UNIT 2 SOLAR COOKING DEVICES

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2.1 INTRODUCTION

The use of solar cooker has been of great importance as it relates to the basic needs of cooking energy for the rural as well as urban people. It is estimated that a major portion of our energy consumption goes for cooking which is as high as 64% in rural areas. The energy sources for cooking are firewood, crop residues and animal dung cakes. Animal dung is available at villager’s houses who own the cattle and crop residues in their farms, but to collect firewood they have to go to the forests and roadside trees, etc. Normally this work is done by women who walk long distances everyday carrying heavy loads on their heads. The distance keeps on increasing day by day as the forests are depleting very fast due to increased demand of firewood by the rural people.

The use of firewood and cow dung cakes for cooking purpose is of great concern as it causes serious health hazards to women because of the smoke it generates while burning. The use of solar cookers not only saves substantial amount of firewood and other available fossil fuels in rural areas but can also save substantial amount of LPG, kerosene and electricity in urban areas.

Solar cookers are not a complete solution to the cooking needs for all the sections of the society. Even then they should be accepted because they give many advantages. The acceptability of solar cookers could be increased substantially, if it could confirm to the cooking patterns of Indian families (which implies at least one large meal cooked during off-sunshine hours). There is large scope for
improving thermal efficiency of existing solar cookers and developing new hybrid types of solar cookers which can be used during off-sunshine hours.

**Solar Cooker : Environmentalists’ Friend!**
Solar cooker is environment friendly and has less health hazards associated with it as compared to traditional cooking in rural areas.

In India, about 150 million tons of firewood, 52 million tons of dried dung, and 36 million tons of agricultural waste are consumed annually for cooking purposes. This non-commercial fuel constitutes about 45 percent of the total energy supply in the country. Villagers will continue cutting trees and using dung cake for fuel unless some kind of alternative cooking (such as solar cookers) is made available to them.

In this unit, you will get a glimpse of solar cooker technology and learn about all necessary aspects of solar cookers.

**Objectives**
After studying this unit, you will be able to
- understand the basic principles of solar cookers,
- understand different types of solar cookers,
- understand advantages and disadvantages of solar cookers, and
- understand the environmental impact of solar cookers.

### 2.2 ADVANTAGES AND DISADVANTAGES OF SOLAR COOKERS

Solar cookers have several advantages and disadvantages for different target users. The target users of the solar cookers are the following:

(a) Rural sector where firewood is consumed to a large extent but at a very low efficiency leading to (i) the fast depletion of forest cover and (ii) environmental degradation.

(b) Urban sector involving middle and high class, consuming commercial fuels.

(c) Commercial sector involving hotels, hospital, kitchens of restaurants, etc.

**Solar Cooker : Keeping it to Yourself**
Use of Solar Cooker is very much personal affair as compared to that of using gas or kerosene because the user is not required to depend upon inter-personal relations as in the case, thereby saving valuable time and energy in transport.
Advantages of Solar Cookers

Solar cooker has many advantages; some of these are:

- Cooking of 4 items at a time (4 pot solar cookers)
- Preservation of nutrition value of food
- No need of constant attention while cooking
- No danger of over cooking and fire accident
- No pollution and keeps vessels and kitchen clean
- Useful for baking and roasting purpose
- Saving of firewood and hence forests when used in rural sector
- Saving of commercial fuels when used in urban sector
- Saving of money and time
- Saving of the environment
- No recurring cost of fuel and maintenance
- Easy to manufacture, use and maintain

Solar Cooker : Provides for Itself

Regular uses of solar cooker can invariably double the life of gas cylinder, if not more. The money thus saved provides for repair charges in the event of unforeseen damages to solar cooker.

Disadvantages of Solar Cookers

Solar cookers have few disadvantages as well. The main disadvantages of solar cookers are:

- It takes long time to cook.
- It cannot substitute for all types of cooking.
- Some mechanism is required to be incorporated so as to ensure its use on cloudy days.

2.3 TYPES OF SOLAR COOKERS

The solar cookers can be broadly divided into two categories:

1. Hot box type solar cooker where solar heat is utilized with little or no concentration of sun rays
2. Concentrating type of solar cookers which concentrate solar energy from a large surface to a smaller area to produce high temperatures.

Solar Cooker : Boon for Hygiene!

Slow and gradual heating rate inside solar cooker ensure near ideal conditions for complete cooking without loss of nutrients and taste.

Obviously, a single design of solar cooker can not meet the requirement of all the above sections. Therefore, you should think of applications for specific designs.
2.3.1 Box Type Solar Cookers

The simplest type of solar cooker is shown in Figure 2.1. This is called box type solar cooker. The solar energy is converted into heat which cooks the food without use of cooking gas or kerosene, electricity, coal or wood. In any sunny day, a solar cooker can cook two meals per day for four to five persons.

A box solar cooker cooks food with the help of solar energy, and helps save conventional fuel. This cooker can be used for the preparation of rice, dal, kadhi, vegetables, meat and fish dishes, snacks, soups, sweets, desserts, sauces, jams, pickles, biscuits, cakes, puddings, and so on. However, it cannot be used for frying or for baking chapattis as it can’t produce high temperatures required for such type of cooking. It supplements cooking fuel but does not replace it totally. It is an ideal device for domestic cooking during most of the year except on cloudy days. Typically, a box solar cooker measures about 60 cm \times 60 cm, and is provided with four pots. Smaller models are also available.

The cost of a box solar cooker varies from Rs. 1800 to Rs. 3000 depending on its size and features. The Ministry of New and Renewable Energy (MNRE), Govt. of India and some State Govts. are providing financial incentive for ISI-mark solar cookers. The incentive for non-ISI-mark solar cooker is less as compared to ISI-mark solar cookers.

**Solar Cooker : Maintains Itself !**

Solar cooker needs little or no maintenance. The money saved as a result of savings of gas and kerosene makes up for expenditure, if any. In this sense, solar cooker maintains itself.

The components of a box type of solar cooker are:

1. Outer Box : made of wood, iron sheet or fibre reinforced plastic.
2. Inner Box : made of galvanized iron, mild steel or aluminum sheet.
3. Thermal Insulation : glass wool, thermocol, etc.
4. Double Glass Cover : filled with some space apart which acts as an insulation.
5. Rubber Strip : used on wooden frame.
6. Mirror : to increase radiation input on the absorbing surface.
7. Cooking Containers : made of aluminium or stainless steel.
8. Absorber Paint : to be used on absorber and outer side of the food containers.
2.3.2 Hybrid Solar Cookers

Existing solar cookers cannot be used during off-sunshine hours and during cloudy days. The temperature inside the cooker is also not adequate in the early morning, late afternoon or in partly cloudy days. Solar cookers can be used at night by making it hybrid, i.e. providing electricity (in urban areas), thermal storage (sensible heat, latent heat of fusion and chemical energy). Hybrid models have also been manufactured, which provide an electrical heater to serve as back up during non-sunshine hours. Solar cookers having electrical backup are now available in the market and these may be rightly called solar ovens.

2.3.3 New Designs for Flat Owners

Solar cookers which can bring sunlight into kitchen and based on double exposure principle may be used in new flats having south facing windows. It consists of an absorber which is painted black from both sides. It is covered with a transparent cover. The space between the absorber and top transparent cover is meant for putting cooking utensils.

It is a stationary system and can collect Sun radiation throughout the day. The Sun’s radiation falling from the top side is directly received by the absorber. The radiations received on the tilted cover are received by the absorber after reflection from the reflector. This type of solar cooker thus acts as a stationary concentrator. The major advantages of such a system are:

- The homemaker need not go outside the kitchen in the open sun.
- The system can be integrated into the building.
- There is no need to keep the cooker in open Sun.
- The cooking can be done faster because of increased temperature in the cooking area.
- Even pressure cookers can be used in the system.

Solar Cooker : Bringing Sun Inside Home!

The use of Solar Cooker requires open space. However, with continuing increase in the number of multi-storied buildings where less of open space is available, it is possible to develop new designs of solar cookers adaptable to the owners living in flats in multistoried buildings.

2.3.4 Window Type Solar Cookers

The kitchen shall be south facing to incorporate window type solar cookers and to avoid handling inconvenience. Already electrical backup solar cookers which can be used at nights also are in the market.

2.3.5 Solar Steam Cooking Systems

The solar steam cooking systems are based on the solar energy concentration technology. A number of solar concentrators are employed for forming a system for tapping solar energy for generating steam which can be effectively used for large scale cooking in community kitchens.

The world's largest solar steam cooking system has been installed by the Tirumala Tirupathi Devasthanam (TTD) at Tirumala in Andhra Pradesh. The system has a capacity to prepare food for 15000 people/day and employs automatic tracking solar dish concentrators, which convert water into high pressure steam. The steam thus generated is being used for cooking purposes in the kitchen. It has also been
Solar Thermal Technologies

supported by a boiler working on diesel so as to make the system reliable under all climatic conditions. The system has been designed to generate over 4000 Kg of steam/day at 180ºC and 10 Kg/cm² of pressure which is sufficient to cook two meals for around 15,000 persons. It is modular in nature and consists of 106 automatic tracked parabolic concentrators arranged in series and parallel combination, each of 9.2 m² reflector area. Each unit of concentrators is connected to a central steam pipeline going to the kitchen. The system is made of indigenous components and the reflectors are of acrylic mirrors having reflectivity over 75% (MNRE, Govt. of India).

2.3.6 Dish Type Solar Cookers

Dish type of solar cookers are used for faster outdoor cooking for about 10-15 persons. Such cookers may be used for cooking food without any conventional fuel for large families or institutions. A dish type of solar cooker uses a parabolic dish to concentrate the incident solar radiation. This solar cooker is also known as SK-14 type of solar cooker. This model of solar cooker is useful for homes and small establishments. On a sunny day, the cooker can deliver power of about 0.6 KW, which can boil two to three litres of water in half an hour. The temperature achieved at the bottom of the vessel can reach 350-500ºC.

The cost of the dish type of solar cooker may vary from Rs. 5500 to Rs. 7000 depending upon the type of reflector and other features. It can save up to 10 LPG cylinders per year upon full use at small establishments. At present, the MNRE, Govt. of India provides an incentive of up to 30% of the cost of the cooker (subject to a maximum of Rs. 1500 per cooker).

2.3.7 Concentrating Solar Cooker (Solar Oven)

The concentrating solar cookers (solar oven) are used to cook food quickly. The area of solar oven to collect the desired amount of solar radiation could be estimated by following the example mentioned below.

Example 2.1

Useful heat needed for cooking is 200 W. Determine the area of the solar oven that will be needed to collect this amount of solar radiation. The efficiency of solar oven is 20% and solar insolation is 800 W/m². If the efficiency of the solar cooker is doubled, what will be the area?

Solution

The simple energy balance gives the following:

Energy needed by the cooker = Solar insolation × Efficiency × Area of the oven

or 200 W = 800 W/m² × 0.2 × Area (m²)

or Area = \( \frac{200}{800 \times 0.2} \) = 1.25 m²

When the efficiency is doubled, the area needed is

Area = \( \frac{200}{800 \times 0.4} \) = 0.625 m²
### 2.3.8 Community Solar Cookers

Like the dish type of solar cooker, the community solar cooker is also a parabolic reflector cooker. However, it is larger than the SK-14 type, and is commonly known as Scheffler cooker. The unique feature of this cooker is that it makes cooking possible with solar energy in the kitchen itself. The cooker has a large reflector ranging from 7 m² to 12 m² of aperture area. Cooking for about 40-50 persons is possible with this cooker. One dish may take about 60-90 minutes to cook, depending on the type of dish and solar insolation available. In areas with good solar insolation, it is possible to cook two meals a day with this type of cooker.

The cooker is provided with a mechanical clockwork arrangement that rotates the primary reflector outside to automatically track the sun.

The community solar cooker is useful in schools, institutional kitchens, canteens, ashrams, hotels, hospitals, police and armed forces’ kitchen, and so on. The cost of this cooker is about Rs. 50 000. The payback period is about 4-5 years.

### 2.4 MATERIAL PROBLEMS IN SOLAR COOKERS

Many problems in solar cookers are associated with materials whether outer box, inner box, insulation, rubber strip or black paint. One important area for improvement is to develop transparent covers having high transmissivity and low value of heat loss coefficient. This will reduce both the cost and weight of solar cooker and increase its thermal efficiency. Use of better thermal insulation such as polyurethane in place of glass wool would also improve the performance of the cooker.

### 2.5 EFFICIENCY OF A SOLAR COOKER

Conventional Solar Cooker with ordinary black paint has efficiency of the order of 20-25 %. It is observed that the efficiency can be improved to 30% if selective coating is used in place of ordinary black paint. The efficiency can be further improved to the tune of 50-60% if nickel-black is used in place of ordinary black paint. Use of anti reflecting coating may increase efficiency by another 8-10%.

### 2.6 HEAT TRANSFER RATE IN SOLAR COOKERS

Cooking is a complicated mechanism involving conductive, convective and in some cases radiative heat transfer. Typically, a heat transfer medium is required to carry the energy from the source to food. Most types of food are cooked when they reach a temperature of about 100°C. To obtain faster cooking rates, the temperature of the heat transfer medium should be higher.

- **Preheating of inside of solar cooker**
  
  Preheating of solar cooker in sun outside at least for 45 minutes before loading reduces cooking time subsequently.
Table 2.1 shows the most common forms of cooking, the heat transfer medium used and the appropriate cooking temperatures. For a given rate of heat received by the cooking pot, the rate of cooking depends on the shape and size of the food, the thermal conductivity of the material, and the type and quantity of heat transfer fluid. Water has the highest convective heat transfer coefficient but its temperature is limited to the boiling point (100°C).

Table 2.1: Performance Evaluation of Cookers

<table>
<thead>
<tr>
<th>Cooking Method</th>
<th>Boiling</th>
<th>Steaming</th>
<th>Frying</th>
<th>Baking</th>
<th>Roasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Transfer Medium</td>
<td>Water and/or Juices</td>
<td>Steam</td>
<td>Oil</td>
<td>Air or hot surface</td>
<td>Air or hot Surface</td>
</tr>
<tr>
<td>Cooking Temperature</td>
<td>100-200°C</td>
<td>100°C</td>
<td>180°C</td>
<td>125-250°C</td>
<td>125-250°C</td>
</tr>
<tr>
<td>Traditional Cooking Device</td>
<td>Cooking Pot or Pressure Cooker</td>
<td>Steamer</td>
<td>Frying Pan</td>
<td>Electric or Gas Oven</td>
<td>Electric or Gas oven</td>
</tr>
</tbody>
</table>

Oil provides the fastest means of cooking, because of the capability of using high temperature, while air is relatively the slowest heat transfer medium. By cooking at temperatures above 100 °C, cooking times and energy requirements are reduced by controlled vapour release and the high heat transfer coefficient of water.

If pressure cookers made of aluminum having bottom blackened with black paint are used in the solar cookers, they may yield better results and less cooking time.

Do you know that solar cookers are fuel rich.
Elegant and Prevalent but not Abundant: Electric stove
Abundant and Elegant but not Prevalent: LPG stove
Prevalent and Elegant but not Abundant: Kerosene stove
Abundant and Prevalent and Elegant: Solar Cooker
Solar Cooker: Fuel is no problem!

2.7 POWER RATINGS OF SOLAR COOKERS

The power rating of different cooking devices in use is given in Table 2.2. You can see that power rating of solar cooker is the least among devices in use. So, any improvement in the power rating of solar cookers will lead to tremendous boost in their use. In this respect lack of control for heating in solar cooker may be overcome by enhancing heat input by focusing solar radiation.

Table 2.2: Power Ratings of Solar Cookers

<table>
<thead>
<tr>
<th>Cooking Device</th>
<th>Rate of Fuel Use</th>
<th>Power Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>0.45 m³/hr</td>
<td>6 KW</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.4 m³/hr</td>
<td>2 KW</td>
</tr>
<tr>
<td>Electric Heater</td>
<td>-</td>
<td>1 KW</td>
</tr>
<tr>
<td>Solar Cooker</td>
<td>-</td>
<td>0.5 KW</td>
</tr>
</tbody>
</table>
2.8 FACTORS WHICH SHOULD BE KEPT IN MIND IN USING SOLAR COOKERS

There are several factors which should be kept in mind while making use of solar cookers. Some of them are listed below:

- Exact amount of water should be added. The level of water along with ingredients should not rise beyond the half way level in the cooking pot.
- The vegetables should be cut in to small pieces before cooking.
- The raw food stuff should be soaked in water before cooking.
- The containers should be covered in order to prevent losses of nutrients and heat except in the case of baking bread and cake.
- Adequate precautions should be taken for handling containers with cooked food. The cloth, gloves or any other device may be used for removing containers with cooked food.
- The solar cooker should be cleaned before and after use. The outer tray and cooking pots should be maintained black.

2.9 LET US SUM UP

Solar cookers are useful for rural sector where firewood is consumed to a large extent but at a very low efficiency leading to the fast depletion of forest cover and environmental degradation. The solar cookers may be used in urban sector involving middle and high class, consuming commercial fuels. The solar cookers may also be used in commercial sector involving hotels, hospital, kitchens of restaurants, etc.

Solar cooker has many advantages like cooking of 4 items at a time in a 4 pot solar cookers, preservation of nutrition value of food, no need of constant attention while cooking, no danger of over cooking and fire accident, no pollution.

The main disadvantages of solar cookers are that it takes a long time to cook. It cannot substitute for all cooking and some mechanism is required to be incorporated as to ensure its use on cloudy days.

Solar cookers can be broadly divided into two categories, box type where solar heat is utilized with little or no concentration of sun rays and concentrating type of solar.

Solar cookers can be used at night by making it hybrid, i.e. providing electricity (in urban areas) and thermal storage (sensible heat, latent heat of fusion and chemical energy).

New designs which can bring sunlight into kitchen and based on double exposure principle may be tried in new flats having south facing windows. The kitchen shall be south facing to incorporate window type solar cookers, to avoid handling inconvenience.

Solar steam cooking systems are based on the solar energy concentration technology. A number of solar concentrators are employed for forming a system.
for tapping solar energy for generating steam which can be effectively used for large scale cooking in community kitchens.

Dish solar cooker is used for faster outdoor cooking for about 10-15 persons with solar energy. Such cookers may be used for cooking food without any conventional fuel for large families or institutions where food is cooked for 10-15 persons everyday.

### 2.10 KEY WORDS

**Concentrating Solar Cooker (Solar Oven)**

The solar cookers which concentrate solar energy from a large surface to a smaller area for producing high temperatures.

**Box Type Solar Cooker**

A device using solar heat with little or no concentration of sun rays for cooking purposes.

**Hybrid Solar Cookers**

Can be used at night by making it hybrid, i.e. providing electricity (in urban areas), thermal storage (sensible heat, latent heat of fusion and chemical energy).