# Solar Cookers and their Present Global Status: A Review

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## Abstract

Nowadays, peoples in the world concentrate on energy, the environment. Presently developing countries are rising concerned about deforestation and finding alternatives to non-renewable energy sources. In recent times developing countries utilize a large percentage of solar energy as a power requirement. Solar cooking contributes to energy saving in the world, control of indoor pollution in homes, cost-saving, and preserving non-renewable energy sources for the future, and also maintaining the earth's global temperature. Solar Energy is the most promising and suitable option to meet energy demands in the cooking sector. But its widely used is remains limited. Most works in solar cookers are studied for research purposes only. In this paper, an effort has been made on various types of solar cookers Design, materials, and present conditions. Eventually, different appropriate technology is explained for future analysis in solar cooking, and Various performance parameters, like FOM, and the power of the cooker are also considered.

**Keywords**. Solar cooker, Figure of Merits(FOM), Manual solar cooker, cooking power, etc.

## 1. INTRODUCTION

Sunlight an immense origin of heat and generates vitality at the rate of $3.8 \times 10^{23}$ kWh in the form of radiant Energy with the help of a nuclear fusion reaction [1]. Solar energy application is immemorial from the origin of human beings on earth. The life of people relies on energy production and its utilization that affects the supply and demand of society. A large amount of Energy depends upon non-renewable sources like fossil fuels, firewood, animal dung, agriculture waste, etc. while the Energy comes in urban places by petroleum and LPG. In the twenty-first century, 82% of world energy comes from the burning of fossils fuels, which results in increased greenhouse gases, global warming, release pollution, and decreases the ozone layer in the environment and more chances of environmental risk therefore to protect the environment it is essential to a renewable source of Energy [2]. The world health organization (WHO) predicts that 4 million people prematurely die due to minute particle pollution that is effect in cooking along the burning of conventional fuels in homes [3]. Solar Energy is the most suitable option for thermal application and is also present in the most abundant quantities among all renewable energy sources [4]. Cooking is essential for the human being and also the life human will depend upon on cooking. However, with increment in population and depletion of resources, food will be scarce in the future [5]. The solar cooker has significant potential to overcome the exhaustion of

conventional fuels in cooking. However, to increase curiosity in solar cookers, therefore required to develop a different type of solar cooker, specific customer needs, satisfaction, economics, and climate condition [6]. Solar cooking is a trouble-free and peculiar method to cook food and sunlight is drop down on the earth. This technique is very constructive in a developing country where the people will depend upon the availability of solar radiation in these regions, where most common peoples people used resources for cooking [7]. Pasteurization and sterilization processes take place in solar cookers. Therefore, researchers are regularly modified solar cookers to increase their performance [8]. In India, only 36% of energy is utilized in solar cooking. solar cooking is the most convenient option due to its economical and extensible [9]. Almost heavily populated countries are blessed in the world with a sufficient amount of solar radiation with a daily mean value between 5 to 7 kWh/$m^2$ and 274 bright days in the year [10]. Conventional fuels increase carbon dioxide by 1.07% in the short period and 1.9% in the long period respectively [11]. In the contemporary scenario, the average annual energy used is increased by 1% in advanced countries, 5% increases in developing countries, and becomes an economic development of their nation. [12,13]. The purpose is to provide information and strengthen the current accomplishment of solar cookers and their future potential.

## 2. WORKING PRINCIPLE

Solar power cooker changes solar radiation towards thermal Energy. This thermal Energy is utilized to prepare food, which is kept inside the cooking utensil. [14]. This trapped heat is present inside the container used to assist in heating and converting it into healthily cooking food. There are three modes of heat transfer in which solar cooker works are concentration, absorption, and retention [15]. The simple flat solar cooker is the cheapest and a temperature 100-150°C (300 F). The sun's radiant energy incident on the glass cover and reached at bottom base. The inside air gets heated due to the contact of the bottom plate, heats, and transfers its thermal energy to the food present inside the pots.

The bottom plate of the solar cooker should be made of black material in order to transfer maximum heat to the utensils (pots). To minimize heat, condition a single transparent window must be replaced with a double transparent window. Reflective glass is used to maximize the incoming solar radiation which can be varied from 0° to 120°. Also, the box must be made like airtight via possible, by decrease the hot airflow from inside to outside. [14].

## 3. CLASSIFICATION

In the current situation of renewable Energy, scientists and researchers working on the efficient design of solar cookers. The classification of solar cookers is a difficult task. Therefore, solar cookers are reclassified into two main categories one is an automatic type of solar cooker and the other is a manual solar cooker which is evidenced in diagram. Generally, box-type cooker and concentrating cooker is mostly used in cooking applications all around the world. [16].

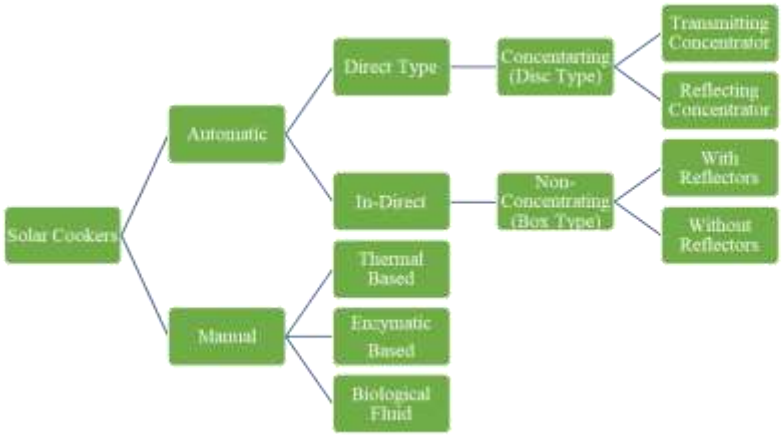


Figure 1. Classification of solar cookers [16]

## 4. TESTING AND PERFORMANCE

Solar cooking is an inspiring technology showing signs of future success and uninterrupted application of solar Energy. The availability of solar Energy and its sustainability in the environment become the most suitable option for energy supply non-renewable energy sources. Therefore, most people are interested in increasing the performance of the solar cooker [17]. Existing International testing standards are applied to estimate the performance of a solar cooker. There are three types of international standards used for testing solar cookers. These are (i) American Society of Agricultural Engineers Standard (ASAE, 2003), (ii) Bureau of Indian Standards Testing Method (BIS 2000), and (iii) European Committee on Solar Cooking Research Testing Standard and others (ECSCR, 1994) [18]. The Figures of merits, Standardized cooking power, and cooking efficiency terms were used to predict the performance of the solar cooker [19]. The figure of merit $F_1$ is described as the ratio of optical efficiency to the heat loss factor by absorber plate and the measure of the differential temperature gained by the absorber plate at a particular level of solar insolation. $F_2$ is more or less independent of climatic conditions and indicates heat transfer from the absorber plate to the water in the containers placed [20]. The first figure of merit, $F_1$, is calculated with the help of a stagnation test under the no-load condition. The second figure of merit, $F_2$ is calculated under full load conditions when water is taken in pots, and reflector is not considered in this test [21]. $F_1$ is based on stagnation-load at without load which is empirically shown as

$$F_1 = \frac{\eta_o}{u_L} = \frac{(T_P - T_\infty)}{I_S} \quad (1)$$

($F_2$) is based on complete load and is mathematically expressed as:

$$F_2 = \frac{F_1(mc)_W}{A(t_2 - t_1)} \ln\left[\frac{1-((T_{W1}-T_\infty)/F_1 I_a}{1-((T_{W2}-T_\infty))/F_1 I_a}\right] \quad (2)$$

The higher value of the figure of merits ($F_1$ and $F_2$) is used in healthy cooking. The temperature range of $T_{W2}$ between 90 to 95ºC and $T_{W1}$ should be taken between ambient and boiling temperatures. From experimental data, it concluded that the water quantity depends on the F2 test in solar cookers. Hence performance tests depend on the amount of water to be taken. The lower limits of $F_1$ and $F_2$ are preferred in order to satisfactory accomplishment

of solar cooker. The eligibility criterion for qualified ISI mark in solar cooker the value of $F_1$ should not than 0.12 and $F_2$ should greater than 0.40[22].

Standardized cooking power- Express in terms of following equations.

$$P = \frac{T_{W1} - T_{W2}}{t} mc_w \quad (3)$$

Where, T∞ is ambient temperature (K), $T_p$ is plate temperature (K), Is is solar insolation, (W/m2), $T_{w1}$ is beginning temperature of water (°C), $T_{w2}$ is finishing temperature of water (°C), P is standardized cooking time to 700, (W/m2), mcw is quantity of water multiplied by specific heat (J $°C^{-1}$), $U_L$ is heat loss factor, $\eta_o$is efficiency of solar cooker, Ia is average solar radiation (W/ $m^2$).

## 5. Studies and Advancement in Solar Cooking System Design Features Over Recent Times

In the modern world, many researchers are focused on creating new designs, geometry, and material to increase the cooking power, and efficiency of solar cookers. Mullick conceived and built a box-style solar oven in 1987, the outer body is made from teakwood, the inner body from aluminum sheet, and the cooking pot is aluminum. Carried the thermal test on solar cooker under different climate conditions and various food and formed the figure of merit ($F_1$ and $F_2$) [36].

Hot-box solar cooker developed for late evening purpose. The material used is a galvanized, aluminum sheet for the outer and inner body, having double walled. A 5kg used engine oil is filled between the inner body and sealed for storage purposes. The maximum stagnation temperature is found to be the same as without storage during the day, the temperature in the storage cooker is raised by 23°C from 1700 to 2400 h, and the efficiency is reported to be 27.5 percent. [10]. Mahavar et al created a small-scale solar rice cooker in 2012 from transparent acrylic (PMMA) thickness of 2.75 mm with an air gap of 13 mm. solar cookers made from opaque material have the disadvantage of the maximum area of the container covered with shadow this leads to increases thermal stress and non-uniform heating. In this work, the radiation enters from the top and horizontal sides of the solar cooker. therefore, increasing the thermal performance of the cooker. The maximum temperature reaches 144°C and cooking 103.5 W. Acrylic and polycarbonate materials have been shown to be appropriate for glazing materials. [23]. Kumar used geometry and Design and build a solar oven with a truncated pyramid shape. the main purpose of this solar cooker was it acts as a dryer for domestic uses, the principle behind was to increase the absorber tray temperature due to its geometry Sunlight falls and is reflected with high intensity in order to maintain a higher temperature. Maximum temperatures of 140 °C and 98.6 °C were attained in the no-load and full-load water conditions, respectively. [26]. Namrata et. al fabricated a masonry and cement plaster solar cooker having a cylindrical shape in 2011. Comparative thermal performance results show that a building-material-housing solar cooker (BHMC) is slightly better than a commercially solar cooker (CSC) [29]. Verma manisha et. al developed a solar cooker made of hardboard for the nuclear family in 2011 and tested on a hot climate for various food. Concluded that it was suitable for the nuclear family due to low cost, less weight as also compared to other good cooking capacities [30]. In 2018 The box-type solar oven, developed and produced by Yettou, is made out of a wooden box. for the hot box, as well as a mirror, aluminium is used for making absorber plate painted black with inclined

area has many benefits When compared to traditional box cookers, expanding the horizontal width improves the amount of sunlight falling on the solar cooker and minimises the level of shadow falling on the absorber. Trials were performed with 2 kg of water in the cookers from 08:00 to 15:00 solar time. Temperature gain in the box-type solar cooker was around 69.8° C during the testing. [24]. In 2018, Ademe introduced a box-style solar cooker with a glazed wiper function. The outer wall is made of a single-walled cardboard box of 50mm. A 1.5 mm thickness iron sheet using for making the inner box. The gap between the outer and inner box is filled with compressed sawdust (insulator) 50 mm thick. Three-reflector is used in this mechanism, the inner one is composed of a 1.5 mm thick iron sheet. The tilted intercept is controlled from the horizontal plane. The foam strip is attached with the exterior glazing and thin threads to the back and front side wooden sticks. The ASA International Test Procedure and the Bureau of Indian Standards were used to evaluate thermal performance. Without a wiper mechanism, $F_1$ = 0.123 $Km^2/W$, $F_2$ = 0.540, the standard cooking power 36 W, and the total efficiency is 22%. With wiper mechanism, $F_1$ = 0.123, $F_2$ = 0.827, standard cooking power 51 W, and a total efficiency of 31.4%. [28]. Mohamad Zeeshan Siddiqui developed a unique design a solar oven that combines the functions of cooker and dryer in a single unit, and conducted an outdoor experiment for evaluating performance. A separate section was made for the cooker and dryer and connected with a small opening provided for air passage to transfer lower portion higher temperature to upper portion higher temperature, which behaves as with a dryer, the air is moved across the box by buoyancy-driven free convection flow. The temperature values of the solar cooker segment were (80 °C – 135 °C) and the dryer segment was (35 °C – 65 °C) under the same environmental conditions. The $F_1$ and $F_2$ were found to be 0.11, 0.303. Utilization factor, COP, and drying performance were calculated to be 34%, 66%, and 14%. [27] Saxena modified the solar cooker and introduced a hybrid design in 2018. To enhance the overall movement of warm air within the cooker, a trapezoidal shape duct is placed Inside the duct is a cooker and a halogen light bulb. Also, spherical balls were kept inside the box. The author found that with these designs the overall efficiency increases from 38.10% to 45.11 [31]. Some researchers also concentrated on improving the Design of solar cooker vessels/pots/utensils and considered very crucial parts of solar cookers and their effects on these parts analyzed [32-35]. Hermelinda presented newly designed pots and applied them to the different numbers of pots to test their thermal performances and found that 35%, 16%, and 12% for first, second, and third cooking pots designs, respectively [36]. In 2019 Samdarshi used a technique to maximize the cooking performance of solar cookers by improving the Design of cooking utensils/pots. In this pot which is made up of stainless steel, the top middle surface of the box is replaced with the glass using an appropriate high-temperature sealant. The heating performance of the box cooker increases due to capture from the top of cooking pots as well as sides of cooking pots [37].

Concentrate type of solar cooker used due to its faster cooking ability and the high-temperature range than simple box cooker. It is based on the three-dimensional parabola principle when directed into the sun and reflected onto the focus.

Badran used reflective aluminum thin foil in a dish satellite for making a portable parabolic solar cooker. Cooking and heating were two fundamental considerations for the analyzed solar cooker. In the cooking method, the pot placed inside the glass box and uncovered pots were analyzed deeply, whereas, in the heating method, the heat transfer of heat energy with the help of a collector [44] Regattieri builds a parabolic-type solar cooker out of a cardboard

box that was previously applied for mankind's relief material and logistic support to the public who need help. The main aim is to utilize the waste cardboard, and performances are measured through the elephant test and disc solar cooker test. The various shapes are tested, and the best result is obtained from parabolic geometry, and efficiency was about 14–18%, like of raw fire [49]. Masum Ahmed used stainless, thin aluminum baffles and mayer tape. For making concentrating solar cooker. Heat conduction takes place in the aluminum vessel cast black is more prominent. This material is easily available and provides good results in cooking food and the efficiency of solar cookers. After conducting the experimental test on parabolic solar cookers with Mylar tape and results showed that reflective materials better as compared to others [56].

**Contribution of some legendary researchers in Concentrating-type cookers.**

| **Work** | **Highlighted Feature** |
|---|---|
| El-Kassaby 1991 | Developed solar cooker which employs for cooking and distillation of water. the shape of the cooker is a parabolic square dish type. If the bottom portion of the pot of the solar cooker is maintained black then efficiency is increased by 30%.[25] |
| Patel and Philip (2000) | Consider three types of concentrated solar cookers and conclude that the Fresnel reflector cooker is better than the parabolic type [38] |
| Oztürk (2004) | Performances of solar cookers were found, 2.8–15.7% and 0.4–1.25% in terms of energy and exergy[39] |
| Pohekar and Ramachandran 2006 | The author described that liquefied petroleum gas (LPG) performance is fast as compared to other cooking devices [40]. |
| Kaushik and Gupta (2008) | Predicted the enhancement of different geometry with Exergy analysis. [41]. |
| Sosa-Montemayor (2009) | A coffee device was developed using a small circular TV dish [42]. |
| Al-Soud et al. (2010) | A biaxial sun tracking system and programmable logic controller were used [43] |
| Badran et al. (2010) | Designed and developed truncated cone-shaped receiver at the focal point made from copper [44]. |
| Purohit and Purohit 2011 | Instruments error around 1-5.5% on solar cookers thermal performance [45]. |
| Prasanna and Umanand 2011 | A new technique is used for circulating the fluid in a kitchen in the form of solar Energy [46]. |
| Huang et al., 2013 | The various optical error was found under the typical condition to maximize the solar power energy to net head efficiency. The results of the experiments revealed that a concentrate-type solar cooker with a spherical receiver had the highest solar energy efficiency [47]. |
| Suple And Thombre, 2013 | A tracking system is used for a concentrated type cooker using the circular disc for indoor cooking [48]. |
| Regattieri 2015 | Modified portable solar cooker using waste cardboard packing the function of this cooker is heating, cooking food, and filtration of raw water and rivers [49]. |
| Krishnan 2015 | Developed disc type solar cooker and found that faster ability to cook food at a specified time with the help of solar radiation [50]. |

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|---|---|
| (Akoy and Ahmed, 2015). | Different solar cookers were fabricated and their performance was examined. The highest temperature was achieved at 86.5 °C for a concentrated solar cooker, 52.36 °C for a simple box cooker, and 43.5 °C for a panel cooker.[51]. |
| Wimmer et al. (2017) | Consider different types of the solar cooker and research on public views on why solar cooker is not used in Austria and Thailand [52]. |
| Indora and Kandpal 2018 | Provides institutional parabolic solar cookers for cooking food also concentrated on features of the economy [53]. |
| Sagade et al. 2018 | Obtained technique for calculating Rating in various box cooker and concentrating type solar cooker using experimental data [54]. |
| Jayaleka 2020 | Working on Spiral Concentrating solar cooker and calculated Optical efficiency and instantaneous efficiency. the overall efficiency found to be 73.5% [55]. |
| Masum Ahmed 2020 | The important objective of this type of cooker is to use various reflective materials to concentrate the solar radiation into thermal Energy [56]. |

These are the calculated results of the researcher on various materials in which tests are conducted in a solar cooker to increase the performance of solar cooker in the world to provide an alternate solution for conventional fuel in the world. These values depend on cooking power, figures of merits, efficiency, temperature, etc.

## 6. CONCLUSION

Solar cookers' present circumstances are focused on increasing their thermal performance and efficiency. Another parameter is also kept in mind regarding safety issues in solar cooking and awareness among the public on how to use the solar cooker and how it is very beneficial for public health and eco-friendly nature. The conventional fuel costs also increase day by day therefore alternate options for cooking. To develop solar cookers for practical purposes, stimulate studies, an experimental approach is needed to find out the most appropriate with different geometries, different materials to improve performance with aesthetic looking and economic costs, and socially acceptable geometry and Design. Reflector can be increase to maximise solar cooker performances and Double glass also used to reduce convection losses. Further studies are also needed regarding the portable transparent solar cooker with time constraints, and it is excellent for when you are working outside from home, and you do not want to waste time in the kitchen.

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