

Shoebox Solar Cooker

Students build and use a simple solar cooker and experiment using the sun to heat food.

Grade Level: (K-4) 5-8

Subject Areas: English Language Arts, Family and Consumer Science, Mathematics, Science, Social Studies, Technology Education

Setting: Outdoors on a sunny day and classroom

Time:

Preparation: One week

Activity: Three 50-minute periods

Vocabulary: Greenhouse effect, Insulation, Solar cooker, Solar oven

Major Concept Areas:

- Natural laws that govern energy
- Development of energy resources
- Management of energy resource use

Getting Ready:

Use an unshaded outdoor setting where the solar ovens can remain undisturbed for at least an hour. You may want to provide students with the materials list the week before the activity is scheduled and have them bring the items from home. An alternative is to build one solar oven and have groups use a single oven to conduct experiments. If possible, invite aides or parents to help with the construction. Have students decide what food they'd like to cook and create a shopping list. You may request that students bring in these ingredients as well. See **Steps 2 and 3** for variations for younger students.

Objectives

Students will be able to:

- construct an effective solar oven;
- explain how a solar oven works; and
- discuss the benefits and challenges of using a solar oven.

Rationale

Operating a solar oven helps students learn about solar energy and heat-related principles and appreciate the importance of energy-related technologies.

Materials

- Each group of students will need copies of the following:
 - [Building a Shoebox Cooker](#) and materials listed on this student page
 - [Using a Shoebox Cooker](#)
 - [Solar Cooking Record](#) (optional)
- Photographs of commercial solar ovens (optional)
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

Did you ever hear the expression, "It's hot enough to fry an egg on the sidewalk?" Sidewalks don't really get quite hot enough to cook on, but you could build a solar box cooker, place it on a sidewalk, and allow it to collect the sun's heat energy and cook many different kinds of food.

Commercial solar cookers are also available (see **Resources**). To work properly, a solar box cooker (also called a solar oven) must hold heat energy long enough for the food to absorb the heat and cook.

Making a solar oven can be both simple and difficult. Collecting energy from the sun is easy. When sunlight strikes a surface and is absorbed, it gets converted to heat energy (or infrared radiation). A glass or Plexiglas cover works like a greenhouse window to let sunlight in but not let the infrared radiation

out. Solar cookers usually include some kind of reflector that increases the amount of energy the cooker receives by reflecting light inside the box onto the cooking container. Keeping the heat energy in the oven is more difficult. Solar box cookers must be carefully insulated and tightly sealed so the captured heat cannot escape.

The key to a successful solar oven is making sure it faces the sun. To keep the solar cooker hot all day, it must be continually turned to follow the path of the sun. For a gradual heating process, place food in an oven and direct it toward the sun's midday position. The food cooks slowly, reaching its peak heat by mid-afternoon. The food is ready to eat by early evening.

Solar box cookers reach between 140 degrees F (60°C) and 266 degrees F (130°C) depending on their construction and intensity of the sunlight. Clear, sunny days provide the best results. However, as long as the cooker faces the sun and is well-insulated, the temperature outside the cooker should have little effect on the cooking rate. So solar cookers can be used in December as well as in July.

The choice of ovenware can affect the cooking time in a solar cooker. Ovenware can be made from glass, ceramic, earthenware, or metal. Each material conducts and retains heat differently. Often dark-colored ovenware is best for solar cookers because it absorbs light energy better than light-colored materials.

What can be cooked in a solar oven depends on the quality of the cooker. Any conventional recipe suitable for a slow cooker works well, because the solar cooker will get hotter than a slow cooker. Baking should be done on clear, sunny days as it requires higher temperatures. Cutting the ingredients into small pieces will help the food cook faster. The foods, especially liquids and moist meals such as stews, need to be sealed in the solar box cooker so water does not condense on the glass cover. Simple solar cookers, such as those made from a shoebox, should be able to do the following:

- Heat water for hot chocolate, tea, or instant soup
- Warm canned soups, vegetables, and stews
- Prepare hot dogs
- Melt cheese, chocolate, or marshmallows
- Make simple pizzas (cheese and tomato sauce sprinkled on prepared crust)
- Bake chocolate chip cookies

Better built solar cookers can cook regular meals. With a well-constructed or commercial oven you can prepare

foods, such as vegetables and grains, that need to be cooked more thoroughly. For example, summer squash, fresh peas, green beans, spaghetti, noodles, instant potatoes and rice cook relatively quickly. White rice, rolled oats, pearl barley, and squash should cook in two hours. Lentils, black-eyed peas, black beans, and potatoes will need about three hours.

Frying eggs may not be the best use for a solar oven, but you can cook eggs in breads, casseroles, and cakes. Whether you decide to make a warm drink on a cold day in December or a complete meal, solar box cooking is fun and delicious.

Procedure

Orientation

Ask if any students have ever been in a car that has been parked in the sun. Have a student describe what it feels like inside the car. Students may have also heard warnings about not leaving pets and children in parked cars because of the risk of heat exhaustion or stroke.

Discuss how sunlight passes through the glass windshield and windows in a car. When the light strikes the interior surfaces of the car, it is absorbed and converted to heat energy. The heat can not escape through the glass and causes the interior temperature of the car to increase.

Steps

1. Ask students if they think heat from the sun can be used to melt things such as chocolate or cheese. Tell students that by applying what they know about heat collecting in a parked car, they can design an oven that uses the sun's energy to cook food.
2. Divide the class into working groups. Hand out and discuss *Building a Shoebox Cooker*, Materials and Procedure for Variation #1, #2, or #3. NOTE: Variation #2 involves cutting and placing foam trays in the box for insulation. Younger students may have a difficult time handling the pieces of foam and will get frustrated when they try to line the shifting trays with foil. Shifting can be minimized by cutting the trays to fit tightly against each other. Small hands may find Variation #3, the two-shoebox method, easier. Variation #1 is the easiest but may not be as effective.
3. Provide students with copies of *Using a Shoebox Cooker* and have them prepare the food they want to cook. Have students test and use their cookers. The *Solar Cooking Record* can be used to document

observations, and this data can also be used to make graphs. NOTE: For younger students, it may be enough to observe that the sun heats food and to note temperature changes.

Closure

Have students share the results of their cooking experiments. Do they think they would regularly use solar ovens? Remind students that the ovens they constructed are simple, and that there are more technical and efficient models available. Inform students that there are companies that sell commercial solar cookers that are very effective at heating food. If available, show pictures of some of these cookers. Students can compare qualities of these cookers to their own.

Discuss ways students can test or improve the cookers. Questions to explore include:

- How well does the cooker work on cloudy days?
- What effect does outside temperature have on the cooking rate?
- Is there any difference when the cooker is used in December than when it is used in June?
- Would a bigger box, more reflectors, or different types of insulation improve the effectiveness of the cooker?

Assessment

Formative

- How well did students construct the ovens?
- Can students explain how a solar oven works?
- How effectively do the solar ovens heat food?

Summative

- Have students plan a party for another class or their parents in which food is cooked in the solar ovens. The event can begin with students explaining how they made the solar ovens and how they work. During the presentation, students can discuss the potential and practicality of solar oven use in their own future.
- Students can research the many different designs for solar cookers and experiment with different

properties and adaptations. For example, try placing a thicker piece of metal, such as a piece of a cookie sheet or baking pan, in the bottom of the solar oven to increase heat transfer and storage.

Extensions

Students may be interested in exploring how solar cookers are currently being used worldwide, especially in places where electricity is unavailable and traditional fuel sources, such as wood, are being depleted (see **Resources**).

Purchase a commercial solar oven or invite a guest speaker (such as a vendor) who regularly uses a solar oven to show and discuss more sophisticated models and methods of solar cooking (see **Resources**). Students can also see solar ovens in use at the [Midwest Renewable Energy Fair](#).

Related KEEP Activities

Use this activity as part of a unit on solar energy or heat. See K-5 Energy Sparks for Theme II: “Sunvestigations” or K-5 Energy Sparks for Theme I: “Exploring Heat.” A solar cooker can also be used to enrich investigations in “Taking Temperatures.” Older students can apply concepts from solar cooking to activities such as “So You Want to Heat Your Home?” Other uses of solar energy such as those found in “The Miracle of Solar Cells” could be done with younger students.

Credits

Activity adapted from “Now You’re Cooking—With the Sun” in Florida Middle School Energy Education Project: Energy Bridges to Science, Technology and Society. Tallahassee, Fla.: State of Florida for the Florida Energy Office, 1994. Used with permission. All rights reserved.

Activity adapted from Hawai’i Extension Service. *Making Shoe Box Cookers*. Contact: Energy, Resources, and Technology Division. Department of Business, Economic Development, and Tourism, 99 Aupuni Street, #101B, Hilo, Hawai’i 96720.

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Building a Shoebox Solar Cooker

Variation 1

Materials

- Shoebox
- Aluminum foil
- Tape
- Clear plastic wrap
- Food that is easy to heat (Try melting cheese on chips, chocolate on graham crackers, etc.)
- Pot holders
- Sunglasses

Procedure

1. Line the shoebox with aluminum foil and tape in place if necessary.
2. Place food on aluminum foil.
3. Cover shoebox with plastic wrap and tape in place.
4. Set box in the sun.

Variation 2 and 3

Materials

- Shoeboxes with lids (one per student or one per group)
Variation 3: two boxes per student or team, one being roughly one inch (2.5 cm) larger than the other in all dimensions
- Foam produce trays, well washed (approximately four per shoebox)
Variation 3: insulating material such as Styrofoam packing material, crumpled newspaper, cardboard, etc.
- Overhead transparencies (one per shoebox)
- White glue (optional)
- Duct tape (Masking tape is an alternative, but it won't last as long.)
- Heavy-duty aluminum foil (approximately two feet (60 cm) per shoebox)
- Chopsticks or twigs (one stick per shoebox)
- Rulers
- Pencils
- Single-hole punch
- Scissors, knife, or razor cutters
- Oven thermometers (one per group)
- Small food containers made of heat-conducting material such as glass or metal (Make sure food containers will fit inside the cookers! Examples include baby food jars, pot pie pans, petri dishes and Pyrex custard cups, or containers made from aluminum foil.)
- Food that is easy to heat (Try melting cheese on chips, chocolate on graham crackers, etc.)
- Plastic wrap
- Pot holders
- Sunglasses
- Decorating materials and paint (optional) NOTE: High-temperature spray paint works best as it won't crack when heated.

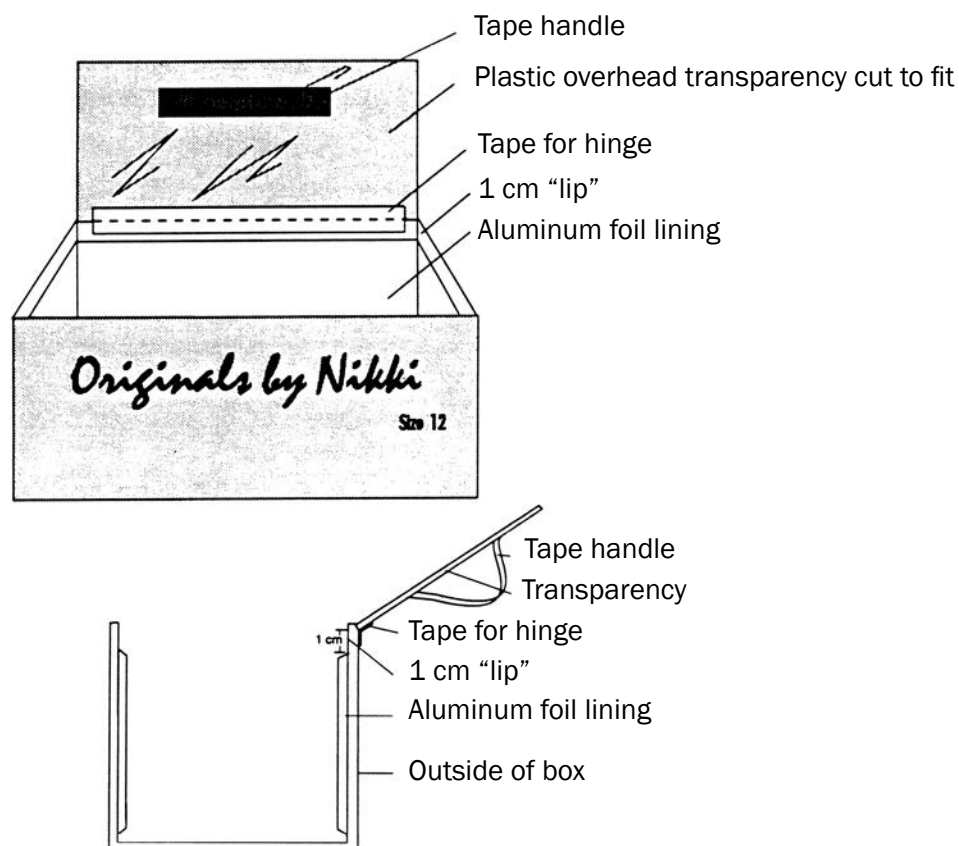
NOTE: For a larger solar cooker, use bankers' boxes instead of shoeboxes and acrylic plastic sheets instead of overhead transparencies. Using bankers' boxes will work best with **Variation 3** (see **Procedure**).

Building a Shoebox Solar Cooker

Variation 2

Procedure

1. Remove and save the lid from the shoebox. Line the inside of the shoebox with foam produce trays. The trays should be placed so that their raised edges are touching the shoebox floor and walls, forming an insulating air space. You may be able to fit trays in the shoebox with minimal cutting. If you have lots of trays, make two layers. If necessary, use white glue to hold the trays in place.
2. Line the interior of the insulated shoebox with aluminum foil, bringing the edges of the foil up and over the rim of the box. Use only one piece of foil (if possible) to help seal the interior of the cooker. If more than one piece of foil is necessary, overlap the edges to reduce heat loss. It may be easier to use two pieces of foil, one sized to the length of the box and one sized to the width. The two pieces of foil can then be laid in the box across each other (crisscrossed).
3. Using duct tape, tape the loose edges of the foil to the outside of the shoebox. This step completes the body of the cooker.
4. Using a ruler and pencil, draw a rectangle on the inside of the shoebox lid 3/4-inch (1.88 cm) from the edges of the lid. Mark one of the long sides "fold."



Building a Shoebox Solar Cooker

Variation 2 (Continued)

5. Using the scissors, knife, or razor cutter, cut carefully along the other three sides of the marked rectangle, so that the shoebox lid has a flap in it. Fold the flap up along the last edge of the rectangle. This flap will be your cooker's reflector.
6. Carefully smooth a piece of foil over the underside of the flap. The smoother, the better! Secure the foil with glue or tape; if tape is used, fold the foil onto the top of the flap and tape it on that side, so as not to cover the shiny bottom of the flap with any tape.
7. Cut a piece of overhead transparency to fit inside the shoebox lid. If at all possible, use a single piece to reduce heat loss. If you have to fit two pieces together, overlap them by at least one inch (2.5 cm).
8. Tape the overhead transparency to the inside of the shoebox lid, completely covering the cut opening. Make sure that the tape is securely fastened to the 3/4-inch (1.88 cm) border around the opening. The overhead transparency lets sunlight into the cooker.
9. Securely place the lid onto the shoebox. Raise the reflector flap. Near one of the top corners, punch a hole in the lid with the single-hole punch. Insert the narrow end of a chopstick in this hole, so that the thick end is resting on the shoebox lid, but not on the overhead transparency. You may need to make a "nest" for the thick end of the chopstick with a bit of tape. The chopstick is your reflector support.
10. Your shoebox cooker is complete!

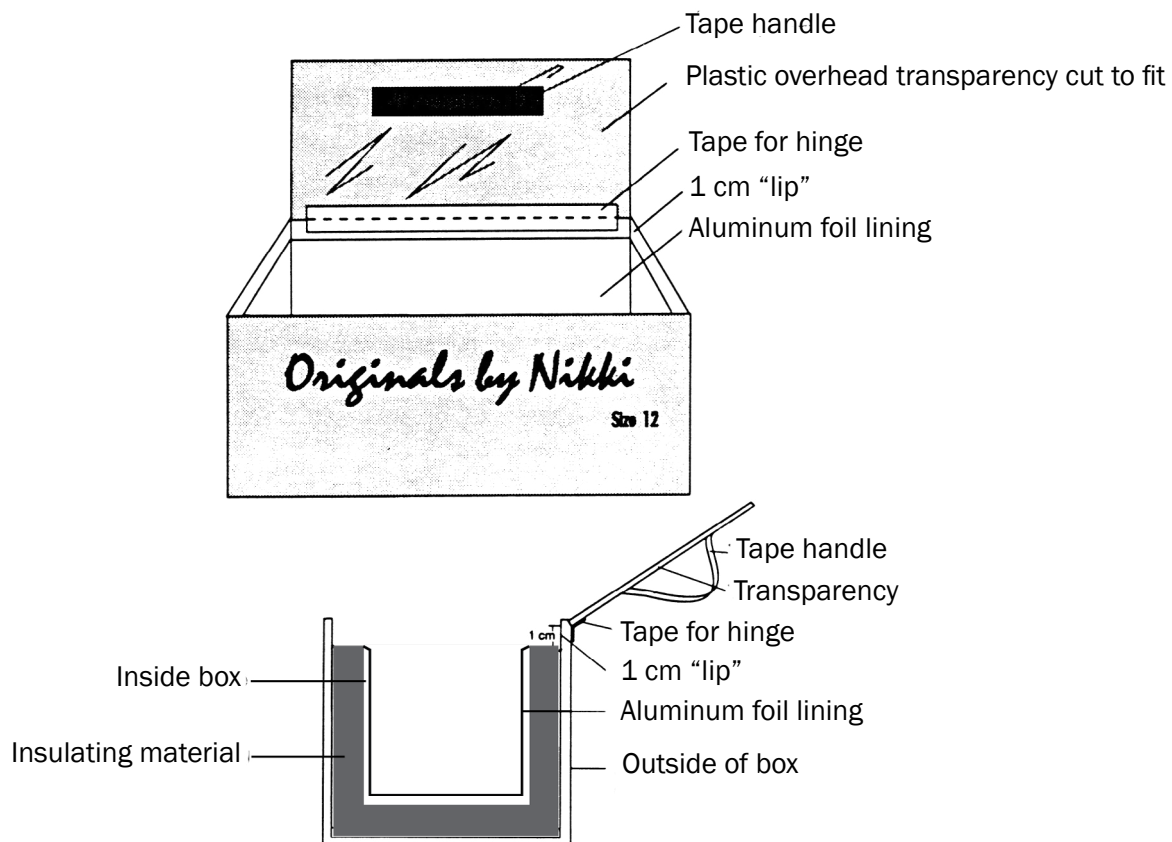
NOTE: You may decorate or paint your solar ovens. Take care not to paint the overhead transparency or the reflector flap. Painting the exterior of the box is a matter of aesthetics; it doesn't affect the box's ability to absorb heat. Experts vary in their opinions of whether the interior of solar ovens should be reflective (to direct more sunlight onto the cooking food) or black (to absorb more heat to help cook the food). If you want the interior to be black, try using black construction paper or electrical tape as painting the interior can expose foods to volatile gases. Set the oven outside in the open with the lid open for a day to allow the gases to escape. An alternative is to line the interior with foil. You may want to conduct an experiment where half the class has a black interior and the other half has foil to discover which method is more effective.

Building a Shoebox Solar Cooker

Variation 3

Procedure

1. Remove the lid from the smaller of the two shoeboxes. Line the smaller shoebox neatly with aluminum foil.
2. Remove and save the lid from the large shoebox. Insulate the bottom of the large shoebox by putting in a layer of insulating material. Pieces of foam trays, crumpled paper, corrugated cardboard, sand, or soil can be used. (You may want to set up an experiment: Which type of insulation works best?) Make the layer no deeper than the difference in height between the two boxes, so that when the small box is set on the insulation inside the big box, the boxes' rims are even.
3. With the small box inside the large box, carefully fill in the air spaces between their four walls with more insulation. The insulation should come up to the rims of the boxes.
4. Cover the top of the insulation with a strip of aluminum foil, securing it on the outside of the large box and inside of the small box with tape. The aluminum foil will keep the insulating material isolated from the cooking chamber within the small box. Try to minimize the amount of tape used on the inside of the small box, to avoid covering large areas of the reflective foil.



Building a Shoebox Solar Cooker

Variation 3 (Continued)

5. Using a ruler and pencil, draw a rectangle on the inside of the shoebox lid $\frac{3}{4}$ inch (1.88 cm) from the edges of the lid. Mark one of the long sides “fold.”
6. Using the scissors, knife, or razor cutter, cut carefully along the other three sides of the marked rectangle, so that the shoebox lid has a flap in it. Fold the flap up along the last edge of the rectangle. This flap will be your cooker’s reflector.
7. Carefully smooth a piece of foil over the underside of the flap. The smoother, the better! Secure the foil with glue or tape. If tape is used, fold the foil onto the top of the flap and tape it on that side, so as not to cover the shiny bottom of the flap with any tape.
8. Cut a piece of overhead transparency to fit inside the shoebox lid. If at all possible, use a single piece to reduce heat loss. If you have to fit two pieces together, overlap them by at least one inch (2.5 cm).
9. Tape the transparency to the inside of the shoebox lid, completely covering the cut opening. Make sure that the tape is securely fastened to the $\frac{3}{4}$ -inch border around the opening. The overhead transparency lets sunlight into the cooker.
10. Securely place the lid onto the shoebox. Raise the reflector flap. Near one of the top corners, punch a hole in the lid with the single-hole punch. Insert the narrow end of a chopstick in this hole, so that the thick end is resting on the shoebox lid, but not on the overhead transparency. You may need to make a “nest” for the thick end of the chopstick with a bit of tape. The chopstick is your reflector support.
11. Your shoebox cooker is complete!

NOTE: Use larger boxes, such as bankers’ boxes, to make a bigger solar cooker. Follow **Steps 1–4** of the procedure. Use the lid of the larger box as the reflector (see **Step 7 and 10**). You may want to tape one long end of the lid to the box. It may also help to cut the corners so the lid lifts up and down like a door. Use an acrylic plastic sheet instead of overhead transparencies, cutting it so that it rests on the insulation layer. Make handles to put in and remove the glass by using rolls of tape or by drilling holes into the acrylic sheet and inserting knobs. You will need sticks that are at least two feet long to support the reflective lid.

NOTE: You may decorate or paint your solar ovens. Take care not to paint the overhead transparency or the reflector flap. Painting the exterior of the box is a matter of aesthetics; it doesn’t affect the box’s ability to absorb heat. Experts vary in their opinions of whether the interior of solar ovens should be reflective (to direct more sunlight onto the cooking food) or black (to absorb more heat to help cook the food). If you want the interior to be black, try using black construction paper or electrical tape as painting the interior can expose foods to volatile gases. Set the oven outside in the open with the lid open for a day to allow the gases to escape. An alternative is to line the interior with foil. You may want to conduct an experiment where half the class has a black interior and the other half has foil to discover which method is more effective.

Using a Shoebox Solar Cooker

Caution: The solar oven can get very hot, so use pot holders. Do not stare at the sun or the sun's reflection in the aluminum; it can damage your eyes. Sunglasses are recommended.

1. Make sure that your food container will fit inside the cooker. Prepare the food you want to cook. For example, sprinkle cheese on nacho chips, make a simple cookie recipe, place pieces of chocolate and marshmallows on graham crackers, etc.
2. Locate a sunny area for the cookers. Watch out for trees, buildings, and other structures that may cast shadows on your cookers. Your cookers will be outside at least an hour, and they must not be shaded. Remember that as the Earth rotates, shadows move and change lengths throughout the day.
3. Put a thermometer in each cooker (or in selected cookers if you don't have enough thermometers). Make sure that the lids are set securely on each cooker and that the reflective flaps are raised. Aim the cookers toward the sun. You can tell when the cookers are aimed correctly by adjusting their orientation until the cookers' shadows are as small as possible.
4. Adjust the reflective flap by moving it up and down and observing the reflected light within the cooking chamber. At the point when the interior is brightest, insert the chopstick support into the hole on the flap, to secure the flap at that angle. NOTE: Because Earth rotates, the cookers' orientation and reflective flap angle may need to be adjusted during the cooking period.
5. Preheat your cooker by letting it sit in the sun. On a sunny day, shoebox cookers can easily reach 200 degrees F (93 °C) in 30 or 40 minutes. Check the thermometers periodically.
6. When the cookers are hot enough (at least 150 degrees F [66 °C]), place your foods in the cooking containers, cover the containers with plastic wrap (optional) and as quickly as possible put the containers in the cookers. The less time the lids are off, the less heat you'll lose. It may help to have one student lift a lid while the other quickly puts the food in.
7. Let it cook! You may wish to keep recording temperatures and weather observations at set intervals.

