

# Residential Solar Cooker with Enhanced Heat Supply

Srinivasan.S\*, Tinnokesh\*\*, Siddharth\*\*

\* Mechanical Engineering, Thiagarajar College of Engineering, Madurai

**Abstract-** Energy has become the utmost necessity of our life. It is required from dawn to dusk to fuel the world. Energy is scattered everywhere around the Earth. Man has always desired to capture it and use it for mankind. One of the most important sources of energy is solar energy. Several methods of capturing solar energy and its usage are practised. The intensity of solar rays is immense and ways are still being discovered to harness the full potential of the rays. Focussing the rays to a point will cause generation of heat. Transferring the energy towards cooking is one such method. Usually a solar cooker is a device that is placed in the open ground under direct sunlight. This causes inconvenience to the users. Recent developments are in progress to make it possible to cook under shelter harnessing energy from the solar rays.

There is extensive potential in the solar rays yet to be harnessed. The existing methods, apart from being inefficient in transferring energy, it fails to store the heat effectively. Introduction of Phase Change Materials (PCM) has done the trick of harnessing sun's energy to cook. By doing so the heat energy storing efficiency is increased and thereby effectively increases the process of cooking. With prices of LPG elevating, using this method proves to be cost effective and energy conserving. Unlike induction stoves, the residential solar cooker uses energy from the solar rays and is cost effective. In the absence of sunlight, the PCM setup still increases the efficiency of heating the utensils.

**Index Terms-** solar cooker, phase change material, wax, solar mini pond, parabolic point solar collector.

## I. INTRODUCTION

The present day solar cooking promises in our expense. It could promise future technology when it comes user friendly. The usage of solar cooker is not predominantly found everywhere because of its seasonal changes.

The intensity of the solar rays is unpredictable and often plays truant during rainy and winter seasons. The harnessed energy is transferred and poorly stored. This reduces the overall efficiency of the device. The time required to cook the food is increased because of lacking in heat storage.

To overcome these major problems, a new design has been devised to heat efficiently using the sunny days and as well as the other dusky situations. This device not only transfers energy efficiently and stores it for continuous usage. The PCM material layered around the vessel stores heat effectively and heats up the vessel. This helps in reducing the fuel consumption to a greater

extent during non-sunny days. The harnessed energy is not liberated thus assuring fast heating process.

## II. EXISTING SYSTEMS

### A. Box Cookers

Box cookers are the most common type made for personal use. They consist of an enclosed inner box covered with clear glass or plastic, a reflector, and insulation. There is a wide variety of patterns and plans that can be adapted to work with available materials. While they do not heat quickly, they provide slow, even cooking. Box cookers are very easy and safe to use, and fairly easy to construct.

### B. Panel Cookers

Panel cookers are flat reflective panels which focus the sunlight on a cooking vessel without the inner box common in box cookers. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds.

### C. Parabolic Cookers

Parabolic cookers reach higher temperatures and cook more quickly than solar box cookers, but are harder to make and use. Parabolic cookers require more precision to focus the sunlight on the cooking vessel. If the sunlight is not focused exactly on the cooking vessel, the food will not cook. When the parabolic oven is used, the temperature must be watched so the vessel does not overheat, burning the food. The risk of burns and eye injury is greater with homemade parabolic designs. While they provide excellent results when used correctly, they are not easy to build at home and require great care to use.

## III. DESCRIPTION

Cooking is vital and it has to be done in all places. Energy required for this operation is only from either LPG or electricity. Troubles will be faced in the production of both LPG and electricity. The effective cooking is also done by the alternative resources like solar energy which is explained below. The intact unit consists of vacuum tubes, phase change materials, cooker surrounded by the jacket, small tank, insulated tubes and parabolic collector. The system is designed with the assumptions of 5 persons in a domestic house. Vacuum cube is taken and copper tubings is done inside it. The intent for choosing PCM is that it has superior latent heat storage. The volume of phase change material is calculated. According to the pondered

volume, phase change materials are crammed into insulated cubical box. The cubical box is chosen as it has lower value of surface area to volume (SA/V) ratio compared to other standard shapes. Hence heat loss will be minimum at the night time. The copper tubes are placed inside the vacuum tube which is bent for greater surface contact and to enhance the better heat transfer and water is promulgated inside the copper tube. This entire setup is positioned in the point focus of the parabolic collector.

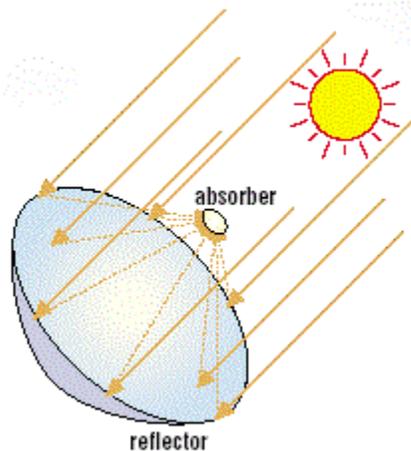


Figure 1:parabolic point collector

The area of parabolic collector is calculated by considering available solar irradiation per unit area and the energy required. Seven coils of copper tube are to be found for better surface area contact in the cube of phase change material located in the centre.since 57kg of PCM is required ,so two parabolic point solar collectors are used. The small tank is sited next to the cooker for condensation of the wet mixture. A pump is also built-in for the circulation of water and it completes one cycle. The temperature of water increases aggressively and it cooks the food in the cooker. If this system is erected in the universe, we can easily face the LPG and electrical power demand. By eliminating the usage of LPG, we can control the carbon emissions in large quantity.

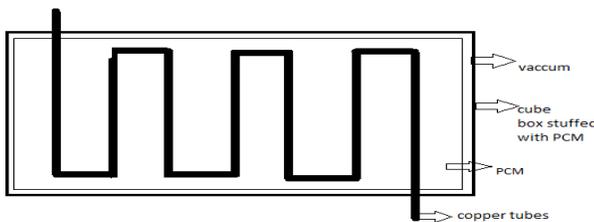


Figure 2: Cube box sectional view placed in parabolic trough

#### IV. WORKING

The entire arrangement works by utilizing heat from the solar irradiation and the efficiency relies upon the effective ways which harness the full potential of the sun. The parabolic collector is selected for the rationale of obtaining point focus in it. The parabolic collector reflects sun rays and converge it into a point where the vacuum tube packed with phase change material is positioned. Copper tubes are mounted inside the phase change material. The water as a working substance is circulated inside the copper tube which absorbs the heat extracted by the vacuum tube. In between the vacuum tube, cube of PCM is located which is well insulated from the surroundings which also plays effective role in heat transfer. Hot water is transferred to the cooker by insulated pipes to eliminate transmission heat loss. Due to the solar irradiation, water gets heated up in step by step process.since preheating is done in the first parabolic point solar collector,its is passed through non radiating pipes towards the second parabolic point collector to acquire required temperature as shown in layout Figure[3]. This hot water is made circulated through the jacket in the cooker. The small tank is sited next to the cooker for the condensation of the wet mixture of water vapour. A pump is used to drive the system of fluids. A valve is fitted for the adjusting of mass flow rate of water. This mass flowrate will controls the cooking temperature. If the mass flow rate is higher, it obtains lower cooking temperature and vice versa. This system surely meets the demand of LPG and power consumption and it also reduces pollution.The process is explained in Figure[3]

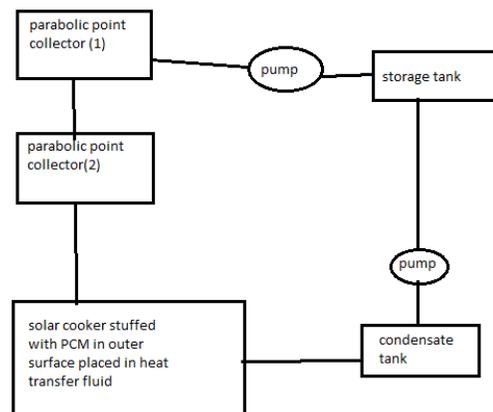


Figure 3:Model layout

#### V. .CALCULATION

##### ASSUMPTIONS:

- 1) It is assumed that 7L cooker is suited for 5 people in a house
- 2) The cooking food is considered to be water
- 3) The location for cooking is chosen to be Madurai, Tamilnadu, India
- 4) It is assumed that maximum final temperature of the food is 130-150C

- 5) Parabolic collector to be designed for PCM to attain maximum temperature of 160C
- 6) Optimum melting point of PCM is 120C
- 7) Time required to cook food during night time is assumed to be 1½ hours

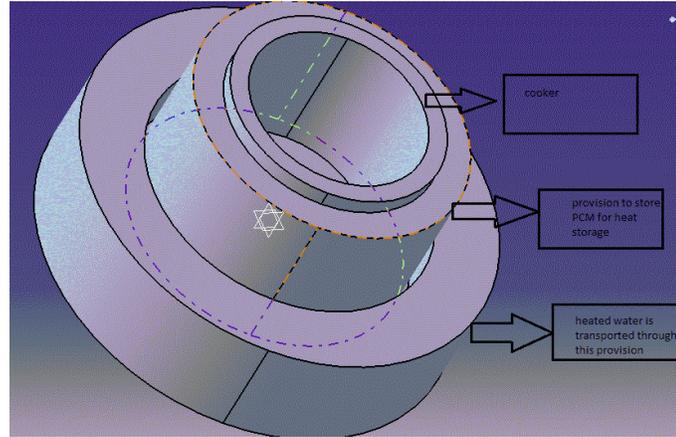


Figure 4:CAD MODEL OF COOKER

**1.ENERGY REQUIRED TO COOK FOOD:**

Volume of the Cooker  $V = 0.007 \text{ m}^3$   
 For water,  
 Density =  $1000 \text{ kg/m}^3$   
 Mass  $m = 7 \text{ kg}$   
 Specific heat (at constant pressure)  $C_p = 4.187 \text{ kJ/kg K}$   
 Initial temperature of food  $T_a = 30\text{C}$  (room temperature)  
 Maximum final temperature of food  $T_b = 130\text{C}$   
 Temperature difference  $dT = 100\text{C}$   
 Required heat energy  $Q = m * C_p * dT$   
 $Q = 7 * 4.187 * 100$   
 $Q = 2930.9 \text{ kJ}$

**2.TIME FOR BACKUP**

Due to absence of sunlight during night time cooking, let maximum time required to cook during night time = 1 ½ h

**3.TEMPERATURE:**

Maximum Cooking temperature  $T_1 = 150\text{C}$   
 Maximum temperature of PCM  $T_2 = 160\text{C}$

**4.PCM SELECTION:**

Required melting point of PCM =  $120\text{C}$   
 Name = S117  
 Melting point =  $117\text{C}$   
 Density =  $1450 \text{ kg/m}^3$   
 Latent heat  $L = 160 \text{ kJ/kg}$   
 Specific heat capacity  $C_p = 2.61 \text{ kJ/kgK}$   
 Thermal conductivity  $k = 0.7 \text{ W/mK}$

**5.MASS OF PCM REQUIRED:**

Heat energy required to boil 1L  $q = 291.14\text{kJ}$   
 By experiment,  
 Time taken to reach boiling point of water = 20 min  
 For 20 min energy supplied =  $291.14 \text{ kJ}$   
 Let us assume backup time  $t = 1 \frac{1}{2} \text{ h}$   
 For 1 ½ h energy required  $Q = 1310.13 \text{ kJ/L}$   
 For 7 Litre,

Total energy required  $Q = 9170.91 \text{ kJ}$   
 $Q = m * L$   
 $m = Q/L$   
 $m = 57\text{kg}$

57kg of PCM can be filled in 77.11cm side of cube .but we have used two parabolic point collector troughs,so two evacuated cubes with copper pipings is made.eventually a cube has a side of 36 cm(approx).two cuboids are used because of getting PCM to obtain its phase change temperature quickly .

**7.DESIGN OF COIL ASSUMPTIONS:**

- \* Copper pipe diameter  $d = 12 \text{ mm}$
- \*Coil diameter  $D = 150 \text{ mm}$
- \* Free gap  $G = 10 \text{ mm}$
- \*No. of turns  $n = 7$
- \*Secondary Length of the coil  $l = 100 \text{ mm}$
- \* Total length of the coil,  
 $L = n * ((2 * \pi * r) + G) + (2 * l)$   
 $L = 53 \text{ cm}$

**8.MASS OF CO2 EMISSION BY LPG;**

LPG contains 70% propane and 30%butane  
 The chemical reactions are:  
 Propane :  
 $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$   
 Butane:  
 $2\text{C}_4\text{H}_{10} + 13\text{O}_2 \rightarrow 8\text{CO}_2 + 10\text{H}_2\text{O}$   
 By atomic weight calculation,it is found 1 ton of LPG emits 3.04 ton(approx)

**FURTHER WORK:**

Since cooker is covered with PCM for cooking at night time with enhanced heat supply system.we can make it to keep fresh to serve by incorporating PCM inside cooker ,at surface where it is supposed to ignited.CAD drawings of proposed further work is shown here in Figure[5].PCM is filled in some extended surface which doesn't affect the cooking methods helps to utilize the waste energy and make it Go Green.

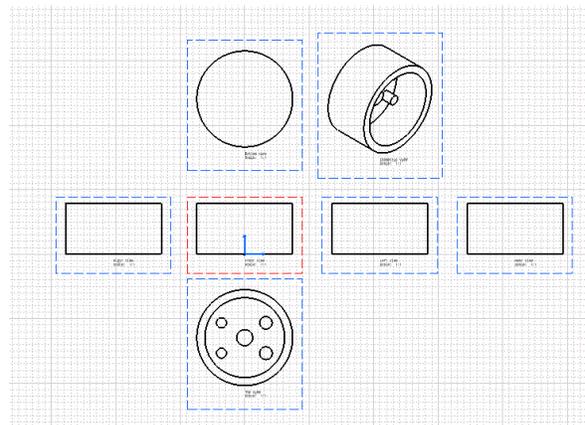


Figure 5:proposed work draft model

**RESULTS AND DISCUSSION:**

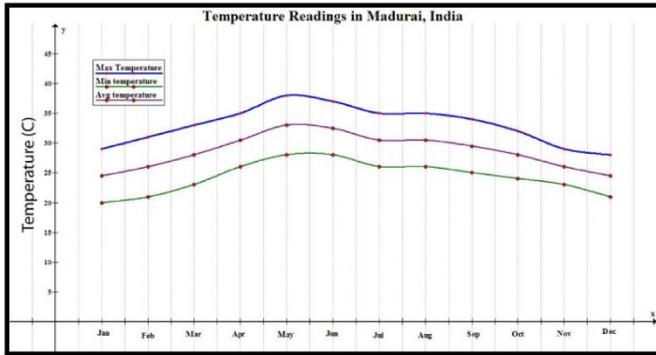


Figure 6: temperature reading in madurai

The above graphs shows the temperature readings in Madurai with average day time temperature as maximum temperature and minimum temperature to be a night time temperature. This graph shows that there will be enough solar irradiation in the tropical regions especially in India to implement the steam cooking which is more suitable for houses and also hotels.

## VI. CONCLUSION

The calculation is performed for above all assumptions and the total system is designed for the domestic house. From the graph, it is found that the average day temperature of Madurai is 35degree celcius.

## REFERENCES:

- [1] <https://pcmenergy.org>
- [2] [www.solarcookers.org](http://www.solarcookers.org)
- [3] solar engineering by tiwari
- [4] [http://en.wikipedia.org/wiki/phase-change\\_material](http://en.wikipedia.org/wiki/phase-change_material)

First author: Srinivasan.S, mechanical engineering, thiagarajar college of engineering, srinivasan648@gmail.com

Second author: Siddharth, mechanical engineering, thaigarajar college of engineering, kesiddhu23@gmail.com

Third author: Tinnokesh.A.P, mechanical engineering, thiagarajar college of engineering, tinnomath@gmail.com

Correspondence author: Srinivasan.S, srinivasan648@gmail.com, 8903422923

hence it meet the cooking requirements by adopting the above design. The drawbacks in this system will be little more investment than other systems. But the payback period will be few years which total cost of cooking will be only the maintenance cost of the system. By improving the design of vacuum tubes, PCM selection, tracking mechanism collector shapes etc., will have a great scope in market.

As our demand for LPG and electrical energy are escalating day by day, the amount of fossil fuel will become scarce on one day. By implementing this system, it eradicate for cooking in night time. the overall system will work only during the daytime then it will not be compact and there will be cooker in each and every house will replace LPG and electric stove. Installation of this system in India reduces more than millions of temperature can be greatly reduced in the future. to this hectic world. The effects of thermo physical properties of PCM, installation methodology, location of pcm are scope of future work.

## ACKNOWLEDGEMENT

We hereby declare that the paper above is our own thoughts developed into a model and working for future works.