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LOW COST SOLAR HEATER: A REPORT OF A PROJECT FOR DISSEMINATION OF THIS TECHNOLOGY IN FORMIGA – MINAS GERAIS

Robes Silvério de Jesus Júnior
Felipe Machado Romeros
Diego Luís Izidoro
Instituto Federal de Minas Gerais (IFMG), Padre Alberico Street, 440, São Luiz, Formiga - Minas Gerais, Brazil.
e-mails: robesjrpp@gmail.com; felipemagaleletrica@gmail.com; diego.izidoro@ifmg.edu.br

Abstract. *Due to its cost, water heating systems by solar collectors didn't have their popularization in mass in Brazil, once it is economically unviable to the population of low income. However, low cost solar heaters have been developed for the last few years aimed at such a consumer market, which have also sought solutions that have a significant impact on the reduction of electricity consumption. The proposal of this work was to disseminate, in the city of Formiga (Minas Gerais) and region, a type of Low-cost Solar Heater (LCSH) and show to the local population the economic feasibility of the implantation, the thermal comfort provided and the benefits to the environment generated by the system. For this, the project was divided into five stages: budget and purchase of materials that make up the system, solar heater construction, preparation of material for extension courses, divulgation and realization of the courses for the community. Most of the building materials for the solar heater were purchased in local home centers. The total cost was approximately six hundred reais. Assembly and installation took place in about twenty hours. To date, two courses have been held and 67 people participated, 32 of the external community. Of that total, 97% stated that they intend to install the LCSH at home and 100% said they intend to indicate the course to others.*

Keywords: *Solar Energy, Low Cost Solar Heater, Sustainable Technology.*

1. INTRODUCTION

Solar energy is a promising alternative to meet the growing challenge of expanding the supply of electric energy on the planet. The distribution of solar radiation in the Brazilian territory is shown in Fig. 1. In some places in Brazil, located mainly in the Northeast, the daily solar irradiation reaches more than 6 kWh/m².

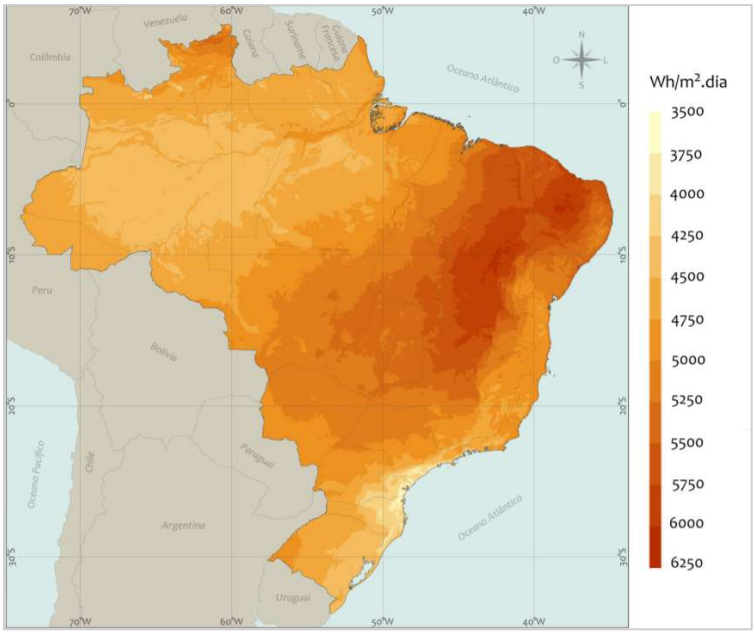

Figure 1. Distribution of solar radiation in the Brazilian territory
Source: INPE, 2017.

The average annual global solar irradiation per day in any region of Brazil is much higher than in most countries of the European Union, where projects to take advantage of solar resources are widely disseminated (Martins; Abreu; Pereira, 2012).

At lower temperatures, up to about 100°C, solar energy can be applied for drying, thermal control of environments and other processes using heated water (INPE, 2017).

In the search for the use of this great energy potential, in the 1970's the commercialization of solar heaters started. The popularization of the solar heating system and consequent growth of its use in residences is mainly due to the possibility of saving electricity, but the benefits can also be observed in the environmental scope, since its use does not emit toxic gases to the atmosphere, besides leaving radioactive residue (Varella, 2004).

Although Brazil nowadays has the third largest total installed capacity of solar heating systems, in per capita values it occupies only the 30th position. The major problem in the large-scale use of solar heating systems in Brazil is associated with two main factors: the lack of awareness of the population and the relatively high initial investment when compared to the most used equipment, the electric shower (INPE, 2017).

Based on this, the proposal of this work was to disseminate, in the city of Formiga (Minas Gerais) and region, a type of Low cost Solar Heater (LCSH) through extension courses for the community aiming to teach people how to build and install their own system and take advantage of its environmental and economic benefits.

2. LOW-COST SOLAR HEATER

In 1999, in order to popularize solar heating systems, CIETEC-USP (Incubator Center of Technological Companies – University of São Paulo) mobilized multidisciplinary teams to develop a solution equivalent to traditional solar heaters, but Brazilian low-income families could also enjoy such technology, since a conventional solar heater is an expensive system, taking into account the purchasing power of the majority of the Brazilian population (Sociedade do Sol, 2009).

The developed system consists of two 0.9 m^2 PVC (Polyvinyl chloride) collector plates connected to each other and painted in black and a thermal reservoir made with a 200 liters plastic drum (Xavier, 2013). Each collector plate is formed by a modular profile of PVC liner with PVC tubes also attached to the ends (Varella and Guerra, 2014). This system is illustrated in Fig. 2.

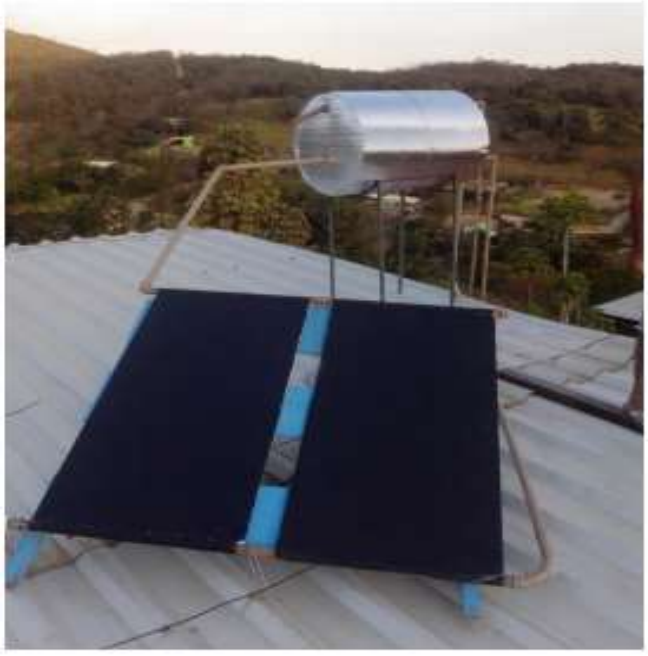

Figure 2. Low cost solar heater with a PVC collector
Source: Gerasol, 2013.

The low cost solar heating system consists of three main components: a cold water reservoir (water tank), a hot water reservoir (thermal reservoir) and the solar collector.

The working principle is the same as a conventional heater and it is illustrated in Fig. 3. Water from the local distribution network enters the water tank. Part of this water goes to the thermal reservoir (also called boiler). The water then follows by gravity into the solar collector. In the collector, the solar irradiation heats the water. The heated water becomes less dense and follows, without pumping, to the thermal reservoir. As the hot water is consumed, more cold water enters the thermal reservoir and the cycle is repeated.

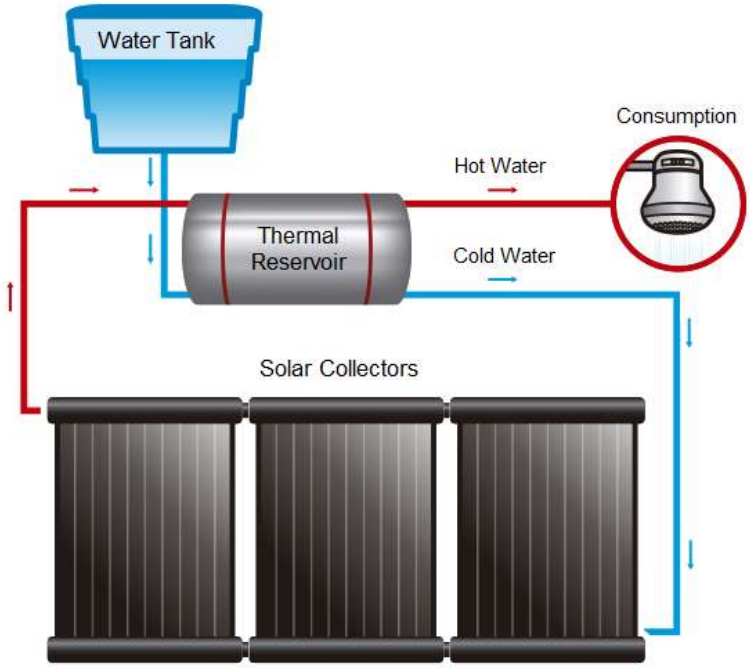

Figure 3. Solar heater working principle

According to Woelz (2002), when the LCSH (Low Cost Solar Heater) project was developed, its cost was equivalent to 10% of the cost of a conventional solar heater. Of course, because it is cheaper, its efficiency is lower, as is the maximum temperature that the water reaches. According to the study by Santos, Oliveira and Novak (2012), an LCSH with PVC boards presents efficiency in the 20% range, while the efficiency of a conventional heater is around 45%. The temperature of the water in a common solar heater reaches above 80°C, whereas in the LCSH this value is at most 55°C, but much higher than the average temperature of the water consumed during bathing (around 36°C). Both efficiency and temperature are easily compensated in the LCSH by means of a larger area in the collector.

3. METHODOLOGY

This work was divided into four stages. Firstly, a price survey was carried out with local home centers in order to obtain the lowest prices. The second stage consisted of the construction and installation of the ASBC system at the campus of IFMG (Federal Institute of Minas Gerais) in Formiga. The third stage was the course divulgation for the community and the preparation of the course material. The last stage was the realization of the extension courses, which purpose is the diffusion of LCSH technology.

3.1 Budget and purchase of materials

At the outset, the necessary materials for the construction of the LCSH system were searched. As a reference, Xavier's list of materials was used (2013) and adapted according to the materials found and available in the home centers of the region. In Table 1 the main materials are listed.

Table 1. List of the main materials required to build the LCSH system.

Item	Materials Description	Quantity
1	Modular PVC lining plates (1245 x 615 mm)	2
2	High density polyethylene (HDPE) Tank 200L	1
3	PVC pipes 32 mm	8 m
4	PVC connections	~ 20
5	Simple Insulation Thermal Cover	1
6	Metallic Insulating Thermal Cover	1
7	Corrugated aluminum sheet	1

Source: Sociedade do Sol, 2009.

3.2 Solar Heater Contruction and Installation

The construction and installation of the low cost solar heater was carried out according to guidelines of the manuals created by the Non-Governmental Organization Sociedade do Sol (2009) and Xavier (2013). Some construction steps are illustrated in Fig. 4.

In the first stage, the thermal reservoir was built. For this, it was used the 200-liter HDPE tank. First the holes were made for water inlet and outlet. Then the connections and other accessories were installed. Finally, the two layers of thermal insulation were placed around the reservoir. The second stage consisted of the construction of solar collectors. For this, it was used the Modular PVC lining plates as the collector panels. First the PVC pipes were cut. Then they were embedded in the plates and glued together. Finally, the collectors were painted black.

Figure 4. Solar Heater Construction

After the construction, the system was installed at IFMG, Formiga campus. The installation was carried out in an already existing structure in place. The collectors were positioned to the orth with a slope of 30 degrees in relation to the ground, according to guidelines of the consulted manuals. The reservoir was positioned above the collectors. As protection, a corrugated aluminum sheet was used. The LCSH already installed on site is shown in Fig. 5.

Figure 5. Low Cost Solar Heater installed at IFMG in Formiga.

3.3 Preparation of teaching materials for the extension courses

For the extension courses for the community, a manual and a mini solar heater were created. The manual is a simplified version of the manuals that have been consulted containing basically: project description, LCSH operating principle, list of materials and tools for the system construction, sizing tips, construction procedures, installation rules and maintenance tips. The manual contains tables, diagrams and photos to facilitate understanding. During the course, each participant receives a manual.

Realizing the need for a practical part in the course, a mini solar heater was also built, shown in Figure 6. With this miniature system, course participants can better understand the operation of the actual system and the assembly and installation procedures. During the course, the proposal is to deliver the parts of the mini solar heater so that the participants themselves can rebuild it.

Figure 6. Mini solar heater built for the course

3.4 Course Divulgation

To publicize the course in the city, posters and flyers were created, disclosed on social networks and distributed in the community. In addition, the Communication Assistance of IFMG – Formiga campus contacted radio and TV stations in the region and requested the divulgation of the course. In Fig. 7 it is shown the poster created (Fig. 7a) and the news on the G1 portal webpage (Fig. 7b).

In the posters and in the news were highlighted information about the possibility of saving electricity and the affordable price, characteristics of this type of heater. It was also emphasized that the course is totally free and does not require any previous specific knowledge. A link was also provided for enrollment in the course.

(a) (b)

Figure 7. (a) Poster for divulgation (b) News about the course (G1, 2018)

3.5 Courses for the Community

After completing the previous steps, the extension courses began to be offered at IFMG, in Formiga, with the aim of disseminating the technology and guiding low income families to install the Low cost Solar Heater in their homes.

During the course, the materials that make up the system, manufacturing standards, technical aspects related to solar energy and the installation and installation procedures of the system were presented.

The LCSH installed at IFMG is used in the course, so participants can see and understand how the system works in practice. The mini heater is used to explain the construction procedures. Participants also receive a technical manual that will serve as a consultation in a manner that they can manufacture, assemble and install the system and publicize the project so that others can enjoy the benefits generated by the ASBC.

Thus, at the end of the course, questionnaires were applied with the objective of evaluating the viability, economic viability, environmental and possible use of the heating system in the interviewees residence.

4. RESULTS AND DISCUSSION

According to the steps presented in the methodology, firstly the materials for the LCSH construction were budgeted at different home centers in Formiga. It is important to highlight that all materials were not found in the same place. Some materials that were not found in the city and could not be replaced by others were purchased in Belo Horizonte, directly from Gerasol BH, a company specialized in this type of products. The total cost of the system (reservoir, collectors and accessories) was approximately R$ 600,00 and it has capacity for 200 liters, enough to supply hot water for a house with four residents. Compared with the cost of a conventional solar heater with the same capacity (from R$ 2.000,00), LCSH is 70% cheaper.

The total construction of the solar heater lasted about 16 hours divided into four days. The installation took place during an afternoon and lasted about four hours. Every construction and installation steps were performed by two or three people. The system, when finalized, only needed repair on small leaks that appeared, but this problem was solved quickly with the use of glue. About R$ 50,00 were spent to make the mini solar heater . Some of its pieces were obtained through donation in home centers.

The publicity was very important to attract the attention of the residents of Formiga and nearby cities. Many people have contacted IFMG to find out more information related to the course. Regarding the courses, initially they had been planned to last eight hours. But later, when all the teaching material was finished, it was decided that the duration would be only of four hours: two hours of theory and two hours of practice. In order to have a greater participation of the external community, the courses offered were maintained on Saturdays. So far, two courses have been held: one in September and another in October, 2018. On both occasions fifty vacancies were made available through an online form and all of them had already been filled out four or five days before the course.

In the first course 34 people participated, of which 18 were from the external community. In the second course 33 people participated, of which 15 were from the external community. The graph of Fig. 8 shows the profile of the course participants.

The course was attended by IFMG students from the undergraduate courses of Electrical Engineering, Administration, Financial Management, Computer Science and Computer Technician. Most of those who were present reside in Formiga-MG. However, there were also people from the cities of Arcos, Divinópolis, Capitólio, Candeias, Nova Serrana, Itapecerica, Pains and Santana do Jacaré. The IFMG staff also participated.

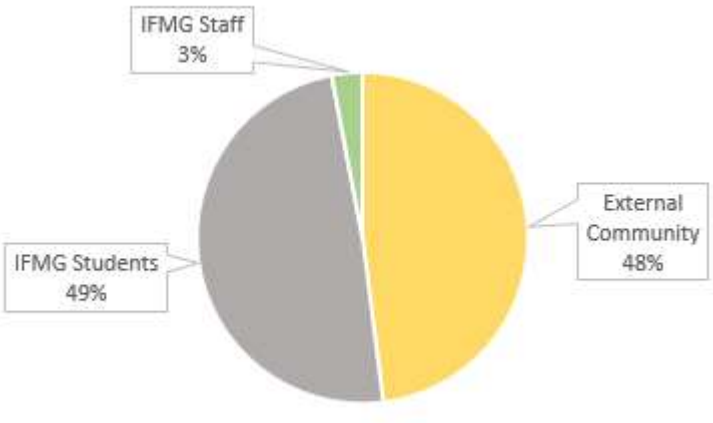

Figure 8. Profile of the participants

At the end of the courses, a questionnaire was delivered to the participants. In general, they reported that the motivation to participate in the course was the possibility of saving energy and money that the LCSH can provide. The low price compared with the conventional system was reported as another great motivator. Of the total participants 97% stated that the course met their expectations; 100% stated that they intend to indicate the course to other people and 90% reported that they want to install the LCSH in their residence.

5. CONCLUSIONS

The proposal of this work was to disseminate, in the city of Formiga (Minas Gerais) and region, a type of Low cost Solar Heater (LCSH) made with PVC plates. For this, a LCSH was constructed and installed at IFMG in Formiga and extension courses were offered to teach people how to build and install their own LCSH and take advantage of the benefits of using it.

So far, the course has been offered twice, with the participation of 67 people from Formiga and region. All of them said that they will recommend the course to relatives and friends. And 90% of them reported that they want to install the LCSH in their residence. Thus, based on these reports, it is considered that the objective of the work is being achieved and the results are satisfactory. However, the course should be offered at other times, so that more people can participate. In addition, it is intended to later evaluate the impact of this work on the community by surveying people who installed the low cost solar heater.

Finally, the authors consider that projects that aim at the interaction of educational institutions and the external community are of great value, transforming the knowledge obtained in the classroom into a social reality transformation, no longer limited only to the students' formation, but the whole community. Therefore, such projects must be carried out more frequently and encouraged by institutions.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE

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