

# An Overview of Solar Cookers

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## Abstract

This paper presents a short review on different types of solar cookers. Several attempts have been made to introduce solar cookers in different countries and have achieved asymmetrical successes. There are still critical issues so far to be resolved in order to make the technology acceptable for wider propagation. They include getting the most appropriate types of solar cookers for specific locations, optimum size/capacity, types of materials to be used, optimal

design and affordable cost. In an attempt to resolve these issues, a comprehensive study involving theoretical review, development work, experimental testing and evaluation of solar cookers was conducted for several years on different types of solar cookers. This paper throws light on features, limitations and feasible applications of different solar cookers. This helps the consumer in selecting most effective and appropriate solar cooker.

**Keywords:** Solar energy, box solar cooker, SK-14, PRINCE-15, solar concentrator.  
like is acute. Variations.

## I. INTRODUCTION

Solar cooker is a device that cooks food using only sun energy in the form of solar radiation. The solar cooking saves a significant amount of conventional fuels. The solar cooking is the simplest, safest, clean, environment friendly, and most convenient way to cook food without consuming fuels or heating up the kitchen.

A major concern of today is the rapidly depleting natural resources. So it is the urgent need of time to reduce the dependency on non-renewable sources, judiciously using the remaining sources and at the same time switching to new and better alternatives and renewable source of energy. [1,2]

In most parts of India, solar energy is available almost throughout the year and can be used as alternate input to meet out energy needs. Solar energy is the cheapest, inexhaustible and can be used for various domestic and agricultural requirements including cooking, drying, dehydration, heating, cooling and solar power generation [3].

Solar cookers have a long history dating back almost 18<sup>th</sup> century when Nicholas-de-Saussure built first ever Solar Box Cooker. Today there are about 60 major designs and more than 100 of however the solar cooking has not caught the imagination of peoples, except in places where shortage of conventional fuel like fire wood and the

Cooking Energy Scenario in India	
URBAN SECTOR	RURAL SECTOR
• LPG (47.96%)	• Firewood (64.10%)
• Firewood (22.74%)	• Other sources of biomass –crop residue (13.10%)
• Kerosene (19.16%)	• Cow-dung (12.80%)
• Other fuels(10.14)	• LPG (5.67%) is now Increasing in importance.

Solar cookers have attracted the attention of many researchers so far. Different types of solar cookers have been developed and tested all over the world. Today, there is challenge to manufacturing and evaluation of efficient and cheap solar cookers. There has been a considerable interest recently in the design, development and testing of various types of solar cookers. [3]

## II. REVIEW OF SOLAR COOKERS

Cooking with the energy of Sun is not a new or novel idea. According to the Halacy and Halacy

(1992) the first Scientist to experiment with solar cooking was a German Physicist named Tschirnhausen (1651-1708). He used a large lens to focus the sun's rays and boiled water in a clay pot.

His experiment was published in 1767 by a Swiss Scientist Horace de Saussure who also discovered that wooden “hotboxes”, he produced enough heat to cook fruit. French Scientist Ducurla improved on the hot box design by adding mirrors to reflect more Sunlight and insulating box. [4]

#### The Solar cookers are needed due to

1. High cost or Unavailability of commercial fuels – Kerosene, Coal, cooking gas and Electricity.
2. *Deforestation* caused by increasing firewood consumption.
3. Use of dung and agricultural waste as fuels instead of for *soil enrichment*.
4. Diversion of human resources for fuel collection.

#### Advantages of solar cooking

1. No attention is needed during cooking as in other devices.
2. No smoke evolution, thus clean.
3. No pollution, thus environment friendly.
4. Vitamins of food are not destroyed; therefore, solar cooked food is with natural taste, aroma and healthier.
5. No soot accumulation on pots.
6. Available every day, thus *renewable*.
7. Solar Energy does not contribute to global warming, acid rain or smog.
8. Solar Energy systems are maintenance free and long lasting.

#### Disadvantages of a Solar Cooker

1. Many solar powered cookers are large and bulky to carry.
2. More time is required for cooking process.
3. Initial cost of efficient solar cooking system is high.
4. Solar energy concentration is influenced by the presence of clouds or pollution in the air.
5. Food cannot be cooked at night.[5]

#### Principle of Solar Cooking

Most solar cookers convert sunlight to heat energy that is utilized for cooking. The ability of a solar cooker to collect sunlight is directly related to the projected area of the collector perpendicular to the incident solar beam radiation. The geometric concentration ratio is defined as

$$CR = \frac{A_t}{A_{rc}}$$

$A_{rc}$  is the area of the receiver/absorber surface [6].

#### Types of solar cookers

A survey of solar cookers worldwide shows that a wide variety of cookers have been designed. However, the available designs of solar cooker fall into four main categories namely, the solar box cookers or popularly known as solar ovens, panel cookers, collector cookers and concentrating or reflector cookers. The feature common to each design is the shiny reflective surface that directs the sun’s rays onto the cooking area and dark inner walls of the cooking area and cooking vessel.

**1. Solar box cooker or solar oven-** It is the most common type of solar cooker made for personal use. It is very simple in construction, consists of a box (square, rectangular, cylindrical) painted black from inside and insulated from all sides except window side which is double glazed is used. Up to four black painted vessels are placed inside the box with the food to be cooked. The cooker takes 1 ½ to 2 hours to cook items such as rice, vegetables.

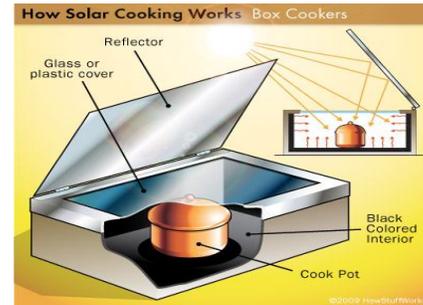


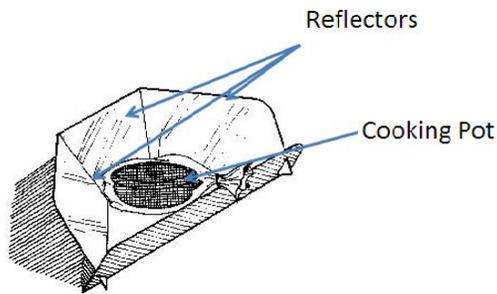
Figure 1. Box Solar Cooker.

#### Feasible Applications of Solar Box Cooker

The cooker is used to prepare simple cakes, roast cashew nuts, dry grapes, etc. It is an ideal device for domestic cooking during most of the year except the monsoon season and cloudy days. The cooking takes place at relatively low temperature, thus cooking is very similar to that of microwave cooking. The cooked items are very tastier, healthier and with all natural minerals, vitamins and proteins. It however cannot be used for frying or Chapatti making.

#### 2. Panel Solar Cooker

The panel cooker is quite similar in operation to the solar box cooker. The same principles are employed but instead of an insulated box only, the panel cooker typically relies on large (often multi-faceted) reflective panels, which focus the sunlight on a cooking vessel. 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. [7]



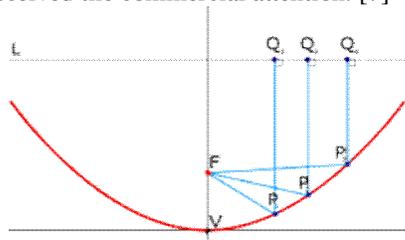
**Figure 2.** Panel Solar Cooker.

### 3. Collector cooker

The collector cooker is made up of two parts that often share a single casing: a collector for collection of heat and a cooking part for exploiting the yield. A typical collector cooker would consist of a flat plate solar collector, side and head mirrors, and the cooker part. The user is not affected by radiation and heat as the cooking part is separate and protected from radiation. Oil is used as the heat transfer medium in order to allow higher temperatures to be reached.

**4. Concentrating type solar cooker-** It uses the principles of concentrating optics. The concentrating solar cookers primarily consists of a reflector to focus the incident solar radiation on the cooking pot, a support with turning mechanism to keep the reflector facing the sun and a cooking pot. Hence the cost and size of reflector is determined by heating capacity desired. Following are the important types of concentrator type solar cookers

- a) Wisconsin solar cooker (Spherical parabolic type)
  - b) Folding Umbrella type solar cooker
  - c) Paraboloid type solar cooker
  - d) Light weight molded aggregate reflector type solar cooker
  - e) Cylindro-parabolic solar cooker
  - f) Multi- mirror or Multi-facet type solar cooker
  - g) Spiral reflector type solar cooker.
- Out of these cookers only Paraboloid type solar cooker have received the commercial attention. [7]



**Figure**

**3.** Parabolic curve showing focus (F), vertex (V), and rays of light brought to the focus.

Table 1 summarizes the advantages and disadvantages of the four types of solar cookers described above.

**Table 1 Comparison of different Solar Cookers [6]**

Type of Cooker	Advantages	Disadvantages
<b>Solar box cooker (solar oven)</b> $T = 150^{\circ}\text{C}$	<ul style="list-style-type: none"> <li>• Uses both direct &amp; diffuse radiation.</li> <li>• Requires little intervention by the user.</li> <li>• Very easy &amp; safe to use. (2-6 kg/day)</li> <li>• Easy to construct.</li> <li>• High acceptance angle.</li> <li>• High tolerance for tracking error.</li> </ul>	<ul style="list-style-type: none"> <li>• slow even cooking <i>i.e.</i> 1.5 to 2 hours</li> <li>• Not use for frying/chapati making.</li> </ul>
<b>Panel cooker</b> $T=200-250^{\circ}\text{C}$	<ul style="list-style-type: none"> <li>• Better performance than box cooker.</li> </ul>	<ul style="list-style-type: none"> <li>• Poor performance on cloudy conditions.</li> <li>• Relies more on reflected radiation.</li> </ul>
<b>Collector Cooker</b>	<ul style="list-style-type: none"> <li>• Uses both direct and diffuse radiation.</li> <li>• Simple, safe and Convenient to use.</li> </ul>	<ul style="list-style-type: none"> <li>• Complicated to build.</li> <li>• Expensive.</li> </ul>
<b>Concentrating (reflector) cooker</b> $\eta = 50\%$	<ul style="list-style-type: none"> <li>• Quite efficient.</li> <li>• Can achieve extremely high temperatures <math>300 - 350^{\circ}\text{C}</math>.</li> <li>• Cooking is quicker. (1/2 to 1 hour)</li> </ul>	<ul style="list-style-type: none"> <li>• difficult to make and use (complex design)</li> <li>• Requires the user's attention.</li> <li>• Strong reliance on direct beam.</li> <li>• Low acceptance angle</li> <li>• Relatively high cost.</li> <li>• Safety problems (burns or eye damage)</li> </ul>

### 5. SK-14 parabolic concentrator

SK 14, is a solar concentrator developed by Dr. Ing. Dieter Siefert. It is a concentrating type parabolic dish solar cooker useful for households and small establishments. A typical dish solar cooker has an aperture diameter of 1.4 meter and focal length 0.28 meter. The reflecting material used for fabrication of this cooker is anodized aluminum sheet which has a reflectivity of over 80%. The tracking of the cooker is manual and thus has to be adjusted in 15 to 20 minutes during cooking time. It has a delivering power of about 0.4 kW which can boil 2 to 3 liters of water in half an hour. The temperature achieved at the bottom of the vessel could be around  $300^{\circ}\text{C}$  to  $350^{\circ}\text{C}$  which is sufficient for roasting, frying and boiling. The cooker having a thermal efficiency of around 45% can meet the needs of around 4-8 peoples and can be used from one hour after sunrise to one hour before sunset on clear days. The cost of the cooker may vary from Rs. 3,500 to Rs. 6,000 depending on

the type of reflectors used and the salient features provided by the manufacturers. [8, 9]



**Figure 4.** SK-14 Domestic Solar Cooker

#### **6. PRINCE-15 (Fabricated) parabolic concentrator**

It is a concentrating type parabolic dish solar cooker with square geometry and useful for households and autoclaving. A typical dish solar cooker has dimension of 1250 mm × 1250 mm and focal length 0.460 meter. The reflecting material used for fabrication of this cooker is anodized aluminum sheet which has a reflectivity of over 80%. The tracking of the cooker is manual and thus has to be adjusted in 15 to 20 minutes during cooking time. It has a delivering power of about 0.6 kW which can boil 2 to 3 liters of water within 20 minutes. The temperature achieved at the bottom of the vessel could be around 350°C to 400°C which is sufficient for roasting, frying and boiling. The cooker having a thermal efficiency of around 50% can meet the needs of around 8 peoples. PRINCE-15 is a concentrator with square or rectangular dish shape. This shape permits use of same sized strips of steel to make bowl. This makes the bowl sturdy. As the members of the dish have same geometric shape this reflector is easy to assemble even by novice people with the help of construction manual.

A new geometry PRINCE-15 solar concentrators with square or rectangular shape is developed by Prof. A. G. Chandak (a consultant of Ministry of New and Renewal Energy Sources, New Delhi) and approved by Ministry of New and Renewal Energy sources, New Delhi.[8,9]



**Figure 5.** PRINCE-15 Solar Cooker

#### **7. PRINCE-15 (Segmented) parabolic concentrator**

PRINCE-15 is a square dish. Such dish can be obtained by cutting Paraboloid with parallel planes. Paraboloid square dish is manufactured in four symmetrical segments as shown in figure 6. One such segment is to be manufactured in sheet metal using die with flange such that flanges can be bolted together to form complete dish. Total dish size in plan is 1250 mm × 1250 mm. One segment size in plan will be around 625mm × 625 mm and with flange of around 25 mm on all sides. [9]



**Figure 6.** PRINCE-15 Segmented Solar Cooker.

#### **8. Community Parabolic Dish Cooker**

SK-23, PRINCE-40 are the Solar Community cookers.



**Figure 7.** SK-23 Community Solar Cooker.

#### **Salient Features**

- Cooking capacity: 40 to 50 persons.
- Dish diameter 2.3 m, Aperture area 4 m<sup>2</sup>, Heat rate at pot is @ 2.5 kW.
- Cost : Rs. 20,000/-
- Best quality German reflectors with more than 85% reflectivity

The PRINCE-40 unit is designed, manufactured, tested and commercialized by PRINCE. Few units are already in use for community cooking, agro-processing, and industrial applications.

### 9. Scheffler Solar Cooker –Direct Cooking Model

Solar concentrators are capable of delivering process temperatures in the range of 80°C to 300°C with reasonable efficiency and hence can be excellent alternatives to replace fossil fuels in industries for mid temperature applications. Majority of the solar dish concentrators designs practiced in the world are paraboloidal dishes symmetrical about their axes. Wolfgang Scheffler launched an idea of oblique paraboloid solar reflectors, now known as Scheffler solar concentrators. Scheffler solar concentrators are termed as flexible surface concentrators. The unique feature of this cooker is that it is possible to cook using solar energy within the kitchen itself.

Initial systems in India were designed of 7 m<sup>2</sup> and immediately shifted to 8 m<sup>2</sup> size. Size of the concentrating dish kept on growing over the years. Commercial size established in 2011 is 16 m<sup>2</sup>. With 16 m<sup>2</sup> dish, if sleeping dishes are to be used pairing with standing dish for steam generation then the stand height of standing dish becomes too tall and impracticable. Hence for this reason almost all installations, including world's largest installation at Shirdi, uses only standing dishes of 16 m<sup>2</sup>, 73 units, with total collection area of 1168 m<sup>2</sup> and heating rate of 37840 kcal/day. Research and Development work is ongoing at Abu by Wolfgang and his team members for establishing solar thermal power plant and dish size developed for power project is 60 m<sup>2</sup>.



**Figure 8.** Standing Scheffler solar primary and secondary reflector

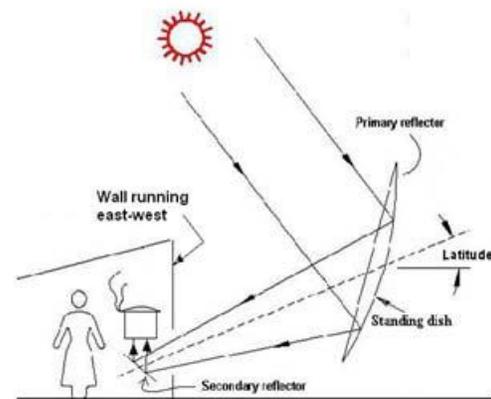
#### Components of Scheffler Cooker

- Primary Reflector,
- Secondary Receiver, and
- Clock mechanism powered by gravity or photovoltaic panels.

#### Salient Features:

Cooking for about 40 to 50 persons is possible with this cooker. One dish may take around 1 to 1 and 1/2 hours depending on the type of dish and solar insolation available.

A typical kitchen with indoor cooking facility is shown in figure 9.



**Figure 9.** Arrangements of Standing Dish with Secondary Reflector Indoor Cooking

#### Limitations of Scheffler Concentrators

1. High capital investment: 16 m<sup>2</sup> unit costs min Rs. 180000 i.e. US \$ 4000
2. Demand typical orientation of kitchen with east-west wall and shadow free south side.

3. Designing, manufacturing and installation is complex.
4. System needs permanent installation and shadow free area throughout the year.
5. Seasonal adjustment and tracking mechanism needs skilled operator.
- 6.

#### Applications:

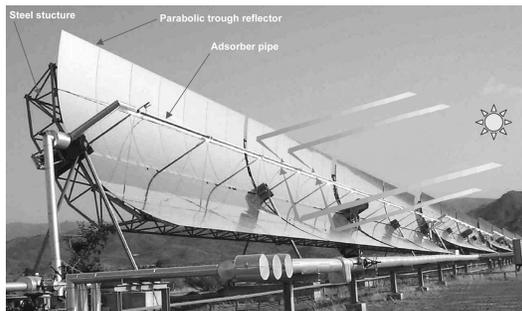
1. Community Cooking.
2. Industrial Heating applications for Low and medium temperature requirement for autoclave applications in hospitals.
3. Major installations till date are in direct and steam cooking applications. (Tirupati, Shirdi, Hyderabad, Mount Abu, Shantivan, for army camp at Leh etc.)
4. Processing of Agricultural produce.

#### Fuel Saving

Around 35 to 40 LPG cylinders per year can be saved on full use in community kitchens. [8, 9, 10]

#### 10. Parabolic trough collector

The parabolic trough collector, Figure 10 is used for steam cooking system. It is capable of generating the Temperatures greater than 260°C, which is sufficient to generate steam. This generated steam can be used for steam cooking or for industrial process heat applications. [4,11]



**Figure 10.** Arrangements of parabolic trough collectors with steam generation system

#### CONCLUSION

Although, the box solar cooker cooks the food with excellent taste and full of vitamins, minerals and proteins. But due to its slow heating rate, its design

could not acquire a significant attraction in the society. In last two decades, the thrust is put to develop concentrating cookers and various designs of concentrators are developed. Paraboloidal solar cookers like SK-14 and PRINCE-15 are designed for a family of 4-6 persons and SK-23, PRINCE-40 are intended as solar cooker for small community, while Scheffler cookers bring sun to kitchen and can be used for small family to community cooking, depending on the collection area of Scheffler dish. These cookers get recognition in the society due to their fast heating rate.

#### REFERENCES

1. Kundapur Ashok, Sudhir CV. Proposal for New World Standard for Testing Solar Cookers. International Solar Cooker Conference at Granada, Spain in June 2007 (also <http://solcooker.tripod.com>)
2. S. R. Kalbande, A. N. Mathur, Surendra Kothari and S. N. Pawar. "Design, Development and Testing of Paraboloidal Solar Cooker." *Karnataka J. Agric. Sci.*, 20(3), (571-574): 2007
3. P. Rajamohan, S. Shanmugan, K. Ramanathan. "Performance analysis of Solar Parabolic concentrator for cooking applications." International Solar Food Processing Conference 2009
4. Solar Cooker International, 1995, *Solar Cookers: How to Make, Use and Understand*, 8th Edition.
5. Solar Cooker International., <http://www.solarcooking.org>.
6. C Z M Kimambo. "Development and performance testing of solar cookers". *Journal of Energy in Southern Africa*. Vol 18 No 3. August 2007.
7. Shaw S. Development of a comparative framework for evaluating the performance of solar cooking devices. Thesis submitted at Rensselaer Polytechnic Institute, USA, 2002 (<http://www.solarcook.org/Evaluating-Solar-Cookers.doc>)
8. Ajay G. Chandak. "Comparative Analysis of Sk-14 and PRINCE-15 Solar Concentrators.
9. www.prince.com, PRINCE (Promoters and Researchers in Non-Conventional Energy)
10. Ajay Chandak, Vishal Sardeshpande, Indu Keoti: 'Paraboloidal Solar Concentrator', Indian Patent application no. 326/MUM/2010).
11. <http://facts-about-solar-energy.com>

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