NOVA

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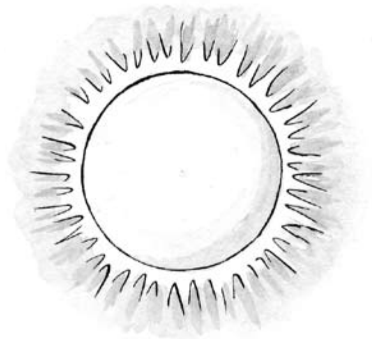
PBS

Saved By the Sun

PROGRAM OVERVIEW



NOVA explores what it would take for solar energy to become a real player in the energy game.

The program:

- looks at the use of photovoltaic panels in homes and describes how they work and how some people are benefiting financially by using solar power.
- notes that increased energy demands, dwindling global fossil fuel resources, and heightened public concern for global warming all contribute to the need for alternative energy sources like solar energy.
- presents the challenges of maintaining power during the summer in Los Angeles and explains that cities currently rely on fossil fuel power plants to survive.
- profiles the Kramer Junction Solar Electric Generating System in the Mojave Desert, the largest solar thermal power plant in the world.
- examines how solar power became a mainstream energy source in Germany.
- explores innovative business models that are supplying solar energy to companies like Whole Foods.
- reports on solar research being conducted at the National Research Energy Laboratory in Colorado, including multi-junction solar cells that were used on the Mars rovers.
- introduces research that draws on nanotechnology to make solar power more affordable.
- concludes by noting that while most of the promising solar energy options will take years to come to the market, decisions need to be made now regarding future energy options.

Taping Rights: Can be used up to one year after program is recorded off the air.

BEFORE WATCHING

1 Organize students into groups and assign each group the United States or Germany. Have each group research energy consumption for its assigned country (including coal, oil, natural gas, nuclear, hydroelectric, geothermal, solar, wind, and wave), the advantages and disadvantages of each type of energy, and the renewability of each (see Links & Books on page 6 for resources). As a class, create a chart that lists students' results. Which of the fuels are the most used? Why might that be? Which are the most harmful to the environment? Which are the cleanest? How do fuel costs compare?

2 Organize the class into four groups and assign each group one of the following topics to take notes on as they watch: ways that solar energy can be collected, advantages and disadvantages of solar energy, solar energy use in Germany, and new solar technologies being developed.

AFTER WATCHING

1 Have students refer to their notes as you lead a discussion concerning the use of solar energy. Could something like the German Renewable Energy Sources Act ever happen in the United States? Why or why not? In what ways are individuals and organizations in the United States working to make solar energy a plausible source of energy in the United States?

2 As a member of the President's Cabinet, the U.S. Secretary of Energy is responsible for federal policy concerning energy production and regulation. Ask students to draft a one-page letter to the secretary outlining what recommendations they would make for U.S. energy policy in the next decade and why.

CLASSROOM ACTIVITY

Activity Summary
Students follow a seven-step invention process to design, build, and test a solar cooker that will pasteurize water.

Materials for Each Team
- copy of "Got Sun? Get Cooking!" student handout
- copy of the "Invention Checklist" student handout
- copy of the "Finding the Focal Point" student handout
- copy of the "Temperature Data" student handout
- meter stick
- 150 ml room-temperature water
- thermometer, with remote sensor if possible
- timer
- ultraviolet protective sunglasses
- 2 different-colored pens or pencils

Suggested Materials for Class
- **for platform:** assortment of cardboard or clear plastic containers (shoeboxes, pizza boxes, ice cream containers, clear plastic tennis ball cans, long potato chip cans with metallic interior, 1- or 2-liter clear soda bottles)
- **for lining platform:** aluminum foil (heavy duty is best), foil wrapping paper, foil-covered foam insulation, or any other reflective material
- **for insulation:** cotton, wool, newspaper, pine needles, straw
- **for holding water:** glass, plastic, or metal container large enough to hold 150 milliliters of water
- **for other construction:** file folders, cardboard, different-colored paper or paint, paintbrushes, clear plastic wrap, clear transparencies, clear sheet protectors, cooking bags, wood skewers, scissors, glue, string, duct tape, clear tape, cardboard cutting tools (must be supervised)
- **additional materials** as determined by class

LEARNING OBJECTIVES

Students will be able to:

- use the invention process to design, build, and test a solar cooker.
- describe how transmission, absorption, and reflection are used in a solar cooker to heat water.
- evaluate what variables contribute to a successful cooker.

STANDARDS CONNECTION

The "Got Sun? Get Cooking!" activity aligns with the following National Science Education Standards (see books.nap.edu/html/nses) and the Principles and Standards for School Mathematics (see standards.nctm.org/document/index.htm).

GRADES 5–8
Physical Science
- Transfer of energy

Science and Technology
- Abilities of technical design
- Understandings about science and technology

Mathematics Standards
- Algebra
- Data Analysis and Probability

GRADES 9–12
Physical Science
- Interactions of energy and matter

Science and Technology
- Abilities of technical design

Mathematics Standard
- Algebra

Video is not required for this activity.

CLASSROOM ACTIVITY (CONT.)

Background

Unlike many of the fossil fuels humans depend upon, solar energy is a clean and renewable resource. Although Earth only receives one ten-billionth of the total output of power from the sun (4×10^{26} watts), more energy strikes Earth in a few hours than is consumed by humans in an entire year.

A solar cooker uses only a small portion of the total energy released by the sun. In fact, most of the radiation that reaches Earth's surface is visible light, or long-wave infrared waves (most short-wave infrared radiation is absorbed by atmospheric water vapor). Most higher-energy wavelengths—ultraviolet, X-rays, and gamma rays—are scattered or absorbed by Earth's atmosphere. Radio waves are very weak and carry almost no energy.

Infrared waves that strike a cooker are absorbed by objects in the cooker as thermal radiation. Light waves that reach a cooker are either transmitted, absorbed, or reflected depending upon the object they strike. An object will either transmit light waves through itself, absorb light waves and convert a large part of them to heat, or reflect light waves off its surface. (When light hits most objects, part of it will be transmitted, part absorbed, and part reflected.)

While many types of cookers exist, all solar cookers operate on the same principle—concentrate energy from the sun on an object to be heated. The three main types of cookers are box, panel, and parabolic. Box cookers, often covered by clear glass or plastic, work by trapping energy inside the box (the transparent covering allows light waves to pass into the box but does not easily let infrared waves out). Glass traps heat better than plastic. A box cooker works best if the interior is painted a dark color to absorb most of the light waves, if the box is insulated to help curb heat loss from the box walls, and if some sort of reflective surface is added outside the box to help focus light waves inside.

Panel cookers work by reflecting light waves down onto the food to be cooked. They often contain many panels positioned to reflect light waves down onto the food. Parabolic cookers also use a reflective surface to focus light; they differ from panel cookers in that they concentrate all incoming light waves to a specific point (called the focal point). The focused light waves are converted to heat when they are absorbed by the food. Parabolic cookers are often the most effective cooker designs because of this feature.

EXPLORE MORE ONLINE

Energy Production Lesson Plan
Visit WGBH's multimedia digital library, Teachers' Domain, to find a lesson plan that encourages students to examine the role of energy in their daily lives, learn about several types of energy production, and explore the risks and benefits of each type. Find the lesson at www.teachersdomain.org/resources/phy03/sci/phys/energy/lp_energypr/index.html

CLASSROOM ACTIVITY (CONT.)

For both panel and parabolic cookers, successful cookers will have a large area of reflecting surface to focus light waves. Parabolic cookers are most effective when the food is placed at or near the cooker's focal point. Regardless of the type of cooker students build, all cookers are most effective if they directly face the sun (or are at least at a 45-degree angle to the sun to catch incoming energy), when their reflective material is as smooth as possible, and when the cooking container is a dark color. The ideal cooking container will be dark, lightweight, and only slightly larger than the water it will hold.

In this activity, students use a systematic approach to design, build, and test a portable passive solar cooker that will pasteurize water in the shortest amount of time. This activity can be done as a guided inquiry or as an open-ended design process. As a collaborative team project it will take seven to ten class periods to complete. To shorten the project time, limit the challenge to one style of cooker, collect materials in advance of the activity, and have teams build and test just one cooker each. Use the results from that test as the basis for a discussion about what makes a solar cooker work.

Procedure

1. Organize students into teams of no more than three. Set up the engineering challenge for students. Tell them that they have been hired by the World Health Organization (WHO) to help solve a major world health crisis: Curb the spread of disease in developing countries by designing an inexpensive, efficient, portable solar cooker that will pasteurize contaminated water and make it safe to drink. (According to WHO between 2 million and 5 million people—many of them children—die each year from diseases resulting from contaminated water.)
2. Provide a guided inquiry about what might make a solar cooker work. Show students a shoebox and invite discussion about how it might be used to make a solar cooker. *(Some students might mention painting it black to absorb heat, others might suggest using a lens to focus the sun's rays or lining it with a reflective surface.)*
3. Discuss what variables are important to consider when designing a solar cooker, including transmission, absorption, reflection, insulation, and sun position in relation to the cooker. Review these concepts with students and discuss what role they can play in the cooker. Explain to students that light rays from the sun are converted to heat when they strike an object.

CLASSROOM ACTIVITY (CONT.)

4 Distribute the student handouts to each team and review the instructions and criteria for success listed on the handouts. Allow students time to research types of solar cookers and to brainstorm materials for their cooker. Once students have completed their research, review the suggested materials listed in this activity and, as a class, determine a final list for the challenge (students may come up with additional suggestions). Note that masking tape does not hold well, and that a magnifying glass should not be used as it could lead to temperatures hot enough to ignite flames. Depending on temperatures, clear plastic wrap may melt.

5 To help students who are building parabolic cookers understand how the curvature affects where the focal point is, have those students use the information on the "Finding the Focal Point" handout to find an online demonstration of how focal point changes with depth of cooker or to derive this point themselves.

6 Allow students time to design and build their prototype. **Only allow one team to use the cardboard cutting tools at a time and supervise their use.** Instruct students to record their invention process in a team journal, including what materials they used and why, and a drawing of the cooker and its dimensions. If possible, have students photograph their solar cookers with a digital camera and insert the images into their journals to supply a visual record of their design.

7 **Review the safety rules at right with students prior to the testing phase of the activity.**

8 Choose a sunny, calm day for testing (cookers are best tested near solar noon). Students can obtain sun path information for their location and time of year from the University of Oregon Solar Radiation Monitoring Laboratory at
solardat.uoregon.edu/SunChartProgram.html

9 Include a control in the experiment, such as a bottle with a thermometer in it that sits in the sun (the thermometer should only show a rise of a degree or so).

10 Have students measure the temperature of their water (in centigrade) at the start of the experiment and then every five minutes. Pasteurization, which kills off most harmful microbes, occurs when water is heated for a short period of time at 65° C. (If you live in a particularly sunny southern latitude you may want to amend the challenge to have students attempt to get the water to its boiling point—100° C. Tell students that although pasteurization occurs at 65° C, many people in developing countries don't have access to a thermometer and instead use the boiling point to ensure that the water has been pasteurized).

SAFETY RULES

- Instruct students to wear UV-protected sunglasses during testing phases of the activity and never to look directly at the sun.
- Conduct the activity on a concrete, stone, brick, or dirt surface.
- Caution students not to place their hands near the focal point of their solar cookers **at any time** during testing.
- Have students use gloves or mitts, or wait until their water containers cool before removing them.
- Have water or a fire extinguisher handy during testing in case of fire.

CLASSROOM ACTIVITY (CONT.)

11 After the first testing session, create a class chart for the temperature data. Have each team first plot and graph its own temperature data on the team's student handout and then present its designed cooker to the class and add its temperature data to a class chart (each team should use a different-colored pen). Discuss with students what worked and did not work on their initial designs.

12 Next, have students choose a variable (or variables) on their designs to improve. Have students redesign their models, noting on their original drawings what they changed and listing the reasons why.

13 When teams have built their second models, conduct another round of testing. After the second testing session, have each team graph its temperature data on its original student handout graph in a different color. As a class, discuss the strengths and weaknesses of the final solar cooker designs. How did the first data set compare with the second? What design factors seemed to be the most important? Was the most efficient cooker (the one that heated the water the fastest) also the least expensive in terms of materials cost? The most portable? Which of the designs appeared to best meet all three criteria?

14 Discuss with students the advantages of using the sun as an energy source. What advantages does the sun have over fossil fuels like coal and oil, which are the currently most-used energy sources? *(The sun is a clean, renewable energy source; fossil fuels increase atmospheric carbon dioxide and are nonrenewable.)* What are some ways that the sun can be collected and used as an energy source? *(Some ways include solar cookers, solar photovoltaic panels on houses, solar home water heaters, and solar power plants.)*

15 To help students understand how a solar cooker uses the sun's energy differently than photovoltaic (or PV) solar panels found on homes, show the portion of the program (2:51) that explains how these panels work. www.pbs.org/nova/teachers/activities/3406_solar.html#video (QuickTime, RealVideo or Windows Media plug-in required.)

After students have viewed the video, ask them to explain the differences between the two methods of using the sun's energy. (*A solar cooker primarily uses absorbed and reflected electromagnetic radiation from the sun to cook food; photovoltaic panels convert the sun's photons into electricity by knocking free negatively-charged particles from silicon atoms.*)

16 As an extension, have students determine which locations on Earth would be the best for using a solar cooker and why, including whether their city or town would be a good location.

WHEN TO DO THIS ACTIVITY

Schedule the activity for a time when the sun is fairly high in the sky, such as early fall or mid to late spring, particularly if you are in a temperate climate above 35 degrees N latitude. Test the cookers in the least windy location available (wind contributes to cooker heat loss).

Classroom Activity Author

Jeff Lockwood taught high school astronomy, physics, and Earth science for 28 years. He has authored numerous curriculum projects and has provided instruction on curriculum development and science teaching methods for more than a decade.

ACTIVITY ANSWER

Student Handout Questions

1 Based on your data, was your first model or your redesigned model more efficient at heating the water? *Answers will vary.*

2 What factors do you believe account for the differences in the efficiency of the two solar cooker designs? *Answers will vary.*

3 List three variables that affect the time it takes to heat water in a solar cooker. *Students may identify the following variables or come up with others:*

a) size of solar cooker
b) area of reflecting surface
c) whether cooker is covered with a transparent material
d) whether cooker is insulated
e) color of cooker's interior
f) position of water being heated in relation to focal point of cooker (parabolic cookers)
g) size and shape of water container
h) position of cooker in relation to position of sun
i) cloud cover
j) time of day water is heated
k) season of year

4 Draw a diagram to show how transmission, reflection, absorption, and insulation played a part in your solar cooker (depending on your type of cooker not all of these concepts may apply). *Diagrams will vary based on the type of cooker students built. Students with box cookers should note that light is transmitted through the clear covering on the box and absorbed by the dark materials inside. Insulating materials inside the box will help retain the heat. Reflecting materials outside the box will reflect some of the light waves in. Panel and parabolic cookers reflect the light waves toward the container of water where they are absorbed. These types of cookers may or may not have a covering or insulation.*

5 If you had to change one design element in your cooker to improve it for a subsequent test, what would it be? Why would you make the change? *Answers will vary.*

6 Compare the use of the sun as an energy source to one of the following types of energy sources: wood, fossil fuels such as coal or oil, nuclear power, wind, or water. *Compared to wood—sun is inexhaustible, burns clean (wood creates smoke that can be harmful to human health); compared to fossil fuels—sun burns clean and is inexhaustible (fossil fuels create CO_2 that contributes to greenhouse gases); compared to nuclear power—sun has no hazardous waste byproducts (nuclear power creates radioactive plutonium and other high-level nuclear waste, nuclear power plants can pose risk of a nuclear accident); compared to wind and water—sun is similar to wind and water in that it is a clean, renewable energy source that gives off no harmful byproducts.*

LINKS AND BOOKS

Links

NOVA—Saved By the Sun
www.pbs.org/nova/solar
Provides information on the latest solar technologies, shows how to convert a home to solar power, details how a photovoltaic cell works, and offers a discussion board.

Building a Solar Oven
www.re-energy.ca/t-i_solarheatbuild-1.shtml
Offers a blueprint for building a solar oven, a list of safety precautions, and a set of comprehension questions.

Energy Quest: Energy Story
www.energyquest.ca.gov/story/chapter17.html
Details different forms of energy, how they work, and the pros and cons of each.

How to Build a Solar Cooker
solarcooking.org/plans
Lists plans for several types of solar cookers with instructions.

National Energy Policy Overview: Germany and United States
energytrends.pnl.gov/germany/ge004.htm
energytrends.pnl.gov/usa/us004.htm
Provides energy consumption statistics for Germany and the United States.

Solar Cookers
pbskids.org/zoom/activities/sci/solarcookers.html
Details how to create your own solar cooker and presents testimonials from kids who have tried it themselves.

World of Energy: Energy Information
www.worldofenergy.com.au/fact_sheets.html
Includes fact sheets that include the advantages and disadvantages of various types of energy.

World Resources Institute: Energy and Resources Searchable Database
earthtrends.wri.org/searchable_db/index.php?theme=6
Provides a searchable database of energy consumption by fuel type and country.

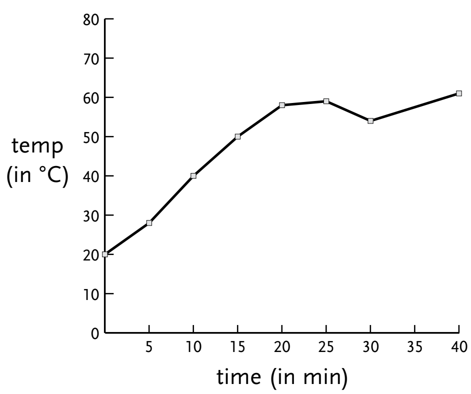
ACTIVITY ANSWER (CONT.)

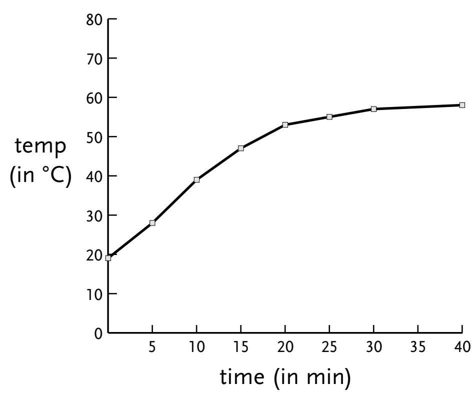
Sample Cookers

In classroom testing of the activity using 200 milliliters of water, the following cookers best met the criteria outlined for students. The cookers, which were all first designs, were tested in Brownsville, Texas (25.54 degrees N latitude) on March 5. The day was sunny with no clouds. The first class tested at about 9 a.m. and the last class finished at 3 p.m. No classes collected data between 11:30 a.m. and 1 p.m.

The two best-performing cookers both used large reflecting panels, a dark container at the base for water, and a cover to retain heat. Both were lightweight and thus relatively portable.

Temperature Data



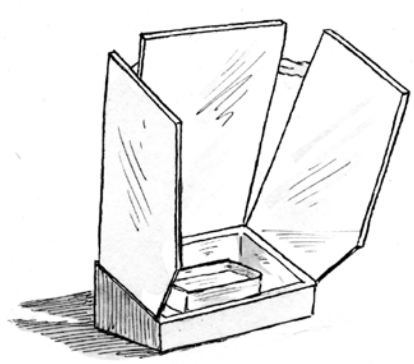


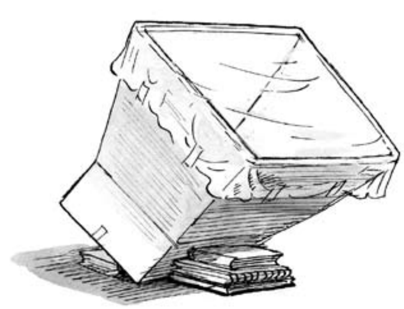
Model 1

Starting temp:	20
5 min:	28
10 min:	40
15 min:	50
20 min:	58
25 min:	59
30 min:	54
40 min:	61

Model 2

Starting temp:	19
5 min:	28
10 min:	39
15 min:	47
20 min:	53
25 min:	55
30 min:	57
40 min:	58





LINKS AND BOOKS (CONT.)

Books

Cooking with Sunshine: The Complete Guide to Solar Cuisine with 150 Easy Sun-Cooked Recipes
by Lorraine Anderson and Rick Palkovic.
Marlowe, 2006.
Describes how a solar cooker works, gives a short history of solar cooking, answers commonly asked questions about solar cooking, and provides instructions for how to build a cooker with cardboard and foil.

Going Solar: Understanding and Using the Warmth in Sunlight
by Tomm Stanley.
Chelsea Green, 2004.
Provides information on the history and basic principles of solar design, the science of sunlight, the nature of materials, and ideas for practical applications. Includes information on solar ovens.

Got Sun? Go Solar
by Rex A. Ewing and Doug Pratt.
PixyJack Press, 2005.
Includes explanations of electricity and solar cells, provides reasons for installing alternate energy systems, and profiles different systems that can be installed in a house.

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David H. Koch HHMI cpb

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The Lemelson Foundation
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Richard and Rhoda
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FOUNDATION

Got Sun? Get Cooking!

According to the World Health Organization (WHO), between 2 million and 5 million people—many of them children in developing countries—die each year from diseases resulting from contaminated water. Your team has been hired by WHO to help solve this major world health crisis. Your challenge is to design the most efficient, inexpensive, portable solar cooker that will attain a temperature needed to pasteurize contaminated water and make it healthy to drink.

Procedure

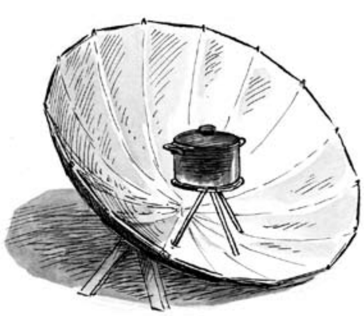
1 Follow the steps on your "Invention Checklist" handout as you design, build, and test your solar cooker.

2 As you test your first design, use the "Temperature Data" handout to record your data. When you have finished testing your first design, plot your data on the graph supplied on your student handout.

3 Present your first cooker to the class and add your temperature data to the class chart. Each team will present its cooker and data results.

4 Choose a variable (or variables) to change on your design for your second model. Note on your original drawing what you changed and include a list of reasons why in your journal.

5 Test your second model and enter the new temperature data on the graph on which you plotted your first data set.



Criteria for Success

The effectiveness of your cooker will be judged by

- its efficiency (pasteurizing water the fastest)
- its cost-effectiveness (uses inexpensive materials)
- its portability (can be easily transported from one place to another)

Questions

Write your answers on a separate sheet of paper.

1 Based on your data, was your first model or your redesigned model more efficient at heating the water?

2 What factors do you believe accounted for the differences in the efficiency of the two solar cooker designs?

3 List three variables that affect the time it takes to heat water in a solar cooker.

4 Draw a diagram to show how transmission, reflection, absorption, and insulation played a part in your solar cooker (depending on your type of cooker not all of these concepts may apply).

5 If you had to change one design element in your cooker to improve it for a subsequent test, what would it be? Why would you make the change?

6 Compare the use of the sun as an energy source to one of the following types of energy sources: wood, fossil fuels such as coal or oil, nuclear power, wind, or water.

Invention Checklist

The first step in any invention process is identifying a need or want for something—in this case it is an inexpensive and environmentally safe way to pasteurize water. One solution to that, the one you will be exploring in this activity, is to research and build a portable, inexpensive solar cooker that can heat water quickly. Use these steps to help guide your invention process.

Step 1—Conduct Research: Use print and Internet resources to investigate solar cookers, particularly the type you will be building, a passive solar cooker. There are primarily three types of passive cookers: box cookers, panel cookers, and parabolic cookers. From your research, come up with a list of solar cooker characteristics that will help you meet your criteria for success. Brainstorm a list of materials that you think may optimize the type of cooker you will be designing and building. Record what you have learned in your journal.

Step 2—Develop a Plan: As a team, choose the materials you want to use to design and build your solar cooker. As you think about which design you would like to use, consider how to most effectively use your materials to concentrate the sun's energy to heat your water.

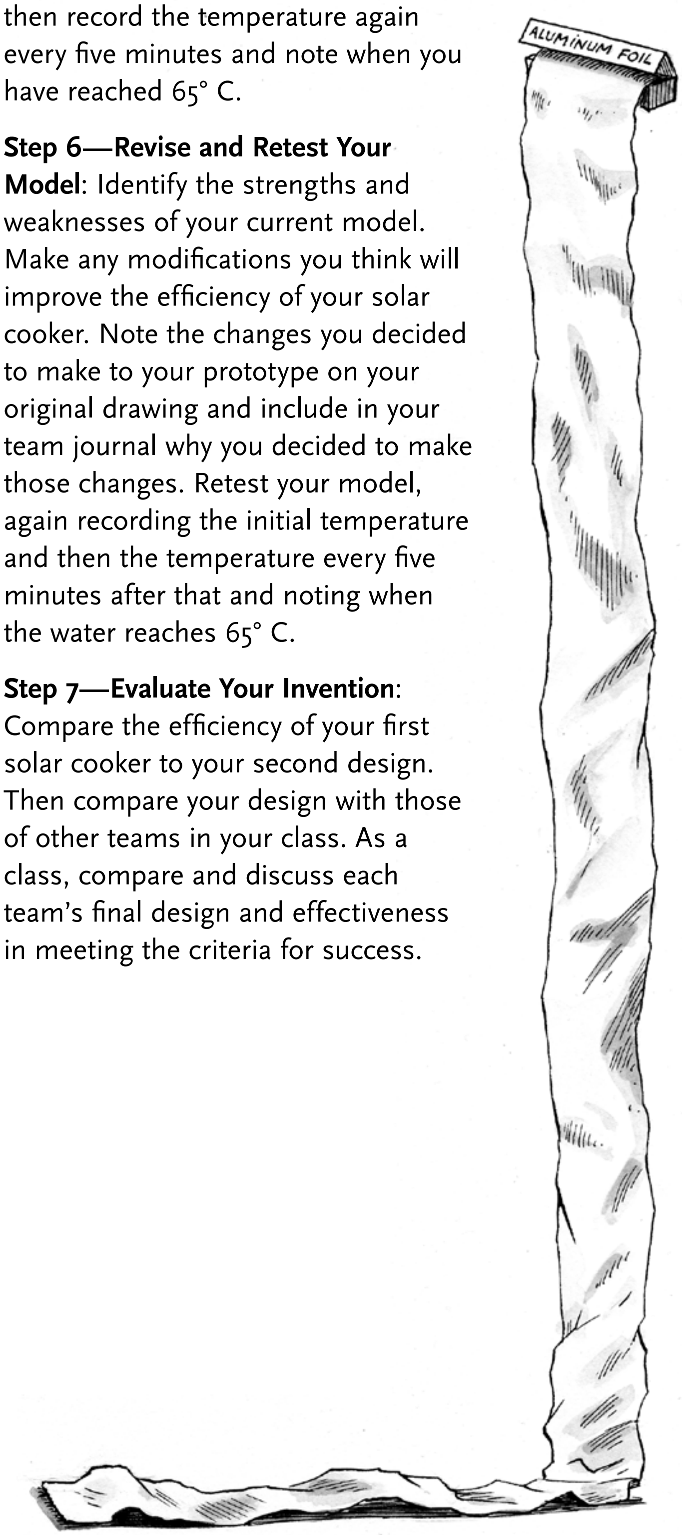
Step 3—Design Your Model: Develop a drawing of your design model. The drawing should indicate the cooker's parts, dimensions, and materials to be used. Consider how you are going to use your thermometer to measure the temperature (if you have to keep opening your cooker to put in the thermometer, the temperature will drop). In your team journal, include a brief description about your design and materials.

Step 4—Build Your Model: Build your model. As you build it, make sure to include detailed notes in your journal about the final shapes, dimensions, and materials used to construct the actual cooker. These will help you later evaluate the cooker's performance.

Step 5—Test Your Model: Record the initial temperature of the water and then record the temperature again every five minutes and note when you have reached 65° C.

Step 6—Revise and Retest Your Model: Identify the strengths and weaknesses of your current model. Make any modifications you think will improve the efficiency of your solar cooker. Note the changes you decided to make to your prototype on your original drawing and include in your team journal why you decided to make those changes. Retest your model, again recording the initial temperature and then the temperature every five minutes after that and noting when the water reaches 65° C.

Step 7—Evaluate Your Invention: Compare the efficiency of your first solar cooker to your second design. Then compare your design with those of other teams in your class. As a class, compare and discuss each team's final design and effectiveness in meeting the criteria for success.



Finding the Focal Point

If you decide to build a parabolic cooker, you will need to find the focal point of your cooker in order to place your water container where the sun's rays will be strongest.

See It Online

To see how this point changes with the depth of your dish, you can use the Focus of Parabola demonstration from Humboldt State University, in which you can increase or decrease the curvature of a parabola to see how the focal point changes. Find the demonstration at
www.ies.co.jp/math/java/conics/focus/focus.html

Determine It Yourself

You can use the following equation to determine the focal point for yourself.

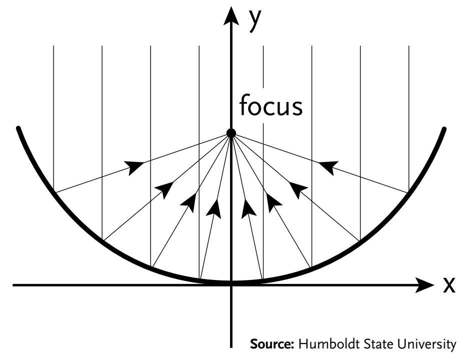
The formula for a parabola is $f = x^2/4a$. To find the focal point of a parabola, follow these steps:

Step 1: Measure the longest diameter (width) of the parabola at its rim.

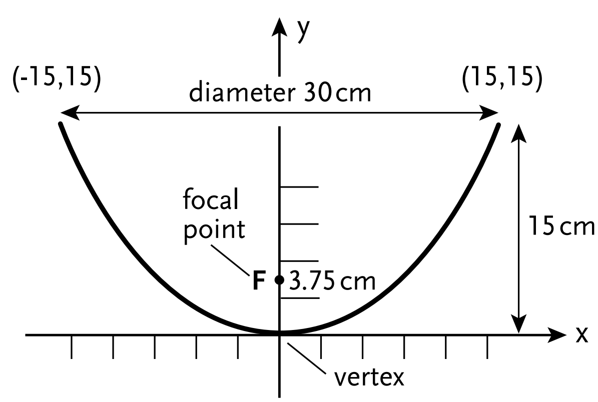
Step 2: Divide the diameter by two to determine the radius (x) and square the result (x^2).

Step 3: Measure the depth of the parabola (a) at its vertex and multiply it by 4 ($4a$).

Step 4: Divide the answer from Step 2 by the answer to Step 3 ($x^2/4a$). The answer is the distance from the vertex of the parabola to its focal point.



The focal point is the point at which light waves traveling parallel to the axis of the parabola meet after reflecting off its surface.



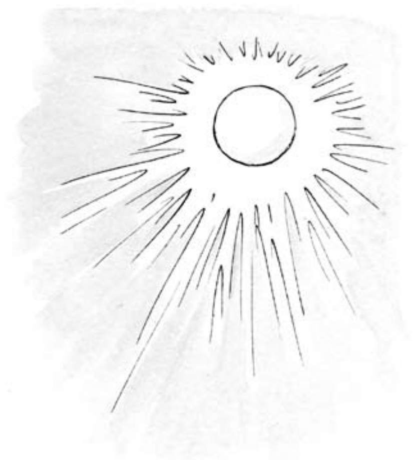
For the above example, the width of a parabola is 30 centimeters, and its depth is 15 centimeters. How far is the focal point from the vertex of the parabola?

$$x^2 = 225 \text{ cm}^2$$
$$4a = 60 \text{ cm}$$
$$225 \text{ cm}^2/60 \text{ cm} = 3.75 \text{ cm (focal point)}$$

Note: Each increment on the graph equals 2.5 centimeters.

Temperature Data

Keep track of your temperature data here, and plot the results of both trials on the graph provided. Use a different-colored pen or pencil for each trial.



Trial 1

Starting temp: ______________

At 5 minutes: ______________

10 minutes: ______________

15 minutes: ______________

20 minutes: ______________

25 minutes: ______________

30 minutes: ______________

35 minutes: ______________

40 minutes: ______________

45 minutes: ______________

50 minutes: ______________

Trial 2

Starting temp: ______________

At 5 minutes: ______________

10 minutes: ______________

15 minutes: ______________

20 minutes: ______________

25 minutes: ______________

30 minutes: ______________

35 minutes: ______________

40 minutes: ______________

45 minutes: ______________

50 minutes: ______________