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Design of a System Generating Electricity by Means of a Solar Heater for a House

Aguirre Contreras Javier[1], Aguirre Muñoz Javier[2], Arzate Perez Miguel[3]

[1]*Autonomous Metropolitan University, Division of Science and Arts for Desing CYAD*

[2]*General Directorate of Technological Education CETis No.29*

[3]*Autonomous Metropolitan University, Department of the Environment*

Abstract

This article discloses a domestic system that allows greater energy efficiency in a home located in Mexico City, which facilitates its contribution to a green urbanism by installing it in the buildings of the City.

The system was designed and built using a solar heater (CalGen) that was installed in a house with four people. Aluminum cans were used in the CalGen as vacuum tubes, the water heated in the cans was used in the shower, in addition the CalGen structure were placed photoelectric cells, which were controlled by an Arduino Uno, in order to increase the efficiency of the solar radiation. The water heated by the CalGen helps to reduce the emissions 3.6 kiolograms (kg) of carbon dioxide (CO_2) per day, since before installing the system the house used principally liquefied petroleum gas (LPG) to heat the water. The water circulating inside the aluminum cans is heated by solar radiation, leaving the water at an average temperature of 37.71°C. The eight photoelectric cells generate 240 watts per day (W/day). The electricity generated by the photoelectric cells is stored in rechargeable batteries. The methodology of the tests and construction of CalGen is shown, as well as the changes that were made from the tests. There is also a cost-benefit study that CalGen had in housing.

It should promote the design of cities where the environment of the quality of life of human beings is healthier and more sustainable, given that the space of cities is being increasingly demanded. Green buildings should not be an optional trend, but a fundamental requirement, taking advantage of and adapting existing spaces more effectively.

Nomenclature

Bout= Output capacity required for the battery bank in A-h.

Ecrit= Daily critical consumption of energy during the critical design month (W/day).

ta= time of autonomy in days.

Vsdc= Nominal voltage of the Direct Current System (D.C).

Q= heat transfer.

T1= Water temperature.

Ta= Air temperature (18°C).

h= Convective air coefficient that equals 2.3.

k= Thermal conductivity of aluminum equivalent to 209 W/m°K

D_1= Inside diameter of cans: 6.41 centimeters (cm) .

D_2= External diameter of cans: 6.50 cnetimeters (cm).

Keywords

energy efficiency; green urbanism; solar heater; photoelectric cells; ARDUINO one; solar energy; liquefied petroleum gas.

1. Introduction

Mexico occupies the first place in the consumption of LPG worldwide, representing in 2012 40% of the total production of Latin America and a per capita volume of 74 kg, being its main destination the residential sector, to be used in cooking and water heating (SENER, 2009). Due to the above mentioned it is necessary to reduce the combustion of LPG, to network the CO_2 emissions, using solar energy as the main source of energy supply, making the development of CalGen with low cost and easy to install. The CalGen helps reduce the consumption of 438 kg of LPG per year.

The installed capacity for electric power generation in Mexico during 2016 was 71.19% and 28.81% from fossil fuels (natural gas, coal and diesel) and clean technologies respectively. In 2016, 64,868 GWh were generated with clean technology instead in 2015 was 62,952 GWh that means almost a 3% annual increase in the use of clean technologies (SENER, 2017).

The consumption of energy has increased due to the increase in number and intensity of use of electronic devices known as gadgets (smartphones, tablets, among others) for example a smartphone brand iPhone 5 consumes 9.5 Wh when charged 100% in one hour with 50 minutes, considering its daily use and a single load, its annual consumption is 45.38 kWh per year (Apple, 2017). The CalGen system would help to reduce the electricity consumption of smartphones, generated mainly by the combustion of fossil fuels.

The proposed objectives of CalGen are the design of an electronic system that allows to increase the efficiency and intensity of electric power generation by using a device known as Arduino Uno in the photoelectric ceilings, which allows its movement according to the displacement of the sun on the horizont. The CalGen will generate 24 Wh, so in ten hours of sunlight approximately 240 W/day would be produced, allowing the recharging of two smartphones brand iPhone 5 at the same time of different brands and models, in addition to providing hot water so that all four people can bathe at any time of the day.

The photoelectric cells are composed of cells sensitive to the wavelengths of the solar spectrum, which convert sunlight into electricity. Photoelectric cells are made of semiconductor materials, mainly silicon. The cells produces a direct current (DC), has low cost maintenance and high durability. For the good operation of it requires high solar radiation, although it can also generate electricity with a high presence of cloudiness (SEMARNAT, 2015).

2. Theoretical framework

For more than 4500 million years, the climate of the planet has tended toward a natural climatic stabilization, which has allowed the appearance and extinction of numerous plant and animal species, according to the biochemical and climatological characteristics of each geological age, which they have happened on the planet. Given the evolution of the Hominid species up to the current Homo sapiens sapiens, the alteration of the global climatic stability caused by the previous species is a proven reality; example of the above is climate change (CC) (UNAM, 2015).
This has directly affected the search for environmentally sustainable energy alternatives, such as clean energies, that mitigate the adverse effects of CC. The transition stage in which today's society finds itself, driven by the intensive and excessive use of fossil fuels (conventional and shale types) (SENER, 2012) and the one in the process of formation, is known as the post-carbon society. The latter uses a sustainable energy model, both economic and environmental, with energy pillars how wind and solar energy to reduce the use of all types of fossil fuels (SEMARNAT, 2008). It is estimated that in the period 2008-2035 the greatest consumption of electricity generated

from renewable sources will be higher at least 20%, especially in the emerging countries called BRICS (Brazil, Russia, India, China and South Africa), while in the rest of the developed countries, expect a more moderate increase (Centro Mario Molina, 2016). A possible alternative to the previous problem is that higher education and postgraduate research centers in developing countries would design and implement projects and prototypes that represent viable, economic and environmental alternatives that must meet the following characteristics:

• Low manufacturing, use and maintenance cost: In economic and social terms, jobs are created, with the development of small and medium enterprises that make possible the use of all the infrastructure offered by the MIPYME projects (public funds for micro, small and medium enterprises) in the production of heaters solar with the proposed characteristics (SE, 2012).

• Environmentally sustainable: Indirect impact on human health, reducing CO2 emissions, due to the decrease in the consumption of LPG used by gas heaters, in addition to reduce the consumption of electricity generated by fossil fuels, this makes it possible to mitigate the effects of CC by taking advantage of solar energy (SEMARNAT, 2006).

This article has as its main purpose the design of a solar heater made with recyclable material such as aluminum cans, so that it generates electricity by means of photoelectric cells, which utilized by a device called Arduino Uno which allows the displacement of the cells according to the movement of the sun on the horizon. The designed system can be used for the following purposes:

• Heat water for the house shower.

• Generate electricity through solar energy.

The development of CalGen will reduce the emission of greenhouse gases (GHG) generated by the consumption of electricity produced and distributed by the Federal Electricity Commission (FEC) or by the Private Initiative (PI) in the area where CalGen will be installed. In the period from 1990 to 2010, the energy sector contributed 66% of the national emission of GHG, while the sectors of solid waste, change of land use and industrial processes contributed with 14.56, 12.24 and 7.15% respectively (UNAM, 2015).The use of solar energy in the country is growing rapidly, due to the fact costs of the photoelectric cell processing material has decreased rapidly.

Currently 95% of solar heaters that are sold nation wide, use vacuum glass tubes, which prevent the loss of conductive and convective heat. In this type of solar heaters, the cost of vacuum tubes represents 70% of their total cost (Thermosol, 2015). Therefore, it is necessary to propose sustainable alternatives that are economically and environmentally sustainable.

3. Research methodology

The emissions of CO2 in the Mexican Republic are a growing problem and the following facts can be mentioned: Mexico issued 3.79 metric tons of CO2 per inhabitant in 2010, ranking 14th in emissions of the same gas globally (Banco Mundial, 2010), what is necessary to reduce both LP gas combustion and electric power consumption, to reduce CO2 emissions, using solar energy as the main source of energy supply, making the development of CalGen low cost and easy to install , will allow the use of solar energy both to heat water and to produce electricity.

The City of Mexico receives on average 5 kWh/m2 of average daily global radiation, this implies that in 1 m2 and with 50% efficiency solar equipment, it receives daily the equivalent of the energy contained in 1.3 m3 of LPG (Harper 2012), however the use of solar heaters of residential type, has had the intensive and extensive use expected by the National Commission for the efficient use of Energy in its work program 2010-2030, due mainly due to its high initial cost, distrust of the potentially consuming public, as well as the expenses inherent to installation, maintenance and repair (Conuee, 2007). In a commercial production CalGen is scalable in size and power, producing greater heat transfer in the aluminum-water system to increase the energy efficiency that makes it possible to have more hot water volume in the shortest possible time, as well as a higher efficient production of electrical energy that can be stored in two rechargeable batteries, which supply electric current to low-consumption electronic devices. Undoubtedly, this prototype is economically and environmentally sustainable, but the provision of solar energy is neither constant nor fluid, so it is necessary to connect it to a gas heater as well as to the electric network of the

FEC.
Hypothesis:
• The use of CalGen in a house or apartment in Mexico City, will allow the heat transfer in the Aluminum-Water system, favoring diminution in consumption and emission of 0.3 and 0.9 kg of LPG and CO2 respectively, in each daily shower/person (INECC, 2009), besides that it will make possible the domestic production of electric energy of 48 Volts (V). It is proposed to place the prototype on the roof of the house avoiding the average emission of 438 kg of CO2 per year.
Overall objective:
• The use of CalGen, will maximize the use of solar radiation by potentiating the amount of heat transferred in the aluminum-water system and the domestic production of electrical energy by storing in two rechargeable batteries, reducing in both cases the minimum time for both replacement of the volume of hot water to charge the batteries with the electricity produced, achieving a reduction in combustion and emission of LPG and CO2 respectively.
Specific objectives:
• To determine the interior temperatures of the air contained in the sealed drawer with a polycarbonate plate, as well as the outlet temperatures of the water contained in the 9x7 columns of aluminum cans.
• To calculate the heat transfer of the aluminum-water system.
• To calculate the savings in LPG consumption when using the proposed technological prototype.
• To determine the kilograms of CO2 not emitted into the atmosphere, by installing the prototype developed in a house or department in the City of Mexico.
• To determine the amount of electrical energy in kW/h that can be produced by eight polycrystalline-type photoelectric cells placed in 2 parallel horizontal lines.
Research on the use of solar energy represents a benefit for urbanism green in both economicall and environmentall. In the following article, the viability of the designed CalGen will be determined, which contributes to improve the quality of life of the man, by describing in detail each of the necessary steps to carry out the construction and placement of the CalGen in a house, located in Mexico City.

3.1. Methodology for the solar heater

A solar heater is a device that captures solar radiation, transforms it into thermal energy and transfers it to water. Its useful life is approximately 20 years (Thermosol, 2015). In addition, by not using fuel to generate heat, solar heaters prevent the emission of GHG (Fig. 1 a, b).

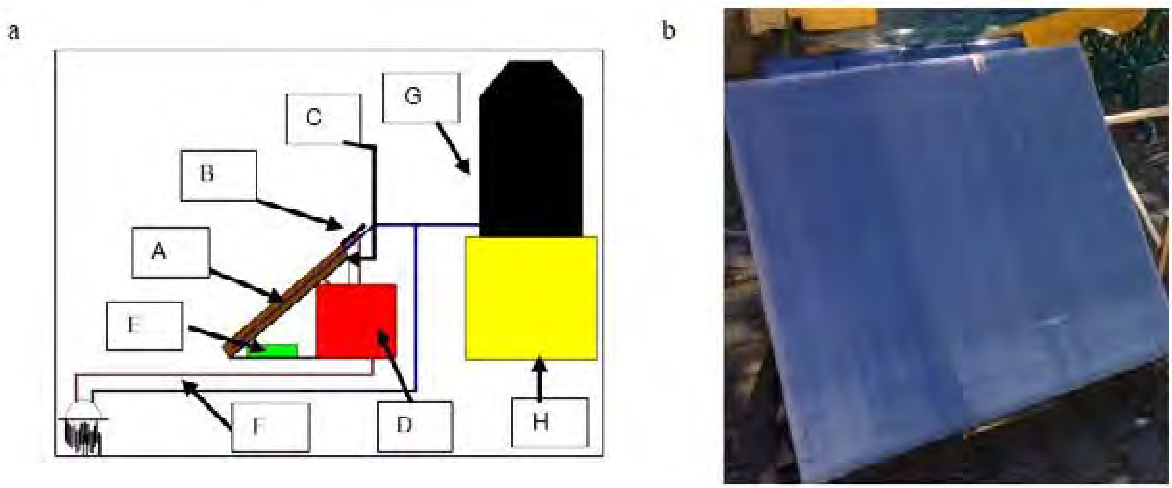

Figure 1. (a)Components of CalGen (b)CalGen built

The components of CalGen are as follows (Table 1).

Table 1. Symbology and name of the part.

Symbology	Name of the part
A	Solar heater
B	Photoelectric cells
C	The adjustable system
D	Hot water tank
E	Charge controller
F	Hot and cold water pipe
G	Water tank
H	Water tank base

The development of CalGen had the following planning:

- To design of the prototype: From June 5 to 10, 2016, the dimensions of the prototype were determined, as well as the potential materials to be used.
- To selection, search and quotation of the best materials. In the month of June of the same year the mentioned procedure was carried out.
- To tests of heat transmission and temperature in aluminum cans without color and painted black from June 5 to 10, 2016, the aforementioned measurement tests were carried out.
- To assembly of the main structure of aluminum cans: With the selected connection and support material, the main structure of the prototype was assembled in June 2016.
- To assembling the Medium Density Fiberfoard (MDF) drawer, Tuboplus connections and Polycarbonate sheet, connected to the insulating tank; installation of solar panels connected to the controller center and this one to the rechargeable batteries. The complete prototype was assembled in the month of June 2016.
- To functionality tests: These were carried out in June 2016. The prototype assembled together with the deposit were placed on a wooden support to verify its optimal functioning.

To develop the CalGen, a plank made of MDF 120 X 80 long and wide with a thickness of 0.6 cm was used, being cut to assemble a protective box of dimensions 97X96X20 cm in length, width and height respectively. The box was painted both internally and externally black matte, the main purpose being the increase in the temperature of the air that is inside the drawer. To facilitate protection, maintenance and thermodynamic efficiency of the prototype, the protective drawer and the smoke colored polycarbonate sheet were sealed with silika gel®. The Tuboplus pipe (NMX-E-226/2 CNCP) used to connect the 9 columns of 7 aluminum cans each (355 milliliters), were 48 sections of 4 cm, sixteen T's, two elbows and two male connectors, all of $\frac{3}{4}$ " , it´s necessary to use the thermofusor to seal each T´s with three sections of 4 cm, in order to avoid heat and water leaks. The thermofusion allows the molecular fusion of the four segments at 260°C, forming a continuous pipe, without the need for threads, solders or adhesives. By column, the aluminum cans were joined one by one using epoxy resin®. The main structure of the prototype can contain 22.37 lilers, verifying that there were no leaks or breaks (Fig. 2).

Figure 2. Columns of aluminum cans and Tuboplus connections

The water circulating inside the aluminum cans (Fig. 3) is heated by solar radiation, leaving the water in the cans at an average temperature of 37.71°C in one hour. The hot water in the tank is used for the four people in the house to shower at any time, since it helps maintain the average temperature indicated throughout the day.

Figure 3. CalGen

The methodology to measure the temperature of the water used for the bathroom of the house is the following:
• The ambient temperature of the place where CalGen was placed.
• The water temperature was taken before entering the solar heater pipe.
• The temperature was obtained inside the hot water tank.
The cold water from the water tank enters the columns of aluminum cans which function as vacuum tubes, while the water passes through it is heated by the heat of the aluminum cans, the hot water being stored in an ex-designed tank professed, which works over demand until it is used again. A digital thermometer brand Bratenthermometer JR-1 was used to measure the following temperatures: ambient, the water temperature before entering the can columns and inside the tank. The measurement schedule was from 12:00 to 13:00 hours from 05 to June 10, 2017 (Table 2).

Table 2. Temperature in °C.

Time	AT(°C)	WT (°C)	TI(°C)
0 minute	18	16	20
10 minute	19	17	26
20 minute	20	18	32
30 minute	21	19	38
40 minute	22	20	43
50 minute	24	22	48
60 minute	24	22	57
Average	21.14	19.14	37.71
Variance	4.68	4.68	141.34
Standard deviation	2.16	2.16	11.88
AT	Ambient temperature		
WT	Water temperature before entering the solar heater		
TI	Temperature inside the hot water tank		

3.2. Methodology for photoelectric cells

The methodology used to measure the electricity generated by the photoelectric cells was the following:
• The electrical energy generated by the photoelectric cells was measured daily from 12:00 to 13:00 pm from 05 to June 10, 2017, given that at the maximum solar insolation at the latitude 19°27´19.238"N and longitude 99°11´5.747"W where the study was carried out (Tacubaya, Mexico City).
• The measured electricity has an error of +/- 0.5% of reading, according to the characteristics of the compact multimeter MUL-005 used.
The electricity generated during one hour of work is the same since the electrical energy of the photoelectric cells is constant, varying only on days with high cloudiness. Eight polycrystalline-type photoelectric cells were used (Fig. 4), since they have a better cost-performance ratio than those of the monocrystalline type (Harper, 2012). The voltage generated by each cell is 6 V with 500 miliampers (mA) connected in series (the serial connections are the positive pole with the negative) and parallel (the connections in parallel are the positive poles with positive and negative with negative) to obtain a voltage of output of 24 V with 1 A. with the previous data the electric power was obtained that is 24 Wh.

Figure 4. Photoelectric cells

The key parameters to have an efficient photovoltaic array are irradiation and solar insolation.
• Irradiation is the intensity of sunlight. Its most comm on units are watts per square meter (W/m2) or kilowatt per square meter (kW/m2). Greater solar radiation is obtained when the photoelectric cells are oriented towards the sun. The average annual solar irradiation in Mexico City is 5.47 W/m2 per day (Harper, 2012).
• Insolation is the amount of solar energy received during a period of time. Its units are kWh/m2, it is necessary to know the average daily insolation. The annual average insolation is 5.5 kWh/m2 in Mexico City (Harper, 2012).
Therefore, an adjustable system or solar tracker was proposed, where the photoelectric cells have a mechanism through which they follow the position of the sun making the use of solar radiation more efficient. The automatic adjustable system uses an Arduino Uno to receive the signal of the photoresistors that it detects when the solar radiation does not incline perpendicular to the photoelectric cells, obtaining the position by means of two servomotors Sg90 (Fig. 5). "With this system an increase between 30 and 40% of solar uptake is estimated" (Harper, 2012).

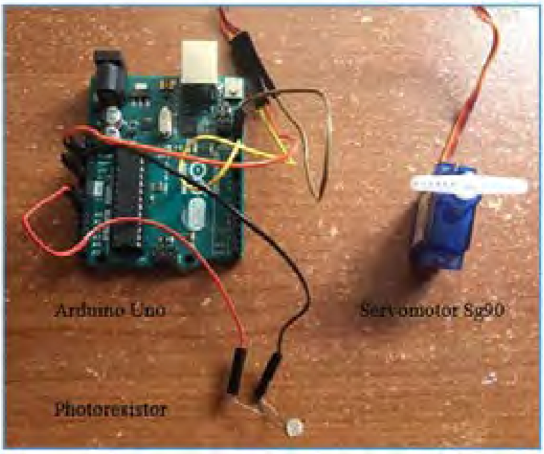

Figure 5. Servomotors controlled by an Arduino Uno

3.3. Methodology to control the adjustable system trough the Arduino Uno

1)Photoresistors: they are connected in the following way.
a)Positive to PIN A0.
b)Negative to PIN GND.
2)The servomotors: they have three colored wires and they are connected to the Arduino Uno the following way.
a)Brown cable to PIN GND.
b)Red cable to 5 volts.
c)Yellow cable to PIN 9.
The solar energy converted into electricity by the photoelectric cells goes to a charging center where the solar charge is controlled, stored in the rechargeable batteries, which supply the power to the gadgets by means of USB-type chargers. The two lead acid batteries (brand Kapton model SB-1207 12 Vdc-7.0 A-h) are connected in series with a voltage of 24 Vdc-7.0 Ah. The batteries are connected to two universal serial bus (USB) (Fig. 6).

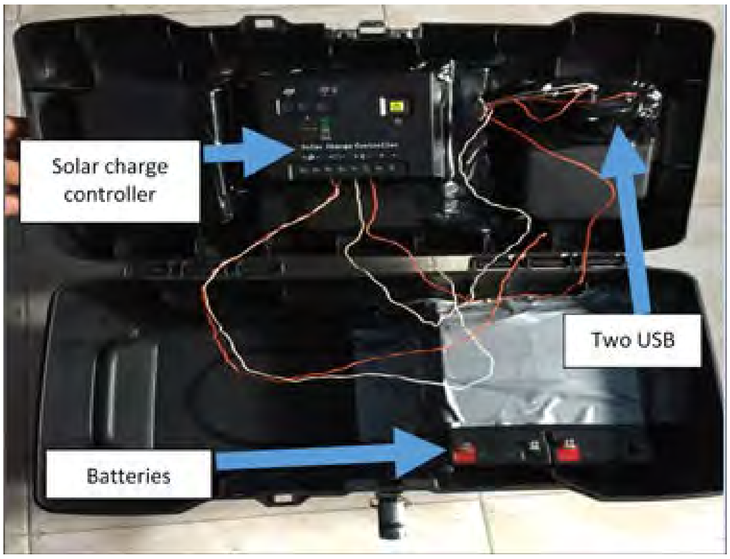

Figure 6. Charge controller

The system requires 19 Wh (a smartphone brand iPhone 5 consumes 9.5 Wh) of power to recharge the two iPhone 5 smartphones during the critical design month and the output voltage is 24 V. If the system requires 9 days of autonomy, then the capacity of the battery is 7.1 A-h. The capacity required by rechargeable batteries is determined by the electrical power requirements that operate the loads during the critical month. To calculate the capacity, use the following Eq.1 (Harper, 2012).

$$Bout = \frac{Ecrit \times ta}{Vsdc} \tag{1}$$

4. Analysis of results

To determine with what material the collector structure was made, the following tests were carried out (from June 1 to 4, 2016):

1. Two columns of 84 centimeters (cm) were evaluated, each column was formed by 7 aluminum cans (355 ml each) painted black joined with epoxy resin and another unpainted, to determine which absorbs the greatest amount of heat, placing in both a stopper and adding 2 liters. of water to each one, being that the aluminumcans painted presents greater efficiency in the increase of temperature (Table 3).

Table 3. Temperature difference between the columns of aluminum painted y unpainted

Time (minutes)	Aluminum cans painted black	Unpainted aluminum cans
0	20°C	20°C
10	26°C	24°C
20	32°C	28°C
30	38°C	30°C
40	43 °C	32°C
50	48°C	34°C
60	57°C	34°C
Average	37.71	28.85
Variance	141.34	23.83
Standard deviation	11.88	4.88

Selected the aluminum material for the pipe, tests were carried out for three days (from June 1 to 4, 2016), to determine in an hour, the internal temperatures of the air and of the water outlet, in order to calculate the heat transfer of the Aluminum-Water system (Giancoli, 2009). The heat transfer of the aluminum-water system of 157.48 and 297.35 kWh at 38°C and 57°C respectively (Table 4 and Fig. 7) To calculate the heat transfer of the aluminum, use the following Eq.2

$$Q = \frac{\pi(T1 - Ta)}{\left[\frac{h}{2k}\log\left(\frac{0.2}{D1} + \frac{1}{D2}\right)\right]} \tag{2}$$

Table 4. Heat transfer of aluminum-water system in unpainted aluminum cans painted in black. Note: Air temperature=18°C

Time	UACWT (°C)	TAWH (BTU/hpie2 °F)	TAWH (kW/h)	WTACB (°C)	TAWH (BTU/hpie2 °F)	TAWH (kW/h)
0	20	52,032.33	15.25	20	52,032.33	15.25
10	24	156,096.99	45.75	26	208,110.42	60.99
20	28	260,161.65	76.25	32	364,225.68	106.74
30	30	312,193.98	91.50	38	537,332.67	157.48
40	32	364,225.68	106.74	43	650,380.50	190.61
50	34	416,258.01	121.99	48	780,484.32	228.74
60	34	416,258.01	121.99	57	1,014,606.18	297.35
UACWT	Unpainted Aluminum Can Water Temperature					
TAWH	Transfer of Aluminum-Water Heat					
WTACB	Water Temperature of Aluminum Cans painted Black					

The 8 photoelectric cells controlled with the adjustable system through the Arduino Uno generated 24 Wh (from 12:00 to 13:00 p.m. from 05 to June 10, 2017), the adjustable system was removed to know how many W are generated, it was obtained as a result that 19.2 Wh were generated (from 12:00 to 13:00 p.m. from 11 to June 15, 2017). According to the previous the 8 photoelectric cells in 10 hours save 240 W/day, which means that in a year the system would save 87.6 kW.

5. Discussion of results

The water heated in the aluminum cans is stored in a stainless steel tank with a capacity of 60 liters and is covered in the interior of Expanded Polystyrene (EPS), in order to keep the temperature of the water heated and average at 37.71°C, in order to use the hot water over demand.

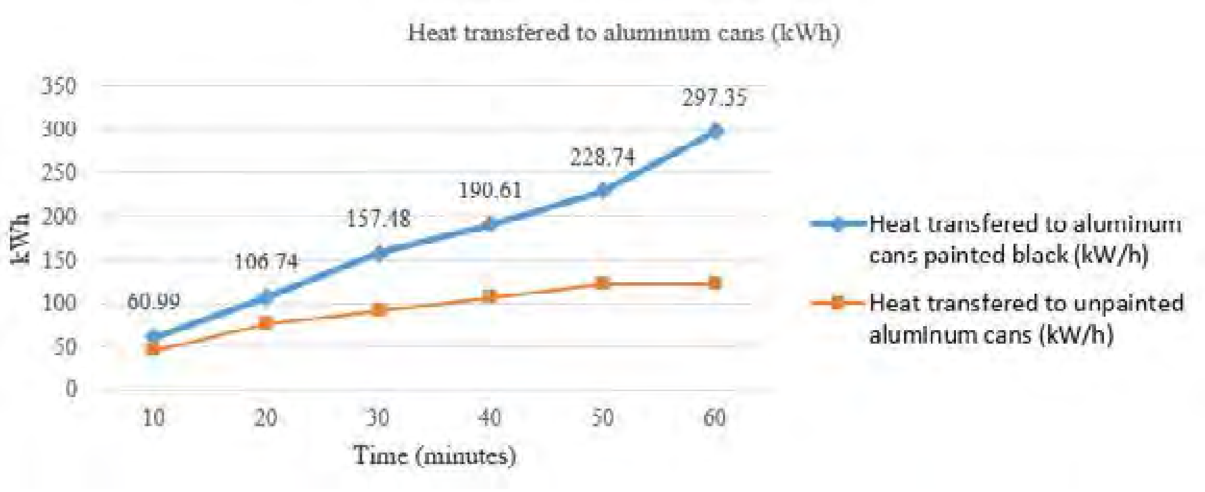

Figure 7. Heat transferred to aluminum cans painted black and unpainted (kWh)

The water heated by CalGen helps reduce the emission of GHG, especially CO_2, since the combustion of one kilogram of LPG produces 3 kg of CO_2 (INECC, 2009). As a result, the family of four people living in the house stops emitting an average of 3.6 and 1314 kg of CO_2 per day and per year respectively (Fig. 8).

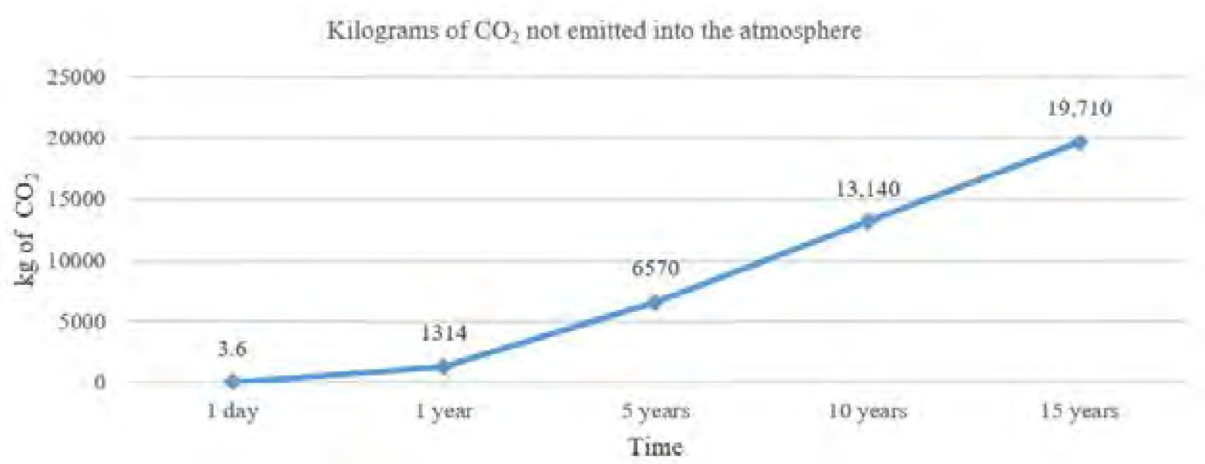

Figure 8. Kilograms of CO_2 not emitted into the atmosphere

According to Harper (2012) an adjustable system increases between 30 and 40% of the solar uptake, according to the experiment carried out from 12:00 to 13:00 pm from 05 to June 15, 2017, it was obtained as a result that the adjustable system allowed a 20% increase in solar capacity.

The total cost of the prototype is $163.53 corresponding to $70.27 and $93.26 for the fixed costs and variable costs (Table 5) respectively. The technical feasibility of the prototype is possible, given the ease of assembly and durability of the components, while the financial viability indicates that the prototype of the dimensions described is self-financing, mainly to the decrease in both gas consumption.

6. Conclusions

In Mexico, photovoltaic projects represent only 0.5% of the total installed capacity in the country, however the technology has presented growth important when going from 170 MW in 2015 to 389 MW in 2016, which represents an addition of 128% to the actual existing capacity (SENER, 2017). Human beings must be aware that solar energy has a lower impact on the environment, so CalGen was proposed as a sustainable product to be installed in the houses of Mexico City.

Table 5. Variable and fixed costs of CalGen

Variable costs		Fixed costs	
Materials	Cost (dollar)	Tools	Cost (dollar)
Polycarbonate (95X95X14)	\$2.51	Drill with drill set	\$17.53
$\frac{1}{2}$ MDF board of 6 millimeters	\$1.81	Super gas torch mid point	\$7.51
Black Industrial Lacquer (0.5 liters)	\$1.30	Disk/cut aluminum	\$2.25
Epoxy Glue \$ 35 each	\$1.51	Caulking gun	\$1.75
Sikasil (glue / polycarbonate)	\$0.76	Brush	\$1.21
Tuboplus $\frac{3}{4}$ " (3.0 meter)	\$7.82	Thermofusor	\$40.02
Tuboplus elbows $\frac{3}{4}$ " (2)	\$1.81	Total	\$70.27
T's of Tuboplus $\frac{3}{4}$ "	\$5.82		
Male Connectors $\frac{3}{4}$ " (2)	\$0.70		
Connection Hoses $\frac{3}{4}$ "	\$2.01		
Nail (20)	\$0.30		
Tank with insulation (58 liters)	\$5.03		
Rechargeable battery (2)	\$7.03		
Charge controller/solar panel 12/24 V	\$8.54		
Photoelectric cells (8,19x6 cm, 6 V, 350 mA)	\$46.31		
Total	\$93.26		

Installing the CalGen in a house allows the family of the four members to reduce their consumption of LPG, since a gas heater consumes 0.3 kg of LPG for a daily shower; if we multiply it by four people, we would obtain 1.2 kg of LPG consumed by the gas heater, the daily saving that occurs in the cost of LPG is \$0.75 dollars per kg (AMEXGAS, 2017), equivalent to \$0.90 dollars in a day, being of \$272.95 annual savings. The total cost of CalGen is \$163.53 dollars which means that the heating investment would recover in 219 days.

The eight photoelectric cells generate 24 W if they work on average 10 hours, you get 240 W/day (0.24 kW/day), which multiplied by \$0.10 dollars (cost of a kWh generated by CFE) (CFE, 2017), represents a daily saving of \$0.02 dollars and annually of \$8.40 dollars. The cost of each photovoltaic cell is \$4.43 dollars if multiplied by the eight cells used is equal to \$35.48 dollars, so in five years the investment of the photoelectric cells would be recovered. Energy efficiency through CalGen allows a better use of the financial resources of people who live in the house. Also it is proposed that CalGen be used to bring electricity to remote places as a solution alternative to light-emitting diode (LED) spotlights in homes after weather and seismic events.

The CalGen is a novel product in the commercial sector of solar heaters, facilitating its sale, because it has the following advantages and innovations:

- Greater commercial durability because all the materials used in its manufacture are of high quality and low cost.
- Economic, because it represents half of the total cost of a commercial solar heater with similar characteristics.
- Environmentally sustainable, due to the significant decrease in domestic consumption of LPG and electricity generation.
- Self-financing, your total investment can be recovered in 219 days due to the reduction in domestic consumption of gas and electricity.
- Minimum cost of installation, repair and maintenance, performing the above operations the company technician.

7. Acknowledgments

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