SOLAR COOKER, DESIGN, CONSTRUCTION AND PERFORMANCE.

ABSTRACT

The main purpose of this project is to replace old usage of firewood as a source of fuel for cooking especially in the villages. According to a survey, each family utilizes two fully grown up trees in a year. Our design of solar cooking is strictly based on cost efficiency, easy availability and workability. The geometry of the cooker includes simplest form of an angled panel surrounded by reflectors for enhanced efficiency. The cooker is surrounded by insulating card board box which act as a heat retaining material to make it work even when sun is low. It is painted black at the outside so as to absorb all the radiation and emit none. The efficiency of this cooker is 89% when there is enough sunlight. The cooker can boil water up to $\mathbf{89}$℃ which is also a sufficient temperature to cook light food stuffs and boil tea.

1.0 INTRODUCTION

1.1 Background of the study.

A cooker is an apparatus, usually of metal and heated by gas, electricity, oil, or solid fuel, for cooking food; therefore we get the different types of cooker such as, solar cooker, charcoal cooker, coal cooker, electric cooker, gas cooker and so on.

A solar cooker is a device which uses the energy and direct sunlight to heat, cook or pasteurize food or drink. Many solar cookers are presently in use and are relatively inexpensive, low technology devices, although some are as powerful and as expensive as traditional stoves. Large-scale solar cookers can cook for hundreds of people. Since solar cookers use no fuel and cost nothing to operate. There are many nonprofit organizations who promote the use of solar cookers worldwide. They help to reduce fuel costs, air pollution and slow down the deforestation and desertification caused by gathering firewood. Solar cooking is a form of outdoor cooking and is often used in situations where minimal fuel consumption is important. Solar cooker reduces accidental fires as well as environmental degradation which may result into health problems. There are many types of solar cookers in the market, including the solar panel cooker, parabolic solar cooker and solar box cooker (Adegoke& Fasheun, 1998).

An electric cooker is an electric powered cooking device for heating and cooking of food. An electric cooker often has four stoves and one or two ovens. There will be knobs to determine the temperature of the ovens and stoves. Unlike gas stoves that are powered by gas, it is powered by electricity. Usually they have four rings on top of the hob.

Besides stoves or ranges, common types include hot plates, slow cookers (or crock pots), electric toasters, rice cookers, electric teakettles, and the now obsolete Dub Cookers.

A gas stove is a cooker/stove which uses natural gas, propane, butane, liquefied petroleum gas or other flammable gas as a fuel source. Prior to the advent of gas, cooking stoves relied on solid fuel such as coal or wood. The first gas stoves were developed in the 1820s, and a gas stove factory was established in England in 1836. This new cooking technology had the advantage that it was easily adjustable and could be turned off when not in use. However the gas stove did not become a commercial success until the 1880s, by which time a supply of piped gas was available in large towns in Britain. The stoves became widespread on the European Continent and in the United States in the early 20th century.

Cooking with the sun's power is a fun way to use a renewable resource, and with excellent results. Food cooked in solar ovens retains its moisture and nutrients as it cooks slowly, and does not burn as with other types of heat. Many organizations are introducing solar cooking to the world's less developed regions to prevent further deforestation in fuel-starved areas. They hope also to liberate the women and their children who must spend their days trying to gather fuel instead of working or going to school. (Bruce research institute, 1974).

In more developed nations, solar cooking helps to decrease the use of fossil fuel and to keep the house cool in summer. Many are finding it a creative and practical way to produce delicious meals with less trouble than it takes to use a conventional range.

Designs for ovens and cookers abound. They range from very affordable home made models to those one can buy ready-made (Coulson& Richardson, 1993).

Solar cooker is very simple to construct compared to other cookers, such as electric cooker, charcoal cooker, coal cooker and gas cooker.

Solar cooker is very cheap due to availability of materials used to construct it compared to other types of cookers such as electric cooker, charcoal cooker, coal cooker and gas cooker.

Solar cooker has no effects to the environment surrounding us compared to other types of cooker such as gas cooker which can cause air pollution, charcoal cooker which can cause deforestation due to availability of charcoal, coal cooker also can cause land degradation due to availability of coal, that’s why solar cooker is preferred to be used simply because can conserve our environment.

1.11.Solar cooker panel

This is a cooker with an aperture incident at 60 degrees vertically that captures most sun radiations. Fun panel cooker combines the best features such as capturing much sun radiations. Due to the easy construction and low cost materials are the simplest solar cookers to build and the most common. The general characteristics of solar panel cookers include; they are inexpensive, there are many models which are collapsible for easy transport and storage can achieve lower temperature but cannot fry foods and can cook only one to two pots of food.

The Sun emits a tremendous amount of energy, in the form of electromagnetic radiation, into space. If we could somehow build a gigantic ball around the Sun that completely enclosed it, and lined that ball with perfectly efficient photovoltaic solar panels, we could capture all of that energy and convert it to electricity and be set in terms of Earth's energy needs for a very long time. Lacking such a fanciful sphere, most of the Sun's energy flows out of our solar system into interstellar space without ever colliding with anything. However, a very small fraction of that energy collides with planets, including our humble Earth, before it can escape into the interstellar void. The fraction of a fraction that Earth intercepts is sufficient to warm our planet and drive its climate system.

At Earth's distance from the Sun, about 1,368 watts of power in the form of EM radiation from the Sun fall on an area of one square meter. Yes, these are the same watts we use to describe the energy usage of light bulbs and other household appliances. If Earth were closer to the Sun, as, for example, the planet Mercury is, the number of watts per square meter (W/m^2) would be greater. If Earth were further from the Sun, the W/m^2 value would be lower. Recall our hypothetical gigantic ball surrounding the Sun. Whatever its size, it would capture all of the Sun's energy; but a larger ball would have that energy spread over a larger inside surface area, and would thus have a lower W/m^2 value; whereas a smaller ball would have a smaller surface and thus a greater W/m^2 value. The surface area of a sphere varies as the square of the radius of the sphere; so the energy per unit area received varies inversely as the square of the distance from the Sun. A planet situated 1/2 as far from the Sun as is Earth would be scorched by 4 times as much energy from the Sun (5,472 W/m^2). A planet twice as far from the Sun as is Earth would be feebly warmed by just 1/4th as much radiation (342 W/m^2). So our planet's distance from the Sun is the first key factor influencing the energy we receive, and thus the behavior of our climate.

If Earth were a flat, one-sided disk facing the Sun and if it had no atmosphere every square meter of Earth's surface would receive 1,368 watts of energy from the Sun. Although Earth does intercept the same total amount of solar EM radiation as would a flat disk of the Earth's radius (see figure below), that energy is spread out over a larger area. The surface of a sphere has an area four times as great as the area of a disk of the same radius. So the 1,368 W/m^2 is reduced to an average of 342 W/m^2 over the entire surface of our spherical planet. Another way to think of this reduction is to realize that half of Earth's surface (the night side) is in the dark and thus receiving no solar energy at a given moment, while areas near the edges of the planet (near the poles and around dusk and dawn) are receiving reduced amounts of energy per unit area.

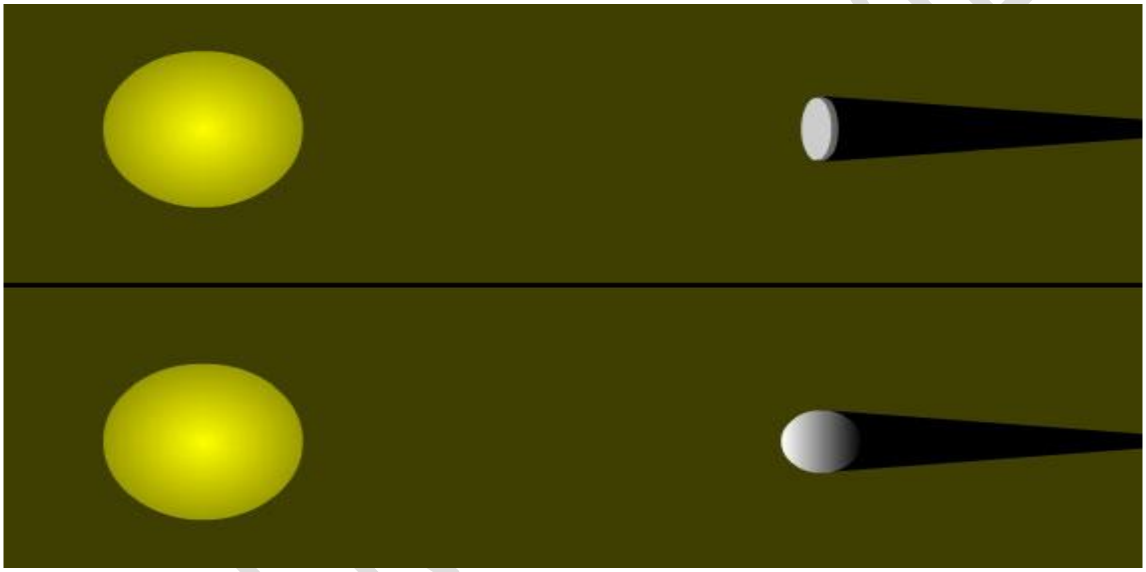


Figure1: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016).

The spherical Earth actually "intercepts" the same amount of incoming solar EM radiation as would a flat disk of the same radius, as shown above. However, the average energy per unit area of Earth's surface is one quarter of that which would strike a flat disk, once we factor in our spherical planet's larger surface area and the fact that half of it is in the dark at a given time (Bouazzi, 1990).

Note that the values for average solar in solation (the term scientists use for the solar EM energy delivered to an area) reaching Earth that has been discussed so far is at the top of the atmosphere www. Ecs-solar.com (accessed12/06/2016).   As you can imagine, as sunlight passes through our atmosphere, some of it is scattered and absorbed, reducing the amount that actually reaches the ground. We'll take up that issue in a bit, but for now we'll continue to simplify our discussion by assuming an airless Earth.

Whenever you glance up at the full moon, you get an eyeful of the subject of our next topic. Unlike the Sun which generates light itself, the Moon does not produce light. The moonlight we see on Earth is reflected sunlight. So, not all of the energy in the form of sunlight that reaches the Moon stays there; some is reflected back into space. Likewise, not all of the energy from the Sun that reaches Earth sticks around here to warm our planet; some is reflected back into space. Take a look at these two images of our planet that were captured by the Galileo spacecraft in December 1990:

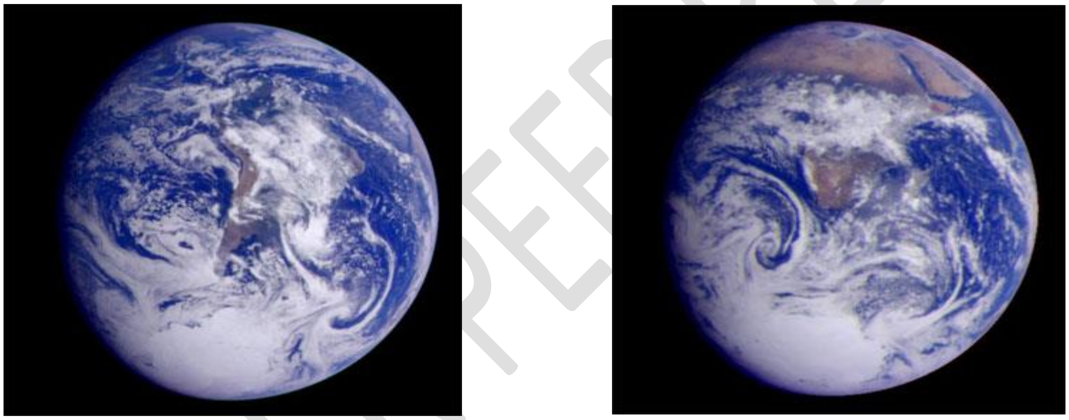


Figure2: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016).

Earth as viewed from space in December 1990. South America is near the center of the left hand picture, while Africa is near the top of the right hand image. Antarctica is visible near the bottom of both images. Note how much sunlight is reflected back into space by clouds and by snow and ice. Note also how light the deserts of northern Africa appear as compared to the Amazon forests of South America and the jungles of central Africa. (Bouazzi, 1990).

Obviously, quite a bit of the sunlight that reaches Earth is reflected back into space. The white clouds that cover much of both images, and the white ice of Antarctica, both reflect most of the sunlight that falls upon them. You can also see how the oceans, the deserts of northern Africa, and the jungles of central Africa and of South America reflect or absorb varying amounts of sunlight.

Astronomers use a quantity called "albedo" to describe the degree to which a surface reflects light that strikes it (Curing et al, 1994). An extremely reflective surface that doesn't absorb any of the light that hits it would have an albedo of 1, while a surface that reflects none of the light that hits it (and that would thus appear pitch black under any illumination) would have an albedo of 0. Fresh snow has an albedo somewhere around 0.8 or 0.9. Forests have albedos near 0.15, while the albedo of desert sands is roughly 0.4. Climate scientists also employ the concept of albedo, though they often express it as a percent; thus they would say that snow has an albedo of 80% to 90%, while the albedo of a forest would be around 15%.

The albedo of a planet (or a locale on it!) clearly affects the ability of that planet to absorb sunlight, thus converting it to heat that can warm the planet and drive its climate. Earth's overall average albedo is about 0.31. Oceans and forests are quite dark, while deserts are lighter, and clouds, snow, and ice are very bright. Without clouds our planet's albedo would be around 0.15, so clouds roughly double Earth's albedo (David& Whitfield, 2000).

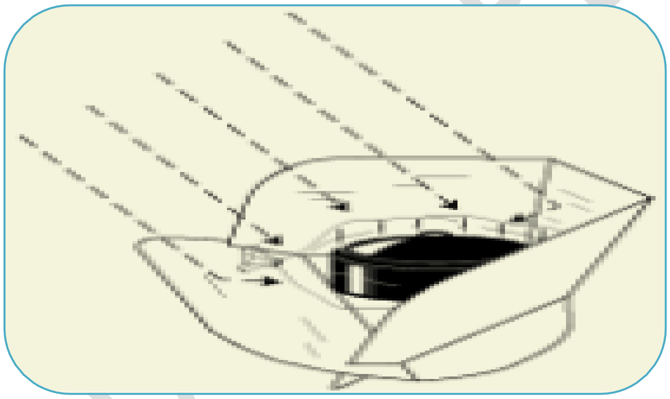


Figure 3: Solar Panel Cookers

www.solarcooker-at-cantinawest.com/solar-cooker-science-project (accessed 05.06.2016).

1.12.Parabolic solar cooker

A parabolic solar cooker was the first type of solar cooker to be discovered. Parabolic solar cookers concentrate sunlight to a single point. When this point is focused on the bottom of a pot, it can heat the pot quickly to very high temperatures which can often be comparable with the temperatures achieved in gas and charcoal grills depending on the type of reflector used.

The general characteristics of parabolic solar cookers including; can cook faster, can dry foods but can damage eyes, more expensive than other models, require periodic realignment to the sun. (en.wikipedia.org/wiki/solar cooker, accessed 15.06.2016).

Parabolic solar cookers appear as shown in the figure 4 below:

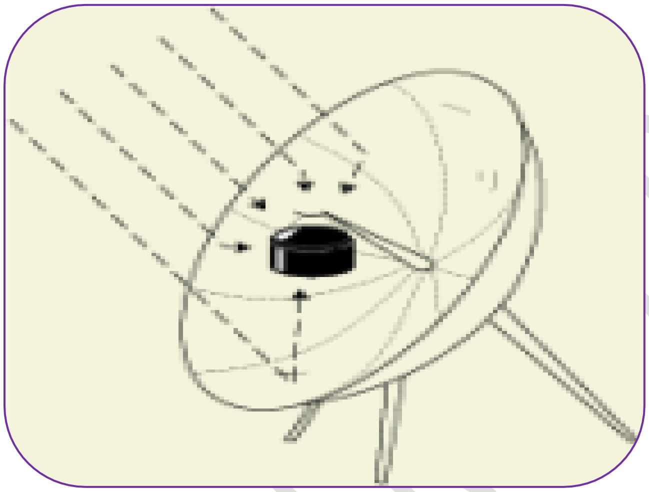


Figure 4: Parabolic solar cookers

www.solarcooker-at-cantinawest.com/solar-cooker-science-project (accessed 05.06.2016).

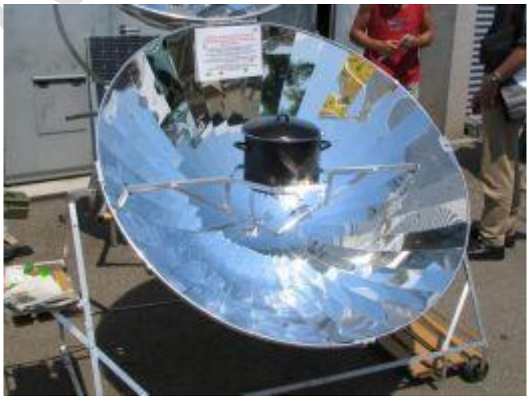


Figure 5**:** Parabolic solar cooker. Photo from thePlanetary Engineering Group Earth Web site (accessed 16.06.2016).

1.13 **Solar box cooker**

A box cooker has a transparent glass or plastic top, and it may have additional reflectors to concentrate sunlight into the box. The top can usually be removed to allow dark pots containing food to be placed inside. One or more reflectors of shiny metal or foil-lined material may be positioned to bounce extra light into the interior of the oven chamber. Cooking containers and the inside bottom of the cooker should be dark-colored or black. Inside walls should be reflective to reduce heat lost by radiation and bounce the light towards the pots and the dark bottom, which is in contact with the pots. The box should have insulated side (en.wikipedia.org/wiki/solar cooker, accessed 15.06.2016).

Solar box cookers appear as shown in the figure 6 below:

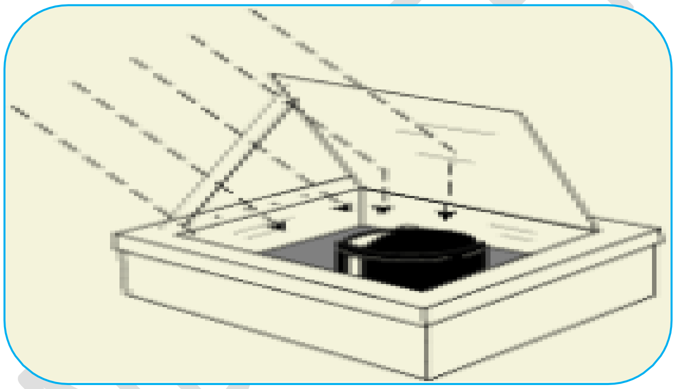


Figure6: Solar Box Cooker

www.solarcooker-at-cantinawest.com/solar-cooker-science-project (accessed 05.06.2016).

1.14. General Introduction.

Principles of building a solar cooker:

> Concentrating sunlight: A reflector surface such as aluminum, mirror or sheet is used to concentrate light from the sun onto a small cooking area. Depending on the geometry of the surface, sunlight can be concentrated by several orders of magnitude producing temperatures high enough to melt salt and smelt metal. For most household solar cooking applications, such high temperatures are not required. Solar cooking products, thus, are typically designed to achieve temperatures of 150°F (65°C) (baking temperatures) to 750°F (400°C) on a sunny day.

> Converting light to heat: Solar cookers concentrate sunlight onto a receiver such as a cooking pan. The interaction between the light energy and the receiver material converts light to heat. This conversion is maximized by using materials that conduct and retain heat. Pots and pans used on solar cookers should be matte black in color to maximize the absorption.

> Trapping heat: It is important to reduce heat being lost by being transferred into another form of energy convection by isolating the air inside the cooker from the air outside the cooker. Simply using a glass lid on your pot enhances light absorption from the top of the pan improves heat retention and minimizes heat loss. A high-temperature plastic bag can serve a similar function, trapping air inside and making it possible to reach temperatures on cold and windy days similar to those possible on hot days (El-Kassaby, 1991).

1.15. Operations:

Different kinds of solar cookers use somehow different methods of cooking, but most follow the same basic principles.

A fun panel solar cooker lets the UV light rays in and then converts them to longer infrared light rays that cannot escape. Infrared radiation has the right energy to make the water, fat and protein molecules in food vibrate vigorously and heat up. The panel cooker usually consists of a cooking vessel (pot or pan) which is usually darkened or blackened, an oven cooking bag or transparent glass bowl along with a reflective panel. These panels can be made from aluminum foil over corrugated carton, or from tin or sheet metal panels polished to a high sheen and also with mirror (Goetzberger & Luther, 1993).

The oven bag or glass bowl allows the suns UV rays to penetrate towards the food in turn trapping the energy; (heat) preventing its escape. The reflector panels concentrate the sun light onto the cooking vessel containing the food, in the same way the panels do so on the solar box cookers. A panel cooker is usually simpler and more economical to build and results in the same cooking effectiveness for most all situations. Some panel cookers can achieve relatively high temperatures depending on the pot and the food being cooked. Since most foods cooked in these types of cookers usually contain more moisture such soups, stews, meats they will usually cook around 225-250° F (Klemens & Vieira, 2003).

It is not the sun's heat that cooks the food, nor is it the outside ambient temperature, though this can somewhat affect the rate or time required to cook, but rather it is the sun rays that are converted to heat energy that cook the food**;** and this heat energy is then retained by the pot and the food by the means of a covering or lid.

An effective solar cooker will use the energy of the sun to heat a cooking vessel and efficiently retain the energy (heat) for maximum cooking effectiveness. The cooking time depends primarily on the equipment being used, the amount of sunlight at the time, and the quantity of food that needs to be cooked. Air temperature, wind, and latitude also affect performance. Food cooks faster in the two hours before and after the local solar noon than it does in either the early morning or the late afternoon. Large quantities of food, and food in large pieces, take longer to cook. As a result, only general figures can be given for cooking time. With a small solar panel cooker, it might be possible to melt butter in 15 minutes, to bake cookies in 2 hours, and to cook rice for four people in 4 hours. With a high performing fun panel solar cooker, you may be able to cook in time less than mentioned above. However, depending on local conditions and the solar cooker type, cooking may take half as long, or twice as long. Our solar cooker design can boil tea for five people for 30 minutes.

Figure7: Solar box type (accessed 25/05/2016). Dimensions (235mmx235mmx140mm)

Figure8: Solar cooker box type. Dimensions (50cm x 40cm x 30cm)

1.2. Statement of the problem

Most people particularly in developing countries cook and heat their homes using solid fuels such as wood, crop wastes, charcoal, coal and dung in open fires and leaky stoves. This is because most are poor thus not being able to use safe means such as electricity and gas. Also the availability of electricity and gas especially in rural areas is low making their use hard. Such solid fuels produce small soot particles that penetrate deep into the lungs and may result into lung cancer after a period of time. Use of solid fuel has also resulted into air pollution, cutting down vegetation which to desertification and deforestation.

The use of solar cookers helps to reduce or to a good extent eliminate uses of solid fuels result into preservation of the environment.

"Who: household air pollution and health". World health organization. (Retrieved 10.05.2016).

1.3. Significance of the project

In Tanzania, the main sources of energy used for cooking are solid fuel such as charcoal, firewood and dung. The liquid fuels such as kerosene, cooking gas, electricity and solar energy are used by people who are well off. The sources are used depending on their availability, expenses and their safety. Most of these are expensive and are not abundantly available. A good example electricity, kerosene and gas while others such as solid fuel are easily available but not safe for health and environment as whole. The use of solar cooker for cooking purposes is needed in most developing countries particularly in villages and remote areas because sun shine is always availability. This is because prices and availability for other safe energies such as electricity and gas is still hard for these areas. Also the solid fuels are not friendly to the environment since they normally cause air pollution. To save the environment is to find alternative ways to produce and use sustainable, clean energy. This is because mankind will continue to use energy in daily life activities. The use of solar cooker can help reduce our reliance on energy derived from burning fossil fuels.

The reasons why we should use solar cookers are:

>Solar cookers are less expensive because the energy from the sun is free and available.

>Sun is freely available and most abundant in Africa.

>Solar cookers do not use any of our limited resources such as water and vegetation hence friendly to our environment.

>Cooking with solar cookers is more healthy way of preparing our foods for consumption as opposed to gas, smoky open fire, microwaves because it uses the natural power of the sun's

energy and preserves more of the natural nutrients of the foods by cooking at slower and lower temperatures.

www.solarcooker-at-cantinawest.com/solar-cooker-science-project (accessed 05.06.2016).

1.4. OBJECTIVES

1.4.1. General Objectives.

The aim of this project to build a fun panel solar cooker using aluminum foil reflector and use it to cook food instead of using electricity or fuel.

1.4.2. Specific Objectives.

The project has the following specific objectives:

> To evaluate materials utilized for the construction of widely used solar cooker.

>To design and construct the solar cooker.

>To describe how fun panel solar cooker works.

>To determine the efficiency of fun panel solar cooker.

>To analyze the performance of Fun Panel Solar Cookers and to improve the workability of cooker.

1.5 Hypothesis

A fun panel solar cooker will be more efficient for Tanzanian context because:

>Aluminum foil is the best reflector because it can last longer without much loss of reflectivity than other reflectors such as mirrors, stainless steel and sheets.

>I think fun panel solar cooker will be much efficient than other types of solar cookers since it is made at angles that allow high collection of sun radiations.

>A fun panel cooker is usually simpler and more economical to build and results in the same cooking effectiveness for most all situations.

>The aluminum foil and foil tape used throughout the construction slow the heat loss due to conduction.

>Aluminum may not be very efficient than mirror because its efficiency is 88% while that of mirror is 94%.

1.6 Literature review

India being a vast country with a population of nearly one billion consumes its significant share of energy consumption towards cooking. The sources available for cooking are firewood, crop residues and animal dung in rural areas and Liquefied Petroleum Gas (LPG), kerosene oil and coal in urban and semi-urban areas. The smoke emitted from these fuels pollutes the environment and the kitchens, and also affects the health of family members, especially the rural women. There are problems in availability of cooking fuels also apart from maintaining the supplies of LPG and kerosene in far-flung areas. Solar cooking has been envisaged as a solution to mitigate these problems to some extent. In India solar energy is abundantly available in most parts of the country. The daily average solar energy incident at many places ranges between five to seven kwh/m2 and there are as many as 250 to 300 clear sunny days each year. On clear sunny days, it is possible to cook both noon and evening meals in a solar cooker. Solar cooking does not fully replace conventional fuels, but it helps in substituting such fuels partly (Kumar et al, 2008).

Different types of solar cookers have therefore been developed which are being promoted in the country by the government of India for use by the individuals and community kitchens. These include solar box cookers, parabolic dish solar cookers, cardboard solar cookers (often referred to as solar panel cookers, these are similar to Solar Cookers International's Cook it), community cookers for indoor cooking and solar steam cooking systems. A solar box cooker is a slow cooking device useful for small families. It can cook four dishes at a time and can save around three Liquefied Petroleum Gas (LPG) cylinders in a year if used regularly. It is an ideal device for domestic cooking during most of the year except the monsoon season and cloudy days. Cookers with electrical back up could be used even during non-sunshine hours. The cooker can be used for preparation of all dishes except for frying or chapatti making. The parabolic dish solar cooker is a fast cooking device useful for homes and small establishments. It can cook all types of food including chapattis for about 10 to 15 people; each dish in about half an hour. The cooker can save around five to ten Liquefied Petroleum Gas (LPG) cylinders depending upon its use in homes or small establishments. The cardboard solar cooker (panel cooker) is a low cost foldable device and can be used for preparing one or two soft to cook dishes at a time in areas having good sunshine and low wind velocities. The cooker is lightweight and can be easily

Carried in a bag to any place. Its cost could be recovered in a couple of months. The community solar cooker for indoor cooking has a large, automatically tracked parabolic reflector standing outside the kitchen, which reflects the sun's rays into the kitchen through an opening in its north wall. A secondary reflector further concentrates the rays on to the bottom of the cooking pot painted black. It can cook all types of food for about 35 to 40 people and can save up to 35 Liquefied Petroleum Gas (LPG) cylinders in a year with optimum use. The solar steam cooking system is comprised of automatically tracked parabolic reflectors coupled in a series and parallel combination, generating steam for use in community kitchens for cooking purposes. It can cook food for hundreds and thousands of people in a very short time depending upon its capacity (Kumar et al, 2008).

An article in the (November 2001 edition of the Solar Cooker Review) described a new solar cooking project in southeastern Turkey aimed at teaching solar cooking skills to rural populations, small-town residents and migrant workers. Project leaders, mostly from the Seyhan Rotary Club of Adana, Turkey, chose the solar Cook it as the first cooker to popularize. A small pilot project was initiated in May 2001 by a delegation of volunteers, including Barbara Knudson, who serves on the boards of directors of both Solar Cookers International and Solar Household Energy, and Rotarians Wilfred and Marie Pimentel from Fresno, California, USA.As the newly trained solar cooks and solar cooking teachers began practicing their trades, steps were taken to fund the program through various Rotary Clubs' contributions together with a matching grant from Rotary International. The funds became available in November 2002. Meanwhile, solar cooking continued to spread in the Adana area. In November 2001 Rotary District 2430 Governor Omar Tezcan ordered 1,000 Cook it's for the Adapazari earthquake damage area. In May 2002 two women involved with the Adana project, Gluer Macun (trainer coordinator) and Sükran Baggier, were sent from Adana to Adapazari. With help from past club president Rotarian Attila Yamani, they demonstrated the usefulness of the simple cookers. Local press and the Governor of Adapazari showed great interest. The Cukurova University Center for Environmental Research, other Rotary and Rota act Clubs, local black-pot and Cook it manufacturers were all quite helpful, writes one of the project leaders, Abdullah Paksoy of the Seyhan Rotary Club. "In April 2002, we held a big lunch picnic at the university campus and served delicious solar-cooked dishes to about 200 people. Two major newspapers reported our activities with color photos. The Seyhan Rotary Club also had 1,600 more Cook it's manufactured in Turkey, where the devices are called Gunes Ocagi. During 2002, about 300 women in the Adana area took classes and learned how to solar cook. Among other activities, the Misis Rotary Community Center of the Seyhan Rotary Club kept working with solar cooking courses. The Adana Street Children Association, led by Dr. Fazilet Aksu, provided a location where street kids were served free solar-cooked lunches. Mr. Paksoy writes, The Adana Rotary Sevensprings (Yedipinar) Center for Handicapped Children provided us with a good urban park where the families and mothers of handicapped children were given lessons on how to solar cook. Both of the woman who've served as park manager, Nagehan and her successor Özlem Savci, are very enthusiastic about our activities. In May 2002 at the Rotary District 2430 conference held in Göynük, Antalya, the Seyhan Rotary club was chosen -- from among 85 clubs -- to receive the District Community Service Project award for its pioneering works to promote solar cooking in Turkey. Solar cooking lessons for women in Adana began in late 2002 at the Say dam Street Community Center. Mr. Paksoy summarizes the attraction of solar cooking in Turkey: "With 3,200 hours of sunshine yearly, southeastern Turkey provides an ideal location for expanding solar cooker usage. The summers are hot (40°C) and dry. Many trees and shrubs are burned here as fuel. Taking advantage of local Rotary organizations shall make progress easier. Already, contacts have been established in the cities of Diyarbakir and Sanliurfa. We have had our share of obstacles, but our team shall prevail to set an example for other needy communities that will benefit by using the sun's abundant and free energy.

2.0. Theory

Black body is an ideal body which absorbs or emits all types of electromagnetic radiation. The term" black body" was first coined by the German physicist Kirchhoff during 1860's. Black body radiation is a type of electromagnetic radiation emitted by a black body at a constant temperature. The spectrum of this radiation specific and its intensity depend only on the temperature of the black body. It was the study of this phenomenon which leads to a new branch of physics called Quantum mechanics (http://www.ehow.com/facts_6171588_newton_s-law-heating-cooling.html2480, accessed 12.06.2016).

According to Stefan's Boltzmann law (formulated by the Austrian Physicists, Stefan and Boltzmann), energy radiated per unit area per unit time by a body is given by

$$R = \epsilon \sigma T^4 \text{..........}(1)$$

Where R = energy radiated per area per time, Є = emissivity of the material of the body, σ = Stefan's constant = 5.67x10-8 $Wm^{-2}K^{-4}$, and T is the temperature in Kelvin scale.

>For an ideal black body, emissivity Є=1, and equation (1) becomes,

$$R = \sigma T^4 \text{..........}(2)$$

>The block diagram of experimental set up to study the blackbody radiation is given below.

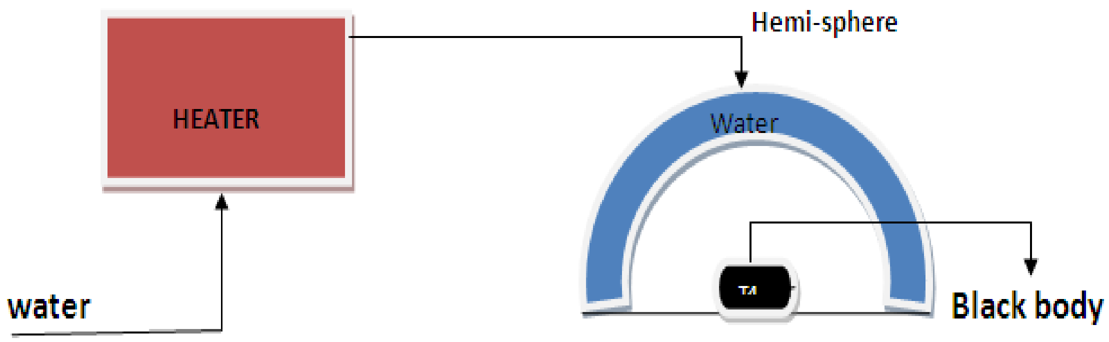


Figure9: Absorb radiation from the metallic hemisphere

>This setup uses a copper disc as an approximation to the black body disc which absorbs radiation from the metallic hemisphere as shown in figure 9 above. Let T_d be the steady state temperatures of copper disc and metallic hemisphere respectively. Now according to the equation (2), the net heat transfer to the copper disc per second is,

$$\frac{\Delta Q}{\Delta t} = \sigma A\left(T_h{}^4 - T_d{}^4\right) \text{..........}(3)$$

Where A is the area of the copper disc and $\Delta Q = (Q_h - Q_d)$.

>Now, we have another equation from thermodynamics for heat transfer a

$$\frac{\Delta Q}{\Delta t} = mC_p \frac{dT}{dt} \text{..........}(4)$$

Where ‘m’ mass of the disc, ‘C_p’’ specific heat of the copper, dT/dt is the change in temperature per unit time.

Equating equations (3) and (4),

$$\sigma A\left(T_h{}^4 - T_d{}^4\right) = mC_p \frac{dT}{dt} \text{..........}(5)$$

Hence,

$$\sigma = \frac{mC_p}{A\left(T_h{}^4 - T_d{}^4\right)} \frac{dT}{dt} \text{..........}(6)$$

We need to balance: total power absorbed = total power emitted

Total power absorbed=power per unit area x area of planet facing sun x fraction of sun light absorbed by planet’s surface.

=1,368 w/m^2 x p x (r_{earth})^2 x (1-albedo)

[Note: we use the “earth as a disc” assumption mentioned earlier to calculate the “area of planet facing sun”.]

Total power emitted= power emitted per unit area x total surface area of planet

=s x t^4 x 4p x (r_{earth})^2

Where “s” is the stefan-boltzmann constant, with a value of 5.7 x 10^{-8} watt / (m^2 x k^4)

When we set the power absorbed and the power emitted equations equal to each other, p and the earth’s radius term cancel out, so we are left with:

1368w/m^2 x (1-albedo) = 4 x s x t^4 or using earth’s average albedo of 0.31 and solving for t

T^4 = [1,368 w/m^2 x (0.69)]/4s which yields t = 254 k (=-19^o Celsius=-3^o Fahrenheit)

Stefan-Boltzmann law

The thermal energy radiated by a blackbody radiator per second per unit area is proportional to the fourth power of the absolute temperature and is given by

$$\frac{P}{A} = \sigma T^4 \; j/\,m^2 s \quad \text{Stefan-Boltzmann Law}$$

$$\sigma = 5.6703x10^{-8}\, watt\, /\, m^2 K^4$$

For hot objects other than ideal radiators, the law is expressed in the form:

Heat radiation

Thermal radiation is energy transfer by the emission of electromagnetic waves which carry energy away from the emitting object. For ordinary temperatures (less than red hot"), the radiation is in the infrared region of the electromagnetic spectrum. The relationship governing the net radiation from hot objects is called the stefan-boltzmann law:

$$P = e\sigma A(T^4 - T_C^4)$$ calculation

P = net radiated power

A = radiating area

σ = Stefan's constant

e = emissivity (=1 for ideal radiator)

T = temperature of radiator

T_C = temperature of surroundings

$$\sigma = 5.6703x10^{-8} watt / m^2 K^4$$

While the typical situation envisioned here is the radiation from a hot object to its cooler surroundings, the stefan-boltzmann law is not limited to that case. If the surroundings are at a higher temperature ($t_c > t$) then you will obtain a negative answer, implying net radiative transfer to the object.

$$\frac{P}{A} = e\sigma T^4$$

Where e is the emissivity of the object (e = 1 for ideal radiator). If the hot object is radiating energy to its cooler surroundings at temperature t_c, the net radiation loss rate takes the form

$$P = e\sigma A(T^4 - T_C^4)$$

The stefan-boltzmann relationship is also related to the energy density in the radiation in a given volume of space (Kumar, 2008).

2.1. Applications:

>Determination of temperature of Sun from its energy flux density.

>Temperature of stars other than Sun, and also their radius relative to the Sun, can be approximated by similar means.

>We can find the temperature of Earth, by equating the energy received from the Sun and the energy transmitted by the Earth under black body approximation.

www.Vlab.amrita.ed. (Accessed 06. 06.2016).

2.2. Solar Radiation and the Earth's Energy Balance.

>Solar energy and gravitational energy are the fundamental sources of energy for the Earth's climate system.

>In the ideal case (referred to as "black body") matter will absorb all the energy impinging on it in the form of electromagnetic waves and as a result will warm up and itself become a radiation source. This "give and take" of energy leads to a state of equilibrium, where the outgoing radiation balances the incoming one.

>The energy radiated from a black body is distributed over all wavelengths, in a "bell-shaped" dependence on the wavelength. Maximum energy is radiated at a wavelength proportional to the inverse of the absolute temperature.

>The total (integral over all wavelengths) energy radiated from a black body is proportional to the fourth power of its absolute temperature.

>The energy flux radiating from a point source falls of as the square of the distance from it. This is why light dims fast as one moves away from its source.

>Using these fundamental laws and knowing the Sun's temperature, we can calculate the so-called "effective" or "emission" temperature of any of its surrounding planets. This is the temperature that the plant will appear to have when viewed from outer space.

>The Earth and other planets are not perfect black bodies, as they do not absorb all the incoming solar radiation but reflected part of it back to space. The ratio between the reflected and the incoming energies is termed the planetary albedo.

>Because of its spherical shape incoming solar radiation is not equally distributed over the planet. At each instant, only the sun lights only half of the planet's surface, with maximum radiation coming in at local noon and less in other times of the day.

>The total daily radiation decreases from equator to pole. Thus the Earth's surface should inherently be warmer at the equator than it is at the poles. However,

>The Earth's axis of rotation tilts at a 23.5° away from the plane of rotation around the sun, that makes the poles point towards the sun during solstice time. This is the reason for the seasons. During solstice, the pole pointing to the sun and the surrounding area receive radiation during all 24 hours of the day while the opposite pole does not receive any solar energy. This has the potential for making the poles as warm as or warmer than the equator in their respective summer time if it were not for the large albedo of the Polar Regions. (Mahavar et al, 2011).

3.0 Methodology

3.1. Materials Used:

MATERIALS	FUNCTIONS
Aluminum foil for reflecting sun rays	For trapping sun radiations
Cardboardbox 235mmx235mmx140mm	Insulator for the aluminum foil so that heat is not lost.
Glue	For gluing the foil on a card board box.
Tape	For joining pieces that join to build a solar cooker.
One pot and lid	For cooking
Thermometer	For temperature measurements at different times.
Sunglasses	For protecting eyes from viewing strong reflected radiations on the aluminum foil.
Sharp knife	For cutting the cardboard box, tape and aluminum foil.
Black polish	For polishing the base of the cooker

3.2. Procedures:

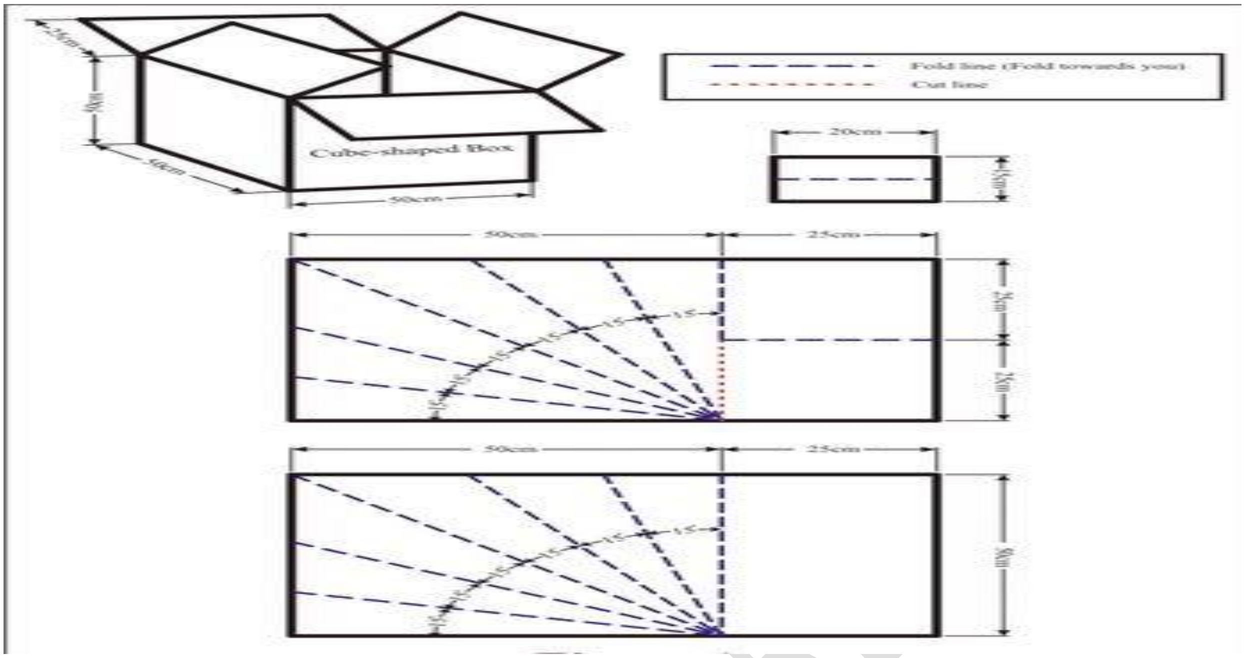
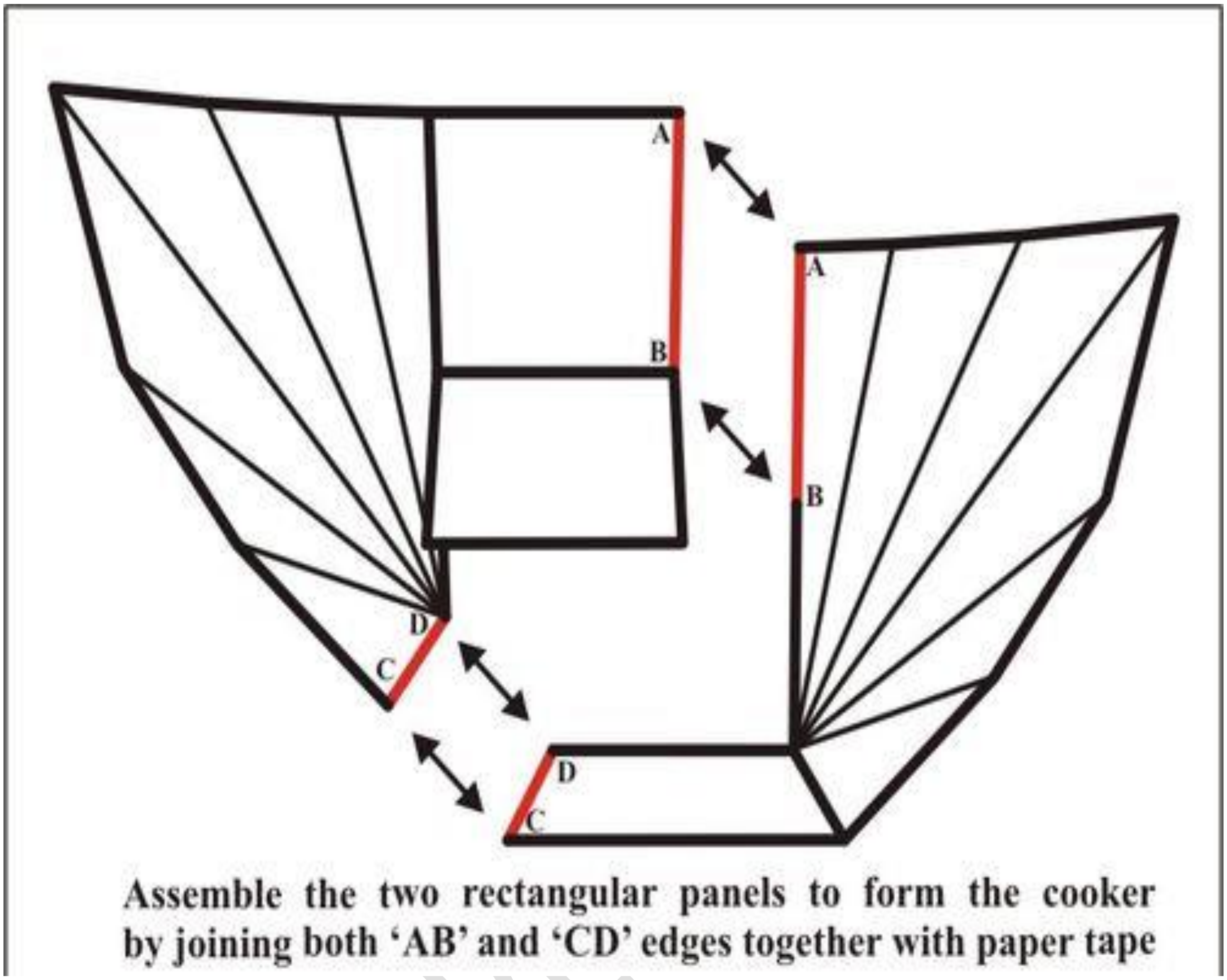


Figure10: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016). (**Fun-panel cooker**)

>The two rectangular panels were assembled to form the cooker by joining both edges AB and CD using a paper tape as shown in the figure10 above.

>The two rectangular panels were obtained from a cube-shaped cardboard box, which has 50cm sides.

>The aluminum foil was glued on one side of the panels.

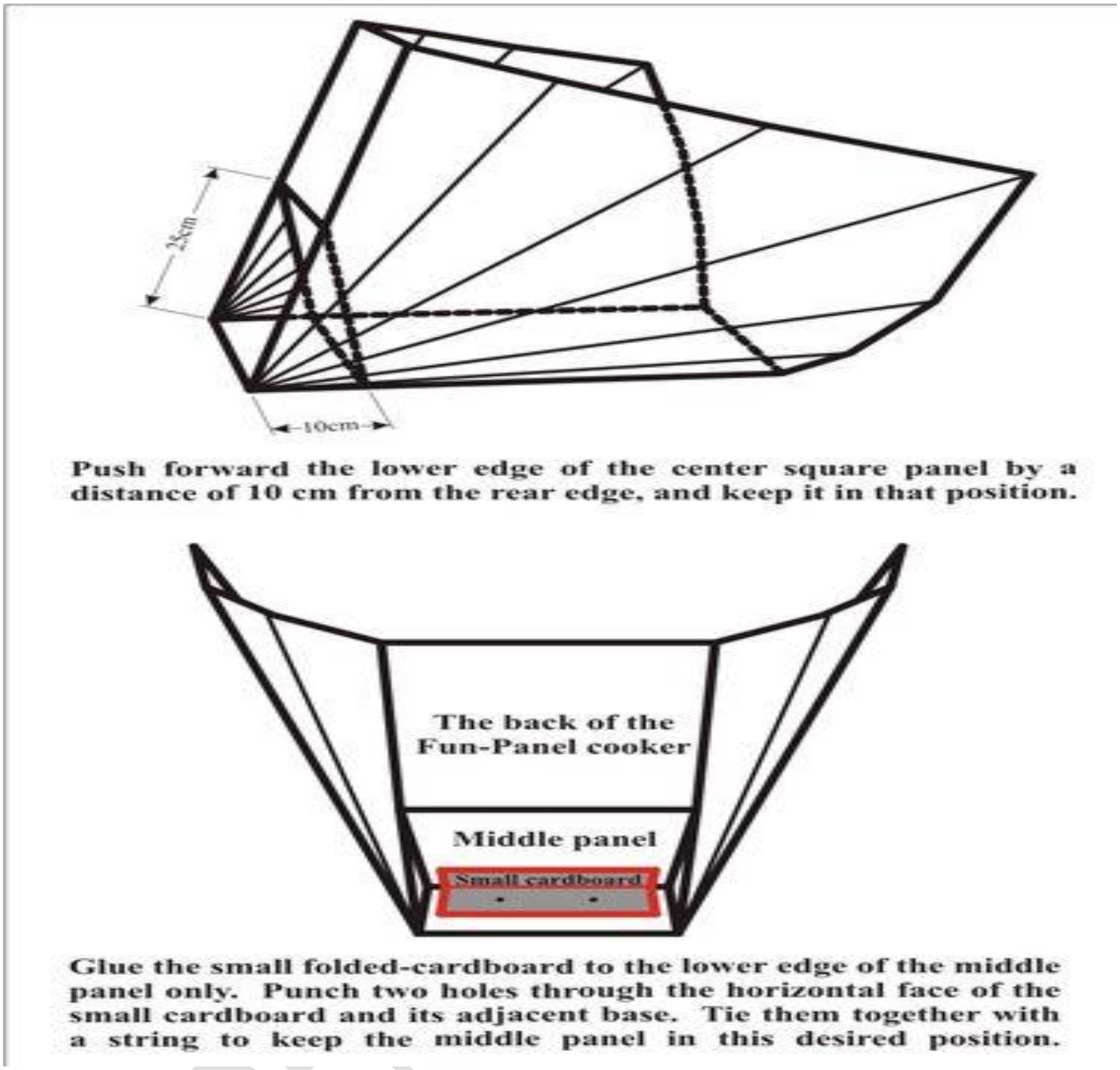


Assemble the two rectangular panels to form the cooker by joining both 'AB' and 'CD' edges together with paper tape

Figure11: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016). (**Fun-panel cooker**)

>The lower edge of the center square panel pushed forward by a distance of 10cm from the rear edge and keeps it in that position

>A small folded cardboard glued to the lower edge of the middle panel and punch the two holes through a horizontal face of a string to keep the middle panel in its desired position as shown in the diagram below:



Push forward the lower edge of the center square panel by a distance of 10 cm from the rear edge, and keep it in that position.

Glue the small folded-cardboard to the lower edge of the middle panel only. Punch two holes through the horizontal face of the small cardboard and its adjacent base. Tie them together with a string to keep the middle panel in this desired position.

Figure12: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016). (**Fun-panel cooker**)

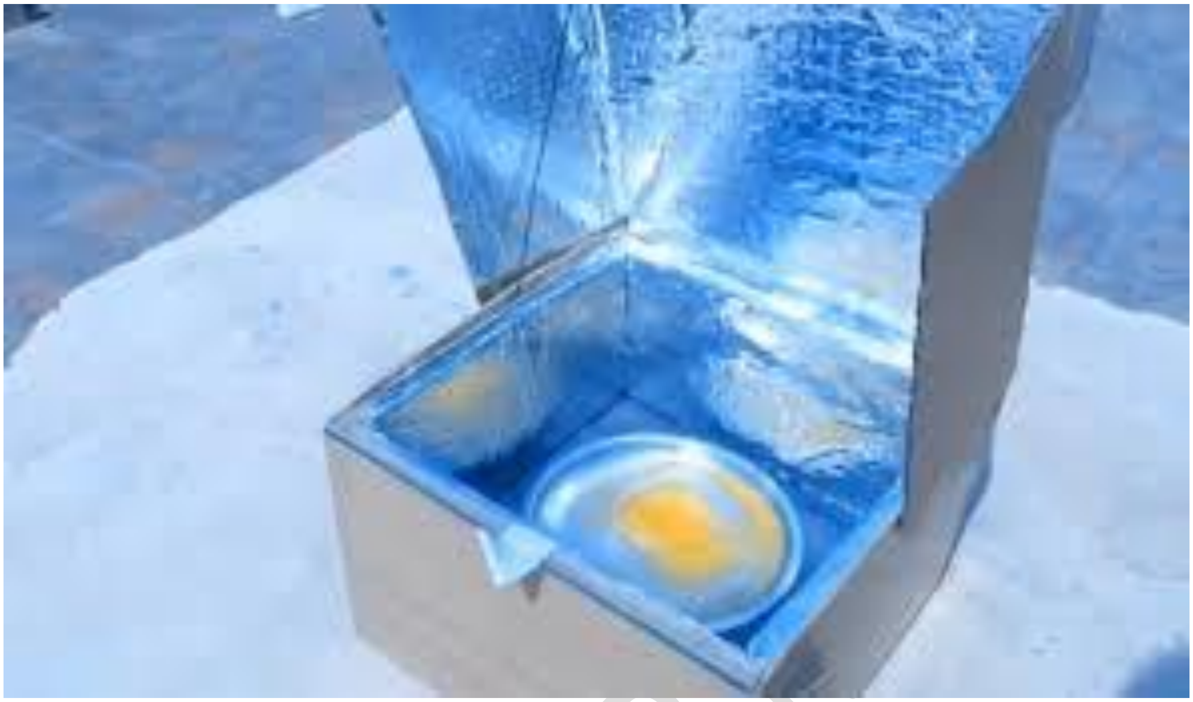


Figure13: https://www.solar cookingatlas.com/solar cooking-picture (accessed 25.5.2016).

Figure14: Solar cooker box type. Dimensions (50cm x 40cm x 30cm)

4.0. Experiment

4.1. Results.

Tables for change in temperature

Table 01: Water

	TIME	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
DAYS	Room Temp (ºC)										
MON	20	37	52	60	65	65	68	70	68	65	60
TUE	26	52	60	69	88	90	90	85	73	60	58
WED	19	40	52	65	70	65	60	63	58	55	50
THU	25	45	50	58	68	70	80	75	69	60	50
FRI	30	60	65	70	80	90	90	90	86	76	60

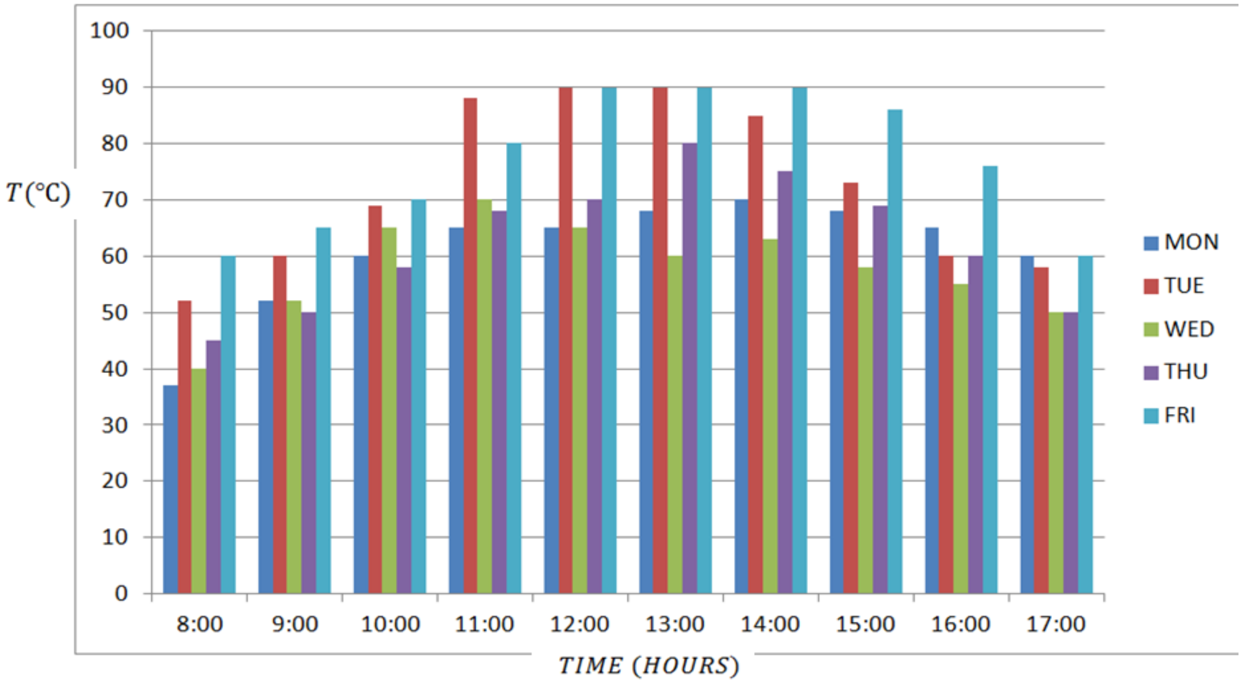


Figure 15: Temperature (^{0}C) against time (hrs) for five days for water.

The bar graph above showing the temperature variation versus time for water for five days. The trend in each bar shows a gradual increase in temperature from the beginning of the day reaches its maximum temperature of about 90^{0}C at 2:00 PM and suddenly begins to fall down from 3:00 PM to its minimum temperature of around 50^{0}C at 6:00 PM.

Table 02: Milk.

	TIME	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
DAYS	Room Temp (◦C)										
MON	26.5	37	52	60	65	68	70	68	65	60	50
TUES	27	40	50	65	70	70	75	65	63	60	55
WED	28	45	50	58	68	70	80	80	75	69	60
THU	27.2	38	40	55	62	69	75	75	69	65	50
FRI	30	40	45	58	65	70	80	80	78	68	65

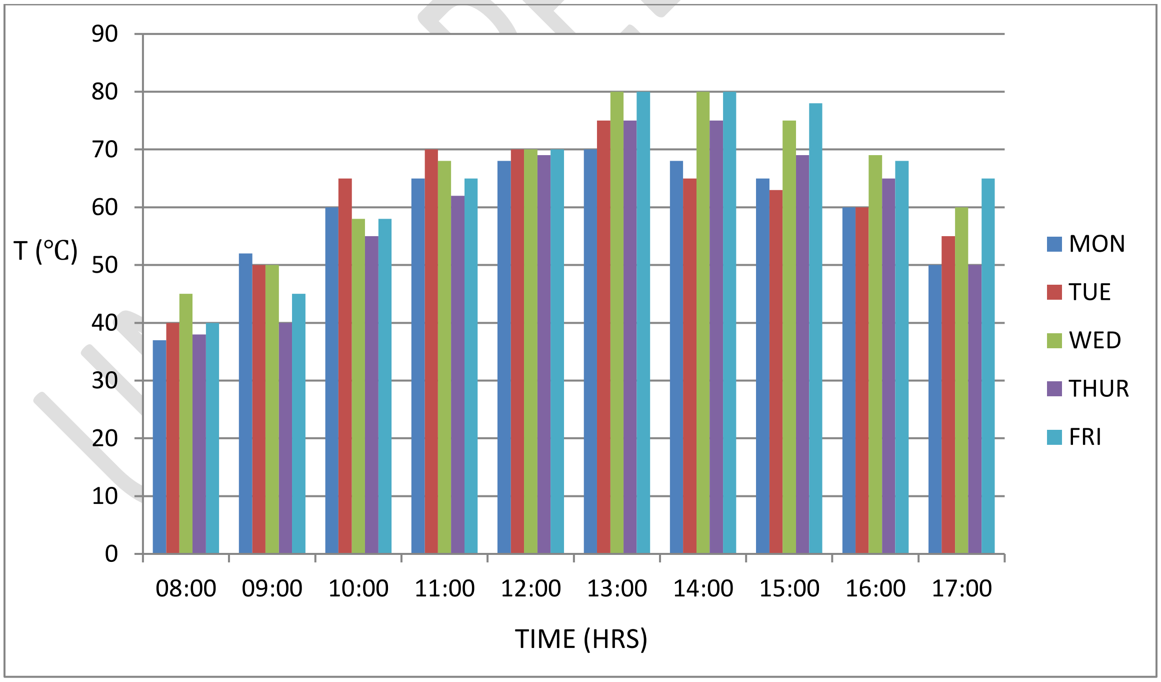


Figure16: Temperature (°C) against time (hrs) for five days for milk.

The bar graph above showing the temperature variations versus time for milk for five days. The trend in each bar shows the gradual rise in temperature from the beginning of the day and reaches its maximum temperature of about 80^0C at 2:00 PM and suddenly begins to fall down from 3:00 PM to its minimum temperature of about 50^0C around 6:00 PM.

Both figures (fig.15 and fig.16) provide us with an ideal that as the sun raises the intensity (brightness) of the sun also increases and the reflection of light and transforming of light and converting light to heat decreases.

These observations can be summarized as the intensity of light reflected and converted to heat by the solar cooker is directly proportional to the temperature change (Matthias et al, 1986).

Table 03: Days against maximum temperature

A. For water

Days	Maximum temperature
Monday	70
Tuesday	90
Wednesday	70
Thursday	80
Friday	90

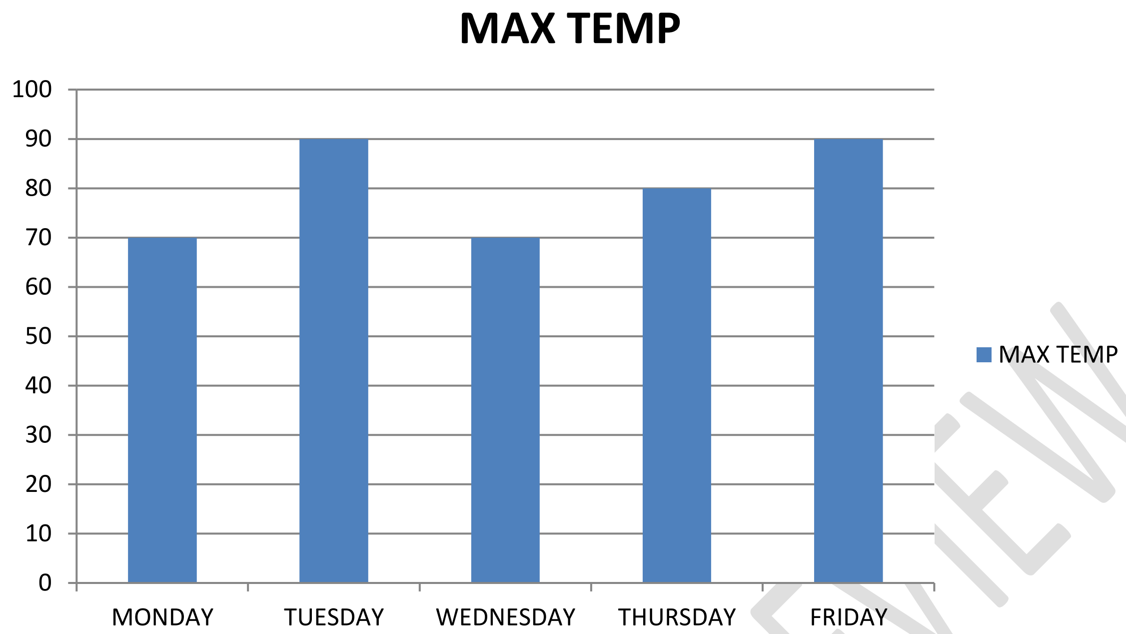


Figure17: showing maximum temperature for water.

B. For milk

Days	Maximum temperature
Monday	70
Tuesday	75
Wednesday	80
Thursday	75
Friday	80

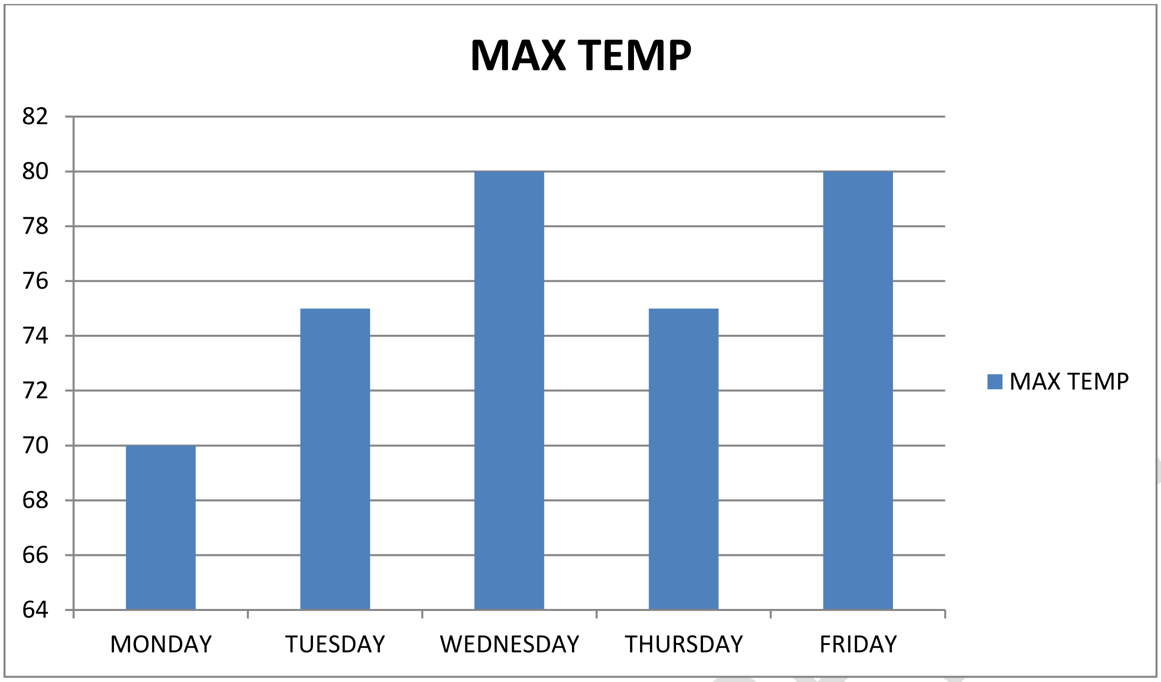


Figure18: showing maximum temperature for milk.

Heat losses during cooking

Water was supposed to boil at 100◦C, maximum temperature reached by the cooker $90℃$. Temperature lost by the cooker is 100◦C-90◦C=10◦C.

$$(10℃ \div 100℃) \times 100\% = 10\%$$

Efficiency of the cooker is given by $(90℃ \div 100℃) \times 100\% = 90\%$

Cooking angle setting**.**

The low angle setting is for looking when the sun angle is less than 60 degrees.

This chapter gives overall implications of the study and the findings already discussed in the previous chapters. Furthermore, the chapter cites discussion, conclusion about the whole study and it suggests some recommendations to the study.

5.1 Discussion

The stagnation test an empty sauce pan reached 120◦C from 30◦C after one hour. The maximum water boiling test shown one liter of water boiled up to 90◦C for one hour at 13:00pm and one liter of milk at 80^{o} C. According to test results, the cooker is more efficient at 10:30am up to 13:00pm. The result of the test shows that the cooker is efficient from 10:30am to 13:00pm. The efficiency increases with increase in suns radiations and decreases when there are low sun radiations. The sauce pan was painted black so as to increase efficiency of the sauce pan to absorb sun radiations at high rate since black body absorbs all light and reflect none. The efficiency of the designed cooker was not 100% due to the fact that aluminum reflector which its efficiency is 92%. Also other heat loss might have occurred during boiling. The design of solar cooker was successful because the cooker designed was efficient because its function was by great percent. The experiment involved the following;

>Determination of boiling and cooking rates by testing water and milk at one hour intervals.

>Determination of maximum attainable temperature by the cooker.

>Determination of effects of cloud covers.

>Heat loss during boiling

>Time taken by the boiling activity.

The results revealed that morning and evening hours sun angles a low and have low solar radiation intensity hence unsuitable for cooking. Reflector cookers have low thermal efficiency because the cooking pan is completely exposed to cooling effect at the surrounding temperature. The reflectors seem suitable in areas with low wind speed.

5.2 Conclusion

The cooker designed can boil water up to 90℃ and milk up to 80^{0}C which is also a sufficient temperature to cook light food stuffs. The objectives of the project were attained by constructing a solar cooker with 90% efficiency. We are continuing to explore methods to increase concentration, and reduce the cost and construction time associated with the device.

5.3 Recommendations

Solar cooking with all its benefits, starting from environment-friendliness to its cost effectiveness, is yet to be accepted as a viable option for cooking. The main reason for this can be traced out as; cooking occurs only in sunshine hours, no ease of cooking as the user has to wait longer for simple cooking processes like boiling, limited number of dishes that can be cooked.

While in the day time cooking will not be an issue, for the night there has to be some form of back-up energy stored throughout the day. This is achieved by selecting a material that has high heat retention capability. However recent studies show that sensible heating is not the option, even if the material has a high Specific Heat. There should an option for Latent Heat storage using phase change materials. Latent heat storage is a relatively new area of research which can be used for storing heat by changing the phase of the material (phase change material in its temperature. To improve the ease of cooking one must separate the traditional model of solar cooker that has its absorber, cooking surface and heat storage system all jammed to the same place. The design can be implemented by having an outdoor arrangement for heat absorption and storage that includes the Phase Change Material, a heat fluid which is regulated by a condenser and steam tank, and finally an indoor cooker installed inside kitchen (Nandwani & Fernandez, 1994).

Also innovations can be by designing a solar cooker which the energy from sun is stored in battery and induction stove is used for heating. This provides cooking temperature required for all types of food unlike the conventional solar (Nandwani, 2008).

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