Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Eléctrica

Tesis

# Sustainable Solution: Solar -Powered Electric Induction Cookers for Rural Areas Without Additional Costs

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Para optar el Título Profesional de
Ingeniero Electricista

Huancayo, 2024

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**Título:**
Solución sostenible: Cocinas eléctricas de inducción alimentadas por energía solar para zonas rurales sin costes adicionales

**URL / DOI:**
10.1109/IEEECONF58110.2023.10520534

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# Sustainable Solution: Solar -Powered Electric Induction Cookers for Rural Areas without Additional Costs

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***Abstract*—With this project has been designed an induction electric stove powered by a photovoltaic storage system, which will make it self-sustainable without generating additional costsin the billing of electricity consumption. This solution is aimed at families in rural areas who still continue to use traditional fuels (wood, gasoline, straw, etc.) for the preparation of their food, which over time generate serious problems in people's health due to the CO2 that is produced. The project involves the implementation of a system of photovoltaic cells at the top of the houses of which would have connections to a set of batteries that would serve as the source to the operation of an electrical induction kitchen inside the house. The project demonstrates the results focused on the generation of energy capable of supplying the operation of the kitchen and for this the Helioscope simulator was used to obtain results in the photovoltaic system. These results will be used to evaluate a government project to help people stop using traditional CO2-producing and health- harmful kitchens, so implementing self-sustainable, renewable- energy induction electric kitches is the most appropriate solution.**

***Keywords— Photovoltaic Storage, Self-Sustainable Electric Kitchen, Renewable Energy.***

## I. Introduction

Today, in rural areas, traditional cuisines also known as "bicharras" are still being used, which are very damaging to the quality of life and health of people who maintain their use [1]. While it is true, the use of these kitchens may traditionally remain firm, but we are ignoring the great damage it causes to users. The gases that are emitted from this type of cooking are highly harmful and are proven to generate acute respiratory diseases that could end up killing many people in the long run [2]

The present project was carried out with the aim of mitigating respiratory diseases produced by the use of solid fuels and in the same way seek to offer a better quality of life to the inhabitants of rural areas as well as in the city itself of Huancayo, where the traditional cooking of clay/adobe or "bicharras" continues to beined due to the lack of resources necessary to be able to maintain month-to-month the payment of a gas balloon to cook their food [3-4].

Similarly, there has been a great inclination in these sectors for the continued use of traditional cuisines without considering the negative effects they have on health over time, and it is evident in neighborhoods such as those of Ocopilla that there are families that have been affected by this pandemic in many respects which resulted in the reduction of the quality of life they had, even going from using a gas balloon to just a kitchen that runs with wood without generating extra costs[5-6].

Like these families living in a city, there are also villagers who are exposed to this type of disease due to the use of traditional cuisines in communities adjacent to the city of Huancayo where the presence of poverty increases a little more and that somehow has no other way out or option than to vulnerate their health with respiratory diseases in exchange for not having to spend on other means that demand monthly money for lack of resources, since, the usage of the aforementioned fuels generates an emission of highly toxic, polluting and harmful gases for the lungs and health in general.

In our country the figure is not encouraging at all because according to a survey conducted by the INEI (2017) about 5 million 700 thousand people still use the already mentioned fuels for the preparation of their daily food by means of traditional cuisines.

To solve the problem identified in areas where traditional kitchens are still being used, it is proposed to develop the design of an induction stove powered by photovoltaic cells that reduces the risk of acquiring respiratory diseases in families that still maintain the use of fossil fuels used in the traditional cuisines, the same emitting polluting gases that harm in a minimal way both the quality of life and the health of users.

## II. Objectives

### A. *General objectives*

Reduce the high rate of people with diseases caused by the use of solid fuels for the operation of their traditional cooking used daily in some sectors of Huancayo as well as in the surrounding rural areas.

## B. Specific objective

Design an electric fireplace or kitchen that is powered by renewable sources such as photovoltaic cells that allow changing the use of conventional kitchens that make use of solid fuels such as wood and straw, causing respiratory diseases in people in the long term.

## C. Social justification

This project is necessary for those sectors that still continue to use conventional methods to cook their daily food, causing damage to their health over time, which will be greatly reduced by replacing them with electric kitchens that make use of photovoltaic cells for their operation [7-8].

## D. Theoretical justification

This project seeks to implement a new design of electric kitchens that is accessible to people who still use timber or straw as solid fuels and harm their health [9]. Electric kitchens have been present for a long time, however, the project is focused on looking for a way to make them self-sustainable by means of renewable sources with the use of photoelectric cells that manage to supply energy the kitchen or stove for its operation, in addition to having a battery that stores during the day and so can give the device operation in case it is at night [10].

## E. Econmic justification

This project also includes the economy of the people, as it is well known that people who continue to use traditional kitchens have low economic resources, which do not allow them to buy or maintain a gas kitchen, however, this project seeks to avoid generating additional costs continuously to make use of an electric kitchen, since it is powered by solar energy [11].

# III. Develompment

## A. Inclination and orientation

Many PV modules are tilted to collect more solar radiation. The optimum amount of energy is collected when the module is tilted the same angle as that of the latitude [12]. However, it should be noted that the minimum tilt angle should be at least 15° to ensure that rainwater drains easily, washing away dust at the same time. At higher latitudes (>30° North or South), the modules are sometimes tilted more above the latitude angle to try to even out seasonal fluctuations [13].

## B. Shadows and reflections

Therefore, shadows should be avoided as much as possible. But what exactly is the influence of a small tree to the east of a PV module, of a 100-meter-high building, or of a wall behind the modules?

First, one should consider that shadow can create problems with hot spots. Suppose of a series of cells, one is in the shadow and the others are in the sun. The cells that are in the sun produce electric current that must also run through the cell that is in the shadow, which is acting as a great resistance. This cell can get very hot by that effect.

Secondly, any shadow has its negative influence on the performance of a solar system. So even a small tree (in addition to the fact that small trees turn into large trees) can have a substantial influence on yield if it is right in the wrong place [14]. As a rule, the influence of surrounding objects can be neglected when the angle of the line from the photovoltaic module to the top of the object with the horizontal is less than 20° [15], as shown in Fig. 1.

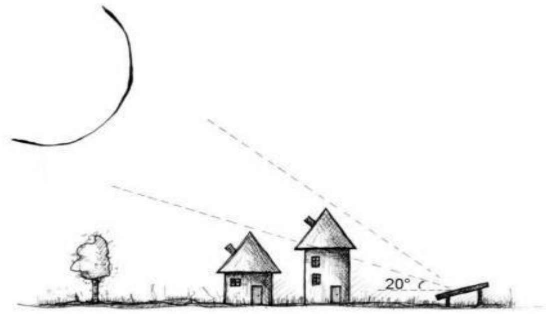


Fig. 1. Shadows

## C. Mathematical calculations

- In the first instance, we delimit the voltage of a 220V input with which the electric cooker will work.
- We calculate the power with the formula, having as a value, we have current (I) of 20.9 A, obtaining a result of the Power (P) of 4598W (4.6KW), equation (1).

$$P = V*I \tag{1}$$

- In Huancayo the month of June is the most critical month with a solar irradiation of 5.16 kwh/m2/day and the peak solar hour is 5 hours per day with an inclination of 15° and an average annual temperature of 12°C, equation (2).

$$\text{Real daily energy} = Erd = 65.57\ kwh/ddda \tag{2}$$

Looking at TABLE I, it can be assessed that induction electric kitchens alone has a greater development compared to the GLP kitchen, knowing that the induction kitchen will have an isolated source that will serve as a supply for its operation without generating additional costs in the monthly billing for the electric service.

TABLE I. IMPLEMENTATION COMPONENTS ON THE ARFUINO ONE

| Gas Kitchen GLP | | Induction electric kitchen |
|---|---|---|
| Efficiency | 40% | 80% |
| Defined Unit | GLP cylinder 15kg | 1kWh |
| Energy per unit | 722.223 kJ | 3600 kJ |
| Energy considering the efficiency factor | 288889.2 kJ | 3.024 kJ |
| Boil unit 10 | 0.0109 Cylinder | 1.0384 kWh liters of water |

## D. Proposal of solution

In order to solve the problem identified in areas where traditional kitchens are still being used, it is proposed to develop the design of an induction stove powered by photovoltaic cells that reduces the risk of acquiring respiratory diseases in families that still maintain the use of fossil fuels used in traditional cuisines, the same that emit polluting gases that harm in a minimal way both the quality of life and the health of users. In order to be able to solve the problem, the solution proposal is presented, which is the design of an isolated solar photovoltaic system for the subsequent supply of the efficient electric greenhouse by means of PV cells.

*1) Design of a Photovoltaic Storage System*

It is proposed to design a photovoltaic storage system that can generate energy using photovalent cells, located on the top of the houses where the installations are carried out, and to store this energy in batteries that have enough voltage for the operation of an induction kitchen inside the house, as shown in Fig.2.

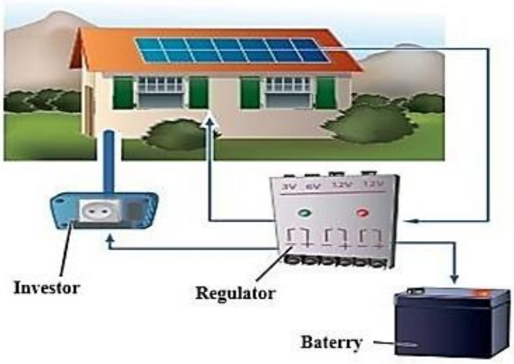


Fig. 2. Proposal Design

For the design of the electric induction kitchen we will have to divide it into 3 parts, which would become subsystems, being the following; a high-frequency generating source, the cooking system and the control system. The operation of the induction kitchen begins at the source that feeds the power part, among which are the rectification and inversion circuits, this to generate voltage and high-frequency currents that will circulate through a working coil. The electrical current that runs through the coil generates an intense electromagnetic field, which through the ferromagnetic material of the base of the beam produces in it high energy that is transformed into heat. The control system performs the control operations relevant to the state of the sensors and the user interface, as shown in Fig. 3.

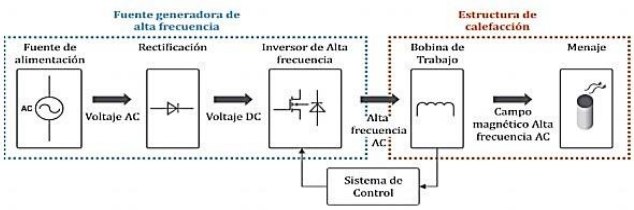


Fig. 3. Control system

## IV. Design

### *A. Mechanical design*

The location of the photovoltaic modules with respect to the angle of inclination to the north having as an optimal angle of 0, a 0.5 meters the part. Fig. 4, shows the roof where the photovoltaic system is installed, there is a total of 23.68 m2 available of which 17.58 m2 will be occupied.

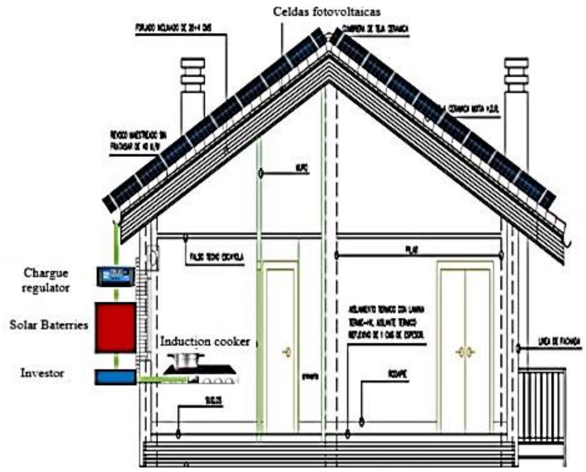


Fig. 4. Mechanical design

### *B. Electric design*

For the electrical design, the spaces of the home were taken into account, as shown in Fig. 5.

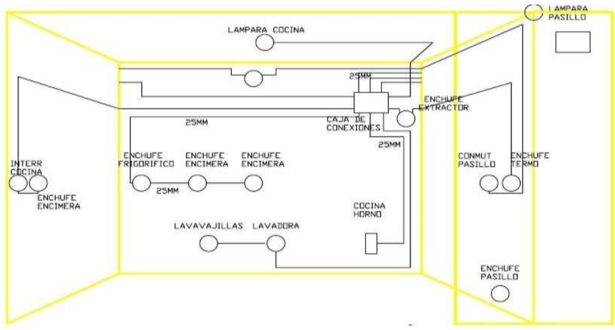


Fig. 5. Electric design

To carry out the design of the electric stove powered by a photovoltaic storage system you will need the following components with their respective characteristics, is shown in TABLE II.

TABLE II. COMPONENTS AND FEATURES

| Materials | Description |
|---|---|
| Photovoltaic module | 18 PV modules will be used for the isolated PV system, where 3 modules are connected in series and 3 in parallel in each part of the roof. |
| Regular or load controller | You will need 2 charging controllers of the brand Victron Energy MPPT (Maximum Power Point), which will be connected in parallel to reach the required power. |
| Batteries or accumulators | Seriously connected deep discharge batteries of the Ultracell brand with a capacity of 1120 Ah will be used. |
| Triphase Inverter | Inverters from the Fronius brand will be used, presenting the latest in technology |
| Drivers | Different driver sections will be used for each section. |
| Metal Structures | Metal structures will be used for the installation of the photovoltaic modules. |
| Rectifer | This will be a component belonging to the electrical induction kitchen and that will be connected to the AC power supply. |

| | |
|---|---|
| High Frequency Inverter | It is a component of the electric kitchen and will be part of the high frequency generating source. |
| Coil | Will serve for the generation of high-frequency AC magnetic field. |
| Control system | Will serve for user interaction with induction electric kitchen. |

## V. Results

After the analysis and simulation of the induction kitchen powered by a photovoltaic system, the same that we developed and compared with a generic inductive kitchen, the following results were obtained, which are not very different from each other, as detailed in Fig. 6 and Fig. 7.

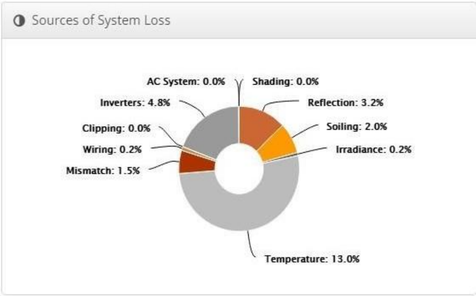


Fig. 6. Analysis 1

| Placa | Aislante | Cubierta | Ajuste potencia standard/diferencia de temperatura (W/ °C) | Valor de la potencia standard cuando ΔT = 50 °C (W) | Tiempo en el que se alcanza los 80 °C en el liquido de prueba (min.) |
|---|---|---|---|---|---|
| Hierro | Lana de vidrio | simple | -0,8459 | 6,85 | 96 |
| Aluminio | Papel compactado | doble | -0,4755 | 19,96 | 132 |
| Hierro | Papel compactado | simple | -0,9722 | 7,46 | 76 |
| Aluminio | Lana de vidrio | doble | -0,5064 | 19,43 | 156 |
| Hierro | Lana de vidrio | doble | -0,7228 | 13,00 | 110 |
| Aluminio | Papel compactado | simple | -0,8320 | 18,57 | 186 |
| Hierro | Papel compactado | doble | -0,7594 | 9,40 | 128 |
| Aluminio | Lana de vidrio | simple | -0,8880 | 16,05 | 144 |

Fig. 7. Analysis 2

### *A. Kitchen efficiency*

It is chosen to make use of the kitchen used in the simulation since while generic and classic induction kitchens offer greater safety and confidence towards people; we must not forget that the results obtained do not vary much and are of little relevance in order to be able to offer that same safety and above all to provide an efficient cooking of the food in the sectors for which our project is being prepared. The following is detailed in a chart analysis the variations that can be mentioned are tiny, of both kitchens both the generic induction and the developed in the present project, as shown in Fig. 8.

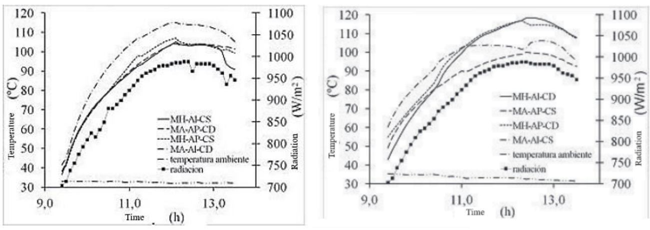


Fig. 8. Analysis of graphs

Next, in the proposed model there is a linear relationship between the temperature jump and the energy received by the kitchen, therefore, linear adjustments are made to find the ratio between the optical efficiency of the kitchen and thermal losses, is shown in Fig. 9.

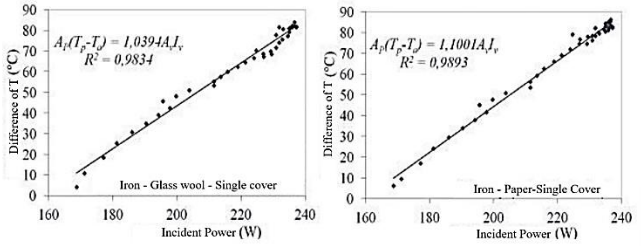


Fig. 9. Power analysis

As the result of the economic status for the construction of the project is shown in TABLE III.

TABLE III. Economic status

| Description | Quantity | Price unit | Price Total |
|---|---|---|---|
| Jinko Solar photovoltaic module 330W | 1 | S/750.00 | S/ 750.00 |
| Charge controller Schneider Xantrex | 2 | S/3, 186.00 | S/ 6,372.00 |
| Batteries Accumulators | 4 | S/1, 103.77 | S/ 4,415.08 |
| Investor | 2 | S/9, 671.25 | S/19,342.50 |
| Metal structure for modules | 4 | S/1, 000.00 | S/ 4,000.00 |
| Arezi 26" induction cooker | 2 | S/499.90 | S/ 999.80 |
| **Drivers** | | | |
| **INDECO TABLE** | | | |
| Driver AWG/Kcmil 6 | 2 0 m | S/7. 53 | S/ 150.60 |
| Driver AWG/Kcmil 6 | 6 m | S/4. 90 | S/29.40 |
| Driver AWG/Kcmil 8 | 1 0 m | S/7. 53 | S/75.30 |
| **Protection System** | | | |
| Fuse de 100 A 22x58 | 1 | S/96 .76 | S/96.76 |
| Fuse holder 22x58 | 2 | S/59 .42 | S/ 118.84 |
| Fuse of 63 A 22x58 | 1 | S/78 .73 | S/78.73 |
| 2-pole plug-in board | 2 | S/19 .79 | S/39.58 |
| **INSTALIATION** | | | |
| Technical staff | 1 | S/1, 000.00 | S/ 1,000.00 |
| Photovoltaic module Jinko Solar 330W | 1 | S/75.00 | S/ 750.00 |
| Charge controller Schneider Xantrex | 2 | S/3, 186.00 | S/ 6,372.00 |
| Batteries Accumulators | 4 | S/1, 103.77 | S/ 4,415.08 |
| Investor | 2 | S/9, 671.25 | S/19,342.50 |
| Metal structure for modules | 4 | S/1, 000.00 | S/ 4,000.00 |
| **TOTAL PROJECT COST** | | | **S/37,468.59** |

## VI. Discussion

Liquefied petroleum gas (GLP) has become one of the main fuels for families in Peru. According to information from the Ministry of Energy and Mines, during the years 2000 and 2010 demand has tripled compared to previous years. Currently, the change of kitchen is optional, despite the fact that liquefied oil gas (LPG) for kitchens is subsidized by the State, so the calculations are carried out to make an economic analysis in this way to see if it is convenient for the consumer to implement this type of induction kitches and if the electrical system will be affected so that the relevant changes are made.

## VII. Conclusion

The results were obtained from the design proposed for the operation of an electric kitchen powered by photovoltaic cells for its application in families with low resources that continue to make use of traditional fuels harmful to their health.

In order to be able to obtain changes in the number of people who continue to use traditional fuels such as wood or wood, more conventional methods such as the acquisition of GLP-powered kitchens, as well as electric greenhouses connected to the grid, were evaluated, however, it should be borne in mind the cost that each would entail, because a monthly payment for electricity consumption or the purchase of the GLP balloons would be being made.

The project noted that the electric kitchen system powered by photovoltaic cells would be the most viable option for more families to use this type of kitchens, because the investment cost would only be made once for the implementation of the full system.

The lifetime of a photovoltaic system is given to 25 years, but with monitoring and respective maintenance the life time reaches 30 years, such maintenance are 2 to 3 times a year, but it takes 20 years of useful life referring to what is stipulated by osinergmin, with respect to the panels the only maintenance that should be given is the cleaning of the dust that deteriorate and decrease its efficiency if it is not given respective service and that can be done by the same user.

In case the life of an electric kitchen is taken as an average of 13 years, considering that it will be an electrical artifact that will be present inside the house without running for risk of damage compared to the solar panel, so it also does not require much maintenance by the user that involve additional costs.

As you can see in the results by implementing the photovoltaic systems not only benefits in the economic but also reduced to the production of CO2 which would help with regard to the environmental pollution that is being caused today, by counting on the PV system you would be reducing the CO2 production, by the lifetime of this system would be decreasing a total of 140.8 tons of CO2.

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