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# EVALUATION OF A HOME-MADE SOLAR BOX HEATER FOR DOMESTIC HEATING

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## ABSTRACT

Quests for alternative energy source remain a challenging concern among researchers. Utilization of inexhaustible source of energy is one of research focus. Most households utilize fuel or electricity to work its intended function like heating and drying. To minimize the utilization of this exhaustible source of energy, home-made devices could be fabricated using locally available materials and fabrication technology to utilize inexhaustible source of energy to finish other households like heating, drying and others. The study was conducted to evaluate the heating performance of a home-made solar box heater for domestic cooking. The solar boxes were made of locally available materials and constructed using local technologies. The performance was carried out using different number of reflectors (one, two and three reflectors), with a constant amount of water of 500 grams as test liquid. The performance was analyzed using descriptive statistics like mean range and regression analysis. The performance of the solar box heaters was tested on the basis of the following parameters; temperature of the het absorber plate, temperature of the heating chamber, and temperature of the test liquid (water). Results of the study revealed that the different number of reflectors affect the temperature of the heat absorber plate, heating chamber, and the temperature of the test liquid (water). The highest temperature of 95.7˚C was recorded by the water in pot in the solar box with three reflectors. The least temperature of 92.87˚C was recorded by water in pot in the solar box with only reflector. The coefficient of determination $R^2$ of 0.996 indicates that 99.6% of the variations of temperature of water in the pot inside the solar box heaters can be attributed to the variations in the number of reflectors used. This further means that the more reflectors, the higher heat energy could be developed inside the home-made solar box. The performance test results suggest the potential of the home-made solar box heater for domestic heating.

**KEYWORDS**: evaluation, home-made solar box, heater, domestic heating

## I. INTRODUCTION

A significant proportion of the Philippine population as in many other developing counties in Asia depends on fossil fuels, biomass and firewood for cooking and heating account for more than 70% of the energy needs of most households. There is no gainsaying the fact that conventional sources of energy for domestic cooking like liquefied petroleum gas (LPG) otherwise called natural gas, kerosene and electricity are characterized by irregular availability, increasing cost and some are not environmentally friendly. Solar energy is one of the main alternative renewable sources of energy crucial to the search for domestic fuel replacements. This is because it is the source of almost all renewable and non-renewable sources of energy. Also, it is the cleanest, it is free from environmental hazards and it is readily available and inexhaustible.

There are several case histories detailing the construction of various types of solar cookers (Sambo et al, 1992-93, reached a maximum temperature; Ogunnigi, 2001; Suleiman et al. 2003; Danshechu, 2003 and Olaguyi, 2003); The Ishisa solar box (commercial solar box cooker) reached a maximum temperature of 72˚C. The sun stove unit (low-cost and low technology solar stove) reached a maximum temperature of 57˚C. The result of the investigations of the other designers suggested that the working fluids of their solar cookers attained maximum temperatures which range from 85˚C at 13.00 hours of certain days of investigation.

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In this study, designing of a solar box heater is highly significant because the use of solar energy to food preparation presents a viable alternative to the use of fuel wood, kerosene, and other fuels traditionally used in developing counties for the purpose of preparing food. While certainly, solar cookers cannot entirely halt the use of combustible fuels for food preparation, it can be shown that when properly applied; solar cooking can be used as an effective mitigation tool with regards to global climate change, deforestation, and economic debasement of poor people.

### A. Objectives of the Study

Generally, this study fabricated and evaluated a home-made solar box heater for domestic use. Specifically, it established performance data on;

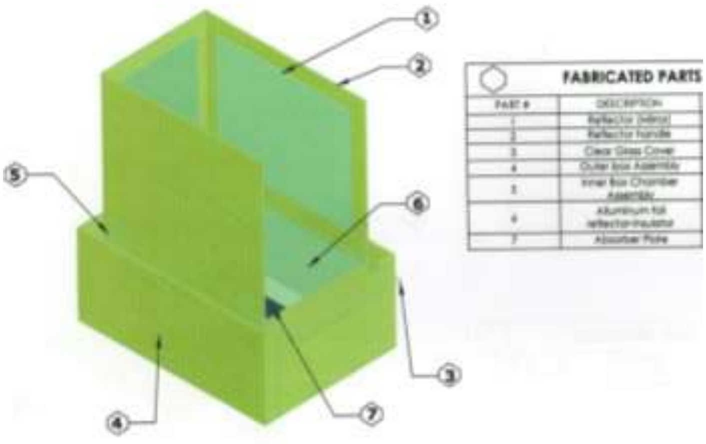
1. Temperature of the heat absorber plate
2. Temperature of the heating chamber
3. Temperature of the water (test liquid)

## II. MATERIALS AND METHODS

### Construction of the solar box heater

This home-made solar heater was constructed using locally available materials and technology. The body of the solar box was made of plywood; reflectors were glued at the reflector handle located at the outside topmost of the box. The reflector handle was attached to the inner box by means of hinge and screws. Aluminium foil insulator and reflector was glued to the inner box to create multiple reflection of insolation and enhance absorbtivity of the absorber plate which was made from galvanized iron sheet and was painted with black paint. For the insulation of the heater, polyurethane was used to minimize heat loss. The space between the outer box and inner box were kept spare. This means that air was the insulator between the two boxes. The solar box was covered with ¼ inch transparent clear glass and three 75 mm diameter magnifying lenses were attached to increase the collection and concentration of beam radiation that goes to the box to create greenhouse effect which is the basis of operation of the solar device. The door on top of the box is sliding.

**Figure**: **1**




**Representative view of the home-made solar box heater**

### Principle of Operation

The operation of a solar box heater was based on the phenomenon/principle of green house effect. According to this principle, when an energetic short wave solar radiation falls on a glass cover, the surface gets heated up. The incident solar radiation will then partly reflected, partly absorbed plate called a solar collector placed below the transparent cover in accordance with the following relations (Duffie and Beckman, 1974):

$$I = rn + an + tn$$

where:

I = incident solar radiation,
rn = absorption at a particular wavelength,

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an = absorptivities and a particular wavelength,
tn = transmitivity at a particular wavelength,

The transmitted solar radiation is re-radiated by solar collector to the space between the glass cover and the solar collector (absorber plate) as a long wavelength infrared solar radiation, which is no more able to pass through the cover to the atmosphere. Consequently, this trapped solar radiation between the glass cover and the absorber plate is then transferred as thermal energy to then desirable materials like cooking pot and its contents placed on the absorber plate for cooking a required food item or heating water.

**Methods of Test and Performance Evaluation**
For the evaluation of the performance tests of the solar box heater, the cooking device was positioned in an open space as shown in figure 2. The performance tests that were conducted are the following:

**Figure 2**

**The Set-up of the solar box heater during the final test**

***Water heating test***
For the water heating test, temperature of the insulator ($T_a$), temperature just above the surface of solar collector which is the heating chamber air temperature ($T_b$), temperature of the solar collector (absorber plate temperature ($T_c$) and temperature of the water ($T_w$) were measured using digital, analogue and infrared thermometers. A black painted aluminium pot that contained 0.5 kg water was placed on the solar absorber plate of the solar box thru its door and the solar box heater was then placed outdoor for observation.

***Final Testing***
The final test was done and observed for three hours (12:00 noon to 3:00 PM). Prior to the outdoor exposure of the solar boxes for observation, initial temperature reading of the solar box parts and specimen under considerations in the study were measured simultaneously. A 500-gram tap water was used in the study. Temperature at different parts of the solar box heater was measured using infrared thermometers, digital thermometer and analogue thermometers. The temperature reading was observed in ten (10) minutes interval to conform to the ASAE solar cooking performance testing standards. When shadows of the box appeared on the absorber plate, the solar box heaters were tracked following the direction of the sun. The performance of the solar box heater was analyzed using descriptive statistics and regression analysis.

***Instrumentation***
Temperature of the water was measured using digital thermometers as shown in figure 3. The temperature of the heating chamber was measured using analogue thermometer. Temperature of the absorber plate was measured using the infrared and digital thermometers.

**Figure 3.**

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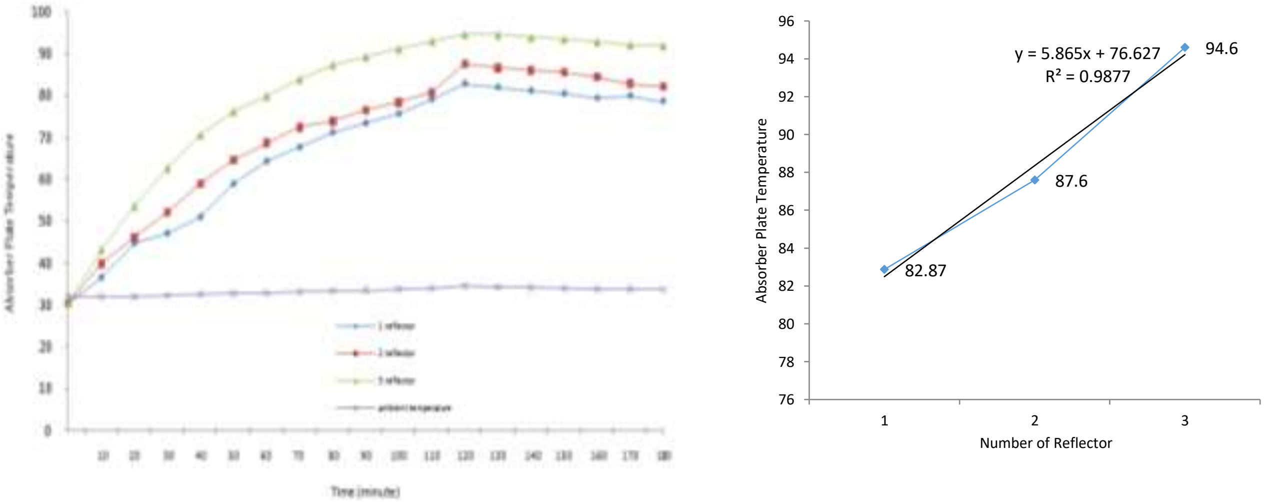
**Temperature measurement at various parts of the solar box heater using digital thermometer**

## III. RESULTS AND DISCUSSION

***Temperature of the Heat Absorber Plate***

The temperature of the absorber plate of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and the relationship between the number of reflectors with the temperature of the heat absorber plate are shown in figure 4. It revealed that the lowest temperature of 82.87˚C was attained by the solar box with only one reflector and the highest temperature of 94.6˚C was attained by the solar box with three reflectors. The trend shown in figure 4a showed that the temperature be likely to boost at the outset up to 120 minutes of observation. Subsequent to the attainment of the maximum temperature at 120 minutes, the temperatures dropped off up to the last part of the observation. Taking account into consideration the peak temperature attained, the difference between the solar collector heat absorber plate and the ambient temperature is reasonably high. This is perhaps a reflection of good emittance properties of the absorber plate and could be due to more re-radiated solar radiation that was reflected by the reflectors. Figure 4b, reflects the relationship between the temperatures of the absorber plate and the number of reflectors. The regression equation developed is a linear equation (y = 5.865x + 76.62) which can be used to predict the temperature of the absorber plate with respect to the number of reflectors. The coefficient of determination, $R^2$ of 0.987 indicates that 98.7% in the variation of absorber plate temperature can be attributed to the number of reflectors.




(a) (b)

Figure 4. The (a) temperature of the absorber plate of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and (b) the relationship between the number of reflectors and the temperature of the heat absorber plate.

***Temperature of the Heating Chamber***

The temperature of the heating chamber of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and the relationship between the number of reflectors and the temperature of the heating chamber are shown in figure 5. It revealed that the lowest temperature of 88.87˚C was attained by the solar box with one reflector and the highest temperature of 93.5˚C was attained by the solar box with three reflectors after 120 minutes of observations as shown in figure 5a. It was observed that the difference in temperature between the heating chamber and the ambient temperature is high. This suggests that the home-made solar box heater could develop and contain heat energy for heating. Figure 5b shows the regression or model equation developed that can be used to predict the temperature of the heating chamber with respect to the number of reflectors. It follows a linear equation of y = 2.315x + 86.73. The coefficient of determination $R^2$ of 0.981 signifies that 98.1% of the variations in the temperature inside of the solar box heaters can be attributed to the number of reflectors used. The more reflectors, the higher heat energy could be developed inside the solar box heater. This could be due to more solar radiation absorbed by the solar box. This shows encouraging heat transfer behavior of a home-made solar box heater developed for cooking/heating operation in tropical areas like the Philippines.

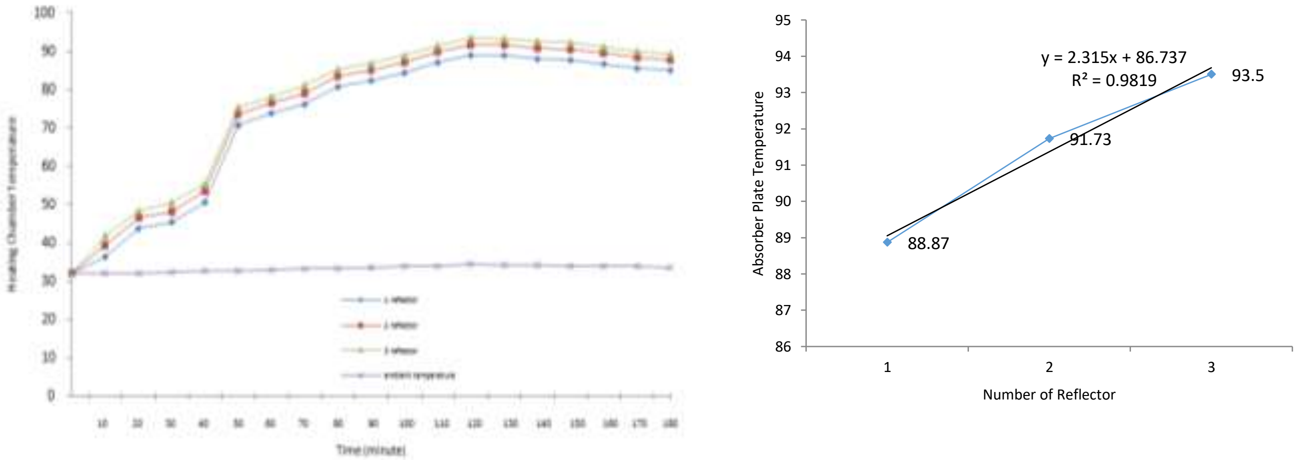
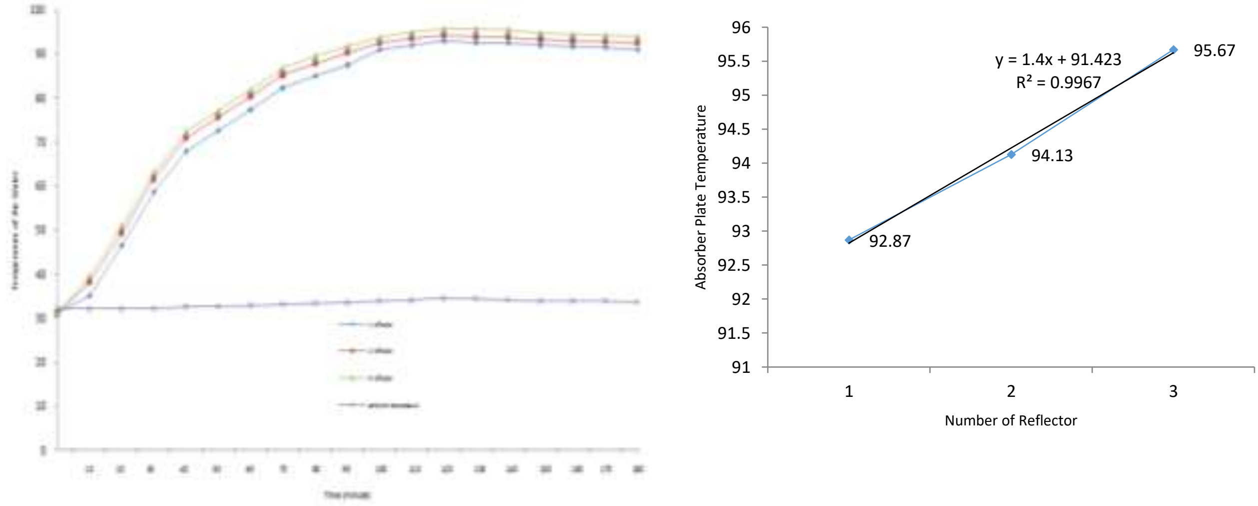



Figure 5. The (a) temperature of the heating chamber of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and (b) the relationship between the number of reflectors and the temperature of the heating chamber.

***Temperature of the Test Liquid (Water)***
The temperature of the water inside of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and the relationship between the number of reflectors and the temperature of the water inside the solar box heater are shown in figure 6. The water in the solar box with only one reflector attained the lowest temperature of 92.87˚C followed by the water in the solar box with two reflectors with a temperature of 94.13˚C. The highest temperature was attained by the water in the solar box with three reflectors with a temperature of 95.7˚C. This temperature was attained after 120 minutes of observation. The temperatures of water in the pot inside the solar box likely to increase from the start up to 120 minutes, however, these readings tend to decrease during the next 60 minutes of observation. This reveals that the home-made solar box heater shows a potential for domestic heating. Figure 6b shows the equation model of y = 1.4x+91.42. The coefficient of determination $R^2$ of 0.996 indicates that 99.6% of the variations of temperature of water in the pot inside the solar box heaters can be attributed to the variations in the number of reflectors used. This further means that the more reflectors, the higher heat energy could be developed inside the home-made solar box. The performance test results suggest the potential of the home-made solar box heater for domestic heating.




(a) (b)

Figure 6. The (a) temperature of the water inside of the solar box heater as influenced by the different number of reflectors for 180 minutes of observation and (b) the relationship between the number of reflectors and the temperature of the water inside the solar box heater.

**Summary**

The study was conducted to evaluate the heating performance of a home-made solar box heater for domestic cooking. The solar boxes were made of locally available materials and constructed using local technologies. The performance was carried out using three treatments (one, two and three reflectors), 500 grams of water as test liquid. The performance was analyzed using descriptive statistics like mean range and regression analysis. The performance of the solar box heaters was tested on the basis of the following parameters; temperature of the het absorber plate, temperature of the heating chamber, and temperature of the test liquid (water). Results of the study revealed that the different number of reflectors affect the temperature of the heat absorber plate, heating chamber, and the temperature of the test liquid (water). The highest temperature of 95.7˚C was recorded by the water in pot in the solar box with three reflectors. The least temperature of 92.87˚C was recorded by water in pot in the solar box with only reflector. The coefficient of determination $R^2$ of 0.996 indicates that 99.6% of the variations of temperature of water in the pot inside the solar box heaters can be attributed to the variations in the number of reflectors used. This further means that the more reflectors, the higher heat energy could be developed inside the home-made solar box. The performance test results suggest the potential of the home-made solar box heater for domestic heating.

## IV. CONCLUSION

1. The tremendous increase of temperatures in the heat absorber plate, heating chamber and the water inside the solar box indicate that the home-made solar box heater could develop heat.
2. The increase in temperature inside the solar box can be attributed to the increase in the number of reflectors. This suggests that the more reflectors, more heat could be developed inside the solar box.
3. The performance of the home-made solar box heater shows the potential of locally made solar box heater for domestic heating.

## V. RECOMMENDATION

Based from the results of this evaluation, utilization of such local technology could be considered for domestic heating like drying of vegetables, grains fruits and other applications requiring heat utilization. It is further recommended that use of more reflectors may be considered to appreciate more heat to be developed at the heating chamber of the solar box heater. Consideration for the use of metals of high thermal conductivity for the heat absorber is likewise recommended.

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