

Solar Energy Science Projects

Curriculum: Solar Power -(thermodynamics, light/electromagnetic, radiation, energy transformation, conduction/convection, seasons, trigonometry)

Grade Level: Middle or High School

Size: Whole class or small groups (3 to 4)

Time: Activities range from 2 to 5 class periods, depending on abilities of students.

Summary: The first three activities contained in the packet focus on the practical uses of solar energy. The activities deal with the heating of solids, liquids, and gases. The final activity investigates the transformation of light to electrical energy. And how different wavelengths and intensity can effect the transformation to electricity. The packet also contains a glossary.

Provided by the Department of Energy's
National Renewable Energy Laboratory
and BP America Inc.



Solar Energy Science Projects

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Glossary

SOLAR ENERGY SCIENCE PROJECTS

Solar energy can be used to heat our homes, heat water, cook our food, and power our lights.

These science projects will help you learn about solar energy and how it works. The first three projects focus on different ways to use solar thermal (or heat) energy. The fourth project focuses on solar electric energy.

Each project is broken into several parts:

- ✱ The purpose of the experiment
- ✱ The materials and equipment you will need to do the experiment
- ✱ Where to find some of the materials
- ✱ How to assemble and conduct the experiment
- ✱ What you may see during the experiment
- ✱ How the specific energy type works.

Some of the experiments may require help from an adult.

To help you understand new terms, we have included a glossary in the back. We have also included a resource list on the back page with information on where to get equipment for the experiments. The list also names places where you can find more information on solar energy.

We hope you learn something from the experiments. But most of all, we hope you have fun!

PROJECT 1: SOLAR AIR HEATER

PROJECT

You will construct a solar air heater to attach to a south-facing window.

MATERIALS AND EQUIPMENT

- ✱ 1 large piece of cardboard
- ✱ Flat black acrylic paint
- ✱ Duct tape
- ✱ Masking tape
- ✱ Measuring tape
- ✱ Paint brush
- ✱ Thin string
- ✱ Thermometer
- ✱ Scissors
- ✱ Thumbtacks (not pushpins)
- ✱ Plastic wrap
- ✱ 1 piece of graph paper
- ✱ Acrylic gesso paste

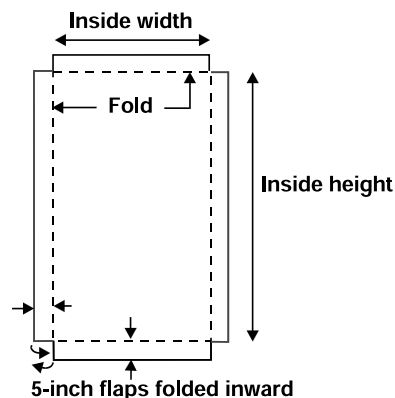
RESOURCES

Cardboard can come from a large appliance or furniture box. The gesso paste, acrylic paint, paintbrush, and graph paper can be purchased at art supply stores or hobby shops. String, duct tape, masking tape, and measuring tape is available at hardware stores.

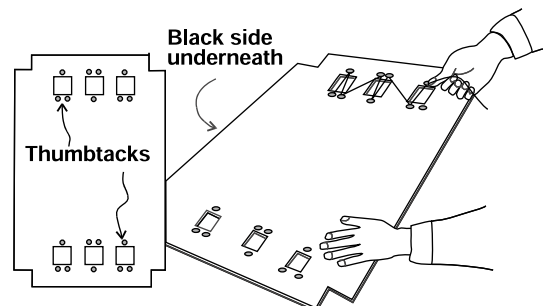
PROCESS

Setting Up the Experiment

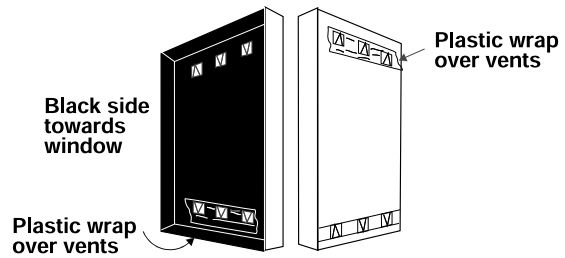
- 1** Find a south-facing window and measure its width and height inside the frame.
- 2** Cut out a piece of cardboard that is 10 inches (25 centimeters) wider and taller than the window.
- 3** Cut a 5-inch (13-centimeter) square out of each corner to make four 5-inch (13-centimeter) flaps that extend from the top, bottom, and sides of the cardboard. Fold the flaps inward. The area inside the folds should be the same size as the window area.



- 4** Apply a coat of gesso paste to the inward side of the cardboard. Allow the paste to dry for 10 minutes.
- 5** After the paste has dried, paint the same side of the cardboard with flat black acrylic paint. Allow the paint to dry.
- 6** Cut vent holes 3 inches (8 centimeters) wide by 3 inches high at about 1 inch (2.5 centimeters) from the top and bottom folds of the cardboard.
- 7** Push thumbtacks into the unpainted side of the cardboard around the vent holes on the inside surface.
- 8** Weave string around the thumbtacks and across the vent holes. This keeps the plastic wrap from blowing through the vent holes.



9 Cover the thumbtacks with thin strips of duct tape to prevent them from falling out of the cardboard.

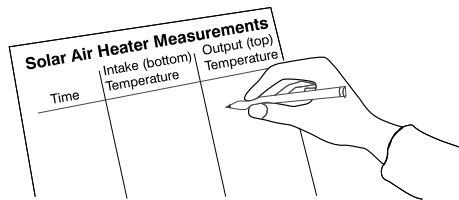


10 Cut enough plastic wrap to cover the vent holes. Decide which is the top and bottom of the cardboard. Tape the plastic to the top of the bottom vent holes on the black side so the plastic hangs as a flap. Do not completely seal the vent holes. Do the same to the top vent holes on the string side.

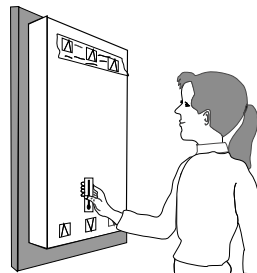
11 Fold the cardboard flaps toward the black side, and place the cardboard inside the window frame. The plastic flap on top should be facing the inside of the room. Tape the cardboard to the window frame using masking tape. You should have air space between the window and the cardboard.

Doing the Experiment

1 Draw lines on the graph paper to make a chart that looks like this.



2 On a sunny day and a cloudy day, take temperature readings every hour for several hours. To do this, hold the thermometer under the plastic flaps covering the vent holes for 2 minutes to measure the collector's air intake (bottom) and output (top) temperatures. Mark your temperature readings on the graph paper.



WHAT DID YOU SEE?

During what time of day was the collector's output temperature the highest? The lowest?
What was the highest output temperature of the collector on a cloudy day? On a sunny day?

HOW SOLAR AIR HEATERS WORK

Solar air heaters, also called collectors, trap the sun's rays to produce heat. They are mostly used to heat homes and water. Most solar collectors are boxes, frames, or rooms that contain these parts:

- Clear covers that let in solar energy
- Dark surfaces inside, called absorber plates, that soak up heat
- Insulation materials to prevent heat from escaping
- Vents or pipes that carry the heated air or liquid from inside the collector to where it can be used.

PROJECT 2: SOLAR WATER HEATER

PROJECT

You will construct a water heater with a collector and storage tank.

MATERIALS AND EQUIPMENT

Collector

- ✱ 10-inch (25-centimeter) square piece of galvanized sheet metal (the thinnest available)
- ✱ 20-inch (51-centimeter) square piece of cardboard
- ✱ Flat black spray paint
- ✱ 10-inch (25-centimeter) square piece of insulation (styrofoam, corrugated cardboard, newspaper, or batting) at least 3 inches (8 centimeters) thick
- ✱ 3-foot (1-meter) soft copper tubing, 3/8-inch to 1/2-inch diameter
- ✱ 16-inch (40-centimeter) square sheet of 3- or 4-mil clear plastic
- ✱ Knife or box cutter
- ✱ Cellophane or masking tape
- ✱ Tubing bender (or have the copper tubing bent at the hardware store)

Water Heater

- ✱ 1- or 2-pound coffee can with plastic lid
- ✱ 2 2-inch (5-centimeter) pieces of soft copper tubing, 3/8-inch to 1/2-inch diameter (must be same diameter as the copper tubing used in collector)
- ✱ Thermometer
- ✱ Cardboard box, slightly larger than coffee can
- ✱ Insulation material (Styrofoam, corrugated cardboard, newspaper, or batting)
- ✱ 100- to 200-watt soldering iron and acid-flux solder

RESOURCES

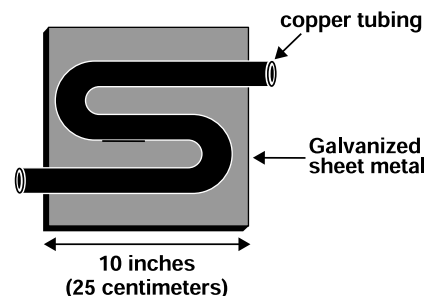
The copper and plastic tubing, tubing bender, box cutter, galvanized sheet metal, and plastic sheet are available at hardware or building supply stores. Soldering irons and flux are available at hobby stores.

PROCESS

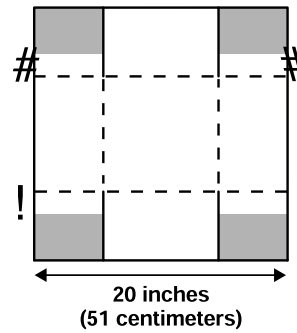
Setting Up the Experiment

TO MAKE THE COLLECTOR

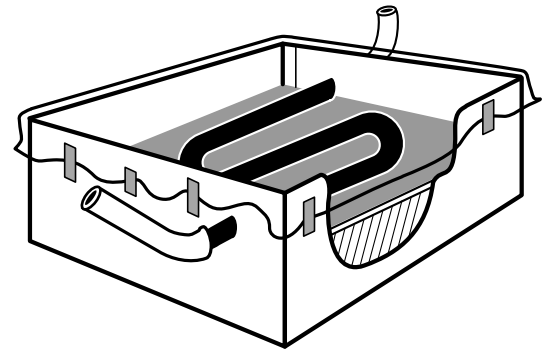
- 1** Bend the copper tubing carefully into an S-shape using a tubing bender to avoid kinks.
- 2** Lay the copper tubing onto the galvanized sheet metal and solder it in place.
- 3** Spray the plate and tubing with the flat-black paint.



- 4** Draw lines on the cardboard.
- 5** Cut on the solid lines, and fold on the dotted lines.
- 6** Cut slots and holes in the cardboard to insert the collector (sheet metal with tubing).
- 7** Fold and tape the cardboard to make a box.

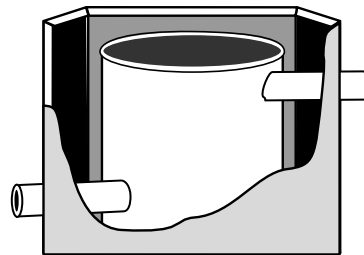


- 8** Put the insulation in the bottom of the box.
- 9** Slide the collector into the box along the slots, and tape the slots tightly closed.
- 10** Place the clear plastic sheet over the top and fold and tape it down to make a tight but removable cover.



TO MAKE THE WATER HEATER

- 1** Punch two holes on opposite sides of the coffee can. One hole must be 1 inch (2.5 centimeters) from the top of the can and the other, 1 inch from the bottom of the can.
- 2** Insert the copper tubing in both holes and solder the joints. The joints must be watertight.
- 3** Cut holes in a cardboard box that will align with the tubes in the can.
- 4** Put the can inside the cardboard box, with the tubes sticking out the holes in the box.
- 5** Put insulation around the coffee can.
- 6** Cut the plastic tubing into two pieces, one slightly larger than the other.



Doing the Experiment

1 Make a chart to record the following data:

Water temperature before: _____

Water temperature after 20 minutes: _____

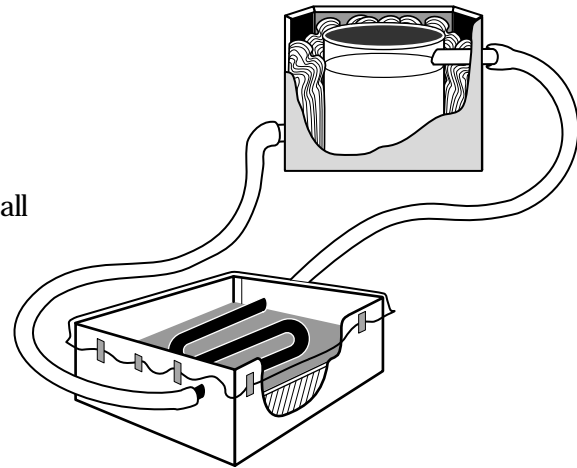
Water temperature after 1 hour: _____

2 Hook the collector and water heater together.

3 Disconnect the plastic tubing from the inlet.

4 Run water through the tubes and the collector until all the air is gone.

5 Reconnect the tubing to the inlet, and fill the coffee can with water to above the level of the inlet.



6 Measure and record the water temperature and replace the lid.

7 Face the collector directly into the sun, placing the bottom of the heater above the top of the collector.

8 Measure and record the water temperature after 20 minutes.

9 Measure and record the data every 20 minutes.

WHAT DID YOU SEE?

What happened to the water level in the can when you first hooked up the system?

How hot did the water get in 20 minutes? In an hour?

Would the solar water heater work if the storage container was placed lower than the collector?

Will the solar water heater work in reverse on a cold night?

Can you detect the water flow in the system using chalk dust or food coloring in the water?

What was the highest temperature you recorded?

HOW SOLAR WATER HEATERS WORK

Solar water heaters use the sun to heat water in collectors mounted on the roof of a house. One type of solar water heater is called a thermosiphon system. As water in the collector heats, it becomes lighter and rises into the tank above. Meanwhile, cooler water in the tank sinks down pipes to the bottom of the collector, causing circulation throughout the system. This is known as thermosiphoning. The storage tank must be above the collector for the thermosiphoning to work.

PROJECT 3: SOLAR HOT DOG COOKER

PROJECT

You will construct a model of a parabolic solar collector that will cook a hot dog.

MATERIALS AND EQUIPMENT

- ✱ 14-inch (35-centimeter) sheet of aluminum foil
- ✱ 11 x 14-inch (28 x 35-centimeter) piece of poster board
- ✱ 1 unpainted wire coat hanger
- ✱ Cellophane or masking tape
- ✱ 2 boxes (one for the collector and one for a stand)
- ✱ 2 nuts
- ✱ 2 bolts

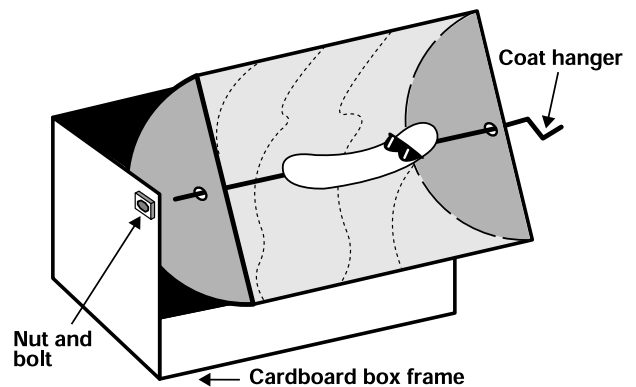
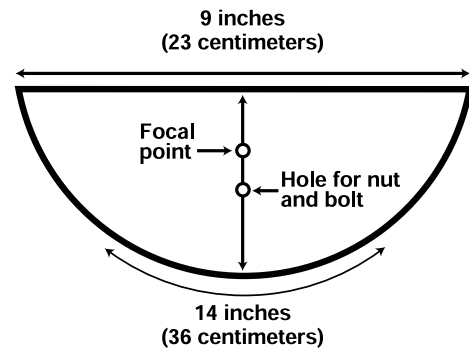
RESOURCES

You can find poster board at art supply stores and nuts and bolts at a hardware store. You can generally get old boxes from a grocery store.

PROCESS

Setting Up the Experiment

- 1** Make the ends of the parabolic trough out of the cardboard using the pattern shown here. (You will need to enlarge the pattern to match the scale given.)
- 2** Tape the aluminum foil to the piece of poster board.
- 3** Curve the the poster board and tape it to the two curved ends.
- 4** Attach the trough to the box frame using nuts and bolts. Make sure the trough can move up and down but will stay in one place.
- 5** Put holes at either end of the trough focal point.
- 6** Straighten the wire coat hanger and bend one end to make a handle.
- 7** Push the coat hanger through the hole on one side. Put the hot dog on the coat hanger, and push the coat hanger through the hole on the other side.



Doing the Experiment

- 1** Place the solar cooker so the mirrored trough faces the sun.
- 2** Adjust the trough up and down until the mirrored surface focuses the sun on the hotdog.
- 3** Cook the hot dog.

WHAT DID YOU SEE?

How long did it take to cook the hot dog?

Did you have to move the cooker to keep the sun focused on the hotdog?

HOW PARABOLIC COLLECTORS WORK

A parabolic collector is made up of a trough and a tube running down the center of the trough. The trough is a long rectangular mirror formed in a U-shape. The mirror is tilted toward the sun to focus the sunlight on the tube. The paraboloid shape is perfect for focusing the sunlight on the tube. The tube carries the fluid to be heated. A tracking device keeps the mirrors pointed toward the sun as it moves across the sky.

Parabolic collectors are used mostly to provide hot water for use in industry and sometimes in homes. They are also used to produce electricity.

PROJECT 4: EFFECTS OF AMOUNT AND WAVELENGTH OF LIGHT ON A SOLAR CELL

PROJECT

You will demonstrate how the amount and wavelength of light affects a solar cell.

MATERIALS AND EQUIPMENT

- * Solar cell
- * 2 pieces enameled or plastic coated wire (8–10 inches [20–25 centimeters] each)
- * Electric motor
- * Soldering gun
- * Solder (rosin core)
- * Sandpaper
- * Knife or wire stripper (optional)
- * 6-inch (15-centimeter) diameter cardboard circle
- * Utility knife
- * Glue (hot or white)
- * Plastic wheel with axle hole in center
- * Black marking pen
- * Stopwatch
- * 1 sheet of black construction paper
- * Several sheets of colored transparency film in a variety of colors
- * Paper and pencil or pen

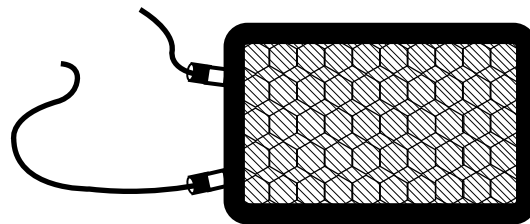
RESOURCES

Solar cells, wheels, and motors are available from science supply stores and hobby shops. Soldering guns and solder are available at hardware stores. Transparency film is available at hobby shops and office supply stores.

PROCESS

Setting Up the Experiment

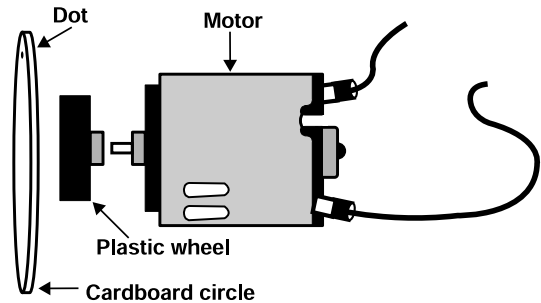
- 1** Strip the ends of each coated wire exposing about 1 inch (2.5 centimeters) of the metal. If the wire is plastic coated, use a knife or wire stripper to remove the plastic. If the wire is enameled, sand the ends to expose the wire ends.
- 2** Plug in the soldering gun to heat it up.
- 3** Melt a drop of solder onto one of the leads on the solar cell. Quickly place the end of one of the stripped wires in the drop of molten solder. Add a tiny drop of solder on top of the wire, making sure the wire is completely surrounded by the solder.
- 4** Repeat the process with the other wire.
- 5** Let the solder cool completely for 10 minutes. Gently pull on the wires to make sure that both are securely attached.
- 6** Melt a drop of solder onto one of the leads on the motor. Quickly place the end of one of the wires attached to the solar cell in the drop of molten solder. Add a tiny drop of solder on top of the wire, making sure the wire is completely surrounded by the solder.
- 7** Repeat the process with the other wire.



8 Let the solder cool completely for 10 minutes. Gently pull on the wires to make sure that both are securely attached.

9 Attach the plastic wheel to the motor by gently pushing the wheel onto the shaft of the motor. Be careful not to chip the solder or break the wires.

10 Glue a 6-inch (15-centimeter) diameter cardboard circle on the face of the wheel.



11 Mark a small dot on the edge of the cardboard wheel. This dot will be used as a frame of reference to measure the speed that the wheel is spinning.

Doing the Experiment

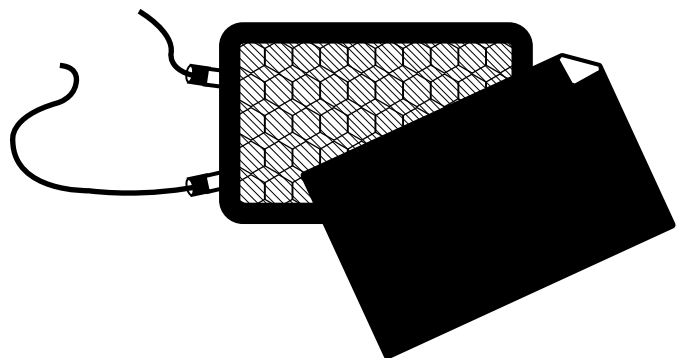
1 Place the solar cell, motor, and wheel in bright sunlight. Observe the spinning motion. (If the motor does not spin the wheel, check the wire connections. It may be necessary to resolder the connections.)

2 Using the stopwatch and watching the dot, count the number of spins in 15 seconds. Multiply this number by 4 to obtain the number of spins per minute. Record the spinning rate on a piece of paper.

HOW THE AMOUNT OF LIGHT AFFECTS A SOLAR CELL

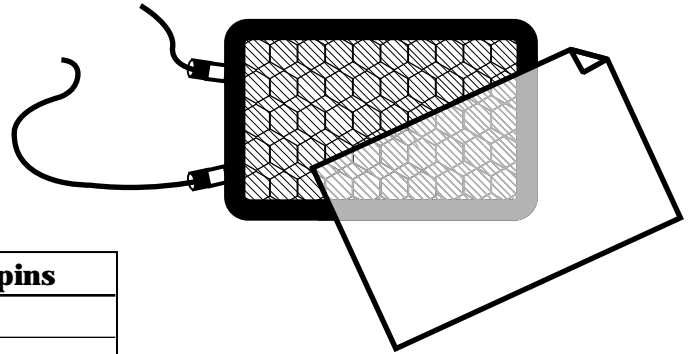
1 Shade one area of the solar cell with the black construction paper. Diagram the portion of the cell shaded and record observations on a piece of paper.

2 Repeat the experiment shading different areas and amounts of the solar cell.



HOW THE WAVELENGTH OF LIGHT AFFECTS A SOLAR CELL

- 1** Cover the solar cell with a piece of colored transparency film. Count the number of spins in 15 seconds. Multiply this number by 4 to obtain the number of spins per minute. Record the spinning rate in a chart similar to the one below.



Colors	Number of Spins
Sunlight	
Red	
Yellow	
Blue	
Green	
Black	

- 2** Repeat the experiment with the other colors of transparency film.

WHAT DID YOU SEE?

How did the spinning motion change when you covered part of the solar cell? All of the cell?

Which colors slowed the spinning the most?

Which colors slowed the spinning the least?

HOW SOLAR CELLS WORK

Solar cells, also called photovoltaic or PV cells, change sunlight directly to electricity. When sunlight strikes the solar cell, electrons are knocked loose. They move toward the treated front surface. An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, like a wire, a current of electricity travels between the negative and positive sides.

Solar cells are used to power calculators and watches as well as lights, refrigerators, and even cars.

GLOSSARY

Parabolic collector - A U-shaped mirrored trough that focuses sunlight onto a tube running down the center of the trough.

Photovoltaic cell - A means of converting sunlight into electricity (see solar cell).

Solar heater - A water or space heating system that uses the sun's energy to heat homes and water.

Solar cell - A means of converting sunlight into electricity (see photovoltaic cell).

Solar collector - A box, frame, or room that traps the sun's rays to produce heat. A parabolic trough is a type of solar collector.

Solar electric energy - Energy from the sun used for electricity.

Solar energy - Energy from the sun. The heat that builds up in your car when it is parked in the sun is an example of solar energy.

Solar thermal energy - Energy from the sun used for heat.

Thermosiphoning - An event where heated water in a solar collector becomes lighter and rises to the top and cooler water becomes heavier and sinks to the bottom.

RESOURCES

Equipment Suppliers

Edmund Scientific Company
101 East Glouster Pike
Barrington, NJ 08007
(609) 547-3488

Frey Science Company, Inc.
905 Hickory Lane
Mansfield, OH 44905
(800) 225-3739

Hubbard Scientific Company
1120 Halbleib Road
Chippewa Falls, WI 54729
(800) 323-8368

Solar Box Cookers International
1724 Eleventh Street
Sacramento, CA 95814
(916) 444-6616

General Resources

Center for Science Education
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
(800) 639-3649

Energy Efficiency and Renewable Energy
Clearinghouse (EREC)
U.S. Department of Energy
P.O. Box 3048
Merrifield, VA 22116
(800) 363-3732

Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922
(407) 638-1000

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