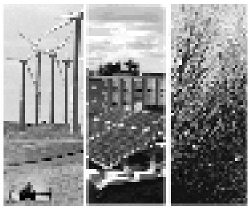


Solar Water Heater

In a solar water heater, water passes through a collector, usually on a roof, where it is heated by the sun. In order to attain the highest temperature possible, the collector is painted black and insulated. Solar collectors can also be used to heat homes and buildings, and power industrial processes.

This experiment shows how sunlight can be used to heat water. Students will build a thermosiphoning water heater, modeled after home solar water heaters.

GRADES: 7–12

SUBJECT: science

TIME: one 45-minute class period to build the water heater; two to three hours to heat the water

MATERIALS: Divide the class into groups of four or five. Each group will need:

- a shallow rectangular cardboard box (without flaps), at least 45 x 30 cm, no higher than 10 cm
- approximately three meters of plastic tubing, approximately 2 mm thick and 1.2 cm in diameter
- black paint and brush
- a bucket that holds at least two gallons of water
- two thermometers
- food coloring
- plastic wrap, Plexiglas, or glass that is the same size as or larger than the box
- aluminum foil
- extra cardboard
- tape
- a sunny day

PROCEDURE:

1. Ask students how energy from the sun gets to Earth. Ask about the difference between heat and light energy. Review the basics of solar energy collection, such as the storage, reflection, insulation, and heat absorption of materials with different colors and densities.

2. Tell students about solar thermal systems. Ask them how they think a system for heating water might work and look. Describe a solar hot water heater and a solar thermal power plant. Describe developments in modern technology.

3. Review how thermosiphoning works. Explain how differences in water temperature can cause differences in pressure. Explain how this pressure difference can be used to siphon water.

4. Distribute the handout "How to Build a Solar Water Heater" (pg. 19). Supervise student construction, helping if problems arise.

5. Ask students to measure the temperature of the water periodically during the three to four hours it is heating. Also ask them to write down the temperatures inside the heater.

FOLLOW-UP:

1. Ask students to name the ways heat was collected and transferred to the water in this activity. Ask them for ways to improve the efficiency of the solar heater.

2. Write the temperatures that students measured on the board. Ask students to draw conclusions about them. You may want to average the temperature readings of the different groups.

3. Ask them how a system would be designed to heat water enough to create steam for electricity. What fluids could be used in place of water?

4. Ask students what limitations sunlight might place on solar thermal system use. Factors to discuss are amount of sunlight, cloudiness, angle of sun, seasonal differences, and location.

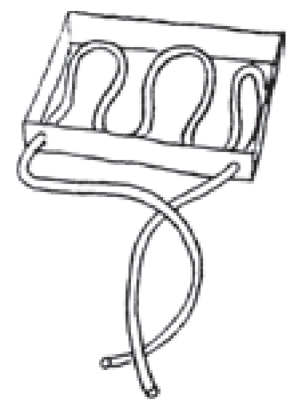
5. Assign independent science research projects on solar thermal systems. Some possible topics are:

    - solar water heaters
    - solar thermal generating plants (parabolic trough, central receiving tower, or parabolic dish collectors)
    - recent developments in either of the above

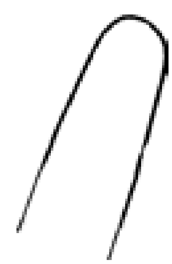
How to Build a Solar Water Heater

1. Poke two holes in the box at opposite ends of one side. Make them the size of the tubing you will use. Glue aluminum foil on the inside of the box and paint the foil black.

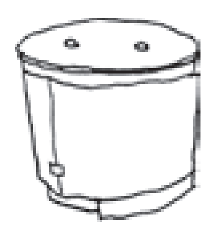
2. Insert tubing through one hole and curl it around the bottom of the box. Poke the tubing out the hole at the other end. Leave roughly equal amounts of tubing sticking out of both ends of the box.



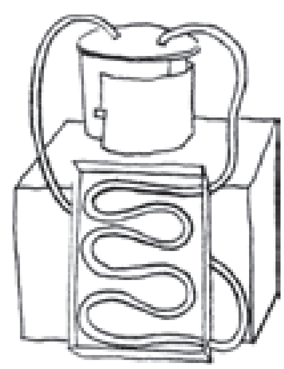
3. Paint the tubing inside the box completely black.
4. If the tubing does not stay at the bottom of the box, pin it down. Do this by bending a paper clip around the tubing and sticking its ends through the bottom of the box. Bend the clip ends on the other side, clamping the tubing down.



5. Tape a thermometer to the bottom of the box.
6. Cover the box with plastic wrap, glass, or Plexiglas. Tape it on so that it is airtight. If you use plastic wrap, stretch it so that there are no wrinkles.
7. If the buckets you use do not have tops, make tops out of cardboard. Insulate the buckets by taping sheets of newspaper around them. Poke two holes in the top of one of the buckets for the tubing. This is your experiment bucket. The other bucket will be your control.



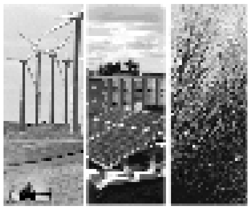
8. Fill both buckets with water. Insert tubing in your experiment bucket. Make sure that one end of the tubing is near the top, the other at the bottom. You may need to cut off some excess tubing to do this.



9. Prop up the box at a slant so that it is facing the sunlight (its shadow should be directly behind it). Place the experiment bucket on some support (books or another box will work), so that it is *completely* above the level of the collector. Arrange the control bucket at the same level.

10. Suck on one end of the tubing in the control bucket to fill the water pipe with water. Make sure there is no air in the pipe when you insert it back in the water.

11. Leave the solar heater and control bucket out in the sun for 3-4 hours and measure the temperature of the water periodically, as well as the temperature inside the heater.



Solar Box Cooker

In this activity, students build a solar box cooker from simple materials. The solar cooker represents a simple technology that is beginning to be used in less developed countries. Many countries depend heavily on wood for cooking. This dependence is creating a serious deforestation problem. In some areas, women and children must spend several hours each day searching for fuelwood. Solar cookers could help improve these people's lives and reduce the rate of deforestation.

This activity is designed to:

- increase student understanding of the principles of solar heating
- increase student awareness of how energy is used in developing nations

You may want to use this activity as part of a global awareness or United Nations day in your class or school.

GRADES: 6–8

SUBJECTS: science, social studies, home economics

TIME: one class period for construction; one to eight hours cooking time
You may want to schedule a special "solar lunch" after the cooker is built. Food can be put in the cooker one to eight hours before the lunch.

MATERIALS: Since each solar cooker requires a lot of materials, you may want your class to build only one or two. A solar cooker requires:

- two large corrugated cardboard boxes with flaps—one fitting inside the other with about 5 cm between them on all sides and bottom (inner box should be at least 46 x 56 cm)
- a flat piece of cardboard about 20 cm longer and wider than the larger box
- a light piece of glass or Plexiglas about 50 x 60 cm
- a thin metal tray, painted black, about 42 x 52 cm
- dark cooking pots
- aluminum foil
- water-based glue
- lots of newspaper for insulation
- string (one foot long)
- a stick (approximately one foot long)

PROCEDURE:

1. Identify particular developing countries on a map and discuss what people in those countries use for energy.

2. Discuss firewood depletion in developing countries. Explain how solar cookers can help solve this problem. Describe some solar box cooker designs.

3. Ask students how energy gets from the sun to Earth. Ask about the difference between light and heat. Review the basics of solar energy collection, such as the storage, reflection, insulation, and heat absorption of materials with different colors and densities. You may want to have students experiment with different insulation materials and investigate the absorptive capacities of different colors before you build your cooker.

Note: Do not use Styrofoam for insulation. The heat could cause it to melt and emit toxic fumes.

4. Build the solar box cooker, using the directions on the student handout (pg. 23).

FOLLOW-UP:

1. Ask students the following questions:

    a. How does the solar box cooker work?
    b. In what parts of the world would solar cookers work the best? the worst?
    c. Are solar cookers difficult or expensive to make? Are there disadvantages to solar cookers? How do these disadvantages compare with the advantages of solar cookers, especially in less developed countries?
    d. How would your life be different if your family relied on a solar box cooker to cook your food?

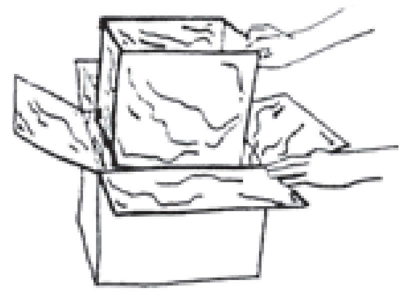
2. Have students research and build other designs for solar cookers.

3. Try using the cooker at different times during the school year. When does it take the longest time for food to cook? The shortest time? Why?

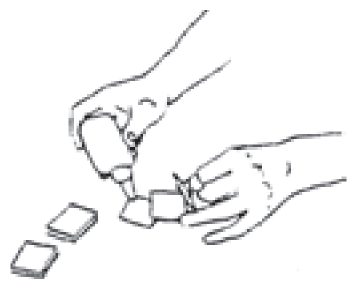
For plans and more information, contact Solar Cookers International, 1919 21st Street, Suite 101, Sacramento, CA 95814; (916) 455-4499; *solarcooking.org/sci.htm.*

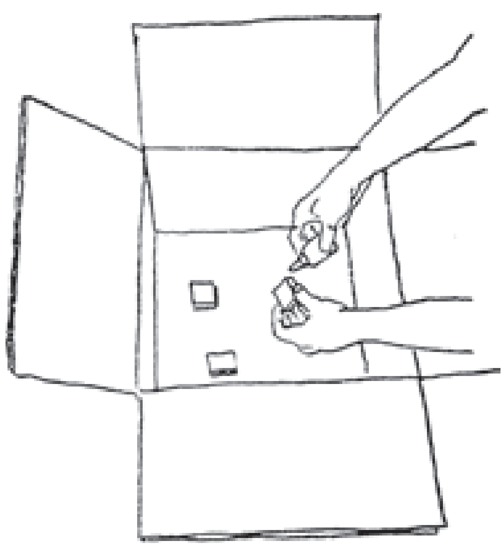
How to Build a Solar Box Cooker

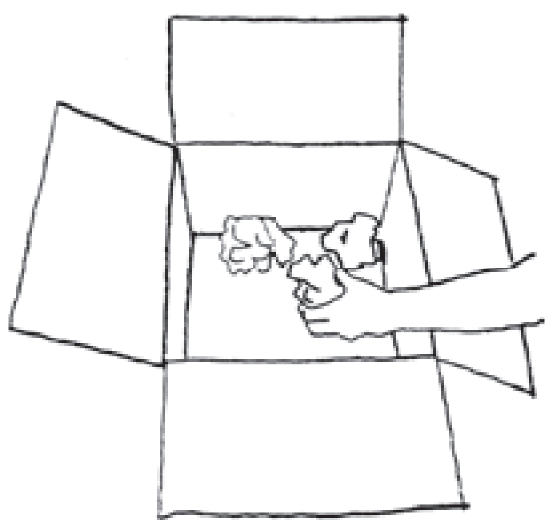
1. **Glue foil on the cardboard.** Dilute the water-based glue in a bowl, so that it will last a long time and you can brush-apply it. Glue foil completely over: (a) the inside *and* outside of the smaller box (cut off the flaps), (b) the inside of the larger box, (c) the inside *and* outside of the larger box's flaps, and (d) one side of the flat cardboard piece.



2. **Add bottom supports and insulation.** Cut out 4 cm squares from the discarded smaller box flaps. Glue them on top of each other to form eight pillars 2–3 cm high. Glue these pillars inside the bottom of the bigger box to support the inner box. Tear up newspaper sheets in fourths and crumple each piece into a lemon-sized ball. Cover the bottom of the bigger box with these balls.

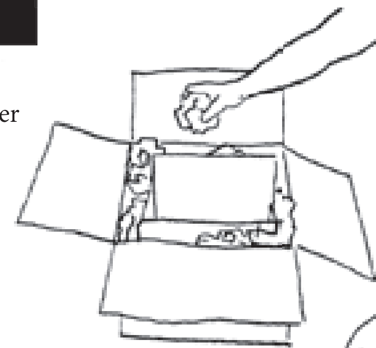




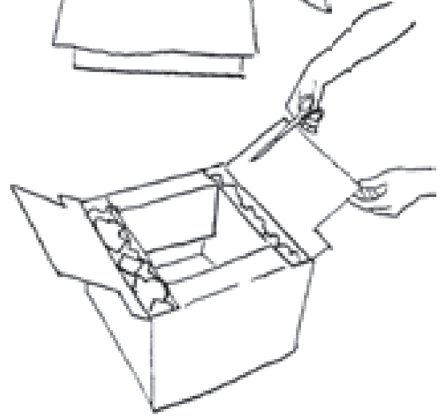


How to Build a Solar Box Cooker

3. **Add inner box and side insulation.** Place smaller box inside the larger box. Stuff more newspaper balls between sides of boxes.

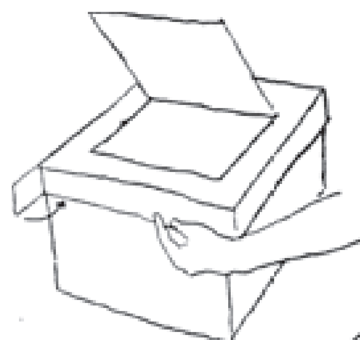


4. **Cut the flaps of the outer box so that they fit in the inner box.** Cut them so that they can be folded over, covering the top space between the boxes as well as the inner wall of the inner box (see diagram). Fold the flaps over and glue them.

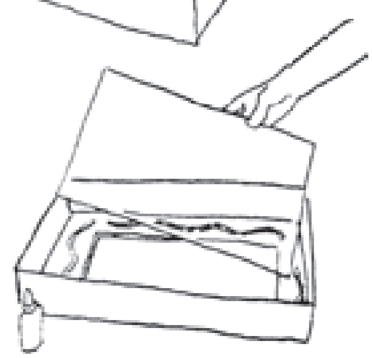


5. **Put the black tray in the box.** Paint it black if it isn't already. Use nontoxic paint.

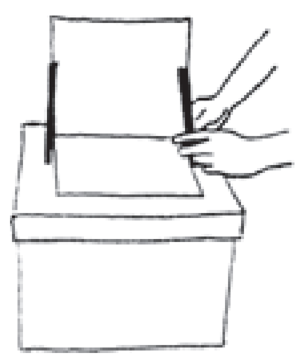
6. **Make the lid.** Take the flat cardboard piece and center it, foil facing down, on top of the box. Fold down what sticks over the edges of the large box. You need to make four cuts in the cardboard to do this. Then, glue the folded edges of the lid together (not to the box). Make sure the lid fits snugly on the box.



7. **Glue the glass to the lid.** Cut 3 sides of a rectangle in the lid. This rectangle should be slightly smaller than the glass. Turn the lid over and glue the glass, around its edges, to the inside of the lid. Press it flat until the glue dries. If you use plastic wrap, stretch it out around the rectangular opening and tape in around the sides.



8. **Make a prop.** Bend up the cut-out rectangle in the lid so that it can reflect sunlight into the cooker. Attach a stick with string to the corner of the reflector and the side of the lid. If it is windy, you may want a prop on both sides.



You are now finished with your solar box cooker and are ready to cook!

Solar Box Cooker: Guidelines for Cooking Food

1. Put your food in covered black pots in the solar box cooker with the lid on.

2. Aim the box so the shiny side of the lid reflector faces where the sun will be in late morning (lunch) or early afternoon (supper). Tie the prop to hold the lid reflector where it shines the most sunlight into the box.

   Warning: Temperatures inside the cooker can reach 275 degrees Fahrenheit. Do not leave cooker unattended in a place where it could be disturbed by other students.

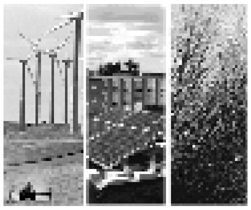
3. Food cooks better:

   - on a warm, sunny day in late spring, summer, or early fall
   - if you put it toward the back of the box
   - if you adjust the cooker often so that its shadow lies directly behind it
   - if you divide the food up into small pots

4. You need not stir the food while it is cooking. If you open the box during cooking, be careful of the high temperatures inside.

5. Most importantly, put the food in early, and don't worry about overcooking—solar cookers seldom overcook. Cooking times for recommended foods are:

   - one to two hours for rice, fruit, above-ground vegetables, pretzels
   - three to four hours for potatoes, root vegetables, some beans (including lentils), most bread
   - five to eight hours for most dried beans



Solar Houses

Solar houses are one of the simplest and oldest uses of solar energy. A solar house is designed to capture solar heat in cold months and remain cool during hot months, thus offsetting use of oil, natural gas, and electricity for heating and cooling.

Passive solar features—parts of a house that do not use mechanical devices for solar heating or cooling—can include south-facing windows, high-density building materials that absorb heat, and overhangs for shading. Active solar features can include pumps and fans that channel warm or cool air into storage spaces where it can be released at night.

This activity introduces students to basic principles of solar heating. Students construct their own model solar houses and then see which attain the highest or lowest indoor heat.

GRADES: 8–12

SUBJECTS: science, industrial arts

TIME: at least one class period to teach basics of solar heating and cooling; one class period to test temperatures of student model solar homes. Solar house construction should be homework, although you may want to have an in-class help session while students are working on their models.

MATERIALS: various materials supplied by the student, possibly including cardboard, plastic wrap, stones, or Plexiglas. Price of materials should not exceed five dollars; encourage students to recycle discarded materials.

PROCEDURE:

1. Ask students if they can name some ways in which the sun's heat is captured or lost by the earth (i.e., reflection, absorption, and radiation). Ask how they think a substance's color, density, and design affect how it absorbs or loses the sun's heat. Describe the basics of solar heating/cooling.

2. Ask students what they think a house that uses solar heating and cooling might look like. How is cool or warm air retained by such a house?

3. Distribute the handout "Solar House Assignment" (page 28). Give students a due date for the project.

4. Since the houses will be tested outside, you may want to make this a solar heating or cooling experiment, depending on the season. If it is fall, winter, or early spring, solar heating is appropriate. Alternatively, you may want to test the same houses both for solar heating in winter and solar cooling in summer. Students might receive extra

credit if they design a solar heated house that remains cool in summer.

5. Test the houses on the first sunny day after they are completed. See handout for specifics about house building and testing.

Note: *As the teacher, you may want to build your own model solar house to show the students after they build their own.*

This activity was contributed by Tom Wellnitz, science teacher at Shore Country Day School in Beverly, Massachusetts.

Solar House Assignment

STUDENT HANDOUT

Your task in this assignment is to build a "house" that will be heated by the sun. Of course, you will not be building a real house, but you will be using many of the same ideas as a solar-heated house. Your house will be the size of a shoebox.

1. The winning house will be the one that, when placed outside on a sunny day between 11:00 AM and 12:30 PM, achieves the highest interior temperature.

2. Each house must be at least 10 cm x 25 cm x 10 cm (exterior dimension).

3. Houses must be attached to a piece of cardboard or wood (50 cm x 50 cm) to prevent being blown away by the wind. You may want to bring the house and base separately to school for ease of transportation.

4. On the base you should draw an arrow. Your house will be placed outside with the arrow pointed toward magnetic north, as determined by a compass.

5. Each house must have at least one window covered with at least 250 sq. cm of glazing material. "Glazing material" is any material that allows light, but not air, to pass through. It might be glass, Plexiglas, plastic wrap, etc.

6. Any materials may be used as long as they do not create a safety hazard. Try to use materials that have been thrown away. Total cost for materials should not exceed five dollars. Present a statement from your "funding agents" (parents) verifying this.

7. Due date: ___________________. Testing date will be the first school day after this date with acceptable weather.

8. Temperature recording: Temperatures will be recorded by placing a standard laboratory thermometer into the house from the side at a height of 8 cm.

QUESTIONS TO CONSIDER:

1. Which direction should the window(s) face?

2. How can you keep heat in the house?

3. Does the color of the interior make a difference?

4. Does the angle of the window make a difference?

5. What allows heat to get in during the winter but not during the summer?

6. In a real solar house, the temperature must be regulated to prevent overheating, even in winter. How is this done?