



The "Minimum" Solar Box Cooker

A great solar oven you can build quickly from two cardboard boxes

Experiments in Seattle and Arizona have proven that solar box cookers can be built more simply than even the simple method we have been using. These discoveries have paved the way for a simpler construction method that allows a cooker to be built in a few hours for very little money.

When we designed this cooker, we named it the "Minimum Solar Box Cooker" because, at the time, it represented the simplest design we could devise. What we didn't communicate with that name was that this is a full-power cooker that works very well, and is in no way "minimum" as far as capabilities.

What You Will Need

- Two cardboard boxes. We would suggest that you use an inner box that is at least 15" x 15" (38cm x 38cm), but bigger is better. The outer box should be larger all around, but it doesn't matter how much bigger, as long as there is a half inch (1.5cm) or more of an airspace between the two boxes. Also note that the distance between the two boxes does not have to be equal all the way around. Also, keep in mind that it is very easy to adjust the size of a cardboard box by cutting and gluing it.
- One sheet of cardboard to make the lid. This piece must be approximately 2" - 3" (4 - 8cm) larger all the way around than the top of the finished cooker.
- One small roll of aluminum foil.
- One can of flat-black spray paint (says on can "non-toxic when dry") or one small jar of black tempera paint. Some people have reported making their own paint out of soot mixed with wheat paste.
- At least 8 ounces of white glue or [wheat paste](#).
- One Reynolds Oven Cooking Bag®. These are available in almost all supermarkets in the U.S. and they can be mail-ordered from [Solar Cookers International](#). They are rated for 400° F (204.4° C)

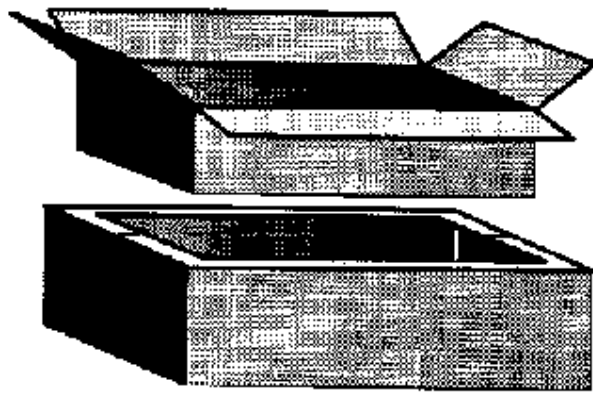


Figure 1

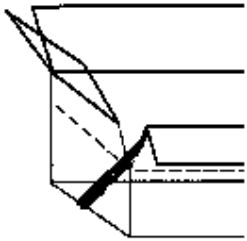


Figure 2

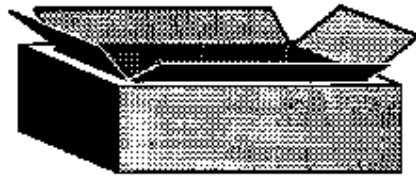


Figure 3

Fold
box
trace

the outer box, Remove the inner box and cut along this line to form a hole in the top of the outer box (Figure 1).

Building the Base

the top flaps closed on the outer and set the inner box on top and a line around it onto the top of the

Decide how deep you want your oven to be (about 1" or 2.5cm bigger than your largest pot and at least 1" shorter than the outer box) and slit the corners of the inner box with a knife down to that height. Fold each side down forming extended flaps (Figure 2). Folding is smoother if you first draw a firm line from the end of one cut to the other where the folds are to go.

Glue aluminum foil to the inside of both boxes and also to the inside of the remaining top flaps of the outer box. Don't waste your time being neat on the outer box, since it will never be seen, nor will it experience any wear. The inner box will be visible even after assembly, so if it matters to you, you might want to take more time here. Glue the top flaps closed on the outer box.

Place some wads of crumpled newspaper into the outer box so that when you set the inner box down inside the hole in the outer box, the flaps on the inner box just touch the top of the outer box (Figure 3). Glue these flaps onto the top of the outer box. Trim the excess flap length to be even with the perimeter of the outer box.

Finally, to make the drip pan, cut a piece of cardboard, the same size as the bottom of the interior of the oven and apply foil to one side. Paint this foiled side black and allow it to dry. Put this in the oven (black side up) and place your pots on it when cooking. The base is now finished.

so they are perfect for solar cooking. They are not UV-resistant; thus they will become more brittle and opaque over time and may need to be replaced

periodically. A sheet of glass can also be used, but this is more expensive and fragile, and doesn't offer that much better cooking except on windy days.

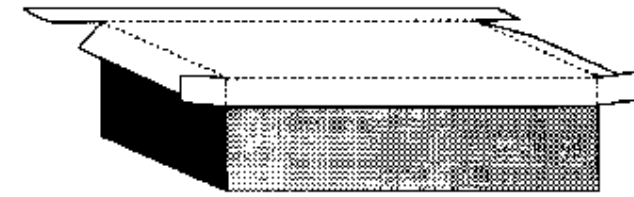
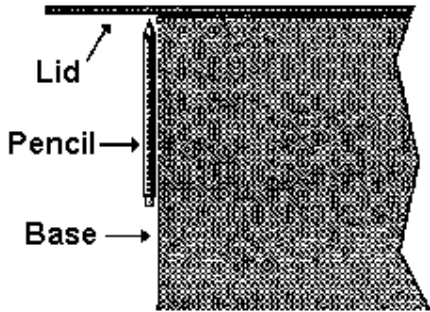


Figure 4

Building

the Removable Lid

Figure 5

Take the large sheet of cardboard and lay it on top of the base. Trace its outline and then cut and fold down the edges to form a lip of about 3" (7.5cm). Fold the corner flaps around and glue to the side lid flaps. (Figure 4). Orient the corrugations so that they go from left to right as you face the oven so that later the prop may be inserted into the corrugations (Figure 6). One trick you can use to make the lid fit well is to lay the pencil or pen against the side of the box when marking (Figure 5). Don't glue this lid to the box; you'll need to remove it to move pots in and out of the oven.

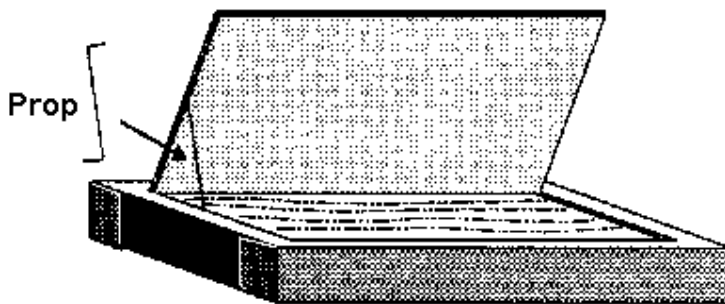


Figure 6

To make the reflector flap, draw a line on the lid, forming a rectangle the same size as the oven opening. Cut around three sides and fold the resulting flap up forming the reflector (Figure 6). Foil this flap on the inside.

To make a prop bend a 12" (30cm) piece of hanger wire as indicated in Figure 6. This can then be inserted into the corrugations as shown.

Next, turn the lid upside-down and glue the oven bag (or other glazing material) in place. We have had great success using the turkey size oven bag (19" x 23 1/2", 47.5cm x 58.5cm) applied as is, i.e., without opening it up. This makes a double layer of plastic. The two layers tend to separate from each other to form an airspace as the oven cooks. When using this method, it is important to also glue the bag closed on its open end. This stops water vapor from entering the bag and condensing. Alternately you can cut any size oven bag open to form a flat sheet large enough to cover the oven opening.

Improving Efficiency

The oven you have built should cook fine during most of the solar season. If you would like to improve the efficiency to be able to cook on more marginal days, you can modify your oven in any or all of the following ways:

- Make pieces of foiled cardboard the same size as the oven sides and place these in the wall spaces.
- Make a new reflector the size of the entire lid (see photo).
- Make the drip pan using sheet metal, such as aluminum flashing. Paint this black and elevate this off the bottom of the oven slightly with small cardboard strips.

Here are some good documents to read to learn more about solar cooking:

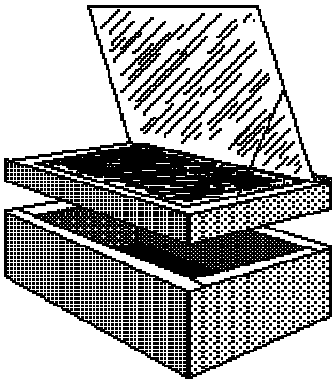
- [Solar Cooking Frequently-Asked Questions \(FAQ\)](#)
- [Developing an Intuitive Feel for the Dynamics of Solar Cooking](#)
- [Principles of Solar Box Cooker Design](#)
- [Solar Cooking Hints](#)
- [Three Reasons Solar Cooking Deserves New Attention](#)
- [Solar Cookbooks](#)

[Solar Cookers International](#)

1919 21st Street, #101

Sacramento, California 95814 info@solarcookers.org

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Principles of Solar Box Cooker Design

By Mark Aalfs, Solar Cookers International
e-mail: aalfs@yahoo.com

Figure 1. Solar box cooker with cover, window, and reflector

The purpose of this paper is to summarize the basic principles that are used in the design of solar box cookers.

People use solar cookers primarily to cook food and pasteurize water, although additional uses are continually being developed. Numerous factors including access to materials, availability of traditional cooking fuels, climate, food preferences, cultural factors, and technical capabilities, affect people's approach to solar cooking.

With an understanding of basic principles of solar energy and access to simple materials such as cardboard, aluminum foil, and glass, one can build an effective solar cooking device. This paper outlines the basic

principles of solar box cooker design and identifies a broad range of potentially useful construction materials.

These principles are presented in general terms so that they are applicable to a wide variety of design problems. Whether the need is to cook food, pasteurize water, or dry fish or grain; the basic principles of solar, heat transfer, and materials apply. We look forward to the application of a wide variety of materials and techniques as people make direct use of the sun's energy.

The following are the general concepts relevant to the design or modification of a solar box cooker:

[Heat Principles](#)

[Materials Requirements](#)

[Design and Proportion](#)

[Solar Box Cooker Operation](#)

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HEAT PRINCIPLES

The basic purpose of a solar box cooker is to heat things up - cook food, purify water, and sterilize instruments - to mention a few.

A solar box cooks because the interior of the box is heated by the energy of the sun. Sunlight, both direct and reflected, enters the solar box through the glass or plastic top. It turns to heat energy when it is absorbed by the dark absorber plate and cooking pots. This heat input causes the temperature inside of the solar box cooker to rise until the heat loss of the cooker is equal to the solar heat gain. Temperatures sufficient for cooking food and pasteurizing water are easily achieved.

Given two boxes that have the same heat retention capabilities, the one that has more gain, from stronger sunlight or additional sunlight via a reflector, will be hotter inside.

Given two boxes that have equal heat gain, the one that has more heat retention capabilities - better insulated walls, bottom, and top - will reach a higher interior temperature.

The following heating principles will be considered first:

- [Heat gain](#)

- [Heat loss](#)
- [Heat storage](#)

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A. Heat gain

Greenhouse effect: This effect results in the heating of enclosed spaces into which the sun shines through a transparent material such as glass or plastic. Visible light easily passes through the glass and is absorbed and reflected by materials within the enclosed space.

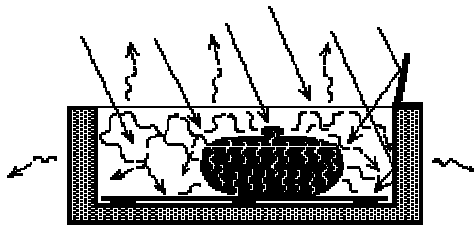


Figure 2. The greenhouse effect

The light energy that is absorbed by dark pots and the dark absorber plate underneath the pots is converted into longer wavelength heat energy and radiates from the interior materials. Most of this radiant energy, because it is of a longer wavelength, cannot pass back out through the glass and is therefore trapped within the enclosed space.

The reflected light is either absorbed by other materials within the space or, because it doesn't change wavelength, passes back out through the glass.

Critical to solar cooker performance, the heat that is collected by the dark metal absorber plate and pots is conducted through those materials to heat and cook the food.

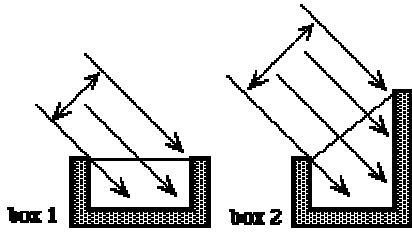


Figure 3. Glass orientation

Glass orientation: The more directly the glass faces the sun, the greater the solar heat gain. Although the glass is the same size on box 1 and box 2, more sun shines through the glass on box 2 because it faces the sun more directly. Note that box 2 also has more wall area through which to lose heat.

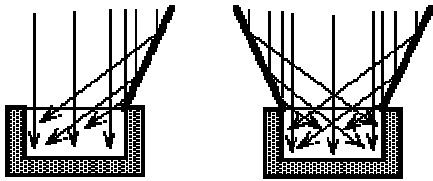


Figure 4. Reflectors for additional solar gain

Reflectors, additional gain: Single or multiple reflectors bounce additional sunlight through the glass and into the solar box. This additional input of solar energy results in higher cooker temperatures.

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B. Heat loss

The Second Law of Thermodynamics states that heat always travels from hot to cold. Heat within a solar box cooker is lost in three fundamental ways: **Conduction, Radiation, and Convection**

Conduction:

The handle of a metal pan on a stove or fire becomes hot through the transfer of heat from the fire through the materials of the pan, to the materials of the handle. In the same way, heat within a solar box is lost when it travels through the molecules of tin foil, glass, cardboard, air, and insulation, to the air outside of the box.

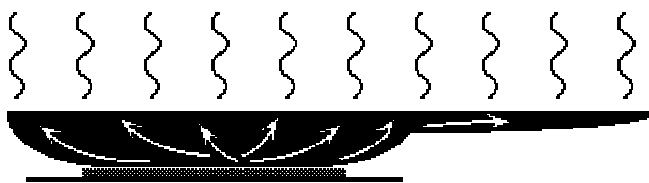


Figure 5. Heat conducted through the pan to handle

The solar heated absorber plate conducts heat to the bottoms of the pots. To prevent loss of this heat via conduction through the bottom of the

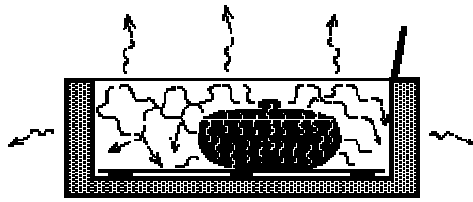


Figure 6. Heat radiates from warm cookware.

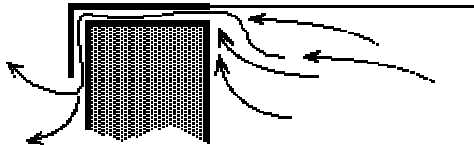


Figure 7. Heated air may escape through cracks.

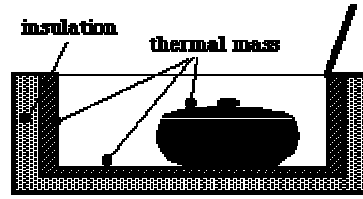


Figure 8. Thermal mass inside of the solar box.

cooker, the absorber plate is raised from the bottom using small insulating spacers as in **figure 6**.

Radiation: Things that are warm or hot -- fires, stoves, or pots and food within a solar box cooker -- give off heat waves, or radiate heat to their surroundings. These heat waves are radiated from warm objects through air or space. Most of the radiant heat given off by the warm pots within a solar box is reflected from the foil and glass back to the pots and bottom tray. Although the transparent glazings do trap most of the radiant heat, some does escape directly through the glazing. Glass traps radiant heat better than most plastics.

Convection: Molecules of air move in and out of the box through cracks. They convect. Heated air molecules within a solar box escape, primarily through the cracks

around the top lid, a side "oven door" opening, or construction imperfections. Cooler air from outside the box also enters through these openings.

C. Heat storage:

As the density and weight of the materials within the insulated shell of a solar box cooker increase, the capacity of the box to hold heat increases. The interior of a box including heavy materials such as rocks, bricks, heavy pans, water, or heavy foods will take longer to heat up because of this additional heat storage capacity. The incoming energy is stored as heat in these heavy materials, slowing down the heating of the air in the box.

These dense materials, charged with heat, will radiate that heat within the box, keeping it warm for a longer period at the day's end.

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MATERIALS REQUIREMENTS

There are three types of materials that are typically used in the construction of solar box cookers. A property that must be considered in the selection of materials is moisture resistance.

- A. Structural material**
- B. Insulation**
- C. Transparent material**
- D. Moisture resistance**

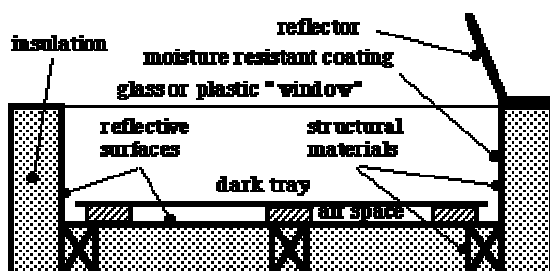


Figure 9: Materials: structural, insulation, transparent, and moisture resistant.

A. Structural material

Structural materials are necessary so that the box will have and retain a given shape and form, and be durable over time.

Structural materials include cardboard, wood, plywood, masonite, bamboo, metal, cement, bricks, stone, glass, fiberglass, woven reeds, rattan, plastic, papier mache, clay, rammed earth, metals, tree bark, cloth stiffened with glue or other material.

Many materials that perform well structurally are too dense to be good insulators. To provide both structural integrity and good insulation qualities, it is usually necessary to use separate structural and insulating materials.

B. Insulation

In order for the box to reach interior temperatures high enough for cooking, the walls and the bottom of the box must have good insulation (heat retention) value. Good insulating materials include: aluminum foil (radiant reflector), feathers (down feathers are best), spun fiberglass, rockwool, cellulose, rice hulls, wool, straw, and crumpled newspaper.¹

When building a solar cooker, it is important that the insulation materials surround the interior cooking cavity of the solar box on all sides except for the glazed side -- usually the top. Insulating materials should be installed so that they allow minimal conduction of heat from the inner box structural materials to the outer box structural materials. The lower the box heat loss, the higher the cooking temperatures.

C. Transparent material

At least one surface of the box must be transparent and face the sun to provide for heating via the "greenhouse effect." The most common glazing materials are glass and high temperature plastics such as oven roasting bags. Double glazing using either glass or plastic affects both the heat gain and the heat loss. Depending on the material used, the solar transmittance - heat gain - may be reduced by 5-15%. However, because the heat loss through the glass or plastic is cut in half, the overall solar box performance is increased.

D. Moisture resistance

Most foods that are cooked in a solar box cooker contain moisture. When water or food is heated in the solar box, a vapor pressure is created, driving the moisture from the inside to the outside of the box. There are several ways that this moisture can travel. It can escape directly through box gaps and cracks or be forced into the box walls and bottom if there is no moisture barrier. If a box is designed with high quality seals and

moisture barriers, the water vapor may be retained inside the cooking chamber. In the design of most solar box cookers, it is important that the inner-most surface of the cooker be a good vapor barrier. This barrier will prevent water damage to the insulation and structural materials of the cooker by slowing the migration of water vapor into the walls and bottom of the cooker.

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DESIGN, PROPORTION, and OPERATION

A. Box size

A solar box cooker should be sized in consideration of the following factors:

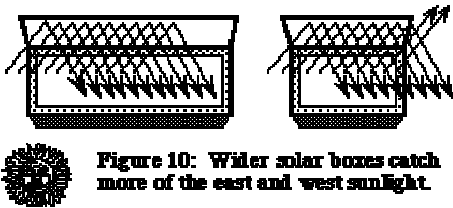


Figure 10: Wider solar boxes catch more of the east and west sunlight.

- The size should allow for the largest amount of food commonly cooked.
- If the box needs to be moved often, it should not be so large that this task is difficult.
- The box design must accommodate the cookware that is available or commonly used.

B. Solar collection area to box volume ratio

Everything else being equal, the greater the solar collection area of the box relative to the heat loss area of the box, the higher the cooking temperatures will be.

Given two boxes that have solar collection areas of equal size and proportion, the one that is of less depth will be hotter because it has less heat loss area.

C. Solar box cooker proportion

A solar box cooker facing the noon sun should be longer in the east/west dimension to make better use of the reflector over a cooking period of several hours. As the sun travels across the sky, this configuration results in a more consistent cooking temperature. With square cookers or ones having the longest dimension north/south, a greater percentage of the early morning and late afternoon sunlight is reflected from the reflector to the ground, missing the box collection area.

D. Reflector

One or more reflectors are employed to bounce additional light into the solar box in order to increase cooking temperatures. Although it is possible to solar cook without reflectors in equatorial when the sun is mostly overhead, reflectors increase cooking performance significantly in temperate regions of the world. See [Reflectors - figure 4](#).

SOLAR BOX COOKER OPERATION

One of the beauties of solar box cookers is their ease of operation. For mid-day cooking at 20° N - 20° S latitude, solar box cookers with no reflector need little repositioning to face the sun as it moves across the mid-day sky. The box faces up and the sun is high in the sky for a good part of the day. Boxes with reflectors can be positioned toward the morning or afternoon sun to do the cooking at those times of day.

Solar box cookers used with reflectors in the temperate zones do operate at higher temperatures if the box is repositioned to face the sun every hour or two. This adjustment of position becomes less necessary as the east/west dimension of the box increases relative to the north/south dimension.

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CULTURAL FACTORS

In addition to the primarily technical aspects of solar box cooker design, factors including culture, appropriate technology, and aesthetics play a major role in the successful technology transfer of solar box cooking.

Through the centuries, the power of the sun has been tapped in numerous ways. With solar cooking, as with other endeavors, some design approaches work better than others. Technology that is designed to efficiently accomplish a given task while meeting certain energy use, environmental, social, cultural, and/or aesthetic standards, is often referred to as "appropriate technology."

Unfortunately, the field of solar cooking has its share of devices that fail these basic technical and social tests. For example, parabolic cookers

can cook food, but when compared to the solar box approach, they are more difficult to build, require specialized materials and constant refocusing, may burn food, and are not likely to be accepted in most social and cultural contexts. In fact, because of the well publicized failures of these devices in several development projects in the '60s, many still believe that solar cooking is not feasible.

The better a given solar box design meets appropriate technology criteria, the more likely it is to be embraced by those using it. A very low-tech approach is to simply dig a shallow pit in the ground, insulate the bottom with dried grass or leaves, insert the food or water in a dark container, and place glass over the top. On the high-tech end of the scale, the very same solar principles could be used with standard building and insulating materials and high performance low-emissivity glazing, to architecturally integrate a solar cooker into the south side of a contemporary kitchen. The solar oven door could be on the wall at a convenient height right next to the microwave.

Cardboard solar box cookers may be appropriate for many cultures because the materials are widely available and inexpensive. But disadvantages of cardboard include susceptibility to moisture damage and lack of durability compared to many other materials.

Aesthetics are usually important. Cultures having rounded forms as the norm may reject the entire solar cooking concept because the box is square. And certain social strata may reject cardboard as too "cheap" a material for their use.

It is important that the basic principles of solar design not be rejected because of the failures of a particular solar devices or technology transfer methodologies!

Certainly, one of the advantages of people designing their own solar box cookers is that they will apply the solar principles using their own materials and aesthetic sense. People that build their houses and furnishings out of wood or bamboo, are likely to include these materials in their cooker design. Surface decoration of solar boxes using various paints and textures also helps to integrate cookers into a given culture. There are many **forms** that can follow the solar **function**.

Location of the solar cooker and the cooking activity, permanence or portability of the solar cooker, time of day when it is used, and importance of cooking as a social activity are other varying factors that will affect the design of solar cookers.

The solar box cooker project in the Indian Himalaya, sponsored by the Indo-German Dhauladhar Project, is a successful application of the principles of solar box cooking to the needs of a particular culture. The non portable cooker is built of earth and brick and is double glazed with glass. An inner tin oven is fabricated from used ghee or oil containers. Husk from a rice sheller provides insulation around the tin oven.

"Materials are derived from the market economy (glass, black paint, nails, etc.), the local economy (labor, wood), and the non-monetary subsistence economy (mud bricks, bamboo, fabric). Using familiar materials and skills makes it easy to train builders and to help people maintain their cookers."²

The Dhauladhar Project participants, through the adaptation of solar cooking concepts to local needs and customs, demonstrated an effective technology transfer process.

Although it is somewhat beyond the scope of this discussion of design principles, other factors critical to the successful long-term implementation of solar cooking deserve note.

In order to successfully transfer solar cooking technology from one culture to another, a durable and long-lived bridge is critical. Individuals from both cultures form that bridge. People from the transferring culture must have a high degree of cultural sensitivity and make a significant time commitment. Success is more likely if individuals from the implementing culture are leaders in their own communities. How well these individuals work together will play a large part in the success or failure of the process. Community is, by definition, a web of interconnected activities. For solar cooking to become a part of local culture, it must be considered in the context of community activities such as local economics, work, healthcare, social activities, energy resources, deforestation, education, the technical infrastructure, and others.

Solar box cooking has already been practiced within a variety of cultures. But we've only scratched the surface. The potentially dramatic benefit of this resource in terms of world hunger, health, and deforestation has yet to be realized.

One of the primary purposes of Solar Box Cookers Northwest is to further the cause of solar cooking worldwide through information distribution and technology transfer. If you would like to work with us, we'd be happy to discuss our work and any of your ideas. We also like to see new designs and photos. Please contact us at the address on the first page of this paper.

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