funcionamiento del sistema web para el riego automático en un Invernadero

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Abstract

The use of technologies in protected agriculture has impacted the way of improving and transforming cultivation processes. Bastida (2004) mentions that protected agriculture is the one that is carried out under production methods that help to aply a certain degree of control on various environmental factors. In the production of crops in greenhouses, these protect different plants from excess cold at certain times of the year, allowing control of temperature, humidity and other environmental factors that favor plant growth. The drip irrigation system is a fundamental element for the production of greenhouse crops. This work describes the operation of the data acquisition module, which its objective its to collect data on humidity and temperature variables through electronic devices such as sensors and the Arduino, and along an interface it is linked to the web system. showing real-time results of automatic irrigation. This project was based on the model in Prototypes

Data acquisition, Irrigation, Greenhouse

Resumen

El uso de las tecnologías en la agricultura protegida ha impactado en la forma de mejorar y transformar los procesos de cultivo, Bastida (2004), menciona que la agricultura protegida es aquella que se realiza bajo métodos de producción que ayudan a ejercer determinado grado de control sobre los diversos factores del medio ambiente. En la producción de cultivos bajo invernadero, estos protegen, las diferentes plantas del exceso de frío en ciertas épocas del año, permite el control de la temperatura, la humedad y otros factores ambientales que favorecen el crecimiento de las plantas. El sistema de riego por goteo es un elemento fundamental para la producción de cultivos del invernadero. El presente trabajo describe el funcionamiento del módulo de adquisición de datos, que tiene como objetivo la toma de datos de las variables de humedad y temperatura a través de dispositivos electrónicos como los sensores y el arduino, y mediante una interfaz se enlaza con el sistema web que muestra los resultados en tiempo real del riego automático. Este proyecto se basó en el modelo en Prototipos

Adquisición de datos, Riego, Invernaderos

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† Researcher contributing as first author.

Introduction

Technology has evolved rapidly that has transformed the way of working and controlling different processes. Protected agriculture is one of the areas in which it has impacted the way crops are produced and harvested. For the Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA, 2015). Protected Agriculture (PA) is that activity that aims to minimize the externality problems that occur in crops grown in the open field. This method has the advantage that crops can be produced out of season and 5 times increase production in relation to open field production, since they have a system that can adapt to the required needs. Water consumption in agriculture represents close to 87% and the global demand for this resource is increasing more and more (FAO, 2003, it is essential that the greenhouse has an irrigation system since the cultivation of plants takes everything a process that needs to be constantly monitored for the proper growth of the plants. The most used technique is drip that supplies water and nutrients to the plant.

This work describes the operation of the data acquisition module, which is supported by the desktop application and is integrated into the web system. For the purposes of this article, mention is made of the desktop application only since it will be addressed in another future work.

This article describes the data acquisition module, the development methodology based on Prototypes, the results, acknowledgments, conclusions and bibliographic references.

Data acquisition module

It is a collection of software and hardware that allows measuring or controlling the physical characteristics of something in the real world such as voltage, temperature, sound level, among others.

For the correctness use of the data acquisition module, the desktop application, the database, the web system and the collection of soil moisture data, data that when obtained serve for decision making by the farmer. Data acquisition refers to the part in charge of taking information from sensors.

Devices for data acquisition module

The following devices were used to design the circuit:

1. LM-393 (Soil Moisture Sensor)
2. Arduino Uno 3
3. Breadboard or Breadboard
4. Relay 5v to 10v
5. Solenoid valve

Sensor

They are electronic devices with which we can interact with the environment, they provide information on certain variables that surround us, in order to process them and generate orders or activate a process. The variables depend on the type of sensor and can be: temperature, distance, acceleration, humidity, pressure, ph. They are used in different areas such as agriculture, mobile telephony, medicine, automotive or in industrial automation processes (Serna at al. 2010). The LM-393 Sensor is a soil humidity sensor. Its function is to measure an electrical signal that calculates the amount of water that is currently in the soil, or in other words, it allows determining the volume of water stored in the soil. the soil after irrigation, so knowing the water consumption by the crop will largely determine the efficiency of the irrigation. see figure 1.

Figure 1 LM393 soil moisture sensor

Arduino

It is considered a development platform based on a free hardware electronic board that incorporates a re-programmable microcontroller and a series of female pins.

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These allow connections to be established between the microcontroller and the different sensors and actuators in a very simple way. One of the most important features of this platform is the possibility of building the board at home since its components can be found in electronic component stores and using a breadboard or a printed circuit that is easy to produce, at low cost. The C++ programming language was used to program the Arduino, see Figure 2.

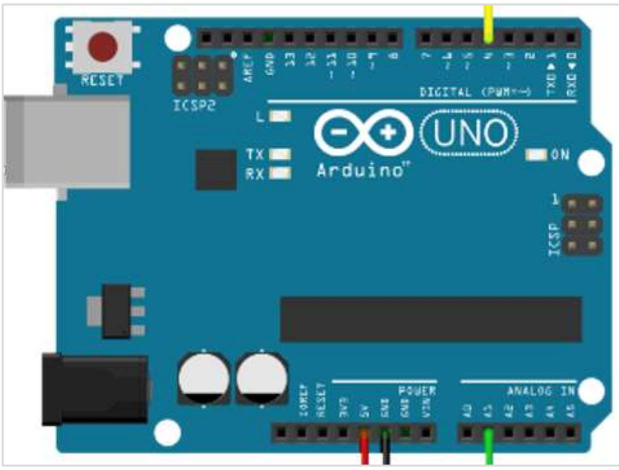

Figure 2 Arduino one

Breadboard

It is a breadboard that allows electronic elements to be interconnected without the need to be weld. Which makes it easier to assemble electronic circuits or systems. It is normally used for testing electronic circuits. If the test is successful, the circuit is designed on a copper plate and weld to avoid the risk of any components becoming disconnected. If the test is not satisfactory, it is easy to change connections and replace components. The breadboard has three easy to identify parts: the center channel, the tracks, and the buses as shown in figure 3.

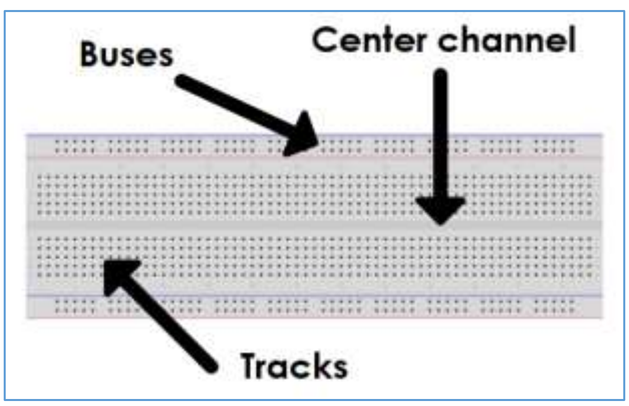

Figure 3 Parts of the Protoboard

Development Methodology

For the development and operation of the two modules, the Prototype model was used. This model aims to directly involve the client in the construction of the required software, and serves as a mechanism to identify and define the software requirements, through an iterative process, (Pressman, 2010, p. 37).

Figure 4 shows the Phases: communication, rapid plan, rapid modeling and design, prototype construction, deployment, delivery and feedback.

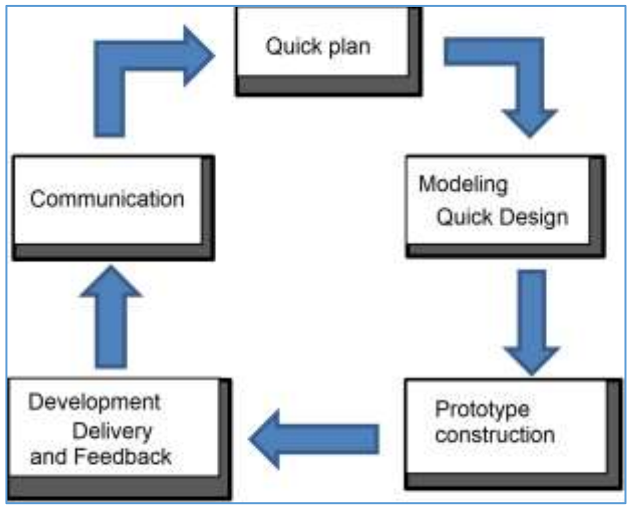

Figure 4 Phases of the model in prototypes
Source: (Pressman, 2010, p. 37)

Description of the phases:

– Communication Phase, in this first phase it is required to obtain soil and moisture data quickly and efficiently. For this, soil moisture sensors will be used, taking into account the requirements for the design of the circuit.

– The Quick Plan Phase. In this phase, the use case technique was used to model the requirements of the data acquisition module. Figure 5 shows a use case for obtaining data from the LM-393 soil sensor.

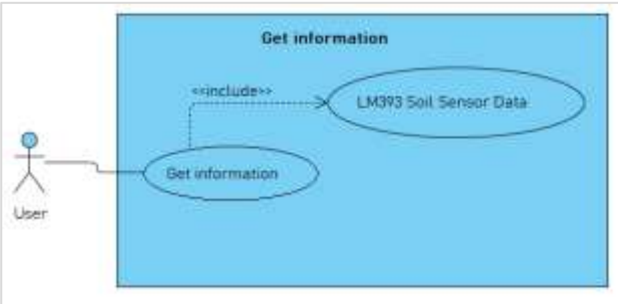

Figure 5 Sensor data collection use case

Table 1, shows a use case to identify the farmer's requirements.

No.	2
Use Case:	LM393 Soil Sensor Data
Actor:	User
Description:	The LabVIEW program displays the values obtained by the sensor on the screen.
Validation	Validation The sensor must be connected

Table 1 Soil moisture sensor use case

– In the Quick Design Modeling phase, the sequence diagrams of the circuit diagram were designed, as an example shown in Figure 6.

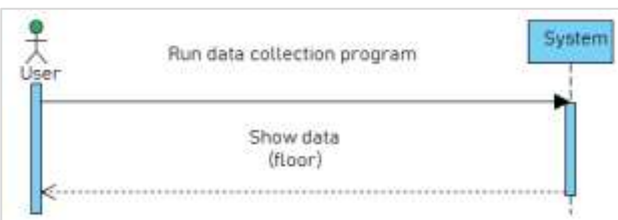

Figure 6 Sequence diagram: data collection

In this phase, the circuit diagram was also designed to obtain data through the LM 393 sensor to obtain soil humidity values, see figure 7.

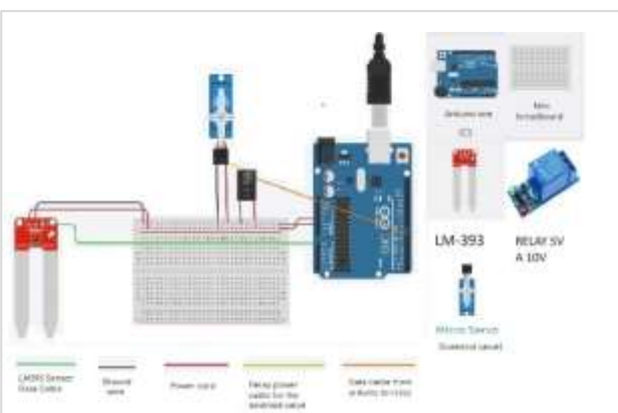

Figure 7 Circuit diagram

– Prototype Construction Phase, the circuit is built, as shown in figure 8.

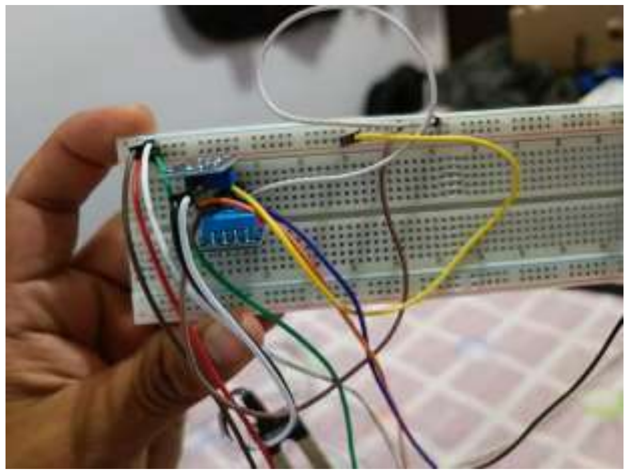

Figure 8 Circuit Construction

Deployment, delivery and feedback phase

Figure 9 shows the final design of the data acquisition module. In this phase, a mock-up was built where the tests of the web system, the desktop application and the operation of the data acquisition module were carried out since due to restrictions Due to the pandemic, at that time they could not be carried out physically in the Greenhouse.

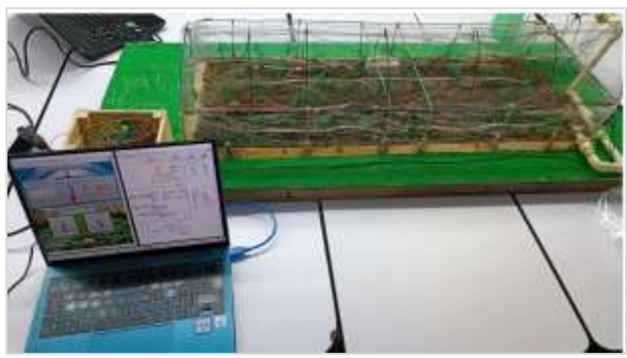

Figure 9 Final design of the data acquisition module

Results

Below are the results obtained from the Data Acquisition module using the web system with the help of the desktop application.

To start, the user must log in to the system with the username and password. See Figure 10.

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Figure 10 System Access Screen

Main screen of the web system

Figure 11 shows the main view of the web system, the options menu, the current system data obtained from the data acquisition module with the values of temperature, humidity and soil moisture, as well as the Water button.

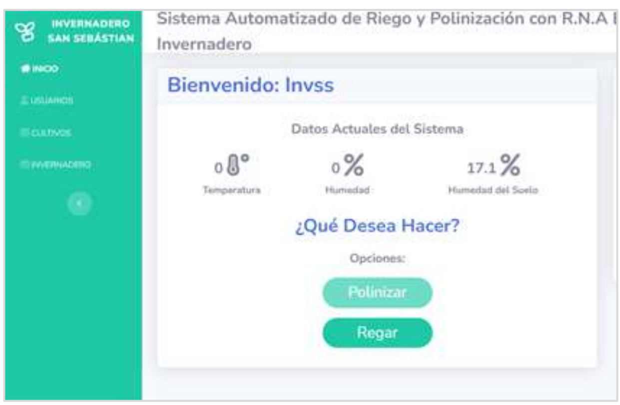

Figure 11 System Access Screen

One of the main functions of the web system is irrigation, and this is where the data acquisition module takes the values sent by the soil moisture sensor to automatically start irrigation.

The process is the following:

– The soil moisture sensor sends the signal to the arduino

– The Arduino is directly linked to LabVIEW in the desktop application part which makes insertions to the database every 5 minutes, indicating the percentage of soil moisture, once it marks that the humidity, if it is very dry a message is sent to the user (user notification) to activate irrigation

– Irrigation is activated from the website once the Irrigation button is clicked, an Update is performed on the status of the insertion that was made in the previous step.

– This change is detected by LABVIEW and sends data to the Arduino.

– The Arduino detects that a signal was sent to digital port 7 of the output and sends a signal to the Relay which changes its state from closed to open and opens the solenoid valve for a certain time until the soil humidity sensor detects that it is already has the correct humidity, see figure 12.

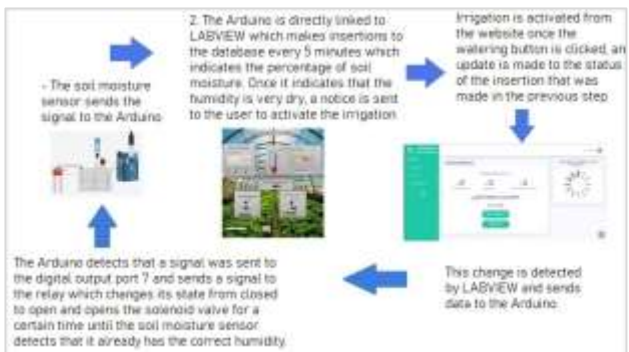

Figure 12 Values sent by the soil moisture sensor

Once automatic irrigation has started, figure 13 shows the irrigation process and the humidity of the beds.

Figure 13 Automatic closing process

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To the Tecnológico Nacional de México/Instituto Tecnológico de Oaxaca for the facilities and spaces for the development of this research work.

The collaboration and dedication of the authors of the article who participated responsibly in the research until the results presented were achieved are appreciated; The objective of this research is to be able to disseminate the findings to the academic community and the general public about the work carried out at the Institution.

Conclusions

Protected agriculture is the most used technique that, due to its characteristics, can produce various types of crops under a greenhouse. Monitoring crops during their development cycle is of utmost importance since when it is carried out, it anticipates the appearance of possible problems that may occur according to Alvarado (2015).

The advantages of greenhouses having an automatic drip irrigation system are greater productivity, the guarantee of producing a quality product, detecting and controlling pests and diseases in time, and the opportunity to market the products. quality on the market

Finally, I can say that the communication capacity of smart devices with electronic circuits opens a range of possibilities for future work. This project will continue with a view to strengthening alternative low-cost solutions that can be acquired by greenhouses located in communities. small and remote areas that help improve the social problems that society faces today.

References

Castañeda, M., Rodrigo, V., Ramos, E., Peniche, V. and Rebeca del R. 2007. Analysis and simulation of the physical model of a greenhouse under climatic conditions in the central region of Mexico. Agroscience 3: 317-335.

Demin, P. (2014). Contributions to improve the management of irrigation systems Irrigation methods: fundamentals, uses and adaptations, 1, 24.

Fernández, S.C. 2012. Analysis and Evaluation of risks of natural incidents in the intensive agricultural production system of Almería. (Doctoral thesis) University of Almería. Spain.

Fernández Fernández, M. M., Aguilar Pérez, M. I., Carrique Pérez, J. R., Tortosa Domingo, J., García García, C., López Rodríguez, M., and Pérez Morales, J. M. (2014). Soil and environment in greenhouses. Seville: Ministry of Agriculture, Fisheries and Rural Development

Flórez Fernández, H., et al. (2021). Web applications with PHP. Bogota Colombia. U Editions.

Gary W. Hansen, J. V. (2014). Database Design and Administration. Mexico: Prentice Hall.

GitHub (2017). Database fundamentals. Taken from https://github.com/yomar-dev/fundamentos-bd

Hernandez (2015). The importance of databases in companies. https://germenstartup.wordpress.com/2015/01/29/la-importancia-de-las-bases-de-datos-bbdd-en-las-empresas/

López Herrera, P. (2016). Comparison of the performance of MySQL and PostgreSQL Database Management Systems.

Agr. Eng. MSc. Miserendino, E., and Ing. Agr. Astorquizaga, R. (2014). Greenhouses: Basic aspects of structure, construction and environmental conditions. Buenos Aires: INTA.

Juganaru Mathieu, M. (2014). Introduction to programming. Mexico: Homeland.

Moreno Reséndez, Alejandro; Aguilar Durón, Juanita; Luévano González, Armando. Characteristics of protected agriculture and its environment in Mexico

MySQL. (2020). MySQL Documentation. https://dev.mysql.com/doc/

Nevado, M. (2010). Introduction to Relational Databases. Spain: Vision Books

Pressman S., R. (2010). Software Engineering. McGraw Hill.

Ramos, M. J., Ramos, A., & Montero, F. (2006). Database managers. Madrid: McGraw Hill.

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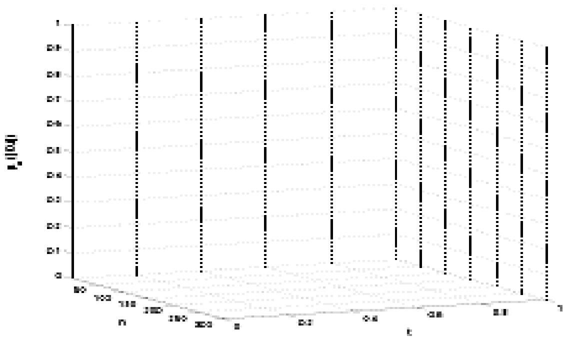

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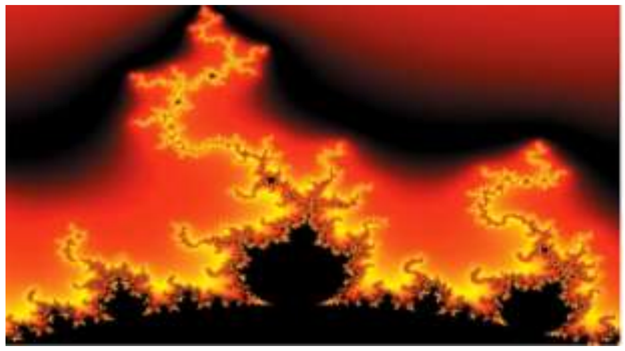

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